Towards a grain-scale modeling of crack initiation in contact fatigue

Lucas Fourel[1)], Etienne Bossy[2)], Jean-Philippe Noyel[2)], Xavier Kleber[3)] and Fabrice Ville[1)]*

[1)]Univ Lyon, INSA-Lyon, CNRS UMR5259, LaMCoS, F-69621, France
[2)]Univ Lyon, ECAM-Lyon, INSA-Lyon LabECAM, F-69005, France
[3)]Univ Lyon, INSA-Lyon, UMR CNRS 5510, MATEIS, France
*Corresponding author: fabrice.ville@insa-lyon.fr

A numerical model for Rolling Contact Fatigue has been developed using FEM to compute stresses and Tanaka-Mura micromechanical model to compute fatigue crack initiation life. Different approaches are compared, homogenous and polycrystalline geometry. Different shear stresses are considered. Mesoscopic modeling allows for calculation of favorable resolved directions as well as realistic grain size distribution. The benefits of modeling moving contact pressure over static contact pressure are shown. Polycrystalline modeling appears to have particular interests for dented surface conditions. Initiation depths are consistent with literature experiments.

Keywords: rolling contact fatigue, mesoscopic model, shear stress

1. Introduction

Rolling Contact Fatigue (RCF) involves crack initiation as the first step of the damage process. Multiple empirical and deterministic models have been developed to predict fatigue crack initiation life [1]. Tanaka and Mura [2] created a model based on micromechanical phenomena of fatigue crack initiation. The number of loading cycles required to initiate a crack N_i is given by:

$$N_i = \frac{A}{d(\Delta\tau - B)^2} \qquad (1)$$

With material constants A and B, slip band length d and shear stress range $\Delta\tau$. This study proposes an implementation of this equation into a numerical model using FEM to compute stresses.

2. Macroscopic modeling

The rolling contact is simulated by applying a moving contact pressure on constrained 2D solid. The area of analysis is a small plane measuring $2a \times 2.5a$ with a, the contact half-width. As a first approach, material is considered as continuous. The contact pressure can be representative for smooth surfaces (Hertz theory) or for dented surfaces.

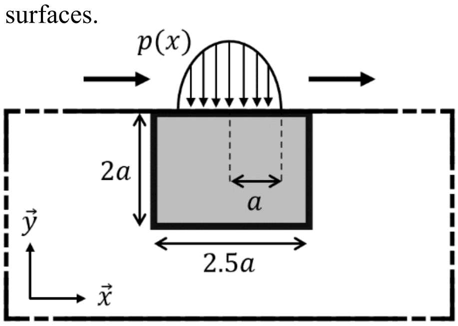

Figure 1: Numerical model with moving contact pressure at centred position.

Different shear stresses can be considered [3]: orthogonal τ_{xy}, maximum τ_{max} and octahedral τ_{oct} shear stresses. In the case of repeated static contact pressure τ_{max} is more critical but in the case of a moving contact pressure $\Delta\tau_{xy}$ should be privileged.

3. Mesoscopic approach

Modelling a polycrystalline geometry improves the grain size distribution and an algorithm can find the direction that maximized shear stress range for each grain.

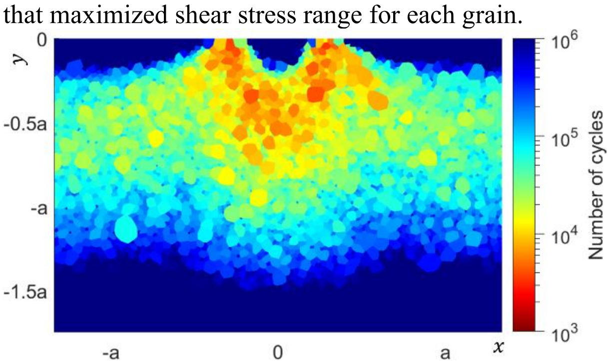

Figure 2: Crack initiation life for a dented contact.

Initiation depths for smooth contacts are consistent with experiments [4] and dented surfaces tend to initiate crack at surface and sub-surface.

4. Discussion

Mesoscopic modeling allows for more physically based results. However, simulating crystal anisotropy would allow to model Persistent Slip Bands that are at the origin of Tanaka-Mura's model.

5. References

[1] Sadeghi, F. et al., "A Review of Rolling Contact Fatigue," ASME J. Tribology, 131, 4, 2009, 041403.
[2] Tanaka, K. et al., "A Dislocation Model for Fatigue Crack Initiation," J. Appl. Mech., 48, 1, 1981, 97-103.
[3] Cheng, W. et al., "Semi-Analytical Modeling of Crack Initiation Dominant Contact Fatigue Life for Roller Bearings," ASME J. Tribology, 119, 2, 1997, 233-240.
[4] Longching, C. et al., "Study on initiation and propagation angles of subsurface cracks in GCr15 bearing steel under rolling contact," Wear, 133, 2, 1989, 205-218.