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FATIGUE OF MATERIALS IN CONTACT FATIGUE

ÚNAVA MATERIÁLŮ PŘI KONTAKTNÍ ÚNAVĚ

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Some studies of a low-cycle material fatigue caused by cyclical contact between two spheres with the same diameters and between the rolling of wheel. The problem was solved by FEM (SW MSC.MARC/Mentat and ANSYS). The results show hysteresis loops from which the number of cycles until fracture can be determined. The realisation of test device for the research of contact fatigue as complement of the loading test machine INOVA, which is directed to look for quantitative coherence between number of cycles to the origin of fatigue cracks in the area of mechanical contact.

Keywords

Low-Cycle Fatigue, Mechanical Contact, Test Device, Hysteresis Loops, Fatigue Cracks, FEM

1. Introduction

For material failures that are caused by the low-cycle fatigue (LCF), it is necessary to describe material behaviour using a closed hysteresis loop. To determine the lifetime of machine parts it is important to find the total number of cycles which cause the initialisation of first fatigue cracks. This paper describes some case of LCF for the cyclical contact. Material behaviours were acquired from experiments.

2. The FE Solution of Cyclical Contact Between Two Spheres

During the pulse pressing of two identical spheres (with diameter ϕ 210 *mm*), the contact area must be a circle plane, see fig.1. A time-dependent periodical force F=F(t) acted in the centre of the sphere, see fig.1. The material is considered to be isotropic and elasto-plastic with kinematic hardening rule, which is sometimes advisable for the LCF phenomenon. In this case, the hysteresis loop (equivalent total strain $S_{\varepsilon t}$ *[1]* - equivalent von Mises stress S_{σ} *[MPa]* dependence) for the critical point of the material was calculated from

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FE solution. The cyclical changing of equivalent plastic strains $S_{\varepsilon p}$ *[1]*, equivalent elastic strains $S_{\varepsilon e}$ *[1]*, equivalent total strains $S_{\varepsilon t}$ *[1]* and mean normal stresses $\sigma_m = (\sigma_1 + \sigma_2 + \sigma_3)/3$ *[MPa]* are shown (cyclical plasticity), see fig.2, and 3.

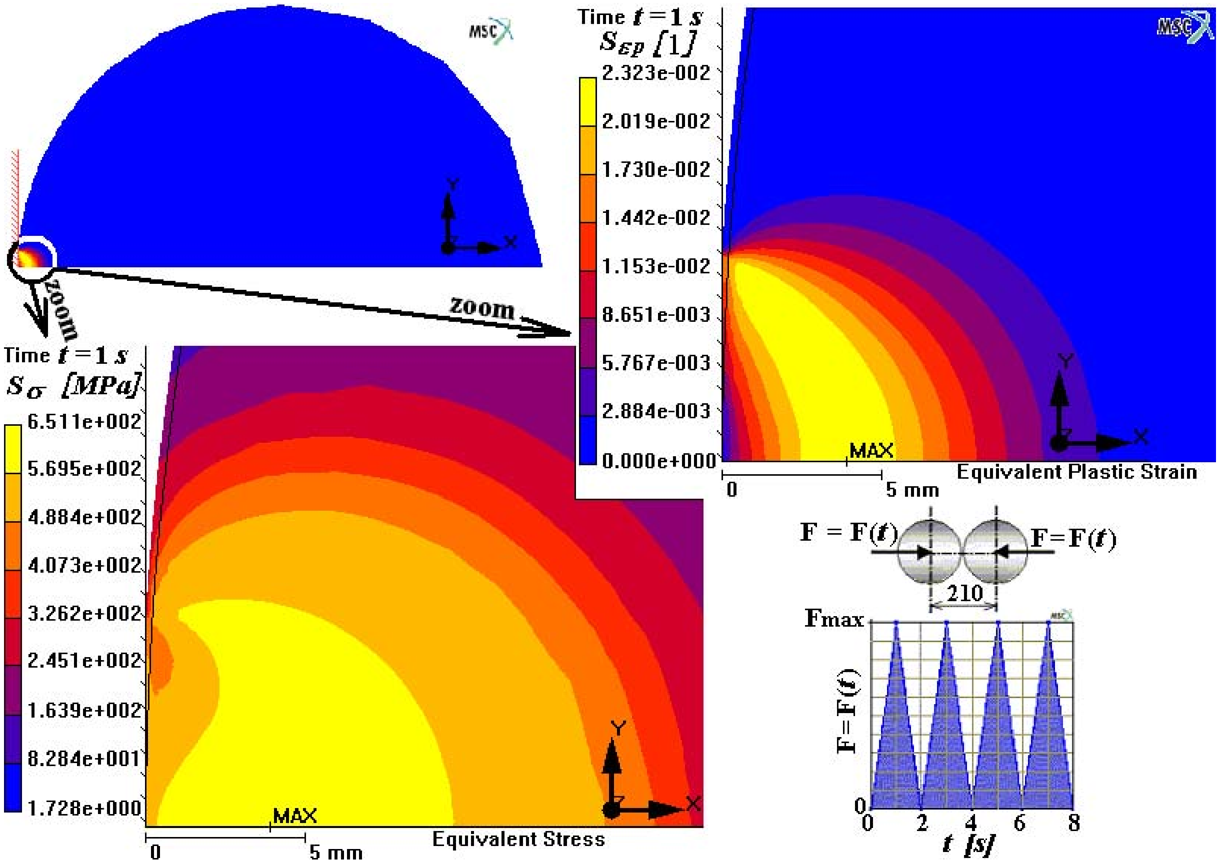

Fig.1 The values of equivalent plastic strain $S_{\varepsilon p}$ and equivalent von Mises stress S_σ.

Hence Fig.2 shows first proposal model of hysteresis loop based on $S_{\varepsilon p}$ - σ_m dependence. This fictive hysteresis loop (shaded area in fig.2) should be important in calculating the number of cycles N_f necessary for fatigue crack initiation via equation: $N_f = \frac{1}{2}\left(\sigma_{m_a}/\sigma'_f\right)^{\frac{1}{b}}\left(1 - \sigma_{m_m}/\sigma'_f\right)^{\frac{-1}{b}}$, where σ'_f *[MPa]* and b *[1]* are material parameters. Figure 3 shows second proposal model of fictive hysteresis loop ($S_{\varepsilon t}$ - $S_{\sigma\,fict}$ dependence) based on the $S_{\varepsilon t}$ - S_σ dependence, where $S_{\sigma\,fict}$ is a fictive equivalent stress. This fictive hysteresis loop (shaded area in fig.3) probably should be important in calculating the number of cycles N_f. The fictive loop was created by reflecting of some parts $S_{\varepsilon t}$ - S_σ dependence about the axis of symmetry ($S_\sigma = 0$ *MPa*). The number of cycles N_f with consideration of mean and amplitude stresses can be calculated using the following equation: $N_f = \frac{1}{2}\left(S_{\sigma\,fict_a}/\sigma'_f\right)^{\frac{1}{b}}\left(1 - S_{\sigma\,fict_m}/\sigma'_f\right)^{\frac{-1}{b}}$.

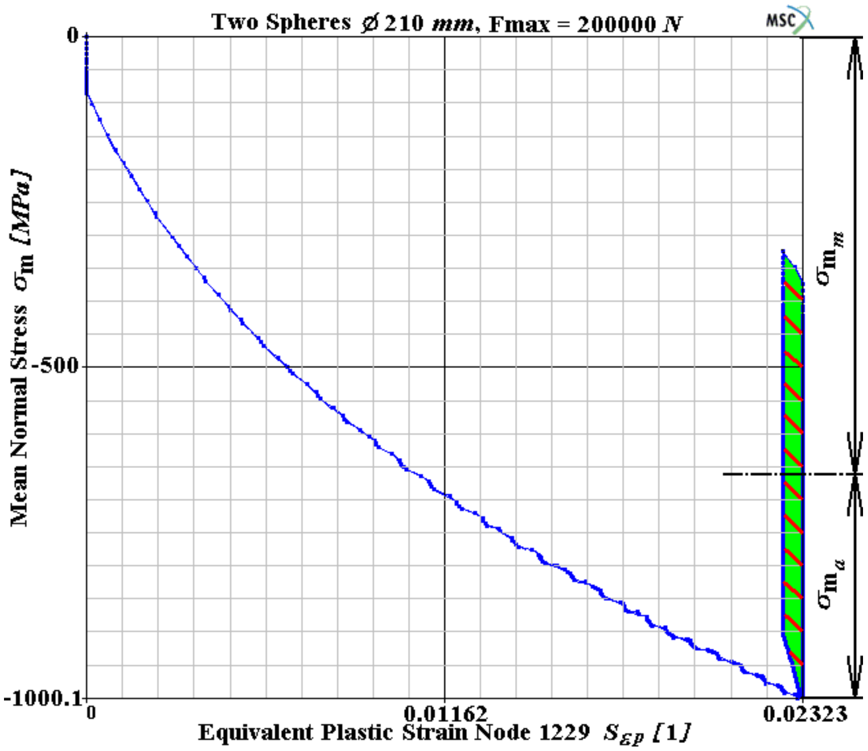

Fig.2 First proposal model of fictive hysteresis loop ($S_{\varepsilon p}$ - σ_m dependence).

3. The Numerical Solution of Cyclical Contact Between the Wheel and Rail

The basic boundary condition is the planar symmetry (YZ-plane). A time-dependent force F=F(t) acted in the centre of the wheel, see fig.4. The material of the wheel is considered to be isotropic and elasto-plastic with multilinear kinematic hardening rule, which is sometimes advisable for the LCF phenomenon.

A time-dependent function of displacement $u_z = u_z(t)$ acted in the axis of the wheel, see fig.4. The problem was solved by FEM. Repeated rolling contact was caused by the mechanical contact with Coulomb's friction between wheel and rail. The friction coefficient was 0.1. The task was to find a loading, which causes the plastic shakedown material response. The relations between stress components σ_x, σ_y, σ_z, τ_{xy}, τ_{yz}, τ_{xz} /MPa/ and total strains components ε_x, ε_y, ε_z, γ_{xy}, γ_{yz}, γ_{xz} /1/ and relation between equivalent von Mises Stress /MPa/ and equivalent total von Mises strain (ε_{HMH} /1/) are shown at fig.5. These values were found at the critical point of the wheel (0.2 mm under surface of wheel).

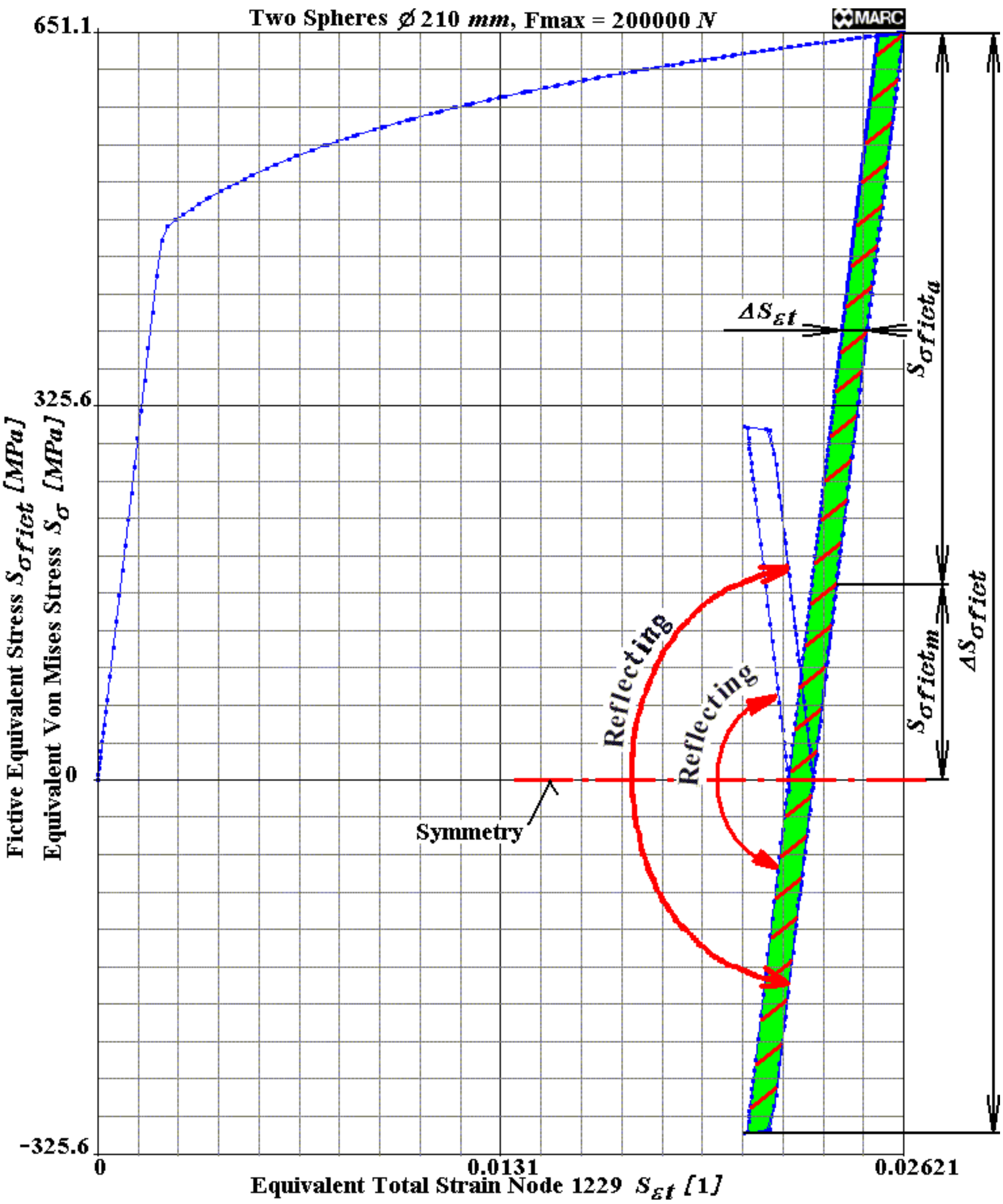

Fig.3 Second proposal model of fictive hysteresis loop. The $S_{\varepsilon t}$ - S_{σ} and $S_{\varepsilon t}$ - $S_{\sigma\, fict}$ dependencies during the solution.

4. REALISATION OF THE TEST MACHINE FOR THE RESEARCH OF CONTACT FATIGUE

The test machine for the research of contact fatigue as a complement of the servo-hydraulic machine INOVA 200kN is shown at fig.6. This machine was proposed and realised in the department of mechanics of Materials at VŠB – Technical University of Ostrava. This machine will be used: For the solution of quantitative coherence between number of cycles to the origin of fatigue cracks in microstructures of different materials by contact fatigue and number of cycles. For initiation of crack by combination of tensile and pressure stresses in the area of the fatigue of materials. For he experimental results which will be also important for future numerical solutions.

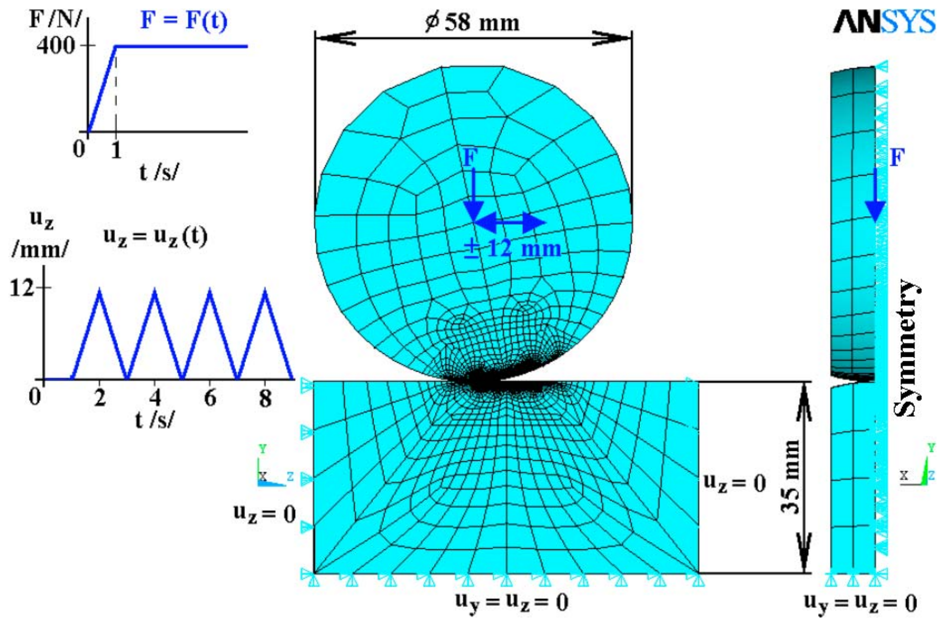

Fig.4 The FE model, boundary conditions and loading.

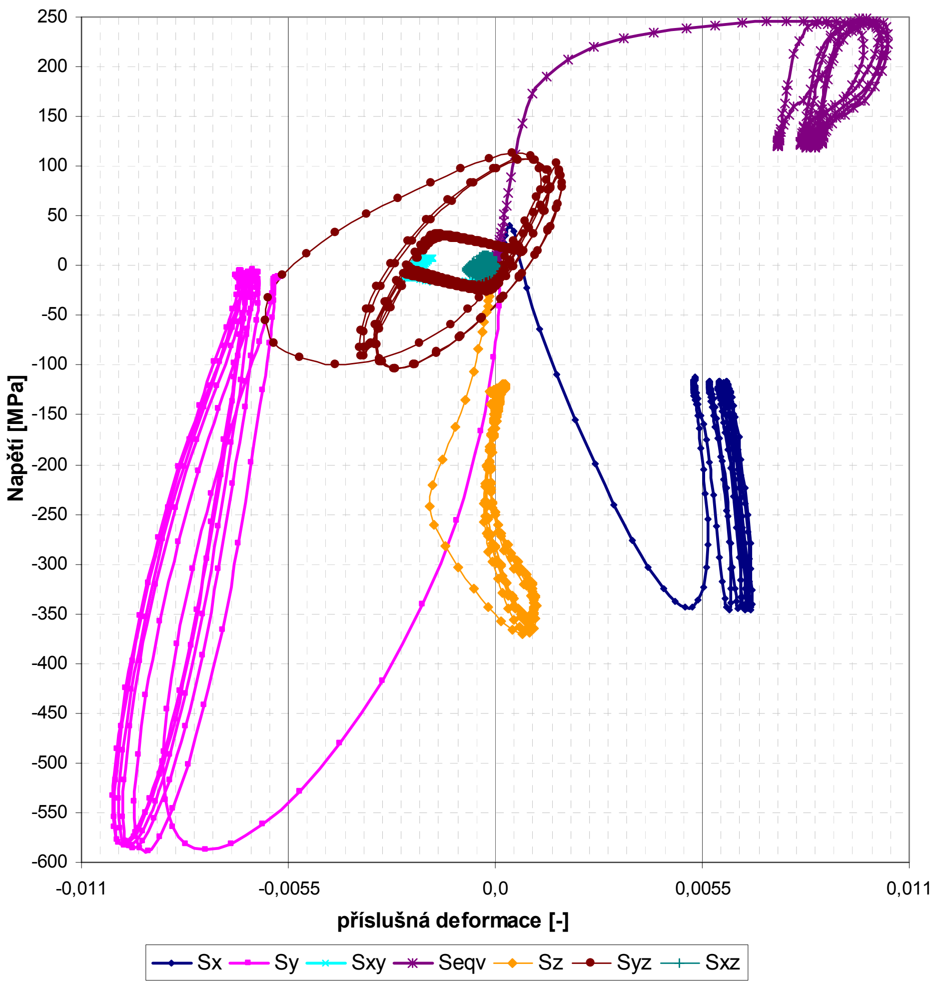

Fig.5 Cyclical changing of stress-strain dependencies.

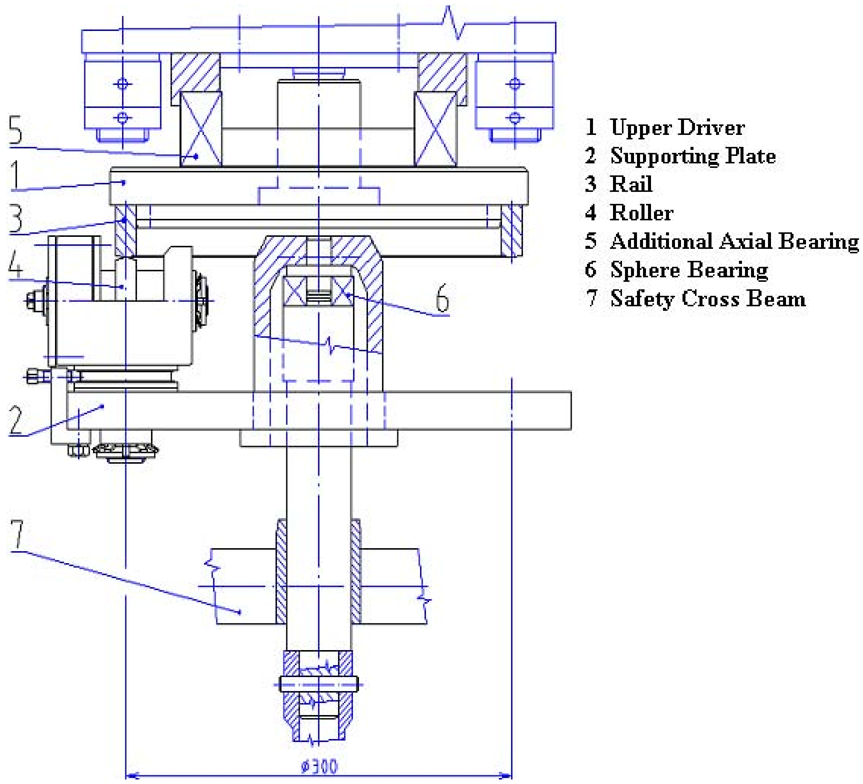

Fig.6 Diagram of the machine for contact fatigue tests.

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