

## STRESS INTENSITY FACTORS ANALYSIS FOR A C-CRACK IN A CERAMIC ROLLER SUBJECTED TO REPRESENTATIVE BEARING SERVICE LOADS

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### KEYWORDS

Rolling contact fatigue; Modelling in tribology; Wear; Ceramic rolling bearing

### INTRODUCTION

Hybrid bearings are used to improve the lifespan and efficiency of rolling bearings. They are essentially made up of ceramic (silicon nitride) rolling elements (balls and rollers). Silicon nitride ceramic rolling elements are widely used in engineering applications due to their excellent mechanical and tribological performance, low coefficient of thermal expansion, and good corrosion resistance [1]. Rolling contact fatigue (RCF) is known to be the first phenomenon to occur in service, resulting in a loss of bearing lifespan and even leading to the spalling of the rolling element [2]. Since ceramic is a brittle material, any surface defects are likely to induce the failure of the rolling element. C-cracks, or ring cracks, are commonly found on silicon nitride rolling elements. Under rolling contact, this surface defect causes the rolling element to fail. The C-crack is assumed to have an internal cone-shaped crack face with a curved-shaped crack front [3]. Under repeated contact loading, the crack grows until it becomes sufficiently large and reaches a critical size, and then a fatigue spall can be formed. This study focuses on the justification of such a crack shape, the determination of the critical crack size, and the prediction of the crack's possible propagation direction. Understanding the physical phenomena and the mechanisms driving the failure of the ceramic rolling element bearings under representative bearing service loads is thus crucial for industrials. This work presents a numerical fracture analysis of C-crack propagation in a silicon nitride roller through the determination of stress intensity factors (SIF) along the crack front. On the one hand, the driving force of sub-surface C-crack propagation is pointed out, and on the other hand, the conical shape of the C-crack is justified [4]. The influence of C-crack orientation under rolling contact on SIF values through location and geometrical parameters has been studied.

### METHODS

A 3D finite element model of a rolling element with a C-crack explicitly described in the mesh (cracked roller mesh) has been developed to study the failure mechanisms under rolling contact. A representative loading seen by a rolling element (roller) in service is determined using a simplified rolling bearings model: a quasi-static rolling bearings equilibrium model. The rolling contact load is simulated by a repeated Hertzian linear contact load with a normal pressure. The numerical calculations of the SIF along the crack front are based on the linear-elastic fracture mechanics (LEFM) analysis. All finite element (FE) models are carried out using Z-set software and Z-cracks tools for fracture mechanics analysis. Contact between the crack lips is considered in the model for the effective numerical calculations of the SIF values. For the study, a focus is made on when the Hertzian contact zone passes across the crack. A parametric study was also carried out to determine the location and geometrical parameters of the C-crack, which has a major influence on the SIF. The overview of the cracked rolling element model is shown in Fig. 1.

### RESULTS

First, the crack propagation driving force is identified, C-crack's shape is justified, and the influence of C-crack's different configurations on SIF is discussed. The SIF analysis shows that  $K_{II}$  dominate the C-crack sub-surface propagation. Indeed, when the pressure passes across the crack, it's subjected to a compressive and a shear stress state. The opening of the crack (mode I) is annihilated because of the contact between the crack lips thus  $\Delta K_{II}^{max}$  the driving force behind the

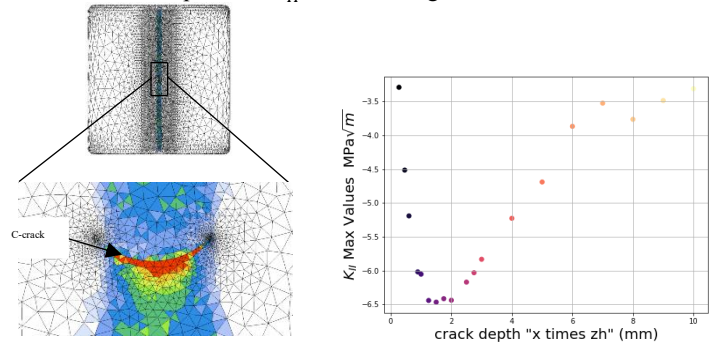


Fig. 1: Contact zone passing across a cracked roller and influence of crack depth on  $K_{II}$  values.

propagation of the C-crack. Secondly,  $K_{II}$  values are mainly affected by crack location and geometrical parameters, and the critical cone angle for the cracked roller is obtained around 45°. Finally, the curve in Fig. 1 shows  $K_{II}$  values reaching his maximum absolute value for a crack depth equal to two times Hertz's maximum shear stress depth. For a crack depth below this critical size, values increase quickly at the beginning and slowly as the length grows, whereas above this critical size,  $K_{II}$  values decrease.

### ACKNOWLEDGMENTS

The authors acknowledge the financial support from ONERA, DGAC through RHEA project and the technical discussion with SKF Aerospace Valence.

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