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## **IMPLEMENTATION OF AN EXPERIMENTAL DEVICE FOR CRACK INITIATION IN THE GIGACYCLIC DOMAIN FOR THE STUDY OF CONTACT FATIGUE**

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### **ABSTRACT**

An ultrasonic experimental device allowing to study the initiation of cracks, in the gigacyclic domain, for rolling contact fatigue has been developed. This device thus makes it possible to carry out 20,000 traction-compression cycles per second, the study of a billion cycles is therefore reduced to 14 hours. In addition, the trivialization of cameras with very short exposure times ( $<1 \mu\text{s}$ ) coupled with recent progress in the field of micrometric speckles makes it possible to use image correlation for this type of study.

**Keywords:** Gigacyclic fatigue, property gradient, image correlation, micrometric speckle.

### **INTRODUCTION**

Material fatigue is a complex subject that has occupied researchers and engineers for decades. These seek to estimate the life of parts or structures subjected to repeated loading cycles in order to minimize construction costs while guaranteeing a certain level of safety. In fields where the safety of people is at stake, in aeronautics in particular, or for the safety of sensitive installations, such as nuclear power plants, extremely low failure rates ( $< 10^{-7}$ ) or even zero for certain critical components are mandatory. It is therefore common to design parts capable of surviving tens of billions of cycles, which also corresponds to tens of years of operation. Demonstrating the reliability of these parts by experiment is extremely long and costly and predictive models are hardly better suited for lack of reliable experimental data.

### **RESULTS AND CONCLUSIONS**

The experimental fatigue system that we have developed is based on the work of C. Brugger, T. Palin-Luc and M. Blanc (Brugger et al., 2016). It consists of a control computer allowing the vibration frequency of the system to be tuned with its resonant frequency, a Branson vibration generator and the associated piezoelectric converter having a range of use between 19,500 and 20,500 Hz, boosters and sonotrodes to amplify the amplitude of the piezoelectric as well as a sample to be tested. The boosters are located on a vibration node, allowing among other things to easily attach this system to a traction machine to apply a non-zero average load.

In order to study the initiation of cracks under multi-axial and non-proportional loading, a hole of small diameter compared to the microstructure (here  $70 \mu\text{m}$ ) will be produced by electro-erosion. For such an assembly to work, the assembly must be sized so that the resonance frequency in traction/compression mode remains within the range of use of the piezoelectric converter, i.e. between 19,500 and 20,500 Hz.

To precisely determine the initiation zone of our specimen, we simulated the strain hardening of a specimen via a finite element simulation and the Swift plasticity model (Jacq, 2001). We applied a displacement of 50  $\mu\text{m}$  at each end of the specimen, see Figure 1. It then appears quite precisely that the most critical zone is located at the equator of the hole along its generatrix. It should be noted that the maximum stress is here located 20  $\mu\text{m}$  below the surface.

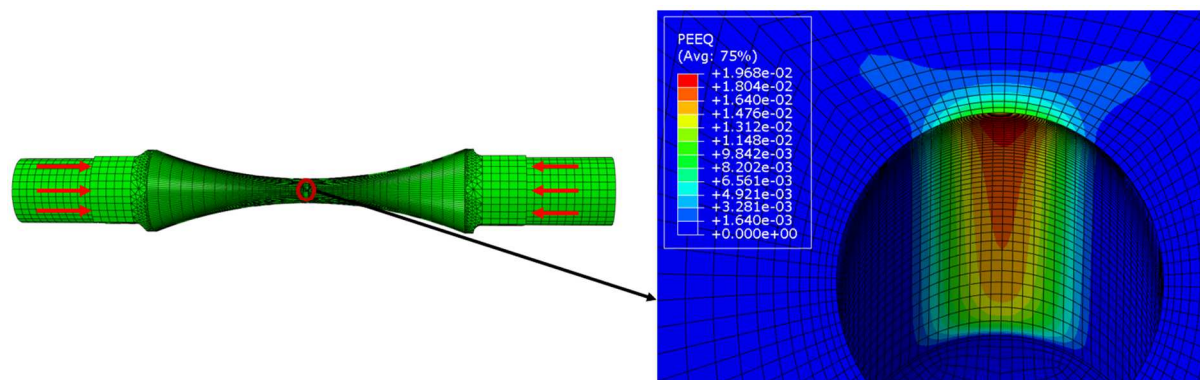


Fig. 1 – Equivalent plastic deformation, following a displacement of 50  $\mu\text{m}$  at each end of the specimen.

In order to follow the deformation of our specimen by image correlation, it is necessary to make a speckle. Our area of interest being 70  $\mu\text{m}$  in diameter, the speckle must have a characteristic size of the order of a micrometer. Among the different methods to obtain a sufficiently resolved speckle pattern (Dong and Bing, 2017) we have chosen microSpeckle Stamping (Cannon et al., 2015). It is relatively inexpensive, repeatable and customizable. Since the speckle pattern can be chosen precisely, it is based on the work of G. F. Bomarito et al. (Bomarito et al., 2017) characterizing an ideal speckle pattern.

This coupled with an adequate acquisition system makes it possible to study the initiation of a crack in a bearing material in the gigacyclic domain.

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