INFRARED TEMPERATURE MEASUREMENT AND X-RAY TOMOGRAPHY FOR INTERNAL FATIGUE CRACK MONITORING DURING ULTRASONIC FATIGUE TESTS

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Abstract
The observation of fatigue cracks in the gigacycle fatigue regime is very difficult because they are very often initiating and propagating in the core of the specimens. This paper presents a methodology for detecting and monitoring internal fatigue cracks during ultrasonic fatigue tests. Using both the heat source located in the reverse cyclic plastic zone at the crack tip and the 3D geometry of the crack (from X-Ray tomography), finite element analysis is done to solve the heat transfert problem. This allow us to related the internal crack growth rate and the temperature field evolution versus time at the surface of the specimen. This proposed method has been successfully applied on specimens in cast aluminum alloy.

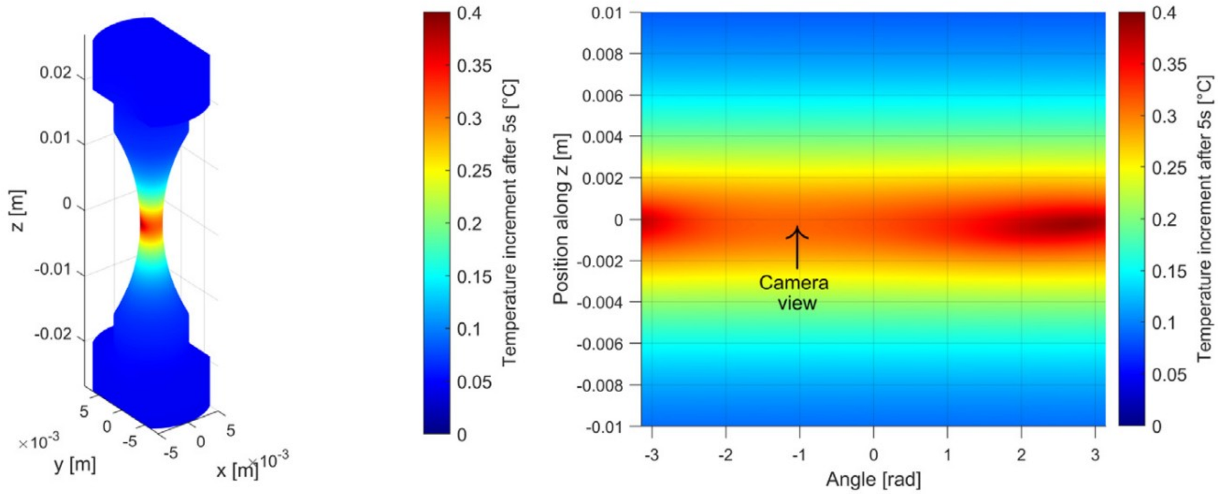
1. Introduction

Very high cycle fatigue and fracture is often associated to internal crack initiation and then propagation. One major problem to study the initiation and the propagation of such internal crack is to observe and to quantify its propagation rate. The objective of the present work is to develop a coupled experimental /simulation methodology in order to assess quantitatively the propagation rate of the crack.

2. Method and results

The technique presented here after is based on: i) the 3D geometry of the crack and on ii) the temperature field measurement at the specimen surface. These two types of experimental data are obtained by in-situ synchrotron ultrasonic fatigue test with an home made ultrasonic fatigue testing machine [1]. Plasticity in the reverse cyclic plastic zone near the crack front generates heat sources due to the dissipation of plastic energy rate and thus an increase of the temperature which propagates through the specimen thanks to the heat conduction. However, at 20 kHz microplasticity in the uncracked part of the specimen contribute to the specimen self-heating too. An appropriate identification of the heat sources due to this microplastity depending on the stress amplitude has been carried out in order to be able to separate the contribution of microplasticity and cyclic plasticity at the crack tip.

With the heat sources due to microplasticity, the geometry of the crack and the heat sources located in the reverse cyclic plastic zone all along the crack front, finite element simulation of the heat transfer problem (Fig. 1) enables to establish a relationship between the internal crack growth rate and the temperature field evolution on the specimen surface [2].



(a) (b)

Fig.1 – simulation of the effect of an internal propagating crack in a specimen loaded in fully reversed tension at 20 kHz on a) the temperature increment at the surface, b) zoom on the temperature all around the central part of the specimen; the black arrow is view point of the infrared camera.

3. Conclusion

By considering both the heat sources due to microplasticity and plasticity in the reverse cyclic plastic zone, a thermomechanical model has been proposed to explain the temperature evolution at the surface of a cracked specimen loaded in fully reversed tension at 20 kHz. The proposed method and technique allow us to detect internal crack initiation and monitor internal fatigue crack growth. This was used on smooth specimens in cast aluminum alloy.

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