CONTRIBUTIONS REGARDING FRETTING FATIGUE PHENOMENON

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Abstract: Fretting phenomenon is a complex deterioration phenomenon that can be found in most technical applications which require the existence of contacts undergoing a small amplitude oscillatory motion. Fretting has two sides, one given by fretting-wear and another one given by fretting-fatigue, both leading to specific deteriorations.

Keywords: fretting, fatigue, friction.

1. INTRODUCTION

An important chapter in approaching fretting is the issue regarding the fretting-fatigue phenomena that characterize this phenomenon. The fretting phenomenon has been approached either from the fretting-fatigue point of view or fretting-wear point of view which characterize this phenomenon. However, the two phenomena coexist and they influence each other at the contact level during a fretting cycle.

In this paper we approached the fretting-fatigue phenomenon characterizing the fretting and we determined a number of fatigue criteria that may allow the prediction of cracks at the contact fretting level. The approach was made taking into consideration the relations encountered in the specialized literature and in addition we introduced relations in dimensionless form, obtaining through this method the fatigue criteria in a form that allows a better quantification of the phenomenon[1].

Fatigue criteria should be written both in traditional form (with consideration of constant friction coefficient) and in a new form in which the friction coefficient between the surfaces is variable [2,3].

2. STATE OF TENSION IN CONTACT

Experiments have shown that the maximum risk of breakage occurs at the edge of contact, so we approached the tensions in the contact for this particular point (|x| = a, y = z = 0).

Tensions in this point are simplified for a biaxial typical loading, static components being associated to the normal force:

\[
\sum_{11p} \mathbf{F}_n, \mathbf{R} = p_0 \mathbf{F}_n, \mathbf{R}^{(11p)} \\
\sum_{22p} \mathbf{F}_n, \mathbf{R} = p_0 \mathbf{F}_n, \mathbf{R}^{(22p)}
\]

for the constant coefficient of friction, respectively:

\[
\sum_{11p} f_{11p}
\]

(2.a)
\[ \sum_{22Pa} = f_{22p} \]  

For variable coefficient of friction. 

In relations (1) and (2):

\[ f_{11P} = -2\nu^2 \frac{3}{3} \]  

\[ f_{22P} = -f_{11P} \]  

The alternating tension induced by the tangential loading is given by:

\[ \sum_{11Q}(Q, F_n, R, \mu, k_{ad}) = q_0(Q, F_n, R) f_{11Q}(Q, F_n, R, \mu, k_{ad}) \]  

\[ \sum_{22Q}(Q, F_n, R, \mu, k_{ad}) = q_0(Q, F_n, R) f_{22Q}(Q, F_n, R, \mu, k_{ad}) \]  

for the constant coefficient of friction, respectively:

\[ \sum_{11Q}(\mu, k_{ad}, c) = c \cdot f_{11Q}(\mu, k_{ad}) \]  

\[ \sum_{22Q}(\mu, k_{ad}, c) = c \cdot f_{22Q}(\mu, k_{ad}) \]  

With: \( q_0 = cp_0 \), \( c \) - the loading coefficient, for a variable coefficient of friction.

In relations (4) we used the:

\[ f_{11Q}(Q, F_n, R, \mu, k_{ad}) = \frac{1}{4} \left[ 1 + \nu \left( \frac{\pi}{2} - \phi_s \right) + k_s \left( -k_s^2 \frac{2}{2} \right) + \nu - 2\nu k_s^2 \right] \]  

\[ f_{22Q}(Q, F_n, R, \mu, k_{ad}) = \frac{1}{4} \left[ 3\nu \left( \frac{\pi}{2} - \phi_s \right) + 4k_s \left( -k_s^2 \frac{2}{2} \right) + 2k_s^2 \right] \]  

with:

\[ \phi_s(Q, F_n, R, \mu, k_{ad}) = \arctan \left( \frac{k_s(Q, F_n, R, \mu, k_{ad})}{-k_s^2(Q, F_n, R, \mu, k_{ad})^2} \right) \]  

and:

\[ k_s(Q, F_n, R, \mu, k_{ad}) = \frac{\alpha_s(Q, F_n, R, \mu)}{a(F_n, R, k_{ad})} \]  

Respectively for relations (5) (where the variable coefficient of friction):

\[ f_{11Qa}(\mu, k_{ad}) = \frac{1}{4} \left[ 1 + \nu \left( \frac{\pi}{2} - \phi_{sa} \right) + k_{sa} \left( -k_{sa}^2 \frac{2}{2} \right) + \nu - 2\nu k_{sa}^2 \right] \]  

\[ f_{22Qa}(\mu, k_{ad}) = \frac{1}{4} \left[ 3\nu \left( \frac{\pi}{2} - \phi_{sa} \right) + 4k_{sa} \left( -k_{sa}^2 \frac{2}{2} \right) + 2k_{sa}^2 \right] \]  

with:

\[ \phi_{sa}(\mu, k_{ad}) = \arctan \left( \frac{k_{sa}(\mu, k_{ad})}{-k_{sa}^2(\mu, k_{ad})^2} \right) \]  

and:
Maximum macroscopic biaxial tension can be expressed by:

\[ \Sigma_{11}(Q,F_n,R,\mu,k_{ad}) = \Sigma_{11Q}(Q,F_n,R,\mu,k_{ad}) + \Sigma_{11P} \left( \mu_c R \right) + \Sigma_{11\text{load}} \left( \mu_c R \right) \]  

Maximum tangential tension and hydrostatic pressure imposed on the edge of contact are:

\[ \tau(Q,F_n,R,\mu,k_{ad}) = \frac{1}{2} \left( \mu_c R \right) f_{11Q}(Q,F_n,R,\mu,k_{ad}) \]  

\[ p(Q,F_n,\mu,k_{ad}) = \frac{1}{2} \left( \mu_c R \right) f_{11Q}(Q,F_n,R,\mu,k_{ad}) + f_{22Q}(Q,F_n,\mu,k_{ad}) \]  

For the constant friction coefficient, as follows:

\[ \tau_0(\mu,k_{ad},c,c_e) = \frac{1}{2} f_{11Q}(\mu,k_{ad}) \]  

\[ p_0(\mu,k_{ad},c,c_e) = \frac{1}{3} c_k f_{11Q}(\mu,k_{ad}) + f_{22Q}(\mu,k_{ad}) \]  

for variable coefficient of friction.

Thus it can be established a criterion for contact fatigue:

\[ d_c(\mu,k_{ad},c,c_e) \geq \frac{\tau_0(\mu,k_{ad},c,c_e)}{c_D} \]  

with:

\[ c_D = \frac{\tau_0}{\sigma_D} \] - parameter depending on the material properties of friction couplings,

and: \[ k_{ad} = \frac{p_0}{\sigma_D} \]

If \( d_c \) is bigger than 1, there is a risk of cracking, otherwise there isn’t. Dang Van criterion was expressed for the case of variable coefficient of friction.
To an effectively use of this criterion, it is graphically represented the dependence of Dang Van fatigue criterion on the dependence parameters. The graphical representation is given in Fig.1:

Satisfying the previous condition, the condition of cracks occurrence can be written in a simplified form through:

- maximum permissible loading:

\[ \Sigma_{\text{11Qfadm}}(c, k_{as}, c_e, k_{aD}) = \frac{c_D - c_D}{k_{as} - 0.5} \sum_{\text{11Qfadm}}(c_e) \]

(13)

The dependence of this maximum permissible loading on various factors is given in Fig.2.
The risk of cracking can also be expressed depending on the maximum Hertzian pressure or through the amplitude of permissible tension corresponding the first term $\Sigma_{11}^Qf_{adm}$.

Von Mises fatigue criterion can be expressed as:

$$\sigma_{eq}(e_{as}, k_{as}, c, c_e) = \sum_{11a} l(e_{as}, k_{as}, c, c_e) \left[ \frac{\left(\sum_{22a} l(e_{as}, k_{as}, c, c_e)\right)^2}{\sum_{11a} l(e_{as}, k_{as}, c, c_e)} - \frac{\sum_{22a} l(e_{as}, k_{as}, c, c_e)}{\sum_{11a} l(e_{as}, k_{as}, c, c_e)} \right]$$  \hspace{1cm} (14)

The Von Mises tension is shown in Fig. 3 according to the dependence parameters. To ensure uniaxiale state of tension, should be minimized the report:

$$S(e_{as}, k_{as}, c, c_e) \frac{\sum_{22a} l(e_{as}, k_{as}, c, c_e)}{\sum_{11a} l(e_{as}, k_{as}, c, c_e)}$$  \hspace{1cm} (15)

Dependence of this report is given in Fig. 4.
The fatigue behavior, respectively cracking appearance and propagation can be determined by using the following criteria too:

- media of requesting tension :
  \[ \Sigma_{11 Ma} \leq \frac{1}{2} \Sigma_{11 Ma} \leq \frac{1}{2} f_{11 p} \]  
  (16)

- tension amplitude:
  \[ \Sigma_{11 Ma} \leq \Sigma_{11 Qa} c_{k_{as}} \leq \Sigma_{11 Qa} c_{k_{as}} \]  
  (17)

Amplitude tension dependence is given in Fig.5

![Fig.5 Tension amplitude: \( \Sigma_{11 Ma} c_{k_{as}} \) ]

4. CONCLUSIONS

Determination of fatigue criteria regarding fretting phenomenon, allows the possibility of predicting the occurrence of cracks due to fretting fatigue. Also, considering the friction coefficient between the surfaces under fretting as being variable brings the theoretical results obtained closer to reality.

REFERENCES