



HAL
open science

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

Adrien Didier, Naïm Naouar, Baptiste Serres, Daniel Nélias

► **To cite this version:**

Adrien Didier, Naïm Naouar, Baptiste Serres, Daniel Nélias. IMPLEMENTATION OF AN EXPERIMENTAL DEVICE FOR CRACK INITIATION IN THE GIGACYCLIC DOMAIN FOR THE STUDY OF CONTACT FATIGUE. 20th International Conference on Experimental Mechanics, Jul 2023, Porto, Portugal. hal-04281971

HAL Id: hal-04281971

<https://hal.science/hal-04281971>

Submitted on 13 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

PAPER REF: 19848

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

Adrien Didier^{1,2(*)}, Naïm Naouar¹, Baptiste Serres², Daniel Nelias¹

¹Univ Lyon, INSA Lyon, CNRS, LaMCoS, UMR 5259, 69621 Villeurbanne, France

²Safran SAE, Centre de Villaroche, 77550 Moissy-Cramayel, France

(*)*Email*: adrien.didier@insa-lyon.fr

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 μm 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 μm below the surface.

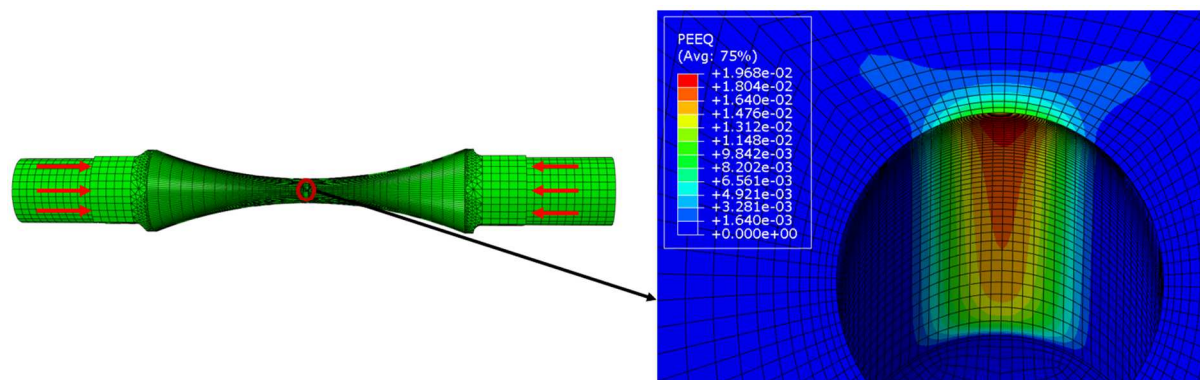


Fig. 1 – Equivalent plastic deformation, following a displacement of 50 μm at each end of the specimen.

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 μm 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.

REFERENCES

- [1] Bomarito GF, Hochhalter JD, Ruggles TJ, Cannon AH, Increasing accuracy and precision of digital image correlation through pattern optimization. *Optics and Lasers in Engineering*, 91, pp.73-85, 2017.
- [2] Brugger C, Palin-Luc T, Osmond P, Blanc M, Ultrasonic fatigue testing device under biaxial bending. *Frattura ed Integrità Strutturale*, 10(37), pp.46-51, 2016.
- [3] Cannon AH, Hochhalter JD, Mello AW, Bomarito GF, Sangid MD, Microstamping for improved speckle patterns to enable digital image correlation. *Microscopy and Microanalysis*, 21(S3): 451_452, 2015.
- [4] Dong YL, Bing P, A review of speckle pattern fabrication and assessment for digital image correlation. *Experimental Mechanics*, 57(8): 1161_1181, 2017.
- [5] Jacq C, Limite d'endurance et durée de vie en fatigue de roulement du 32CrMoV13 nitruré en présence d'indentations, PhD Thesis INSA Lyon, 2001.