# *CHARACTERISATION OF 3D DAMAGE MECHANISMS OF A CAST AL ALLOY DURING IN-SITU HIGH TEMPERATURE LOW CYCLE FATIGUE TESTS USING SYNCHROTRON X-RAY TOMOGRAPHY AND DIGITAL VOLUME CORRELATION*

Dahdah N.[1], Limodin N.[1], El Bartali A.[1], Witz J.-F.[1], Charkaluk E.[1], and Buffiere J.Y. *[2]

[1]LML Centrale Lille 59650 Villeneuve dAscq, France
[2]MATEIS INSA Lyon 69100 Villeurbanne France

**Keywords:** synchrotron x-ray tomography, in-situ, fatigue, digital volume correlation

**Summary:** The damage mechanisms of a cast Al alloy (A319) are studied in-situ during low cycle fatigue at high temperature (250 °C) using synchrotron X-ray tomography. 3D images of the development of damage under load are obtained and correlated with the local strain levels obtained with Digital Volume Correlation

## INTRODUCTION

In the automotive industry, the Lost Foam Casting (LFC) process is gradually replacing the traditional die casting process for producing engine parts in Al alloys. The advantages of LFC are that it allows to optimize the geometry of cast parts as well as to reduce the production cost. One drawback, however, is that LFC generates a coarser microstructure and more porosity than, for example, die casting because of slower cooling rates. In this work the low cycle fatigue mechanisms of a LFC Aluminium-Silicon alloy (A319) used for making automotive cylinder heads have been studied. In situ fatigue tests monitored by synchrotron tomography have been carried out at (moderately) high temperatures representative of service conditions.

## EXPERIMENTAL METHOD

Low Cycle Fatigue tests monitored by synchrotron X-ray tomography have been carried out at ID19 beamline (ESRF) using an in-situ test rig developed at MATEIS laboratory [1] to study crack initiation and growth at 250 °C in dog bone specimens extracted from automotive cylinder heads. The scan duration was 45 s with a 2.75 $\mu m$ voxel size. Uniaxial fatigue tests at constant stress amplitude (R=0.1) were performed with a maximum stress of the order of 150% of the yield stress at the corresponding temperature. 3D displacement fields within the samples were measured by Digital Volume Correlation (DVC) all along the fatigue life. In the present study, a 3D image correlation platform developed at LML laboratory, YaDICs, has been used [2].

## RESULTS

The reconstructed 3D images allowed visualizing the various elements of a highly three dimensional microstructure, *i.e.* eutectic AlAl2Cu, iron based intermetallics phases and eutectic Si. The latter cannot be imaged with laboratory tomography (figure 1a); all these constituents formed a natural speckle for DVC.

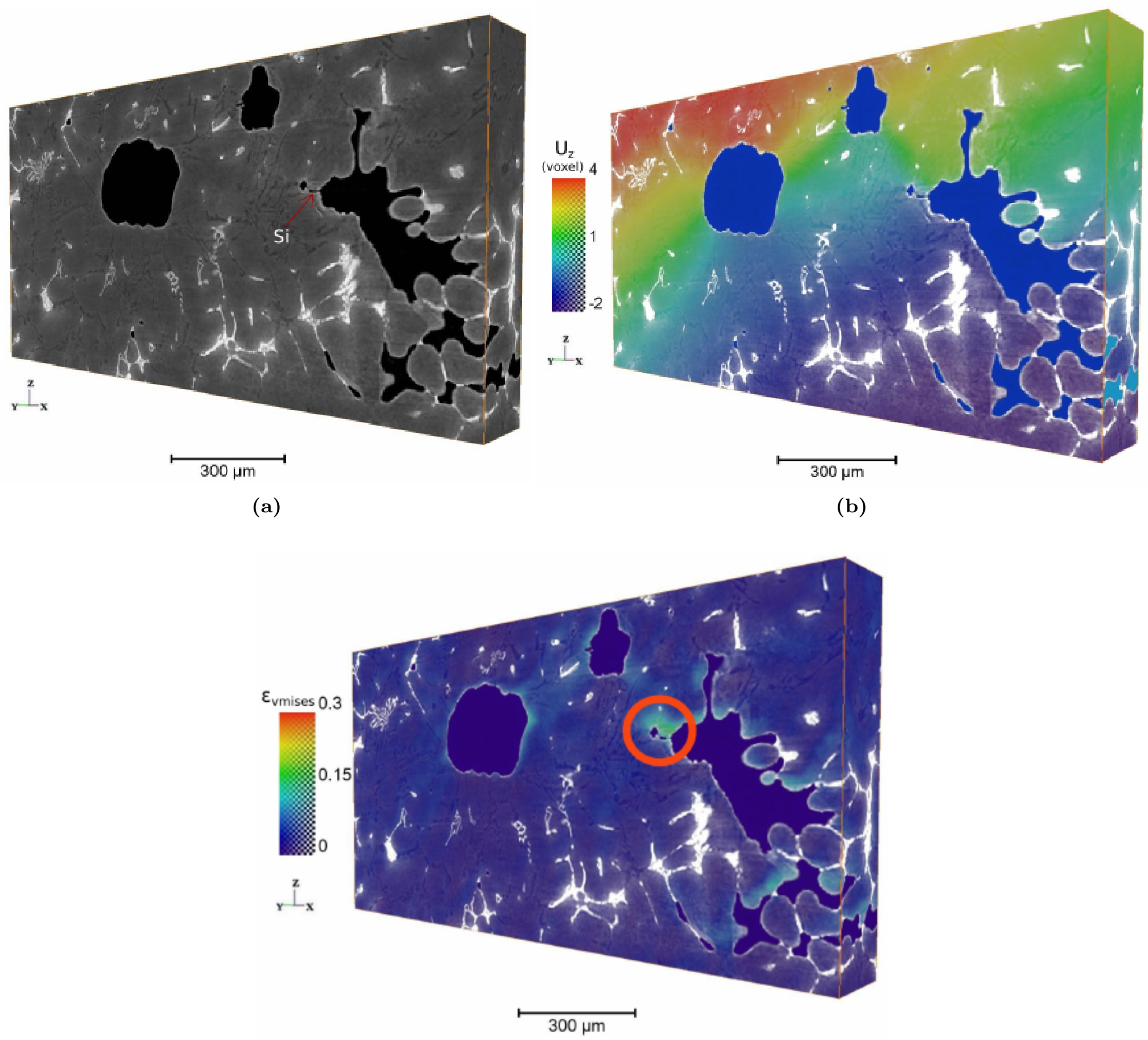
Through the measured displacement fields the development and localization of strain could be monitored during low cycle fatigue. It is shown that the complex 3D microstructure of the alloy produces heterogeneous local strain fields which can be correlated with damage initiation and propagation (figure 1b and c). The analysis reveals, for the first time, local strain levels responsible for damage initiation within the various components of the microstructure.

*e-mail: jean-yves.buffiere@insa-lyon.fr

## References

[1] S.Dézécot, J.Y.Buffiere, A.Koster, V.Maurel, F.Szmytka, E.Charkaluk, N.Dahdah, A.El Bartali, N.Limodin & J.F.Witz. In situ 3D characterization of high temperature fatigue damage mechanisms in a cast aluminum alloy using synchrotron X-ray tomography,*Scripta Materialia*, 113, 254–258, 2016.

[2] N.Dahdah, N.Limodin, A.El Bartali, J.F.Witz, R.Seghir, E.Charkaluk & J.Y.Buffiere. Damage Investigation in A319 Aluminium Alloy by X-ray Tomography and Digital Volume Correlation during In Situ High-Temperature Fatigue Tests,*Strain*, 52, 324–335, 2016, doi: 10.1111/str.12193.




(a) (b) (c)

**Figure 1:** In situ low cycle fatigue testing of a cast Al alloy at T=250 °C; the uniaxial cyclic tensile load is vertical (a) 3D reconstruction of the complex microstructure of the alloy showing pores (in black) Si and intermetallic particles; the red arrow indicates a crack that has formed after one fatigue cycle on a Si particle (b) vertical displacement field in voxels (c) map of Von Mises strain showing strain localisation in the pore vicinity (scale bar in real values).