Institute *of* **Physics**

Tribology Group

Spring Newsletter

May 2006

Contents

Announcement of Tribology Group 16th Annual General Meeting to be held on 18th October 2006 at 12.30 pm

Tribology Group of The Institute of Physics

The Group was formed in 1980 by Professor David Tabor to provide a forum for the discussion of new research in fundamental aspects of interacting surfaces. The Group Committee meets quarterly to organise and develop the group activities particularly the one-day meetings. At present the Committee is made up of xx members drawn from industrial and academic institutions. The Group organizes three or four meetings in each year covering a variety of topics. These meetings usually take the form of one-day seminars with invited speakers and are held at the Institute of Physics. The committee would welcome feedback from Tribology Group members concerning the usefulness of these meetings. So comments please with regard to the subject matter, meeting format, publicity, timing and venue.

For more details of the committee members, group activities and meetings please visit the Institute of Physics website: www.iop.org

If you have any comments on the newsletter or suggestions for future seminar topics please contact me at the address below.

Dr Philippa Cann

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Tribology Group Activities in 2005

Annual General Meeting

The 15th Annual General Meeting was held 19th October 2005 at the Institute of Physics.

Chair's Report for 2004-2005

Prof. W.M. Rainforth

The Tribology Group of 2004/2005 brings together many dedicated, lively tribologists who have done an excellent job of organising topical meetings. The committee is truly multidisciplinary, covering all important disciplines related to tribology, including lubrication, mechanics, materials science, corrosion, nanocontacts and so on. Such an excellent range of expertise is unique in the UK tribology community.

The Tribology Group has held a good range of meetings over the last year (details in Hon. Secretary's report). We have worked within the new financial rules for meetings and have still been able to invite some overseas speakers in the line-up for meetings in order make them as attractive as possible. The topics continue to reflect the breadth of the subject (e.g. from 'Polymer Tribology' to the '.Boundaries of Experimental and Modelling Expertise').

Meetings are now organised on the basis that numbers will be lower than in previous years, with mid 20s being normal. However, even with

late registrations we have not had to cancel any meetings, which is an improvement on 2003/2004.

Next year will see the 25th Anniversary of the Tribology Group. We are all looking forward to a one day celebration event at the IoP on February 1st, where we have invited former members of the Tribology Group to give talks on any subject that is close to their heart. The day will provide a very special insight into the UK research on Tribology and will finish with an evening meal, where no doubt many fond memories will be regaled.

This is my last report as Chair. I have thoroughly enjoyed chairing the committee over the last 3 years and it has been a privilege to work with so many dynamic colleagues. I would like to thank all current and former members of the committee for their support.

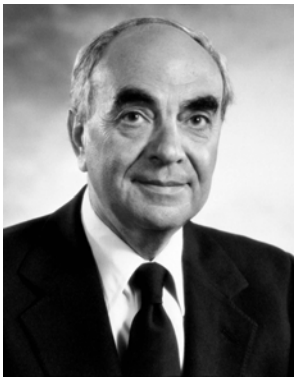
25th Anniversary Meeting 1st February 2006

The first inaugural meeting of the Institute of Physics Tribology Group took place at the Cavendish on 30th July 1980. At the meeting, Professor Tabor, FRS, was elected the first Chairman, with Dr DM Rowson as Secretary and Treasurer. We were all greatly saddened by the death of Professor Tabor in November last year at the age of 92. He was undoubtedly one of the leading tribologists of our time. Indeed, Professor Tabor conceived the name 'tribophysics' shortly after the 2nd world war. Professor Tabor held the position of Chairman of the Tribology Group for 3 years until November 1983, during which time 11 meetings were held around the UK. The inaugural meeting was at Cranfield, entitled 'Tribology: Contrasts in Frictional Processes', and attracted a healthy number of delegates, as can be seen from the picture above. The tradition of holding focused meetings on a wide variety of themes in a wide variety of locations continues today, as does our cooperation with other professional societies, such as the IMechE and the IoM[3]. Professor Tabor's closing report as Chairman included the words: 'the last 3 years have been very interesting and worthwhile experience and I must now lay down my office confident that the Group is in good hands and that its future is assured'. The meeting today celebrates 25 years of the Tribology Group, during which the starting traditions have been continued and expanded, with many

distinguished members along the way, several of whom are here today. We look forward to the next 25 years!

Prof WM Rainforth, Chair 2002-2005

Prof PH Shipway, Chair 2005-2008



Professor David Tabor, FRS

Meeting Programme

Invited speakers were drawn from past members of the committee. The wide range of topics exemplified the diversity and breadth of research in Tribology.

Professor Brian Briscoe opened the meeting with a short talk reflecting on the scientific contribution of Professor Tabor to Tribology.

The meeting was attended by x delegates including y students, which was in part made possible by the generous financial support of our sponsors.

The Organisers gratefully acknowledge sponsorship of this event by Phoenix Tribology, EPSRC, Unilever, NPL, Shell, PCS Instruments, Micro Materials, and BP

Meeting programme

The Scratching of Polymer Surfaces

Professor Brian Briscoe *Imperial College London*

The proposed presentation will review various facets of the damage incurred on polymer surfaces when hard indenters are slid over their surfaces. The key variables are introduced and their significance reviewed. The generic optical damage features are first summarised and the construction of subjective damage maps is outlined. The results obtained primarily from two machines are described; the pendulum and Eldridge type devices. The relative merit of each is briefly discussed as is the value of nanoscratching devices. The friction behaviour is also reviewed as is the likely influence of frictional heating and subsurface craze formation. The interrelationship between normal and scratch hardness is noted for one polymer and the role of lubrication is illustrated. Profilometer and reflectivity data are provided to introduce the phenomena of marring and the loss of surface gloss. Finally, the future prospects for the advancement of knowledge in this area is outlined.

Nano-Wear of Two Phase Ceramics and its Impact on Data Recording

Professor John Sullivan *Aston University*

The two-phase Al_2O_3-TiC ceramic (AlTiC) has many applications. One of the most common uses of AlTiC is for data recording heads where it is used as a bearing surface to support the magnetic sensing elements.

Using Linear Tape Open (LTO) drive and metal particle (MP) tape media as the experimental platform; the wear of the AlTiC at very low loads and for very smooth surfaces has been studied. X-ray photoelectron spectroscopy (XPS), Auger electron Spectroscopy (AES) and Atomic Force Microscopy (AFM) were employed to analyse the AlTiC surface changes during wear at a variety of environmental conditions. Under all experimental conditions the results showed the TiC phase of AlTiC to have been oxidized to form a surface layer. This gave rise to classical oxidational wear of that phase; with the delamination of the TiO_2 to form pullouts on the AlTiC surface and subsequent three-body abrasive wear particles were produced. The rate of oxidation of the TiC and hence the rate of production of the three-body wear particles increases with atmospheric water vapour content. In the experimental system chosen for this investigation, this results in an increase in differential wear, and hence pole tip recession of the magnetic metal poles of the recording heads. Pole tip recession was shown to correlate with increase in oxidation rate and also increase with atmospheric water vapour content. The wear of the Al_2O_3 phase was probably due to micro adhesive wear with a wear rate much lower than that of the TiC phase.

Tribological Challenges in Small Devices

Professor John Williams *University of Cambridge*

Micro-electro-mechanical systems, MEMS, is a rapidly growing interdisciplinary technology dealing with the design and manufacture of miniaturised machines with major dimensions at the scale of tens, to perhaps hundreds, of microns. Because they depend on the cube of a representative dimension, component masses and inertias rapidly become small as size decreases whereas surface and tribological effects, which often depend on area, become increasingly important. Although our explanations of macroscopic tribological phenomena often involve individual events occurring at the micro-scale, when the overall component size is itself miniaturised it may be necessary to re-evaluate some conventional tribological solutions. While absolute loads are small in such micro-devices, tribological requirements, especially in terms of device longevity which may be limited by wear rather than friction, are demanding and will demand imaginative and novel solutions. Not only is the available material set limited by the fabrication process but, in addition, while this results in components with small linear dimensions they are not, by conventional standards, of high precision and this too impacts on their tribological behaviour.

Using Nanomechanical Testing and Advanced Analysis to Solve Tribological Problems in Surface Engineered Components

Professor Steve Bull *University of Newcastle*

Nanomechanical testing is becoming increasingly important in device development as the dimensions of components shrink. For instance, submicron tribological coatings and surface treatments are being developed for consumer goods and it is often the mechanical response of electronic and optical coatings which limits performance. The key assessment techniques used for assessment of such properties are often based on contacting probes, but extra information can be obtained if this is combined with high resolution analysis techniques. In some cases it is possible to use these analysis techniques to generate further useful mechanical information, such as the residual stress in thin films, at higher spatial resolution than is possible with conventional measurement techniques.

The use of the nanoindentation to assess the mechanical properties of bulk materials and thin coatings is now widespread as the test is generally easy to perform, reliable and quantitative. However, the interpretation of nanoindentation data for coated systems (and nanodevices) is not always simple and there are considerable questions about the meaning of the hardness numbers generated even. Deformation mechanisms can be complex involving plastic deformation and fracture of the coating and substrate and interfacial failure. High resolution electron microscopy and atomic force microscopy is an essential part of understanding these deformation mechanisms.

Fracture is an almost inevitable consequence of highly loaded contact in ceramic-coated systems. For relatively thick coatings fracture is often

similar to that observed in bulk materials but as the coating thickness is reduced the substrate plays an increasing role in controlling fracture behaviour. Both through-thickness and interfacial fracture may be observed depending on the relative toughness of the substrate, coating and interface. Through-thickness fracture is exacerbated by plastic deformation in the substrate and therefore the load support from the substrate is critically important in determining the type and extent of fracture observed. The effect of fracture on the nanoindentation load-displacement curves and the hardness and Young's Modulus values obtained from them will be discussed and a new method to extra toughness information from the data will be introduced. The use of acoustic emission to monitor plasticity and fracture during the indentation cycle will also be discussed.

Erosion revisited

Professor Ian Hutchings *University of Cambridge*

Erosive wear occurs when small hard particles strike a surface, and is an important mechanism of material degradation in powder processing and pneumatic transport, gas turbine engines and gas-solid phase industrial processes such as coal combustion. Erosion can also find useful application in the processes of abrasive jet cutting and machining. The mechanisms by which material is removed in erosion, and models which have been developed for the process, will be discussed, with particular focus on the evolution of the subject over the past 25 years and the substantial challenges which are still present.

From wipers to JKR

Dr Alan Roberts *formerly TARRC*

This talk traces the early development leading to the establishment of the JKR equation, a modified Hertz equation that takes account of adhesion between solids making elastic contact. The development arose out of an investigation to improve understanding of the action of windscreen wipers. Optical interferometric observations of the contact area between model smooth-surfaced hemi-cylindrical rubber wiping elements and lubricated glass pointed the way forward. The observed dry contact width made with the glass was found to be greater than that predicted by the classical Hertz equation, especially so under small applied loads. The extended contact was accounted for in terms of the equilibrium work of adhesion between the solid surfaces. A complication was the viscoelastic response of the rubber, and this aspect has received considerable attention both experimentally and theoretically over the years. Although originally intended for 'soft' contacts, the JKR equation has been used to interpret results for harder materials, such as metal micro-contacts. In recent times it has enjoyed a renaissance with the rise of nanotechnology. The equation is often employed to interpret results from the Surface Force Apparatus and the Atomic Force Microscope.

Taction

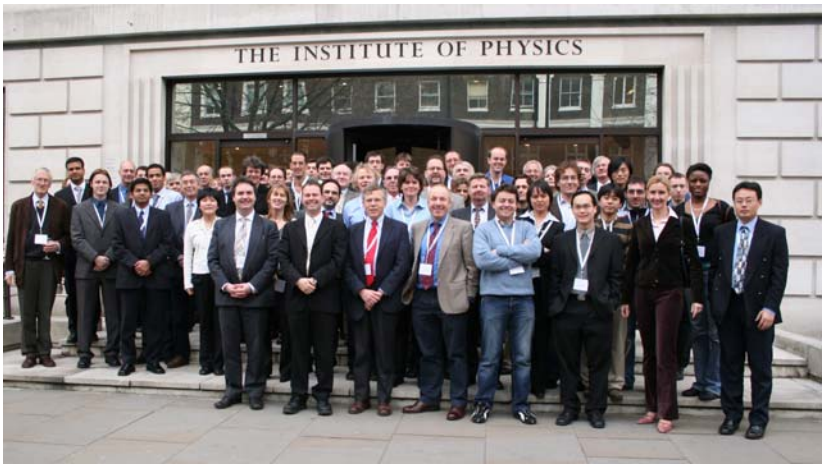
Professor Mike Adams *Unilever and Birmingham University*

The tactile sensitivity of the human fingers is remarkable in allowing the perception of subtle textures such as roughness, smoothness, hardness, stickiness, slipperiness, oiliness, coarseness and graininess. This depends on a distributed array of four types of bio-transducer in the skin (*mechanoreceptors*) each with different characteristics that provide capabilities such as spatial acuity, vibrotactile frequency discrimination and also topographical feature detection with a spatial resolution as small as 100 nm. Taction is a complex process involving a mechanical disturbance of the skin, the excitation of thousands of mechanoreceptors and the rapid processing of the neural discharge information in the brain, which is key in controlling the manipulative dexterity of the fingers. The tribological properties of skin play a key role in the in- and out-of-plane deformation of the fingertips and hence in the activation of the mechanoreceptors. The presentation will focus on some of the unresolved issues associated with these tribological properties and the relationship with those of synthetic polymers. For example, there is conflicting evidence about whether or not the coefficient of friction decreases with the applied normal load when a spherical probe is employed on dry skin. There is little corresponding data reported for wet skin and also on the influence of the probe material. However, the published work suggests that the friction of skin increases in the wet state and it also increases to some maximum value while drying. Moreover, under certain circumstances the motion is intermittent for wet skin; the example of sliding a wet fingerpad over the rim of a drinking glass is well known.

Soft EHL - the tribology of tyres and tongues

Professor Hugh Spikes *Imperial College London*

There is growing interest in isoviscous-elastic or "soft-elastohydrodynamic" lubrication (soft-EHL). This normally occurs in lubricated, non-conforming contacts when one or both of the bodies is highly elastic, e.g. an elastomer or human tissue. This regime of lubrication is found in engineering systems such as lubricated seals, windscreen wipers and between tyres and wet roads. It is also prevalent in many biological systems, such as natural and replacement human joints, the tongue-palate contact during oral processing and in human skin and hair contacts treated with personal care products. Surprisingly thick hydrodynamic lubricant films can be formed in soft-EHL contacts, even by low viscosity lubricants such as aqueous solutions and this has practical relevance in both engineering and biological applications. This presentation describes work to measure and model both rolling and sliding friction of a variety of fluids, ranging from simple Newtonian liquids to multiphase fluids, in soft-EHL contacts over a wide range of entrainment



1st February 2006 25th Anniversary Delegates

Past Meetings

The following one-day meetings were organised by the Tribology Group in the year 2004-2006.

Control of wear and friction through thick coating technology 11th November 2004 held at National Physical Laboratory

Future challenges in Tribology – Exploring the boundaries of our experimental and modelling expertise 2nd December 2004 (co-sponsorship with I.Mech.E).

Tribology of Micro and Nano Contacts and Devices, 22nd February 2005 (co-sponsorship with IMechE and NPL) held at National Physical Laboratory

Polymer Tribology, 23rd June 2005 (joint meeting with IOP Polymer Physics Group) held at University of Birmingham

A celebration of 25 years of Tribology at the Institute of Physics 1st February 2006

Measurement of the Mechanical Properties of Surfaces by Indentation

10th May 2006 to be held at National Physical Laboratory

Future Meetings 2006-2007

Tribology 2006: Surface Engineering and Tribology for Future Engines and Drivelines

12-14 July 2006, IMechE, 1 Birdcage Walk, London

Biotribology 18th October 2006, Institute of Physics London

Vibration in Tribology 28th February 2007 Institute of Physics London

Tribology Group Committee News

The committee has seen a number of changes over the past year. Professor Philip Shipway has succeeded Professor Mark Rainforth as Chairman.

Dr Simon Johnson has succeeded Professor Margaret Stack as Honorary Treasurer. Dr Philippa Cann

Dr Mike Hempstock , Dr Rita Kapadia, Dr Emyr Roberts, Dr Paul Tweedale, Dr Steve Roberst and Dr Richard G. Wellman have stood down from the Committee. The Chairman wishes to thank them for their contribution over the years.

Two new members have joined the Committee they are Dr Ben Beake and Dr Hong Wei Wang.

Dr Ben Beake, CChem, MRSC, MInstP, CSci, FIoN is a Senior Research Scientist at Micro Materials Ltd. After a degree and PhD (1994) in Chemistry both from the University of Exeter, he worked at the Universities of Hull, Nottingham and UMIST, before joining Micro Materials in 1999. He is a Fellow of the Institute of Nanotechnology. His research focuses on developing new nanomechanical test methods and applying them to the study of the mechanical and tribological properties of thin films and coatings to aid their design and optimization for given applications. Specific research interests include: nanoscale impact and fatigue testing of wear-resistant coatings;

nanomechanical testing at high temperatures – correlating results to tool performance; nanotribological properties of thin films.

Dr.Wang is Senior Metallurgist in gas turbine components and materials at ERA where he proposes and manages multiple projects on condition assessment and failure analysis of turbine blades and vanes for power stations. He also provides consultancy to turbine repair companies on superalloy manufacturing and coating issues. He last worked as Materials Scientist R&D Manager on thermal spray coatings at Greenhey Engineering Services and previously as Materials Scientist on carbon-carbon advanced brake lining composites at Surface Transforms plc. In 1994-2001, he was employed as a Postdoctoral Research Associate in UMIST, performing research on solid lubricants, anodising, corrosion, erosion, and wear at its Corrosion and Protection Centre. He gained PhD (fatigue modification by ion implantation, 1994), MSc (wear of shape memory alloys, 1990), and BEng in physical metallurgy (1987). He has published over 30 papers and authored a large number of non-publishable technical reports. He has wide research experience and maintains broad knowledge and interest in many fields, such as tribology, corrosion, high temperature degradation, and broad surface coating techniques. He is a UK Engineering Council registered Chartered Engineer and a Professional Member of IoP and IoMMM

Committee Members

Chairman

Professor Philip Shipway, University of Nottingham

Honorary Treasurer

Dr Simon Johnson, Unilever Research, simon.johnson@unilever.com

Honorary Secretary

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