Experimental report

26/11/2021

Proposal: 1-02-295 **Council:** 4/2020

Title: The residual stress state at internal interfaces produced by direct energy deposition type additive manufacturing process

Research area: Materials

This proposal is a new proposal

Main proposer: Alexander EVANS

Experimental team: Thilo PIRLING
Sandra CABEZA

Local contacts: Sandra CABEZA

Samples: Fe-17.9Cr-12.3Ni-2.1Mo-1.1Mn-0.3Si-0.1N

Instrument	Requested days	Allocated days	From	To
SALSA	4	4	19/05/2021	24/05/2021

Abstract:

Additive manufacturing processes such as direct energy deposition describes the layerwise production of components or repair of existing structures. Both the new manufacture of either components manufactured by AM or a combination of conventional wrought or cast with AM will involve the production of interfaces between fully cooled material and newly deposited AM material. At these interfaces, the cooling behaviour is different compared to continuous deposition. These differences have been observed to create discontinuities of the residual stress fields which should be studied further to understand their implication on applications. This proposed experiment aims to characterize with higher spatial resolution the residual stress state at these interfaces and the influence of process parameters on their generation and their stability during heat treatment.

The residual stress state at internal interfaces produced by direct energy deposition type additive manufacturing process

Preliminary experimental report (proposal 1-02-295)

Experiment requested 4 days, awarded 4 day
Experiment scheduled in period 19/05/2021-24/05/2021 (20/05/2021-24/05/2021)
Experimental team: Alexander Evans (Virtual), Thilo Pirling (ILL), mail-in experiment due to CoVID-19

Aims

The aim of this proposal is to study the effect of process parameters on the residual stress changes at interfaces created in DED with high spatial resolution. The second aim is to characterise the stability of these interfacial residual stresses following a typical stress relief heat treatment of 450°C/4h.

Experiment

The scope of the experiment was reduced and modified for the following reasons;

- Point density of measurements increased to capture strain changes near internal interfaces

The specimen for the as-built and heat-treated condition were modified for manufacturability (to avoid structure collapse during printing) to pyramid type geometries with approximate nominal geometry of 40x40x75mm for two specimens (as-built and heat treated) and 40x40x105mm compared to 30x30x60mm. D0 combs (dimension of combs were 3x3mm cross section) were extracted from similar twin specimens printed with the same parameters. The layer thickness between DED/DED interfaces was approximately between 20mm-35mm depending on the specimen. The wrought/DED interface was not systematically studied as the focus was placed on the DED/DED interfaces. 2x samples were produced using 2 different process parameter sets. 1x specimen was be heat treated at 450°C/4h to observe any stress relaxation at these interfaces. Using a neutron wavelength of approx. 0.15 nm, the Fe-311 diffraction line will be recorded for strain measurement at 2Θ around 86°. The gauge volume will be defined using 2mm x 2mm x 2mm collimators. The step size was originally planned at 3mm. However, following the first measurements, it was agreed with the Instrument Scientist to increase the pitch of measurement points to better resolve the gradients in the vicinity of the internal interfaces. It was subsequently increased to between 1-3mm pitch. Strains were measured in 3 orthogonal direction to calculate triaxial residual stresses in the 2x as-built specimens. Due to the increase in point density in all specimens, only the strains and d0 in the building direction were able to be measured in the heat-treated specimen within the allotted measurement time. This strain component was chosen based on previous work indicating that this is the dominant direction in DED structures and therefore would allow

for an assessment of the efficiency of the heat treatment to relax residual strains. In addition, due to the increased time required for the higher point density, it was decided to focus on the orthogonal strains rather than measuring additional strain components to determine the principal stress direction and magnitude.

Initial results

The final analysis corrected for d0 are currently being performed. An illustration of the residual strain data is shown in Figure 1 for the transverse component of specimen PAG 7 (as build). The final data will be reported in the final experimental report following the completion of the analysis including position sensitive d0 corrections.

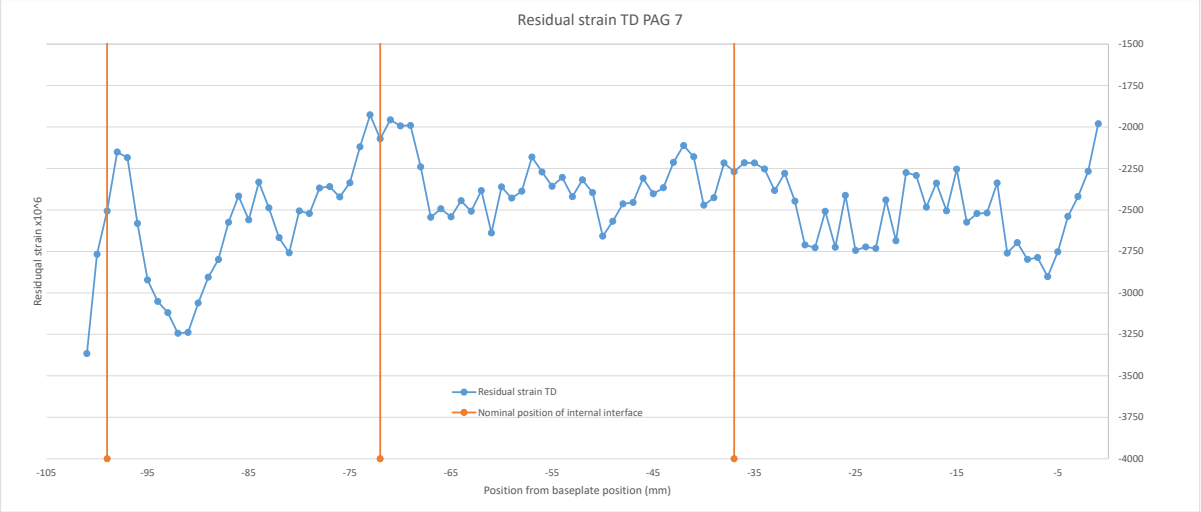

Figure 1. Bulk strains for the as build condition of specimen PAG 7 in the transverse direction from the baseplate (Position 0mm). The nominal position of the internal interfaces are shown with orange lines.

Outcomes

In summary, the experiment is considered successful in terms of measuring the strain gradients associated with internal interfaces within DED structures. The experiment will also provide an insight into the change d0 as function of build height to permit the calculation of the bulk residual stresses. Publications are already in planning for the effect of internal interfaces on the residual stress state in DED structures, such as those which can exist during hybrid manufacturing or repair technologies.