# OPTICAL AND INFRARED COUPLED FULL-FIELD MEASUREMENTS AT A MICROMETRIC SCALE

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## 1. INTRODUCTION

Most of isotropic metallic materials are made of an aggregate of grains with random crystallographic orientations. Among these grains some are favourably oriented for plastic gliding, with respect to the loading axes. This induces local heterogeneities as these grains can exhibit plastic strains whereas other grains still undergo pure elastic response [1]. This plasticity triggers the occurrence of slip bands at the surface of the material due to the deformation as well as a thermal dissipation that can be detected at the structure scale. Hence, under monotonous or cyclic loading, the material behaviour may be thermally and mechanically different from one grain to another. Studies about the dissipation due to plasticity have already been published [2, 3]. They aimed at exploiting the average temperature of the whole specimen to account for its damage but they concerned only the macroscopic scale whereas the key phenomenon arises at the grains scale. Thus no information is available either about the kinematical behaviour or about the thermal one of the material at the mesoscopic scale of damage. Nevertheless, in recent years, techniques of full-field measurements with a high resolution have become widespread. That's why we leant on these new possibilities to develop an experimental method enabling to access a full-field measurement of both kinematical and thermal fields of a same zone at the grains scale.

## 2. EXPERIMENTAL SETUP

### 2.1 Full-field measurements

Thermal fields are grabbed thanks to an infrared camera equipped with a high magnification lens whose spatial resolution is 30µm/pixel, corresponding to an observation zone of 9.6 x 7.2 mm². An image correlation technique [4] computes kinematical fields from images captured by a CCD camera. On this camera, a high magnification lens and extension tubes allow us to reach a spatial resolution of 6.5µm/pixel which corresponds to a working zone of 8.9 x 6.7 mm².

### 2.2 Fully-coupled measurements

Realizing fully-coupled measurements induces several technical constraints. First the thermal properties of the material such as conductivity and diffusivity must be adapted to the acquisition frequency of the infrared camera in order to get the thermal data before it is spread within the sample by conduction effects. Hence an austenitic stainless steel AISI 316L, widely studied in the laboratory, was chosen. Moreover a heat treatment was performed on this steel in order to get a mean grain size of 100µm ensuring several pixels of the cameras within a grain. Then a crucial point on which relies these fully-coupled measurements is the coating applied on the sample. Image correlation technique is based upon the computing of a moving speckle. Thus, black and white paint is usually applied on the sample to simulate a speckle. Infrared measurements however need the surface to be dark and having a homogeneous emissivity close to 1. These two types of requirements appear to be opposite. Thus, a special coating was developed, which is compatible with both techniques requirements at the concerned mesoscopic working scale. As a result the method which has been set up gives the possibility to perform fully-coupled mechanical and thermal full-field measurements at the mesoscopic scale

## 3. FIRST RESULTS

The experimental setup described above has been used during a uniaxial monotonous tensile test performed on AISI 316L stainless steel. Figure 1 illustrates the axial strain field measurement at the end of the macroscopic elastic domain (left) and in plasticity regime (right).

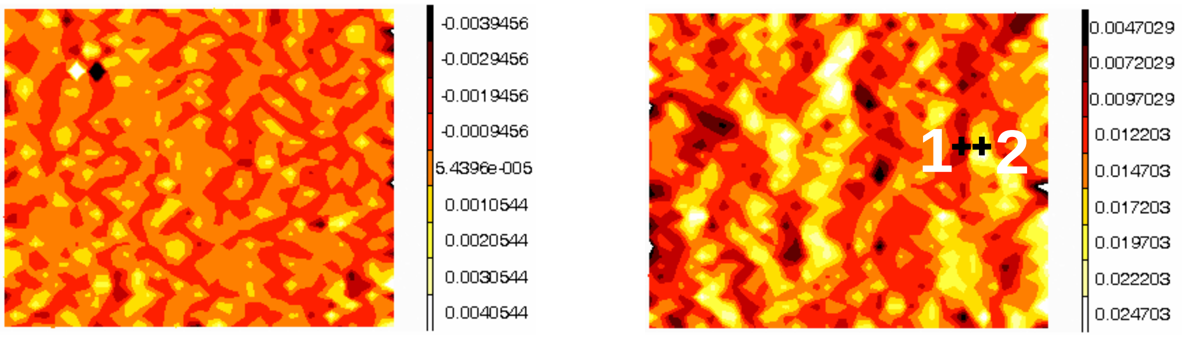

**Figure 1- Full-field strain measurements at the end of the macroscopic elastic domain (left) and in plasticity regime (right)**

One can make the following observation about the mechanical heterogeneous response of the material : whereas point 1 and 2 are very close together (see figure 1, right), point 2 shows a higher strain level under plasticity than point 1. The figure 2 shows the thermal response of the two neighbouring points of the figure 1. The curve is extracted from the thermal fields grabbed during the test. The first dashed line indicates the time at which the first strain field of image 1 was captured, the second dashed line corresponds to the time at which the strain field of image 1 was captured, during plasticity.

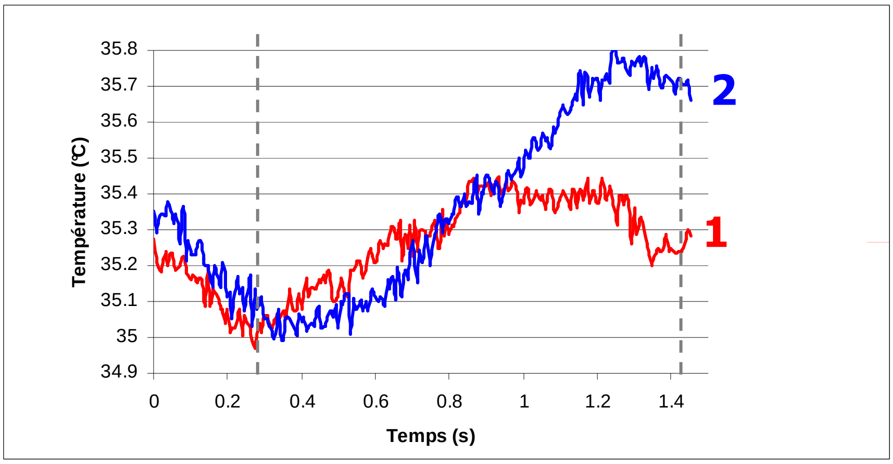

**Figure 2- Thermal responses of two neighbouring points of the figure 1**

The thermal response of these two points confirms that different mechanical local behaviours are linked to different thermal behaviours. Point 2, which undergoes a higher plastic strain rate, is the one whose temperature is higher. As a result, the technique we made use of enables to investigate the behaviour of AISI 316L at the scale of the damage and of the crack initiation during a tensile test as it has been presented as well as in low cycle fatigue, which is under progress.

## 4. REFERENCES

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