Investigation in modeling and simulation of mixed-mode fatigue crack growth induced by rolling contact in steel parts of helicopters gearbox with a surface gradient in mechanical properties.

PhD thesis 2018-2021 (CIFRE contract) at:

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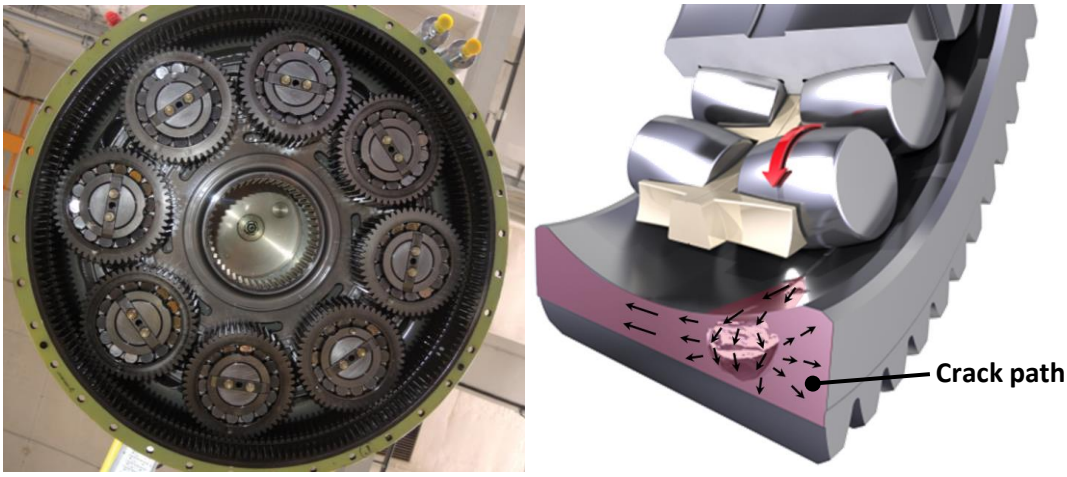

Figure 1

Industrial problem

The outer ring of planet gears submitted to heavy rolling contact at high frequency in the main gearbox of helicopters (Figure 1) are made of steel, superficially hardened by carburizing, which also induces biaxial compressive residual stresses, supposed to inhibit fatigue crack initiation. However, in circumstances that remain unclear [1], a fatigue crack was able to nucleate and grow, mainly in shear mode, with catastrophic consequences. In order to improve the sizing of critical components regarding this kind of failure mode, the design parameters influencing the crack propagation have to be understood. The complex 3D path of such a crack is difficult to predict, because 1) crack growth under such a combination of cyclic shear and high compression has ha rdly been investigated so far, 2) the gradient in residual stresses, microstructure and mechanical properties between base metal and the carburized layer complicates the problem, 3) the lubricant used in gearboxes might trigger fatigue crack growth, by reducing crack face friction, which is critical in shear mode [2] and 4) the

crack presents many aborted branches whose origin and growth mechanisms are not fully understood, but that certainly have a significant influence on the main crack path and growth rate.

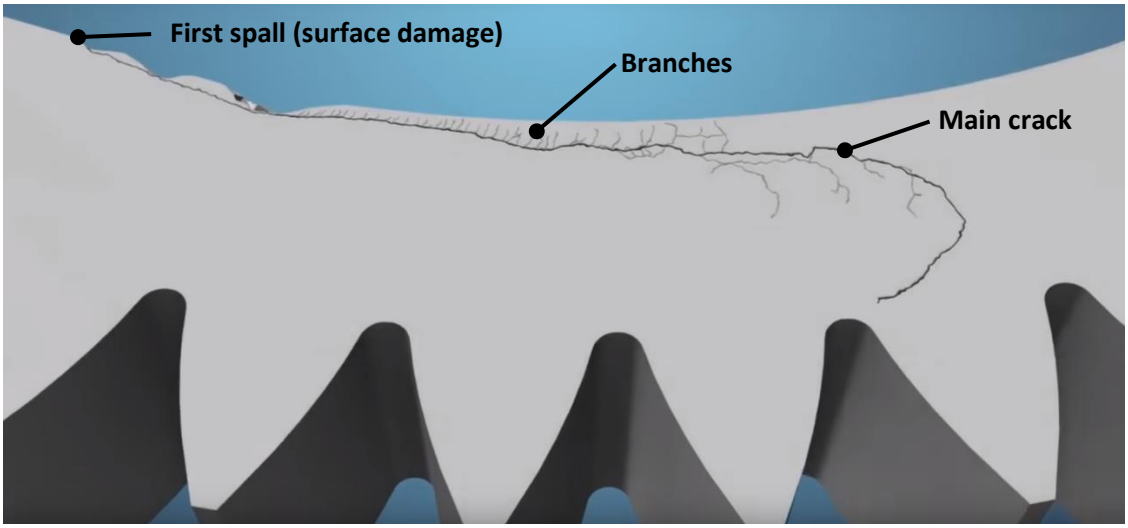

Figure 2

Outline of the thesis

The purpose of the thesis is to develop a fatigue crack growth model able to predict the observed crack paths and kinetics, and simulation tools [3,4] including the residual stresses, gradient in properties, contact and friction of crack faces, as well as the multiple branches, enabling to simulate in 3D, on the industrial component (planet gear), the complete crack propagation observed in situ

An experimental study of fatigue crack growth in loading conditions as representative as possible of those encountered in helicopter gearboxes will be run, using a biaxial testing machine with 4 actuators available at Onera. Digital image correlation will be used to monitor crack growth and derive the effective stress intensity factors (allowance made for closure and friction effects) from the near-tip displacement fields [5]. Tests will be run in air, or in a lubricant. The crack paths (characterized at the macro-scale, but also at the micro-scale, in relation with the microstructure through SEM observations) as well as the crack growth rates will be analyzed with respect to the effective stress intensity factors. A rationalization of the crack paths based on the maximum growth rate criterion [6-9] will be attempted. In case this is not successful, a "local approach" based on elastic plastic computations of the stress and strain fields ahead of the crack tip and a local application of fatigue damage models [10-12] will constitute an alternative.

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The candidate should have a Master or engineering degree in mechanics of materials/ structures. Training in Fracture Mechanics and some practice of finite element simulation are required. He/she should also appreciate experimental mechanics. To apply, send your resume (mentioning the e-mail address of a referent teacher or internship supervisor) and transcripts for your master or engineering degree at V. Chiaruttini and V. Doquet