7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

A SAM/X-FEM Numerical Approach for 3D Rolling Contact Fatigue Crack Growth in Bearing Raceway

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In order to insure the safety of bearings and aeronautic structures submitted to rolling contact fatigue, understanding the complex crack growth behavior is crucial. To this end, a novel efficient numerical approach is developed to model the three-dimensional fatigue crack propagation under rolling contact loading. This numerical strategy is validated with existing results. Several numerical experiments are performed to improve knowledge of fatigue crack propagation phenomenon under rolling contact fatigue.

Keywords: Rolling Contact Fatigue, 3D Fatigue Crack Growth Simulation, Rolling Element Bearings

1. Introduction

Rolling Contact Fatigue is a typical life limiting failure mode of mechanical components such as rolling element bearings. Due to the cyclic passages of rolling elements, fatigue cracks can initiate on bearing raceways. The propagation of these cracks, mainly in shear mode, can either foster spalling or cause dramatic failure of bearings with deep subsurface propagation. In order to predict bearings' fatigue scenario, a numerical study of this complex phenomenon is conducted. Based on a SAM/X-FEM coupling, a novel numerical approach is proposed to simulate in a fast and robust way the 3D fatigue crack propagation under rolling contact conditions. A comparison with results from literature references and experimental data shows the capacities of the developed model. Finally, a parametric study is carried out to identify the parameters which significantly influence the crack propagation.

2. Methods

2.1. SAM/X-FEM coupling method

Despite the recent developments in numerical computation, 3D crack propagation simulation is still a challenge. To shorten computation efforts, an efficient SAM/X-FEM coupling strategy based on the submodeling technique is proposed. First, the proposed procedure consists in solving the global contact problem between rolling elements and raceways by means of the Semi-Analytical Method [1]. Next, using results from this global contact analysis, boundary conditions for the subsequent local analysis are determined and prescribed on a small region containing the crack called local model or submodel. The coupled X-FEM/LATIN method [2] is then employed to solve the 3D frictional crack local problem.

2.2. Validation

The SAM/X-FEM coupling strategy was validated through comparison with results extracted from literature. Kaneta's stress intensity factor (SIFs) variations are taken as reference [3]. Figure 1 exhibits K_{II} variations during the passage of a spherical contact over a semi-circular crack in a half space for different surface friction coefficients.

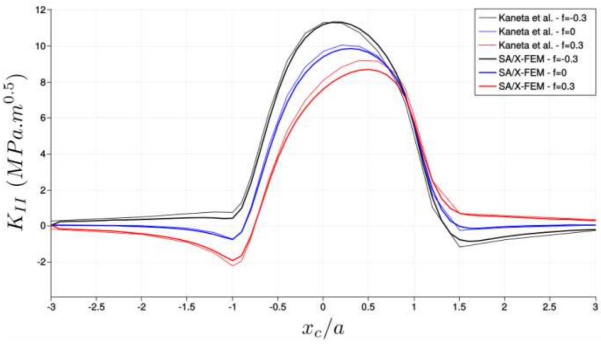

Figure 1: Comparison of K_{II} variations. Thin curves: [3]; Thick curves: SAM/X-FEM.

The results given by the developed approach show good agreement with the reference. It proves the great potential of this development and its efficiency.

3. Discussion

To properly characterize complex crack propagation behavior under RCF condition (multi-axial non-proportional loading), the prediction of the crack growth path and rate is a crucial issue. Therefore, several existing crack growth path criteria together with crack growth laws are tested and compared to experimental data. To improve the sizing and the service life of bearings, a parametric study is conducted with the SAM/X-FEM model to investigate the influence of several parameters (contact geometry, frictional coefficient between contact surfaces, frictional coefficient between crack faces, initial crack geometry and orientation, etc.) on crack growth behavior. Results of these studies will be exposed.

4. References

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