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A THERMOMECHANICAL WEAR MODEL FOR THE BRAKE SHOE-WHEEL CONTACT

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Abstract

Tribological phenomena in the brake-shoe- wheel contact defined the durability of brake shoes. Contact friction temperature changes the strenght of cast-iron material of brake shoe. The correlation of material and operation parameters defines the wear maps. The dimensionless Von Mises parameter is used to limit the elastic deformation for a hertzian contact of " brake-shoe hot zone". Dimensionless contact pressure is obtained by to overlap the thermal and elastic normal and friction stresses.
The thermoelastic instability of brake-shoe-wheel transforms the initial nominal contact.
The thermomechanical wear model is defined by the fatigue strenght of cast iron material at the braking parameters. The effects of material properties and braking parameters on durability are analysed

_Key words:__Fatigue wear; Wear mape;Durability; Brake shoe-wheel contact._

1. INTRODUCTION

In recent years it has noticed some new efforts have been made which seem lead to systematization of the wear theory. Wear is a complicated phenomenon, due to the many operating variables with which it is associated.

The correlation material, medium and operation parameters defines the wear maps [1, 2].

The region of contact experiences a temperature rise which may affect the respective surface. For the sliding friction pairs, the temperature increase can be substantial.

A localised change in material properties, an enhancement in fatigue and, ultimately, failure of the mechanical pairs can result.

Ting and Winer [3] analysed the complete stress field of the sliding contact by superimposing thermal stress on the isothermal stresses induced from surface tractions.

Cowan and Winer [4] proposes the thermomechanical wear by the plastic deformation with material field criteria.

2. FRICTION FATIGUE WEAR MODEL

In friction contact the tangential stresses are variable and the wear process is accepted as a cumulative fatigue phenomenon [5].

In relative sliding process between friction surfaces, the tangential stresses (τ) from the real contact area determine the fatigue of surface layer and the appearance of wear particles.

The tangential stresses are determined by both normal and tangentiale loads and friction forces.

It is considered the vector of normal stresses $\{\sigma_0\}$, the vector of initial static tangential stresses $\{\sigma_0\}$ and the friction coefficient f, after the molecular-mechanical friction theory

$$f = f_0 + \tau_f / \{\sigma\} \quad (1)$$

where f0 is the molecular friction component (property of material); τ_f – the shearing strength of surfaces layer (property of both materials in contact is defined the property of material couple); $\{\sigma\}$ - the total normal stresses (isothermal, σ^i, and thermal, σ^t, normal stresses).

In this case, the tangential stresses (τ) which determine the fatigue and wear particles is

$$\tau = \{\tau_0\} + f\{\sigma\} = \tau_f + \{\tau\} \quad (2)$$

where $\{\tau\}$ is the vector of tangential sliding stresses.

The friction fatigue phenomenon is defined by the Wohler curve type

$$\tau N^c \geq \tau_c = m\sigma_c \quad (3)$$

where N is the number of cycles for the appearance of wear particle; c – a fatigue material coefficient; τ_c, σ_c – critical tangential and normal strength (brittle or ductile material) for one cycle; m – proportionality constant.

The failure strength of material, σ_c, can be typically expressed by a linear function of temperature

$$\sigma_c = \sigma_{co} - nT = \sigma_{co} - n\frac{1-\nu}{E\alpha_t}T^* p_o G_t \quad (4)$$

where σ_{co} is the reference failure strength at a reference bulk temperature; T – temperature rise above the reference bulk temperature; n – a thermal coefficient; E, ν, α_t – material's elastic modules Poisson's coefficient, thermal expansion coefficient; T_a - dimensionless temperature

$$T_a = \frac{Tk}{Q_0 a} = \frac{Tk}{\gamma f p_0 v a} \quad (5.1)$$

$$G_t = \frac{E\alpha_t}{k(1-\nu)}\gamma f v a \text{ - sliding fatigue} \quad (5.2)$$

Wear control parameter (k, γ, v, a are thermal conductivity, heat partition factor, relative velocity, contact radius); p0 – is initial Hertzian maximum pressure; Q_0 is the heat flux, $Q_0 = \gamma f p_0 v$.

It is used (2), (3) and (4) equations and it obtained the occurence condition for the wear particles after N thermomechanical sliding cycles

$$p_{aob} = \frac{N^{-c}}{\sqrt{3}I_{p2} + \frac{nG_t(1-\nu)}{E\alpha_t}T_a} \quad (6)$$

where $p_{aob} = p_o / \sigma_{co}$ the dimensionless hertzian fatigue pressure.

The I_{p2} function is dimensionless Von Mises parameter for thermoelastical stresses: $\bar{\sigma}^i_{ij}(\bar{x}, \nu, F_0)$ and $\bar{\sigma}^t_{ij}(\bar{x}, \nu, F_0)$

where $\bar{x}$ is the contact location and Fo is Fourier number (F_0 = Dt/a^2, D – thermal diffusivity, t – sliding time).

For the dimensionlessl isothermal stresses, $\bar{\sigma}^i_{ij}$, it is accepted the Hamilton and Goodman's solution [6] and the Yang and Winer's solution for the thermal stresses [7].

Figure 1 shows the Von Mises parameter for the thermoelastic normal and friction stresses contact (I_{p2}) and thermal stresses (I_{2a}).

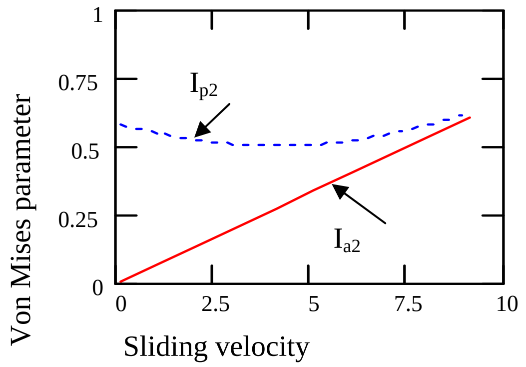

Fig.1: *Von Mises parameter vs. sliding velocity.*

In this figure, can see that for a certain sliding velocity, the Von Mises parameter, for thermoelastic normal and friction stresses, has a minimum value.

The effect of friction coefficient about the Von Mises parameter can be see shown at the Figure 2.

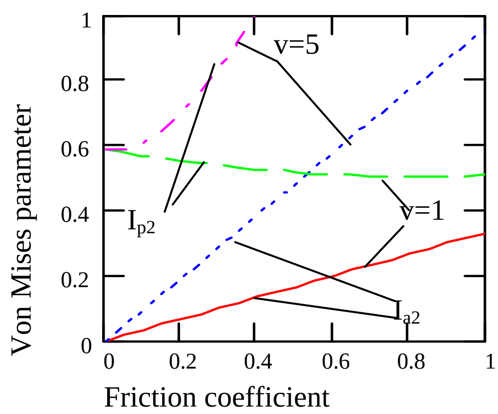

Fig.2: *Von Mises parameter vs. friction coefficient.*

The friction fatigue wear map can be determined only by numerical solution for the equation (6).

The formation of thermal asperities on nominally flat surfaces in sliding contact has been demonstrated by Barber [8], Burton and Heckman [9]

The experimental results show that thermoelastic instability of brake shoe appears for the braking proccesus and the „hot zones" are spherically [10].

The thermal effects are associated with the Fourier number. If an operating point is located in the fatigue wear region, the occurence of wear depends on the magnitude of Fourier number F_0 and the cycle number N.

3. THERMOMECHANICAL WEAR MAPE

The plastical loading capacity of brake-shoe material is defined that the dimensionless hertzian which the Von Mises parameter to reach the unit value.

When the "hot zone" deformations are elastically, the fatigue wear mape for brake-shoe material can be defined, by numerically solution of eq. (6).

The wear mape of brake-shoe material correlates the working parameters of brake with the friction and the wear material

Thus, the Figures 3, .4 and 5 show the fatigue wear mapes for brake shoe as a function to sliding velocity (v), friction coefficient (f) and Fourier parameter (Fo), respectivelly.

These numerical results are evaluated by the following parameters:

-contact point position: dimensionless radius ρ = 0.2; friction coefficient f =0.2; Fourier number F_0 =5; partition heat coefficient ε=0.5; radius «hot zone» r_a =0.0008 m; number cycle N $=10^3, 10^5, 10^6$ – Fig. 3;

ρ = 0.2; θ =0; Z =0; F_0 =1,3,8; ε=0.5; v =1; r_a =0.0008; N $=10^3, 10^5, 10^6$ – fig. 4;

ρ = 0.2; θ =0; Z =0; f =0.2; ε=0.5; v =1,3,5; r_a =0.0008; N $=10^3, 10^5, 10^6$ – fig.5.

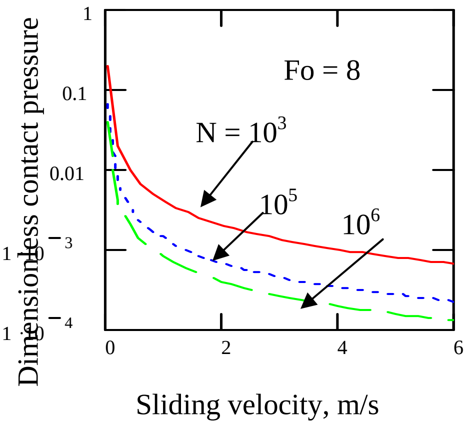

Fig.3: *Dimensionless pressure vs. sliding velocity.*

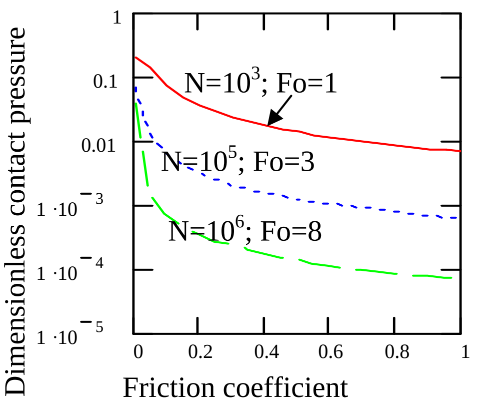

Fig.4 : *Dimensionless contact pressure vs. friction coefficient.*

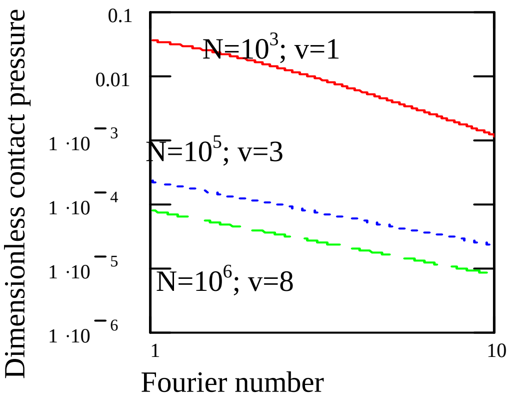

Fig.5: *Dimensionless contact pressure vs. Fourier number.*

The durability of "hot zone" can be evaluated by the eq. (6), when the contact pressure and the friction coefficient are known.

For example, the figures 6 and 7 show the durability of "hot zone" as a function to the friction coefficient and the braking velocities.

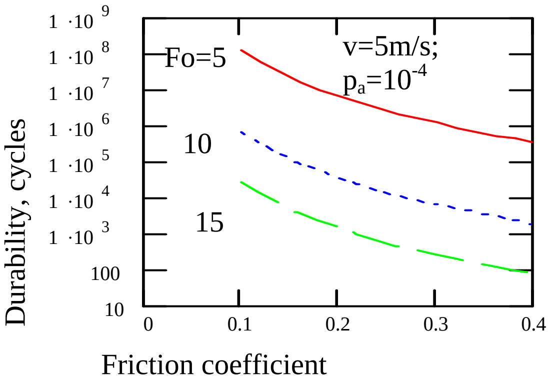

Fig.6: *Influence friction about durability*

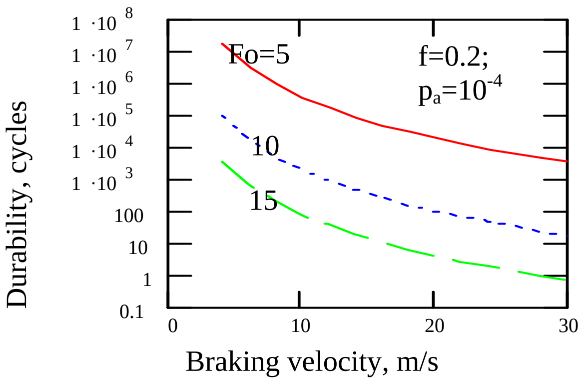

Fig. 7: *Influence velocity about durability.*

The durability curves shown on the fig. 6 and 7 were calculated for following braking conditions: nominal contact pressure of brake shoe and wheel- 0.8 MPa; the braking system of a wheel has four brake-shoes; the efficiency of brake-shoes is similarly; the weight of waggon – 0.5 MN; initial curvature radius of "hot zone" -8 mm; steel materials for wheel and cast iron for brake shoes.

4. CONCLUSIONS

The dimensionless Von Mises parameter defines the contact pressure and the friction condition for elastically deformation.

The dimensionless Von Mises parameter has a minimum as a function to sliding velocity

The durability of brake –shoe is function to friction coefficient and velocity for every braking cycle.

The fatigue wear mape for brake-shoe material can be used to define the durability of braking systemes.

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