SYNTHESIS OF MECHANISMS OF FRETTING PHENOMEN

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Abstract. *Fretting as a damaging way of the surface in contact is known for over 80 years. In the last 20 years there have been important achievements in the experimental research, understanding and description of the mechanisms that lead to this phenomenon. As fretting mechanisms can be discussed in close relation with many other aspects (egmovement, materials, contact, geometry, load, test device dynamics etc), and general presentation will be followed .*

Keyword: fretting, fretting mechanism, fretting-wear, fretting-fatigue, fretting maps.

1. Introduction

Fretting is considered to be one of the most important damages involving a wide range of technical applications, from the nuclear power plant to that of implants in the human body. Waterhouse [1] calls it "a scourge of industry," and Berthier and Vincent [2] [3] qualify him as a "nuisance of machine building."

FLGates and DWHoeppner [4] define the fretting as follows: "When two elements (at least one of which undergoes a cyclical stress) are pressed, and a small tangential sliding displacement occurs between them and appear on the contact surfaces pitting scars, this action being called fretting.

Following ASM18 definition [5], fretting occurs between two contact surfaces subjected to a low amplitude oscillatory motion. This leads to degradations that may take various forms, leading to dysfunctions of the form:

-lock of mechanical systems (grip)

-gaming (wear)

- the cracking of the cracks.

The purpose of this paper is to present and discuss in synthesis the many developments that have led lately to increasing the understanding of the mechanisms that govern the phenomenon of fretting.

2.Terminology used

The first studies on the problems of fretting debut in 1911 with the discovery of the presence of wear residues (red powder) in the fatigue testing machines of two steel surfaces in contact, by Eden and Al. These damage have been associated with corrosion, but are fully identified as a consequence of fretting.

In the framework of the "Low-Wear Output" research program, within the Material-Mechanical-Physical Laboratory, Lyon Central School of Lyon, [6] the degradation process known as fretting or "fretting corrosion" being the process that occurs between two surfaces in contact, subjected to a normal force and trained in a low-oscillatory motion.

French researchers [7] identify three modes of expression of fretting: fretting wear, fretting fatigue and fretting corrosion. In the case of fretting wear, the movement of surfaces is due to external vibrations, the relative displacement of surfaces as a consequence of the fatigue test can lead to fretting fatigue, while the presence of oxide residues or the predominance of the chemical reaction results in fretting corrosion.

Considering the most commonly used name, it can be concluded that fretting is a particular and complex form of deterioration (including fundamental forms of wear such as adhesion, fatigue, abrasion and corrosion), generally manifesting that wear and / or fatigue fretting, which occurs on surfaces in a loaded (or unloaded) contact that have a relative low oscillation movement, motion that can be caused by traction, bending or alternating torsion, vibration, etc. [8]

3. Mechanisms of wearing fretting-classical approaches

Generally when trying to predict the damage of a contact, it is only considered the final stage of the contact, ie the breakdown or loss of material. This final state may include several intermediate stages and even the competition between several damage mechanisms. [9]

On the other hand, any aspect of deterioration of a contact should begin with the description of the process and behavior of the contact since the first signs of deterioration.

In the end it can be appreciated that any problem of contact is fully elucidated when addressing all aspects: mechanical, thermo-tribological, physical, chemical and metallurgical.

Godfrez et al. [10] showed that the phenomenon is being installed just after the first cycle of request. Feng et al. [10] hypothesized that fretting would be a multi-stage process that reaches a stationary regime when a thin layer of oxide forms.

Waterhouse [10] assumed that microsurgical breakdown contributes to the deterioration of fretting, while Wright pointed out that oxidation is the main factor of deterioration of fretting.

VVKovalevski proposes an adhesive model of the wear of the fretting in the initial stage of the process at low amplitudes, showing that during the fretting, two types of cracks are formed in the surface layer leading to the exfoliating wear, respectively the wear by damage to local volumes of surface layer. It is noted that in the case of fretting fatigue, only the second type of cracks can grow to a fissure that breaks the fatigue. [11]

Based on recent studies, including direct phenomena observations, Jun 'Iti Sato identifies the following processes of the wear mechanism of fretting:

1-plastic deformation is located within the sliding regions (e.g. plastic deformation resulting from the shear stress) followed by adhesion and oxidation that accompany plastic deformation.

2 - Fatigue, the primary fatigue where adhesion occurred, ie the generation of particles of wear and adhesion on the surface of the other, or adhesion elsewhere on the surface of the same material as well as peeling on both surfaces.

3 - formation of a layer of wear particles between contact surfaces, wear thus achieving a stationary mode.

In 1970 Hurriks reviewing the mechanisms of fretting noticed that they mainly involve the following stages:

-initial adhesion and transfer of material.

-producing wear particles in the normally oxidized state;

- stationary wear condition;

The same author, analyzes the fretting wear of soft carbon steel for temperatures between 20-200 °C and 200-500 °C respectively.

Significant changes in wear around the temperature of 200 °C are observed, Hurriks pointing to this behavior by altering the wear mechanism around the temperature of 200 °C. The wear is considered "common fretting" with the production of "red powder", it decreases quantitatively after exceeding the temperature of 200°C. Over this temperature the transition to wear of fretting is essentially governed by the continuous formation of the oxide layers and their properties.

4.Mechanisms of wear-and-tear-modern approaches

G.H. Farrahi et al. [12] identifies for alloyed steels with a flat plan / dry contact, a three-phase fretting wear mechanism

The three phases are:

Phase I - is in the initial stage, the wear rate is high until the initial oxide film is removed, consequently metal / metal contact occurs, adhesive transfer and plastic deformation occur. This phase takes place in the first few hundred cycles and is equivalent to the normal wear cycle.

Phase II - represents an incubation period in which new oxide particles are produced, which makes the friction that has increased in Phase I shrink as the waste material accumulates. At this stage, the wear rate is relatively low.

Phase III - the final phase that starts around 2106 cycles, during which the wear rate rises again but not as much as in Phase I.

Vingsbo (1988) proposes a representation of fretting wear through maps called "fretting maps". They are traced according to various sample parameters and are representative for damage.

Dynamic recording of:

-the tangential force exercised at the interface

-the imposed placements in contact

allows in addition to distinguish the three conditions for accommodating the movement through the forms of the fretting wear loops (fig. 1). Three modes of degradation are generally associated.

Soldering conditions

They are characterized by limited interference and very slight damage to the surface. To be visible, this damage must accumulate after a large number of cycles. The cycle is characteristic of classical deformation.

Soldering-sliding conditions

For increasing amplitudes of movement and tangential forces, plastic deformations in contact will play an important role. At the same time, a slip at the level of the asperity at the periphery of the contact occurs and little by little transforms the hysteresis loop into an elliptical shape. The cycle characterized by a soldering zone at the center of the contact, surrounded by a sliding area at the periphery (in sphere / plane contact) is typical of a partial slip. In fretting wear, it corresponds to conditions that lead to fatigue. Hysteresis loops can be deformed by a tangential stress drop after contact surfaces wear. Generally, the boundary between the soldering mode and the soldering mode is progressive and difficult to determine with precision.

On the contrary, the boundary between the joint-sliding and sliding mode is easily identifiable.

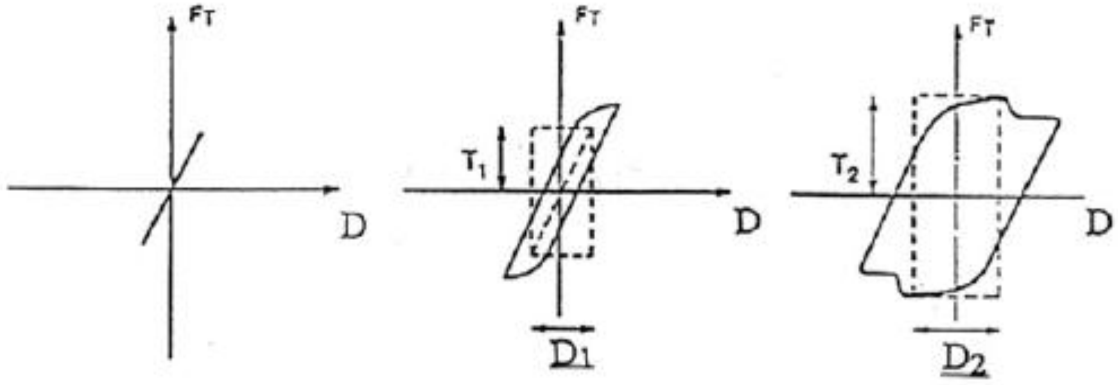


Fig.1. Evolution of tangential force F_t for different amplitudes of displacement D.
a) soldering conditions, b) soldering-sliding conditions, c) total sliding conditions.

Total sliding conditions

This mode corresponds to a macroscopic glide. The recording of dependence tangential-displacement force corresponds to the transition from static friction to kinematic friction. All contact asperities are broken by the semicircle and the plastic deformation can occur in volume at the contact area. The contact surfaces are very deep and characteristic of wear.

Studies on 10-year-long fretting by the powerful Lyon teams (ECL, INSA) led by Professors L. Vincent, Y. Berthier and M. Godet showed that a three-body contact can be broken down into 5 elements the base. These elements were called "places" (positions, locations) and were denoted by codes S1, S2, S3, S4, and S5 (fig.2) [2,3]

The difference in speed between two points A and B in the S1 .... S5 can be adjusted (accommodated) along line AB, in four different ways marked with M1 ... M4 (Fig.3) , so:

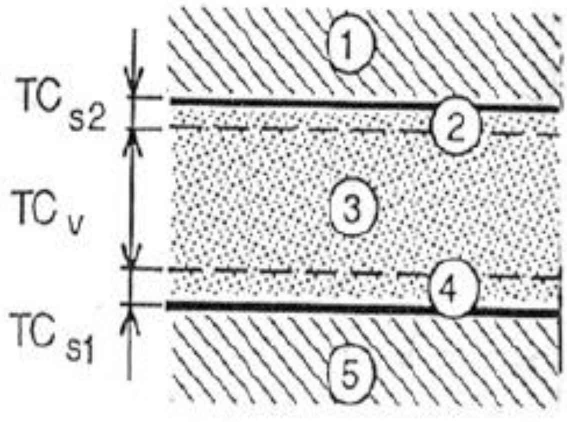
M1 -elastic; M2 - normal operation; M3 - shearing; M4 –rostogolire.

a) M1-elastic

All elastic solids deform under the external stresses. These deformations can lead to significant displacements that can be taken into account in the complete study of adaptation modes. By definition, these deformations are reversible.

b) M2-normal breakdown

All solids break when they are subjected to traction or compression beyond their breaking limit. A rupture in the contact plane causes additional unnecessary forced displacements.



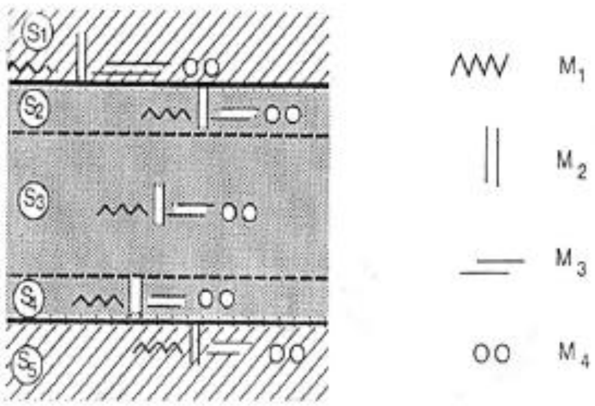


Fig.2 Modes of accommodation Fig.3 Modifications of accommodation

c) M3-shearing

In this way, a material can be broken by shearing when it is subjected to a very important request. Shearing is not always parallel to the slip surface. This mode is equally irreversible.

d) M4 - Rolling

The formation of cogs, inside any contact, is fully involved in accommodating the movement in contact.

In summary there are 3 main positions (surfaces) and four ways of accommodating the movements in different contacts.

These positions and ways have been identified in 11 out of 12 mechanisms.

Each mechanism can be scanned by a S_iM_j code that identifies the corresponding position and accommodation.

It is noted that 9 of the 12 mechanisms are individually modelable (except: S_1M_4, S_2M_4, S_3M_4) but the fact that each mechanism is individually modelable makes the phenomenon as a whole impossible to model.

5. Perspectives on the mechanisms of the phenomenon of fretting

From research carried out to date, it results that, depending on particular requirements, fretting can cause the following forms of damage: wear particles and oxides (body three), cracks at different angles and different surface dimensions, scratches, surface plastification, subframe cracking and / or dislocations, fretting craters, pitting. [13,14]

In a more or less appropriate future, the following should be considered:

-development and standardization of appropriate terminology;

-consideration of triplet mechanisms-first bodies-body three;

- attempting a global modeling of the fretting;

-confirmation of the validity of the proposed mechanisms by conducting research on real situations - different machine organs.

6.Conclusions

Over time there have been different assessments of the phenomenon of fretting. Accomodation methods can not act alone. For example, there can be no accommodating movement only by breaking the third S_3M_2 body, as the displacement is measured between the first bodies

It can be noticed that the development of a general fretting mechanism continues to be a desiderate The correct interpretation of the data provided by the laboratory fretting tests and their extrapolation to a real problem must take into account, among other things, the correct identification of the accommodation mechanisms

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