Experimental report

15/10/2016

Proposal: 1-02-167 **Council:** 10/2014

Title: Residual stress measurements on Ti6Al4V samples produced by additive manufacturing with an integrated structural health monitoring system

Research area: Engineering

This proposal is a new proposal

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Samples: Ti6Al4V

Instrument	Requested days	Allocated days	From	To
SALSA	6	6	16/10/2015	22/10/2015

Abstract:

The objective of this work is to measure residual stresses on Additive Manufacturing (AM) Ti6Al4V samples produced by laser metal deposition with an integrated structural health monitoring system. It is important to mention that there have been no previous neutrons measurements on that kind of samples. This work is a part of a research project funded by an SBO Project of the Agency for Innovation by Science and Technology (IWT) of Belgium, where a new concept, the so-called effective structural health monitoring (eSHM) system has developed. The basic physical principle of the system is checking the absolute fluid pressure changes in a 3D network of capillaries or cavities that are integrated with AM techniques in the interior of a part made by AM. A pressure change in the capillary indicates the presence of a crack. Within this project, the residual stresses of 4-point-bending fatigue samples will be measured and compared with FE simulations results by other collaborators of the project. Furthermore, the samples will be subjected in 4-point-bending fatigue tests.

Residual stress measurements on Ti6Al4V samples produced by laser metal deposition with an integrated structural health monitoring system

Abstract:

During this investigation, we measured residual stresses on additively manufactured (AM) Ti6Al4V samples that were produced by laser metal deposition (LMD). The samples had an internal cavity or else capillary which served as an integrated structural health monitoring system. This investigation was a part of a research project where a new concept of "effective structural health monitoring system" developed. Residual stress is one of the main parameters in additively manufactured specimens that can affect the fatigue response of a structure. The main objective of this investigation was to measure the residual stresses around the capillary region since it is important to ensure that the capillary has no effect on the crack nucleation during fatigue.

Main part:

In AM of metals, complicated residual stresses tend to be blocked into the parts during the building process, due to the thermal gradients encountered during solidification. The presence of residual stresses causes deformations or crack formation in LMD processed components. In order to investigate the residual stress state in our samples, we measured in total three samples of LMD Ti6Al4V by means of SALSA instrument. One sample without capillary, one with capillary (Ø 1 mm) and one with capillary (Ø 1 mm) and autofrettage. The autofrettage process applied in order to improve the fatigue life of the current specimen and compare it with the sample without the autofrettage. One of those samples is shown in fig.1 with the dimensions and the measurement regions. The total time of measurements was six days and the intension was to create stress maps that could help us to identify the residual stress distribution. In addition to those three samples, measurements on d0 samples were also conducted. It is of high importance to know the residual stress distribution on these samples especially when they are subjected in 4-point-bending fatigue testing.

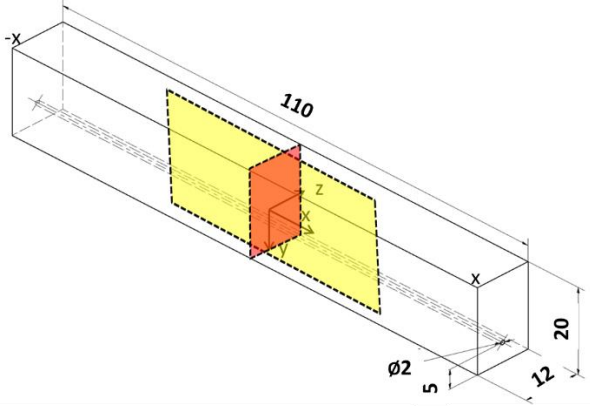

Figure 1. Three dimensional representation of the four-point bending specimen that was used for this study. The dimensions of the sample and the integrated straight hollow channel are in mm.

For the measurements we used a gauge volume of 1.5 mm × 1.5 mm × 1.5 mm and the (400) reflection of a bent perfect silicon crystal monochromator was used. The wavelength that was chosen during the measurements was equal to 1.806 Å. For the two samples with the capillary, 27 points were measured in total on the yellow cross-section (see fig.1, yellow plane) and 18 point on the red cross-section (see fig.1, red plane). On the sample without capillary, 63 points were measured on the yellow cross-section (see fig.1, yellow plane) and 18 point on the red cross-section (see fig.1, red plane). The measurement time was 20 min per measurement point. For the X and Y direction, the strains were calculated based on the $\{20\bar{2}1\}$ reflection ($2\theta = 95.7^{o}$). However, the $\{20\bar{2}1\}$ peak was not present during the measurements of the Z direction. Instead, the $\{10\bar{1}3\}$ reflection ($2\theta = 86.2^{o}$) was selected. In order to improve the peak-fitting

and to avoid the background noise of the measurements, a background function was generated based on the current peak measurements.

Summary:

Figure 2 shows the residual stress distribution of the red cross section of the sample that was subjected in the autofrettage process. It is depicted that the 21 measurement points (shown in red) were not sufficient in order to define a stress map with good resolution. The analysis indicated that six days were not enough in order to produce stress maps with a fine mess for the three samples.

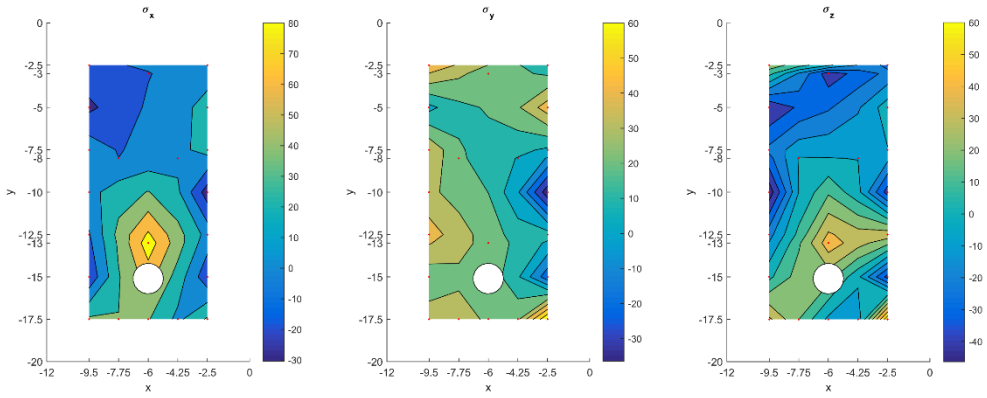

Figure 2. Residual stress distribution (X, Y and Z) of the autofrettaged sample with the integrated capillary.