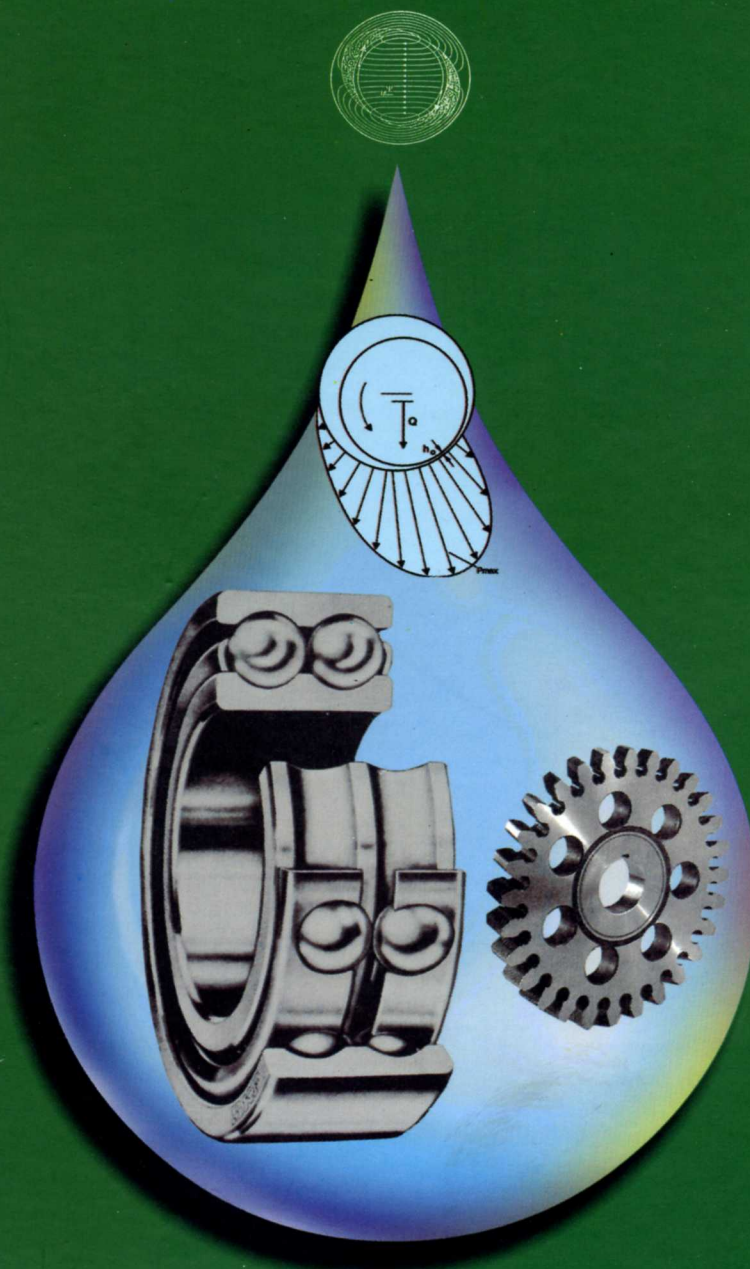


TRIBOLOGY IN 2000 AND BEYOND

Proceedings of the Second International
Conference on Industrial Tribology

December 1-4, 1999

Hyderabad, India



Editor : H. Prashad



Tribology in 2000 and Beyond

Tribology in 2000 and Beyond

Editor

H. Prashad

BHEL, Corporate R&D Division
Vikasnagar, Hyderabad - 500 093, India



Printed at
KALA JYOTHI PROCESS LTD.
Hyderabad, India.

**SECOND INTERNATIONAL CONFERENCE
ON
INDUSTRIAL TRIBOLOGY**

DECEMBER 1-4, 1999

HYDERABAD, INDIA



Organized by



**BHARAT HEAVY ELECTRICALS LIMITED
CORPORATE R&D DIVISION**

Under the Aegis of



TRIBOLOGY SOCIETY OF INDIA



Dedicated to



The Almighty, whose blessings, continued inspiration and silent guidance has nurtured us to follow the path of untiring research for the ultimate progress.....

November, 1999

Dr. Har Prashad

ICIT-99

Steering Committee of ICIT-99

Shri M.K.Mittal

Director (E,R&D)

B.H.E.L.

(Chairman, Steering Committee)

Dr.A.K.Bhatnagar

Director(R&D)

Indian Oil Corporation Ltd

Shri H.L.Zutshi

Chairman and Managing Director

Hindustan Petroleum Corporation Ltd

Dr.J.Bhatia

Managing Director

Fuchs Lubricants (India) Ltd.

Prof.D.V.Singh

Vice Chairman (President TSI)

All India Council for Technical Education

Prof.(Dr.) T.C.Rao

Director

Regional Research Laboratory(CSIR)

Dr.G.Sundara Rajan

Director

International Advanced

Research Centre (ARCI)

Shri Sudhir Singhal

Director

Indian Institute of Petroleum

Dr.S.K.Bhattacharyya

Director

SAIL

R&D Centre for Iron and

Steel (RDCIS)

Shri R.S.Guha

Director (Petroleum)

IBP Co. Limited

Prof.G.N.Mathur

Director

D.M.S.R.D.E.

Shri K.K.Dhingra

Executive Director

Petroleum Conservation

Research Association

Shri S.Mani

Director/MP

Research Designs and

Standards Organisation (RDSO)

Ch.Surendar

Executive Director

(Operations)

Nuclear Power Corporation

Dr.Shrikant Bhawe

Head

Thermal Engg

Larsen & Toubro Ltd

Shri S.A.Bohra

Chief Engineer(MS)

Nuclear Power Corporation

Sri C.V.Chandrasekharan

Managing Director

Balmer Lawrie and Co Ltd

Shri G.S.Ravi

Director

Standard Oil Additives

Shri N.R.Bhoopatkar

Chief Executive

Apar Industries Ltd

Dr.A.Prabhakara Rao

General Manager Incharge

B.H.E.L., Corporate R & D Division

Editorial Board

ICIT '99 - TECHNICAL COMMITTEE

Chairman : **Dr. Har Prashad**, BHEL, Corporate R & D, Hyderabad

Lubrication Basics:

Prof. D. V. Singh

All India Council for Technical Education
Indira Gandhi Sports Complex
I.P.Estate, New Delhi-110002

Lubricants

Dr. J. Bhatia

Fuchs Lubricants (India) Ltd.
Karmayog Building
Parsi Panchayat Road
Andheri (E), Mumbai-400069

Lubricants :

Mr. Sudhir Singhal

Indian Institute of Petroleum
P.O.Mohkampur
Dehradun-248005

Surface Engineering :

Dr. A. Sethuramiah

ITMMEC, IIT
Hauz Khas
New Delhi-110016

Tribology of Materials :

Dr. A. K. Jha

Regional Research Laboratory
Near Habibganj Naka
Bhopal-462026

Condition Monitoring :

Dr. B. S. Prabhu

Professor
Mechanical Engg
IIT,
Chennai

Tribotesting and Analytical Techniques.

Mr. A. K. Mehta

IOC, R&D Centre
Sector 13,
Faridabad-121007

Dynamic Fluid Sealing, Seals and
Rotodynamic Coefficients

Prof. M. K. Ghosh

Banaras Hindu University
Institute of Technology
Department of Mech Engg
Varanasi-221005

Tribology in Power Sector and Allied
Industries.

Dr. Har Prashad

BHEL, Corp R&D
Vikasnagar
Hyderabad-500093

Special Topics in Tribology:

Prof. M. C. Dwivedi

IIT, Dept of Chemical Engg
Mumbai-400076

NATIONAL PLANNING AND ORGANIZING COMMITTEE

Dr.P.Jagannathan

Chairman, Organizing Committee
BHEL, R&D, Hyderabad

Prof.D.V.Singh

President, TSI
A.I.C.T.E., New Delhi

Mr.Sudhir Singhal

Immediate Past President
TSI, I.I.P., Dehradun

Dr.J.Bhatia

Vice President, TSI
Fuchs Lubricants (India) Ltd.
Mumbai

Mr.A.K.Mehta

Secretary, TSI
I.O.C., R&D, Faridabad

Mr.V.Narayan Sharma

Treasurer, TSI
Balmer Lawrie & Co
Calcutta

Dr.M.R.Tyagi

Jt.Secretary, TSI
I.I.P., Dehradun

Dr.A.K.Bhatnagar

Director
I.O.C., R&D Centre
Faridabad

Prof.B.S.Prabhu

Professor, I.I.T., Chennai

Mr.C.Misra

TISCO, Jamshedpur

Mr.K.Balasubramanian

Fidelity Industries Ltd
Chennai

Dr.Har Prashad

Jt.Secretary, TSI
Convener & Organizing
Secretary, BHEL,
Corp R&D, Hyderabad

ORGANIZING COMMITTEE

BHEL, Corporate R&D Division, Hyderabad

Dr.P.Jagannathan

Shri S.K.Goyal

Dr.S.K.Roy

Dr.K.K.Chaturvedi

Shri K.Venugopal

Shri H.Krishnan

Dr.(Mrs.) P.Kamalam

Shri P.K.Kakkar

Shri N.S.Rao

Shri M.Mukundan

Dr.C.K.Rao

Chairman

Shri A. Vishwanathan

Shri E.D. Vinod Kumar

Sri Vijay Mohan

Shri C.B.M.Prakash

Dr.U.M.Choudhari

Shri B.K.Dhingra

Shri A. Yadagiri

Shri P.Nagaraju

Shri S.Sudhakar

Shri P.B. Janwadkar

Shri P.Rajasekhar

Dr.Har Prashad

Convener

FOREWORD

Over the years, Tribology has played a major role in ensuring safe and efficient operation of variety of industrial machinery. It has gained increasing importance in many respects including energy conservation by optimum design of machinery following correct tribological practices. Industry has realized that Tribology is a techno-economical tool for maintainability and reliability. Tribology Society of India has made a significant contribution in creating awareness of Tribology by way of organizing conferences, seminars and publications of News Letters and TSI Journal.

The **Second International Conference on Industrial Tribology** with a theme of **Tribology in 2000 and Beyond** offers a platform to focus the achievements of Tribology by 2000 and the future advancement of this discipline in the 21st Century. The Conference will mainly deal with the use of synthetic, environment friendly, multigrade lubricants, friction modifiers, increased wear resistant surface treatment, use of magnetic bearings and optimum energy saving bearing design to enhance the performance of the equipments. The papers included in this proceeding will certainly be of interest to the delegates drawn from wide cross-section of industries like steel, petroleum, engineering, power generation as well as from academic institutions and research laboratories from India and abroad.

I hope that the Conference will be able to identify the likely knowledge gaps and evolve a plan to fill up the gaps for the benefit of Tribologists of our country and abroad.

I wish the Conference all success.

Dr. A. Prabhakara Rao
General Manager Incharge
BHEL, Corporate R&D Division
Hyderabad

FROM THE ORGANISING SECRETARY

Effective utilization of energy is technically not effective without the technological advancement in Tribology. Researchers and practicing engineers both have to interact very closely to fill up the know-how and know-why gaps prevailing between theory and practice in this area. Also, the Government has to take measures to draw attention of people for adopting the correct tribological practices in this regard.

The theme of the conference - **Tribology in 2000 and Beyond** - was chosen considering present know-how gaps and status of Tribology in this century and the orientation to be adopted in the next century. It would be a matter of great satisfaction if appropriate thoughts and directions for perspective development can emerge out of the deliberations of the conference.

Tribology in 2000 and Beyond is divided into ten broad areas besides keynote / plenary session. Each area has been dealt by individual session organizer of International repute for selection, review of the papers and conduct of the session. Besides this special session on ***“Energy Efficient Bearings and Tribology in 2000 and Beyond”*** by presentations of papers selected exclusively in the frontier areas is also organized. One day four parallel Technical courses relevant to industries are also planned before the conference. Furthermore, panel discussion is planned on ***“Automotive Pollution - Role of Lubricants”*** apart from the ***“Tribology in 2000 and Beyond”***.

ICIT-99, under the aegis of Tribology Society of India is the second conference after 1984, being organized by BHEL, Corporate R&D division at Hyderabad. On behalf of organizers, I thank the Executive Committee of TSI for granting us this privilege and opportunity.

ICIT-99 is the result of inspired team effort. Apart from my colleagues from BHEL, Corporate R&D Division and the Executive Committee of TSI, I am grateful to the Tribologists and practicing professionals of our country and abroad, who have contributed towards this venture. I am thankful to all the delegates, authors and keynote speakers, who have participated/contributed to this conference. I am thankful to the Chairman and Managing Director of BHEL, Director (Engg, R&D), General Manager Incharge R&D, Steering Committee members for their encouragement and valuable guidance, as also the sponsors, co-sponsors and supporters who have extended their whole-hearted assistance in organizing the conference.

Dr. Har Prashad
Sr. Dy. General Manager
B.H.E.L., Corporate R&D Division
Hyderabad, India

CONTENTS

Organizers	V
Dedicated to	VII
Steering Committee	VIII
Editorial Board : ICIT '99 - Technical Committee	IX
National Planning and Organizing Committee	X
Organizing Committee, BHEL, Corporate R&D Division, Hyderabad	X
Foreword	XI
From the Organizing Secretary	XII

KEYNOTE / PLENARY

1. Tribology in the Twenty First Century Bo Jacobson	1
2. Synthetic Lubricants Scenario in 21st Century S.P.Srivastava	7
3. Aluminium Machining - A New Challenge D.Hoerner	18
4. Energy Efficient Journal Bearings Through Lubrication Jack Schofield	19
5. Complexity of Future Development of Lubricants and Lubrication Systems - Machine Tool Lubrication. Theo Mang	26
6. Tribology Under Electrical Environment Har Prashad	34
7. Gear Lubricants as Design Elements - a Tool for Gear Designers Wilfried J.Bartz and Klaus Michaelis	41
8. Bearings in 2000 and Beyond B.C.Majumdar	52
9. Tribology Practices in Steel Industry C.Misra	59

LUBRICATION BASICS

10. Transient Response of Capillary Compensated Hybrid Journal Bearing System During Starting and Stopping Operation 75
Vijay Kumar, Satish C.Sharma and S.C.Jain
11. Engine Journal Bearing: Design and Case Study Analyses 83
H.Hirani, K.Athre and S.Biswas
12. Some Experiments on Magnetically Suspended Test Rotor 93
V.Kamala, P.Muthu, U.K.Choudhary and A.Rajamani
13. Effect of Load Direction on the Hydrostatic/Hybrid Performance of a Multirecess Orifice Compensated Flexible Journal Bearing 101
Satish C.Sharma, S.C.Jain and B.V.N.Surendra Kumar
14. Transient Orbit Analysis for Acceleration and Deceleration of Rotors using Finite Element Method 109
R.K.Purohit and O.P.Singhal

DYNAMIC FLUID SEALINGS, SEALS AND ROTODYNAMIC COEFFICIENTS

15. Effect of Fluid Inertia on Stability of Oil Journal Bearings considering Time History of Film Shape 117
S.K.Kakoty and B.C.Majumdar
16. Unbalance Vibration Control of Flexible Rotors Employing Radial and Angular Damping of Active Magnetic Bearings 124
S.Jana, R.Bhattacharyya and B.Samanta
17. Life Prediction Model of Treated Surfaces under Rolling Contact Accounting for Tractional Effect 131
D.Dinakar and M.M.Mayuram
18. Rotodynamic Coefficients and Stability of Multilobe Hybrid bearings 138
M.K.Ghosh and M.R.Satish
19. Estimation of Leakage and Dynamic Characteristics of Labrinth Seal, using Finite Element Method 146
D.Rame Gowda, P.Chandrasekhar and B.S.Prabhu
20. A Methodology to Evalute Non-linear Dynamic Coefficients in a Hydrodynamic Journal Bearing 154
T.V.V.L.N.Rao, S.Biswas and K.Athre

LUBRICANTS : INDUSTRIAL AND SOLID LUBRICANTS, GREASES, ADDITIVES, SPECIALITY LUBRICANTS INCLUDING LUBRICANTS AT EXTREME TEMPERATURES AND CONDITIONS

21. Mo-S Complexes as Multifunctional Lubricant Additives 162
V.K.Verma, R.Singh, A.Bhattacharya, A.K.Tripathi, P.K.Singh and Vandana Srivastava
22. Synthetic Aluminium Complex Grease: A Tribological Evaluation 168
Using a Four-ball Test
Tarunendr Singh and M.F.Sait
23. Effects of Average Molecular Weight and Concentration of Styrene-isoprene 173
Co-polymer on Tribological Characteristics
Mahendra Pal
24. Degradation Kinetics of Hydrogenerated Poly (Styrene-co-Isoprene) 179
N.M.Desai and N.C.Joshi
25. Effect of Emulsifier Chemistry on Wear Behaviour of Invert Emulsion 185
Fire Resistant Hydraulic Fluid
A.K.Jain, B.S.Nagarkoti, D.V.Prasad, M.P.Bangwal, A.B.Shah and M.F.Sait

LUBRICANTS : AUTOMOTIVE, METAL WORKING AND POWER TRANSMISSION

26. Effect of Water Soluble Metal working coolants on Surface State of 190
High Hardness Steel at Finishing Treatment
Mishchuk O.A., Protsishin V.T. and Rizhov Yu.E.
27. Metal working Fluid : An Environmental View 196
Mahendra Pal
28. A Laboratory Technique for Evaluation of API GL-5 Level Auto Gear Oils 200
R.P.S. Bisht and V.K.Jain

SURFACE ENGINEERING : COATING AND RHEALOGY OF SURFACE FILMS, WEAR MECHANISM, MODELLING, EROSION AND WEAR OF MACHINE COMPONENTS

29. HVOF Deposited WC-12% Co Coating on Ti-alloy for Improved Erosion Resistance 205
Manish Roy, B.E.Narkhede and S.N.Paul
30. Abrasive Wear of Al Alloy-Al₂O₃ Particle Composite: A Study on the Combined 216
Effect of Load and Size of Abrasive
D.P.Mondal, S.Das, Sunita Gupta, A.K.Jha and B.K.Prasad

31. Response of Plasma Sprayed Alumina - Titania System to Three - Body Abrasion 224
S.L.Ajit Prasad, M.M.Mayuram and R.Krishnamurthy
32. Effect of Experimental Factors on the Slurry Erosive Wear Behaviour of a 232
 Few Hardfacing Alloys with Varying Chromium Content
R.Dasgupta, A.K.Jha, B.K.Prasad, O.P.Modi, S.Das and A.H.Yegneswaran
33. Erosive-Corrosive Wear Characteristics of a Zinc-Based Alloy and Composite 241
 under the Conditions of Varying Slurry Composition and Distance
B.K.Prasad, O.P.Modi, S.Das, R.Dasgupta and D.P.Mondal
34. Fractal Characterization of Running-in Behaviour of an IC Engine Piston 247
 Rings and Cylinder Liner Surface Combination
K.C.Joseph and N.Raman
35. Aluminium Matrix Composites: A Potential Material for Automobile and 258
 Engineering Applications
S.Das, D.P.Mondal, O.P.Modi, and A.H. Yegneswaran
36. Mechanism of Material Removal during Erosion-Corrosion of an 265
 Al-SiC Particle Composite
S.Das, D.P.Mondal, R.Dasgupta and B.K.Prasad
37. Improvement in Lubrication during Cold Rolling of Electrical Steel 273
Madhu Ranjan, P.Pathak, A.K.Marik, P.P.Sen Gupta, R.C.Thakur and G.M.D.Murty

TRIBOLOGY OF MATERIALS

38. Antifrictional Coatings with Organomineral Fillers for Heavy-Duty Friction Joints 280
I.I.Zlotnikov, V.A.Smurugov and S.V.Piskunov
39. Erosive Wear Studies of Unidirectionally Carbon Fibre Reinforced Epoxy 283
 Composites
U.S.Tewari and A.P.Harsha
40. Comparative Study of Wear on the Rollers during Flow Forming of Different Materials 291
C.S.Krishna Prasada Rao, M.Komaraiah and G.Chandra Mohan Reddy
41. Factorial Designing of High Stress Abrasive Wear Response of Steels 299
R.Dasgupta and A.Roy
42. Wear Characteristics of H.S.S.Cutting Tool during Turning Operation of 306
 Cast Aluminium Alloy-Sic/Gr Composites
M.S. Bhagyashekar, C.S. Ramesh, A. Ramachandra, and K.Chandrashekara
43. A New Three Stage Mechanism for Low Stress Abrasion 312
 in Glass Fibre Polyester Composites
Navin Chand and Somit Neogi

