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SIMULATION OF PITTING FORMATION IN GEARING

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Abstract: *In the presented article is presented a numerical simulation approach of pitting arise phenomena on the gear teeth. The basic assumption of the presented approach was that pitting (pits on the contact surfaces) is a result of fatigue crack propagation under (rolling) contact loading conditions. The solution approach consisted of numerical simulations of fatigue cracks growth in the FEM framework. Fatigue crack growth simulations are based on evaluation of the so called Paris law in conjunction with FEA of crack tip loading conditions and fracture criteria evaluation. Penetration of the fluid lubricant into fatigue (pitting) cracks is simulated using special cavity finite elements, which allow to introduce so called lubricant closure inside crack. A simplified distribution of residual stresses in the surface layers of teeth is included as well. The simulations were carried out under the commercial code ABAQUS CAE FEM programme which allows to develop in-house codes using the Python scripting language. Mentioned programme codes are the basis of all FEA including the simulation of the contact loading conditions and the incremental crack growth.*

Keywords: ***gears, pitting, FEM simulation, crack propagation.***

1. Introduction

Pitting is understood as fatigue damage of components caused by cyclic contact load, when material particles come off and shallow pits arise in contact surface (gear teeth, rolling bearing, rails and railway's wheels). Pitting formation leads to degradation (in extreme case to loss) of functionality of afflicted device, to escalation of vibrations, noise and other negative effects.

Many attempts to mathematical description of pitting wear were implemented in recent years. The basic assumption of these attempts is that initiation and fatigue crack propagation are in progress before pit rise and that a pressured fluid lubricant penetrates into cracks and influences its growth (Fajdiga et al, 2004). The presented article belongs to the mentioned approaches. The fatigue crack growth is numerically simulated by finite element method. The crack growth starts from the surface initial crack. The contact conditions between real gear teeth near the pitting crack mouth are computed and the pressured fluid lubricant penetration into pitting crack is assumed.

2. Implemented phenomenological fatigue crack growth theories

The basic assumption of the presented crack growth simulations is validity of the small scale yielding (SSY) conditions. The rate of fatigue cracks propagation can be described by phenomenological theory – the Paris law.

3. Experimental works

Experimental works were carried out at two basic levels. Firstly, simple so called CT test specimens were employed to provide data for validation of the crack growth prediction models under program ABAQUS and secondly, shortened fatigue tests of the real gearing were carried out using special testing machine (Niemann closed testing chain, Fig. 2 - Petr, K. 2010) to provide real pits shapes and gearing lifetime.

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4. Pitting crack growth simulations

Simulations were performed under the commercial FEM code ABAQUS, which provides both computation tools for evaluation fracture mechanics criterion J-integral and Python language interface for in-house programme codes (developed at the Faculty of Mechanical Engineering CTU in Prague) submitting, which provide full automatic FE model creation and simulation control (Špainel, M., 2008).

The numerical prediction of pitting formation presented in this article is based on the simulations of the gearing contact conditions, which induce boundary conditions for subsequent fatigue crack growth computational predictions. The parametric FE model is conceived as the planar model, which combines two 2D models (one with pitting crack and one without) to simulate kvasi-3D contact conditions during gearing meshing. In the FE models the complex tribological relations (so called EHD lubrication conditions) are approximated by friction coefficient f and special cavity model, which allows to include pressured fluid lubricant penetration into the pitting cracks. The residual pressure distribution in the subsurface layers was approximately estimated on the basis of experimental measurement using X-Ray diffraction. Linear elastic isotropic material model was assumed and all FE analyses are assumed as quasistatic and planar considering plane strain conditions.

5. Results and conclusions

The achieved results show, that the chosen numerical approach to the simulation of pitting damage formation can be used. However the developed FE model is very complex due to credible description of physical background. Many parameters can be change and experimental verification of their values does not exist. From this point of view, the large sensitivity study of the most important parameters has to be done. On the basis such complex results, the FE model can be finally validate.

The main result and outputs of the above mentioned research are:

- The complex parametric FE model for pitting crack growth was created.
- The advance cavity model for simulation of penetration of pressured fluid lubricant into pitting cracks was introduced.
- The methodology for implementation of residual stress into subsurface layers of material was developed.
- The complex experimental tests of real gears were performed and evaluated.

In the future the attention will be focused on the extension of experimental base. Especially, on the validation of fatigue cracks growth under non-proportional mixed model loading conditions.

In the simulation domain, the large sensitivity study of FE model parameters will be carried out and the real heat treatment of contact surfaces will be simulated in the special program code SYSWELD to achieved more accurate information about residual stress distribution.

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