THE FRETTING WEAR

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ABSTRACT: *Fretting damage is often the origin catastrophic failures or loss of functionality in many industrial applications. Considered as a plague for modern industry, fretting is encountered in all quasi-static loadings submitted to vibration and thus concerns many industrial branches. The main parameters were reported to be amplitude displacement, normal load, frequency, surface roughness and morphology, and residual stresses. The present paper argues that adhesion forces and elastic deformation in the contact zone may contribute significantly to the relative*

KEYWORDS: fretting, wear, energy;

1.INTRODUCTION

The analyzation of the wear produced inside the frame of the fretting phenome can be made based on the total amount of the dissipated energy through the fretting contact frame [1], [2] A connection can be made between the total wear volume and the total dissipated energy. The integration of the local energy along the sliding direction respectively perpendicularly on the sliding direction allows the obtaining of the dissipated linear energy thus managing to determine the measure of the wear on an axial plan respectively transversal.

The dissipated energy through an entire fretting cycle can be obtained from the summing of the fretting energy curves.

$$\Sigma E_d = \sum_{i=1}^{n} E_{di} \tag{1}$$

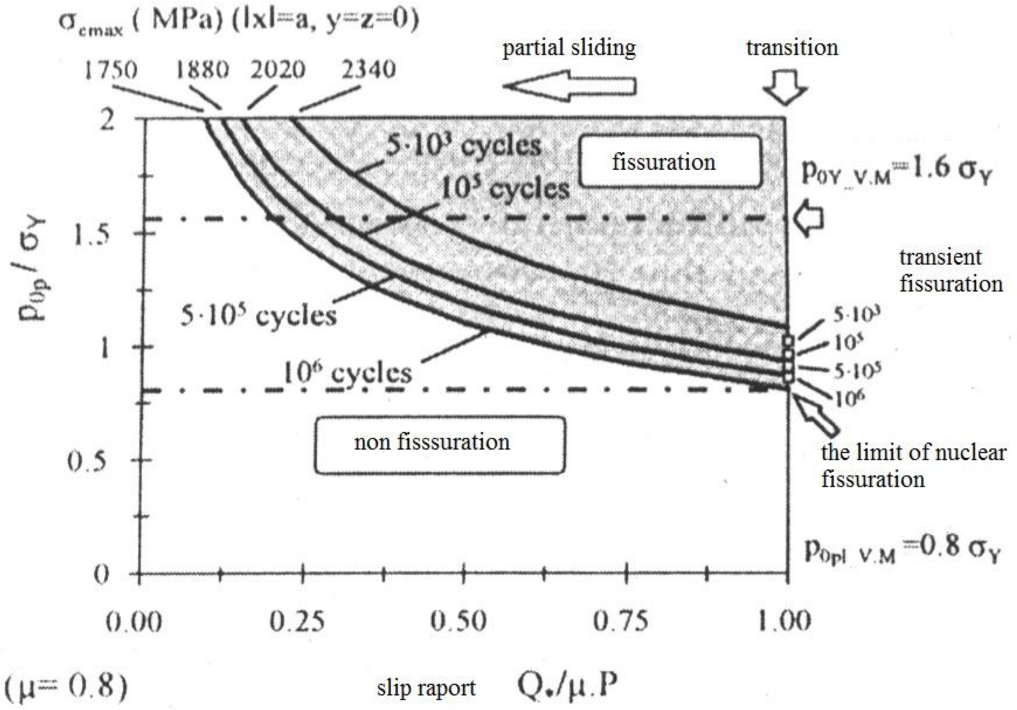

Fig.1. The illustration of the nuclear fissure based on the fretting maps.

The different limits of fissuration are associated with the critical values of Von Mises and drawn based on the normalized pressure for a maximal value of the friction coefficient μ=0.8

The fretting cycles Q $\rightarrow \delta$ for different variables can be deduced from fig.2.

The aria of the fretting curves corresponds to the dissipated energy through the cycle, for a tangential force, a size of the cycle δ_0 and a known moving direction. It can be considered that, the fretting cycle has a rectangular form, the tangential sliding force being defined through:

$$Q_0 = \mu_s P = E_d /(4D) \text{ with } D = \delta_0 \qquad (2)$$

Also:

$$\sum E_d = \sum_{i=1}^{N} E_{di}(Q_{si}, D_i) \qquad (3)$$

This simplification presents small differences in comparison with the energy obtained through the integration of the dissipate energy through the partial sliding phase.

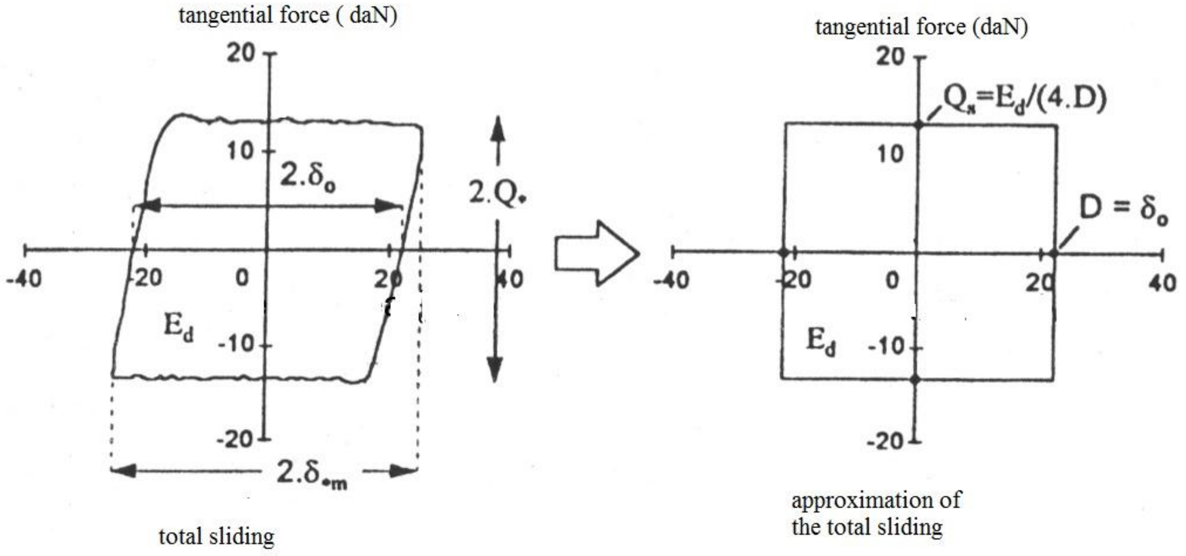

Fig.2. The simplification of the total sliding fretting cycles

2. THE QUANTIFICATION OF THE WEAR VOLUME

The wear volume based on the dissipated cumulated energy is given in fig.3

The dependency is linear confirming the obtained results for the contacts that are under small pressure [3],[4], [5].

The wear volume can be measured through:

$$W_V = \alpha_V \sum E_d \qquad (4)$$

where: α_V -is the coefficient of the volume of wear energy ($\mu m^3 J^{-1}$)

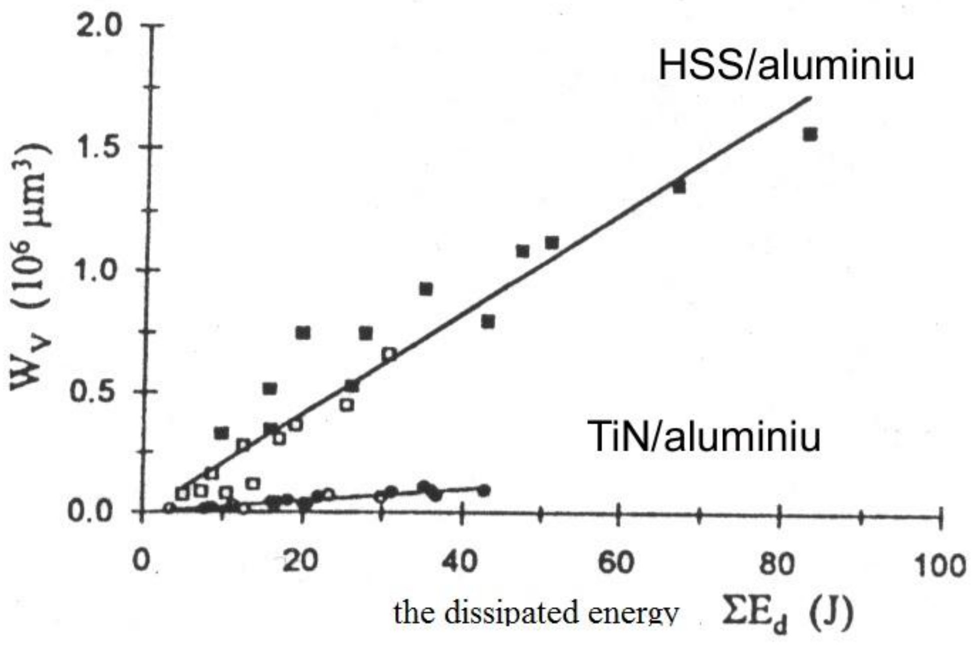

Fig.3 The correlation between the wear volume (W_V) based on the dissipated energy, cumulated $\sum E_d$

3.THE ANALYSE OF THE LOCAL DISSIPATED ENERGY

The local dissipated energy can be deducted through the use of the Hertziene tension and of the distribution filed of tensions (fig.4) [6],[7].

The distribution of the Hertziene tension is given by [8], [9]:

$$q(r) = \mu_s p(r) = q_0 \left[1 - \left(\frac{r}{a}\right)^2\right]^{1/2} \quad \text{cu: } r = \sqrt{x^2 + y^2}$$

$$q_0 = \frac{3Q_s}{2\pi a^2} = \left(\frac{6Q_s E^{*^2}}{\pi^3 R^{*2}}\right)^{1/3} \tag{5}$$

For the simplification we consider the normalized coordinates through the contact razes X=x/a,Y=y/a and the sliding total report e=D/a

The contact tension is expressed through :

$$\text{If} \quad r \le a\,; q\left(\frac{r}{a}\right) = q_0\left(1 - \left(\frac{r}{a}\right)^2\right)^{1/2} = q_0\left(1 - y^2 - x^2\right)^{1/2}$$

$$r \rangle a \;;\; q\left(\frac{r}{a}\right) = 0 \tag{6}$$

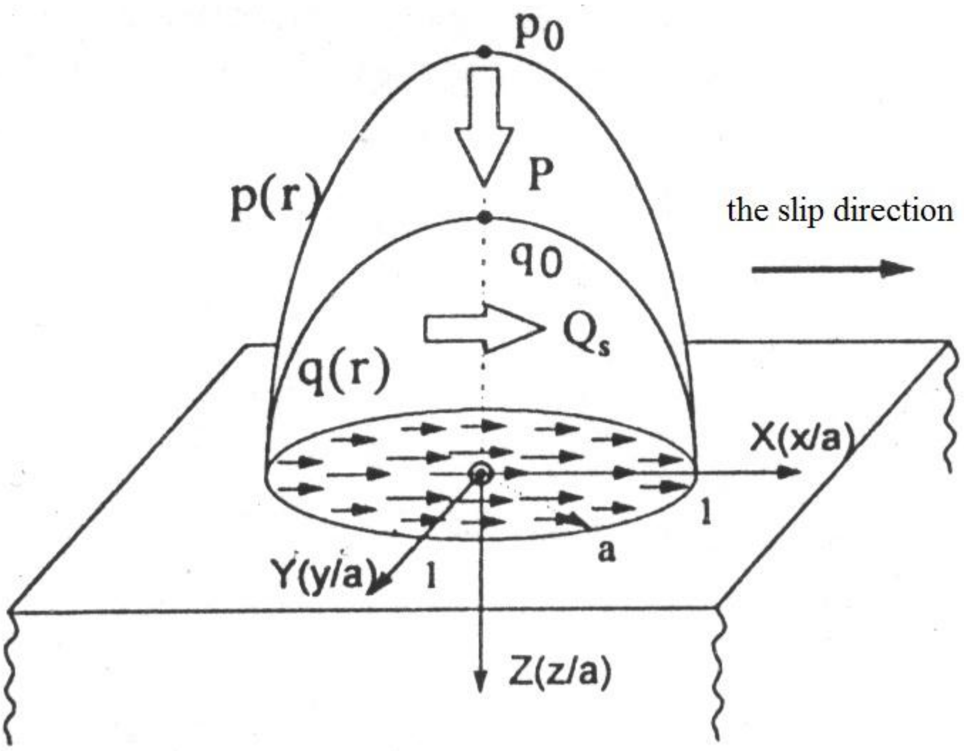

Fig.4. The pressure and distribution of the tension field for a contact sphere/plane that is sliding

The local dissipated energy through the time of two fretting cycles in point M(X,Y) is :

$$E_d\left(X,Y\right)=q_0 a\int_{X-e}^{X+e}\left[1-Y^2-X^2\right]^{1/2}dX \quad \left(Jm^{-2}\right)\text{ ,for } r\rangle a \qquad (7)$$

The limit between fretting and reciprocal sliding is given by the limited value „e”.

If e<1, an unexposed surface exist and the coarse fretting sliding conditions predominate.

If e>1, all surfaces are exposed to the atmosphere and the contact that is under the reciprocal sliding conditions (fig.5) [10], [11]

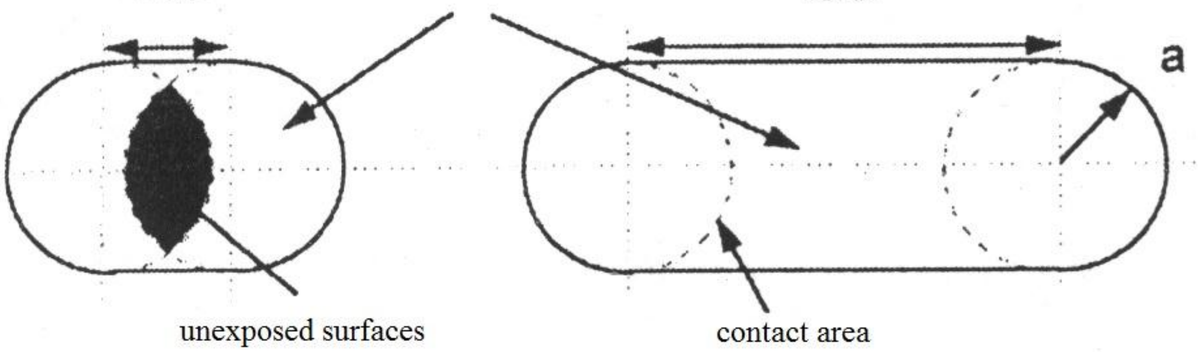

Fig.5 The differences between the total sliding fretting and the reciprocal sliding

In both cases the dissipated local energy can be calculated analytical. For a local analysis focused on two main axes and two side distribution axes it can be observed a maxim point in the centre of the contact. The distribution of energy is given in fig.6 and fig.7 making it possible to be integrated in order to determine the dissipated energy on a line.

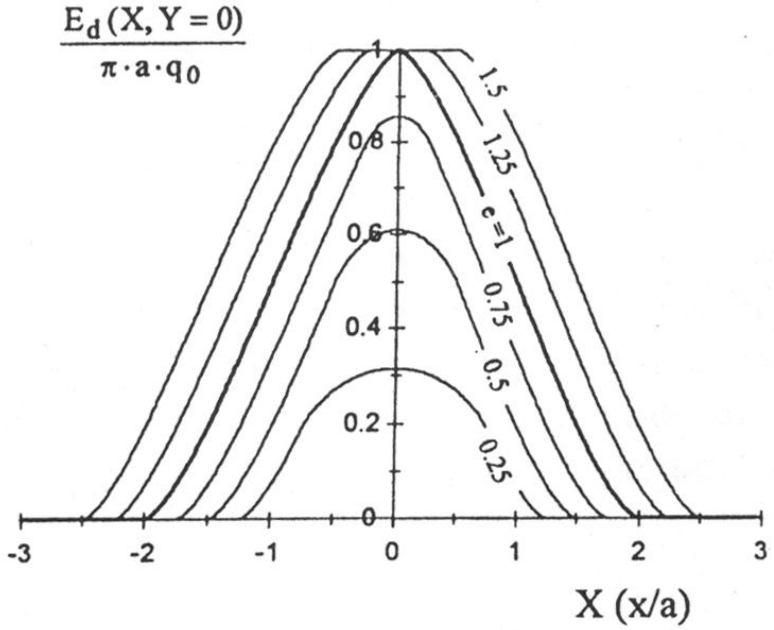

Fig.6 The axial distribution of the dissipated energy in one cycle, for different conditions: e<1 total sliding of fretting, e>1 reciprocal sliding

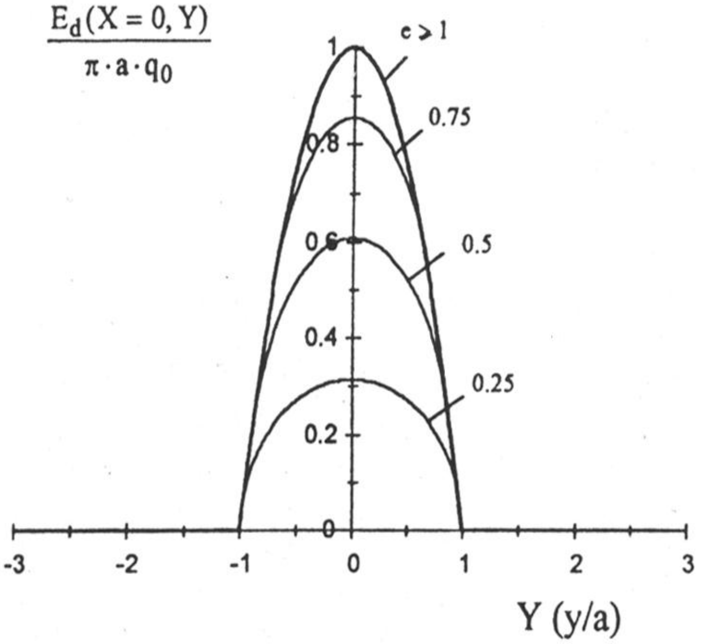

Fig.7 The side distribution of the dissipated energy in one cycle, for different conditions: e<1 total sliding of fretting, e>1 e>1 reciprocal sliding

3.1.Linear axial energy

The linear axial energy along axe X will be:

$$E_{dA} = \int_{-\infty}^{+\infty} E_d(X, Y = 0) dX \quad (Jm^{-1}) \tag{8}$$

it being dependent of „e”

$$E_{dA} = 2\pi a^2 q_0 e = 2\pi a q_0 D$$

Also:

$$E_{dA} = (Q_s e)/3 \tag{9}$$

3.2.Linear side energy

Along the perpendicular axe Y, the dissipated side energy $E_{dL}(Jm^{-1})$ will be:

$$E_{dL} = \int_{-\infty}^{+\infty} E_d(X = 0, Y) dX \tag{10}$$

which depends on the conditions of total sliding. In the conditions of total sliding of fretting, e<1 we have:

$$E_{dL} = \frac{2\pi a^2 q_0}{3}(3e - e^3) \qquad \text{or}$$

$$E_{dL} = Q_s(3e - e^3) \qquad \text{for e<1} \tag{11}$$

In the conditions of reciprocal sliding $e \geq 1$, this energy is constant:

$$E_{dL} = \frac{4\pi a^2 q_0}{3} \quad \text{or}$$

$$E_{dL} = 2Q_s \quad \text{for } e \geq 1 \tag{12}$$

3.3.Local maxim energy

The local dissipated energy is maximum in the central point E_{d0} (Jm^{-2}) depending on the sliding conditions.

In the case of the total sliding of fretting, e<1:

$$E_{d0} = E_d(X = 0, Y = 0) = 2aq_0\left[e(1 - e^2)^{\frac{1}{2}} + \arcsin(e)\right] \tag{13}$$

or:

$$E_{d0} = \frac{3Q_s}{\pi a}\left[e(1 - e^2)^{\frac{1}{2}} + \arcsin(e)\right] \qquad \text{for e<1} \tag{14}$$

In the case of reciprocal sliding:

$$E_{d0} = \pi a q_0 \qquad \text{or} \qquad E_{d0} = \frac{3Q_s}{2a} \qquad \text{for } e \geq 1 \tag{15}$$

In fig.8 different energy dependencies are shown depending of the contact raze „a”, the tangential force of sliding Qs and the parameter „e”.

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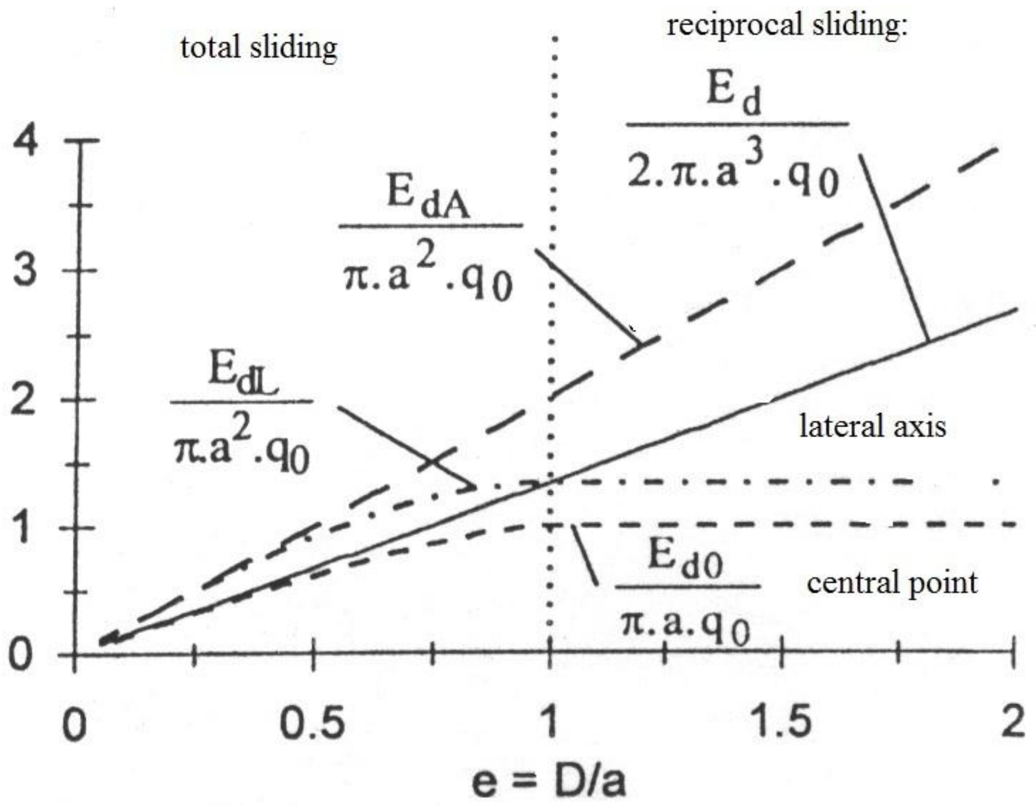

Fig.8 The evolution of the main energy variable depending on the total sliding condition „e" for the alternant cycle $\left(2\pi a^2 q_0 = 3Q_s\right)$. For small amplitudes, it will be considered the partial sliding component $\left(\delta_t = 1.8\mu m \langle\langle a = 150\mu m\right)$

Dissipated energy:

$$E_d = 4Q_s D = \frac{8}{3}\pi a^3 q_0 e \qquad (16)$$

and the linear axial energy $E_d = 4Q_s D = \frac{8}{3}\pi a^3 q_0 e$ presents a linear dependency to the sliding report „e", also the side linear energy E_{dL} and the value of the maximum local energy tend to a constant value in the moment when the conditions of reciprocal slinging are met.

The experimental studies, [12],[13],[14],[15] have confirmed the linear dependency between the dissipated energy and the total volume of wear. Thus determining the wear volume with the help of some 3D profilometers and the dissipated energy through the integration of the fretting cycles in the test period it can be observed that they remain independent regarding the surface evolution [16],[17].

CONCLUSION

The fretting phenomenon is a complex process of deterioration, very common in machine building. Investigation of fretting phenomenon may be based on displacement in the contact with the two components: reversible and irreversible.

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