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Discussion

A review of some tribo-dynamics phenomena from micro to nano-scale conjunctions

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Dr T.G. Mathia, (*LTDS–CNRS–ECL, France*). Please comment and extend your approach if we take into consideration rheology and physico-chemical properties of mono layers (lubricating and hydrophobic) in your predicting methodology. From the contact mechanics point of view can the body spherical (semi-spherical) stress tensor equation be supposed in your view? If yes, the hydrostatic stress state can cause plastic deformation, especially of ductile metallic bodies? What is the preferential choice of materials: electrical conduction or dielectrics?

Reply by the authors

The current analysis includes the contact angle that water makes with an exposed surface and one that is covered with surface active material (SAM). This depends on the surface topography and liquid–vapour interfacial surface tension (the free surface energy). Thus, indirectly the physico-chemical properties of the SAM are included in the model, which also takes into account the hydration potential. Of course, a more detailed thermodynamic analysis would enhance the predictions.

As regards the contact mechanics issues, the model used here considers the JKR approach for rough asperity contacts, which presumes elastic behaviour. Clearly, when very few asperities carry the load, plastic deformation of some can take place which is not considered. Presuming that our colleague is referring to the nano-tribological contact, the applied load is quite low and devices made of hard ceramic substrates remain within the elastic limit. However, the SAM layer can perish, wear of which is not addressed in the current model. If our colleague is referring to our earlier larger contacts in the micro-scale, then the results are all within the elastic limit, indicated by Tresca and Von Mises Criteria, where applicable (not shown in the paper). The compressive surface stress guards against any localised sub-surface yielding to spread.

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Erosion behaviour of human tooth enamel in citric acid solution

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Professor R. Dwyer-Joyce, (*University of Sheffield, UK*). Some clinical scientists recommend brushing teeth before meals. Whereas normal children are taught to brush their teeth after meals. Their reasoning is that acid drinks and foods soften the enamel and so cleaning with an abrasive tooth paste might cause excessive wear. It is better, they argue, to wait for the enamel to re-harden then clean your teeth. In your experiments it would be interesting to introduce rest periods after your immersion periods in citric acid and then test for scratch resistance after the enamel has "rested". Do you have any thoughts on whether this may have any effect on your results?

Reply by the authors

Erosive substance loss of enamel is mainly caused by demineralization. However, it has been reported that the erosion of enamel is a dynamic process with de-mineralization and re-mineralization periods [1]. When the pH of saliva returns to neutrality, re-mineralization may occur [2], which could re-harden the surface of acid-eroded enamel to some degree. In order to understand the effect of re-mineralization in detail, the re-mineralization behavior of human tooth enamel and its effect on the friction and wear properties are being investigated by us.

Professor J. Klein, (*Weizmann Institute, Israel*). How does the pH of your experiments, pH = 3.2, compare with that of citrus drinks such as orange or grapefruit juice?

Reply by the authors

Nowadays, most drinks are acidic, as shown in the following table.

The pH value of general soft drinks [3–5]

Liquid	pH
Pure orange juice	3.8
Pure apple juice	3.6
Pure grape fruit juice	3.4

Coca-Cola	2.9
Magic-energy drink	2.9
Gatorade-sport drink	3.3
Herbal tea	3.2
Traditional tea	4.8
Mineral water (lemon flavour)	4.2

Professor Shirong Ge, (*China University of Mining and Technology*, *China*).

1. Is it erosion or corrosion in the case studied?
2. Please state the loads and speeds for the tests on friction and wear.

Reply by the authors

1. It should be noted that the term "erosion" in this paper only has its meaning in dentistry, that is, it refers to the surface loss of teeth caused by chemical dissolution [6].
2. The load was 20 mN and the speed was 0.5 mm/m for the tests of friction and wear.

References

[1] Bartlett DW, Blunt L, Smith BGN. Measurement of tooth wear in patients with palatal erosion. British Dental Journal 1997;182:179–84.
[2] Amaechi BT, Higham SM, Edgar WM. Influence of abrasion in clinical manifestation of human dental erosion. Journal of Oral Rehabilitation 2003;30:407–13.
[3] Phelan J, Rees J. The erosive potential of some herbal teas. Journal of Dentistry 2003;31:241–46.
[4] Jensdottir T, Bardow A, Holbrook P. Properties and modification of soft drinks in relation to their erosive potential in vitro. Journal of Dentistry 2005;33:569–75.
[5] Magalha AC, Stancari FH, Rios D, Buzalaf MAR. Effect of an experimental 4% titanium tetra fluoride varnish on dental erosion by a soft drink. Journal of Dentistry 2007;35:858–61.
[6] Mair LH. Wear in dentistry current terminology. Journal of Dentistry 1992;20:140–44.

Friction of human skin against smooth and rough glass as a function of the contact pressure

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Dr D.J.W. Barrell, (*University of Leeds*, *UK*). How were the skin samples prepared for the tests? Was skin oil removed and would you expect it to make a significant difference?

Reply by the authors

Skin surface lipids (from sebum) are expected to have an influence on friction. In the present study, however, the skin of the subjects was cleaned with ethanol before each measurement series in order to minimise possible effects of lipids and sweat (Section 2.1). In addition, dry glass surfaces were cleaned with ethanol before each measurement, i.e., possible residuals of substances transferred from the skin were removed. Palmar skin is known as sebum poor, so that lipids probably play a minor role for the friction at this anatomical site. The influence of skin surface lipids on friction is an interesting topic for future research, in which tribological investigations should be combined with the chemical and physical characterisation of skin lipid films.

Professor Shirong Ge, (*China University of Mining and Technology*, *China*).

1. How is the contact pressure, because the contact area varies with normal loads.
2. Please explain the mechanism of CoF-decays with increasing contact pressure.

Reply by the authors

1. The pressure-dependence of the skin contact area was studied in experiments, in which the skin was pressed against a pressure sensitive film (Tekscan) at varying loads (Section 2.2). These experiments were carried out independently of the friction measurements.
2. Dowson [1] reviewed the friction mechanisms of human skin. Friction coefficients decreasing with increasing contact pressure are expected if adhesion is the predominant adhesion mechanism and in the case of hydrodynamic lubrication effects.

[1] Dowson D. Tribology and the skin surface. In: Wilhelm K-P, et al., editors. Bioengineering of the skin: skin surface imaging and analysis. CRC Press: Boca Raton; 1997. p. 159–79.

Influence of crosslinked poly-ethylene structure on wear of joint replacements

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Professor J.B. Medley, (*University of Waterloo*, *Ontario*, *Canada*). Do you believe that wear factors accurately represent wear behaviour? Can they be used to predict wear of implants in vivo?

Reply by the authors

Simple equations for sliding wear (such as the Archard equation), relating the wear rate to operating variables, such as load and distance, provide only an approximation of implant wear. Wear rates of components within the body are prone to variation in a myriad of operating conditions for a given individual. Therefore, wear data used to calculate a wear factor should be treated with caution; particularly when this data comes from a POD machine. The wear factor is of merit for initial screening of candidate biomaterial behaviour. *In vitro* pin-on-plate wear behaviour should be seen as indicative of that *in vivo* and not predictive. More reliable estimation of *in vivo* wear rates may be derived from joint simulator testing.

Professor J. Klein, (*Weizmann Institute*, *Israel*). Does annealing of the PE (without x-linking) improve its wear characteristics.