IndiaTrib 2025

13th International Conference on Industrial Tribology

14 -16th December 2025

Organized by

Indian Institute of Technology Bhilai

and

Tribology Society of India

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Prof. em. Dr. Nicholas D. Spencer
President, ITC
www.itctribology.net

December 13, 2025

To the attendees of IndiaTrib2025, Bhilai

Dear Friends and Colleagues:

It is with great pleasure that, in the name of the ITC, I welcome you to **IndiaTrib2025** in Bhilai, the Steel City of India.

In the coming days, you will experience the warm welcome of your colleagues from IIT Bhilai and will have the chance to learn of the latest breakthroughs and developments from both the Indian tribology community and that beyond its borders. The ITC, of which I am President, exists to facilitate communication between tribologists worldwide. This conference is indeed a wonderful opportunity to forge strong connections between colleagues in our field at every stage of their careers.

This conference unfolds at a moment of profound uncertainty—geopolitical and climatic. Where former lies in the hands of elected leaders, the latter calls upon us, as tribologists, to rise to the challenge. Our work is not just technical; it is transformative. By creating lubricants that cut CO_2 emissions and reduce energy consumption, and by designing tribological systems that strengthen the reliability of wind turbines and electric vehicles, we become architects of a more sustainable future. In the pursuit of net-zero, our contributions are not small steps—they are vital strides toward a world where science and innovation light the path to hope.

Despite the vital role we play in addressing some of the world's greatest challenges, tribology often remains hidden—quietly working "below the radar." It is our responsibility to change that. We must not only help the public understand the critical importance of tribology, but also inspire engineers across disciplines—especially those outside mechanical engineering—to recognize the power of our field. Tribology deserves a place at the heart of every engineering curriculum, and its principles should spark curiosity in classrooms as early as high school. The societies that represent us carry a profound duty: to lead, to champion, and to ignite awareness in their communities. By doing so, we ensure that tribology is no longer invisible, but celebrated as a cornerstone of innovation and sustainability.

In the name of the tribology community, I would like to congratulate the organizers on their hard work, and I hope you find enrichment from the many presentations at the exciting conference that they have planned.

Sincerely,

Nicholas D. Spencer
President, International Tribology Council

TRIBOLOGY SOCIETY OF INDIA

(Affiliated to International Tribology Council, U.K.)

Registered Office: R&D Centre – Indian Oil Corporation Limited, Sector – 13, Faridabad – 121 007 (Haryana), INDIA
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Message from Prof. Satish V. Kailas, President TSI

Tribology, the science and technology of friction and wear, is one of the most interdisciplinary and fascinating areas. To be considered a tribologist, one needs to have exposure to physics, chemistry, biology, mathematics, materials science, mechanical engineering, and various other related fields. It is nigh impossible to be a tribologist who can handle all these areas. Thus, one can develop expertise in a few aspects of tribology and excel in that. The contributions one can make in this field are still immense, and every day/week/year can be a new experience with new knowledge and deeper expertise. Thus, conferences such as IndiaTrib would play a crucial role in enhancing your tribology expertise by providing exposure to various aspects of the field. IndiaTrib is one in the series of conferences, and the present one is being held at IIT Bhilai with the support of the Tribology Society of India. In this conference, being held from the 14th to the 16th of December 2025, there would be 6 plenary Speakers, 11 keynote speakers, 27 invited speakers, 150 oral presentations, and 21 poster presentations. Organizing such a conference requires considerable effort, and I would like to thank and congratulate the team from IIT Bhilai for their dedication and hard work. I do wish the conference all the best.

On a different note, this will be the last time I will play a role as President of the Tribology Society of India. A new team, led by Harish Hirani as President, will be taking over. I would like to thank the members of the Tribology Society of India and its Executive Committee for their support in running the society. Do wish you all the best.

Prof. Satish V Kailas
President, Tribology Society of India
Professor, Department of Mechanical Engineering
Indian Institute of Science, Bangalore, India

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Message from the Secretary, Tribology Society of India

Dear TSI Members and IndiaTrib 2025 Delegates,

It gives me great pleasure to extend a warm welcome to all of you to *IndiaTrib 2025*, the 13th edition of our international conference, being organised by IIT Bhilai from 14th to 16th December 2025 at Bhilai. The theme of the conference, *"Tribology for Mankind,"* is particularly apt, reflecting the profound impact that this multidisciplinary field can have on improving the quality of human life. The deliberations during this event are expected to offer deep insights into the role of tribology in addressing contemporary challenges in areas such as energy efficiency, healthcare, mobility, manufacturing, and other domains where innovative solutions are urgently required.

Since its inception, IndiaTrib (earlier known as ICIT) has served as the flagship programme of TSI, consistently promoting awareness and advancement of tribology across the country and fostering stronger industry–academia collaboration. Over the course of the two and a half days, we will have the opportunity to engage with some of the most distinguished experts in tribology research, education, and practice.

I would like to express my sincere gratitude to Dr. Soumya, Dr. Vijay, and the entire organising team of IIT Bhilai for their dedicated efforts in hosting this mega event. I trust that the discussions and interactions during the conference will inspire further research and innovation in your respective fields. Thank you for your participation in IndiaTrib 2025. Once again, I warmly welcome all of you to this grand event and wish the conference a resounding success.

Mr. Rajendra Mahapatra
Secretary, Tribology Society of India

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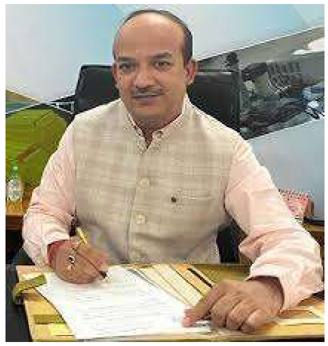

Message from Prof. Rajiv Prakash, Director IIT Bhilai

A warm welcome to all of you for showing your gracious presence in IndiaTrib2025 at IIT Bhilai. At the outset let me extend my sincere gratitude to the Tribology Society of India for providing an opportunity to IIT Bhilai to host IndiaTrib2025. It is our pleasure to organize 13th International Conference on Industrial Tribology – IndiaTrib2025 under the aegis of Tribology Society of India at the beautiful campus of IIT Bhilai. The theme of the IndiaTrib2025 conference is “Tribology for Sustainable Growth”, which aims to create significant impetus in the research and development of materials with excellent tribology properties for their application in every field, particularly Energy, Space, Transportation and Manufacturing.

I am happy to learn that in the next three days around 175 researchers will be presenting their research work through oral and poster presentations, 17 distinguish professors, scientists from the various reputed institutes in India and abroad are going to enlighten the participants through their plenary/keynote talks which will be supported by 27 more talks by invited speakers to be delivered during each parallel session. Such a large gathering of researchers reflects the success of the organizing committee in attracting the attention of the tribology research community through extensive outreach activities. I congratulate all the members of the organizing committee for their sincere efforts till now and wish them all the best for successful execution of their charted plan.

I hope, IndiaTrib2025 opens doors of opportunity to share ideas and fostering collaboration to aspire the innovative solutions. I would like to personally welcome each one of you to this conference on behalf of IIT Bhilai and hope that you have a pleasant stay at the beautiful campus.

Prof. Rajiv Prakash
Director, IIT Bhilai

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Message from Organizing Secretary, IndiaTrib2025

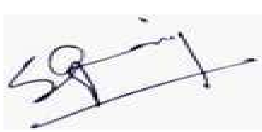
It gives me immense pleasure to welcome all the delegates, speakers, and participants to the 13th International Conference on Industrial Tribology – IndiaTrib2025, being organized at the Indian Institute of Technology Bhilai under the aegis of the Tribology Society of India**.**

IndiaTrib2025, with its central theme "Tribology for Sustainable Growth," has been conceived as a vibrant platform for researchers, academicians, industry professionals, and young scholars to exchange ideas, present cutting-edge research, and deliberate on contemporary challenges and future directions in tribology. The enthusiastic response to the conference, reflected through a large number of high-quality paper submissions, plenary and keynote lectures by eminent experts from India and abroad, and active participation from academia and industry, is truly encouraging.

The technical program has been carefully curated to cover diverse aspects of industrial tribology, including advanced materials, surface engineering, lubrication, wear mechanisms, manufacturing applications, and sustainability-driven solutions. I sincerely hope that the interactions during the oral and poster sessions, invited talks, and informal discussions will lead to meaningful collaborations and long-term professional associations.

I take this opportunity to express my heartfelt gratitude to the Tribology Society of India, the distinguished speakers, session chairs, reviewers, sponsors, and all members of the organizing and technical committees for their unwavering support and dedicated efforts. I also acknowledge the enthusiastic involvement of student volunteers, whose contributions are vital to the smooth conduct of the conference.

On behalf of the organizing committee, I warmly welcome you all to IIT Bhilai and wish you a stimulating technical experience and a pleasant stay on our campus.



Prof. Soumya Gangopadhyay
Organizing Secretary,
IndiaTrib2025

INVITED TALK SPEAKER

Dr. A K Mondal
IIT BHU, Dept of Metallurgical Engineering

Impression creep behaviour of selected magnesium alloys and nanocomposites

ABSTRACT

The impression creep test is a special type of indentation creep test. It uses a cylindrical indenter to impress the specimen surface, and the depth of penetration is recorded as a function of time. The technique is helpful in studying the creep behavior of many materials. The impression creep test has been successfully employed to investigate the creep behavior of Mg–Al–Ca–Mn, MRI230D, AZ91, AZ91+Ca, AZ91+Sb, and AZ91+Ca+Sb alloys, as well as their nanocomposites. The values of stress exponent (n) and activation energy of creep (Q) have been calculated using the impression creep tests to determine the dominant creep mechanisms operating in these magnesium alloys and nanocomposites. The creep behaviour of some of these materials has also been evaluated using the conventional tensile and compression creep tests for comparison. The results obtained using the impression creep tests are in good agreement with those obtained from conventional creep tests. In this talk, a brief introduction to impression creep will be provided. Additionally, the results obtained from impression creep tests on some magnesium alloys and nanocomposites will be discussed, along with their comparison to the results produced by conventional creep tests.

Keywords: Magnesium alloy; Nanocomposite; Microstructure; Impression creep

INVITED TALK SPEAKER

Dr. Anil Kumar Choubey
CSIR - Institute of Minerals and Materials Technology Bhubaneswar

Influence of Reinforcement Particle Size on the Microstructural Evolution and Tribological Behavior of Aluminum-Based Composites

ABSTRACT

Al-based metal matrix composites (MMCs) are a popular class of materials for aerospace and automobile applications due to their lightweight, high specific strength, large stiffness, and wear resistance. In addition, MMCs offer the possibility to tailor their properties to meet specific requirements, which renders this type of material quite unique in comparison to conventional unreinforced materials. In order to improve the properties of the composites, the development of reinforcements with enhanced specific properties is a necessary prerequisite along with the compatibility between the reinforcement and the matrix. Several processing methods have been developed to produce AMCs such as powder metallurgy, spray deposition, mechanical alloying (MA), and various casting techniques, i.e., squeeze casting, rheo-casting, and compo-casting. Among them, powder metallurgy (PM) through solid-state sintering is found to be one of the simplest and most appropriate for the fabrication of composites. It has excellent control over the microstructure, including size, morphology, and volume fraction of matrix and reinforcement. In this study, the effect of Mg-7.4%Al reinforcement particle size on the microstructure, mechanical, and topological properties in pure Al matrix composites is investigated. The samples were prepared by hot consolidation using 10 vol.% reinforcement in different size ranges (~20 µm to 100 µm). The result shows that reinforcement particle size has a strong influence on the microstructure, tensile strength, and wear properties. As the particle size decreases from 80–100 µm to ~20 µm, both tensile strength and ductility increase from 195 MPa to 295 MPa and 3 to 4%, respectively, due to the reduced ligament size and particle fracturing. Wear test results also corroborate the size effect, where accelerated wear is observed in the composite samples reinforced with coarse particles.

Keywords: Composite; Tribology; Particle Size; Reinforcement; Microstructure

INVITED TALK SPEAKER

Dr. Atul Singh Rajput
NIT, Surathkal

Fabrication and Post Processing of Additively Manufactured Parts

ABSTRACT

Additive Manufacturing (AM), especially Laser Powder Bed Fusion (LPBF) of Ti-6Al-4V, enables patient-specific biomedical implants but suffers from poor surface quality, leading to high wear rates and the release of metallic debris. These particles may trigger systemic toxicity and clinical complications such as Aseptic Loosening, Adverse Reactions to Metal Debris (ARMD), ALVAL, and Pseudotumours. To overcome these limitations, this work presents a Hybrid Electrochemical-Assisted Magnetorheological Finishing (H-ECMR) process designed to enhance surface finish without damaging the underlying material. H-ECMR combines controlled mechanical abrasion with electrochemical dissolution, significantly improving surface morphology and corrosion performance. The process increases oxide layer thickness from 8 nm to 78 nm, offering superior corrosion resistance. However, LPBF-fabricated components often contain features—such as holes and pockets—that trap Carbonyl Iron Particles (CIPs), preventing uniform polishing. To address this, a Feature-Based Hybrid MRF Planning System (FHMRF-PS) was developed to automate paraffin-wax masking of such features prior to finishing. Multiple toolpath strategies, including Zig-Zag, Hilbert, Peano, Spiral, and Trochoidal patterns, were evaluated for finishing uniformity. Trochoidal motion demonstrated the most consistent material removal across the surface. The proposed method was applied to LPBF-fabricated femoral heads and bone plates, reducing the initial roughness ($Ra \approx 14.67$ μm) to 33.14 nm. SEM, AFM, and optical profilometry confirmed substantial improvement in surface integrity. Post-processing also enhanced corrosion resistance (0.081 mm/year to 0.0103 mm/year) and wear resistance (18.86×10^{-5} to 0.96×10^{-5} mm3/min). The resulting negative skewness and low kurtosis values further indicate superior tribological behavior. Overall, this integrated finishing approach significantly improves the functional performance and biocompatibility of AM-based implants.

INVITED TALK SPEAKER

Debajyoti Bhaduri
Senior Lecturer High-Value Manufacturing Research Group
School of Engineering , Cardiff University

From Waste to Worth - Circular Hybrid Manufacturing of Sustainable Additive Manufacturing Parts from Production Scrap

ABSTRACT

Sustainable manufacturing is gaining momentum to meet United Nations Sustainable Development Goals by minimising the environmental footprint of manufacturing processes. To achieve 'Net Zero' emissions by 2050, circular economy models in manufacturing, in contrast to the conventional linear economy, are increasingly being adopted via material recycling, reduction of energy consumption and energy recovery. For additive manufacturing (AM), despite the immense benefits offered by the technology in terms of design freedom and material waste reduction, conventional AM powder production routes involving melting and atomisation processes (such as gas, water and plasma atomisation) consume substantial energy and have high carbon footprints. To mitigate this, reuse of commercial powders as well as alternative powder generation routes via solid-state crushing/ball milling (BM) of machining chips have been sporadically explored.

The holistic vision of the current research centres on the circular economy approach to produce sustainable metal AM powders by recycling production scrap and to provide solutions to 'zero waste' of materials. In particular, the research aims at developing Circular Hybrid Manufacturing (CHM) process chains to generate AM powders for powder bed fusion and metal binder jetting processes, via ball milling of machining chips, to fabricate and post-process high-value AM components.

INVITED TALK SPEAKER

Dr. Harish Barshilia
CSIR-National Aerospace Laboratories,Bangalore

Nanostructured PVD coatings with superior erosion, corrosion and wear resistant properties for aerospace applications

ABSTRACT

There has been a lot of progress in the last decade or two in producing nanostructured ceramic coatings with high performance. Nanostructured materials, i.e., whose crystallites have dimensions of the order of few nanometers, exhibit extremely fascinating and useful properties because of large volume fraction of atoms in the grain boundaries. Ceramic nanostructured coatings exhibit additional functionalities, viz., their stability at high service temperatures. Both the concepts, namely, nanolayered multilayer and nanocomposites have been used to design nanostructured ceramic coatings with improved mechanical properties. Even though, a large number of ceramic nanocoatings have been developed in recent years, addressing erosion, corrosion and wear problems in gas turbine engine (GTE) at high temperatures is a big challenge. This is due to the fact GTE blades, especially compression blades, undergo exposure to harsh environments (e.g., from high temperatures to freezing temperatures, erosion and corrosion). Ceramic coatings are known to have limitations in terms of low fracture toughness. To address this concern, a small amount of metal is added to the ceramic matrix, which improves the mechanical properties significantly. In this lecture, we will address the erosion, corrosion and wear issues in the compressor blades of a gas turbine engine. In particular, we will discuss in detail the fabrication of third generation Ti/TiN and TiCr/TiCrN nanolayered multilayer coatings deposited using a sputtering process. In depth studies on the role of bilayer thicknesses will be presented on the erosion/corrosion behaviour on coupon level samples.

INVITED TALK SPEAKER

Dr. Kranti Kiran
Klüber Lubrication India Pvt. Ltd

Sustainability and Energy Efficiency through Energy Efficient Lubricants

ABSTRACT

As industries accelerate toward decarbonization and Net Zero targets, lubrication engineering remains one of the most underutilized yet powerful levers in improving energy performance and reducing emissions. Energy-efficient synthetic lubricants enable tangible sustainability impact across high-load, energy-intensive sectors such as cement, steel, textiles, and refinery—all with minimal capital investment and accelerated return on investment. Backed by independently verified results from third-party energy audits conducted in collaboration with Grant Thornton Bharat (GTB), energy efficiency solutions contribute to:

- Friction loss reduction
- Extended component life and lubrication intervals
- Optimized Total Cost of Ownership (TCO)

The main objective of this study is to position lubrication not just as a functional necessity but as a strategic enabler of ESG compliance, BRSR alignment, and sustainable industrial transformation.

Key words: Lubrication; Energy Efficiency; Friction; Synthetic lubricants

INVITED TALK SPEAKER

Dr. Prosenjit Das
Dept. of Materials Engineering, Division of Mechanical Sciences, IISc Bangalore,

Load-Dependent Three-Body Abrasive Wear Behaviour of 42CrMo4V Steel Against 316LN Stainless Steel, in presence of Mining Abrasives

ABSTRACT

The present study focuses on the three-body abrasive wear behavior of 42CrMo4V steel, a high-strength alloy commonly employed in heavy-duty mining and excavation appliances/equipments. To replicate the actual service conditions, abrasive particles are collected from the operational site of Neyveli Lignite Corporation India Limited (NLCIL), where silica-rich lignite ash and mineral fragments dominate the wear environment. The wear tests are conducted on a three-body abrasion tester, using 42CrMo4V steel as the pin specimen and 316LN stainless steel as the disc material, with silica-rich abrasive particles at the pin–disc interface. The tests are conducted on a three-body wear tester at a track diameter of 100 mm, disk rotational velocity of 500 rpm, and test duration of 20 minutes, corresponding to a total sliding distance of approximately 3.14 km. Loads of 30 N and 50 N are applied to study the influence of contact pressure on material removal behavior. Experimental results revealed that weight loss and corresponding wear volume increased monotonically with both time and load. After 20 minutes of sliding, the 42CrMo4V pins exhibited a total weight loss of 0.063 g at 30 N and 0.075 g at 50 N, yielding specific wear rates of 8.6×10^{-5} $mm^3/(N\cdot m)$ and 6.1×10^{-5} $mm^3/(N\cdot m)$, respectively. The wear trend demonstrated a nearly linear progression with time, indicating steady-state abrasive interaction dominated by micro-cutting and ploughing mechanisms. The wear debris and worn surfaces are characterized using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) to determine the prevailing wear mechanisms.

Keywords: 42CrMo4V steel, 316LN stainless steel, three-body abrasive wear, silica-rich abrasive, tribology, micro-cutting, mining environment

INVITED TALK SPEAKER

Suhrit Mula
IIT Roorkee

Tribological Response of Fe–Ni Invar based ODS Steels and AA5083-SiC nanocomposites

ABSTRACT

Around 23% of total energy produced worldwide is spent on friction and wear in machinery (~1.4% of the global GDP annually). Hence, implementing advanced materials in tribology can significantly reduce these losses. In this regard, ODS steels, Al-alloy nanocomposites etc. are emerging as next-generation structural materials for extreme environments exposure (wear, corrosion & irradiation) due to their better thermal stability, higher strength and resistance to degradation overall. The Fe–Ni invariant-based Ti/Al/Zr added ODS steels were developed through mechanical alloying followed by SPS enabling formation of nanoscale complex Ti–Y–O, Y–Zr–O, and Y–Al–O dispersoids uniformly dispersed in matrix. Temperature-dependent tribological response was evaluated using pin-on-disk wear tests at 20, 300, and 500 °C to quantify variations in wear rate, coefficient of friction (COF), and dominant wear mechanisms. Microstructural characterization (SEM–EBSD/EDS, XRD) confirmed refined grains and thermally stable nanoscale oxides played vital roles in improving hardness and load-bearing capability, hence wear resistance. At higher temperature (e.g., 500 °C), formation of multi-oxide dispersoids provided higher stability against softening, limiting severe adhesive wear and mitigating delamination as compared to wear at room temperature. Besides tribological response, corrosion behavior and proton irradiation characteristics of these ODS steels were also investigated. Nanoscale complex stable oxides dispersed in a fine-grained matrix proved to be more effective against proton irradiation while exhibiting bit inferior corrosion resistance. Overall, synergistic strengthening achieved through nanoscale dispersion of complex oxides could enable Fe–Ni ODS steel as a strong candidate for high-temperature, sliding-contact components in nuclear and advanced energy systems.

Aluminium alloy nanocomposite could be widely adopted in structural applications in marine, aerospace, and automotive sectors due to its unique properties like light weight, high specific strength, better wear and corrosion resistance. However, sliding contact between two mating surfaces causes friction and wear damaging surface/sub-surface causing safety issue. Friction stir processing (FSP) is an effective technique to improve microstructural characteristics by refining matrix grains with uniform dispersion of reinforced nanoparticles. This study investigates pin-on-disk wear behavior of AA5083–SiC nanocomposites (1–3 wt.%, nanosized SiC particles) produced by stir casting followed by FSP at room (RT) and cryogenic (cryo) temperatures. Among all RT-FSPed samples, improvement in wear resistance of the 2 wt.% sample (lowest specific wear rate of 2.98 $\times 10^{-5}$ $mm^3 N^{-1} m^{-1}$ with 0.43 COF) is attributed to the uniform SiC particles distribution, formation of finer equiaxed grains (~4 µm) resulting in higher strength (224 MPa, 84 HV) as compared to AA5083 sample (152 MPa, 75 HV, ~6 µm grain). Further, cryo-FSPed 2 wt.% sample was found to achieve a more uniform distribution of nanosize SiC particles in the refined matrix grains (~2 µm) resulting in superior wear resistance (2.67×10^{-5} $mm^3 N^{-1} m^{-1}$) due to its higher strength (230 MPa, 89 HV). The cryo-FSPed 2 wt.% sample also exhibited the lowest average surface roughness and sub-surface deformation depth among all the samples. Analysis of worn-out surfaces and wear debris confirmed delamination, abrasion, and adhesion as the dominant wear mechanisms.

Keywords: Fe–Ni Invar ODS steel; Nanoscale complex oxides; Mechanical alloying; Spark plasma sintering; AA5083–SiC nanocomposites; Stir casting; Friction stir processing; Pin-on-disc wear; Electron microscopy

INVITED TALK SPEAKER

Dr Ramkumar P
IIT Madras, Dept of Mechanical Engineering

Systematic approach for contact mechanics-based FEM wear simulation

ABSTRACT

Wear is a complex phenomenon which depends on various parameters such as load, velocity, material properties, surface, and environmental conditions, etc. Hence, wear prediction is a challenging part of engineering. The first objective of this research work is to numerically predict the wear of steel-on-steel, using Pin-on-Disc (PoD) tribometer setup. The second objective is to predict the total wear by incorporating transient wear condition. The wear coefficient and coefficient of friction obtained from the experiments are given as input to the 2-D elastic FEM model using FEM based software ABAQUS. The Archard's wear law is then used to obtain the wear depth for each wear cycle increment. Finally, the geometry of the pin is updated during each wear increment using the UMESHMOTION and Augmented Lagrangian-Eulerian (ALE) technique. To reduce time, three different extrapolation techniques are used. Based on the accuracy, the linear extrapolation technique is found to be most effective, while the constant pressure extrapolation technique is most useful in reducing the computational time. Transient component is calculated using Gauss Newton regression method. Further, total wear is modelled by addition of linear and transient wear components. Simulated total wear has good agreement with experimental wear error within 11% for both the loads.

Keywords: Contact Mechanics; FEM; steel; UMESHMOTION; wear

INVITED TALK SPEAKER

Dr. Subhasis Sinha

IIT Banaras Hindu University

Wear and tribological behavior of biocompatible complex concentrated alloys

ABSTRACT

Complex concentrated alloys (CCAs) have tremendous potential for various tribological applications due to their scope for compositional design and microstructural tailoring for remarkable properties. In the present work, the tribological behavior of some refractory metal based CCAs was investigated. Response surface methodology-based mathematical modeling was performed on a Ti42Nb42Mo6Fe5Cr5 CCA to optimize the tribological input parameters for minimized specific wear rate (SWR) and coefficient of friction. Experimentally, the tribological properties of a biocompatible Ti35Zr35Nb15Mo5Cr5Fe5 CCA in as-cast and annealed conditions was evaluated in simulated body fluid (SBF) solution. The samples were tested under applied loads ranging from 10 N to 25 N, and the sliding time varied from 30 min to 120 min to investigate the effects of load and sliding time on wear and friction. The SWR of the as-cast and 1100 °C annealed biocompatible CCA at 10 N applied load and 30 min sliding time is 1.53×10^{-7} $mm^3/N \cdot mm$ and 7.27×10^{-8} $mm^3/N \cdot mm$, respectively. These values are significantly lower than those of traditional implant biomaterials such as 316L stainless steel and Ti-alloys. Furthermore, SEM and AFM were used to examine the worn surface and establish a correlation between the topographical parameters and the wear rate.

Keywords: Complex concentrated alloys; Wear resistance; Friction; Scanning electron microscopy; Atomic force microscopy

INVITED TALK SPEAKER

Dr. Suman Saha
Department of Mechanical Engineering, IIT (ISM) Dhanbad Dhanbad

Scopes of reducing frictional power wastage to improve energy efficiency for enhanced sustainability during machining

ABSTRACT

With the global concern on sustainability, manufacturing industries are exploring potential scopes for improving energy-consciousness and resource-efficiency without compromising product quality and economic viability. Machining is still one widely used secondary manufacturing and finishing process in a larger range of industries with global estimated market value of USD 354.92 billion in 2022 and further growing at 6.5% CAGR. During conventional machining, mechanical energy is spent mainly for two different aspects—for inducing shear deformation of the work material and for overcoming the frictional hindrances. This frictional energy expenditure at the chip-tool interface has no direct role in material shearing and chip formation although it remains inherently present in every machining process. Accordingly, reduction of friction-induced waste energy can be regarded as a significant leap forward for enhancing sustainability in machining sector. This article aims to highlight various strategies adopted by researchers in the literature to reduce the dynamic coefficient of friction at the chip-tool interface with an aim to reduce frictional energy wastage during machining. The following broad strategies for improving energy efficiency are covered in this manuscript.

1. Reduction of frictional energy loss through application of cutting fluid
2. Frictional energy reduction through micro-texturing on tool surfaces
3. Frictional energy reduction through anti-friction coating on tool
4. Frictional energy reduction through tool profile modification
5. Frictional energy reduction through optimization of process parameters
6. Frictional energy reduction by deploying chip breaker
7. Frictional energy reduction by inducing external vibration
8. Frictional energy reduction by cryogenically hardening the workpiece
9. Frictional energy reduction by forcefully curling the chip
10. Reduction of frictional energy loss by integrated heat recovery system

Keywords: Machining; Sustainability; Friction; Texturing; Cutting fluid

INVITED TALK SPEAKER

Dr. Tushar Banerjee
NIT Jamshedpur

Synthesis and Characterization of Electroless Ni-P-Al2O3/Ni-P/Stannate Multilayer Composite Coating on AZ91D Magnesium Alloy for Enhanced Tribological and Corrosion Performance

ABSTRACT

Magnesium alloys have gained significant attention in aerospace and automobile industries owing to their high strength-to-weight ratio, superior damping properties and good machinability. However, they suffer from poor wear and corrosion resistance. The present work hence aimed to improve the surface properties of AZ91D Mg alloy through deposition of a multilayer composite coating. The coating architecture comprised of an environmentally friendly chemical conversion based stannate layer, followed by electroless Ni-P intermediate layer and a top composite layer of Ni-P–nano Al_2O_3. The properties of the coating were comprehensively evaluated through FESEM, EDS, GIXRD, microhardness test, scratch adhesion test, pin-on-disc tribological test and potentiodynamic polarization test. FESEM images revealed uniform dispersion of nano-Al_2O_3 clusters within the Ni-P matrix. The co-existence of Al_2O_3 along with Ni was also confirmed through GIXRD analysis. Highest microhardness of 750 $HV_{0.05}$ and critical load of adhesion of 48 N was achieved when 4 g/L of nano-Al_2O_3 was added to the electroless bath. The same sample also exhibited significantly reduced coefficient of friction to 0.1–0.15 as compared to 0.7–0.8 for uncoated AZ91D Mg alloy. The corrosion rate also notably dropped from 0.3056 mm/year for bare alloy to 0.000070 mm/year after deposition of the multilayer composite coating.

Keywords: Electroless Ni-P-Al_2O_3 composite coating, AZ91D Mg alloy, Coating adhesion, Tribological properties, Corrosion resistance

INVITED TALK SPEAKER

Dr. VC Srivastava
NML, Jamshedpur

Energy-efficient Q&P Technology for High-performance Wear-Resistant Steel

ABSTRACT

In recent years, the quenching and isothermal partitioning (Q&P) process has shown to achieve multi-phase microstructure. In this, the desired strength is provided by the hard phases such as bainite, martensite and carbides; whereas, the soft retained austenite phase improves the ductility and impact toughness of steel. The Q&P process involves forming a mixture of martensite and austenite by quenching the steel to a temperature between Ms and Mf, followed by isothermal holding for the carbon diffusion from martensite to the untransformed austenite, and thereafter quenching to room temperature. As an alternative to the isothermal holding, the heat remained with the hot-rolled coil after quenching on the run-out-table can also serve the purpose of carbon diffusion, and thereby, eliminating the need for an additional facility for isothermal holding. This energy-efficient process is known as the quenching and nonisothermal partitioning process, which has gained a lot of attention from researchers in recent times. Therefore, in the present work novel alloy steels and their processing schedules were designed and optimized using thermodynamic and kinetics simulation software, as well as employing various empirical calculations. Subsequently, a comprehensive investigation was performed to understand/establish the composition–processing–structure–properties relationship to achieve superior wear resistance along with adequate strength combined with sufficient ductility and toughness.

Keywords: Quenching and nonisothermal partitioning, Retained austenite, Toughness, Strength, Wear-resistance

INVITED TALK SPEAKER

Dr. Anil Kumar
VNIT Nagpur

Multi-Scale Tribological Behavior of Plasma Sprayed Fe-Based Amorphous Coatings

ABSTRACT

Fe-based amorphous/nanocrystalline coatings offer high strength and wear resistance, yet their deformation and creep mechanisms under multi-scale contact remain poorly understood. This work aims to bridge this gap by systematically investigating their nano- to macro-scale mechanical response and establishing structure–property correlations essential for advanced surface engineering applications. Coatings synthesized via plasma spraying at varying plasma powers were evaluated using nanoindentation, micro indentation, nano scratch, and ball-on-disc wear testing. Multi-scale scratch experiments revealed that deformation was dominated by plowing accompanied by shear banding, evidenced by serrations in lateral force and friction curves. High-load nano scratch produced prominent shear bands with limited fracture, whereas further load escalation triggered surface chipping. Nanoindentation demonstrated conspicuous loading-rate-sensitive "pop-ins" and a strong indentation size effect. Macro-scale wear testing showed fatigue-assisted abrasive and oxidative wear as the dominant mechanism under dry sliding. A key outcome of this study is the first comprehensive assessment of room-temperature creep in such coatings. Micro- and nano-indentation creep tests showed enhanced creep resistance for coatings deposited at higher plasma power due to lower porosity and increased crystallinity. Mixed amorphous–intermetallic regions exhibited lower creep displacement than fully amorphous ones, providing new insight into phase-specific creep contributions.

Keywords: Fe-based amorphous/nanocrystalline coating; Multi-scale deformation behavior; Shear band; Nano scratch; Dry sliding wear.

INVITED TALK SPEAKER

Dr. Anirban Mahato
IIT Patna, Mechanical Engineering Department

Origin and Consequences of Unconstrained Flow in Sliding

ABSTRACT

Unconstrained plastic flow is inevitable in sliding asperity contact and in severe surface plastic deformation processes, such as surface mechanical grinding, wedge sliding, and friction stir processing. Unconstrained flow exhibits striking similarities to highly non-laminar Kelvin–Helmholtz–type fluid flow instability, which produces defects on the sliding surface. In this work, the mechanism of the defect formation is captured using high-speed imaging, image analysis, and the Electron Backscatter Diffraction technique in a model wedge sliding configuration. The finding shows that a favorably oriented cluster of surface grains deformed coherently to form a big bump on the unconstrained surface. The big bump consists of many small bumps of dimensions comparable to a single grain. These two different sizes of bumps establish dual-scale folding at the wedge face and transform into large crack-like defects with multiple branches on the sliding surface. Additionally, image analysis reveals the presence of an alternate layer with higher strain and a relatively less strained region, which corresponds to refined and elongated grains, respectively. As these defects alter the functional characteristics of the metal surfaces, care must be taken to suppress the dual-scale folding by controlling the initial microstructure of the workpiece and process variables.

INVITED TALK SPEAKER

Dr. Anirban Naskar
IIT Hyderabad, Dept of Mechanical & Aerospace Engineering

Wear Characteristics of Coated Cutting Tools under High-Speed Dry Machining: An Extreme Tribological Environment

ABSTRACT

High-speed dry machining represents a critical tribological environment encountered in manufacturing, characterized by extreme temperatures, stresses, and sliding velocities at the tool–chip and tool-workpiece interface. This talk addresses the behavior of advanced coated cutting tools exposed to these harsh environments, highlighting the wear mechanisms. Initially, a comparative assessment of state-of-the-art CVD- and PVD-deposited coatings (Al2O3, TiCN, TiAlN) is discussed in relation to their properties and wear characteristics. Plastic deformation-induced necking, grain spallation, dissolution-diffusion, and abrasion were among the wear mechanisms that were observed; these mechanisms varied according to the cutting condition, specifically the cutting velocity and coating material parameters. Based on these findings, TiAlN, identified as the most wear-resistant coating, was further examined using Direct Current Magnetron Sputtering (DCMS) and High-Power Impulse Magnetron Sputtering (HiPIMS) deposition methods. The HiPIMS-coated tools, exhibiting denser morphology, higher hardness, and compressive residual stress, demonstrated superior flank-wear resistance. A combined weighted metric of surface roughness and hardness was proposed as a predictive indicator of flank-wear for TiAlN coating, showing strong correlation with experimental findings. The presentation concludes by linking these findings to extreme-environment tribology and the critical role of coating selection and deposition processes in sustaining tool performance during high-speed dry machining.

Keywords: High Speed Dry Machining; Tool Wear Mechanism; PVD and CVD; HiPIMS.

INVITED TALK SPEAKER

Dr. Chiranjit Sarkar
IIT Patna, Dept of Mechanical Engineering

Tribological Characterization of Hybrid Magnetorheological Brake using Brake Inertia Dynamometer

ABSTRACT

The braking performance of magnetorheological (MR) brake can be improved by utilizing hybrid mode of operation of MR fluid in brake and by enhancing the rheological properties of MR fluid. This work presents an MR drum brake, which can operate in shear mode as well as in shear plus compression mode, i.e., hybrid mode. The use of compression mode increases the interactions of iron particles with the contacting surface of the rotor and stator, which affects the gap of the MR zone, which is one of the performance parameters for MR brakes. Hence, the presented work attempted to prepare an MR fluid that offers not only good tribological properties as well as best braking performance with MR drum brake. So, MR fluids have been prepared using the same percentages of different additives such as graphite flakes, MWCNTs, and zinc oxide. The rheological, tribological, and braking performance of these prepared MR fluids have been studied using a rheometer, tribometer, and brake inertia dynamometer, respectively. The study found that zinc oxide-based MR fluid is the most suitable MR fluid for the presented MR drum brake in terms of braking performance and tribological aspects.

Keywords: MR drum brake, Graphite flakes, MWCNTs, Zinc-oxide, Rheology, Tribology, Braking performance.

INVITED TALK SPEAKER

Dr. Gourhari Ghosh

Department of Mechanical Engineering
Indian Institute of Technology Jodhpur

Effect of surface roughness on the tribological behaviour of thermally sprayed hard coating

ABSTRACT

Surface roughness is a critical parameter in tribological systems and has a pronounced effect on the operational performance and lifespan of the engineering components. Due to the inherent surface roughness, the real contact area between rubbing surfaces is significantly smaller than the idealized area and that results in, corresponding variations in the subsurface stress distribution. In the present study, tribological behaviours of hard WC-Co coating having different surface roughness are thoroughly investigated. In the case of rough surface, the tribological response is found to be governed by the entrapment of big wear debris (WC particles and Co matrix) between the contacting surfaces and that finally, promotes the three-body abrasion. Such a self-perpetuating abrasion process dissipated considerable energy and that results in, higher friction coefficient. For the highly finished coating, the reduced local stresses at the asperity contacts facilitate material removal via plastic flow or micro-cutting and that leads to the generation of ultrafine debris. These fine debris coalesce on the wear surface to develop a tribofilm. The tribofilm enriched with oxidized layer (WO3 and CoO) behaves as a solid lubricant and that finally, contributes to reduce the wear rate. A revised specific wear- rate model is developed by integrating areal surface roughness, mechanical properties, and WC grain diameter and a good agreement is observed between the measured and predicted values.

Keywords: Areal surface roughness (Sa); Thermal spray coating; Tribological behaviour; WC- Co coating; Tribofilm

INVITED TALK SPEAKER

Dr. Manjesh K Singh
Indian Institute of Technology Kanpur

Tribological and Rheological Insights into the Lubrication Potential of Eco-friendly Thixotropic Lubricants

ABSTRACT

Toxicity from conventional oil and grease lubricants can be mitigated by introducing water-based lubricants with improved rheological properties. We present a thixotropic colloidal gel of silica nanoparticles formed in the presence of NaCl. Our experiments demonstrate that thetrib logical performance of the formulated gel can be optimized by tuning its rheological properties. We achieved an optimal combination of super-low friction and negligible wearusing a and chemically robust gel formed through van der Waals interaction between the flocs which provides self-repairing properties and continuous tribo-film formation. These attributes enable the gel to maintain and regain its structure during periods of inactivity, while also forming a thin film with sufficiently low viscosity to slip into the interfacial contact zone and continuously replenish it with lubricant.

Keywords: Tribology; friction; lubrication; nano-silica; rheology, thixotropy.

INVITED TALK SPEAKER

Dr. Meghanshu Vashista

Department of Mechanical Engineering

Indian Institute of Technology (B.H.U.)

Application of Barkhausen Noise for Tribological Application

ABSTRACT

Thin solid films are protective layers produced by surface engineering techniques to provide enhanced life with superior performance against wear and corrosion. In manufacturing of component against tribological application, generally residual stresses are induced in the component. induction of tensile residual stress not only reduces the fatigue strength but also detrimental for the service life of manufactured component during its application. Measurement of residual stress is essential for assessment of performance and service life of manufactured component. X-ray diffraction is well established technique for measurement of residual stress, but it is time/work consuming, costly and laboratory-based technique which cannot be used in field application. On the other hand, Barkhausen Noise (BN) technique is preferred technique for assessment of residual stress as it is fast, eco-friendly, less costly and above all it can be employed for field application and applied on any complex shape component. In BN technique a external magnetic field is applied over the component to move the magnetic domains of material. The movement of magnetic domain generates a electric pulse that can be captured using sensor inform of a signal. This signal is sensitive towards microstructure, hardness, grain size as well residual stress, which enables it for measurement of surface integrity of manufactured component.

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Recovery behavior of polymers under progressive loading

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ABSTRACT

Polymers are increasingly used in engineering applications where surface mechanical and tribological performance governs their service life. However, the viscoelastic nature of polymers makes it challenging to quantify their deformation and recovery behavior under mechanical loading. The progressive loading micro-scratch testing method is used in this study to assess the surface response of five engineering polymers: HDPE, PTFE, PMMA, PEEK, and PVC. The need to establish a quantitative relationship between intrinsic mechanical properties and scratch parameters ultimately motivates this research. Progressive scratch tests were conducted under various normal loads to measure tangential force, penetration depth, residual depths, and scratch width. The recovery rate was computed using penetration and residual depths to evaluate the elastic recovery behavior. The findings show that while the recovery rate was unaffected by applied loads, tangential force and scratch depth increased linearly with load. Their intrinsic mechanical properties showed PTFE the lowest recovery rate and HDPE the highest. With PTFE exhibiting the steepest slope, the scratch width similarly increased with load. These results show that the recovery rate, when combined with other scratch parameters, offers a reliable way to evaluate viscoelastic polymers' tribological and mechanical performance, which helps engineers choose and design better project materials.

Keywords: Viscoelastic behavior; recovery rate; progressive loading; polymer tribology; micro-scratch testing.

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Towards Enhanced Chemical and Mechanochemical Properties of Near-β Titanium Alloy (Ti-13Nb-13Zr) through Laser Surface Nitriding

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ABSTRACT

This study investigates the corrosion and tribocorrosion behavior of laser surface nitrided Ti 13Nb-13Zr, a near-beta titanium alloy, processed using a 6 kW high-power diode laser in continuous wave mode. Advanced characterization techniques, including FESEM, HRTEM, and XPS, confirmed the formation of a refined nitrided layer with improved microstructural features and chemical bonding. Electrochemical analysis via potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) in Hank's solution demonstrated a significant increase in corrosion resistance, attributed to the passive film stability and reduced ion dissolution. Furthermore, tribocorrosion studies (in Hank's solution) under open-circuit potential revealed a lower coefficient of friction and reduced wear volume in the nitrided alloy, indicating enhanced mechanical durability under simultaneous wear and corrosion conditions. These findings establish laser surface nitriding as an effective approach to augment the surface integrity and service life of Ti-13Nb-13Zr alloys in demanding operational environments.

Keywords: Laser surface nitriding; β-Titanium alloy; Ti-13Nb-13Zr; corrosion resistance; tribocorrosion.

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On the Issue of Conventional Test Methods for EV Fluids

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ABSTRACT

As electric vehicle (EV) adoption rises, optimizing lubrication solutions is crucial. Low viscosity EV fluids, primarily transmission fluids, enhance energy efficiency by reducing frictional resistance, leading to increased vehicle range. These specialized fluids also offer good thermal management for cooling, and robust protection against wear for gears and bearings within the drivetrain. Achieving these performance characteristics requires carefully balancing low viscosity with appropriate base oils and sophisticated additive packages to ensure durability and reliability in the unique environment of an EV. This study assesses and compares friction, wear and shear stability of various EV oils using standard tests like ASTM D4172 and CEC L-45-99. Applying a custom wear test at $1/10^{th}$ of the conventional load is better able to differentiate the anti-wear additives in EV fluids. On the contrary, a longer duration shear stability test ~ 10 times the conventional test differences in friction and viscosity loss of low viscosity EV fluids. Research on next-gen EV fluids using established configurations like four ball test and taper roller bearing KRL test requires modified protocols to better evaluate friction and wear characteristics.

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Thermal Conductivity Meets Tribology - Evaluating Material Performance with Four Ball Tester

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ABSTRACT

Understanding how material properties impact tribological performance is a key focus of academic research in materials science and mechanical engineering. One such critical property is thermal conductivity. Materials with high thermal conductivity can better manage frictional heating by reducing localized temperature rise that may lead to wear, surface damage, or failure of lubricants. Using the four ball tester, we investigated how materials with varying thermal conductivities influence friction, temperature rise, and wear under dry conditions. Material pairs such as 440C bearing steel, tungsten carbide and silicon nitride were tested under fixed load and speed in a four ball tester under dry sliding conditions. Friction and temperature increase was investigated using precision sensors close to the contact area. Lower thermal conductivity materials (e.g., 440C steel, ~24 W/m-K) experienced higher and more unstable friction coefficients. In contrast, materials like silicon nitride and tungsten carbide maintained lower and more stable friction. For advanced ceramic materials and coating used in niche dry bearing applications, these tests that correlate real time friction, temperature increase and wear offer valuable insights for material design.

The results reveal a clear connection between thermal conductivity, friction stability, and thermal loading.As electric vehicle (EV) adoption rises, optimizing lubrication solutions is crucial. Low viscosity EV fluids, primarily transmission fluids, enhance energy efficiency by reducing frictional resistance, leading to increased vehicle range. These specialized fluids also offer good thermal management for cooling, and robust protection against wear for gears and bearings within the drivetrain. Achieving these performance characteristics requires carefully balancing low viscosity with appropriate base oils and sophisticated additive packages to ensure durability and reliability in the unique environment of an EV. This study assesses and compares friction, wear and shear stability of various EV oils using standard tests like ASTM D4172 and CEC L-45-99. Applying a custom wear test at 1/10th of the conventional load is better able to differentiate the anti-wear additives in EV fluids. On the contrary, a longer duration shear stability test ~ 10 times the conventional test differences in friction and viscosity loss of low viscosity EV fluids. Research on next-gen EV fluids using established configurations like four ball test and taper roller bearing KRL test requires modified protocols to better evaluate friction and wear characteristics.

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Influence of Journal Imperfections on Dynamic Performance of Two- lobe Journal Bearings Operating with Nano-lubricants

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ABSTRACT

This study offers an in-depth dynamic analysis of a 2-lobe journal bearing system incorporating geometric imperfections commonly arising from manufacturing processes. The bearing is lubricated with nanolubricants, formulated by blending SAE 30 base oil with titanium dioxide (TiO) and multi-walled carbon nanotubes (MWCNTs). To accurately model the lubrication behavior, the Dowson equation serves as the foundational mathematical framework, while the Reynolds equation governing the fluid film pressure distribution is solved numerically using the Finite Element Method (FEM). The investigation focuses on the impact of various journal imperfections—specifically barrel-shaped, bellmouth, and undulated profiles—that typically result from manufacturing tolerances or wear. Steady-state and dynamic performance metrics were computed and compared across these different journal geometries. The findings reveal that the synergistic use of a two-lobe bearing design coupled with barrel-shaped journal profile, and hybrid nanolubricants significantly improves the system's stiffness and damping characteristics. These improvements lead to enhanced operational stability, evident from enhanced threshold speed at which instability occurs. Overall, the results demonstrate marked advantages over conventional cylindrical bore journal bearings lubricated with standard oils, highlighting the potential for improved reliability and performance in practical applications.

Keywords: Two-Lobe, Imperfect Journal, nano-lubricants, FEM, Dynamic characteristics.

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Visualization of Stress Distribution of Rubber in Contact Area with SPR Method

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ABSTRACT

Rubber materials exhibit complex behavior at contact interfaces, making high- precision modeling for shear and peel phenomena a significant challenge. This research proposes a real time measurement technique for the spatial distribution of stresses within the contact surface during rubber material contact and peel, contributing to the development of high-precision models. The surface plasmon resonance (SPR) method employed for measurement utilizes a phenomenon where the reflectance sharply decreases at specific wavelengths when the measurement light source is incident on a metal film at an angle exceeding the critical angle for total internal reflection. By utilizing the dielectric constant dependence of this resonance wavelength, it becomes possible to estimate dielectric constant variations (density changes) through measurement of reflectance variations. By attaching a thin polydimethylsiloxane (PDMS) film to the contact surface and measuring its density variation, the stress distribution within the contact surface can be readily assessed. In experiments, we captured images of the PDMS sphere contact state and the peeling process, then evaluated the temporal changes in pressure within the contact surface and the negative pressure distribution caused by peeling based on changes in reflectance. We also introduce the calibration method for density and pressure used in this measurement technique.

Keywords: Surface plasmon; Rubber; Static friction; Contact pressure distribution; Contacting sensor.

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Investigation of rubber–rough surface friction through micro-scale single asperity tests

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ABSTRACT

Friction between rubber and rough surfaces is a critical factor in mechanical components such as tires. Because rubber friction is strongly influenced by flexibility and viscoelastic properties, many studies have investigated how these characteristics affect friction. Extensive research, including theories by Persson and Popov, has been conducted on multi- asperity contacts. However, the friction mechanisms of a single asperity, representing rough surface contact at the micro-scale, remain insufficiently understood. In particular, contact theories that account for the deformation field under large deformation, as well as explaining the interaction between adhesive and hysteresis friction, are beyond the scope of existing theories. In this study, to address these challenges, friction tests were conducted between rubber and a micro-scale single asperity with a tip radius of several micrometers, designed to mimic an asperity on a rough surface. The friction coefficient was measured under conditions difficult to handle with existing friction prediction theories, such as deep asperity penetration and cases where adhesive and hysteresis friction produce large forces. The friction mechanisms were then discussed based on the results. This work facilitates a more detailed understanding of rubber–rough surface friction mechanisms and contributes to improving friction prediction accuracy.

Keywords: Rubber; Friction; Asperity; Rough surface; Hysteresis Friction.

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Consideration of adhesive friction mechanism of soft materials using a single asperity pull-off test

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ABSTRACT

In recent years, there has been growing interest in the design of tactile interfaces that enable precise grip force control and comfortable tactile sensations in robotic hands, and understanding the friction characteristics of soft materials is considered essential as a fundamental technology. Several basic models have been proposed that relate the adhesive force and friction force generated at the interface between the surface of a soft material and the opposing surface, and some of the mechanisms involved have been clarified. However, in materials with viscoelastic properties, such as polymers, the interface characteristics change significantly depending on deformation rate and temperature, limiting the applicability of conventional models like the Persson-Brenner model and the Greenwood model. This study aims to understand the mechanisms behind the emergence of adhesive and frictional forces at the true contact point scale from the perspective of material viscoelastic properties. Specifically, we used a single-indenter friction tester with a ruby indenter of 500 μm curvature radius to precisely measure the sub-mN-order adhesive and frictional forces that emerge at the interface with the elastomer. We then investigated the relationship between the velocity dependence of adhesive and frictional forces and the temperature- frequency characteristics based on the material's tanδ.

Keywords: Soft material; Viscoelastic; Frictional force; Adhesion force; Microscale Tribology.

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Effect of Mechanical, Thermal and Duplex Pre-processing Treatments on ZrN coating

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ABSTRACT

Zirconium nitride (ZrN) coatings have become promising surface modifications for Ti6Al4V alloys used in orthopedic implants because they are more resistant to corrosion, harder and more biocompatible. But the performance of the coating depends on pre- processing treatments that affect adhesion, crystallinity and phase stability. This study looked at how different types of pre-processing, including mechanical, thermal and duplex (mechanical + thermal) processes, affect ZrN coated Ti6Al4V alloy surface. Micro-blasting as a mechanical pre-treatment made the surface rougher and created places for the coating to stick better. Thermal treatment helped stabilize oxides and made it easier for Ti-Zr intermetallic to form at the interface between the coating and the substrate. Duplex pre- processing combined the best of both worlds, making a coating that was dense, even and had better crystallinity. X-ray diffraction (XRD) and Raman spectroscopy were used to find crystalline phases in the coatings. FESEM-EDS and AFM were used to learn more about the surface morphology, elemental distribution and nanoscale roughness. Wettability studies showed that surfaces treated with duplex were very hydrophilic, which helped cells interact with the material. The electrochemical evaluation in 0.9 wt.% of NaCl showed that duplex pre-treatment provided the best corrosion resistance, greatly lowering ion release compared to single process. In general, duplex pre-processing of Ti6Al4V before ZrN deposition is a way to make coatings that are strong, stable and biocompatible for advanced orthopedic uses.

Keywords: Coating, Micro-blasting, Oxidation, Pre-processing, ZrN

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Analysis of Herringbone grooved journal bearing including non-Newtonian effect

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ABSTRACT

Herringbone grooved journal bearing (HGJB) are supposed to be more stable as compared to plane journal bearing (PJB), particularly at light load condition. It is noticed that in most of the published work on HGJB, the numerical analysis is performed by assuming the Newtonian behaviour of the oil lubricant. However, in order to improve the performance of the lubricant, long chain polymer additives are mixed with the base oil which leads to non- Newtonian behaviour. In the present work, to include the non-Newtonian nature of the oil lubricant, power law model is used in the analysis of HGJB. Modified Reynold's equation is discretised using finite difference method. In addition, Reynold's boundary condition is applied to implement the cavitation condition. Further, the effect of design parameters namely, depth ratio, width ratio, helix angle and number of grooves on performance parameters are studied at various power law constant (n). From the obtained results, it can be concluded that the dilatant behaviour of lubricant, generates higher load capacity, lower friction variable, lower attitude ratio and larger end flow rate, as compared to the pseudoplastic behaviour of the lubricant. From this study, the optimal configuration of the design parameter of HGJB are also identified.

Keywords: Herringbone grooves; power law model; dilatant fluids, pseudoplastic fluids; finite difference method.

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Investigation of the effect of convective fluid inertia on the steady state behavior of Herringbone grooved journal bearing using first order perturbation method

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ABSTRACT

Owing to the presence of herringbone grooved textures either on the inner surface of bearing or the journal surface, convective fluid inertia terms may be significant in case of herringbone grooved journal bearing. First order perturbation method is used to considered the fluid inertia effect. This approach yields a zeroth and first order equations, which are solved to determine the classical pressure solution and a pressure contribution term on account of fluid inertia. These equations are transformed to non-orthogonal coordinate system which is aligned with the grooves geometry. Finite difference method is adopted to discretise these governing equations. Reynold's boundary condition is applied to implement the cavitation condition. Further, the effect of design parameters namely, depth ratio, width ratio, helix angle and number of grooves on performance parameters such as load capacity, attitude angle, friction and oil flow rate are studied at various modified Reynold's number (Re). Results show that, perturbation method may be applicable for small depth ratio ($\delta \leq 0.25$), since, assumptions related to small perturbation in velocity and pressure terms may not be applicable for larger depth-ratio (δ)

Keywords: Herringbone grooved textures; convective fluid inertia effect; perturbation method; modified Reynold's number; finite difference method.

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Numerical analysis of the slider bearing and tilting pad bearing using multigrid method

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ABSTRACT

Hydrodynamic bearings analysis involves the solution of Reynold's equation. Usually, numerical approach is adopted; where, this equation is solved iteratively. The convergence rate gets stalled on account of the application of relaxation through a single grid level. On the contrary, carrying out the relaxation at multilevel grids, both high and low frequency error components get reduced and thereby improving the convergence rate. In order to demonstrate this fact, one-dimension numerical analysis of slider bearing and tilting pad bearing is performed using multigrid method. In addition, an inverse approach is utilised; where, for a given load conditions and geometric configuration of the bearing, performance parameters are evaluated. It is felt that such an exemplary may be useful for pedagogical learning. Governing equations are discretised using finite difference method. Moreover, a computer code is developed in MATLAB software. Finally, the results obtained through single grid level and multigrid method are compared.

Keywords: Inverse approach; multigrid method; 1D-slider bearing analysis; 1D-tilting pad bearing analysis; finite difference method.

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Modeling synthesis of Ricinoleic Estolide Esters using RSM for their physicochemical and tribological properties

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ABSTRACT

Bio-lubricants, in contrast to the conventional mineral sourced lubricants, have limited flexibility of physicochemical properties especially the kinematic viscosity. This limitation, by virtue of the molecular structure of bio-lubricants, restricts the use of the bio-lubricants to formulate lubricants of various viscosity grades. Estolides, the oligomeric derivatives of fatty acids like ricinoleic acid, owing to the flexibility of variation in the degree of oligomerization can be utilized to develop lubricants of various viscosity grades. In the current study, we utilize statistical modeling tool of response surface methodology to model the physicochemical properties like kinematic viscosity, viscosity index and pour point along with tribological properties like friction, anti-wear and load carrying capacity as an effect of variation in structure of estolide esters with lauryl alcohol achieved by changing the reaction parameters like amount of catalyst and the reaction time. The relationship of the reaction parameters on the degree of oligomerization, physicochemical and tribological properties was established and the generated models were then utilized to synthesize estolide esters of desired viscosity grades from ISO VG 32 till ISO VG150 as required for various industrial applications.

Keywords: Estolides; Estolide Esters; Bio-Lubricant; Response Surface Methodology; Optimization; Tribology.

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Tribological performance of basalt fibre reinforced composite (BFRC) with varying weight fractions of MWCNT

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ABSTRACT

Fibre-reinforced polymer (FRP) composites have seen significant advancement and widespread use in recent decades, often replacing conventional materials. This growing preference is largely due to their excellent strength-to-weight. Fibre-reinforced composites are extensively used in tribological applications due to their high wear resistance, low friction coefficient. The present investigation examines the effect of multi-walled carbon nanotube (MWCNT) reinforcement on the tribological behaviour of basalt fibre-reinforced epoxy (BFRC) composites under dry condition. Basalt fibre composite laminates were prepared using the hand lay-up process and subsequently cured in an autoclave. The tribological performance of composite laminates were examined under different weight percentages neat, 1%, 2% and 3% of MWCNT. Pin-on-disc experiments were conducted on apparatus TR 20 (by: DUCOM) to evaluate the coefficient of friction and specific wear. The experiments were performed under different loads (5 N-25 N) and sliding distances (100-200 m) at rotational speed of 200 RPM under dry condition against silicon carbide paper of 400 grit size in accordance with ASTM -G99.

Keywords: Basalt fibre-reinforced epoxy, Multi-walled carbon nanotube, Tribology.

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Mechanical and tribological properties in glass fiber- filled polytetrafluoroethylene (GF/PTFE) composites for snow clearance applications

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ABSTRACT

This study investigates the potential of glass fiber-reinforced polytetrafluoroethylene (GF/PTFE) composites as an alternative to conventional metallic blades for snow clearance applications. Composites containing 25 wt% glass fibers were fabricated and evaluated for their tensile and tribological properties. Tensile tests were carried out using a Universal Testing Machine (UTM) at a crosshead speed of 4 mm/min, while wear behavior was examined under dry sliding conditions using a ball-on-disc tribometer with an AISI 304 steel counter body (10 mm diameter). The tests were conducted at a sliding velocity of 0.12 m/s under a normal load of 20 N for 900 seconds. The GF/PTFE composite exhibited around 49% improvement in UTS compared to pure PTFE. Tribological analysis revealed a remarkable reduction in wear, with the wear rate decreasing from the order of 10^{-4} $mm^3/N\cdot m$ for pure PTFE to the order of 10^{-9} $mm^3/N\cdot m$ for the GF/PTFE composite. The substantial enhancement in both tensile strength and wear resistance is attributed to the homogeneous and random distribution of short to medium glass fibers, which efficiently transfer load and restrain PTFE chain mobility. These results demonstrate that GF/PTFE composites are a highly promising candidate for snow clearance systems, offering improved durability, mechanical integrity, and reduced surface abrasion under harsh operational conditions.

Keywords: Polymers; PTFE; GF/PTFE composites; snow blades; Mechanical and wear performance.

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Tribological Characteristics of Sustainable Composites with Reinforcements s Coatings: An Overview

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ABSTRACT

There is an ever increasing interest on the use sustainable composites as materials in tribological interfaces. There is a great potential in the use of sustainable composites impacting tribology for environment and sustainability. This study aims to present an overview of tribological characteristics of sustainable composites with reinforcements & coatings. An overview of the sustainable composites is presented considering the influence of composites properties with reinforcements & coatings. The enhancements in the friction and wear characteristics of sustainable composites with reinforcements (fibers, fillers, and particulates) & coatings are investigated. The Potential of Reinforcements tailored for Sustainable Composites were investigated using ML classification and regression algorithms based on Reinforcements Material Properties, Reinforcements Physical Properties, Hybrid Reinforcements, Sustainability Impact, Properties of Sustainable Composites with Reinforcements. Potential of Coatings tailored for Sustainable Composites based on Coatings Properties, Coatings Interfacial Properties, Hybrid Coatings, Sustainability Impact, & Properties of Sustainable Composites with Coatings. The synergistic effects of reinforcements (material, physical & hybrid) as well as coatings (material, interfacial & hybrid) properties significantly enhance friction and wear characteristics. The current trends and future prospects of sustainable composite applications in tribological interfaces are highlighted.

Keywords: sustainability; composites; reinforcements; coatings; tribology.

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Integrating Tribological Testing and Grey-Box Modelling for Predicting Tool Wear in TiN and AlTiN Coated Milling Tools

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ABSTRACT

Milling tools are vital for metal manufacturing but routinely face wear, heat, and vibration challenges that compromise tool life and product quality. Advanced coatings such as TiN and TiAlN enhance performance, offering greater heat resistance, hardness, and reduced friction and edge build-up. Yet, traditional tribological tests often fail to represent actual milling conditions. In this study, pulsed-DC and HIPIMS techniques were used to deposit TiN and TAliN coatings on cemented carbide tools for both tribological and milling tests. Notably, while coated tools display similar wear behavior at room temperature, temperature variation effectively isolates the role of different coating elements. Data generated from tribological tests, especially the evolution of the coefficient of friction as coatings deteriorate, was used for predictive modelling. All measured parameters served as inputs for a Grey-Box machine learning framework, enabling accurate tool wear prediction. Correlating model experiments with real-world milling validates this approach, yielding vital insights into wear mechanisms and optimizing coating performance for industrial applications.

Keywords: Grey-Box Model; Machine Learning; Milling Tools; HIPIMS.

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Tribological studies of Epoxy composite coatings using Zirconia oxide nanoparticles at elevated temperatures.

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ABSTRACT

Epoxy resins are widely used as protective coatings but their tribological applications are limited by low load-bearing capacity and poor thermal resistance. This study investigates epoxy coatings reinforced with zirconia (ZrO_2) nanoparticles (Ep–Zr) deposited on stainless steel substrates and tested under dry sliding conditions. Reciprocating wear tests were conducted at room temperature, 75 °C, and 100 °C using a 10 mm steel ball counterface, 3 N load, 5 Hz frequency, and 10 mm stroke length for 9000 cycles. Characterization was carried out by FE- SEM, XRD, and FTIR, while mechanical properties were evaluated via nanoindentation and nanoscratch. Compared to pristine epoxy, Ep–Zr coatings showed reductions in the coefficient of friction (11.1% at room temperature, 19.2% at 75°C) and specific wear rate (94% and 80.7%, respectively). At 100 °C, pristine epoxy failed, while Ep–Zr remained stable with a coefficient of friction of 0.70 and wear rate of 0.00285 $mm^3/N{\cdot}m$. The results confirm the superior wear resistance and thermal stability of ZrO_2- reinforced epoxy coatings.

Keywords: Epoxy coatings, nano particles, nano hardness, adhesion strength, tribology

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Wheel–Rail Tribology and Twin-Disc Testing: Principles, Challenges, and Future Directions – A Review

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ABSTRACT

This review paper comprehensively examines the tribological effects at the wheel-rail interface, focusing on the insights gained from twin-disc test rigs. It outlines the fundamental principles of friction, wear, and lubrication, emphasizing their crucial role in railway operations. The report details the design, operational principles, and simulation capabilities of twin-disc setups, acknowledging their advantages in controlled experimentation while also addressing their inherent limitations in fully replicating real-world conditions. A thorough analysis is presented on how contact parameters, material properties, surface topography, and environmental factors influence friction, wear and rolling contact fatigue (RCF). Furthermore, the application of twin-disc testing in evaluating friction management strategies is discussed. The paper concludes by synthesizing key findings, identifying existing research gaps, and proposing future directions for advancing the understanding and management of wheel-rail tribology.

Keywords: Twin disc, Rolling contact fatigue, Wear, Lubrication.

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Enhancing Thermal and Oxidative Stability of Industrial Gear Oil Using Nano Additives: A Tribological Evaluation of Graphene and Titanium Dioxide

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ABSTRACT

Lubricants in tribological systems are routinely exposed to elevated thermal and oxidative stresses, which accelerate degradation and compromise system reliability. This study investigates the role of nano additives—graphene (G) and titanium dioxide (TiO_2)— in enhancing the performance of industrial gear oil. Nano-enhanced formulations were evaluated through standardized tribological, thermal, and oxidative tests. Graphene-based formulations demonstrated superior anti-wear and oxidation resistance, with the highest RPVOT break time observed in the 0.1% variant. The dual-additive formulation exhibited the highest thermal onset temperature, indicating improved thermal stability. All formulations- maintained viscosity indices within the same range, suggesting minimal impact on flow behaviour. The observed improvements are attributed to the nano additives' ability to form protective tribofilms, enhance thermal conductivity, and inhibit oxidative degradation. These findings support the strategic integration of nano additives in lubricant design to extend service life, reduce wear, and improve energy efficiency in high-performance tribological applications.

Keywords: Nano-additives; Graphene; Titanium-dioxide (TiO_2); Tribology; Thermal stability.

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Influence of Surface Conditioning and Emulsion Chemistry on Lubrication Efficiency in Aluminium Hot Rolling

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ABSTRACT

The performance of lubricants in the hot rolling of aluminium is influenced by both the surface condition of the ingot and the chemical composition of the rolling emulsion. This study investigates the combined effects of surface conditioning—achieved through Barrel Brush (BB) treatment—and variations in ester and acid concentrations on tribological behaviour, using the Coefficient of Friction (COF) as the key performance indicator. Tribometer-based tests were conducted across emulsions with various ester and acid concentrations, both with and without BB treatment. BB conditioning was found to significantly improve surface cleanliness by reducing oxide layers and residual particulates, thereby enhancing lubricant metal interaction and reducing coating thickness. The lowest COF values were observed in emulsions with 8.25% ester and 2.6% acid under elevated temperature and load conditions. Meanwhile, emulsions with 7.55% ester and 2.5% acid showed up to a 15% reduction in COF at room temperature when BB treatment was applied, indicating its compensatory role in conditions with weaker boundary lubrication. These findings highlight the importance of jointly optimizing surface preparation and emulsion formulation to enhance lubricant efficiency in hot rolling. Surface conditioning emerges as a critical factor in improving tribological performance and minimizing energy losses, particularly when emulsion chemistry alone is insufficient.

Keywords: Aluminium; hot-rolling; Lubricant; COF; Tribometer.

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Lubrication and Surface Engineering Strategies for Water-Lubricated Bearings in Screw Compressor Applications

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ABSTRACT

Water-lubricated bearings offer a sustainable alternative to oil-based systems in water-injected screw compressors used in mechanical vapor recompression, steam compression, and heat pumps. This study investigates the feasibility of elastohydrodynamic lubrication (EHL) in water-lubricated tribocontacts and evaluates surface engineering strategies to enhance tribological performance. Theoretical and numerical models were developed to analyze film formation in area (thrust pad), line (journal), and point (ball) contacts. Despite water's low viscosity, the results indicate that EHL regimes can be achieved under high-speed, moderate-load conditions representative of screw compressors. Instrumented tribometers were adapted for aqueous lubrication and used to replicate sliding and mixed rolling-sliding conditions across relevant temperature and load spectra. A range of advanced coatings, including diamond-like carbon (DLC) and oxide ceramics, were screened for corrosion and wear resistance in water-lubricated environments. Additionally, eco-friendly nano- additives, such as graphene oxide and silica nanoparticles, were evaluated for their film-forming and friction-reducing capabilities. Coating– additive synergies were identified that significantly improved durability and load-carrying capacity. The findings provide new insights into the viability of EHL in water-lubricated systems and offer practical guidelines for surface engineering in compressor bearing design

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Flow of WBC cells of blood samples using microfluidic chip and cytometric analysis

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ABSTRACT

In Poiseuille flow, lateral migration of randomly distributed fluid particles was observed by Segre and Silberberg which suggested the existence of some form of lift force acting on these particles. Additionally, the particles reach a stable dynamic equilibrium at the annulus. Later theoretical analyses suggested that there are two opposing forces that dominate in this situation for neutrally buoyant particles: 1) the wall-induced lift force (or wall effect lift force), due to the interaction between the particle and the adjacent wall, which directs the particle away from the wall and 2) the shear gradient induced lift force, due to the curvature of the velocity profile, which directs the particle away from the channel centre. A microfluidic chip is a miniaturized device made from glass, silicon or polymers consisting of microchannels that manipulates tiny amounts of fluids for various applications, particularly in biological and chemical experiments. RBCs and WBCs being different in size and masses (WBCs being heavier than RBCs), will experience different lift forces and hence the resulting equilibrium alignment of WBCs and RBCs will be different as the blood flows through the microfluidic chip. Based on the difference in alignment the two-way microfluidic chip separates the blood into two flows: one RBC dominated blood flow and the other WBC dominated flow. Hence this study was undertaken in Microfluidic lab of IIT BHU to separate White Blood Cells (WBCs) and Red Blood Cells (RBCs) from a given blood sample and observing the flow of WBC cells through the computer connected with the CBC machine. In the machine, the WBC dominated sample flows through a passage in which the WBC cells are centrally aligned and their flow can be observed in detail using a computer connected to the CBC machine. Same goes for the RBC dominated blood flow. But due to the very small size of the RBC cells and the not so visible in the computer during the blood flow. Hence the working principle of a microfluidic chip to separate different cells of a given blood sample was thoroughly realized and flow of WBC cells was observed under different flow rates using Cytometry analysis / CBC machine.

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Tribological Analysis for Single Point Incremental Forming of stainless Steel 316L sheet using WC tool.

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ABSTRACT

The Single Point Incremental Forming (SPIF) is one of the rapid prototyping processes which is capable to form complex free form surfaces without using dedicated dies. SPIF of hard to form sheet material such as stainless steel, is associated with significant degradation of tool tip surfaces. This degradation consequences in increase in surface roughness of the formed component. Due to degradation, the radius of curvature of hemispherical tool tip will also get affected and causes inaccuracies in geometry of the formed component. The present work investigates the effect of key process parameters i.e. Feed rate and tool spindle speed on surface roughness and wear/deposit on the tool tip surface. Hence, this paper discusses the tribological behavior of AISI 316L stainless steel sheet while single point incremental forming using hemispherical ended tungsten carbide tool. Experimental results show that maximum surface finish and minimum deposit will be obtained with zero tool spindle speed condition. Higher feed rate with tool spindle speed condition results in high deposition on tool tip surface which consequences in reduction in quality of surface finish of formed component.

Keywords: SPIF; Tool wear; Deposit; Roughness; Stainless steel.

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Modeling and Experimental Study of Alcohol-Based Additive Chain Length Effects on Friction, Energy Efficiency, and Lubricant Stability in Aluminium Cold Rolling

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ABSTRACT

Cold rolling of aluminium requires efficient lubrication to minimize friction, lower power consumption, and control heat transfer. Alcohol-based boundary additives are attractive because of their strong interaction with aluminium oxide surfaces, yet their tribological performance is strongly governed by molecular chain length. In this study, rolling model experiments were conducted on both softer and harder aluminium alloys using 6.5% alcohol additives of varying chain length (C12, C14, C16, and C18). Longer-chain alcohols reduced friction and power consumption, enhancing overall rolling efficiency. However, practical challenges arise: C16 and C18 exhibited phase separation near room temperature due to low pour points, complicating storage, blending, and operational stability. To address this, further studies were carried out with medium-chain alcohols—C12, C14, and C16—within optimized concentration ranges: C12 (0–10%), C14 (0–10%), and C16 (0–2%). Both modeling and experimental analyses confirmed a strong correlation between chain length, tribological response, and energy efficiency, while highlighting the stability trade-offs of longer molecules. These results suggest that carefully tailored blends of medium-chain alcohols can achieve both stable lubrication and energy-efficient rolling. The study provides a framework for designing alcohol-based additives for aluminium cold rolling across alloys of different strengths.

Keywords: Aluminium cold rolling; Alcohol additives; Chain length; Energy efficiency; Lubricant stability.

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Impact of tribology in lubricants industries - how can academia support industries?

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Friction, wear, and lubrication account for a surprisingly large share of the world's energy losses and maintenance spend; targeted tribology can cut these losses materially while boosting asset reliability and sustainability. Recent syntheses estimate that ~23% of global energy consumption originates from tribological contacts—an enormous opportunity for industry, especially in high-duty Indian sectors like steel, mining, automotive, rail, textiles, wind, and food processing. Academia is a critical force multiplier when it translates fundamental insights on surfaces, interfaces, and chemistries into deployable lubricants, greases, coatings, textures, and test methods. The talk explores selected industry–academia collaboration models such as scholarships, short courses, and forums, highlighting proven formats from the USA and Europe—like government-funded consortia (DOE/Argonne), University Technology Centres (e.g., SKF at Imperial College), Austria's COMET competence centers, and nCATS (Southampton) for testing and consulting. It concludes with the needs of lubricants industries and some recommendations for India academia.

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Nano-Wear and Tribological Behaviour of TaN/CrN/ZrN Thin Films Deposited for Biomedical Applications

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ABSTRACT

The increasing demand for durable, wear-resistant, and biocompatible coatings in biomedical implants motivates the development of advanced nitride-based thin films. In this study, TaN/CrN/ZrN multilayer coatings were deposited on biomedical-grade substrates using magnetron sputtering to enhance surface durability under physiological conditions. The multilayer architecture was designed to utilize interface strengthening and crack-arresting mechanisms. The coatings were evaluated for structure, morphology, and hardness. Nano-wear tests were carried out to assess resistance to plastic deformation, while tribological studies under simulated body fluid conditions measured friction and wear performance. Results showed that the multilayer films exhibited higher hardness and significantly lower wear volume compared to monolayer coatings. The friction coefficient remained consistently low, indicating stable sliding behaviour. The combined action of TaN, CrN, and ZrN layers contributed to effective load distribution, suppression of crack propagation, and improved overall surface protection. These findings indicate that TaN/CrN/ZrN multilayer thin films are promising candidates for biomedical applications, offering a balance of mechanical strength and tribological stability required for long-term implant performance.

Keywords: Thin films, Tribology, TaN/CrN/ZrN, Nano-wear, Biomedical coatings, Multilayer architecture

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Wear and Tribology of Multilayer NiCoCrAlYTaHf/YSZ Coatings on Superni-718

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ABSTRACT

This study investigates the wear and tribological performance of multilayer thermal barrier coatings (TBCs) deposited on Superni-718 superalloy substrates. A dual-layer architecture consisting of a NiCoCrAlYTaHf metallic bond coat and an 8 wt.% yttria-stabilized zirconia (Y_2O_3-ZrO_2) ceramic top coat was synthesized using direct current (DC) magnetron sputtering. The microstructural characteristics, hardness, adhesion strength, and surface morphology of the coatings were systematically analyzed. Tribological behavior was evaluated under varying loads and sliding conditions to assess wear resistance and frictional response. Results reveal that the multilayer coating exhibits enhanced hardness, improved adhesion, and significantly reduced wear compared to the uncoated substrate. The superior performance is attributed to the synergistic role of the NiCoCrAlYTaHf bond coat in improving coating adherence and the Y_2O_3-ZrO_2 ceramic layer in providing thermal and mechanical protection. These findings highlight the potential of DC magnetron sputtered multilayer TBCs in improving the durability and reliability of Superni-718 components for high-temperature applications.

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Optimization of Friction and Wear Behaviour of AZ91D Magnesium Matrix Composite Reinforced with Boron Carbide and Graphite under Dry Sliding Conditions

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ABSTRACT

As present study explores the enhancement of mechanical and wear characteristics of AZ91Dmagnesium alloy through reinforcement with Boron Carbide (B_4C) and Graphite (Gr), fabricated using the stir casting method. A key objective was to assess the influence of different operational factors—specifically, applied loads (10 N, 20 N, 30 N) and sliding distances (1 km, 2 km, 3 km)—on the tribological behavior of the developed composites under dry sliding conditions. The experimental design followed an L9 orthogonal array approach. Micro Vickers hardness testing and compression testing were performed to evaluate mechanical strength, while wear loss and coefficient of friction were measured using pin-on-disc tribometer. SEM and EDS analyses provided confirmation of the homogeneous dispersion of the reinforcements as well as the surface morphology of the tested samples after wear. The incorporation of B_4C enhanced the composite's hardness and tensile strength, while the hybrid combination with Graphite further reduced wear loss and CoF. Analysis of variance (ANOVA) confirmed that applied load had the most significant impact on wear behavior. These findings demonstrate the combined effect of B_4C and Gr in improving the overall tribological performance of AZ91D composites.

Keywords: *AZ91D, Stir Casting, Hardness, Composite, Wear loss, ANOVA*

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Integrated assessment of performance, circularity, and carbon footprint for hydraulic fluids using re-refined Group II, virgin Group II, and biodegradable synthetic ester base stocks

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ABSTRACT

Hydraulic fluids play a pivotal role in the performance and reliability of industrial, mobile, and marine systems. As sustainability imperatives reshape procurement and formulation strategies, the choice of base stocks, particularly between virgin Group II, re-refined Group II (RR-Group II), and biodegradable synthetic esters (HEES), has emerged as a critical determinant of environmental impact, circularity, and technical efficacy. This study presents an integrated assessment framework that consolidates life cycle analysis (LCA), performance testing, and circularity indicators to guide fluid selection in diverse operational contexts. The paper synthesizes fluid test reports, existing literature and augments it with new component-level testing, including Danfoss Vickers 35VQ25 pump and FZG gear tests, to isolate base-stock effects under standardized conditions. All fluids tested were ISO VG 32 and blended with zinc free additive packages to ensure comparability. Results reveal that RR- Group II base oils deliver up to 80% lower cradle-to-gate greenhouse gas emissions compared to virgin Group II, without compromising on viscosity, wear resistance, or compatibility. HEES fluids, while exhibiting higher carbon intensity and cost, offer superior lubricity, oxidative stability, and biodegradability, making them ideal for ecologically sensitive applications. A multi-criteria decision matrix is proposed to balance technical performance, carbon footprint, circularity, biodegradability, and cost. RR-Group II emerges as a compelling option for mainstream hydraulic applications where sustainability and supply-chain resilience are prioritized. HEES is recommended for niche environments requiring stringent environmental compliance. The study also identifies key limitations in current LCA methodologies and calls for expanded cradle-to-grave assessments and long-term field data to validate laboratory findings. By integrating technical, environmental, and circularity metrics, this paper provides a robust framework for fluid specification and procurement, enabling stakeholders to make informed, context-sensitive decisions that align with both operational and sustainability goals.

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Assessing Coating Durability under Rain Impact: A Study with DUCOM Rain Erosion Tester (ISO 1G3G2-3)

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ABSTRACT

The durability of protective coatings is critical in components exposed to harsh rain erosion environments, particularly in aerospace and energy sectors. Rain impact causes progressive material loss, compromising surface integrity and performance of components. This study evaluates coating and composite material behavior using the DUCOM Rain Erosion Tester, employing a pulsed jet impingement method compliant with ISO 19392-3 standard. Polymer coated Al-6061 and composite specimens were subjected to high-velocity water droplet impacts with controlled parameters: impact velocities ranging from 150 to 250 m/s, droplet diameter of 2 mm, impact angles of 45° and 90°, and impact frequencies up to 50 Hz that simulate real-world service environments. Mass loss measurements demonstrated coating degradation correlating strongly with increased velocity and exposure duration; while composites exhibited characteristic surface degradation and delamination under similar conditions. Pulsed jet method effectively simulated realistic rain impact cycles, revealing coating failure after extended exposure intervals as specified by ISO 19392-3. These results confirm the DUCOM Rain Erosion Tester's capability to precisely replicate standardized rain erosion phenomena, delivering critical insights into the protective behavior and failure mechanisms of advanced coatings and composites. This advanced testing approach supports material optimization for enhanced lifespan and reliability in demanding operational environments.

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Potential of Carbon-Based Nano-Oil as MQL Medium in Grinding Using Touch-Dressed cBN Wheels Having Patterned Grit Distribution

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ABSTRACT

The present study investigates the performance of carbon-based nanofluids as cutting fluids during surface grinding of AISI 52100 steel under a minimum quantity lubrication (MQL) environment using single-layer brazed microcrystalline cBN wheels with patterned grit distribution. These brazed wheels, unlike conventional electroplated ones, offer higher grit exposure and larger inter-grit spacing, facilitating efficient chip removal and lubricant access. Microcrystalline cBN wheels were touch-dressed to increase active grain density and maintain stable wheel topography, thereby enhancing grinding performance and fluid interaction. Graphite and diamond nanoparticles were dispersed in palm oil to formulate nanofluids, with pure palm oil serving as a reference. Preliminary pin-on-disc tests using a cBN-brazed steel pin and hardened AISI 52100 disc revealed improved wettability and frictional behavior for graphite-based nanofluids, while diamond-based suspensions yielded smoother surfaces due to their lapping effect. Subsequent grinding tests showed that touch- dressed wheels exhibited better performance consistency. Incorporating nanoparticles significantly enhanced palm oil's lubricating ability, reducing specific grinding energy by 46% with graphite and improving surface finish by 28% with diamond nanoparticles. Overall, graphite and diamond nanofluids demonstrated superior lubrication and cooling efficiency, promoting stable grinding wheel topography under MQL conditions.

Keywords: Microcrystalline brazed cBN wheel; Nanofluid; Pin-on-disc test; Anti-frictional characteristics; Touch dressing.

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Influence of WC reinforcement on the Wear Characteristics of AISI 316L WAAM Cladding on Medium Carbon Steel

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ABSTRACT

This study investigates the tribological and mechanical performance of tungsten carbide (WC)-reinforced SS316L stainless steel claddings fabricated via Wire Arc Additive Manufacturing (WAAM) on medium carbon EN8 steel substrates. Two reinforcement levels 10 wt.% (10WC) and 20 wt.% (20WC) WC were incorporated into the cladding to enhance wear resistance and hardness. Wear tests were conducted using a ball-on-disc tribometer at room temperature (29 °C) and elevated temperature (500 °C) under two loads (10 N and 40 N). Results show that both WC-reinforced claddings significantly outperformed the uncoated EN8 base steel in wear resistance, with 10WC exhibiting superior performance under harsh conditions due to uniform particle distribution and minimal interfacial changes. The 20WC sample achieved the highest hardness (approximately 3.9 times that of the base material) via multiple strengthening mechanisms, including Orowan, grain refinement, load transfer, and dislocation effects. Coefficient of friction (CoF) decreased with increasing load, linked to tribo-oxidation and debris formation, with minimal variations at elevated temperatures. Compared to similar studies on WC reinforced steels, these claddings show comparable or better wear reductions (up to 60%) but highlight challenges like agglomeration and thermal mismatch stresses affecting long-term integrity under cyclic loading. These findings underscore the role of WC content in optimizing WAAM claddings for high load, high-temperature applications, with potential benefits from gradient distributions.

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Development Of Sustainable Biocomposite from Terminalia Chebula (Haritaki) Particulates for Tribological Applications

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ABSTRACT

Creating environmentally friendly materials like polymer matrix composites (PMCs) enhanced with natural fillers has grown in recent decades. Particulate fillers are often used in tribological applications to enhance friction and wear of polymeric materials. High cost of particulate fillers sometimes restricts their use. However, low-cost particulate fillers obtained from bio-waste, industrial waste and constructional waste can be used if research out successfully in polymer-based composite for tribological applications. The main objective of this study is to investigate the mechanical and erosive wear properties of Terminalia Chebula seed particulate (a bio waste) reinforced epoxy composite. The characterization of Terminalia Chebula seed particulate was carried out using SEM, FTIR, EDX and XRD. Mechanical characterization and erosive wear study of fabricated composites (0, 10, 20, 30 and 40 wt. %) was performed at ambient temperature with various operating parameters. An air jet erosion test rig (designed as per ASTM standard G76) is used for the purpose. The experimental results shown that mechanical and erosive wear property of neat epoxy has increased significantly by TCP filler reinforcement. The outcomes of the solid particle erosion test clearly indicate the semi-ductile nature of the composite behaviour. The surface morphology of worn and fractured surfaces was carried out using SEM to find out the failure mechanism.

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Enhanced Wear Resistance of Laser Powder Bed Fused 316L Stainless Steel via WS_2 Nanoparticle Reinforcement

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ABSTRACT

The limited wear resistance of 316L stainless steel often compromises the longevity and reliability of components in biomedical implants and industrial machinery. To address this, the present study explores the strategic reinforcement of 316L with tungsten disulfide (WS2) nanoparticles fabricated via Laser Powder Bed Fusion (LPBF). Composites with 1, 3, and 5 wt.-% WS2 were produced to systematically evaluate their microstructure, mechanical properties, and tribological performance under dry sliding conditions at 25°C and 37 °C. Microstructural analysis revealed significant grain refinement and homogeneous WS2 distribution, which contributed to enhanced hardness, with the 5 wt.-% composite achieving a peak cross-sectional hardness of 254 HV. Tribological tests demonstrated a dramatic improvement in wear resistance, particularly for the 5 wt.-% WS2 composite, which exhibited a 21% and a remarkable 44% reduction in volumetric wear rate at 25 °C and 37 °C, respectively, compared to the unreinforced 316L. Analysis confirmed that this superior performance was governed by the formation of a protective WS2-rich tribofilm, which minimized direct metal-to-metal contact. This work successfully demonstrates the potential of LPBF-manufactured 316L/WS2 composites to serve as high-performance materials for applications requiring for advanced biomedical implants and industrial components.

Keywords: 316L stainless steel, Tungsten disulfide (WS2), Additive manufacturing, Metal matrix composites.

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Optimization of Process Parameters for tribological performance using the synergistic effect of PAO-based nano lubricants incorporating chemically functionalized nano additives and ionic liquid

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ABSTRACT

This study addresses the optimization of various process parameters using Response Surface Methodology (RSM), followed by tribological evaluation of PAO 4-based nanolubricants and hybrid nanolubricants under optimized process parameters. Initially, oleic acid-functionalized boron nitride (oBN) nanosheets were synthesized via a hydrothermal process, and its successful functionalization was confirmed using XRD, FTIR, Raman, HR-SEM, and TEM. The RSM with a CCD was applied to determine the optimal conditions for tribological performance in a reciprocating-type tribo rig setup. The key parameters considered were applied load (20N–50N), sliding velocity (0.03–0.07 m/s), and oBN nanosheet concentration (0.025 wt.%–0.1 wt.%). Model validation showed high accuracy, with R2 values of 0.9812 for COF and 0.9589 for wear volume, confirming the predictive reliability of the RSM. The optimized tribological conditions were identified as a load of 35N, a sliding velocity of 0.05 m/s, and 0.0625 wt.% concentration of oBN nanosheet. Following optimization, a range of nanolubricants and hybrid nanolubricants were formulated, and their anti-wear and anti-friction performances were assessed through tribological testing, worn surface analysis, and Raman spectroscopy. The results indicated that a hybrid nanolubricant incorporating 0.0625 wt.% of oBN nanosheet and 1 wt.% of ionic liquid in PAO-4 achieved 33.15% reduction in Coefficient of Friction (COF), 81.47% decrease in wear volume (WV), 40.74% reduction in wear track width (WTW), and a 69.59% decrease in root mean square roughness (Sq), demonstrating significantly improved tribological performance compared to PAO 4. These findings provide valuable insights into the development of advanced lubricant formulations from a research perspective.

Keywords: Response Surface Methodology, Boundary lubrication, nanoadditive, Ionic liquid

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Enhanced Rheological and Tribological Performance of Jatropha Based Bio lubricants Using rGO/MoS_2 Hybrid Nanoparticles for Sustainable Industrial Applications

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ABSTRACT

The study develops high-performance bio lubricants from on-edible Jatropha oil enhanced with reduced graphene oxide/molybdenum disulfide (rGO/MoS_2) hybrid nanoparticles as a sustainable alternative to petroleum-based lubricants. Trimethylolpropane esters (JTMPE) were synthesized through a three-step transesterification process, and rGO/MoS_2 nanoparticles were prepared at a3:2 mass ratio using hydrothermal synthesis and incorporated into the JTMPEatconcentrations of 0.1 to 1.0 wt%. Rheological characterization revealed exceptional viscosity-temperature stability, achieving the highest viscosity index of 230.58at1.0 wt.% concentration, representing a 16% improvement over the base JTMPE while maintaining Newtonian behavior. Tribological evaluation using a four-ball tribometer demonstrated optimal performance at 0.6 wt.% concentration, achieving 38.9% friction reduction and a 34% wear scar diameter reduction compared to base JTMPE. Extreme pressure testing revealed that a1.0 wt.% concentration achieved a load wear index of 32.14 kgf, representinga57%improvement. Lubrication regime analysis showed a transition from boundary to mixed lubrication above 0.3 wt.% concentration. Surface morphology analysis through FE-SEM and EDAX confirmed protective tribo film formation containing carbon, molybdenum, and sulfur elements, validating the synergistic lubricationmechanism. The superior performance is attributed to the favorable interaction between the polar molecular structure of the biolubricant and the hybrid nanoparticles, facilitating enhanced dispersion stability and tribo film formation. These findings establish rGO/MoS_2-enhanced JTMPE as a viable sustainable lubricant for demanding industrial applications.

Keywords: Trimethylolpropane ester; Four Ball Tribometer; Antiwear; Extreme pressure; Sustainable lubrication

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Beyond Oil Sampling: Aiot-Driven Tribology for Predictive and Sustainable Maintenance

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ABSTRACT

Unplanned failures from lubricant degradation and wear debris drive significant costs, while periodic lab sampling lacks timeliness. This paper presents an AIoT framework that transforms oil condition monitoring into a continuous, shop-floor signal for predictive maintenance and sustainability. Inline laser-particle sensors, paired with viscosity and temperature channels, stream data via industrial protocols (Modbus TCP/OPC-UA to edge; MQTT/TLS to cloud). Analytics fuse standards-based metrics (ISO 4406 cleanliness, particle size distributions, wear ratios, viscosity drift) with a hybrid CNN–LSTM model and Bayesian change-point detection, generating early warnings, lead-time estimates, and actionable recommendations.

A 180-day deployment on a continuous caster showed ~30% fewer lubrication-related breakdowns and ~40% lower oil consumption through targeted filtration and extended drain intervals, validated by inspections and lab assays. Robust operation was ensured through sensor calibration, edge buffering, model-drift monitoring, and secure role-based access aligned with IEC 62443. Contributions include: (i) a sensing-to-insight stack for tribological assets, (ii) a learning framework combining standards and deep sequence modeling for interpretable decisions, and (iii) plant-scale evidence of reliability and sustainability gains. Ongoing work explores multimodal fusion, adaptive re-training, and technician-facing explanations to enhance trust and actionability.

Keywords: Tribology; Predictive maintenance; AIoT; Laser particle counting; Oil condition monitoring; CNN–LSTM; Bayesian change-point detection; IEC 62443.

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Influence Of Operation Conditions on Grease Performance in Rolling Element Bearings

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ABSTRACT

Greases are the primary lubricants used in rolling element bearings due to their ability to stay in place and provide long-term protection. Despite their widespread use, research on grease behaviour under operational stresses remains limited compared to oils. Greases are subjected to harsh and varying conditions, including high loads, elevated temperatures, and intense shear forces, which can significantly influence their performance and reliability. Understanding how greases behave under such conditions – especially across different production batches – is essential for ensuring consistent quality and functionality.

This study investigates the tribological and rheological properties of a high viscosity grease produced in multiple batches. The results reveal that mechanical and thermal stresses can alter the structural integrity and thermal stability of the grease. Notably, a correlation was observed between rheological parameters and leakage behaviour, suggesting that flow properties may serve as indicators of in-service performance. These findings underscore the importance of precise manufacturing controls and batch consistency in developing greases tailored for demanding applications. The study advocates for further research into additional influencing factors, such as thickener structure, additive interactions, and long-term aging, to deepen our understanding of grease behaviour under real-world operating conditions.

Keywords: Greases, lubrication, bearings, stresses, rheology

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Evolution of Morphological and Wettability Behaviour During Reduction of Graphene Oxide

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ABSTRACT

Surface wettability plays a decisive role in determining the functional performance of nanomaterials in diverse applications ranging from lubrication and coatings to biomedical and energy devices. In the present investigation, a nanomaterial surface (especially Graphene Oxide) is reduced using different techniques which leads to a systematic modification of its morphological characteristics, with emphasis on interfacial adhesion, surface texture, and energy dissipation at the sliding contact. Detailed surface morphology was investigated using Scanning Electron Microscope (SEM), providing insights into the structural modifications induced during the reduction process. Complementary chemical characterization was carried out through Raman Spectroscopy and Fourier-Transform Infrared (FTIR) Spectroscopy, confirming the progressive removal of oxygen-containing functional groups and the enhancement of graphitic domains. Wettability studies were performed using a Contact Angle Goniometer, which revealed a systematic transition in hydrophilic to hydrophobic nature with degree of reduction. These combine analyses not only establish the correlation between surface morphology, chemical purity, and wettability but also provide a foundation for tailoring reduced graphene oxide for practical applications. The findings of this work are expected to be particularly useful for tribological performance enhancement, moisture harvesting technologies, next-generation lubrication, thermal management, bio-interface and other related technologies.

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Synergistic Enhancement of Rheological and Thermal Properties in Polyalphaolefin-Based Hybrid Nanolubricants Using Melamine Functionalized Graphene Oxide and Imidazolium Ionic Liquid

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ABSTRACT

This research explores the synergistic effects of melamine-functionalized graphene oxide (mGO) and imidazolium ionic liquid (IL) on the rheological properties and thermal stability of polyalphaolefin (PAO)-based hybrid nanolubricants. By incorporating mGO, with its enhanced surface functionality, and IL, known for its low volatility and high thermal resistance, into PAO, the study achieves notable improvements in key lubricant characteristics. Rheological tests show that the hybrid nanolubricants have increased viscosity, better shear stability, and improved viscoelastic behavior, due to strong intermolecular interactions between mGO's melamine groups and IL's ionic structure, which support uniform nanoparticle dispersion and good interfacial compatibility with the PAO matrix. Thermogravimetric and differential scanning calorimetry analyses further confirm superior thermal stability, with the nanolubricants exhibiting higher decomposition temperatures and lower oxidative degradation rates compared to pure PAO. The synergistic interaction between MGO and IL creates a durable protective network that reduces thermal breakdown at high temperatures. These results highlight the potential of mGO-IL hybrid nanolubricants for advanced tribological applications in demanding industrial and automotive systems, where enhanced lubrication, wear resistance, and thermal endurance are crucial.

Keywords: Graphene; Functionalized Graphene oxide; Ionic liquid; Nanolubricants; Rheology

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Investigation of velocity slip on PVP lubricated conical porous hybrid journal bearing system

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ABSTRACT

In recent years, porous journal bearings are widely preferred in various industrial applications (viz., automotive industry, medical instruments, household appliances, etc.) attributed to their inherited advantages of self-lubrication, low maintenance and quite operation. Additionally, various coating materials are applied on bearing's surface to improve the tribological behavior of journal bearing system. Moreover, different kinds of long chain polymer additive particles are mixed in the base oil to improve their tribological performance. At higher pressure conditions, these lubricants can be idealised as Piezo-viscous polar (PVP) lubricant. Therefore, a novel form of Reynolds equation has been developed to examine the influence of velocity slip on the behavior of conical porous journal bearing operating under PVP lubrication. Incorporating Galerkin's orthogonality technique, the modified form of Reynolds equation is solved to evaluate the oil film pressure distribution and subsequently, other static and dynamic performance parameters of bearing system. The computed results have been presented for selective range of velocity slip coefficient and permeability parameters. These simulated results indicate that the synergistic effect of velocity slip and bearing's porosity significantly affect the performance of conical bearing. Furthermore, the usage of PVP lubrication offers substantial enhancement in bearing's performance characteristics vis-à-vis Newtonian lubrication.

Keywords: Velocity slip, Porosity, Conical bearing, Couple-stresses, Piezo-viscosity.

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Effect of recess shapes on the tilted operation of orifice compensated hydrostatic thrust pad bearing with PVP lubricant

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ABSTRACT

Tilting in the operation of a Hydrostatic thrust pad bearings (HTPB) system is foreseeable due to thermal distortion, manufacturing tolerance, and assembly errors etc. Furthermore, advancements in manufacturing technologies provide flexibility to manufacture complex shape or form of recess in a HTPB systems. Moreover, in order to gain the lubricating performance, various types of natural and synthetic polymers are blended into the base oil. Long-chain polymer-based additives provide a polarity effect in the lubricants. At high-pressure working conditions, the lubricant may achieve piezo-viscosity. This article aims to perform a comparative numerical study to investigate the combined influence of different recess shapes (circular, annular, rectangular and square) and tilting on the performance of the orifice compensated HTPB lubricated by piezo-viscous-polar (PVP) lubricant. To model the behaviour of such lubricant in a HTPB system, Barus' law and Stocks' micro-continuum theory concurrently used to obtain a modified form of Reynolds' equation. A finite element model is developed to solve the modified Reynolds equation and thereby characteristic parameter of a HTPB system. The results indicate that recess shapes substantially influence the performance of an orifice-compensated tilted HTPB system significantly. HTPB system operating with PVP lubricant offers 31.73% to 69.34% enhanced values of damping coefficient and 33.68% to 56.08% reduced values of oil flow rate than Newtonian lubricant.

Keywords: FEM; Hydrostatic thrust; tilting; piezo-viscous-polar.

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Poly-ethylene glycol esters of fatty acids and estolides – their synthesis and applications

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ABSTRACT

The transition from mineral oil-based lubricants to sustainable and high-performance bio lubricants is critical for mitigating environmental impact and improving economic stability. Polyethylene glycol (PEG) esters of fatty acids represent a promising class of tunable biolubricants and surfactants due to their renewable feedstock and superior functional properties. However, their widespread adoption is hampered by conventional chemical synthesis routes that has higher carbon footprint and produces harmful side-products, preventing their use in cosmetics, home and personal care applications. Herein, we report a energy efficient and green biocatalytic platform utilizing lipase-catalysed esterification for the synthesis of a portfolio of high purity (98%+) and contaminant-free PEG esters. This work includes the reaction of oleic acid and oleic estolide with polyethylene glycols of varying chain lengths (PEG 200, 400, 600) in the presence of a commercial lipase catalyst under solvent-free and mild temperature conditions and the characterisation of the synthesised esters for its application in lubricants and Emulsifying esters. This work establishes a technologically superior and sustainable manufacturing route for PEG esters, and study of its tribological and surfactant properties for its use as metal working fluid.

Keywords: Self emulsifying esters; Metal working fluids; Estolide esters; Bio-lubricant; Enzymatic pathway; Green synthesis.

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Tribology-driven sustainable design: mechanical evaluation of nano modified epoxy coatings for wind turbine blades

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ABSTRACT

Increasing the operational lifespan of green energy systems is crucial in addressing issues related to end-of-life and promoting recyclability within a circular economy framework. Sustainable solutions that can mitigate the carbon footprint are being utilized quickly. This work investigates the relative performance of protective coatings developed for wind turbine blades, which are a key component and often compromised by erosion. Epoxy and nano modified epoxy were fabricated using varying small weight percentages of nano- modifier. Performance analysis of all nanomodified and pristine epoxy is evaluated by tensile testing, single-edge notch fracture toughness tests, hardness assessments, and controlled water- jet erosion. The findings show that adding nanoscale reinforcements to epoxy matrices considerably increases durability without compromising process viability. These improvements imply that nano-modified epoxy composites offer a viable path toward stronger, more durable blade protection. This strategy could significantly contribute to lowering material deterioration, increasing service intervals, and bringing wind energy technology into line with more general sustainability objectives.

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Heat Treatment-Induced Phase Evolution and Tribological Performance of Electroless Ni–B–Sn and Ni–B–W–Sn Coatings with Layered Architectures

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ABSTRACT

This study examines the effect of heat treatment on the structural and tribological response of electroless Ni–B–Sn and Ni–B–W–Sn coatings with varied layer architectures including single, bi-layer, duplex, and multilayer designs. Coatings were deposited on low-carbon steel substrates and subsequently heat treated at 300 °C and 400 °C to assess thermal stability and wear behaviour. X-ray diffraction (XRD) revealed that the as-deposited coatings were predominantly amorphous, while heat treatment promoted partial crystallization. Reciprocating wear tests at room temperature showed that heat-treated coatings performed better than their as-deposited coatings, although the extent of improvement depended on the coating architecture. Heat treatment at 400 °C yielded higher crystallinity, leading to reduced wear, whereas at 300 °C retained a mixed amorphous–nanocrystalline state. The wear track morphology as revealed by FESEM demonstrated that surface degradation is governed by the interdependent effects of heat treatment and coating architecture. These insights provide a clear pathway for designing thermally stable, wear-resistant electroless coatings tailored for demanding applications in automotive, aerospace, and tooling industries.

Keywords: Multi-layer coating; Ni-B-Sn; Ni-B-W-Sn; Heat treatment; FESEM; XRD.

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Predictive Machine Learning Models for Tribological Performance of Al6061 – Based Composites

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ABSTRACT

Aluminium 6061 (Al6061) metal matrix composites (MMCs) reinforced with TiO_2, CNTs, graphene, and SiC offer high strength, low weight, and wear resistance for automotive and aerospace applications. However, their tribological behavior wear rate, friction force, and interface temperature shows complex, non-linear dependence on factors like reinforcement type, temperature, and sliding speed, making prediction difficult. Conventional pin-on-disc tests are costly and limited in handling multi-variable interactions. This study reviews existing literature and proposes a data-driven machine learning (ML) framework using Random Forest, XGBoost, SHAP, and clustering techniques to predict tribological performance efficiently. The approach reduces experimental effort and supports virtual screening for optimized material and process selection.

Keywords: Al6061; Metal Matrix Composites; Machine Learning; Wear Prediction; Random

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Tribological Insights into Tea Pest Management: Evaluating Servo Orchard Spray Oil Against Oligonychus coffeae

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The tribology of tea cultivation—encompassing surface interactions between plant tissues and external agents—plays a critical role in pest management strategies. In this context, Servo Orchard Spray Oil, a petroleum-based horticultural formulation developed by IndianOil, was rigorously assessed for its tribological efficacy against the tea red spider mite (*Oligonychus coffeae*), a notorious pest that compromises leaf integrity and crop yield.

Laboratory investigations focused on the oil's behavior as a surface-active agent, examining its performance at 0.5%, 1.0%, and 1.5% concentrations. Key tribological parameters included contact-mediated mite mortality, interference with oviposition mechanics, and surface repellency. The oil's film-forming capability altered the leaf's surface energy, impeding mite adhesion and locomotion. This led to concentration-dependent mortality and a significant reduction in egg deposition and viability—highlighting the oil's potential to disrupt the pest's reproductive cycle through surface modification. Field trials under natural infestation conditions reinforced these findings. Servo Orchard Spray Oil demonstrated comparable bio-efficacy to Propargite 57 EC, a conventional miticide, by reducing mite populations through tribological interference rather than chemical toxicity. The oil's ability to form a persistent, non-phytotoxic barrier on leaf surfaces contributed to its effectiveness, without compromising the tribological properties critical to tea quality—such as leaf texture, liquor clarity, and flavor profile. Importantly, no adverse wear or degradation of tea leaf surfaces was observed, affirming the oil's compatibility with the delicate tribological balance required in commercial tea production. Sensory evaluations confirmed that the treatment did not alter the tactile or gustatory attributes of processed tea.

In conclusion, Servo Orchard Spray Oil exemplifies a tribologically-informed approach to sustainable pest control in tea plantations. By leveraging surface modification and lubrication principles, it offers a non-invasive, eco-friendly alternative to synthetic pesticides, aligning with integrated pest management and long-term crop health.

Key words: Tribology of tea, Oligonychus coffeae, Servo Orchard Spray Oil, surface interactions, pest control, leaf lubrication, bio-efficacy, sustainable agriculture.

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Combined Simulation and Experimental Study

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ABSTRACT

This study investigates the effects of nature-inspired textured tools on the turning process of 1020 steel, combining both simulation and experimental approaches. Deform 3D simulation is used to analyse the cutting forces, temperature, and surface roughness, while experimental trials are conducted to validate the simulation results. The textured tool is designed based on biomimetic principles, replicating the surface features of lotus leaves and butterfly wings. The results show that the nature-inspired textured tool reduces the cutting forces and temperature by 20.5% and 12.8% in simulation, and 22.1% and 15.3% in experimentation, respectively, compared to a conventional i.e. non-textured tool. The surface roughness is also improved by 25.6% in simulation and 28.9% in experimentation. The study demonstrates the potential of nature-inspired textured tools in improving the efficiency and effectiveness of machining processes, and highlights the good agreement between simulation and experimental results.

Keywords: Nature-inspired texture; Texture pattern; Conventional Turning; 1020 steel; Integrated optimization method.

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Deform 3D Simulation of Turning of Steel using Nature-Inspired Textured Tool

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ABSTRACT

This paper presents a numerical investigation into the effects of nature-inspired textured tools on the turning process of mild steel using Deform 3D simulation. Machining is the process of removing material from a workpiece surface using a cutting tool, in order to generate the desired product. During the machining, the performance of the tool fully depends on surface tribology, machining parameters, etc., and enhancing the tool's performance is a challenging task. To overcome these issues, surface texturing is essential for the tool. In this article, an attempt is made to develop the python snake skin- inspired (PSSI) texture pattern on the rake surface of the cutting tool for performance enhancement. The textured tool is designed based on biomimetic principles, replicating the surface features of lotus leaves and butterfly wings. The simulation results show that the textured tool reduces the cutting forces and temperature by 23.1% and 15.6%, respectively, compared to a conventional tool. The surface roughness of the workpiece is also improved by 28.5%. The study demonstrates the potential of nature- inspired textured tools in improving the efficiency and effectiveness of machining processes. Lastly, a comparative study is performed to justify the current results with existing results.

Keywords: Turning; Mild steel; Nature-inspired textured tool; Deform 3D simulation; Biomimetic design.

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Comparative Studies of the Mechanical, Wear, Biocompatibility, and Antibacterial Properties of the High-Entropy Steels and 316L

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ABSTRACT

In the present investigation, the non-equiatomic FeMnNiAlSiC, FeMnNiCrAlSiC, and FeMnNiTiAlSiC high entropy steels were successfully prepared using the spark plasma sintering (SPS). The phase formed after the SPS were mainly consisted of dual-phase structures of FCC and B2, along with the nanoprecipitates of silicides and carbides. The present alloys were compared to the standard bioimplant 316L alloy in hardness, elastic modulus, wear rate, cell culture (MG63 cell), and antibacterial (E. coli and S. aureus) properties. The hardness and elastic modulus values of the SPSed samples were found in the range of 7.8 GPa to 10 GPa and 180-205 GPa, which is far better than the 316L alloy. The wear rate of the SPSed samples of the high entropy steels was evaluated in the range of 1.6-2.0 x 10^{-5} mm^3/mN at the 20 N load conditions. These high entropy steels showed excellent biocompatibility in MG63 cells as compared to 316L. Further, these alloys have better antibacterial and wear-resistant properties as compared to the 316L. The preliminary studies in the high entropy steels suggested that they have potential as biomaterials for bioimplant applications.

Keywords: High Entropy Steel; Spark Plasma Sintering; Mechanical Properties, Wear, Biocompatibility, Antibacterial properties.

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Experimental investigation of 20W-40 engine lubricant dosed with TiO2 and SiO2 nano particles on horizontal single cylinder four stroke air cooled diesel engine for improvement of performance

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ABSTRACT

The about 15% power developed by the Diesel engine was lost due to friction in various parts, which resulted into lower performance. Hence, attempt was made to reduce the frictional power by modifying the engine lubricant with the use of TiO2 and SiO2 nano particles. In this study, samples of 20W-40 engine lubricant oil dosed with 1500 ppm TiO2 and SiO2 nano particles was prepared using ultrasonicator and use in horizontal single cylinder four stroke air cooled diesel engine to investigate the thermal efficiency and fuel consumption. The performance of engine was tested under various load conditions and compared with plain 20W-40 engine lubricant. It was observed that brake thermal efficiency and fuel consumption were improved due to addition of nano particles in 20W-40 engine lubricant as compare to without nano particles under all loads. The improvement of Brake thermal efficiency was 24.99% and 41.14% and reduction of Brake specific fuel consumption of 20 % and 29.13 % in 20W-40 engine lubricant + 1000 ppm TiO2 and 20W-40 engine lubricant + 1000 ppm SiO2 samples was obtained compared to 20W-40 engine lubricant. Overall, findings of this study indicated that nano particles plays very important role for lowering frictional power loss.

Keywords: 20W-40 lubricant, frictional power, Horizontal engine performance, TiO2, SiO2

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Buckling Behavior of Piezoelectric Laminated Composite Plates under UDL and SSL with Refined Second Shear Deformation Theory

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ABSTRACT

The Present study contributes to tribology by improving the understanding of deformation and stability mechanisms in piezoelectric laminated composite plates, which directly influence frictional behavior, wear progression, and interface contact reliability in smart structural component. By accurately predicting shear distribution and buckling characteristics under combined mechanical and electrical fields, the work supports the design of surfaces and layered systems with improved resistance to instability-induced damage, delamination, and tribological degradation. A comprehensive analytical and simulation framework is employed to assess the mechanical and electromechanical buckling response. The governing equations are formulated using the principle of virtual work and solved analytically for simply supported configurations to provide clear insight into stability behaviour. The newly developed Refined Second Shear Deformation Theory (RSSDT), based on Grover's kinematic assumptions, is implemented to capture realistic through- thickness shear strains without requiring correction factors. Numerical simulations are carried out for various lamination schemes, aspect ratios, boundary conditions (CCCC and SSSS), and loading patterns (UDL and SSL). Parametric studies reveal the influence of piezoelectric coupling intensity and polarity on the critical buckling load. Although experimental validation is not included, the simulation results match well with benchmark, demonstrating the strong predictive capability of RSSDT for lightweight smart structure design.

Keywords: Piezoelectric laminated composites; buckling behaviour; Refined Shear Deformation Theory (RSSDT); Smart structures.

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Development of Wear Map for Hybrid Aluminium Matrix Composite for High Temperature Applications

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ABSTRACT

High-temperature wear is a critical factor in aerospace, automotive and defence industries, where components operate under thermal and frictional conditions. Metal matrix composites (MMCs) offer a reliable solution for these high-temperature wear environments due to their enhanced strength, wear resistance, and thermal stability. In this study, aluminium alloy 7075 was reinforced with in-situ synthesised TiB2 and Al_2O_3 hybrid particles by using the Al–TiO_2–B system through a liquid metallurgy process. This method ensured a uniform distribution of reinforcement, fine grains and created strong interfacial bonding between the matrix and particles. The fabricated composites were characterised using X-ray diffraction (XRD) and Optical Microscopy to confirm the formation of phases and their dispersion. Mechanical testing revealed that the hybrid reinforcements significantly enhanced hardness, tensile and compressive strength compared to the unreinforced alloy. Tribological performance was evaluated under varying loads and temperatures to construct a comprehensive wear map for the hybrid Al 7075–TiB2–Al_2O_3 composites. This study examines the relationship between temperature and dominant wear mechanisms, providing valuable insights for designing lightweight, thermally stable tribological components for aerospace and automotive applications.

Keywords: High Temperature Wear; Wear Map; Hybrid Composite; Stir Casting; Microstructure.

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Tribofilm Formation under Varying Slide-To-Roll Ratios and Evaluation of its Friction, Noise, and Vibration Response

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ABSTRACT

In the boundary lubrication regime, tribological performance (friction, noise, and vibration) is governed by the tribofilm, a physically or chemically adsorbed layer on the sliding surface. Characterising this layer is essential for evaluating boundary lubricants. This study introduces a new method to characterise tribofilms, validated using stearic acid, a widely used saturated fatty acid additive. The method forms a tribofilm under variable Slide-to-Roll Ratios (SRR), followed by a pure sliding test on the same wear track while simultaneously recording the frictional dissipation, noise, and vibration. This ensures that the actual tribological response of the formed tribofilm is captured. A Force-Controlled Pendulum Tribometer (FCPeT) was developed to implement this approach, without alteration of the actual tribo-contact condition. The friction, noise (L_{eq} (dB)), and vibration (RMS (m/s^2))results showed an increase from 0% SRR (0.1, 9 dB, 0.002 m/s^{2}) to 50% SRR (0.125, 20 dB, 0.010 m/s^2), then decreased up to 200% SRR (0.1, 10 dB, 0.002 m/s^2), before stabilising. This identified a critical SRR near 50%, where performance was poorest. XPS analysis revealed that low SRR promotes a physically adsorbed layer, and high SRR favours chemical adsorption, which takes the load. Around ~50% SRR, neither dominates, causing reduced performance.

Keywords: Tribofilm, Slide to Roll Ratio, Friction, Noise, Vibration, Force- controlled, Pendulum tribometer

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Enhanced Tribological and Machining Performance of h-BN Nanosheet Based Green Cutting Fluids for Ti6Al4V under MQL

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ABSTRACT

In this study, a coconut oil-based nano-cutting fluid was developed by dispersing hexagonal boron nitride nanosheets (h-BNNS). The tribological and physical properties of nano-fluids with varying h-BNNS concentrations were evaluated. Lubrication significantly reduced the coefficient of friction compared to dry conditions, with h-BNNS-based emulsions outperforming the base oil. Among all, the 0.25 mg/ml and 0.5 mg/ml emulsions exhibited superior performance and were selected for further machining analysis. The 0.5 mg/ml h-BN+GCF emulsion showed the best tribological behaviour in pin-on-disk tests under minimum quantity lubrication (MQL). Titanium alloy (Ti6Al4V), widely used in aerospace applications, suffers from poor machinability and high tool wear. The cutting performance of the developed h-BN+GCF emulsion was examined during turning of Ti6Al4V under MQL conditions. Detailed analysis of flank wear, crater wear, and chip surface morphology revealed a descending trend in wear severity from dry machining to base oil, 0.25 mg/ml, and 0.5 mg/ml nano-lubrication. This improvement is attributed to the synergistic effects of enhanced lubrication and tribofilm formation, which reduce friction and thermal stress while extending tool life. The study demonstrates the potential of h-BN-based green cutting fluids for sustainable and eco-friendly machining.

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From Grain to Chip: A Tribological Perspective on Tool Wear in Micro Turning of L-PBF Inconel 718

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ABSTRACT

Inconel 718 (IN-718), a nickel-based superalloy, is widely used in aerospace and high temperature applications due to its exceptional mechanical and thermal properties. While conventional forging and casting dominate its production, laser powder bed fusion (L- PBF) offers enhanced design flexibility and refined microstructures. This study investigates the influence of manufacturing routes on tribological performance during micro-turning of IN 718, with both forged and L-PBF samples subjected to identical heat treatment. Microstructural characterization revealed that L-PBF samples developed finer grains and a 39% hardness increase, compared to 15% in forged counterparts. Systematic micro-turning trials at varying cutting speeds and feed rates quantified cutting forces, surface finish, and tool wear. Forged IN-718 exhibited higher cutting forces, whereas L-PBF samples enabled superior surface quality. Despite similar wear mechanisms, microstructural differences dictated tool degradation: at low feeds, plowing-controlled wear decreased with speed, whereas higher feeds amplified thermal wear. These findings demonstrate that manufacturing-induced microstructure critically governs friction, wear, and overall machinability of IN-718, providing mechanistic insights for optimizing precision machining of advanced superalloys.

Keywords: Inconel 718; L-PBF; Micro-turning; Wear mechanisms; Tribological performance.

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Lubrication-Driven Friction and Wear Mechanisms: Insights from Ti6Al4V/WC Pairs

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ABSTRACT

The tribological response of Ti6Al4V against tungsten carbide is of significant interest in applications demanding high wear resistance, yet the role of lubrication in such systems remains insufficiently understood. This study examines the effects of lubrication on friction and wear using a pin-on-disc configuration under varying loads (30, 50, and 100 N) and sliding speeds (1, 1.5, and 2 m/s) with a lubricant flow rate of 50 ml/min. The coefficient of friction (COF), specific wear rate, and wear volume were evaluated, supported by Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDX). Results revealed that lubrication unexpectedly increased the COF, with a maximum value of 0.57 at 30 N and 1.5 m/s, while the highest specific wear rate of 15.77 mm^3/Nm was linked to the absence of a protective tribo-layer. SEM analysis indicated a combination of adhesion- and fatigue-driven mechanisms characterized by step-like surface features, and EDX confirmed titanium transfer from the disc to the pin, evidencing counterface wear. Overall, the findings demonstrate that lubrication can intensify both friction and wear in Ti6Al4V/WC systems, emphasizing the need for tailored lubrication strategies to optimize component performance and durability.

Keywords: Ti6Al4V; Tungsten carbide; Lubricated sliding; wear mechanisms; Tribo-layer formation.

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Smart Aqueous Biolubricants Based on PNIPAM Microgels and TiO2 Nanoparticles for Implant Wear Mitigation

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ABSTRACT

This study explores the biotribological performance of smart aqueous lubricants comprising thermo-responsive poly(N-isopropylacrylamide) (PNIPAM) microgels and titanium dioxide (TiO2) nanoparticles, designed for potential application in implant wear mitigation. The influence of temperature, TiO2 concentration, and molecular structure of the hybrid system was examined under sliding conditions relevant to biological interfaces. At ambient conditions (~20 °C), the lubrication behaviour was primarily governed by PNIPAM, where lower TiO2 loadings promoted smoother frictional transitions and superior wear resistance. Hybrid variants functionalized with silane groups demonstrated enhanced wear protection compared to their non-silane analogues, while maintaining a comparable coefficient of friction (COF). At 40 °C, above the volume phase transition temperature (VPTT) of PNIPAM, the contribution of TiO2 nanoparticles became dominant. Increased TiO2 content led to improvement in wear resistance and reduction in COF, overshadowing the structural effects of PNIPAM. Notably, the non
silane hybrid with the highest TiO2 content exhibited the most effective wear mitigation under these conditions. Comprehensive surface analyses using Raman spectroscopy, SEM- EDS, and TOF-SIMS revealed temperature-dependent tribofilm chemistry and confirmed a synergistic interaction between PNIPAM and TiO2 during sliding. These findings elucidate the mechanisms governing the adaptive lubrication behaviour of hybrid aqueous systems and provide valuable design insights for next-generation biolubricants.

Keywords: PNIPAM; Microgels; Nanoparticles; TiO2; Tribofilms.

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Metallic FGMs Generated Using Ballistic Impact for Improves Fretting Fatigue Life of Tool Steel Components

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ABSTRACT

Frictional properties play a vital role in contact problems and become more critical when the part is subjected to fretting fatigue loading [1, 2]. Sometimes, parts need to have varied frictional properties along the longitudinal and/ or lateral direction. It is difficult to have a monolithic metallic component with varying mechanical properties. Composite materials are used for the same purpose; however, composites have poor frictional properties. In the present work, the ballistic impact method was used to generate microstructure-based metallic functionally Graded Materials (FGMs) [3].

Projectiles made of M2 tool steel were impacted at different velocities (300 m/s to 800 m/s) using aero-ballistic range setup to have different mechanical properties. Samples were cut along the mid- plane to study the properties. The coefficient of friction (CoF) and the width of the wear tracks were measured. The friction and wear properties using tribology test was performed on the projectile using a Multifunctional Tribometer manufactured by Rtec MFT5000, USA. The tribology reciprocating test condition was chosen as the tool steel sample and Silicon nitride ball of diameter 10 mm.

Study shows improved wear resistance near the leading edge as compared to the far field. Both friction and wear performance were found to be the function of position at the deformed projectile, which is indicative of FGMs. Further, these properties were found to depend upon the position along the longitudinal axis. Therefore, the existence of characteristics of FGMs is evident in the deformed projectile samples. Hence, an FGMs, deformed projectile, produced by ballistic impact can be used for enhanced fatigue life for components needing varying frictional properties.

Keywords: Metallic FGMs, Ballistic Impact, Coefficient of Friction; Tool Steel; Fretting Fatigue life

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Experimental Investigation on Cavitation-Induced Hydrodynamic Pressure Generation in Textured Surface

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ABSTRACT

An experimental study was conducted to analyze the effect of cavitation on hydrodynamic pressure generation in textured surfaces with full-film lubrication. The study aimed to observe the lubricant flow pattern and measure the changes in pressure along the mean radius line. A transparent runner and a textured disc with two square textures (10 mm × 10 mm, 200 µm height) were used to perform the experiment. It was noted that cavitation began at the trailing edge, resulting in pressure building up at the leading edge and causing a hydrodynamic lift. Tests done at speeds between 60 and 600 rpm with a constant load of 124 N revealed that the cavitation zone gets bigger as the rotational speed goes up. As the rotational speed increases, a corresponding decrease in cavitation pressure is observed and an increase in hydrodynamic peak pressure up to a certain speed, indicating superior load-carrying capacity. After the critical rotational speed, hydrodynamic peak pressure starts decreasing, as does load-carrying capacity, though cavitation pressure decreases. The results indicate that controlled cavitation on textured surfaces can significantly enhance the generation of hydrodynamic pressure and lubrication performance in tribological applications.

Keywords: Cavitation; Hydrodynamic Lubrication; Textured Surface; Load-Carrying Capacity; Tribological Performance; Hydrodynamic peak pressure.

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Mutual Effects of Interfacial Charge Transfer and Visible Light during Solid-Liquid Contact

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ABSTRACT

Charge transfer during mechanical contact is a key factor affecting interfacial interactions and surface forces, which are focus in tribology and related interface studies. Building upon charge transfer known to occur between water and polymer, this study proposes a "semi-embedding" strategy of composite surface to excite electroluminescence from luminescent particles near the interface. Multiphysics simulations confirm the presence of a strong interfacial electric field, over MV/m, at the solid-liquid interface. By fully utilizing this field, bright luminescence, visible even in daylight, can be directly excited by the dynamic contact between droplet and composite surface without requiring any pretreatment. With symmetry considerations, beyond the light emission promoted by interfacial charge transfer, significant influence of light absorption on interfacial charge transfer is discovered in further experiments. Consequently, a model of photo-excited electron transfer and dissipation during charge transfer is proposed, elucidating the mechanism by which light modulates charge transfer at solid-liquid interfaces. These mutual effects between light, as an important pathway for the conversion of interfacial energy, and interfacial charge transfer not only provide a novel method for real-time visualization of the interfacial charge transfer process but also offer insights for exploring the carrier forms and mechanisms of electrification during solid-liquid contact.

Keywords: Charge transfer; Contact electrification; Solid-liquid interface; Droplet luminescence; Electroluminescence; Visible illumination.

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Tribological Behavior of Centrifugal Brake Drum Surface with Different Thickness of DLC Coating by CVD Process

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ABSTRACT

Diamond-like carbon (DLC) coatings were successfully deposited on cast iron substrates using chemical vapor deposition (CVD) with acetylene and argon gas mixtures at flow rates of 10, 20, and 30 sccm. Each gas flow condition was applied for durations of 60, 120, and 180 seconds to evaluate the influence of deposition parameters on coating performance. The resulting films exhibited a uniform thickness of approximately 1.5 µm and demonstrated enhanced wear resistance across all conditions. Raman spectroscopy confirmed the characteristic DLC structure, while atomic force microscopy (AFM) was employed to validate the coating thickness and surface morphology. These findings suggest that optimized CVD parameters can yield high quality DLC coatings on cast iron, suitable for wear-critical applications. The wear investigation done by tribometer considering pin on disk phenomenon results obtained represents low wear on 10 SCCM of CVD process at constant RF of 60.

Keywords: Diamond-like carbon (DLC); Chemical vapor deposition (CVD); Cast iron substrate ; Acetylene–argon gas mixture; Raman spectroscopy; Atomic force microscopy (AFM).

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Influence of phase mechanical characteristics on scratch behaviour of Fe-13Cr-1C hardfaced alloy coating

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ABSTRACT

The effect of heat treatments on scratch behavior of Fe-13Cr-1C hardfaced coating was investigated and elucidation was done through mechanical characteristics of its matrix and carbide phases. Mechanical property of carbide phase along with its morphology can significantly influence the micro- and nano-scratch performance. The diverse nature of scratch responses was observed, and this can be attributed to the softening or hardening effects emanated from morphological changes, phase transformations, and heterogeneity of phase mechanical behavior. These led to fluctuations in surface interactions during the scratch, which influenced friction and depth. When compared with as-received sample, the micro- scratch depth of water quenched reduced by ~40.7% and coefficient of friction remained almost same. However, the nano-scratch tests on individual phases revealed the difference in response, i.e. relatively a steady one for matrix phase and unpredictable / unreliable for carbide phase. For enhancing coating's tribo-performance, it is felt necessary to consider the mechanical behavior of phases along with its bulk-scale material properties.

Keywords: Coating; heat treatment; mechanical property; scratch testing; friction.

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Fretting Wear Behaviour of 42CrMo4 Steel used in Large Bore Engine Components

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ABSTRACT

Fretting wear is a widespread problem in diesel locomotives that gradually deteriorate vital engine parts like connecting rods causing complete engine failures. Along with accelerated component failure, this phenomenon results in significant financial losses due to early engine damage and high maintenance needs. The purpose of the present research is to provide a tribo-mechanical analysis of fretting wear tests on chromoly (42CrMo4) steel. The test conditions were motivated by the kind of loading that connecting rods experience during engine operation. The investigation explores the complex interactions of chromoly steel surfaces examining wear progression, material degradation, impact of coefficient of friction between surfaces, and different slipping regimes under controlled experimental conditions, followed by correlating the outcomes in simulation environment. The tests are done on a non-conformal contacts, “Cylinder-on-Flat” configuration with the ‘like-material’ interface. The study focused precisely on monitoring key parameters such as contact pressure, sliding amplitudes, cycles to failure and surface wear, providing comprehensive insights into fretting wear initiation and propagation. The findings help in developing a focused fretting wear assessment methodology for chromoly steel components used in large bore engines. Detailed analysis of the experimental data provides definitive insights into chromoly steel fretting behavior under simulated operating conditions.

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Dry Sliding Wear Behaviour of High Carbon Carbide-free Nanostructured Bainitic Steel

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ABSTRACT

The growing demand for high-strength steels in tribological applications necessitates the development of materials with superior wear resistance and reduced friction. Among various candidates, bainitic steel has gained prominence owing to its outstanding combination of strength and toughness. In this study, carbide-free nanostructured bainitic steel was developed through austempering at 250 °C, while the same steel was subjected to patenting at 550 °C to obtain a fine pearlitic structure for comparison. Microstructural characterization using optical microscopy, scanning electron microscopy (SEM), transmission electron microscopy (TEM), and X-ray diffraction (XRD) revealed the formation of nanoscale bainite along with filmy and blocky retained austenite in the austempered steels, whereas lamellar pearlite was observed in the patented counterparts. Increasing the austempering duration enhanced the bainitic transformation and reduced the volume fraction of blocky retained austenite. Tribological behaviour of the high-carbon bainitic and pearlitic steels, tested against a tungsten carbide counter disc, showed that both the specific wear rate and coefficient of friction decreased as the applied load increased from 10 N to 50 N. The bainitic steels, exhibiting higher hardness, demonstrated superior wear resistance compared to the pearlitic steels. SEM examination of worn surfaces indicated that abrasive wear dominated at lower load (10 N), while at higher load (50 N), the bainitic steel exhibited a transition to combined adhesive–abrasive wear, and the pearlitic steel showed a mixture of oxidative, adhesive, and abrasive wear mechanisms.

Keyword: Nanostructured bainite, specific wear rate, strain-induced martensite, pearlite, wear mechanism

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Comprehensive Investigation of Tribological Behavior of Alternative Al–Si Alloys of Jet Engine Casings and Housings for Aerospace Applications

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ABSTRACT

With their low coefficient of thermal expansion, outstanding casting qualities (such as high fluidity, small shrinkage rate, and small hot crack propensity), and exceptional wear resistance, Al-Si cast alloys are a great choice. Electronic packaging materials, engine parts and accessories, and non-structural components of hydraulic and mechanical systems including cooling fans, valve housings, turbine impellers, fasteners, rollers, bucket bars, and manifolds are common uses for Al-Si alloys in the aerospace industry. Various mechanical, environmental, microstructural, and processing challenges affect Al-Si alloys used in the front parts of jet engines, like the fan case and the housing of the low-pressure compressor. These challenges stem from factors such as ambient temperatures ranging from 150 to 200 °C, high cyclic and impact loads, low-pressure spool speeds ranging from 3000 to 8000 rpm, and ambient pressures ranging from approximately 2 to 4 bar. Additionally, aluminum and silicon metals are generally among the cheapest industrial metals on a per-kilogram basis. Hence, this study investigated the tribological properties of Al-Si alloys (5-40%) prepared from permanent mould casting. A pin-on-disc type tribometer was used for experiments under the loads of 40, 75, 120 and 190 N, rotating speeds of 300, 600, 900, 1200 and 1500 rpm and temperatures of 100, 150, 200, 250 and 300 °C. Friction and wear of Al-Si alloys have been examined in relation to their alloy composition, sliding speed, temperature and load. The wear rate is significantly influenced by alloy composition, applied stress, temperature, and sliding speed. With an increase in the amount of silicon present in the alloy, the rate of wear lowers while the load- bearing capability of the alloy improves. The wear mechanism differs based on the alloy composition and the conditions of the experiment. This was thoroughly examined, and the findings were evaluated to identify an appropriate Al-Si composition for high-temperature applications in dry conditions. These insights are crucial for the selection and design of material combinations that meet specific mechanical and tribological demands, ultimately improving the lifespan of jet engine casing/housing for aerospace applications.

Keywords: Al-Si alloy, Aerospace, Jet engine casing/housing, Wear, High-Temperature, Dry friction

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In-Situ Investigation of the Friction and Wear Behavior of Polymeric Composite Coatings for Hydrogen Valve Applications

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ABSTRACT

This study investigates protective polymer coatings designed to reduce hydrogen diffusion in steel valve components used in hydrogen refueling stations (HRSs). Two composite coatings were examined. Polytetrafluoroethylene filled with 5-10 wt.% mica (PTFE-mica) and Polyurethane filled with 2 wt.% titanium dioxide (PU-TiO_2), chosen for their low hydrogen permeability. The coatings were deposited by spray coating technique on 316 stainless steel (SS) discs and tested in atmosphere air, nitrogen (N_2), and hydrogen (H_2) (0.2 MPa for N_2 and H_2) using a custom-built multi-environment pin-on-disc tribometer. PTFE- mica consistently showed lower friction and wear than PU-TiO_2, with coefficient of friction (CoF) reductions of ~57% in H_2, ~33% in N_2, and ~33% in air. The specific wear rate (SWR) was also lower by ~53% in H_2, ~16% in N_2, and ~30% in atmosphere air, confirming superior durability. FESEM analysis revealed a fibrous morphology for PTFE-mica and a dense structure for PU-TiO_2, with thicknesses of 34 μm and 36 μm, respectively. CHNS analysis showed lower hydrogen absorption for PTFE-mica (0.87%) compared to PU-TiO_2 (5.61%), indicating better hydrogen barrier performance. Overall, PTFE-mica exhibited excellent tribological stability and hydrogen resistance, making it a promising coating material for steel valve components in hydrogen infrastructure.

Keywords: In-situ Tribology Test; CHNS; Hydrogen absorption; Lubricity of gases; Tribochemical reaction.

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Study on Wear Behaviour of Water Hyacinth Derived Fiber Particulate Composite and Short-Fiber Composite under Dry Sliding Conditions

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ABSTRACT

The invasive spread of water hyacinth (*Eichhornia crassipes*) plant creates ecological pollution whereas beneficial recovery of the resources and improvement of mechanical strength can lead to wider commercial applications. Natural fibers of water hyacinth plant were extracted using a suitable fiber decorticator machine followed by drying and analysis of the physical and chemical properties of the water hyacinth derived fiber were done. Fiber particulate composite and short fiber composite with epoxy were prepared by hand laying. The weight fraction of particulate and fibers were varied from 10 to 40 %. The composites were investigated for self-conditioning wear behavior. The composites were designed to promote controlled fiber pull-out in reinforced composites. The wear behavior was studied at varying loads of 10 N, 20 N and 30 N and different sliding speeds (0.1-0.5 m s^{-1}) in dry environment with sliding distance of 100 m. The SEM was done to study the fiber-epoxy interface, and the fiber pull out on wear. The composites were tested for other mechanical properties *viz.* tensile strength, flexural strength, compression strength and hardness as well.

Keywords: Natural fiber; fiber composite materials; wear behavior; tribology.

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Tribological Evaluation of MWCNT Reinforced Aluminium Composites Using a Shearing Cooling Roll (SCR) Rheocasting Process

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ABSTRACT

Aluminium matrix composites reinforced with multiwall carbon nanotubes (MWCNTs) are promising for tribological applications. Non uniform dispersion and weak interfacial bonding often limit its performance. A rheocasting route is employed using an in-house shearing cooling roll (SCR) setup under inert atmosphere to fabricate A356 alloy with 0, 0.25, and 0.5 wt. % MWCNTs and evaluate their hardness, friction, and wear behaviour. Wear tests are carried out using a ball-on-disc tribometer under varied loads of 10 N and 20 N, at a sliding velocity of 0.25 $m.s^{-1}$ and sliding distance of 1000 m. Controlled semi-solid flow during SCR processing promoted a uniform solid fraction, refined non-dendritic α-Al grains, improved wetting, and homogeneous distribution. 0.25 wt. % MWCNT composite achieved ~23% higher hardness and ~30% lower wear rate compared with base alloy, attributed to effective load transfer. FESEM and EDX analyses of the worn surfaces revealed a transition from severe adhesive wear in the base A356 alloy to predominantly mild adhesive damage in the 0.25 wt.% MWCNT composite. Further MWCNT addition caused agglomeration, degrading the mechanical and tribological performance of composite. The results show that SCR-based rheocasting is a scalable method for producing aluminium nanocomposites with refined microstructure and improved tribological performance.

Keywords: Aluminium Composites; MWCNTs; Shearing Cooling Roll; Semi-solid processing; Tribological Performance.

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Rheological and Tribological Assessment of Bio-Based Viscosity Modifiers: Advancing Tribology for Sustainability

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ABSTRACT

Viscosity retention is essential for lubricant performance in engine, gear, and hydraulic oils across variable temperatures and mechanical stresses. Viscosity modifiers (VMs) maintain lubricant film thickness and stability under these conditions. Driven by the need for sustainability and high performance, this study evaluates conventional and bio- based VMs in mineral, synthetic, and emerging bio-based base stocks. VMs at varying concentrations were tested for structural stability and performance under extreme thermal and shear conditions. Testing employed standard methods including KRL shear (CEC L-45-99), high-temperature high-shear (ASTM D4683, D5481), and diesel injector shear (ASTM D6278). Rheological properties were assessed through stress sweep, flow curves, and creep recovery under rotational and oscillatory modes. Results demonstrate bio- based VMs perform comparably to conventional counterparts, supporting their role as sustainable solutions in tribological applications. Insights into VM-based stock interactions inform development of high-performance lubricants designed for extreme environments.

Keywords: Viscosity Modifiers; Tribology; Rheology; Bio Additives; Sustainability

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Tribological Performance of ZDDP-Enhanced Lubricants Under Electrified Pure Sliding Conditions

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ABSTRACT

The EV technology has advanced over time, outperforming conventional ICE in certain areas. Despite the progress, EV powertrains face unique challenges from inverter- induced electrical environments, leading to shaft voltages and currents that can cause premature wear and fatigue in bearings and gears. However, lubricant additives have been extensively optimized for ICE vehicle applications, but their performance under the electrified conditions of EVs remains underexplored. This study investigates the tribological response of a lubricating additive like zinc dialkyldithiophosphate (ZDDP) blended with a low-viscosity synthetic base oil (PAO6) on AISI 52100 steel test pairs under electrified and non-electrified pure sliding conditions. Tribological tests were carried out using a modified Pin-on-Disc (PoD) setup under boundary lubrication conditions at elevated temperatures. Post-test surface characterization was performed using Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS), 3D surface profilometry, and Raman spectroscopy. The results indicate that ZDDP addition reduced wear scar by 50% but increased pit formation compared to pure PAO6 under electrified and non-electrified conditions. A detailed analysis of wear volumes and surface morphologies reveals the protective mechanisms provided by ZDDP in demanding operating environments. This work enhances understanding of additive behavior under electrification and guides next-generation EV lubricant development.

Keywords: EV powertrains, ZDDP, pure sliding, surface characterization, friction, wear

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Influence of Laser Shock Peening Process Parameters on Compressive Residual Stress Distribution in AISI 304L Stainless Steel

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ABSTRACT

This study investigates the compressive residual stress distribution in AISI 304L stainless steel by varying Laser Shock Peening (LSP) parameters, including shot strategy, pulse count, and bidirectional spot overlap by Finite Element Analysis (FEA). A Johnson-Cook material model was implemented in Abaqus/Explicit simulations to replicate the high-strain-rate plastic behaviour caused by nanosecond laser pulses. In this study, the laser intensity was modelled as a Gaussian pressure profile with an 8 ns duration, peaking at 4 ns over a spot of 0.3 mm diameter and a power density of 3GW/cm^2. This study focused on the influence of shot strategy (Overlapping Instantaneous Pulses (OIP) and Sequential Pulses (SP)), pulse count (2, 4 and 6 per spot), and bidirectional spot overlap on the magnitude of compressive residual stress over the surface and along the depth of the material. Results showed that LSP with OIP caused higher near-surface compressive residual stress than SP, with diminishing result after four pulses per spot. The overlap configuration was found to be crucial, with X25–Y75 yielding the highest surface compressive stress and X50–Y75 producing the deepest and most uniform compressive residual stress field. As a whole, the Laser Shock Peening of AISI 304L stainless steel with four Overlapping Instantaneous Pulses (OIP) per spot and X50–Y75 overlap achieves maximum depth of compressive residual stress while maintaining low surface roughness on the surface.

Keywords: Laser Shock Peening; Abaqus/Explicit; Finite Element Analysis; Residual Stress; Pulse overlap; AISI 304L Stainless Steel

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Influence of MWCNT-mixed μ-EDM textured micro-dimples on the tribological behaviour of Laser-powder bed fused Ti-6Al-4V

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ABSTRACT

Surface micro-dimples are claimed to enhance the tribological behaviors of materials during biomedical applications. Hence, in this study, the effects of circular and square-shaped micro- dimples fabricated on laser powder bed fusion (LPBF) processed Ti-6Al-4V and their forged counterpart using MWCNT- mixed μ-EDM and their effects on the tribological behaviors were compared. MWCNTs were incorporated into the dielectric fluid to improve the dimensional accuracy of the micro-dimples, while maintaining a constant texture density of 10.57%. The surface topography, elemental composition, and wear mechanisms were analyzed using 3D-profilometry, SEM, EDS and Raman-spectroscopy. The tribological behavior was evaluated under linear reciprocating motion in a face-to-face configuration. The circular-dimpled-LPBF sample exhibited a 19.42% reduction in the coefficient of friction compared to the square-dimpled-LPBF counterpart.

Moreover, the circular-dimples demonstrated enhanced resistance to crack propagation and micro-abrasion, leading to a 12% reduction in material removal. In contrast, the square-dimpled surface showed higher wear and friction, accompanied by debris accumulation, micro-chipping, and corner-induced stress concentrations. The forged and untextured samples displayed comparatively higher CoF and material loss than the textured samples. Overall, the circular-dimpled LPBF sample exhibited superior surface integrity and wear resistance, underscoring its potential for biomedical implants that demand exceptional durability and tribological efficiency.

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Evaluation of Mechanical and Tribological Properties of Mechanically Alloyed and Cold-Sprayed CoCrFeNiSi HEA

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ABSTRACT

High-entropy alloys (HEAs) have emerged as a promising class of multi-principal element materials offering a unique combination of strength, ductility, thermal stability, and corrosion resistance, making them attractive for surface engineering and additive repair technologies such as cold spray. In this work, equiatomic CoCrFeNiSi HEA powders were developed and systematically processed for cold spray applications. A mechanical alloying route was employed using high-energy ball milling with milling durations varied from 5h to 20h to study the effect of milling time on powder morphology, phase evolution, mechanical response at the particle scale, and residual stress state. Powder characterization included scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) analysis of the constituent elemental powders and the alloyed powders prior and post-milling to assess changes in particle morphology, size distribution. Particle-scale mechanical properties were assessed by nanoindentation for individual and HEA powder to evaluate hardness and modulus. X-ray diffraction (XRD) was performed after each milling interval to track phase formation, with emphasis on the evolution of solid-solution phases (e.g., FCC/BCC). Subsequently, heat treatments were applied to the milled powders followed by XRD for residual stress analysis. Further, dry tribological performance of the alloy was evaluated using ball-on-disc tribometer employing unidirectional/rotary configuration.

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Influence of surface slip on solid-liquid interfacial drag reduction and flow control

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ABSTRACT

In the present study, the effects of surface slip on the hydrodynamics (lift and drag coefficients) and flow around a two-dimensional NACA0012 hydrofoil at the Reynolds number of 1.0×10^6 at 0°- 10°angles of attack are numerically investigated. Three slip positions (both surfaces, the upper surface, the lower surface) and eight slip lengths from 1 μm to 500 μm are applied on the hydrofoil surface. For the both surface slip and the upper surface slip conditions, surface slip has been found to increase lift and reduce drag by postponing the flow transition, laminar separation bubble, and flow separation on the hydrofoil surface. Slip can also induce upshift of the mean velocity profile, decrease the displacement thickness, and mitigate the turbulent kinetic energy in the flow field. However, counter-intuitive effects are found under the lower surface slip condition, where the total drag demonstrates a non-monotonic variation with the angle of attack. The effects of the surface slip length and the underlying mechanisms are clarified. Finally, the flow map demonstrating the complex interaction between the surface slip and the flow is presented, which shall provide valuable insights for practical applications of slippery materials for drag reduction and flow control.

Keywords: surface slip, slippery materials, drag reduction, flow control

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Erosive Behaviour of 0.896C Bainitic Alloy Steel Against

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ABSTRACT

The erosive behaviour of 0.896C bainitic alloy steel against alumina was investigated. As- cast 0.896C steel was austenitized at 900°C and then austempered at 250°C to achieve bainitic transformation. It was characterised through optical microscopy, hardness measurement, X-ray diffraction (XRD), and Scanning Electron Microscopy (SEM). Solid particle erosion experiments were conducted at ambient temperature using an Air Jet Erosion Tester over impact angles of 15°, 30°, 60°, and 90° and velocities of 40, 60, and 90 m/s, with alumina as the erodent. The steady-state erosion rate (SSER) was determined, and the erosion behaviour was evaluated using the power law model ***(E = k*v^n)***, yielding a velocity exponent ***(n)*** of ***2.779***, which indicates ductile erosion behaviour. The SSER was maximum at a 30° impact angle for 90 m/s, a 60° impact angle for 60 m/s, and a 30° impact angle for 40 m/s. The SSER was minimum at 90° impact angle for all impact velocities. SEM analysis revealed that at lower angles and speeds, ploughing and microcrack development were observed; medium angles resulted in surface scratching and chip formation. In comparison, higher angles led to large cracks and craters with embedded aluminium oxide fragments, highlighting the impact mechanics.

Keywords: Alumina; Bainite; Erosion; Microscopy; Microstructure; and Steel.

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Study of friction and adhesion behaviour of PDMS elastomer: influence of mixing ratio and process parameters

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ABSTRACT

Friction and adhesion between soft elastomers such as polydimethylsiloxane (PDMS) and glass are fundamental interfacial phenomena that influence performance in various scientific and technological applications. The combination of PDMS elastomer flexibility, transparency, and chemical stability with the rigidity and smoothness of glass makes this pairing ideal for systems requiring controlled adhesion and friction, including microfluidics, lab-on-a-chip devices, soft robotics, and wearable sensors. Reliable and tunable interfacial properties are essential for sealing microchannels, stabilizing diagnostic platforms, and ensuring effective motion or gripping. In this study, interfacial friction and adhesion between PDMS elastomer and borosilicate glass were systematically examined using a tribometer. Two key parameters were varied: (i) the PDMS base to curing agent mixing ratio and (ii) curing conditions, specifically temperature and time. The resulting changes in PDMS elastomer elastic modulus were correlated with frictional and adhesive responses. The findings show that a higher elastic modulus, achieved through increased curing agent content and elevated curing conditions, results in greater friction but reduced adhesion, whereas a lower modulus enhances adhesion while reducing friction. These results demonstrate the critical role of mixing ratio and processing parameters in governing PDMS elastomer and glass interfacial behaviour.

Keywords: PDMS elastomer (Sylgard^{TM} 184), Mixing ratio, Process parameters, Friction, Critical displacement, and Adhesion.

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Influence of μ-EDM Textured Tool Geometries on Tribological Performance in Machining of Ti-6Al-4V under Dry and MQL Environment

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ABSTRACT

Dry machining of Ti-6Al-4V exhibits significant tool wear, increased cutting forces, and compromised surface integrity. While laser and focused ion beam-based texturing can mitigate these challenges, but their high costs and thermal impact limit their practical application. This study focuses on the ultra- fine micro-texturing of tungsten carbide (WC) cutting inserts (CNMG 120408, Make: Sandvik), creating slot, dimple, and hybrid (slot + dimple) patterns on the rake face. The process utilized an in-house-fabricated ultra-fine micro-electrode followed by a single-step micro-electrical discharge machining (μ-EDM) method for making textures on inserts. The impact of these textures on tribological performance was evaluated during the turning of Ti-6Al-4V under both dry and minimum quantity lubrication (MQL) conditions at a cutting speed of 120 m/min, feed of 0.2 mm/rev, and depth of cut of 0.5 mm. Among the tested textured tool geometries, the dimple-textured tool demonstrated the most promising results, achieving 15-18% reductions in cutting force and 19- 21% reductions in surface roughness compared to the untextured tool, while doubling tool life. The study demonstrates that μ-EDM texturing is an economical and reliable approach for customizing surface texture, aimed at improving wear resistance and machining efficiency of WC tools in the cutting of titanium alloys.

Keyword: μ-EDM; Ti-6Al-4V; Tungsten carbide; Wear; Tribology; MQL.

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Tribological and thermal performance of apple waste and bitter almond oils as green metalworking fluids in hard turning of steel

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ABSTRACT

The study investigates the potential of bio-based oils extracted from apple waste and bitter almond as sustainable cooling and lubrication agents for the hard turning of AISI 52100 steel. The oils were obtained through solvent extraction using n-hexane, yielding 18.4 wt.% from apple residues and 28.6 wt.% from bitter almond. Rheological characterization revealed viscosities of 42.6 cP and 53.8 cP at 40 °C, with flash points of 216 °C and 232 °C, respectively, demonstrating adequate thermal stability and favorable pseudo-plastic flow behavior. Tribological performance was evaluated using a four-ball tester in accordance with ASTM D4172. The wear scar diameters were 0.46 mm for apple waste oil and 0.42 mm for bitter almond oil, compared with 0.58 mm for commercial mineral oil. The respective coefficients of friction were 0.083 and 0.072, indicating an improvement in anti-wear and load-carrying capacity. During hard turning trials conducted at a cutting speed of 150 m/min, feed of 0.1 mm/rev, and depth of cut of 0.5 mm, the bio-oils reduced the average surface roughness (Ra) to 0.45 µm and 0.38 µm, lowered cutting temperature by approximately 18 °C, and decreased tool flank wear by about 31 % relative to mineral oil. The results demonstrate that oils derived from apple waste and bitter almond possess desirable tribological and thermal characteristics, making them viable, environmentally benign substitutes for petroleum-based cutting fluids in precision machining and sustainable manufacturing applications.

Keywords: Bio-lubricant, Hard turning, Apple waste oil, Bitter almond oil, Tribological performance

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Tribology and Rheology of Nano-Clay-Stabilized Colloidal Pickering Emulsions

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ABSTRACT

In tribology and mechanical processing, emulsions serve as efficient lubricants and coolants. Traditionally stabilized by surfactants, they can also be formed using solid particles, known as Pickering emulsions. These emulsions offer advantages such as low toxicity, higher stability, cost- effectiveness, and ease of recovery compared with conventional systems. In this study, an organophilic phyllosilicate nano-clay (Garamite 1958®) was employed to formulate water-in-oil Pickering emulsions with an oil-to-water ratio of 2:3, where water served as the dispersed phase. The prepared emulsions were characterized by their rheological properties; viscosity, viscoelastic parameters such as storage modulus (□□′) and loss modulus (□□″), and tribologically evaluated for lubrication performance. Lubrication tests were performed on a ball-on-disc tribometer using a steel- steel tribo-pair under unidirectional rotary sliding. The coefficient of friction and specific wear rate were evaluated at varying loads and sliding speeds. Optical profilometry was used to evaluate the wear response. Worn surfaces were characterized using scanning electron microscopy and energy dispersive spectroscopy. The Pickering emulsion lubricant markedly reduced both friction and wear. The observed wear tracks were analyzed to elucidate the wear mechanism. A lubrication mechanism is proposed to explain the reduced friction and wear behavior.

Keywords: Pickering emulsion; lubrication; nano-clay; rheology.

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The mixed lubrication calculation of low-modulus polymer considering surface forces

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ABSTRACT

Polymer materials exhibit unique advantages in industrial and biomedical applications, which have characters of self-lubrication, and wear resistance. However, challenges such as high friction coefficients at low velocity and surface plastic flow exist. Surface modification through hydration effect can enhance tribological performance, yet the mechanistic influence of surface forces (mainly hydration force) on mixed lubrication in low elastic modulus polymers remains unclear, with existing numerical methods facing convergence limitations. This study extends the mixed lubrication model considering surface forces to low elastic modulus polymeric materials, establishing a robust numerical framework for predicting pressure distribution and friction coefficients under ball-on-disc conditions in aqueous electrolytes with surface force interactions. The investigation further examines plastic deformation in polymer tribopairs, and systematically compares the effects of varying elastic moduli and hydration repulsion intensities on surface force efficacy. These findings establish a foundation for advanced numerical simulations of complex water-lubricated conditions and provide theoretical insights for surface modification methods of polymers.

Keywords: surface forces, mixed lubrication, hydration lubrication, polymer, numerical calculation

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Microstructure-Governed Friction and Wear Response of LPBF and Forged Inconel 718 under Dry Sliding Conditions

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ABSTRACT

This study investigates the influence of manufacturing route and heat treatment on the dry sliding wear behaviour of Inconel 718 produced by Laser Powder Bed Fusion (LPBF) and conventional forging. Linear reciprocating ball-on-flat tests were conducted under dry air at room temperature using an Al_2O_3 counterface (Ø 6.35 mm) at normal loads of 10–50 N, a 6 mm stroke, and a frequency of 10 Hz. Specimens were evaluated in three metallurgical conditions: as-built/as-received, double-aged, and fully heat-treated (homogenised, solution annealed, and double-aged). The as-built LPBF alloy exhibited higher friction and wear due to microstructural anisotropy, residual porosity, and the absence of γ'/γ'' strengthening precipitates. Heat-treated LPBF specimens showed pronounced tribological enhancement, with up to an order-of-magnitude reduction in wear rate attributed to γ'/γ'' precipitation strengthening, matrix homogenisation, and the formation of a stable tribolayer. The fully heat- treated forged alloy exhibited the lowest wear rate and most stable friction (average coefficient of friction, CoF ≈ 0.52), while the LPBF alloy in the same condition achieved comparable performance. These findings demonstrate that suitable post-processing can substantially enhance the tribological performance of LPBF Inconel 718, making it a viable alternative to wrought counterparts for high-temperature applications.

Keywords: Inconel 718; LPBF; Sliding wear; Heat treatment; Tribological performance.

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Enhancing Roll Campaign Life in Rail Mills Using Oil-in-Water Roll Pass Lubrication

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ABSTRACT

Roll Pass Lubrication (RPL) using an oil-in-water dispersion offers an innovative approach to reduce roll wear in hot rolling operations. While it has been applied in flat rolling mills, its use in structural rolling, particularly in rail production, had not been explored earlier. This study investigates the implementation and performance of RPL at a rail mill, focusing on roll campaign life, surface quality, and rolling efficiency. Based on prior experience from hot strip mills, a customized RPL system was developed in collaboration with an oil supplier who also formulated a suitable hot rolling lubricant. The system included oil and water pumping units, dispersion mechanisms, adjustable spray headers for different roll diameters, and a PLC–HMI based control and data logging setup. Operational parameters such as oil flow rate and dispersion ratio were optimized to enhance lubrication effectiveness and minimize roll wear. Implementation results showed a significant increase in roll campaign life across all stands. The average campaign size increased by about 12% at the Breakdown Stand, 10% at the Universal Rougher Stand, and 2.5% at the Universal Finisher Stand, contributing to higher mill productivity. Rail surface quality remained within acceptable standards, confirming the suitability of RPL for structural rolling applications.

Keywords: Roll Pass Lubrication; Roll wear; Grinding off-take; Roll Campaign Life; Hot Rolling Lubrication.

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Digital Twin Based Centrifugal Pump Fault Prediction Using Machine Learning

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ABSTRACT

Learning for predictive maintenance in industrial pump systems, industrial operations in power plants and manufacturing facilities depend on critical machinery such as compressors, pumps, blowers, electric motors, and turbines. Failure of these components can lead to complete system shutdowns or severe efficiency losses, resulting in increased energy consumption. Centrifugal pumps, widely employed in industries including paper, chemical, and mining, require continuous monitoring to prevent operational faults. This study investigates fault detection in centrifugal pump systems through frequency-domain vibration analysis under three conditions: healthy operation, shaft misalignment, and impeller defects. Vibration signatures were acquired using an accelerometer and analyzed via FFT techniques, revealing distinct frequency spectra for each condition. A digital twin of the pump system was developed in ANSYS Twin Builder to simulate similar fault scenarios. Machine learning algorithms—Support Vector Machine (SVM), Decision Tree (DT), and K-Nearest Neighbor (KNN)— were trained on frequency spectra generated from the digital twin to classify faults. Comparative performance analysis demonstrated that the Decision Tree algorithm achieved superior classification accuracy. These findings highlight the potential of integrating digital twin technology with machine

Keywords: Centrifugal pump, vibration analysis, digital twin, machine learning

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Reducing frictional loss through multi-nozzle optimum Minimum Quantity Lubrication (MQL) for energy-efficient and sustainable end- milling

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ABSTRACT

In Minimum Quantity Lubrication (MQL), a small volume of cutting fluid is mixed with compressed air, and the mixture is delivered at the cutting zone as a spray consisting of fine oil droplets. Inadequate oil flow rate may leave the tribologically active cutting edges partially dry compelling higher frictional energy wastage at the chip-tool interface. Excessive flow hampers manufacturing economy and sustainability without improving machinability. This study introduces a novel analytical model to assess the optimal oil flow rate for a dual-nozzle MQL system during end-milling to balance lubrication efficiency, machinability, energy usage, and sustainability. When nozzles are placed at angle with transverse direction at disengaged side of the end-mill rotating at rpm and having and rake and flank face wear lengths, the optimum MQL oil flow rate can be expressed as follows.

Keywords: Machining; Power loss; Sustainability; Friction; MQL; Energy efficiency.

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Experimental Investigation on the Effect of Ferrocene Nanoparticles as a Diesel Additive on the Performance and Emission Characteristics of a 4- Stroke VCR Diesel Engine

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ABSTRACT

This study investigates the impact of ferrocene nanoparticles as a diesel fuel additive on the performance and emission characteristics of a four-stroke, single-cylinder variable compression ratio (VCR) diesel engine. Experiments were conducted using a nanoparticle concentration of 200 mg/L in diesel across three different compression ratios. Key performance parameters such as brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC), along with emission parameters including NOx, CO, HC, and smoke opacity, were systematically measured and analysed. The selected nanoparticle concentration was based on recommendations from previous research. The primary objectives of this investigation are to evaluate the potential of ferrocene nanoparticles to enhance engine performance and control harmful emissions, and to identify the optimal compression ratio for achieving these improvements. Furthermore, the study examines how the addition of ferrocene influences variations in BTE and BSFC, with the ultimate goal of optimising engine operation for improved efficiency and cleaner combustion.

Keywords: Ferrocene, VCR, BTE, BSFC, Combustion

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Surface characteristics of Additive Manufactured SS316L Lattice Structures

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ABSTRACT

Laser Powder Bed Fusion (LPBF) is a versatile additive manufacturing technique capable of producing metallic components with complex geometries and controlled porosity. In this study, SS 316L lattice structures were fabricated using LPBF to evaluate surface enhancement through chemical post-processing. Despite the precision of LPBF, the as-built components exhibit poor surface quality due to the presence of unmelted and partially melted powder particles. This challenge is amplified in lattice structures, where extensive internal surfaces and intricate features promote powder entrapment, making conventional finishing methods such as mechanical and electrochemical polishing largely ineffective. To overcome these limitations, a dynamic chemical polishing process was employed. The etchant comprised ortho-phosphoric acid (H_3PO_4), nitric acid (HNO_3), and hydrofluoric acid (HF), with sodium dodecyl sulfate (SDS) added as a surfactant to improve wetting and ensure uniform dissolution. The solution was diluted with deionized water to regulate reaction kinetics, and samples were immersed for durations ranging from 30 to 150 minutes at 30- minute intervals. The process produced a significant reduction in surface roughness (Sa) compared with the as-built condition, confirming the effectiveness of chemical polishing for intricate lattice architectures. However, extended polishing beyond the optimal duration resulted in over-etching and increased Sa due to excessive material dissolution. These findings highlight the need for precise control of chemical polishing parameters to achieve consistent and uniform surface refinement in LPBF-fabricated lattice structures.

Keywords: Laser Powder Bed Fusion; Lattice structures; Chemical Polishing; Surface finish.

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Study on Shear Behavior and Friction Mechanism of Interfacial Water

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ABSTRACT

The shear behavior of interfacial water is involved in a wide range of scenarios, from water-based lubrication in industrial equipment to friction in artificial joints. However, the mechanism by which the structure of interfacial water molecules influences friction remains a subject of ongoing debate. Observing the structure and behavior of sheared interfacial water molecules can help uncover the underlying mechanisms of water based lubrication. In this work, we investigate variations in friction by modifying material properties, surface wettability, and solution ion characteristics. Combined with sum-frequency generation(SFG) vibrational spectroscopy and molecular dynamics(MD) simulations, we reveal the microscopic mechanism by which interfacial water molecules influence friction. It is found that an increased proportion of "liquid like" water contributes to a reduction in the friction coefficient at the shear interface. This study, to some extent, establishes a unified understanding of how water molecular structure affects water-based lubrication, laying a foundation for the development and application of low-friction materials.

Keywords: surface properties; water molecular structure; friction.

Abstract ID: 1762415913440-0H8M22
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Laser Assisted Multicomponent Alloy Surface on AISI 316L Stainless Steel for Improved Corrosion and Tribocorrosion Resistance

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ABSTRACT

In the present study, a detailed kinetics and mechanism of electrochemical degradation (in 3.56 wt.% NaCl solution) of concentrated multicomponent alloy surface developed on AISI 316L stainless steel by laser surface alloying (using a 6.6 kW continuous wave fiber optics delivered diode laser with a beam diameter of 3.6 mm) with CoCrFeMnTi has been carried out. The corrosion resistance property (in 3.56 wt.% NaCl solution) of the surface (after LSA) was improved under selected parameters, with the maximum corrosion resistance observed for the sample laser processed at 1800 W applied power and 6 mm/sec scan speed. The tribo-corrosion kinetics were significantly reduced (2.60-3.21 x 10^{-7} mm^3/Nmm) as compared to AISI 316L SS (3.94 x$10^{-7}$$mm^3$/Nmm). Finally, a detailed mechanism of the synergistic effect of wear and corrosion was proposed.

Keywords: AISI 316L SS, Laser surface alloying, CoCrFeMnTi, corrosion, tribocorrosion

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An in-depth review of current tribochemical slurry development in the utilization of cobalt as a bulk interconnect in IC fabrication

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ABSTRACT

As semiconductor technology scales toward the 5 nm node and beyond, cobalt (Co) has emerged as a promising interconnect material for back-end-of-the-line (BEOL) integration, progressively replacing copper (Cu) in advanced integrated circuits (IC) to sustain performance and lifetime requirements. This transition is primarily driven by Co's shorter electron mean free path, superior electromigration resistance, and favorable deposition characteristics. Chemical mechanical planarization (CMP) remains an indispensable process for achieving atomic-level planarity required for constructing the multi-level interconnection; it operates *via* tribological action in which metal surfaces interact with abrasives and slurry over the polyurethane pad to ensure high material removal rates (MRR) and defect-free surfaces in bulk interconnect fabrication. Formulating an optimized slurry that includes both chemically active and economically viable additives is essential for achieving enhanced chemical reactivity, precise selectivity, and a smooth finish. Even with significant progress, a comprehensive understanding of the development of different slurry components in Co CMP remains unexplored. In this review, research progress on various components—abrasives, oxidizers, pH adjusters, chelating agents, corrosion inhibitors, and surfactants—and their respective action mechanisms were explored in detail, along with electrochemical and surface characterization to evaluate their performance and interactions.

Keywords: Cobalt; CMP; Slurry; Interconnect; Integrated circuit; MRR.

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Effect of Phosphorus Concentration in Electroless Ni-P Coating for Wear and Corrosion Protection

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ABSTRACT

Electroless Ni-P coatings have been in good demand in recent years due to its highly desirable characteristics such as superior corrosion and wear resistance, good mechanical properties, uniform coating thickness, excellent surface finish and good adhesion strength. These composite coatings possess improved hardness, good corrosion resistance than pure nickel coatings and this method has generated a lot of interest in automotive, aerospace, chemical and mining industries. The aim of this work is to examine the effects of Phosphorous % in a commercial hypophosphite bath for the electroless deposition of Ni-P coating on EN31 steel and compare various mechanical, tribological and corrosion resistance in acid medium. The coatings were characterized with respect to coating thickness, hardness, XRD, topography and elemental analysis by FE-SEM-EDS. The tribological tests were then carried out and the friction coefficient showed significant decrease compared to base substrate thus enabling the use of the Ni-P coating on the substrate as a solid lubricant. The Low P coatings were found to have better load bearing and wear resistant ability than the high ones. With increasing P concentration, the corrosion resistance of the coating is increased in acidic medium, inferred from EIS studies.

Keywords: Electroless Ni-P Coating, Tribology, Wear, Friction, Corrosion

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Laser Surface Alloying of Ti6Al4V with FeCoCrMnTi: Comprehensive Study on Dry Wear Performance

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ABSTRACT

This research investigates the laser surface alloying (LSA) of Ti6Al4V using a multicomponent equi-atomic FeCoCrMnTi premixed elemental powders applied through a continuous-wave, fiber delivered diode laser. Precursor powder layers with a thickness of approximately 0.8–1 mm were first deposited and subsequently melted using a 6.6 kW Yb-YAG diode laser (LDF 6000-40, Laserline, Germany) operating within the 900–1100 nm wavelength range and featuring a 3.6 mm spot size. The alloying process was performed under nitrogen and argon shielding atmospheres, with laser power and scanning speed optimized as the primary processing variables. To maintain consistent alloying, successive tracks were overlapped by 25%. Microstructural and phase characterizations were carried out using FEG-SEM and EBSD techniques. The optimized parameters led to notable enhancements in mechanical behavior, including a significant rise in microhardness and a marked decrease in wear rate. Wear mechanisms were analyzed under different loading conditions and linked to the corresponding microstructural features. These outcomes highlight the potential of LSA as a reliable surface engineering method to strengthen titanium alloys for enhanced tribological performance in aerospace and automotive applications.

Keywords: Titanium; Laser; Alloying; multicomponent; Wear

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Enhancing Tool Life and Tribological Behavior of H13 Inserts via Additive Manufacturing during Machining of Aluminum Alloy 6061

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ABSTRACT

This study investigates a novel approach for fabricating turning inserts using Additive Manufacturing (AM) technologies, specifically Fused Filament Fabrication (FFF) and Laser Powder Bed Fusion (LPBF). Conventional H13 tool steel inserts, produced via powder metallurgy and machining, often exhibit limited design adaptability and poor tribological stability when cutting aluminum alloys. AM routes overcome these drawbacks by enabling controlled microstructural refinement, improving heat dissipation and enhancing load-bearing capacity. The tribological performance of the fabricated inserts was evaluated during the turning of aluminum alloy 6061 under dry and flood conditions by analyzing the tool life, wear morphology, surface roughness, cutting force and chip morphology. Under flood conditions, the LPBF insert exhibited superior tribological performance, achieving tool life that was 29% and 34% higher than those of the FFF and conventionally manufactured inserts, respectively. The improvement was attributed to its dense microstructure and high hardness, which reduced adhesive and abrasive wear, limited frictional heating and enhanced interface stability. Overall, AM-fabricated H13 inserts demonstrated strong potential for improving wear resistance in sustainable aluminum machining operations.

Keywords: Additive manufacturing; H13 tool insert; Aluminum alloy 6061; Machinability, Tool wear.

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Enhanced High-Temperature Tribological Performance of Zirconia-Toughened Alumina Composites Reinforced with Ti_3AlC_2 MAX Phase

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ABSTRACT

The present study investigates the effect of Ti3AlC2 MAX phase addition on the tribomechanical performance of zirconia-toughened alumina (ZTA) composites. The Ti3AlC2 content is varied from 0 to 5 wt.%, and the composites are fabricated using hot-press sintering technique at 1300°C for 1 h under a constant pressure of 100 MPa in presence of argon atmosphere. Ti3AlC2, a ternary layered carbide exhibiting both ceramic and metallic characteristics, imparts unique mechanical behavior to the composites. The sintered ZTA– Ti3AlC2 composites are characterized for their microstructure, mechanical properties, and wear performance. The results show that adding Ti_3AlC_2 significantly improves fracture toughness and damage tolerance but slightly reduces hardness at higher contents due to the MAX phase's softer nature. Tribological tests, conducted using a ball-on-disk setup at a load of 40 N, sliding speed of 0.5 m/s, and sliding distance of 1000 m under both room temperature (RT) and 600°C conditions, demonstrate that the Ti3AlC2 -reinforced composites exhibit superior wear resistance, particularly at elevated temperatures. Overall, the addition of Ti3AlC2 significantly improves the mechanical and tribological performance of ZTA composites, underscoring its potential as an effective reinforcement for high-temperature applications.

Keywords: Ti AlC MAX phase; Zirconia-toughened alumina (ZTA); Hot press sintering; Wear resistance; High-temperature tribology.

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Tribological behaviour and wear mechanisms of multilayer TiN/AlTiN coated and uncoated tungsten carbide tools under dry sliding conditions

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ABSTRACT

The mechanisms governing wear evolution in multilayer hard coatings remain a key challenge in tribology. This study investigates the dry sliding behaviour of TiN/AlTiN multilayer-coated (thickness 1 µm/5 µm) as well as uncoated tungsten carbide (WC) cutting tools in a pin-on- disk configuration. The cylindrical surface (2 mm) opposite the cutting edge of a commercial tool served as the contact surface against C45 steel disks with a 50 mm wear- track radius. Tests were performed at sliding velocities of 10, 40, and 80 m/min under normal loads of 20 and 30 N for 60 minutes. The TiN/AlTiN-coated tools exhibited lower and more stable friction coefficients and significantly reduced wear volumes compared to uncoated tools (80–90 % lower wear coefficients ≈8–10× better wear resistance). The enhanced performance is attributed to the formation of a dense, oxide-rich tribofilm that effectively suppressed both adhesive and abrasive wear. In contrast, uncoated tools exhibited unstable frictional behaviour and severe material loss due to grooving and transfer. Wear evolution analysis indicated gradual wear progression in the TiN layer before transitioning to the AlTiN sublayer, while uncoated tools showed accelerated nonlinear wear at higher velocities. The quantified wear coefficients together with the tribofilm chemistry provide mechanistic insight into layer-by- layer wear in TiN/AlTiN coatings and define key experimental inputs for future, physics-based tool-life modelling under dry machining conditions.

Keywords: Multilayer coatings; TiN/AlTiN coating; C45 Steel; tool wear; dry machining

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Shear-Assisted Tribochemistry and Tribofilm Growth using MXenes on Steel Surfaces

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ABSTRACT

Tribofilm formation at sliding interfaces of moving components is crucial for reducing friction and wear in boundary lubrication regime for enhancing energy efficiency and reliability. At the nanoscale, these films emerge through stress- and shear-driven tribo-chemical reactions. Conventional additives such as zinc dialkyldithiophosphates (ZDDPs) have provided valuable insights, but their limited adaptability and environmental concerns drive the search for alternatives. MXenes, a family of two-dimensional transition metal carbides and nitrides, offer promise due to their layered structure, tunable surface terminations, and strong interfacial reactivity. In this study, modified MXene nanosheets were dispersed in PAO4 base oil via ultrasonication and tested on 52100 bearing steel. During sliding, the nanosheets entered the contact zone, aligned under shear, and underwent tribochemical interactions with the steel surface. Repeated cycles promoted the nucleation and growth of tribofilm where MXenes acted as both solid lubricant lamellae and chemically active agents. PFQNM- based DMT modulus analysis further confirmed that the tribofilm exhibited lower stiffness than the steel substrate, indicating its protective and compliant nature. These findings highlight the potential of MXene-based dispersions to form robust nanoscale tribofilms for advanced, energy-efficient lubrication.

Keywords: MXene; Tribofilm; Bearing Steel; Boundary lubrication; PFQNM.

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Improvement in Wear and Corrosion Resistance Properties of Laser Processed TiC/TiN/TiCN Reinforced Ti Matrix Composites under different Shrouding Environment

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ABSTRACT

The present study deals with the formation of an in-situ synthesized TiC/TiN/TiCN surface on Ti6Al4V alloy through preplacement of graphite powder followed by laser melting using a continuous wave diode laser. The effect of laser power and shrouding environment (argon and nitrogen) on the microstructure, phase, mechanical property and electrochemical behaviour of the laser composite surfaced (LCS) Ti6Al4V were investigated. Microstructural analysis revealed that in-situ formed TiC and Ti2C phases (under argon) and TiCN, TiN/Ti2N (under nitrogen) had either dendritic or granular morphology. The surface hardness of the LCS Ti6Al4V was found to be directly proportional to the phase/volume fraction of TiC/TiN/TiCN in the treated region, reaching values between 900 to 2100 VHN, which was nearly 3–7 times higher than the substrate. A detailed investigation into the fretting wear behaviour of the LCS samples showed excellent resistance to wear and improved COF values under a certain set of laser parameters. Additionally, the electrochemical behaviour in Hank's solution revealed that the kinetics and mechanism of corrosion improved after LCS (specially under nitrogen environment). The improved wear and corrosion resistance along with superior hardness results in a suitable material combination, strongly supporting the use of LCS Ti6Al4V for load-bearing bioimplant applications.

Keywords: Ti6Al4V, Laser composite surfacing, Shrouding environment, Wear, Corrosion.

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Tribological behavior and Wear Mechanism of Selective Laser Melted Inconel 718: Dry wear test VS 3.5% NaCl solution wear test

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ABSTRACT

This study examines the tribological behavior of selective laser melted (SLM) Inconel 718 fabricated using three scan strategies 0°, 67°, and chessboard under dry and 3.5 wt.% NaCl aqueous environments. The chessboard strategy exhibited the highest wear resistance with the lowest coefficient of friction (COF ~0.46) and wear volume (~0.106 mm³), while the 0° rotation showed the poorest performance (COF ~0.53, wear volume ~0.131 mm³). The 67° rotation displayed intermediate behavior (COF ~0.49, wear volume ~0.122 mm³). Under dry conditions, adhesive wear dominated the 0° rotation, whereas abrasive wear was prevalent in the chessboard pattern; the 67° rotation showed primarily abrasive wear with limited adhesion. In 3.5 wt.% NaCl solution, wear resistance significantly improved due to lubrication and reduced frictional heating, resulting in markedly lower COF and wear volume values. The 0° rotation exhibited COF ~0.19 and wear volume ~0.004 mm³; the 67° rotation showed COF ~0.07 and wear volume ~0.002 mm³; and the chessboard pattern achieved the best performance with COF ~0.06 and wear volume ~0.0003 mm³. Overall, in the saline medium, mild abrasive wear predominated across all scanning strategies, highlighting the effectiveness of the lubricating environment in suppressing severe wear.

Keywords: Selective Laser Melting; Inconel 718; Scanning strategy; Dry wear; Wet wear.

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Nanoparticle-Enhanced Lubrication for Improved Performance in Hot Steel Rolling: An Experimental Study

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ABSTRACT

Hot rolling is a vital process in the steel industry for achieving precise dimensions, desired mechanical properties, and optimal surface finish. Controlling friction and wear at the roll bite is essential for maintaining operational efficiency and product quality. Conventional oil-in-water dispersion lubricants are commonly used to reduce rolling force and wear; however, they face limitations under the harsh conditions of high temperature, elevated roll force, and the presence of oxide scale on the steel surface. Nanotechnology offers a promising alternative through nanoparticle-enhanced water-based lubricants, which can reduce friction, wear, and thermal effects while improving surface finish. This study investigates the application of nano-lubricants at the roll bite during hot rolling of steel using an Experimental Rolling Mill (ERM). A comprehensive evaluation was conducted, including physico-chemical characterization and tribological performance analysis. Pin-on-disc tests confirmed significant friction reduction compared to conventional lubricants, and optimized nanoparticle concentrations yielded stable dispersions with enhanced lubricity. A custom-designed nano-lubrication system was developed to ensure uniform nanoparticle dispersion (40–60 nm) using sonication and high-shear mixing. Laboratory-scale trials at the ERM assessed the effects of nano-lubricants on rolling force, surface roughness, and oxide scale formation. Results showed a 15–23% reduction in rolling force, demonstrating the effectiveness of nano-lubrication in improving process performance. These findings underscore the potential of nanoparticle-based lubricants as a viable solution for advancing hot rolling operations in the steel industry.

Keywords: Nano-lubrication; hot rolling; tribology; roll bite lubrication.

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Influence of Self-lubricating Graphite Particles on the Tribological Performance of Al Alloy Composites Prepared by Spray Deposition Technique

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ABSTRACT

In the current study, Al alloy composites with the dispersion of self-lubricating graphite particles have been prepared by spray deposition technique and the effect of these dispersed particles on tribology has been investigated. The tribosurfaces of the samples have also been investigated using SEM with EDS, profilometer and AFM, which have been correlated with tribological results. The wear rate and COF decrease with addition of graphite particles up to a certain wt.%, after that these begin to deteriorate. The optimum weight percent (wt.%) of graphite particles in the composite is found to be 3 wt.% for acquiring the lowest wear rate and COF. These advanced composites hold the potential to future green manufacturing and engineering sustainability, particularly in high-performance tribological applications.

Keywords: Self-lubricanting particle; Al-Si alloy; spray deposition; wear and friction

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Nano-mechanical and micro-mechanical behavior of the multicomponent γ brass

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ABSTRACT

The γ brass is one of the complex intermetallic found in the Cu-Zn alloy system. It has found its application in wire-EDM, coating application, precision mechanical assemblies, and fasteners in electric/electrical hardware. Its high brittleness nature has limited its application. Recently many high entropy intermetallic like high entropy Laves phase [1], high entropy sigma phase [2], B2type high entropy intermetallic [3], etc were synthesized successfully.

In attempt to get a better combination of strength and ductility, we have put forward an attempt in synthesizing γ brass in multicomponent system. The 60h milling of $(CoCuFeMnNi)_{25}Zn_{75}$ was carried out. The XRD analysis shows the presence of the BCC γ brass. The TEM analysis confirms the presence of nanostructured grains and BCC γ brass. Further on acquiring HR images, presence of amorphous images is noticed. The thermal stability was analyzed using Differential Scanning Calorimetry (DSC) shows the presence of exothermic peaks at 267 °C. Further on performing Spark plasma sintering at 600 °C and 5 mins, the XRD analysis shows the evolution of SC γ brass. The SEM analysis showed all elements were uniformly distributed. The indentation Behaviour showed a hardness 4.2 ± 0.2 GPa. The degree of plasticity is found to be 0.73. The nanoindentation analysis of the sample is also carried out. It showed a hardness of around 6 ± 0.1 GPa. The maximum depth of the indentation is 270 nm.

Keyword: Multicomponent γ brass, indentation Behaviour, spark plasma sintering

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Microstructural and Tribological Evolution of Hybrid Al 5052/SiC–GNP Surface Composites under Varying Shoulder-to-Pin Ratios: A Solid-State Approach Towards SDG 12 Compliance

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ABSTRACT

Friction stir processing offers an environmentally sustainable and energy-efficient solid-state route for surface modification of lightweight alloys, aligning with the United Nations Sustainable Development Goal 12 (Responsible Consumption and Production) through efficient material utilization and enhanced component life. Hybrid surface composites of Al 5052 alloy reinforced with nano-SiC and graphene nanoplatelets (GNPs) were fabricated using FSP, varying the tool shoulder-to-pin diameter ratios (D/d) of 3.0, 3.25, and 3.5 to study their effect on microstructural and tribological performance. The specimen processed with a D/d ratio of 3.25 exhibited the most homogeneous distribution, with an average grain size reduction from 88 µm (base alloy) to 7 µm. Correspondingly, microhardness improved from 85 HV for the base alloy to 123 HV, 131 HV, and 142 HV for D/d ratios of 3.0, 3.25, and 3.5, respectively, indicating a combined strengthening effect of SiC-induced load bearing and GNP-assisted dislocation pinning. Ball-on-disc reciprocating tribological testing demonstrated a significant reduction in wear rate from 9.1×10^{-6} mm^3/m (unprocessed) to 7.1×10^{-4} mm^3/m at the optimum D/d = 3.25. The superior performance at this ratio is attributed to the synergistic interplay between enhanced plasticized zone dynamics, refined microstructure, and improved interfacial bonding.

Keywords: Aluminium alloys; Friction stir processing; Sustainable Development Goals; Reinforcements; Graphene nanoplatelets.

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Tribological Investigation of Abrasive Flow Finished Laser Powder Bed Fused H13 Tool Steel: Effect of Extrusion Pressure and Media Composition on Surface Morphology

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ABSTRACT

The fabrication of die casting molds using hot work tool steel ensures high hot hardness and requires complex geometric features for improved performance and durability. In this context laser powder bed fusion (LPBF) provides design flexibility for manufacturing intricate H13 components but often generates poor surface morphology, making post-processing an essential process. The current work focuses on improving the tribological properties of laser powder bed fusion fabricated H13 tool steels by employing abrasive flow finishing as a post processing step. The flow finishing experiments are conducted at extrusion pressures 8 MPa, 9 MPa and 10 MPa, by maintaining constant finishing cycles for all the trails. Five variants of viscoelastic abrasive media were formulated by altering the ratio of base polymer to crosslinker in the precursor and were used in the finishing experiments. The surface morphology of AM coupons after abrasive flow finishing displayed significant improvement. The tribological properties of AM coupons after abrasive flow finishing were evaluated by performing the wear tests. Coefficient of friction was identified as key parameter of surface integrity. The results establish a correlation between rheological properties and tribological response. The wear performance of additively manufactured tool steels depends on surface morphology resulted during the post-processing.

Keywords: Abrasive flow finishing; Tribology; Viscoelastic; Extrusion; Surface morphology.

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Mechanical and tribological performance evaluation of marine grade AA5052 welds fabricated using a portable friction stir welding machine

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ABSTRACT

The study investigates the performance of welds produced using a laboratory-fabricated portable friction stir welding (P-FSW) machine designed for on-site applications. A pair of 1 mm thick AA5052 sheets was welded with tool speeds ranging 18,000-22,000 rpm and a low travel speed of 10 mm/min, ensuring good weld quality despite the challenges associated with low axial load in compact FSW machines. Defect-free joints produced were tested for tensile and hardness properties, identifying the weld with optimum mechanical strength suitable for lightweight structures. The samples underwent slurry erosion and corrosion tests in simulated marine conditions under varying slurry speeds, concentrations, particle sizes, and varying pH. Post-analysis surface characterization was performed through SEM-EDS analysis. The microstructure of the welded sample showed refined grains, higher HAGB fraction, and increased Al_3Fe content. The welded samples exhibited up to 12% higher erosion resistance but about 17% lower corrosion resistance compared to the base metal. Overall, the developed P-FSW machine demonstrated reliability in producing defect-free, high-performance thin AA5052 welds, ideal for on-site repair applications.

Keywords: Portable FSW, Onsite welding, Erosion, Corrosion, AA5052.

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Evaluation of Tribo-Mechanical Behaviour of additively manufactured Inconel 718 Through Post Processing Interventions

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ABSTRACT

Direct Energy Deposition (DED) serves as a method of metal additive manufacturing that facilitates the fabrication and repair of large and high-value Inconel 718 components for aerospace, marine, and energy applications. However, the inherent nature of the powder fed layered deposition process induces non uniform cooling, leading to residual stresses, surface irregularities, and partially bonded layers. To address these limitations Abrasive Flow Finishing (AFF) was adopted as a post-processing technique to enhance surface quality and tribological performance. Visco elastic media formulations were customized with varying mesh sizes of #54, #60 and #80, selected based on the initial surface conditions of specimens. AFF experiments are performed on the specimens using piston velocities 20mm/s, 25mm/s and 30mm/s, with each finishing trial performed for a total of 300 cycles. Tribological experiments were carried out to evaluate the wear rates before and after finishing. Residual stress evaluation through X-ray Diffraction (XRD) confirmed a noticeable reduction in near-surface tensile stresses after finishing, attributed to micro plastic deformation and surface conditioning caused by the viscoelastic media. The combined improvements in surface finish, reduced wear rate, and lowered tensile surface stresses validates the effectiveness of AFF as a post-processing method for enhancing the functional performance of DED-manufactured Inconel 718 components.

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Enhancing Tribological Performance of Wire Arc Additively Manufactured SS316L through CO -Based Forced Interlayer Cooling

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ABSTRACT

This study explores the influence of CO -based forced interlayer cooling on the microstructural, mechanical, and tribological performance of wire arc additively manufactured (WAAM) SS316L components. The active cooling approach effectively reduced interpass temperature, leading to refined cellular-dendritic morphology and suppression of columnar grain growth compared to naturally cooled samples. Microstructural refinement contributed to moderate increases in hardness (8-10%) and yield strength (6%), indicating improved structural uniformity and reduced thermal stresses. The tribological analysis revealed a significant enhancement in wear resistance, with CO -cooled samples exhibiting up to 35% lower wear rate and approximately 28% reduction in average friction coefficient under dry sliding conditions. The worn surfaces displayed fewer abrasive grooves and more stable oxide layers, suggesting a transition toward mild wear behavior. These improvements are attributed to the combined effects of grain refinement, improved hardness, and reduced surface oxidation. Overall, CO -based interlayer cooling offers an effective and economical strategy for tailoring surface durability and enhancing tribological reliability in WAAM-fabricated SS316L components.

Keywords: WAAM; HAM; Interlayer cooling; Dwell time; Wear performance.

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High-Temperature Wear Behaviour of CoCrCuFeMo and CoCrCuFeTi High-Entropy Alloys

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ABSTRACT

High-entropy alloys (HEAs) have emerged as promising candidates for high-temperature engineering applications due to their superior wear resistance and mechanical properties. The present study investigates the microstructure, mechanical properties, and high-temperature tribological properties of in-house-developed CoCrCuFeMo and CoCrCuFeTi HEAs using a pin-on-disc set-up at room temperature, 200 °C, 400 °C, and 600 °C. X-ray diffraction studies indicate that the CoCrCuFeMo alloy shows a single-phase face-centred cubic (FCC) structure. In contrast, the CoCrCuFeTi alloy shows a dual-phase crystal structure of body-centred cubic (BCC) and FCC. The HEA systems developed exhibit Vickers hardness values of 7.8 GPa for CoCrCuFeMo and 7.9 GPa for CoCrCuFeTi when subjected to a 0.05 N load with a dwell time of 15 seconds. The phase transition was observed in the wear behaviour of the developed HEAs with increasing temperature, changing from abrasive wear at room temperature to oxidative wear accompanied by flake formation at 600 °C. Comparative studies further show that the CoCrCuFeMo alloy exhibited a lower wear rate, indicating its superior high temperature wear resistance. The microstructural and tribological studies were systematically characterized to establish structure-property correlations. This study provide insights into the design of HEAs with tailored wear resistance for next-generation engineering materials.

Keywords: High-entropy alloys; Phase and microstructure; Mechanical properties; Wear resistance; Abrasive wear mechanism.

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Analysis of the tribological properties of plasma-sprayed graphene nanoplatelets reinforced Al_2O_3-13%TiO_2-20%Y_2O_3

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ABSTRACT

Industries such as aerospace, automotive, mining, and metallurgical processing operate under severe sliding, abrasive, and high-temperature conditions where component degradation leads to high downtime and maintenance costs. Advanced ceramic coatings with improved hardness, stability, and solid-lubricating characteristics are therefore essential for enhancing operational reliability. In this context, graphene nanoplatelet (GNP)–reinforced Al_2O_3– 13%TiO_2– 20%Y_2O_3 coatings offer a promising materials solution by combining the high wear resistance of alumina-titania ceramics with the exceptional lubricity and mechanical reinforcement provided by GNPs. In this study, coatings containing 0.5 wt% GNPs were deposited on SS 316 substrates using atmospheric plasma spraying and compared with uncoated steel and Al_2O_3– 13%TiO_2–20%Y_2O_3 (AT-20Y). Microstructural and phase analyses were performed using SEM, EDS, FE-SEM, Raman spectroscopy, and XRD. Surface and mechanical characteristics—such as hardness, porosity, roughness, and fracture toughness— were also assessed. The coatings exhibited significantly higher hardness than the substrate, while the ATY-0.5G coating demonstrated the best wear resistance due to the synergistic solid- lubricant action and structural reinforcement provided by GNPs. Overall, the improved performance of the GNP-reinforced coating highlights its strong potential for deployment in industrial environments where enhanced durability, reduced friction, and extended component life are critical performance requirements.

Keywords: Graphene-Reinforced Ceramic Coatings; Atmospheric Plasma Spraying (APS)

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Tribological Performance and Artificial Neural Network Prediction of CaF_2/PTFE Hybrid Solid Lubricant in Eco-friendly $Ca(OH)_2$/Castor Oil Grease Under Extreme Conditions

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ABSTRACT

This study investigates the tribological performance of a sustainable calcium hydroxide/castor oil grease formulated with biodegradable raw materials and reinforced with calcium fluoride (CaF_2, 0.5–2.5 wt.%) and polytetrafluoroethylene (PTFE, 0.5 wt.%). Anti-wear behavior was evaluated using a pin-on-disc tribometer under varying loads (80–160 N), speeds (80–240 rpm), and temperatures (40–200 °C). The optimized formulation (CaF_2 2 wt.% + PTFE 0.5 wt.%), identified through the TOPSIS multi-criteria decision-making method, reduced the coefficient of friction by 73% and 66%, and the specific wear rate by 28% and 22%, compared with additive-free calcium grease and commercial lithium grease, respectively. Smooth friction curves, Fleischer's wear model, and ANN predictions confirmed robust performance in high wear regimes, while SEM and Raman analyses indicated reduced surface damage and lubrication film formation. The proposed bio-grease demonstrates reliable extreme pressure properties, offering an environmentally friendly alternative to petroleum-based lubricants and supporting circular economy principles in industrial lubrication.

Keywords: Bio-based calcium grease; Tribological performance; Calcium fluoride (CaF_2); Polytetrafluoroethylene (PTFE); Sustainable lubrication.

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Assessment of frictional and noise reduction performance of UTTOs in tractor's wet brake application

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ABSTRACT

Universal Tractor Transmission Oil (UTTO) is a multifunctional fluid used in tractors to lubricate and protect the transmission, hydraulic system, final drive, and PTO (Power Take-Off). It also provides the required frictional and cooling performance to the wet brake and clutch of the tractor. Wet brakes in tractors can generate chatter noise and vibration on engagement. This type of noise event is usually observed at the end of the brake application and can be mitigated by using the UTTO with desired lubricating properties. In this study, a force-controlled pendulum tribometer was employed to simulate the friction-generated noise and stick-slip phenomena in wet brakes of the tractor. A half-inch condenser microphone was mounted near the tribo- contact zone to capture the noise signal, and the angular displacement of the pendulum was recorded using an optical encoder. The entire test setup is placed inside a hemi-echoic chamber to reduce the reverberations. The frictional and noise characteristics of various UTTO candidates were assessed using the pendulum tribometer. SRV and four-ball wear tester were used to generate the boundary friction data. The results from this lab study were in line with the field observations.

Keywords: Noise, Friction, Wet brakes, Pendulum Tribometer

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Probing the Environment-Dependent Nanotribology of Graphite

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ABSTRACT

Graphite's lubrication properties are highly sensitive to the surrounding environment. Factors, such as water vapor, oxygen and other ambient gases or adsorbates, strongly influence its frictional behaviour and overall tribological performance via adsorption and intercalation within the near-surface layers. Here, we present nanotribological studies on highly ordered graphite surfaces in two distinct environments: water and *n*-hexadecane. The liquid molecules are commonly known for their immediate formation of solid-like structures at the graphite- liquid interface, driven by minimization of free interfacial energy. Using atomic force microscopy, we investigate friction and wear behaviour of the graphite surface in distinct environments. We find that graphite surface exhibits increased friction and poor wear resistance in the presence of water molecules in comparison to that in ambient conditions, whereas presence of *n*-hexadecane molecules shows reduced friction of graphite surface and exhibits a nonmonotonic load dependence We also performed molecular dynamics simulations to elucidate the molecular-level mechanisms underlying the observed frictional and wear behaviour. This study aims to develop a comprehensive understanding of the effects of a liquid environment on interactions at the sliding interface. These findings open novel ideas towards the design of advanced lubrication strategies for nanoscale devices, graphene-based coatings and energy- efficient tribological applications.

Keywords: Nano wear; n-hexadecane; atomic force microscopy; graphite

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Role of Microstructural Features in Governing Rolling Contact Fatigue Resistance of High Nitrogen Steel

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ABSTRACT

High nitrogen steel, commercially known as Cronidur 30 (CR30), has gained attention as a potential replacement for conventional 440C steel in aerospace bearing applications due to its superior corrosion resistance and reliable performance. Although both steels exhibit comparable hardness, their rolling contact fatigue (RCF) behavior differs significantly under varying contact conditions. CR30 shows excellent RCF resistance under pure rolling, attributed to its fine nanoscale precipitates, but performs poorly under slip-dominated conditions compared to 440C. To understand this contrasting behavior, single-pass scratching tests were conducted to examine the role of microstructural features on scratch and wear resistance. The results reveal that 440C steel exhibits higher scratch resistance owing to the presence of coarse carbides that effectively hinder material removal and improve abrasion resistance. In contrast, the uniformly distributed fine precipitates in CR30 provide limited resistance to abrasion and plastic deformation, resulting in increased material loss under slip conditions. The study highlights how the size and morphology of precipitates govern localized deformation and wear mechanisms, thereby influencing the overall rolling contact fatigue resistance of high nitrogen steels.

Keywords: rolling contact fatigue; cronidur-30; wear mechanism; pure rolling; slip

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High-Temperature Wear Mechanism Transition in Laser-Cladded Tribaloy T400 Coating on Stainless Steel

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ABSTRACT

Laser cladding is an advanced surface engineering technique that enables the development of wear-resistant coatings with refined microstructures and strong metallurgical bonding. In this study, Tribaloy™ T400—a cobalt-based alloy known for its excellent wear resistance and high-temperature performance due to its high Laves phase content—was deposited on AISI 316 stainless steel using a 6.6 kW Yb-YAG fibre-coupled diode laser (LDF 6000-40, Laser line, Germany). A total of 10 samples were produced by varying laser power (800–2200 W) and scan speed (5–10 mm/s), while keeping the powder flow rate and laser spot diameter (3.6 mm) constant under an argon shielding environment. Microstructural analysis revealed a transition from columnar to equiaxed dendritic growth with increasing energy input, influenced by thermal gradients and solidification rates. Dry sliding wear tests conducted under varying loads (10–50 N) demonstrated a strong relationship between processing parameters, microstructure, and wear resistance. The results confirm the suitability of laser cladded Tribaloy™ T400 for high-performance applications in harsh environments, such as aerospace, power generation, and automotive components.

Key words: Tribology, Cobalt Laser, cladding, Wear

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Tribological And Corrosion Behavior of Friction Stir Welded Similar and Dissimilar Aluminium Alloys

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ABSTRACT

The present investigation examines the tribological and corrosion behavior of friction stir welded (FSW) joints of similar (Al6061–Al6061, Al5083–Al5083) and dissimilar (Al6061– Al5083) aluminium alloys. The welded specimens exhibited notable enhancement in microstructures, which significantly influenced their wear and corrosion responses. The Al5083 welds exhibited lowest wear rate and friction coefficient, that can be attributed to their higher hardness and refined grain structure within the stir zone. In contrast, Al6061 joints displayed comparatively higher wear loss due to softer microstructural features and greater adhesive wear tendency. The dissimilar Al6061–Al5083 welds demonstrated intermediate wear behavior, indicating partial transfer of mechanical characteristics between the two alloys within the mixed stir zone. Corrosion testing in a 3.5 M NaCl medium revealed a distinct difference in electrochemical stability among the joints. The Al5083 weld exhibited the highest corrosion resistance, as evident by its lower corrosion current density and more positive corrosion potential, owing to the presence of magnesium-rich phases that promoted passive film formation. The Al6061 weld showed the most active corrosion behavior, with pronounced pitting and localized attack near the thermo-mechanically affected zone. The dissimilar welds presented moderate corrosion performance, reflecting the galvanic interaction between the alloys and the heterogeneous microstructure formed during welding. Overall, the Al5083 welds demonstrated superior wear and corrosion resistance, while the Al6061 joints performed the weakest under identical conditions. The dissimilar welds offered a balanced compromise between the two, indicating that appropriate control of tool parameters and alloy combination can tailor the surface durability and corrosion stability of FSW aluminium joints for service in marine and structural applications.

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Influence of Weld Parameters on the Wear Behavior of Friction Stir Welded AA5052 in Marine Environment

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ABSTRACT

The study focused on the influence of weld parameters on the wear behaviour of friction stir-welded marine-grade AA5052 in marine conditions. The variation in the weld parameters introduced microstructural variability, which in turn influences the wear behavior distinctly. The material-volume removed, wear mechanisms, and the tribo-chemical interactions have been focused on this study. The welds were established at tool rotation speeds and weld speeds of 800, 1000, and 1200 rpm; 60, 80, and 100 mm/min. Friction stir welding introduced extensive grain refinement (upto 8μm), equiaxed grains, enhanced grain boundary misorientations, and increased the intermetallic-phases like Al3Fe. The wear was analysed using a liner reciprocating tribometer utilising 3.5% NaCl for simulating marine environment. The 1200/100 sample exhibited 65% higher wear resistance than cast in dry conditions due to refined grains, higher HAGBs, and increased IMCs. However, in marine conditions, 800/80 samples performed 42% better than cast and 51% better than 1200/100, as the IMCs that improved dry wear resistance influenced negatively. During dry wear, cast samples showed severe adhesion, delamination, and oxidation, whereas welded samples exhibited abrasion and mild oxidation. In marine conditions, all welded samples displayed significant micro-abrasion. Worn surfaces indicated enhanced passivation in both environments. Detailed worn-surface characterization confirmed the formation of Al_2O_3, $Al(OH)_3$, and $AlCl_3$, emphasizing the tribo-chemical interactions governing wear.

Keywords: Friction Stir Welding;Wear;Marine;Corrosion;Surface.

Abstract ID: 1763133408003-BU84N9

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INFLUENCE OF LASER SURFACE MODIFICATION ON TRIBOCORROSION BEHAVIOR OF INCONEL 718 SUPERALLOY

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ABSTARCT

The main objective of this study was to investigate the influence of laser surface melting (LSM) on the electrochemical tribocorrosion behavior of as-received Inconel 718 superalloy in a 3.5 wt.% NaCl aqueous environment. The tribocorrosion tests on laser surface-melted Inconel 718 superalloy at various laser power levels (100, 150, 200, 250, and 300 W) with a constant scan speed of 960 mm/min were performed to evaluate the corrosion performance. Additionally, the microstructural evolution was examined using optical microscopy and scanning electron microscopy (SEM), while micro-hardness was determined using a Vickers hardness tester. The study provides valuable insights into the combined effects of wear and corrosion, highlighting the effect of LSM parameters on the performance and durability of Inconel 718 in harsh environments.

Keywords: Inconel 718; Tribocorrosion; Laser surface melting; Microstructure; Wear.

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Thermal Degradation of EV Motor Bearing Grease: Insights from Contact Angle and Corrosion Behaviour

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ABSTRACT

The passage of current through the bearings of an electric vehicle (EV) motor leads to lubricant degradation by localised electric discharge. This localised discharge generates temperatures exceeding the operating temperature and flash point of the grease, resulting in accelerated thermal degradation. In addition, operation in a humid environment makes the bearings susceptible to water contamination, further accelerating lubricant degradation and overall wear. It has been reported that even 1% water contamination can result in a 90% reduction in bearing life. To investigate the thermal degradation behaviour, the grease was thermally aged at 100, 120, 160, and 220 °C based on its operating temperature and flash point. Its ability to repel water was evaluated using the contact angle method by contact angle method. FTIR analysis revealed that the structural stability of the grease was retained up to 120 °C, while significant structural degradation occurred beyond 160 °C. The structural degradation affects the grease by depleting the additives, which eventually impacts the corrosive property of the grease, making it important to analyse the corrosive properties of the grease.

Keywords: EV motor bearings, NLGI 3 Grease, Corrosion, Structural degradation, Water contamination

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Impact of Electrical Current on Bearing Vibration and Failure Progression

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ABSTRACT

Stray electrical currents in electric-drive systems can damage rolling bearings even when mechanical loads are absent. This study examines the influence of a constant electrical current on the vibration behaviour and failure progression of deep-groove ball bearings operated under no-load conditions. A controlled DC current was applied across the bearing raceways, and vibration signals were recorded continuously using an accelerometer-based monitoring setup. Key indicators such as RMS, kurtosis, crest factor, and high-frequency spectral components were analysed to track defect initiation and growth. The results show that electrical current alone significantly increases vibration levels and accelerates surface degradation compared to unpowered baseline bearings. Early signs of pitting and high-frequency vibration peaks emerged much sooner in electrically loaded bearings, indicating rapid fault development. The findings demonstrate that electrical stress, independent of mechanical loading, can substantially reduce bearing life, emphasising the need for improved insulation, grounding, and monitoring strategies in modern electric machinery.

Keywords: Bearing wear; Electrical arcin; Pitting progression; Rolling element bearings.

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Study on Reciprocating wear characteristics of Ti64 /Ti64USSped under variable load

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ABSTRACT

By means of ultra sonic shot peening technique nano-structure of the surface of Ti64 alloy was modified. This was done to enhance the tribological properties of the alloy. The new surface formed was investigated for reciprocating wear performance against AISI52100 tribopair. Comparing with non-ultrasonic shot peened sample an increase in surface hardness of the surface was found which was attributed to ultrasonic shot peening. The micro hardness was measured using Vickers hardness test. The tribological test was carried out for both samples with different loading condition. SEM, EDX of the worn surface was carried out to know the mechanism of wear.

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Experimental Investigation on Tribological Aspects of Dry Electrochemical Polished SLM Fabricated H13 Tool Steel

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ABSTRACT

The Selective Laser Melting (SLM) process, a subset of laser powder bed fusion (LPBF) technology, has emerged as a promising method for fabricating complex components with minimal material usage and reduced overall weight. However, the surface quality of SLM fabricated parts often limits their functional performance, particularly in tribological applications. This study investigates the tribological behaviour of SLM-processed H13 tool steel subjected to Dry Electrochemical Polishing (DECP) under varying processing parameters. DECP is an advanced post processing technique, integrates the benefits of mechanical and electrochemical polishing in an environmentally sustainable, electrolyte free system.

Tribological tests were performed on as built and heat-treated H13 specimens both before and after DECP. The influence of surface topography, microstructural modifications, and hardness on wear performance was systematically evaluated. The wear mechanisms were analysed using scanning electron microscopy (SEM). The results shows that DECP significantly improved surface smoothness and reduced friction and wear rates compared to untreated samples. The findings highlight DECP as an effective and eco-friendly post- processing route for enhancing the surface integrity and tribological performance of additively manufactured H13 tool steels, making them more suitable for high-performance tooling and die applications.

Keywords: Dry Electrochemical Polishing, H13 tool steel, wear, Heat Treatment

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Effect of ageing treatment on the wear and corrosion performance of micro-arc oxidation coated 7075 aluminium alloy

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ABSTRACT

Understanding the role of ageing treatment on microstructure stability, hardness, and compactness of coatings is limited to develop wear and corrosion resistant Al-alloys. This study investigates the effects of ageing treatment on the wear and corrosion behavior of alumina coated aluminium 7075 alloy. The alumina coating was performed by following the Micro-arc Oxidation (MAO) process. A linear reciprocating tribometer was used to evaluate the wear resistance of the base and the coated alloy. Corrosion rates were evaluated using electrochemical tests with the Tafel extrapolation method. Finally, the ageing treatment induced microstructure evolution was correlated with the hardness, wear, and the corrosion behaviour of the MAO-coated Al-alloy.

Keywords: Aluminium 7075 alloy; Ageing treatment; Precipitates; Micro-arc oxidation; Wear; Corrosion behavior.

Abstract ID: 1763179838567-4TJ2RC

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Biomechanical Characteristics of Nanostructured Silica-Coated TAV Alloy for Biomedical Applications

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ABSTRACT

Ti-6Al-4V (TAV), widely used in biomedical implants, remains prone to surface degradation and biotoxicity, necessitating improved tribological performance. This study introduces a scalable method that deposits porous silica-nanoparticle coatings via PMMA degradation on additively-manufactured TAV. A coating with 75wt% SiO_2, 10wt% PMMA, and 0.27 porosity-fraction acts as an effective interfacial barrier, eliminating bone-implant modulus mismatch, achieving load-bearing capacity 30x higher than human hip-joint, 99% wear reduction and 99.9% corrosion efficiency. Optical-profilometry, contact-angle measurements and FESEM-EDS reveal the surface morphology, adhesion, and underlying wear mechanisms. This work demonstrates nanosilica-based porous coatings as high- performance alternatives to current biomaterials for next-generation biomedical implants.

Keywords: PMMA; Ti alloy; Ceramic Coating; Bio-tribology; Nanoparticles.

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Machine Vision–Enabled Framework for Lubricant Degradation Monitoring and Prognostics

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ABSTRACT

Lubricant degradation remains a critical concern in industrial, automotive, aerospace, and especially Electric Vehicle (EV) systems, where elevated thermal loads accelerate deterioration during high load–speed operations. This research introduces an intelligent monitoring and prediction framework for assessing lubricant health using machine learning (ML) combined with sensor-based data acquisition. Visual data from heated greases (like NLGI 2 , subjected to 80-150 °C) are continuously captured to observe degradation-related changes in color and clarity. Following preprocessing steps-cleaning, normalization, and augmentation—these images are analysed using a Convolutional Neural Network (CNN) capable of identifying intricate degradation features. Model performance is assessed through precision, recall, F1- score, and confusion matrix metrics, while viscosity predictions are validated using ASTM D4440 standards. Additional ML approaches, including Random Forest, Support Vector Machine (SVM), and pre-trained networks such as ResNet-50/101/152, EfficientNet-B0/B3, DenseNet-121, and InceptionV3, are evaluated for comparative effectiveness. When integrated with IoT and cloud-based platforms, the proposed system can lower operational expenses, increase equipment lifespan, and reduce downtime—potentially cutting production recovery time by up to 40%. Overall, this study supports the development of advanced intelligent maintenance strategies that enhance machine reliability and promote environmentally sustainable lubricant usage.

Keywords: Lubricant degradation; Machine Learning; Predictive Maintenance; Real- time Monitoring.

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Architectural Modulation of Electroless Ni-B-Sn and Ni-B-W-Sn Coatings: Microstructural study, Enhanced Tribological, and Corrosion Performance

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ABSTRACT

In this study, three distinct architectures: bi-layer, duplex, and multilayer coatings (up to five alternate layers) of Ni-B-Sn and Ni-B-W-Sn were deposited on low carbon steel substrate using electroless method. The aim of the present study was to explore the influences of Sn and W incorporated in Ni–B layers and their effect on microstructure, hardness, wear, and corrosion performance. Field emission scanning electron microscope (FESEM) analysis revealed that multilayer architectures exhibited a compact cauliflower-like morphology with refined nodules and strong interfacial cohesion, while X-ray diffraction (XRD) confirmed nanocrystalline structure. The inclusion of W enhanced the deposition kinetics and deposition rate. The microhardness of duplex coating with Ni-B-Sn and Ni-B-W-Sn base has improved remarkably as ~ 1147±141.9 $HV_{0.1}$ and ~1149± 59.96 $HV_{0.1}$ respectively. Reciprocating wear tests at room temperature have shown an improved performance than high temperature test (300 ºC). Electrochemical analysis also showed an improved corrosion resistance for multi- layer coatings compared to bi-layer and duplex Ni-B-Sn and Ni-B-W-Sn. Thus, this developed coating architectures with different layer of Ni-B-Sn and Ni-B-W-Sn produced a dense, wear resistant, and corrosion-resistant surface with improved tribo-mechanical stability.

Keywords: Electroless Ni–B–Sn; Ni-B-W-Sn; Multilayer coatings; Microhardness; XRD; Corrosion.

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Effect of Swept Back Angle on Wear of Thermal Protection System in Hypersonic Vehicles

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ABSTRACT

Reusable hypersonic vehicles (RHV) are the class of aerial vehicles, which can fly at speeds five times higher than the speed of sound (Mach, $M > 5$) and can be reused for future flights. A protective material layer (insulative and/or ablative) known as thermal protection system (TPS) is necessary to shield the RHV from extreme thermal loads encountered at such high speed. The thickness of TPS material is crucial and depends on various geometrical parameters e.g. sweep-back angle, which significantly affects fluid flow characteristics, material wear rate thus the thickness of this TPS layer. The accurate prediction of ablation rate is essential for multi- mission reliability. This study investigates the effect of swept back angle on the ablation of the TPS material at a given flight condition due to the skin friction heating. High-fidelity flow simulation at $M = 7$, and altitude $H = 35$ km are performed using ANSYS Fluent to understand the boundary-layer behaviour, surface heat flux, temperature, and pressure distribution. The aerothermal results from ANSYS-Fluent are imported in ANSYS Workbench, where the wear model is implemented to evaluate the ablation-induced material removal. This investigation will provide an understanding of TPS degradation mechanism, which is critical for RHV designs, and it will help in designing an optimal configuration with enhanced durability.

Keywords: Aerodynamic Heating, Ablative Material, Thermal Protection System, Reusable

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Tribological Behaviour of Al-Cu-Fe Quasicrystal Reinforced Aluminium Matrix Nanocomposites

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ABSTRACT

Preliminary XRD and SEM analysis confirmed the retention of the Al-Cu-Fe icosahedral quasicrystal (IQC) phase and its uniform distribution within the aluminium matrix. Tribology, encompassing friction, wear and lubrication, is essential in evaluating materials intended for surface-contact applications. In this work, an aluminium matrix composite reinforced with 40% IQC was processed and examined for its wear behaviour and microhardness. The composite exhibited an ultimate compressive strength (UCS) of 407 MPa, consistent with the strengthening contribution of the IQC phase reported in literature. Under dry sliding conditions, the wear resistance of the IQC-reinforced composite improved significantly, attributed to the intrinsic hardness, quasi-periodic structure, and limited plasticity of the icosahedral phase which act as effective barriers to material removal. Microhardness also increased markedly compared to the unreinforced Al matrix, demonstrating improved surface integrity. These results highlight the strong potential of IQC-reinforced aluminium composites for advanced tribological applications requiring lightweight materials with superior wear performance.

Keywords: Al-Cu-Fe quasicrystal; tribology; wear; microhardness; aluminium matrix composite.

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Pressure Analysis with Respect to Speed and Water Supply in Water Lubricated Hole Entry Bearing

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ABSTRACT

The paper investigates the use of two computational modeling techniques: a rotordynamics software tool and CFD simulations. These approaches are complemented by experimental pressure measurements to deliver a comprehensive analysis of pressure behaviour in water lubricated bearings operating at constant rotational speed with controlled water supply. The study systematically examines the influence of inlet water pressure, flow rate, bearing geometry, and lubricant medium on hydrodynamic pressure development and film stability under fixed-speed conditions. Pressure data obtained from embedded sensors are used to validate CFD results, ensuring an accurate depiction of fluid film formation and internal pressure distribution across various operating regimes. The results include detailed pressure–speed and pressure–flow rate characteristics, revealing trends in load-carrying capacity, lubrication efficiency, and steady-state bearing performance. Beyond technical insights, the research emphasizes significant environmental and practical advantages of water lubrication, including lower contamination risks, improved workplace safety, and simpler disposal compared to oil-based systems. Continuous pressure monitoring is also shown to be effective for the early detection of wear, misalignment, and lubricant deterioration, strengthening predictive maintenance programs in industrial applications. Overall, this work establishes a foundation for optimizing pressure behaviour in water-lubricated bearing systems, advancing safer, cleaner, and more sustainable engineering practices that align with modern environmental and industrial goals.

Keywords: Journal bearing; sustainability; pressure behaviour; water-lubricated bearing; wear detection; preventive maintenance.

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Lubricant degradation under combined electrical and mechanical loading conditions

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ABSTRACT

Lubricant degradation under combined electrical and mechanical Loading has become a significant reliability concern in electric-vehicle bearings. Common-mode voltages from the motor's variable-frequency drive induce bearing currents that discharge through the lubricant film when its dielectric strength is exceeded. These events disturb the grease structure, weaken additive action and gradually reduce film protection. Once electrically affected, the lubricant becomes more sensitive to shear, oxidation and evaporation, leading to a steady decline in film stability. As this layer weakens, friction increases and surface features such as pitting, frosting and fluting start to appear, which are recognised as early indicators of bearing distress. Controlled test setup experiments followed by microscopic and spectroscopic analysis, help trace these degradation pathways and identify conditions that influence lubricant performance.

Keywords: Bearing Current; Grease Breakdown; EV Lubrication; Fluting

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Vibration analysis of hybrid journal bearing to detect instances of wear causing events inside the bearing by using OROS software with lubricants of varying viscosities

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ABSTRACT

This study investigates the influence of lubricant viscosity on the pressure distribution and wear characteristics in hybrid journal bearings. Dimensional and fluid property data were provided as input to obtain maximum pressure (Pmax) values using two computational approaches— Dyrobes and ANSYS. The results from both simulations were successfully obtained and compared, revealing that as the viscosity of the lubricant decreases, the discrepancy between the Pmax values predicted by Dyrobes and ANSYS increases. This divergence suggests a potential rise in turbulence intensity under low-viscosity conditions, as supported by existing literature indicating that lower viscosity promotes higher turbulence levels. To validate these observations, experimental measurements of Pmax are planned and vibration-based monitoring using OROS analysis equipment. The outcomes of this work are expected to establish a correlation between viscosity-induced wear and pressure variations in fluid film bearings, providing a more comprehensive understanding of their dynamic behavior under varying lubrication conditions.

Keywords: vibration analysis; journal bearings; water lubricated bearings; wear analysis; CFD; FEM.

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Cu–Zn interfacial adaptation and intermetallic regulation in friction-stir-surfaced Cu–Al–Cu laminated composites

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ABSTRACT

A multilayer laminated composite of Cu–Al–Cu was produced through a solid-state additive manufacturing process based on multi-pass friction stir surfacing (FSS) and Zn galvanization of the outer Cu layers to improve tribological behavior and surface integrity. The consecutive deposition of Cu, Al, and Cu layers formed a continuous metallurgical bond with minimal formation of θ-($CuAl_2$), η_2-(CuAl), and γ-(Cu_9Al_4) intermetallic compounds at the Cu/Al interfaces. The post-galvanizing process led to the creation of compact Cu_5Zn_8 and $CuZn_5$ intermetallic layers on the outer Cu surfaces, which facilitated surface hardening and even distribution of load on the surface during sliding. Microstructural characterization established dynamically recrystallized grains, refined diffusion zones, and a stable interfacial structure maintained by the solid-state processing. Dry sliding tribological tests against hardened steel showed that the specific wear rate was reduced by 35-40% and that the friction coefficient was reduced by about 25% relative to uncoated Cu-Al-Cu laminates. The combined effects of the Cu-Zn intermetallic layer, which enhanced surface hardness, and the ductile Al interlayer, which facilitated subsurface strain accommodation, led to improved wear resistance. Furthermore, this approach promotes sustainability by utilizing Zn-mediated surface adaptation by solid-state lamination that reduces overall weight and enhances the durability of components, thereby contributing to less frequent replacements and lower resource consumption in industrial processes.

Keywords: Friction stir Surfacing; Solid-state additive manufacturing; Wear resistance; Lightweight materials; Sustainable manufacturing.

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Micro Machining of Semi-hemispherical Micro Dimples on Piston Surface for Reduced Frictional Losses in Internal Combustion Engines

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ABSTRACT

Frictional losses in piston ring liner interface change with engine load and speed, and consume a large percentage of the engine's indicated power, along with combustion, heat, exhaust, pumping and other losses. Texturing on the contact surfaces is a proven technique for friction reduction. Tribologically, micro dimples prevent lubricant from leaving the contact zone, improving mixed friction at low relative speeds. Furthermore, the fabrication of micro dimples reduces the true area of contact, increases heat dissipation, and stores worn-out materials. Previously explored lab-based tribology experiments demonstrated the benefits of creating semi-hemispherical micro dimples on the Al alloy piston material with the gray cast iron liner material. To analyse the effect of texturing on real engine conditions before commercialization, engine experiments have been conducted with uniquely textured pistons. Texturing on pistons was performed with micro ball nose end mill cutters in a 4-axis vertical machining center. Initially three pistons were textured for dimple depth of 40, 100 and 150 µm with aspect ratio of 1:6 and area density of 10 %. Textured pistons were tested in a single-cylinder, 4-stroke, water-cooled compression ignition engine fitted with generator. This engine was fueled with diesel, lubricated with SAE 20W40 engine oil and mostly utilized for agricultural purposes. Based on the results of engine experiments, including combustion, performance and emission parameters of untextured and textured pistons, two pistons were textured with area density of 5 and 15 % for best performing dimple depth. Results of combustion, performance and emission for varying dimple depth and area density of textured surfaces were analysed in detail to find the suitable dimple geometry for maximum friction reduction.

Keywords: Conventional Micromachining, Ball nose end mill cutter, Semi-hemispherical Micro dimples, Piston-ring-liner Interface, Internal Combustion Engines, Friction

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Electroless Synthesis and Tribological Evaluation of Self-Lubricating Ni-B-W-hBN Composite Coatings: Unveiling hBN's Role

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ABSTRACT

Electroless deposition has become a versatile method for fabricating alloy and composite coatings that exhibit superior mechanical and tribological performance, with applications across a wide range of industrial sectors. In this work, Ni-B-W alloy and Ni-B-W-hBN composite coatings were synthesized on low-carbon steel substrates via electroless plating, and their microhardness, fracture toughness, and coefficient of friction were compared. Particular emphasis was placed on the role of hexagonal boron nitride (hBN) reinforcements as solid lubricants within the Ni-B-W matrix (for Ni-B-W-hBN composite coating) and on identifying the key process parameters that enable the hBN-reinforced composite to outperform the Ni-B-W alloy coating. The results show that incorporating hBN particles substantially increases coating hardness and fracture toughness while simultaneously lowering the steady-state coefficient of friction under the tested load. This study highlights the interplay among bath composition, coating microstructure, and tribological response, providing insight into the factors that drive the development of a mechanically and tribologically superior coating through hBN incorporation. The rational design of self-lubricating Ni-B-W-hBN composite coatings demonstrated here holds considerable promise for industrial applications where reduced friction and enhanced wear resistance are critical.

Keywords: Electroless coating; Ni-B-W-hBN; Hardness; coefficient of friction; Fracture toughness.

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Correlation of Depth, Diameter and Aspect Ratio of Semi-Hemispherical Micro Dimples for Improved Lubrication in Piston-Ring-Liner Interface

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ABSTRACT

Surface texturing on the piston surface can improve lubrication in piston-ring-liner interface. Textured micro dimples can serve either as a micro-hydrodynamic bearing in cases of full or mixed lubrication or as a micro reservoir for lubricant in cases of boundary lubrication. Material wear, friction, restricted lubricant flow and fluctuation in hydrodynamic load carrying capacity were main challenges to find suitable dimple geometry to enhance tribological performances in this interface. Based on the prior works, semi-hemispherical shape of micro dimples seems advantageous compared to round, square, triangle, diamond, trapezoid and ellipse shapes of micro dimples due to symmetry. However, suitable depth, diameter and aspect ratio of semi-hemispherical micro dimples vary according to the load, speed and lubrication conditions. Hence, theoretical model of a single semi-hemispherical micro dimple was established and detailed numerical study was performed to analyze the effect of dimensional variation in hydrodynamic load carrying capacity between conformal contacting surfaces. Load, speed and lubrication parameters were included with reference to the experimental work of an agricultural compression ignition engine. Based on the results of numerical simulations and prior tribology experiments for limited set of dimple depth and diameter, artificial neural networks were trained to predict the hydrodynamic load-carrying capacity and coefficient of friction, respectively. Results of computations show that dimple dimensions have obvious influences on load-carrying capacity of contacting surfaces and coefficient of friction of contact surfaces. The results of these simulations were used to determine a suitable range of dimple dimensions for texturing on the piston surface and to conduct real-time engine experiments for industrial applications.

Keywords: Piston-ring-liner Interface, Surface Texturing, Semi-hemispherical Micro Dimples, Simulation, hydrodynamic load-carrying capacity, artificial neural networks, coefficient of friction.

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Wear and corrosion analysis at interface of functionally graded structure by using twin-wire arc additive manufacturing

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ABSTRACT

Twin-wire arc additive manufacturing (WAAM) based on directed energy deposition has emerged as a well-suited approach for developing graded and multi-material metallic structures. In this work, functionally graded structure (FGS) was developed by combining austenitic stainless steel (SS316LSi) and low-carbon steel (ER70S-6) within a single build. The fabricated FGS exhibited a well-formed interface, free from porosity and welding defects. At interface, two distinct metallurgical regions were clearly visible. Microstructural examination showed that stainless steel side primarily consisted of γ-austenite with δ-ferrite, while ER70S6 side displayed a combination of polygonal and acicular ferrite, transitioning to coarser lamellar grains with increasing distance from interface. Elemental diffusion of Cr, Ni and Mo into ER70S-6 region was confirmed through EDS and XRD, contributing to phase transformation and strengthening. Mechanical testing indicated that stainless steel region has highest tensile strength and elongation, whereas FGS achieved intermediate properties (UTS 549.95 MPa, YS 335.15 MPa), but higher than those of ER70S-6. Wear studies revealed an increase in coefficient of friction and wear rate with applied load, with oxidative and adhesive wear dominating near interface. Corrosion analysis showed localised attack influenced by compositional gradients. Graded interface demonstrated strong metallurgical bonding and favourable mechanical and surface performance.

Keywords: Wire arc additive manufacturing; Functionally graded structure; ferrous alloys; Wear characteristics; Corrosion

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Experimental and numerical investigations on the machining performance of self-lubricant CrAlN-Ag coatings in dry turning operations

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ABSTRACT

The influence of silver (Ag) alloying on the tribological and machining performance of CrAlN self-lubricating coatings was investigated during the turning of AISI 1045 medium carbon steel. Finite element simulations were performed to predict tool behaviour, with particular emphasis on chip temperature and tool-wear rate. The numerical predictions showed good agreement with the experimental results, falling within an acceptable deviation range of 5–10%. The results indicate that CrAlN–Ag coated inserts with an optimal Ag concentration (~8.6 at.%) provide a balanced combination of the hard CrAlN matrix and the soft, low-friction Ag phase. This synergy leads to significant reductions in chip temperature, cutting forces, and machined surface roughness. In contrast, excessive Ag content (≥11.8 at.%) caused premature tool wear due to deterioration of the coating's mechanical integrity, while insufficient Ag content (~2.4 at.%) reduced the effectiveness of the solid-lubricant mechanism. Overall, the findings highlight the critical role of optimising Ag content to maximise the machining performance and durability of CrAlN-based self-lubricating coatings.

Keywords: Solid lubricant coatings; CrAlNAg coatings; Turning; Finite element analysis; Tool wear.

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Microstructural Signatures of Fold-Induced Defects in Sliding

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ABSTRACT

A clear distinction between different types of surface defects is essential for accurately interpreting deformation mechanisms in tribological contacts. Post-sliding characterization methods often reveal a wide variety of defects, while analytical or numerical models attempt to predict their origins. In this work, the microstructural signatures of fold-induced defects are identified using FESEM, Electron Backscatter Diffraction (EBSD), and Nanoindentation characterization techniques, supported by *in situ* image analysis. The morphology of these defects closely resembles cyclic cracks originated by ratcheting, low-cycle fatigue, and delamination mechanisms. Fold-induced defects can be categorised mainly into three groups, namely, (i) isolated single crack-like defect, (ii) overlapping multiple single crack-like defects, and (iii) crack- like defects with multiple branches. The unique features of these defects, which distinguish them from the cyclic cracks, are (a) the refined microstructures around the cracks with elongated grains (approximately one order of magnitude higher than the refined grains) in the adjacent region and
(b) a significant variation of microstructure within a short distance (comparable to the initial grain size). *In situ* imaging, combined with EBSD analysis, reveals that the unconstrained deformation of surface grains or grain clusters produces these defects through a folding mechanism, rather than a cyclic loading process.

Keywords: Sliding; Surface folding; Crack-like defect; Cyclic cracks; Microstructural signature

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Establishing co-relation in shear stability of engine oils at laboratory conditions vis-à-vis real-world field conditions

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ABSTRACT

Shear stability of engine oil is its ability to resist viscosity loss when subjected to high mechanical stress. Multi-grade engine oils contain viscosity modifiers to maintain thickness and when these modifiers are broken down by shearing, the oil's viscosity drops, leading to reduced wear protection & engine damage. Diesel Injector Shear Test (ASTM D6278) is most popular laboratory test for engine oil shear stability. However, shear stability may vary during field trials based on its application type though it shows similar results in laboratory conditions. In this research, shear stability of various engine oils are analysed and established correlation between laboratory and field conditions. This correlation is useful for oil formulators and engine manufacturers to ensure that lab-tested oils perform reliably in field conditions. This study consists of shear stability analysis of diesel engine oils & motorcycle engine oils at the laboratory vis-vis during field trials. Different viscosity modifiers (24/35 SSI) are used to formulate these engine oils and shear stability are tested at different cycles (30, 90 & 240 Cycles). It is observed that majority shear happens in first 30 cycles during laboratory testing and real-world field trials exhibit higher shear tendency (2 to 3 times) vis-a-vis laboratory conditions.

Keywords: Shear stability; engine oil; viscosity modifier; field trial.

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Role of V-Alloying in TiAlSiN-Based Coatings for Machining 42CrMo4: A Comparative Study of TiAlSiN, $TiAlSiV_4N$ and $TiAlSiV_{11}N$ on Al_2O_3/SiC Tools

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ABSTRACT

This work presents a comparative evaluation of TiAlSiN, $TiAlSiV_4N$ and $TiAlSiV_{11}N$ coatings deposited on Al_2O_3/SiC cutting tools for the machining of 42CrMo4 steel. The study focuses on understanding the role of increasing vanadium content on coating microstructure, thermal stability and cutting performance. All coatings were characterized using XRD, SEM/EDS and nanoindentation prior to machining. TiAlSiN exhibited a fine nanocomposite morphology with adequate hardness but showed early crater formation due to limited oxidation resistance. Introducing 4 at.% V resulted in $TiAlSiV_4N$, which demonstrated improved toughness and a moderate reduction in cutting forces. However, the highest V-content coating, $TiAlSiV_{11}N$, clearly outperformed the others, achieving up to 50% lower flank wear and exhibiting the most stable force profile throughout the cutting tests. Tribological analysis revealed the formation of a protective V-oxide tribolayer that reduced interfacial friction and minimized chip–tool adhesion. Additionally, $TiAlSiV_{11}N$ exhibited superior thermal softening resistance, thereby delaying coating degradation under high-speed cutting conditions. Overall, increasing V concentration significantly enhanced the coating's self-lubricating capability and structural integrity, with $TiAlSiV_{11}N$ offering the most promising performance for demanding machining operations of hardened alloy steels.

Keywords: TiAlSiN coatings; V-doped TiAlSiN; Al_2O_3/SiC inserts; 42CrMo4 machining; cutting performance

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Influence of Ti–Si–N and Ti–Si–V–N Coatings on Tool Wear, Cutting Forces and Tribo-Mechanics in Turning 42CrMo4 with Al_2O_3/SiC Inserts

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ABSTRACT

This study investigates the machining performance of uncoated, TiSiN and TiSiVN-coated Al_2O_3/SiC cutting inserts during the turning of 42CrMo4 steel under dry conditions. The objective is to understand how V incorporation into Ti–Si–N coatings influences tool wear, cutting forces and tribological behaviour when applied on ceramic composite substrates. Cutting trials were conducted at industrially relevant speeds, followed by a full characterization of flank wear, crater wear, chip morphology and frictional response. The uncoated inserts exhibited rapid abrasive and adhesive wear, resulting in unstable cutting and increased force fluctuations. TiSiN coatings significantly improved edge stability but were limited by brittle chipping and progressive oxidation at elevated temperatures. In contrast, the TiSiVN coating delivered the best overall performance, showing a 30–45% reduction in wear rate and consistently lower cutting forces. SEM and EDS analyses revealed that V addition promoted the formation of a dense, lubricious, and V-rich tribofilm, which suppressed micro-fracture and reduced friction at the tool–chip interface. The enhanced thermal stability and crack-deflection characteristics of TiSiVN further contributed to superior tool life. The results confirm that V alloying is an effective strategy to improve the cutting efficiency of TiSiN coatings on ceramic tools for machining hardened steels.

Keywords: TiSiN coatings; TiSiVN coatings; Al_2O_3/SiC tools; 42CrMo4 steel; tool wear

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Comparative Finite Element Evaluation and Material Selection Strategies for Heavy-Payload UAV Frame

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ABSTRACT

Heavy-payload unmanned aerial vehicles (UAVs) have become integral to logistics, industrial inspection, agriculture, and emergency response, where the structural integrity of the airframe under high static loads is paramount. This study presents a finite element–based static structural analysis of a quadcopter X-frame intended for heavy-lift applications. A pre- modelled frame was evaluated under a total lift-off load of 15 kg, simulated as a 90 N static force applied to each arm. Three structural materials—aluminium alloy, carbon-fibre composite, and epoxy resin—were investigated using Finite Element Analysis (FEA) to quantify stress distribution, deformation behaviour, and corresponding factors of safety (FOS). The simulations demonstrate that carbon-fibre composite offers the most favourable structural response, characterised by minimal deformation and high safety margins, reinforcing its strength-to-weight advantages. Aluminium alloy provides a practical balance between mechanical resilience, cost, and manufacturability. In contrast, epoxy resin exhibits excessive deformation, limiting its suitability for primary load-bearing roles. These outcomes emphasise the importance of material-specific evaluation in the development of reliable heavy-payload UAV systems. This work establishes a systematic, simulation-driven framework for preliminary structural assessment and provides a foundation for further research involving dynamic loading, fatigue analysis, and multi-objective optimisation of advanced UAV airframe materials.

Keywords: Heavy-payload UAV, static structural analysis, finite element analysis, quadcopter frame, material selection, carbon-fibre composite, aluminium alloy.

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Biotribological Testing of Implant Materials and Development of a Biotribometer

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ABSTRACT

Biotribology is a rapidly growing field in tribological research. The global hip implants market is projected to reach $11.8 billion by 2029, with a CAGR of 8.6%. Increasing trends are observed for other implants as well. Wear rate of articulating joints needs to be evaluated to determine the life of joints. The current work focuses on the use of wear screening device for hip implant wear tests of various materials. This screening device (Prosthetic biotribometer) consists of three reciprocation stages and three rotational stages, which provide cross-shear motion at the pin surface. The specific wear rate of the UHMWPE pin was found to be 2.83×10^{-6} mm^3/Nm under serum-lubricated conditions. After 96 hours of the test, the serum absorption was minimal. Abrasion and burnishing were found to be the primary wear mechanisms, whereas protuberances were identified at the center position of the pin.

Keywords: Biotribometer; Biotribology; UHMWPE; Wear

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Compositional Dependency of Ni-Cu-Al Alloy on Tribo-mechanical Properties Fabricated by Multi-wire WAAM-TIG

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ABSTRACT

The study explores in-situ fabrication of multi-material structures of different compositions by introducing a three-wire feed mechanism in tungsten-inert-gas based wire arc additive manufacturing (WAAM-TIG), utilising its volumetric energy source. The concurrent wire feed mechanism successfully alloyed the fed materials, ensuring both compositional and geometrical uniformity. Two samples were fabricated, i.e. Ni-Cu-Al-1 alloy with equal percentages, and another Ni-Cu-Al-2 (15-80-5%, similar to shape memory alloy). Further, in- depth tribo-mechanical analysis was performed to establish the process. The micro-indentation hardness study revealed higher hardness for Ni-Cu-Al-1 (~420 $HV_{0.3}$) compared to NiCuAl-2 (~193 $HV_{0.3}$). Similarly, the tensile testing strength showed improved performance for Ni-Cu- Al-1, with a yield strength of ~356 MPa, ultimate tensile strength of ~450 MPa, and ~38% strain, whereas NiCuAl-2 exhibited ~320 MPa yield strength, ~417 MPa UTS, and ~4.4% strain. The conducted wear analysis yielded coefficients of friction of 0.36 for Ni-Cu-Al-1 and 0.57 for Ni-Cu-Al-2, with specific wear rates of 5.16×10^{-5} mm^3/N-m and 4.28×10^{-5} mm^3/N- m, respectively. Scratch hardness tests further assessed surface resistance and fracture behaviour. The findings highlight the critical role of alloying elements in tailoring mechanical properties and guiding the design of advanced structural materials used in aerospace actuators, microelectromechanical systems, latch mechanisms, and many other applications.

Keywords: Additive manufacturing; WAAM-TIG; Ni-Cu-Al alloys; Tribo-mechanical properties; Multi-materials.

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Enhancement in Tribological Performance of Copper through Interpass Arc Remelting during WAAM-TIG Fabrication

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ABSTRACT

The presented experimental research explores the enhancement in tribological performance of additively manufactured pure copper, the most widely used material in various industrial applications. Interpass arc remelting was adapted after every layer of deposition to minimise the defects, such as porosity and inconsistent fusion between the depositing and deposited layers. A comparative study was conducted between as-deposited and remelted samples in both continuous and pulsed modes of arcing. It was observed that the scratch hardness measured at three wall locations showed a progressive increase from bottom to top. It was found to be 0.43 to 0.55 GPa, 0.71 to 0.83 GPa, and 1.03 to 1.09 GPa for as-deposited, remelted in continuous and pulse mode, respectively. The coefficient of friction was also found to exhibit a similar trend, increasing from 0.22–0.25, 0.28–0.31, and 0.40–0.44 for as-deposited, remelted in continuous, and pulse mode, respectively. Correspondingly, the specific wear rate was found to be significantly decreased, i.e. $\sim 6\times10^{-4} mm^3N^{-1}m^{-1}$, $\sim 4\times10^{-4} mm^3N^{-1}m^{-1}$, and $\sim 3\times10^{-4} mm^3N^{-1}m^{-1}$ for as-deposited, remelted in continuous and pulse mode, respectively. The conducted SEM analysis on the wear track confirmed the presence of dominant adhesive wear and minimal traces of abrasive wear, particularly in pulsed arc remelting, indicating strong densification.

Keywords- Additive manufacturing; WAAM-TIG; Arc-remelting; Tribological performance; Pure copper.

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Development of Ti6Al4V–IN718 Functionally Continuous Gradient Material by Dual Wire WAAM-TIG and its Tribo-mechanical Characteristics

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ABSTRACT

The present experimental study employed dual-wire WAAM-TIG to control the mass flow rate of Ti6Al4V and IN178 to fabricate functionally continuous gradient material. A gradient structure was fabricated by introducing two consecutive layers of Ti6Al4V with a content ranging from 20% to 15%, and further to 10% throughout the deposited 10-layered wall. The effect of Ti6Al4V content on the tribo-mechanical characteristics of fabricated Ti6Al4V-IN178 gradient structures was investigated, which showed a strong correlation between composition and yielded properties. The micro-indentation hardness was found to decrease with reduction of Ti6Al4V content to ~661.5 HV0.3 , ~400 HV0.3 and ~265 HV0.3 at 20%, 15% and 10%, respectively. However, the specific wear rate showed an increasing trend from $\sim1.28\times10^{-5}$ to $\sim1.39\times10^{-5}$ and $\sim1.51\times10^{-5}$ $mm^3\ N^{-1}\ m^{-1}$, while the coefficient of friction exhibited an inverse trend. SEM analysis revealed dominant adhesive wear with minor abrasive features across all compositions. The tensile test was also performed, showing maximum UTS (~830 MPa) and yield strength (~448 MPa) at the 20% Ti6Al4V region, accompanied by the lowest elongation (~20%). These strengths were found to be decreasing with Ti6Al4V content, along with increasing ductility, which is attributed to grain refinement effects as observed in the microstructural analysis.

Keywords: Additive manufacturing; WAAM-TIG; FGM; Tribo-mechanical properties; Ti6Al4V– IN718.

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A Comprehensive Wear and Corrosion Evaluation Across the Weld Zone of Frictional Stir Welded SS304

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ABSTRACT

Conventional fusion welding poses drawbacks such as harmful gas evolution, gas entrapment, and a higher heat-affected zone (HAZ). Hence, a better alternative would be friction stir welding. SS304 is preferred for hydrogen storage facilities, and employing friction stir welding for its joining is a novel area of exploration. Friction stir welding introduces a different microstructure to the material with respect to the bare material, which can significantly affect its performance in harsh environments. In this work, a comprehensive study of the wear and corrosion behaviour of friction stir welded SS304 (Tool Speed: 500 rpm; Welding Speed: 25 mm/min) is performed. Ball-on-flat reciprocating tests and electrochemical techniques are employed to evaluate and compare, wear and corrosion performance in ambient and saline environments. The Nugget Zone (NZ), Advance Side (AS), Retraction Side (RS) of weld regions exhibited distinct grain sizes, intermetallic morphology, and grain arrangements, which influenced their behaviour, hence analysed separately. The AS and RS regions showed enhanced wear behaviour in dry conditions, whereas in marine conditions, the NZ exhibited better wear resistance. Moreover, the NZ showed the highest corrosion resistance, while the AS and RS displayed a negative trend. Refined grains and carbides contributed to improved wear and corrosion resistance, however, Fe-rich Intermetallic Compounds (IMCs) deteriorated corrosion performance and adversely affected wear behaviour in marine environments.

Keywords: Friction Stir Welding; Wear; Corrosion; Marine; Microstructure; Intermetallic.

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Mitigating Tribological Anisotropy in WAAM-Fabricated Ti-6Al-4V Using Low-Heat-Input Arc Strategies

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) of Ti-6Al-4V produces coarse, columnar grains that are known to cause anisotropic mechanical properties. However, the tribological consequences of this microstructural anisotropy remain largely unexplored. This study investigates the extent of wear anisotropy in WAAM Ti-6Al-4V and evaluates advanced low-heat-input arc modes—Surface Tension Transfer (STT), Precision Pulse, and Rapid Arc—as potential approaches to control it. These processes are benchmarked against a conventional pulsed gas metal arc welding (GMAW) baseline. Ti-6Al-4V walls were fabricated using each arc mode, and samples were extracted from both horizontal (H) and vertical (V) orientations. The investigation correlates process-specific microstructures and hardness profiles with the resulting tribological performance (wear rate and friction) and dominant wear mechanisms. The findings establish a processing framework demonstrating how arc-mode selection can serve as an in-process tool for mitigating tribological anisotropy and enhancing the durability of WAAM Ti-6Al-4V components.

Keywords: Ti6Al4V; Wear Study; Surface Tension Transfer; Precision Pulse; Rapid Arc.

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Structural, Microstructural, Mechanical, and Wear Properties of Ti-Zr Nb-Fe-Mn Refractory High Entropy Alloys

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ABSTRACT

The TiZrNbFeMn, $Ti_{40}Nb_{20}Zr_{10}Fe_{20}Mn_{10}$, $Ti_{40}Nb_{20}Zr_{15}Fe_{15}Mn_{10}$, $Ti_{40}Nb_{20}Zr_{15}Fe_{10}Mn_{10}Cr_{05}$ (at%) refractory high entropy alloys (RHEAs) were designed and synthesized using the vacuum arc melting (VAM) for implant applications. These alloys were compared to Ti-6Al-4V and Ti 13Zr-13Nb in the structural, microstructural, thermal stability, mechanical, and wear properties aspects. The above analysis was investigated by X-ray diffraction (XRD), scanning electron microscopy (SEM), differential scanning calorimetry (DSC), micro indentation, and a wear instrument. The phase observed in the as-cast RHEAs mostly consists of BCC (a = 3.302 Å) (cI2) and hexagonal C14 Laves phase (a = b = 5.037 Å; c = 8.280 Å) (hP12). The RHEAs were exhibiting microhardness and elastic modulus in the range of 8-10 GPa and 127-150 GPa, respectively. These RHEAs showed excellent wear resistance and hardness as compared to Ti 6Al-4V and Ti-13Zr-13Nb alloys. Based on the mechanical and wear properties, these RHEAs are promising candidates for coating applications in harsh environments.

Keywords: Refractory high entropy alloys; phase stability; mechanical properties; wear properties; coating application.

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Harnessing Microwave-Assisted Sintering to Improve the Tribological Properties of Si-Modified Cu–Ni–Al Shape Memory Alloys

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ABSTRACT

This study examines the tribological performance of Si-modified Cu–Ni–Al shape memory alloys (SMAs) fabricated using microwave-assisted powder metallurgy, with an emphasis on how silicon additions influence wear resistance and surface integrity. Four alloy compositions were prepared: a base Cu–Al–Ni SMA (Cu-84%, Al-14%, Ni-2%) and three Si-containing variants with 0.5, 1.0, and 1.5 wt.% Si. Processing parameters, including traverse distance, rotational speed, sintering duration, and applied load, were optimized to achieve uniform densification and refined microstructures suitable for tribological evaluation. Microwave sintering promoted rapid diffusion, reduced porosity, and enhanced interparticle bonding compared to conventional routes. Microstructural analysis revealed that Si addition resulted in the formation of fine, hard intermetallic phases and stabilized martensite variants, contributing to improved hardness and load-bearing capability. Tribological testing demonstrated a progressive reduction in wear rate and coefficient of friction with increasing Si content, attributed to higher surface hardness, improved microstructural homogeneity, and the formation of a stable protective tribo-layer during sliding. Among the compositions, the alloy with 1 wt.% Si exhibited the best combination of microstructural refinement, hardness, and wear resistance. Overall, the results establish microwave-processed Si-modified Cu–Ni– Al SMAs as promising candidates for wear-critical smart material applications.

Keywords: Cu–Ni–Al shape memory alloy; microwave sintering; silicon modification; powder metallurgy; tribology; wear resistance; coefficient of friction; microstructural refinement.

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Performance Evaluation of CAE and HiPIMS AlTiN-Coated WC Inserts for Turning Inconel 617: A Comparative Study with Uncoated Tools

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ABSTRACT

This study presents a comparative evaluation of AlTiN coatings deposited by cathodic arc evaporation (CAE) and high-power impulse magnetron sputtering (HiPIMS) to address the limited understanding of coating-performance differences in machining applications. Although CAE is widely used industrially due to its strong adhesion, HiPIMS has gained scientific interest for generating dense, high-energy plasma through high pulse peak power and low duty cycle. Uncoated, CAE-AlTiN, and HiPIMS-AlTiN coated WC inserts were assessed during dry turning of Inconel 617 by analysing cutting force, cutting temperature, crater depth, flank wear, and surface roughness, followed by wear mechanism evaluation under flood cooling at different machining durations. Results show that CAE-AlTiN provides higher coating adhesion and superior wear resistance at higher cutting speed (200 m/min), while HiPIMS-AlTiN reduces the coefficient of friction and cutting temperature more effectively, performing better at lower speed (100 m/min). HiPIMS coatings, however, exhibit greater material adhesion at higher speeds due to partial removal of the coating. CAE-AlTiN demonstrates more stable flank wear progression, lower notching, and reduced crater wear compared to HiPIMS and uncoated tools. Hence, the study highlights the speed-dependent advantages of each coating technique and provides important insights for selecting suitable PVD coatings for machining Inconel 617.

Keywords: Inconel 617; AlTiN coating; CAE; HiPIMS; Tool wear.

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Surface-Integrity-Driven Corrosion and Wear Behaviour of Nitinol Processed through Near-Dry EDM with Multiphase Dielectrics

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ABSTRACT

This study examines near-dry electrical discharge machining (NDEDM) using brass, copper, and titanium electrodes under hybrid dielectrics (Air + DI water and Air + EDM oil mist) on biocorrosion and tribological behaviour of Nitinol. Potentiodynamic polarization results show strong dependence of corrosion on electrode–dielectric combinations. Compared with raw Nitinol (I_{corr} = 1.258 µA/cm²; corrosion rate = 17.17 µm/year), titanium electrode with air assisted DI water produced greatest improvement, reducing I_{corr} and corrosion rate by 85.7%, achieving 0.179 µA/cm² and 2.45 µm/year. Copper EDM-oil conditions enhanced corrosion resistance, decreasing I_{corr} by 63.7%. Brass with EDM oil exhibited severe degradation, increasing I_{corr} by 241% and corrosion rate by 275%, attributed to non-uniform and carbon rich recast layers. FESEM and SEM analyses corroborate these findings. Ti-based NDEDM generated smooth, dense recast layers, whereas brass EDM-oil surfaces showed porous, cracked morphologies with re-solidified debris. Copper-based machining produced intermediate surface quality with fewer defects than brass. Wear tests supported these results: Ti Air +DI water samples showed lowest wear, reflecting improved passive film stability, while brass EDM-oil specimens exhibited highest wear due to brittle recast delamination and weak layer adhesion.

Keywords: Biocorrosion; multiphase dielectrics; microhardness; near-dry electrical discharge machining; surface integrity; wear behaviour.

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Experimental Evaluation of Compound Gear and Bearing Faults Using an Optimized Stacked Learning Approach

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ABSTRACT

Gearboxes are critical subsystems in power-transmission machinery and often operate under harsh and varying conditions. Gearboxes have numerous components such as shaft, gear bearing etc. which makes the detection of localized and compound faults particularly challenging, especially when gear and bearing defects occur simultaneously. This study presents an intelligent feature selection and classification framework for reliable diagnosis of compound faults in bearings and gears under various load and speed conditions. Localized compound faults in gear and bearing for healthy and various faulty conditions are tested. A comprehensive set of time and frequency domain features was extracted and evaluated for their discriminative capability. Principal Component Analysis (PCA) was employed to emphasize dominant variance patterns and to enhance the separability of fault signatures. The selected features were subsequently classified using multiple machine learning models and an advanced stacked generalization architecture. The stacking framework integrates predictions from several high performing base learners and uses a meta-model to produce refined final classifications. The proposed approach achieved an accuracy exceeding 98%, demonstrating its effectiveness in identifying localized and compound faults in gearbox systems and its potential for robust condition monitoring applications.

Keywords: Gearbox, Compound Fault, Vibration, Principal Component Analysis, Machine Learning.

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A Hybrid Ensemble Learning Approach for Classification of Compound Faults in Gearbox System

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ABSTRACT

Power transmission elements are essential components in industrial machinery, where gearboxes play a critical role in transferring power. However, under continuous operating conditions, these systems frequently experience compound faults, arising from the simultaneous degradation of gears and rolling element bearings. Such combined defects introduce complex, non-stationary vibration signatures. This paper presents an ensemble machine learning techniques approach for detecting and classifying compound gear and bearing faults through vibration signal analysis. Time and Frequency Domain features were extracted from collected vibration signals. An ensemble model, incorporating Random Forest, Gradient Boosting, and Support Vector Machine classifiers, is proposed to improve classification accuracy. The model is evaluated on experimental datasets, showing superior performance in distinguishing between normal and faulty conditions. The fused model employs a weighted decision mechanism to maximize predictive reliability. Results demonstrate that the ensemble approach achieves highest classification accuracy more than 97% and F1 score. Robustness of classifier compared to individual classifiers, highlighting its potential for supporting predictive maintenance and enhancing the operational reliability of industrial power transmission systems.

Keywords: Gearbox, Compound Fault, Vibration, Ensemble Machine Learning

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Tribo-Mechanical Characterization of Fe–Mn–Si–Cr–Ni Shape Memory Alloys Developed via Vacuum Induction Melting

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ABSTRACT

Fe–Mn–Si–Cr–Ni shape memory alloys (SMAs) were produced using Vacuum Induction Melting (VIM) and examined for their tribo-mechanical behaviour under dry sliding conditions. A Taguchi L9 experimental design was adopted to evaluate the combined influence of load (10–30 N), speed (200– 800 rpm), track diameter (20–60 mm), and sliding time (300–900 s). The alloys exhibited a predominantly austenitic structure with stress-assisted ε-martensite, providing a mechanically stable matrix during surface deformation. Wear testing revealed that increasing load and speed intensified surface damage, while smaller track diameters promoted the development of compacted debris layers. Microscopic observations showed that wear mechanisms evolved from mild abrasion at lower loads to a mixed mode involving micro-ploughing, adhesion, and oxidative wear at higher operating conditions. The ability of the alloy to undergo strain-induced martensitic transformation contributed to localized hardening, helping to suppress severe delamination. In several runs, a coherent oxide-rich tribo-film formed on the worn surface, acting as a protective barrier that reduced metal-metal contact and stabilized friction. This study confirms that VIM-processed Fe–Mn–Si–Cr–Ni SMAs exhibit favourable tribological performance governed by the interplay between microstructural stability, transformation assisted hardening, and tribo-film formation.

Keywords: Fe–Mn–Si–Cr–Ni SMA; vacuum induction melting; tribology; wear mechanism; tribo- film; strain-induced martensite; Taguchi design.

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Feature-Based Bearing Fault Diagnosis Using PCA and Machine Learning for Predictive Maintenance in Rotating Machinery

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ABSTRACT

Rolling element bearings are essential components in rotating machinery, and their failure can result in considerable operational downtime, increased maintenance costs, and reduced reliability. Primary and accurate identification of bearing faults is essential for predictive maintenance plans that enhance operational efficiency and life of the equipment. Conventional fault detection methods like RMS/kurtosis-based evaluation, FFT spectrum analysis, and envelope analysis are based on domain expertise whose performance can change because these model are sensitive to noise and data availability. The dataset used in this paper consist of vibrational signals collected from bearings experimental setup, including both healthy bearings and faulty bearings which is used for condition monitoring. To reduce feature redundancy and enhance model efficiency, Principal Component Analysis is applied, transforming the features into a lower-dimensional space while retaining the most significant variance.The PCA reduced features are classified using Random Forest and Support Vector Machine models. The result of the proposed work shows that the performance of the SVM algorithm is better than other machine learning models.

Keywords: Bearing Fault Diagnosis, Principal Component Analysis, Random Forest, Support Vector Machine, Condition Monitoring.

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Probing the Synergistic Role of SiC–Al_2O_3 Dual Reinforcements in Enhancing Wear Resistance of Zn Composites

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ABSTRACT

Zinc-based metal matrix composites with ceramic reinforcements are gaining attention for applications requiring improved wear resistance. In this work, a dual-reinforced Zn–SiC–Al_2O_3 composite containing Zn, SiC, and Al_2O_3 was developed and evaluated for its tribological performance under dry sliding conditions. Pin-on-disc wear tests were performed at a load of 30 N, sliding velocity of 1 m/s, track diameter of 40 mm, and a total sliding distance of 500 m (corresponding to 478 rpm and 500 s). The two tested samples recorded wear losses of 0.027 g and 0.007 g, highlighting the influence of reinforcement distribution and microstructural uniformity on the overall wear response. The dual ceramic reinforcement enhanced wear resistance through a combined load-bearing effect, reduction in micro-ploughing, and improved surface stability. SiC particulates restricted severe abrasion by acting as hard obstacles, while Al_2O_3 promoted the development of compacted oxide layers that functioned as protective tribo-films. Surface analysis indicated a transition from abrasive wear in samples with higher mass loss to oxidative and mechanically mixed layer–controlled wear in samples with lower wear loss. These results demonstrate that the synergy between SiC and Al_2O_3 significantly improves the tribological behaviour of the zinc matrix, making such composites promising for wear- critical engineering applications.

Keywords: Zinc matrix composites; SiC reinforcement; Al_2O_3 reinforcement; dual-reinforced MMC; dry sliding wear; tribo-film; wear mechanism; abrasive wear; oxidative wear; pin-on-disc.

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CFD Analysis of Load Capacity Enhancement in Hydrodynamic Journal Bearings Using Micro-Textured Surfaces

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ABSTRACT

Surface texturing has gained significant attention as a passive and efficient method for enhancing the tribological performance of hydrodynamic journal bearings. By modifying the pressure distribution within the lubricating film, textures influence fluid flow behavior and improve bearing characteristics. This study presents a detailed CFD investigation on how micro-scale surface textures affect the load-carrying capacity of journal bearings. Three widely used texture geometries—micro-dimples, elliptical pockets, and transverse micro- grooves are analyzed parametrically by varying texture density and depth-to-diameter ratio. A rotating moving-wall boundary simulates journal motion, while the bearing liner incorporates periodically distributed textures. Results indicate that well-designed textures substantially increase hydrodynamic pressure through enhanced micro-wedge effects and controlled cavitation behavior, thereby improving load support. Spherical dimples with moderate depth provide the highest-pressure enhancement, whereas excessively deep textures promote flow separation and reduce performance. Grooved textures generate directional flow benefits, particularly under higher eccentricity ratios. Overall, the study demonstrates that optimized surface texturing can reduce frictional losses, increase efficiency, and improve the long-term reliability of journal-bearing systems.

Keywords: Journal-Bearing; CFD; Lubricating Film; Pressure; Textured Patterns.

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Experimental Investigation of Performance Characteristics of Water-Lubricated Hydrostatic Journal Bearings Using Test Rig

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ABSTRACT

This paper presents an experimental study examining the performance of water lubricated hydrostatic journal bearings using custom-designed test rig under varying operating conditions. The fluid film thickness is maintained around 40 to 60 microns throughout the tests to ensure consistent hydrodynamic performance. The experiment evaluates the performance of bearing through start-stop cycles, to assess durability and operational stability. The data provide insights for WLB into the suitability for high-load, high-speed applications, emphasizing its potential for reliable operation in water-lubricated environments. The findings offer valuable insights into potential of water as a sustainable, cost-effective lubricant, aiding in the development of greener tribological solutions in industrial systems.

Keywords: Hydrodynamic performance, Start-stop cycles, Sustainable lubrication, Cost-effective tribology, Green tribological solutions

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Comparative analysis of the effect of slip flow on the static performance characteristics of rigid, full foil and partial foil gas journal bearings

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ABSTRACT

A fluid layer develops between the contacting surfaces of gas foil journal bearings (GFBs), serving as a lubricant and generating the pressure necessary to support the load. It works with a very thin layer of lubricating gas frequently, which is only a few microns thick; hence, while simulating the bearing's behavior, rarefaction effects at the wall must be considered. In this paper, the effect of slip flow on rigid, full-foil, and partial-foil types of gas-lubricated journal bearings has been investigated. The governing equation is being discretized through the finite difference method, and it is iteratively solved using the Gauss-Seidel method. The results indicate that, when slip is considered, the pressure created within the bearing is reduced, and the minimum film thickness is higher in the case of slip flow as compared to without slip flow effect for a given load and eccentricity value. This study also emphasizes the effect of slip flow on maximum peak pressure, load-carrying capacity, attitude angle, minimum edge, and minimum mid-film thickness of gas journal bearings.

Keywords: Gas Foil Journal Bearings; Slip Flow; Finite Difference Method; Static Performance; Gauss-Seidel Method.

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A Comprehensive Review of Magnetic Bearing Technologies for Modern Compressor System

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ABSTRACT

Magnetic bearing technology has become a transformative solution in modern compressor systems, providing oil-free, contactless rotor support through either actively controlled electromagnetic fields or passive permanent magnets. By eliminating lubrication, frictional losses, and mechanical wear inherent in conventional bearings, these systems enhance operational efficiency, reliability, and service life while ensuring contamination free performance and essential requirement in sectors such as food and beverage processing, pharmaceuticals, HVAC and refrigeration, aerospace propulsion, and high-speed industrial compressors. Active Magnetic Bearings (AMB) offer precise rotor positioning, real-time vibration control, and superior adaptability to transient operating conditions however, their implementation demands advanced control electronics, continuous power supply, and complex algorithms. In contrast, Permanent Magnetic Bearings (PMB) provide energy efficient, inherently stable operation with minimal power consumption, though their load capacity and stiffness remain fixed by design. Despite significant advancements, challenges persist, including high capital cost, susceptibility to electromagnetic interference, thermal management issues, and the need for robust fault tolerant architectures. This review consolidates recent developments in AMB and PMB technologies for compressor applications and identifies critical research gaps that must be addressed to enable wider, more cost-effective industrial adoption.

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Efficiency and Power Loss Evaluation of Gear Oils using Worm Gear Test Rig

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ABSTRACT

Worm gears are critical transmission components widely used in applications requiring compact design and high reduction ratios. However, worm gears are often less efficient than other gear types due to the high sliding contact between the meshing gear teeth, which results in significant frictional power losses. Therefore, careful lubricant selection is important for improving energy efficiency and ensuring sufficient wear protection. The worm gear test rig is designed to simulate real-world industrial conditions, with dynamometers measuring input and output torques, allowing systematic study of lubricant effects under controlled speed and load scenarios.

This work presents a comprehensive methodology for screening and evaluating the performance of gear oils using the worm gear test rig. Four oils of varying ISO viscosity grades (220, 320, 460, and 680 cSt) were thoroughly tested across a matrix of input speeds (1000- 2500 RPM) and set output torques (20-60 Nm). The input torque needed to achieve the set output was precisely measured, and gear efficiency was calculated to reveal power losses and the effects of lubricant viscosity. The results highlight clear trends, with the best results obtained using the 460 cSt lubricant, while lower and higher viscosity oils were suboptimal due to insufficient film strength resulting in high worm gear wear, or excessive churning and total power losses. Comparative analysis demonstrates that optimal lubricant selection can boost worm gear efficiency within industrially relevant regimes. These findings offer practical guidelines to enhance worm gearbox performance and energy savings by combining targeted oil selection with machine-specific operational requirements.

Keywords: Worm gear test rig, Worm gear power losses, Gear oil optimization

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A New Type of Texture Profile for Tilting Pad Thrust Bearing

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ABSTRACT

Various textured profiles applied to tilting-pad bearings are studied using both analytical formulations and numerical modelling. The investigation combines theoretical analysis with CFD-based simulation. Results show that the textured surface has better load capacity than a plain surface. The comparative analysis reveals that the *composite profile* of texturing exhibits a superior load-carrying capacity compared to other existing textured profiles. The analytical model developed for this composite profile explains the underlying mechanism responsible for its enhanced load capacity. The identified optimized texture profile may also be applicable for other types of bearings.

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Title: Optimal Laminated Additive Manufacturing (Opti LAM): Automation and Integration of Laser and CNC

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ABSTRACT

This research paper addresses the challenge of imprecise operations and unsynchronized actions in the Optimal Laminated Additive Manufacturing (Opti LAM) machine, where the laser and CNC operate as separate entities. The current process involves manual intervention due to estimated time delays, leading to overlaps in layers and increased processing time. The primary goal is to achieve fully automated, synchronized operation, mimicking a 3D FDM printer, to eliminate manual intervention and enhance precision. The paper proposes establishing a relationship between the laser and CNC through sensor-based feedback loops and an automated workflow. This integration aims to improve coordination, precision, and the marketability of the product, while also expanding the machine's scope for use with various materials. Using sensor-based feedback in the current era of Iot and Industry 4.0

Keywords: Automated; Laster; CNC; Synchronization; OptiLAM, Sensor.

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Integration of CNC (Computer Numerical Control) with FDM (Fused Deposition Modeling)

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ABSTRACT

Ice 3D Printing is an emerging additive manufacturing technique that utilizes frozen water as a sustainable and recyclable structural material. Unlike conventional thermoplastic- or resin-based processes, Ice 3D Printing operates under subzero conditions, enabling the layer-by- layer deposition and rapid solidification of water into complex three-dimensional geometries. This study presents the design, fabrication, and experimental validation of a custom-built Ice 3D printing platform featuring a cryogenically controlled print bed maintained at −20 °C and a CNC-driven extrusion system adapted from an open-source FDM architecture. The control system was implemented using a RAMPS 1.4 + Arduino Mega 2560 controller running a modified Marlin firmware, enabling precise regulation of solenoid valves and pump flow for water deposition. Challenges related to nozzle freezing, thermal leakage, and layer adhesion were analyzed, and design improvements were introduced through chamber insulation and thermostat-based temperature control. The results demonstrate the feasibility of fabricating stable ice structures with controlled geometry and interlayer bonding, establishing a foundation for future research in cryogenic additive manufacturing. Potential applications are envisioned in biomedical molding, architectural prototyping, and eco-friendly sacrificial tooling.

Keywords: CNC, RAMPS 1.4 + Arduino Mega 2560, Peristaltic Pump

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Square Rod Laser Cutting Machine

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ABSTRACT

This research paper addresses the challenge of imprecise operations and unsynchronized actions in the Optimal Laminated Additive Manufacturing (Opti LAM) machine, where the laser and CNC operate as separate entities. The current process involves manual intervention due to estimated time delays, leading to overlaps in layers and increased processing time. The primary goal is to achieve fully automated, synchronized operation, mimicking a 3D FDM printer, to eliminate manual intervention and enhance precision. The paper proposes establishing a relationship between the laser and CNC through sensor-based feedback loops and an automated workflow. This integration aims to improve coordination, precision, and the marketability of the product, while also expanding the machine's scope for use with various materials.

Keywords: Automated, Laster, CNC, Synchronization.

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Evaluation of frictional and wear characteristics of Ti6Al4V and WC-Co pair in dry pin-on-disc configuration

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ABSTRACT

This work evaluates the tribological characteristics of Ti6Al4V and WC-Co under dry conditions at various loads and sliding speeds using a Pin-On-Disc tribometer. The pair under dry conditions is studied at different machining conditions to analyse the higher wear rates. Coefficient of friction, specific wear rate of the pins, and wear volume of Ti6Al4V are the parameters that have been calculated and plotted versus speed and load, and their comparison study has been carried out. The lowest COF was 0.277 at 50 N load and 1 m/s sliding speed. The highest COF was found as 0.438 at 50 N and 1.5 m/s. The maximum pin specific wear was observed for the load of 50 N and 2 m/s speed which is 8.858 x 10-6 mm3/N-m. Abrasion tracks from the titanium disc, along with SEM characterizations, are utilized to evaluate the wear mechanisms of the system. The wear mechanism is primarily adhesion at lower loads. For higher loads, the mechanism changes to oxidative wear. At loads of 100 N, a step-like feature known as the smearing effect is observed, which combines high abrasion, adhesion, and fatigue wear features.

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Crack Propagation and Fatigue Assessment of a Notched Top Coat in Thermal Barrier Coatings using Finite Element Analysis

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ABSTRACT

This study investigates the crack propagation and fatigue behavior of a horizontally notched topcoat in a thermal barrier coating (TBC) system using finite element analysis. A three dimensional model of the ceramic topcoat, composed of 8 wt.% yttria-stabilized zirconia (8YSZ), is developed in ANSYS 2020 R1 to simulate real-world surface flaws. Crack propagation is evaluated using the SMART Crack Growth tool based on linear elastic fracture mechanics (LEFM), revealing mixed-mode fracture behavior dominated by Mode I with contributions from Mode II. Fatigue life is assessed independently using a stress-life approach, identifying critical stress concentrations and fatigue-sensitive regions near the notch. The study found a drastic reduction in fatigue life when loading exceeded 0.75 of the baseline,underscoring the importance of conservative design margins. The decoupled approach to crack and fatigue analysis provides a foundational understanding of notch-induced failure mechanisms in TBCs and lays the groundwork for future Multiphysics simulations incorporating self-healing mechanisms.

Keywords: Thermal Barrier Coating; Crack; Notch; Fatigue.

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Experimental investigation on comparative tribological aspects of as-built and viscoelastic polymer-based abrasive finished surgical steel surfaces

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ABSTRACT

Additive manufacturing (AM) of surgical stainless steel 316L (SS 316L) offers significant advantages in producing complex geometries and custom-designed components. However, the process often results in high surface roughness and defects that adversely affect tribological performance. This study aims to evaluate the tribological properties of SS 316L produced by selective laser melting (SLM) and to investigate the effects of viscoelastic abrasive finishing on friction and wear behavior. Samples were subjected to varying normal loads and sliding velocities in dry sliding conditions using a ball-on-disc tribometer. The coefficient of friction (CoF) and wear volume were measured and analyzed. viscoelastic abrasive finishing significantly improved surface roughness, reducing average roughness by 70 %. Tribological tests revealed that viscoelastic abrasive finishing samples exhibited lower CoF and wear volume across all tested parameters compared to as-built samples. Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy analyses showed smoother wear tracks and reduced material transfer on polished surfaces. Response Surface Methodology was employed to model the relationships between normal load, sliding velocity, and tribological performance. The empirical models derived from Central Composite Rotatable Design accurately predicted CoF and wear volume, highlighting the importance of surface finishing in enhancing the tribological properties of AM-fabricated SS 316L.

Keywords: wear morphology, friction, biomaterial, viscoelastic abrasive finishing, surface morphology

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Experimental investigation on comparative tribological aspects of as-built and laser polished Inconel 718 surfaces

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ABSTRACT

In718 is a nickel-based superalloy with strong strength at high temperature, and its performance in wet water lubricated sliding is important for applications such as pump shafts, valve components, marine pump wear rings, and hydro turbine parts where water acts as the lubricant. This study investigates laser polishing as a non-contact method to refine surface morphology and improve wet sliding behaviour of additively manufactured In718. Surface features were quantified with 3D profilometry, and wettability assessed by contact angle measurement. Tribology tests quantified friction and wear volume under water lubrication, and using a ball on disc tribometer under wet sliding with varying normal loads and sliding velocities. Laser polishing modified surface topography, wherein reduction in roughness by 42% influenced wetting. Water contact angle dropped by 38% after laser polishing, showing stronger spreading and improved liquid stability. These surface modifications shaped tribological behaviour, reducing coefficient of friction by 46% and wear volume by roughly 50%, linked to reduced asperity contact and more stable lubricant retention at the interface. The relationship between surface topology, improved wetting, and lower friction and wear shows that laser polishing can modify addively manufactured In718 surfaces suited for stable wet sliding applications.

Keywords: wear morphology, friction, laser polishing, surface morphology

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Assessment of tribological behaviour of additively manufactured Inconel 718 coating using advanced micro-topographical analysis

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ABSTRACT

Additively manufactured (AM) Inconel 718 has been explored for a wide range of engineering applications; however, as-deposited AM components often exhibit poor surface quality. For hard materials such as Inconel 718, post-processing is typically required to achieve the desired surface finish. In this study, Inconel 718 coating was deposited using the laser-directed energy deposition (LDED) process. The surface was initially ground to reduce the roughness to the sub-micron range, followed by precision surface finishing using chemical- assisted magnetorheological finishing (CAMRF) with a glyceregia reagent. Although surface microtopography plays a critical role in chemical-magnetorheological finishing, limited efforts have been made to systematically characterize micro-topographical features. This work presents a robust methodology for the quantitative evaluation of microtopographic features of polished surfaces. The proposed framework integrates 3D areal surface parameters with advanced analytical tools, including scale-sensitive analysis (SSA), continuous wavelet transforms (CWT), power spectral density (PSD), and lattice analysis. SSA and CWT enable the assessment of multiscale complexity and fractal characteristics, while PSD quantifies the contribution of different wavelength components to the overall surface structure. The combined analyses demonstrate that the CAMRF-finished surface exhibits a smooth, periodically textured, and uniform pattern, characterized by lower fractal complexity and improved spectral coherence.

Keywords: Additive Manufacturing, Inconel 718, Tribological behaviour, Micro topographical analysis, chemical-assisted magnetorheological finishing

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Tribological Enhancement of 304L Stainless Steel via TIG-Arc Assisted In Situ AlCrCoCuFeNi High-Entropy Alloy Coating

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ABSTRACT

This study evaluates the tribological performance of AISI 304L stainless steel coated with an in-situ AlCrCoCuFeNi high-entropy alloy (HEA) layer using TIG arcing. The process produced a dense, metallurgically bonded coating with refined dendritic and interdendritic structures. XRD analysis confirmed the formation of dual FCC + BCC solid- solution phases. The surface hardness increased from 215 ± 10 HV for the base metal to 625 ± 20 HVafter HEA coating, representing a nearly 190% improvement. Under dry sliding conditions (20 N, 500 m sliding distance), the coated surface exhibited a wear rate of 1.8 × 10 mm³/N·m, significantly lower than the uncoated substrate (7.4 × 10 mm³/N·m), indicating a 75% reduction in wear rate. The coefficient of friction decreased from 0.62 to 0.38 due to the formation of a stable, protective tribo-film. Overall, the AlCrCoCuFeNi HEAcoating developed via TIG arcing provides substantial enhancement in hardness, wear resistance and frictional behavior, demonstrating its potential for extending the service life of 304Lstainless steel components in demanding tribological applications.

Keywords: High-entropy alloy (HEA) coating; TIG arcing; AlCrCoCuFeNi; 304Lstainless steel; Tribology; Wear resistance; Coefficient of friction;

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High-Temperature Tribological Performance of TIG Arc–Engineered Ti 6Al-4V Reinforced with In-Situ Synthesized Ceramic Particulates

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ABSTRACT

Improving the surface durability of Ti-6Al-4V (Ti64) is essential for its use in aerospace, biomedical and automotive components subjected to severe thermomechanical conditions. This study aims to enhance the hardness and wear resistance of Ti64 through conventional Tungsten Inert Gas (TIG) arc surface engineering incorporated with in-situ synthesized ceramic reinforcements. Boron carbide (B_4C), tungsten carbide (WC) and silicon carbide (SiC) particulates were introduced during TIG processing to generate hard boride and carbide phases within the alloy surface. Microstructural characterization using XRD, FESEM and EDS confirmed the formation of refined composite layers containing uniformly distributed B, W and C-rich precipitates, including nano to microscale TiB and TiC phases. The modified surfaces exhibited substantial hardness improvements, increasing from 250 HV in the base metal to 840 HV in B_4C reinforced regions. Tribological evaluation using pin-on-disc tests at room temperature, 150°C and 300°C revealed that ceramic reinforcement significantly improved wear resistance, with B_4C + TIG samples showing the most superior performance. Wear reductions reached 50% at room temperature and up to 85% at 150°C, while maintaining minimal degradation at 300°C. Overall, TIG arc processing with ceramic reinforcements provides an effective and scalable strategy to achieve high-performance, wear-resistant Ti64 surfaces for demanding engineering applications.

Keywords: TIG surface modification; Ti-6Al-4V; Ceramic Reinforcements; High-temperature wear; Microstructural refinement.

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Electrical Sliding Tribology of Solid Lubricant Reinforced Copper Composites: Role of Sliding Interface Dynamics

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ABSTRACT

Solid lubricants are widely used to reduce friction due to their layered structures. While most tribological studies focus on varying reinforcement concentrations, in the present study, a systematic comparison across different solid lubricants under combined electrical and mechanical loading is carried out. Copper matrix composites reinforced with equal amount of WS2, MoS2, graphite, and h-BN are processed via spark plasma sintering, and their performance under dry sliding condition is assessed for electrical sliding contact application. Tribological tests were conducted using a ball-on-disc reciprocating setup and friction, wear, and electrical contact resistance (ECR) under varying normal loads, and DC currents are evaluated. Cu composite with graphite reinforcement resulted in lowest coefficient of friction, whereas WS_2 and MoS_2 led to higher friction. Adhesive wear was predominantly observed in monolithic Cu with increasing severity of contact stresses, whereas solid lubricant reinforcements attributed to dominant ploughing wear mechanism. Delamination and arc erosion phenomena were also observed on the worn surfaces. This research work contributes to understanding of copper composite with different layered material reinforcements for electrical sliding applications such as micro-electro-mechanical systems, flash drives, or slip rings.

Keywords: Electrical sliding; current-carrying friction; electrical sliding contact; solid lubricants; layered materials.

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Scratch Response and Damage Mechanism of SiC-Zr_2CN Composites: Role of Zr_2CN content and Applied Load

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ABSTRACT

Scratch testing has emerged as a powerful technique for evaluating the mechanical and tribological response of advanced ceramics and composites. In the present investigation, scratch behavior of silicon carbide-*in situ* zirconium carbonitride composites were performed using a sphero-conical diamond indenter under varying loading conditions of 10N and 20N, respectively. The findings highlight that the presence of Zr_2CN content significantly lowered the COF and wear rate of the composites in comparison to monolithic, irrespective of test conditions. Extensive cracking, fracture and pull-out were observed as the major material removal mechanism for monolithic SiC ceramics while tribo-oxidation along with surface deformation and ridge formation were observed for SiC-Zr_2CN composites.

Key Words: SiC; Zr_2CN; Composites; Scratch behavior; Wear mechanisms.

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Microstructural Anisotropy and Its Impact on Tribocorrosion Performance in additively Manufactured Co–Cr–Mo Alloys

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ABSTRACT

Additive manufacturing (AM) of biomedical alloys such as Co–Cr–Mo offers significant potential for producing complex, patient-specific implants. However, the layer-by-layer fabrication often introduces anisotropy due to solidification texture and grain morphology. This study examined how build orientation affects the tribocorrosion behavior of a selective-laser-melted Co–28Cr–6Mo alloy. Despite the weak crystallographic texture achieved through a rotational scanning strategy, tribocorrosion tests in simulated body fluid revealed an anisotropic wear rate under fretting conditions. Quantitative analysis of tribocorrosion results using mechanistic models showed that wear was dominated by mechanical rather than electrochemical contributions, and that the observed anisotropy in wear was mainly governed by anisotropic mechanical properties. Larger, elongated grains aligned with the build direction, compared to smaller, equiaxed grains perpendicular to it, resulted in measurable tensile anisotropy. In contrast, the corrosion rate remained largely independent of build orientation. Overall, this work highlights how AM-induced microstructural features influence the functional performance of Co–Cr–Mo alloys and underscores the importance of optimizing manufacturing parameters for reliable load-bearing orthopedic implants.

Keywords: Tribocorrosion; Fretting; Additive manufacturing; Co-Cr alloys; Biomedical implants

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Fretting Behaviour and damage mechanisms of ZA-3/La_2O_3Composites: Strengthening and Failure Mechanisms

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ABSTRACT

The escalating demand for lightweight, dimensionally precise, and high-throughput manufactured components has positioned Zamak alloys as technologically superior alternatives to conventional non-ferrous materials, enabling next-generation design freedom. In this work, La_2O_3-reinforcedZA-3composites (0–1 wt%) were developed through a rigorously controlled squeeze-casting route to enhance their mechanical and fretting performance. The casting protocol—regulated melt superheat, argon shielding, synchronized stirring, and high-pressure solidification—facilitated homogeneous particle dispersion, minimized porosity, and promoted the multidimensional regulation of theα-Zn and β-Al phases, contributing to improved microstructural stability. Mechanical characterization revealed a continuous rise in hardness and tensile strength with increasing La_2O_3 content, with the 1 wt% composite exhibiting the highest strengthening. Fractographic analysis showed fine, equiaxed dimples in the unreinforced and 0.5 wt% samples, indicative of ductile fracture, whereas coarse dimples, particle pull-out, and void coalescence in the 1 wt% specimen signaled a transition to semi-brittle rupture caused by interfacial stresses.

Fretting wear evaluation under varied stroke lengths, loads, and frequencies demonstrated significant wear reduction in La_2O_3-modified alloys. Prolonged reciprocating motion promoted the retention and compaction of tribo-oxides within the contact zone. Owing to their larger molar volume relative to the base metal, these oxides generated a glazing or "sticking" layer that limited metal–metal interaction and stabilized friction. The coefficient of friction progressively declined with cycling as the interface transitioned from asperity-dominated contact to a quasi- lubricious glazed state. At elevated loads, wear progressed through a hybrid mechanism involving oxide-film rupture, intermittent metal contact, micro-crack nucleation, and oxide- assisted delamination.

Overall, La_2O_3 reinforcement markedly enhanced the mechanical and fretting durability of ZA-3, with 0.5–1 wt% offering optimal performance for reciprocating load applications.

Keywords: Zamak; Fretting; Casting; Mechanistic studies

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Tribological and corrosion characteristics of pure Cu and Cu-Ni alloy fabricated via vacuum arc melting.

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ABSTRACT

Copper-nickel alloys offer low electrical resistivity, high-temperature stability, and balanced mechanical properties, making them suitable for various applications, including heating cables, control resistors, marine hardware, and electrical components. The Copper nickel alloy and pure copper were fabricated through vacuum arc melting process. The tribological and corrosion performance of Copper- Nickel alloy is studied and compared with pure copper. Tribological tests were conducted using a ball- on-disk tribometer at room temperature, with sample surfaces sliding against stainless steel balls in dry conditions. The Cu-Ni alloy exhibited both a lower wear rate and a lower corrosion rate compared with pure copper, because the nickel strengthens the material and improves its resistance to wear.

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Beneficial Effect of Novel Dual Phase SiC/Si_3N_4 Reinforcement on Sliding Wear Behavior of Aluminum Alloy

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ABSTRACT

The present investigation is focused on the effect of reinforcement of heat treatment induced dual phase SiC/Si_3N_4 nanostructures on the mechanical and wear behavior of 6061AA. The composite with dual phase SiC/Si_3N_4 nanostructures exhibited excellent combination of hardness of 109 VHN, ultimate tensile strength of 309 MPa, toughness of 5.88 x 10^9 J/m^3, elongation of 23% and strength coefficient of 608 MPa. In sliding against steel ball, the friction coefficient and wear volume respectively decreased to 0.24 and 0.54x10^{-3} mm^3 for the composites reinforced with dual phase SiC/Si_3N_4 nanostructures as a result of enhanced strain hardening and tribo-oxidation. The innovative SiC/Si_3N_4 nanostructures reinforced 6061AA composites exhibit potential to extend the tribological applications regime of conventional aluminium composites.

Keywords: Aluminium Alloy, SiC/Si_3N_4 Nanostructures, Hardening, Wear Mechanism

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Mechanical and Sliding Wear Behaviour of Cryorolled Aluminium Alloy Heat Treated SiC Reinforced Composites

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ABSTRACT

The present study investigates the influence of Cryorolling on the mechanical and sliding wear properties of 6061AA heat-treated SiC reinforced composites. The average grain size of aluminium matrix in the cryorolled nanocomposites reduced to ~12 µm due to the addition of heat-treated nano size SiC reinforcement particles. Aluminium alloy 6061 composites reinforced with heat-treated nano size SiC heated at 1400□C, a combination of superior mechanical properties of hardness of 152 VHN, ultimate tensile strength of 452 MPa, toughness of 4406 x10^6 J/m^3 and elongation of 11%. The friction coefficient and wear volume for unreinforced aluminium alloy decreased from 0.65 to 0.57 and 1.74x$10^{-3}$$mm^3$ to 1.22x$10^{-3}$$mm^3$ upon cryorolling. Among the investigated composites an enormous reduction of 35% in COF and 24% in wear volume obtained for heat treated nano SiC composites. The 6061AA composites reinforced with heat-treated nano size SiC particle exhibit better wear resistance compared to those prepared without heat-treated SiC particles and non-cryorolled composites. This can be attributed the presence of SiC/Si_3N_4 nanostructures, effect of grain size reduction and high dislocation density achieved via cryorolling is maximum for composite reinforced with heat-treated nano size SiC particles.

Keywords: Aluminium Alloy, SiC/Si_3N_4 Nanostructures, Cryorolling, Microstructure, Phase Analysis, Wear Mechanism

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Experimental Investigation and optimization of mechanical properties for natural fibre moringa PLA composite using fused deposition modelling

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ABSTRACT

This study focuses on the experimental investigation and optimization of 3D printing materials, specifically a new composite material made from PLA (polylactic acid) reinforced with natural fibres such as PLA + 0.8% Moringa Drumstick Powder + 0.1% Graphene. The goal of the research is to optimize the mechanical properties and surface finish of these composites using Taguchi's Design of Experiments (DOE) methodology. The composite materials were formulated, with fibre composition and PLA especially Moringa Drumstick Powder for which the farmers were confused to deal with the damaged moringa due to its mass production but not getting the financial support. Present study investigates the effects of six process parameters on the properties of the printed material: printing temperature, printing speed, layer height, infill pattern, infill density, and raster angle. A L9 orthogonal array design is employed for testing across tensile strength, compressive strength, flexural strength, and surface roughness (Ra), with tensile testing, compression testing, and flexural testing following ASTM standards. Using the Taguchi method, the optimal combination of process parameters is identified for improving material strength, ductility, and surface quality. The study focuses on minimizing surface roughness (Ra), maximizing tensile strength, compressive strength, and flexural strength, as well as ensuring robustness in the material's performance under various conditions. The results from the analysis provide a comprehensive understanding of how each factor influences the material overall performance, guiding the optimization of 3D printed natural fibre-reinforced composites for advanced and sustainable additive manufacturing applications.

Keywords: 3D printing; PLA composite; Natural fibres; Taguchi; Optimization; Sustainable additive manufacturing.

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Experimental study of mechanical characterization and tribological properties of overlapped IN718 ratios on SS316L using Laser-assisted direct energy deposition (LADED)

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ABSTRACT

Laser cladding has emerged as an effective surface modification technique to enhance the performance of engineering alloys, particularly in high-temperature and wear-critical applications. In this study, Inconel 718 (IN718) was deposited on stainless steel 316L substrate using a 2-KW fiber laser direct energy deposition system with overlapping ratios of 25%, 50%, and 75% to investigate the influence of overlap on the coating quality, microstructure, mechanical, and tribological properties. The variation in overlapping ratio significantly affected the dilution, microstructural refinement, and surface morphology of the clad tracks. Higher overlap ratios promoted better layer uniformity of the deposited layer. Also improved surface roughness from Ra value 10µm to 6µm (as deposited) across the deposited cladded layers at 50% of overlap. Tribological performance was evaluated through wear track ball-on-disk, wear tests under 10N load and track diameter of 8 mm at speed of 50 mm/s for a run length of 90 m, demonstrating that coatings with optimized overlap exhibited lower wear rates from $4.309x10^{-3}$ mm^3 N/m at 25% to $3.33x10^{-3}$ mm^3/Nm at 50% and friction coefficients like 0.7 of bulk and coated owing to improved metallurgical bonding. The study establishes a correlation between laser processing parameters, mechanical strength, and tribological response, providing insights into optimizing IN718 laser cladding on 316L stainless steel for superior surface durability in demanding applications.

Keywords: Repair; Laser-assisted Additive manufacturing; Tribological properties; Wear; Super alloy IN718.

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Tribological behaviour of laser based additively manufactured Ti6Al4V-hydroxyapatite composite in different biofluids for orthopedic implant application

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ABSTRACT

Damaged articulating joints can be repaired or replaced with synthetic biomaterials, which can release wear debris due to articulation, leading to osteolysis. In a recent work, it has been shown that it is possible to achieve a better combination of mechanical strength (hardness and lower elastic modulus) as well as in vitro bioactivity and cytocompatibility properties in direct metal laser sintering (a kind of additively manufacturing technique) manufactured titanium-hydroxyapatite (Ti-HA) composites. Although titanium and hydroxyapatite are well reported for their good biocompatibility, nanosized hydroxyapatite (HA) and titanium (Ti) particles can cause severe toxicity to cells. In order to address this issue, sliding wear study of HA–Ti composites under different biofluids (i.e., Physiological saline solution, phosphate buffer saline and simulated body fluid) was performed to assess the coefficient of friction, wear rate as well as wear debris formation, in vitro. The experimental results reveal that lowest corrosion rate was obtained in Ti64-10 HA composite than the Ti64-5HA in simulated body fluid. The difference in the tribological properties has been analyzed using the COF, Wear rate and the wear mechanism. Overall, the results suggest the potential use of Ti64-composites over existing Ti6Al4V based bio-composites in orthopedic as well as dental applications

Keywords: additive manufacturing, bio tribology, composite, hydroxyapatite, bio fluids

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Sustainability and Energy Efficiency through Energy Efficient Lubricants

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ABSTRACT

As industries accelerate toward decarbonization and Net Zero targets, lubrication engineering remains one of the most underutilized yet powerful levers in improving energy performance and reducing emissions. Energy-efficient Synthetic lubricants enable tangible sustainability impact across high-load, energy-intensive sectors such as cement, steel, textiles, and refinery all with minimal capital investment and accelerated return on investment. Backed by independently verified results from third-party energy audits conducted in collaboration with Grant Thornton Bharat (GTB), Energy Efficiency solutions contribute to: Friction loss reduction, Extended component life and lubrication intervals, Optimized Total Cost of Ownership (TCO) . Main objective of this study is to position lubrication not just as a functional necessity but as a strategic enabler of ESG compliance, BRSR alignment, and sustainable industrial transformation.

Key words: Lubrication; Energy Efficiency; Friction; Synthetic lubricants

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Enhanced tribological performance on hierarchical micro/nano textures fabricated using micro-milling and anodization

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ABSTRACT

This study presents the development and tribological evaluation of hierarchical micro/nano textures on Ti-6Al-4V for orthopedic implant applications. Micro-textures inspired by natural surface architectures- such as snake scales, leaf veins, and shark-skin patterns were fabricated using precision micro ball-end milling. These mechanically generated microstructures served as the foundation for subsequent anodization, enabling the growth of TiO_2 nanotube arrays and the formation of multiscale hybrid textures. The influence of texture geometry on nanotube formation, wettability, and friction behavior was systematically investigated. Results show that the hierarchical textures significantly regulate nanotube growth and enhance surface functionality. A super-wetting surface was achieved, with the contact angle reduced from 73.8° for the untextured substrate to 17.6° for hybrid textures. Tribologically, leaf-vein-inspired textures exhibited superior performance by effectively dispersing contact stresses and entrapping debris, thereby mitigating three-body wear. The coefficient of friction decreased by 36.82% compared to the polished surface, while the wear volume was reduced by approximately 68.2% relative to the untextured sample. Overall, the combined micro-milling and anodization approach demonstrates strong potential for improving the surface performance of titanium alloy implants through synergistic multiscale texturing.

Keywords: Ti-6Al-4V; Micro milling; Anodization; Wettability; Bio-tribology.

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Stribeck curve-based characterization of nanoparticle-based MQL for reduced wear of advanced coated and uncoated microdrills, and Micro drilling performance on Ti-6Al-4V alloy

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ABSTRACT

This study examines the impact of Minimum Quantity Lubrication (MQL) utilizing nano powder-enhanced cutting fluid on the micro-drilling of Ti-6Al-4V alloy. The current work focused on the Stribeck curve-based characterization of a nano MQL-based lubricant and an advanced coated ball of 6 mm diameter under a 5N load, aimed at minimizing friction and wear, using a ball-on-disc tribometer. Additionally, micro-drilling was done on the Ti-6Al- 4V alloy using cutting fluid combined with alumina (Al_2O_3), and WS_2 nanoparticles separately to evaluate the cutting performance (cutting force, specific cutting energy) and surface integrity of the hole, such as surface roughness of the hole, circumferential deformation layer, oversize error, and tool wear under the AlTiSiN and DLC Coating. AlTiSiN-coated tools have a low chemical affinity for titanium alloys, which is a huge advantage as a low coefficient of friction leads to less adhesive wear, decreased reactivity, which in turn leads to better surface finish, and longer tool life, but DLC coatings reduce BUE and ensure surface quality of the drilled hole.

The findings of this study show how the cutting fluid and tool coating affect cutting performance and friction behaviour at the cutting interface between the tool and the workpiece during Ti alloy micro-drilling. The Stribeck curve depicts the behaviour of the cutting fluid and tool coating in relation to friction and wear track roughness.

Keywords: Micro-drilling, Coating, Surface roughness, Dynamic fluctuation, Oversize error, Circumferential deformation layer, NMQL, Tool wear, and Ti. Alloy.

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Effect of advanced coatings on the coefficient of friction and wear behaviour of AZ31B magnesium alloy against tungsten carbide counterfaces in dry sliding condition

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ABSTRACT

This study investigates the various tribological characteristics of AZ31B magnesium alloy under dry conditions using 6 mm diameter tungsten carbide balls in a ball-on-disc tribometer. The objective of this work is to analyse the influence of uncoated and advanced coated counterfaces, such as AlTiN, DLC, and TiB_2, on the frictional response, wear characteristics, and surface conditions of AZ31B magnesium alloy under varying sliding speeds, loads and at a fixed sliding distance. The results indicate that the highest friction coefficient and significant abrasive wear occur with uncoated carbide balls compared to their coated counterparts (AlTiN, DLC, and TiB_2). Interfacial adhesion can be seen between magnesium and the AlTiN-coated counterface, attributed to a strong chemical affinity, increasing wear and friction. In contrast, DLC coating exhibits the lowest coefficient of friction (COF), which might be attributed to the formation of a graphitic transfer layer, which results in a smoother surface and reduces material removal. The TiB_2 coating exhibits superior anti-wear performance than AlTiN and DLC coating, due to its high hardness and low chemical affinity with magnesium, resulting in the formation of low severity confined abrasion tracks.

Keywords: Wear; AZ31B magnesium alloy; Coatings; COF; Chemical affinity.

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Unique ID: IT25-210

Study of Tribological behaviour in Ni-enhanced (Mg-Al-Si-Cr-Fe) High Entropy Alloy System

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ABSTRACT

High entropy alloys are known for their high strength, mechanical and tribological properties owing to high configurational entropy and severe lattice distortion. In the present study, equiatomic combination of Mg-Al-Si-Cr-Fe powder blend with and without addition of Ni was subjected to high energy ball milling followed by Spark plasma sintering process. The SPSed samples were subjected to detailed microstructural, mechanical and tribological study. SEM- BSE images and X-ray diffraction revealed presence of multiple phases. Compositional variation at microscopic level was studied using EDS and elemental mapping. Both HEAs had parent BCC phase with B2 and trace amounts of intermetallics formation was also observed. Vickers Indentation was used to measure hardness and fracture toughness. The fracture toughness study demonstrated higher toughness in the Ni-enriched HEA, while the samples without Ni addition demonstrated crack formation during indentation at much lower load as compared to fracture toughness. Crack propagation through various phases was studied by SEM-BSE images. Pin on disk type tribometer wear test was performed on alumina disk. SE images reveal formation of tribo-layer, and fatigue crack formation on the wear tracks. Also, the Ni-enriched HEA produces uniform tribolayer, while an abrasion mode of wear was dominant in the Ni-free HEA.

Keywords: Ball milling; Crack propagation; Spark plasma sintering.


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