EXPERIMENTAL AND NUMERICAL INVESTIGATION OF FRETTING FATIGUE

Miroslav Španiel, Jiří Kuželka, Josef Jurenka, Martin Nesládek, Jan Růžička

1) Czech Technical University in Prague, Faculty of Mechanical Engineering
Technická 4, 166 07, Prague, Czech Republic
Corresponding author: miroslav.spaniel@fs.cvut.cz

1. Introduction

Fatigue damage near contact interface is usually referred as fretting fatigue. Evaluation of such a case done in scope of classical fatigue criteria based only on stress/strain state results into overestimated life till crack initiation. We assume fretting fatigue to be accelerated due to small relative tangential movements of contacting surfaces. Stress field at the vicinity of contact interface, friction and partial slipping of contact surfaces are the factors having significant influence on damage. Fretting fatigue occurs in pressed joints, turbine blades lock joints, slot couplings and in other typical machines parts.

Our research deals with phenomenological fatigue criteria developed for evaluation of fatigue damage under fretting conditions. The possibility of employment of conventional fatigue criteria to evaluate fretting fatigue is based on incorporation of certain corrections with respect to the fretting wear. Ideally, it should include surface damage causing quantities i.e. relative slips and surface shear stress. Ding et al. [6] introduced a simple parameter $D_{fret}$ correcting the multiaxial SWT criterion. According to the authors, the main contribution of $D_{fret}$ is that SWT can now handle the increase in the fatigue life in the transition domain between the partial and gross slips.

Presented work is focused on verification of specific multiaxial fatigue criteria by the fatigue tests. New testing equipment was developed for this purpose and a digital image correlation method was newly employed in this field to calibrate the FE model.

2. Fatigue experiments under fretting conditions.

Original equipment for testing of fatigue under fretting conditions developed at the Faculty of Mechanical Engineering of the Czech Technical University in Prague was designed for a single dog-bone specimen in contact with two cylindrical fretting pads. The main advantages of the proposed setup are both possibility of its use in standard fatigue testing machines and the simplicity of the partial-slip regime accomplishment thanks to the cylinder on a flat contact geometry. The present state of the equipment prepared for the experiment is shown in Fig. 1.

![Fig. 1: The setup for the fretting fatigue testing. The equipment is clamped in the jaws of electromagnetic pulsator AMSLER](image)

3. Comparison of experimentally and computationally estimated contact slips

The Dantec Dynamics Q-450 optical system was used for relative displacements measurements. Since displacements in order of $\mu m$ had been measured at high frame rate, the demands on pattern quality and lighting were quite high.

Regarding 1Mpix resolution of CCD chip the objective and extension tubes were used to achieve spatial resolution of approximately 8$\mu m$/pix with the field of view of about 5x8mm. The viewed surfaces were clothed in a...
very fine contrast stochastic speckle pattern created with airbrush considering the recommendations in [1]. Two special high frequency lamps with 1kW power were used for sufficient lighting. The images of the vicinity of the contact interface between the specimen and pad were recorded by a high speed NanoSense Mk III camera with the frequency of 2 kHz (corresponds to 20 images per loading cycle). Data were acquired during a relatively short period of about 50 cycles after every 200 thousand cycles. The data related to the sequence of images of the contact interface, traction force transmitted by pads and pressure force P were gathered.

The acquired sets of image sequences were processed in the commercial image correlation software Istra 4-D. The displacements were evaluated in a 0.1 mm (12 pix) equally spaced grid. Each grid point corresponds to a subset 0.2x0.2 mm (25x25 pix). The obtained results were further post-processed by Matlab scripts. The point with maximal contact pressure (and thus the centre of the contact area) was estimated on the basis of displacement field in case of pure pressure loading of 10 kN magnitude. At this point, a coordinate system for relative slip evaluation was introduced. The Hertz contact theory was applied for the estimation of the contact area width.

The relative slips were computed as a difference between the displacements along a line near the contact edge on the specimen and the pad. The time behavior of the contact slips on the top, in the middle and on the bottom of the contact area is shown in Fig. 2. The changing character of slipping from the more loaded side (top) to the less loaded side (bottom) can be observed.

4. Conclusions

Several measurements were performed in order to acquire reliable values of the contact slips for further FE model calibration. As can be seen from the time history of the relative contact slips, this quantity has a changing character with respect to the position along the contact. This behaviour cannot be simulated by a relatively cheap steady-state numerical solution. An explicit dynamic formulation of the problem might give a better correlation of this quantity which is a further goal of this project.

By varying the parameters of the numerical model (especially friction) a better correlation can be expected between the numerical and experimental data. In this case the Coulomb friction with the coefficient 0.8 was used. It reflects the average tribological conditions in the contact. By contrast, the experimental data were measured in the beginning of the cyclic loading. This could be an explanation for the observed shift in Fig. 3.

5. Acknowledgements

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References