EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Reports supporting requests for additional beam time

Reports can be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Inter-relationships Among Build Height, Residual Stresses, Distortion and Properties of Ti-6Al-4V Tubes Manufactured by Laser Metal Deposition (LMD)	**Experiment number**: MA4218
Beamline:	**Date of experiment**: from: 15/09/2018 to: 20/09/2018	**Date of report**: 20/02/2019
Shifts: 6	**Local contact(s)**: Thomas Buslaps	*Received at ESRF:*

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Aims of the experiment and scientific background

Component distortion is caused by residual stresses which arer a function of build-height. Understanding this relationship allows for prediction of optimium build-height giving minimal distortion of thin walled Ti6Al4V LMD components. The original objective of this study was to investigate the relationship between build height and through-thickness residual stresses. However, to ensure that sufficient data was acquired for each height, measurments were limited to the tube thickness centerline. This still allow quantification of the influences of residual stresses on the dimensional stability of the tube sections. The LMD tubes were manufactured with a 40 mm inner diameter and a wall thickness of 4 mm. Sample height varied from 10 mm (14 layers) to 70 mm (110 layers) and consited of four Series 1 (machined) and four Series 2 (as-built) samples (Figure 1).

Figure 1. Set-up of both Series 1 & 2 samples on ID 15.

Manufacturing of Laser Metal Deposition(LMD) samples

Eight samples of varying height (see Figure 1) were manufactured for the ESRF experiment. An aditional specimen was prepared for d_0 measurements as seen in Figure 2.

Figure 2: d_0 specimen machined by EDM wire cutting and set-up on beam line.

Tubes were manufactured using a 4.0 kW Trumpf laser cell which allows control of process parameters, i.e. laser power, focus position, laser scanning speed and bed rotational speed, thus providing a reliable and repeatable process. The LMD are given in the Table below:

Titanium Grade 5 ASTM (Ti-6Al-4V) powder			
Power	1900W	Powder mass flow rate	8 g/min
Traverse Velocity	0.01 m/s	Powder Carrier gas	Helium
Nozzle angle	8° in retreat direction	Shielding gas	Argon
Nozzle standoff	12 mm	Powder particle size	40 - 100 µm
Layer height	0.6 mm	Powder particle shape	Spherical
Laser spot size	3 mm		

The Experiment:

After setting up the two energy dispersive detectors, a set of tube specimens were mounted as shown in Figure 1 and measurements made in both the hoop and axial directions. Figure 3 shows a typical diffraction pattern in the α-phase of the Ti-6Al-4V alloy fitted with GSAS after conversion to virtual angle dispersive diffraction. This allowed access access to additional peak profile functions. The peaks are clearly separated and easy to fit, but as evident in Figure 3, some peaks are missing due to the large grain size. This issue provided the rationale for choosing energy dispersive diffraction measurements. The resultingstrain maps are currently being processed to provide residual stress data that can then be related to specimen height and to the influence of machining. These residual stress maps will eventually be related to the dynamic load performance of LMD Ti-6Al-4V tube components and correlated with the LMD microstructure in an ongoing PhD project.

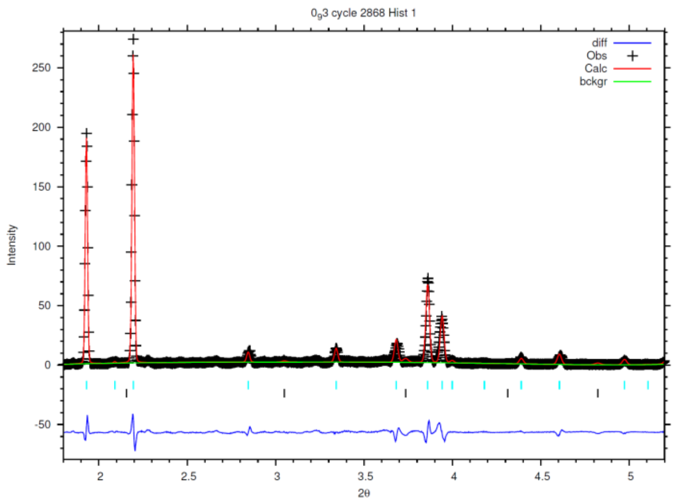

Figure 3. Typical energy dispersive virtual 2θ diffraction spectrum for the Ti-6Al-4V LMD tube, fitted using GSAS.