HUBER-MISES-HENCKY EQUIVALENT STRESS –
A SURFACE FAILURE INDICATOR

Luminita IRIMESCU, Emanuel DIACONESCU
Mechanical Engineering Department
University of Suceava, Romania
Email: lumi@fim.usv.ro, emdi@fim.usv.ro

Yves BERTHIER
Laboratoire de Mécanique des Contacts et des Solides
L’Institut National des Sciences Appliquées de Lyon, France
Email: Yves.Berthier@insa-lyon.fr

ABSTRACT
The microslip phenomenon takes place in both rolling and sliding contacts. In the latter case it occurs in fretting, when the main cause of failure is surface degradation. Both cases are experimentally investigated in order to visualise microslip initiation. The position of the first obtained microslip marks is in good agreement with positions of maximum Huber-Mises-Hencky stress.

These results associate the micro-slip initiation with contact stress field and proves the ability of Huber-Mises-Hencky stress to assess the occurrence of failure at the interface of an elastic contact in sliding or rolling motion.

INTRODUCTION
Micro-slip phenomenon occurs between contacting surfaces when a frictional load, less than that necessary to produce macro-slip, is applied to contacting surfaces. This phenomenon is one of fundamental mechanisms involved in rolling friction.

Its origins were first investigated in 1876 by Reynolds [1] who attributed rolling friction to the integral of sliding friction on contact area. In 1921, Heathcote [2] obtained three micro-slip regions investigating the contact between a ball and a closely conforming groove. The tangential traction between the alternating micro-slip zones was considered as the main source of rolling resistance. Bentall and Johnson [3] proposed a numerical method for analysis of an elastic strip passing between two rollers. Vermeulen and Johnson [4] deduced equations for stresses acting in the points of contact area of an elliptical contact. They revealed that, for small values of friction coefficient, yielding is initiated beneath the surface, as in the case of a pure normal load.

FRETTING CONTACT
Fretting is defined as a low amplitude oscillatory movement between bodies in mechanical contact. The characteristic of fretting is the division of contact area in two parts: a stick zone and a micro-slip zone.

In fretting, the surface degradation is the main cause of failure.

Experimental results
The experiments were performed using the testing machine "Tribomab" from Contact Mechanics Laboratory, INSA Lyon. This simulates the fretting conditions in normally and tangentially loaded contact.

A sphere-plane configuration was chosen with a sapphire sphere and a steel plane possessing an artificial screen (carbon coating).

![Figure 1. Images acquisition of contact interface](image)

The thickness of carbon layer measured by laserprofilometry is of a few nanometers. The normal load is 180N and the movement amplitude increases from 10µm at initial stage to 40µm at the end of experiment. The acquired images show that first microslip marks occur at the extremities of a diameter placed along sliding direction, Figure 1.

To understand this result, global stress state generated by normal and tangential tractions on contact interface is calculated.

Numerical results
Huber-Mises-Hencky equivalent stress is numerically computed in every contact point, because it is considered to be responsible for surface failure.
Numerical results for this stress are illustrated in Figures 2a) and b) as a 3D graph and contour lines, respectively.

![Figure 2. Huber-Mises-Hencky equivalent stress at the contact interface](image)

The first experimental marks of screen micro-shearing were localised on the zones of maximum equivalent stress. This proves the ability of Huber-Mises-Hencky stress to assess the occurrence of microslip at the interface of an elastic contact in fretting.

**ROLLING CONTACT**

**Experimental results**

In order to emphasise the existence of micro-slip zones on normally loaded rolling contact, experiments were performed on the testing machine "PEDEBA" (PEtit DEBAttements) in the Contact Mechanics Laboratory, INSA Lyon, Figure 3.

![Figure 3. Contact geometry](image)

A steel torus-steel plane configuration was chosen, on the steel plane possessing an artificial screen (gold coating). The contact zone visualised after 10 cycles with optical and scanning electron microscopy reveals regular scratch marks symmetrically disposed with respect to longitudinal central axis of contact. The scheme of micro-slip orientations on the plane sample after 10 cycles of repeated rolling is illustrated on Figure 4.

![Figure 4. Contact zone on the plane sample](image)

On a central strip of the contact and on the back edge, the flow of gold screen is opposite to rolling direction. On two strips placed towards the lateral edges of the raceway this flow tendency is along rolling direction. Thus, three contact strips are experimentally obtained on the contact zone.

**Numerical results**

Global state stress on contact interface is obtained by superposing the stresses produced by both micro-slip and normal force. The former are evaluated using an analytical model developed by the authors [5]. Computing Huber-Mises-Hencky stress in every contact point, three zones of maximum stress are found: one at rear edge of the contact and two symmetrically placed towards lateral edges, Figure 5a.

![Figure 5. Equivalent stress](image)

The position of experimental marks is in good agreement with the positions of the three maxima of equivalent stress, both on transverse and longitudinal directions with respect to rolling, Figure 5b. It can be concluded that these marks are generated by the microslip occurring in the points of contact area and the failure of investigated contact is surface initiated.

**CONCLUSION**

For both analysed contacts, in sliding and rolling motion, Huber-Mises-Hencky stress proves to be a good surface failure indicator, the experimental results being in good agreement with theoretical predictions.

**REFERENCES**