Experimental report

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Proposal: **1-02-272**

Council: 4/2019

Title: Effect of the residual stresses oncyclic behavior of additively manufactured Ti-6Al-4V

Research area: Materials

This proposal is a new proposal

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Samples: Ti-6Al-4V
Ti-6Al-4V heat treated1
Ti-6Al-4V heat treated2

Instrument	Requested days	Allocated days	From	To
SALSA	4	3	12/07/2019	15/07/2019

Abstract:

The freedom of design of Additively Manufactured laser beam melting parts allows a more organic design using thinner, weight saving structures. The high temperature gradients during the LBM process introduce residual stresses (RS) into the produced parts. Non-optimized scanning procedure high RS can result in cracking and distortion of the produced part even during fabrication. Therefore, to achieve advance mechanical performance, stress-relieving heat treatment has to be performed. It has been reported in that the conventional heat treatment, which is applied to forged and cast Ti-6Al-4V, does not lead to expectable results. Therefore, heat treatment optimization for LBM is required. This study aims to understand the influence of RS and heat treatment on low cycle fatigue behavior in LBM specimens of aerospace alloys Ti-6Al-4V.

Experimental report (proposal 1-02-272)

Effect of the residual stresses on cyclic behavior of additively manufactured Ti-6Al-4V

This study aimed to understand the influence of residual stress and heat treatment on low cycle fatigue (LCF) behavior in Laser Powder Bed Fused (LPBF) specimens of aerospace alloys Ti-6Al-4V. Therefore LCF Ti-6Al-4V (cylindrical) samples in as-built (AB) conditions and after two different heat treatments (HT) were investigated. Initially, three samples were planned to be studied, however, only 3 days of beamtime were granted (instead of 4 proposed days), thereby only two samples (AB and HT) were considered.

The diffraction angle 2θ=78° for 103-α Ti reflection was used. Sample was mounted on the cradle, which allowed to rotate sample around the longitudinal axis. Initial plan of experiment (investigation of surface-bulk transition with small gauge volume) has been changed due to not sufficient diffracting signal during first test. This problem was attributed to spatially resolved crystallographic texture of the material, which was not observed during prior characterization by X-ray diffraction. Therefore, the primary collimator has been changed to 2 mm x 2 mm, instead of 0.6 mm x 2 mm, and three strain components were measured in the bulk of the samples (final set up is shown in Fig. 1). Due to heavy time constrains the change of secondary optic was not possible. However, even with bigger gauge volume it was not always possible to measure at every location due to texture issue, therefore prior the measurements Ω or φ scans were performed to find the angular position with the highest intensity. Thus, for example, the axial strain component deviated by 4° from the drawing in Fig. 1c. Overall, 5 points across AB sample diameter and 4 points across HT sample diameter were measured in three orthogonal directions. The counting time of 45 mins was set.

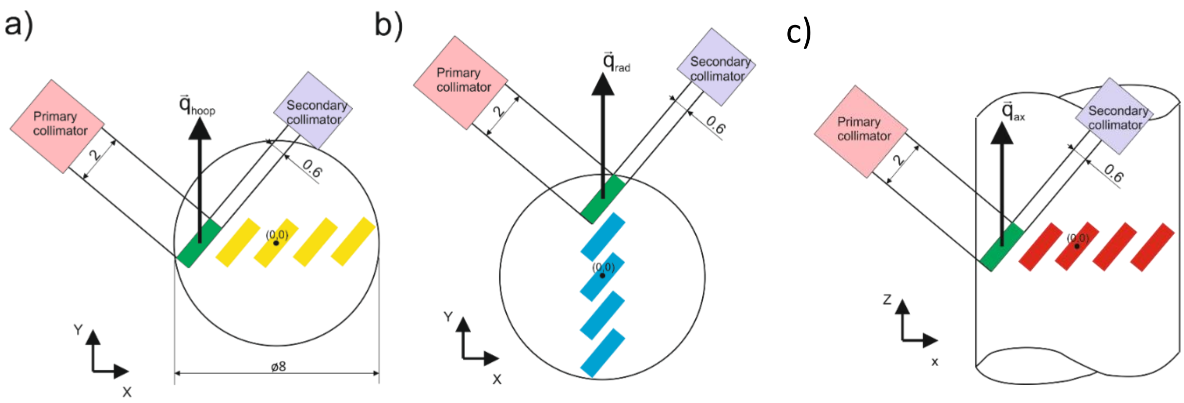

Fig. 1. Schematic set-up of the sample on SALSA beamline for a) hoop component; b) radial component; c) axial component.

The obtained diffractograms were fitted using LAMP software using Gaussian function. In order to calculate strain from lattice spasing, the d_0 reference is neccesery. For this purpose, a cube 3x3x3 mm^3 cut from sister samples was measured. However, d_0 value only shifts the residual stress, thus, the stress ranges could be always compared. To calculated stresses the diffraction elastic constant obtained experimentally (by *in-situ* tensile test) were used.

Resulting residual stress profiles across the sample diameter for three orthogonal directions in AB and HT sample are shown in Fig. 2. Thus, the stress range for AB sample is larger than for HT (320 MPa vs. 200 MPa), this fact supports the idea of the stress relaxation after heat treatment. Unexpectedly, a similar tendency was observed for both samples: the stress profiles are asymmetric across the diameter. The additional investigation by destructive techniques (e.g., contour method) will be performed to explain the assymetry of the stress profile.

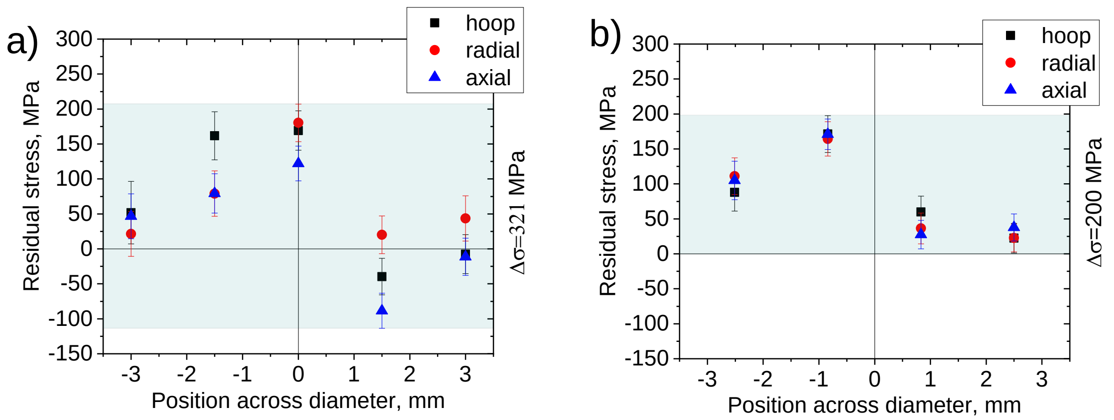

Fig. 2. Residual stress profile across the sample diameter for a) AB, b) HT.