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# Tribologia

TRIBOLOGY GROUP, Dept. of Mechanical Engineering, STRATHCLYDE UNIVERSITY, Glasgow, Scotland, UK



## Tribology Group:

### Leader : Prof. Margaret Stack

#### Graduate students

1. Mr. Mathew T. Mathew
2. Mr. Buddhadev Jana (Editor)
3. Mr. Yashodhan Purandare
4. Mr. Tarek M. Abd El Badia

#### Undergraduates

5. Miss Emma Hendry
6. Miss Michelle Tinney
8. Mr. David Toner

#### Erasmus students

9. Mr. Jirka Rodling

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Tribology in sport- a downhill skier in action

## Group Leader, Professor M. M. Stack

**Tribology** is a derivation of the Greek word "*Tribos*" which means "rubbing". The activities of this research group cover areas where:

wear occurs due to surfaces which rub against each other (**sliding wear**),

particles may be entrained in the contact (**3 body wear**)

particles may cause impact on the surface (**erosion**) or gouge out the surface (**abrasion**)

and where wear occurs due to formation and collapse of bubbles of air at high pressures (**cavitation**).

In particular, their interactions with corrosion (**tribo-corrosion**) are being examined and

the rationale for defining such interactions-so important for Engineers charged with controlling such processes-is being studied. Significant progress has been made in the past 10 years in the UK in the study of **tribological phenomena**, particularly in the areas of **erosion-corrosion** and abrasion and the development of **engineering "maps"** of such processes. This group is concerned with developing maps for **particulate erosion, micro-abrasion, sliding wear and cavitation, in corrosive environments**, both at room and at elevated temperatures. These maps may indicate a wide range of phenomena i.e. the **mechanism of wear**, the extent of **wastage** and **interaction** between the processes, all **components** of tackling the complex area of **Tribology** from the perspective of the Mechanical Engineer. Over 110 papers have been generated on this work to date.

<http://www.tricor.net.strath.ac.uk/>

## Group Activities

The Tribology group of the University of Strathclyde, Glasgow is one of the most colourful groups in the Department of Mechanical Engineering and its objective to maintain the world class research standards of the Department and the University.

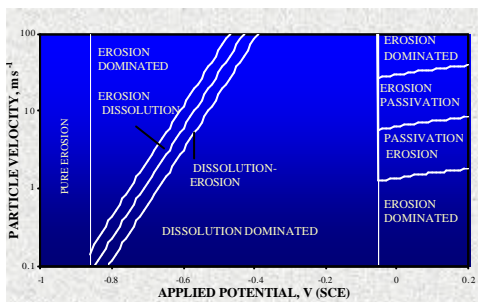
To maintain its high quality research activities, the Tribology group engages in various activities and some of them are listed below:

1. Weekly group meeting: Group members meet once in a week (at 3pm every Friday) to discuss everything under the sky - right down from research work to the 'Isle of Skye', the beautiful tourist spot in Scotland.
2. Conferences: Members of this group have

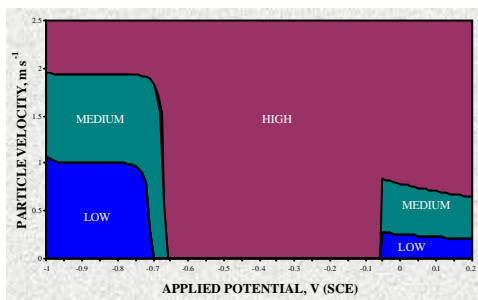
attended major conferences in the area in the past two years ICMCTF, Wear of Materials and the Gordon research conference in Tribology.

3. Collaborations: The group has strong collaboration with various research institute and industries in UK.

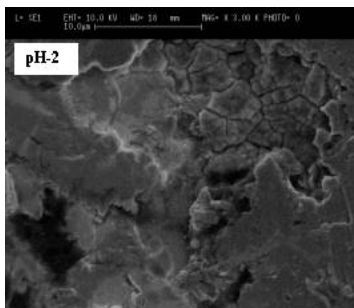
4. Prize and awards: group members are involved in various competitions in United Kingdom and this year one of the members, Mr. Buddhadev Jana was selected as the Scottish region finalist in the young persons lecture competition organized by Institute of Materials Minerals and Mining, UK. Matthew Mathew was shortlisted for the Bodycote best paper award.



Regime map for iron at pH 5



Wastage map for iron at pH 5



Micro-abrasion-corrosion of a Ni-Cr/WC MMC based coating at pH 2

## Modelling in Erosion-Corrosion by B. D. Jana

Erosion and corrosion have been studied widely – with people researching the former since the Stone Age and the latter since the Iron Age. However, there is still a lack of understanding on the nature of the interaction.

To unveil the mystery of the combined effect of erosion and corrosion, the Tribology group in University of Strathclyde has been working extensively in this field. Critical simulations and experimental techniques have been adopted and developed in the group

The group is renowned world wide for its authoritative work on mapping on

the incredibly complex erosion-corrosion process. Various rules for defining regimes of interaction have been established and various reasonable assumptions are made to simplify the complex process.

I am in second year of PhD studies and working on the footsteps of many other researchers in the field. I am involved in constructing such erosion-corrosion maps for range of pure metals and composite coatings.

I received ample appreciation of this work while presenting a poster in the Gordon research conference in Tribology 2004, USA.

## Micro-abrasion-corrosion By M.T.Mathew

In recent years, the study of micro-scale abrasion of materials has become of increasing interest due to its application to tribology of bio-medical materials. These include the wear mechanism observed in artificial hip and knee joints (often polymeric materials) where wear may occur at relatively low loads and for particle sizes typically less than 10  $\mu\text{m}$ .

Other bio-medical applications of micro-abrasion include oral environments i.e. dentistry, where micro-abrasion and corrosion may accelerate each other. Here, acid dissolution may significantly enhance the micro-abrasion process. On the other hand, if the particles are also corrosive, they may have a role in modifying both the wear and corrosion on the surface.

One significant limitation of academic research in micro-abrasion is that there has been little work carried out to study in a quantitative manner the effects of micro-abrasion on the corrosion rate. These effects are important to characterize because (as indicated above) micro-abrasion in bio-medical applications typically occurs in corrosion solutions in which the pH and electrochemical potential may vary significantly. Understanding the combined effects of the tribological and corrosion variables is critically important for optimizing materials selection and tribo-corrosion parameters in such conditions.

## Interesting Books in Tribology by B. D. Jana

There are various books on Tribology among them some are considered epics of Tribologist and those are listed below.

1. I. M Hutchings, Tribology: Friction and Wear of Engineering Materials, Butterworth-Heinemann, 1992.

2. J.A. Williams, Engineering Tribology, Oxford University Press, UK, 1994.

3. Friction, Wear, Lubrication, K. C. Ludema, CRC Press, US, 1996



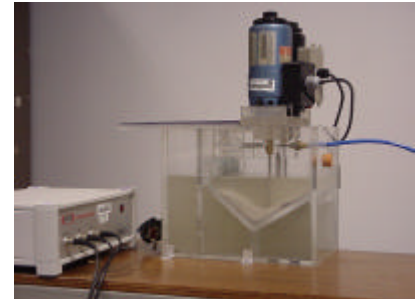
## *Erosion-Corrosion Studies of Superlattice Coatings by Yashodhan Purandare*

Increasing demands of superior tribological surfaces have caused the development of many coating deposition processes and different types of coatings. Arc bond and dc magnetron sputtered superlattice PVD coatings are promising developments in the surface engineering field because they can result in high hardness and wear resistance owing to their multilayered structure. In addition, the use of more noble metals in the coatings can increase their corrosion resistance. The behaviour of a surface can be significantly different in tribological conditions than in tribo-corrosion conditions. The nature of the interaction between the surface and the particles in corrosive environments is very complex and poorly understood.

CrN/NbN superlattice PVD coatings have performed well in tribological conditions but but their behaviour in combined tribo-

corrosive environments has not been analysed thoroughly. These coatings are known for high hardness and wear resistance and are believed to have better corrosion resistance owing to high adhesion and base layer of CrN.

This project involves assessing the behaviour of CrN/NbN superlattice PVD coatings in aqueous erosion-corrosion conditions. The effect of impact angle of the slurry on the erosion-corrosion mechanism together with effects of velocity are being assessed. The research aims to investigate the material degradation mechanisms and their mode for CrN/NbN superlattice coatings and the substrate M2 tool steel. The project is a result of collaboration between the Surface Engineering Group of Sheffield Hallam University and the Tribology Group of the University of Strathclyde



*Impinging jet slurry erosion-corrosion rig.*

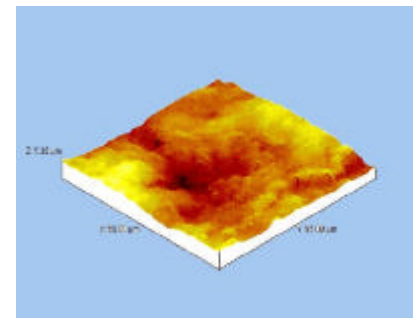
## *Construction of Erosion Rig- Some Challenges, By Tarek M. Abd El Badia*

My research topic is “Electrochemical studies of erosion-corrosion of thermally sprayed coatings”. I am building a solid-liquid impingement testing apparatus to carry erosion corrosion tests. Erosion-corrosion has been shown to be the fifth most important degradation mechanism in the offshore and chemical sector. The continual drive to reduce the weight loss of machine parts exposed to slurry erosion (erosion-corrosion) has resulted in the development of coatings based on hardmetals. Among these, thermally sprayed coatings of WC (Tungsten Carbide) are of interest because of the potential to improve wear resistance through incorporation of hard particles into the matrix.

Although the first attempt at the construction of this rig was by the Tribology group in Cambridge, 1990, Mr. Yashodhan Purandare, my colleague, has modified the design. In my work, I have carried out further modifications i.e. replacing the stirrer for mixing the slurry by taking the bypass tube

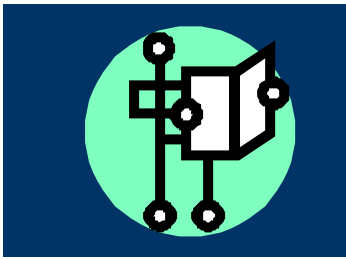
from the main pump which has improved mixing of the slurry, saving energy and making the process more economical to run. In addition, I have used another type of pump (3-phase) with variable speeds to avoid any increase in testing temperature. I also attempted to avoid metallic elements in the slurry circuit, which is essential to satisfy the requirements for the electrochemical studies on corrosion. Therefore, I hope that this design will be an improvement on existing rigs of this kind.

Acknowledgment, Professor M. Stack, all members of Tribology group, all technicians in mechanical workshop especially Erik, Jerry and Tom. Without their help it would have been impossible for me to do this work.



*AFM of eroded surface of WC/Co-Cr based coating*





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*See us at:*

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## Facilities in Our Tribology Lab

**1. Impinging Jet Erosion Apparatus** with electrochemical interface for measuring corrosion current densities during the erosion test. (Velocity range, 1-12 m/s, particle size range from 50µm to 1mm). **ACM potentiostat with computer controlled data acquisition system**

**2. Rotating Cylinder Electrode Apparatus** with electrochemical interface as above. In this system, the hydrodynamics are well characterized. (Velocity range 1-8 m/s, particle size range from 50 to 750 µm)

**3. Micro-Abrasion Apparatus (Plint**

**TE66).** This facilitates abrasion tests for very small particle sizes-in the order of 10µm. There is no restriction on particle shape. (Load ranges 1-5 N, Rotational speed range 50-150 rpm). This has applications to many areas of tribology, in particular to micro-abrasion in hip and knee joints

**4. Pin on ring apparatus for sliding in corrosive conditions.**

This standard apparatus, with a long history in the tribology literature, has been modified in order to assess the corrosion rate in the sliding contact, in an aqueous medium

## Some Experience from ICMCTF-2004, by M. T. Mathew

The International Conference on Metallurgical Coatings and Thin Films (ICMCTF) is organized by the Advanced Surface Engineering Division of the AVS at San Diego, USA- from 19th-23rd April 2004. Since its inception in 1974, this is the premier meeting that promotes global exchange of information among scientists, technologists and manufacturers in the area of thin films. A full week of activities was anchored by an extensive technical program comprised of more than 700 papers including some 75 invited presentations to be presented in 55 oral and poster sessions. This year the ICMCTF expanded on its traditional strengths in the areas of coatings for use at high temperatures, wear protection, optical and decorative purposes, magnetic and electronic applications as well as in biotechnology. There were focused sessions

on pulsed plasma, self organization and computational studies, and Biomedical applications. The conference was opened on Monday morning with a Plenary Lecture by Prof. Milfred S. Dresselhaus, Massachusetts Institute of Technology, Cambridge, Massachusetts on Carbon Nanomaterials as they Relate to Energy Production and Storage. An extensive 50-booth exhibition provided a unique interface between the market place and the laboratory for the need of equipment, materials and services. In addition, there was a tutorial offered on 'Writing Good Scientific Papers'. A special post session Discussion after the E5/G4 session by Professor Tim Ovaert entitled "Future Directions in Green Manufacturing and Dry Machining" attracted an enthusiastic attendance.

## Highlights of Gordon Conference by Buddhadev Jana

The Gordon Research Conference in Tribology is a biennial conference and this year it was organized in Roger Williams University, Rhode Island, USA-from 17<sup>th</sup> June -3<sup>rd</sup> July 2004, a short distance from Newport. The theme of the conference was "Today's Problems & Tomorrow's Solutions-Challenging Our Needs in Tribology Research!" and the conference was chaired by Professor Trevor Page of the University of Newcastle, UK, Although it is not easy to explore tribological problems as the subject involves interdisciplinary studies, GRC was capable enough hunting its solutions by gathering interdepartmental academic and industrial researchers around the globe.

GRC provides a platform for interactions

between attendees in a unique fashion comparing with many other technical conferences through its informal discussion sessions. The Conference was divided into various sessions of different tribological topics; each headed by a renowned discussion leader and contained more than one lecture by leading experts in the field. There was ample time for discussion provided after each lecture. In addition, the Tribology conference was characterized by a lively poster session run by Professors Margaret Stack and Trevor Page. Moreover, the scenic venue of Roger William University, Bristol, RI, USA in the pleasant summer of USA added a haunting colour to the conference.