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# Local assessment of residual stresses in a metal using FIB-DIC-FE: application to two-phase austeno-ferritic alloys

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## Abstract

The presence of high residual stresses in additively manufactured metals is a well-known phenomenon. It is an unavoidable consequence of the interactions between high energy inputs and metallurgy involved in the processing, causing the development of irreversible strain mechanisms to accommodate the thermally induced internal stresses. As for other processing techniques involving high temperatures and metallurgy, these residual stresses must be considered with great concern as they can significantly affect the mechanical behavior (fracture, fatigue) of the produced part. Their magnitude can be measured on a millimeter scale with conventional techniques (e.g. X-Ray Diffraction), but this only provides an indication of the average state of stress in a highly heterogeneous context -both from the point of view of the microstructure and from that of the stress field.

The FIB-DIC method (1) is based on the removal of matter by micrometric Focused Ion Beam machining and Digital Image Correlation measurements from Scanning Electron Microscopy pictures to evaluate the 2D strain state resulting from the local relaxation of residual stresses. SEM enables to select the position and the shape of the machining operation and to collect the images provided to the DIC algorithm. The Finite Element method, by reproducing the operation of FIB machining in the microstructural context of the experiment, provides the mean to relate the measured relaxation strains to the local internal stress field being relaxed during machining. The generalization and automation of this FIB-DIC-FE method could lead to the possibility of mapping and quantifying multiaxial residual stresses at the intragranular scale of a metal alloy, considering the grains and their orientation in the vicinity of the machined grain.

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In this work, a robust experimental protocol was developed to optimize the experimental parameters (machining, speckles, imaging, image processing, etc.) and applied to austeno-ferritic alloys. This specific alloy has a microstructure consisting of a few hundreds of micron-size grains. It is suspected that one phase induces stresses in the other, which affects the alloy ageing rate (2). The FIB-DIC method was applied in order to measure the residual stresses in both phases, as well as the potential gradients within the grains. The experiment is also coupled with Finite Elements modelling to consider the local properties anisotropy influenced by the crystalline orientation of the grains. Finally, the results are compared to the values obtained by X-ray diffraction, enabling the capabilities of the FIB-DIC method to be assessed.

(1)A. M. Korsunsky, M. Sebastiani, and E. Bemporad, "Focused ion beam ring drilling for residual stress evaluation," *Mater. Lett.*, vol. 63, no. 22, pp. 1961–1963, 2009, doi:10.1016/j.matlet.2009.06.020.

(2)J. Renaux, "Influence de l'austénite et des impuretés sur le vieillissement thermique de la ferrite des aciers inoxydables austéno-ferritiques," 2024.