Investigating residual stresses and SCC in additively manufactured stainless steel by neutron diffraction

INDUSTRIAL PILOT PROJECT

THE INDUSTRIAL CHALLENGE

Residual stress and porosities are known to have a detrimental effect on the mechanical and corrosion properties of any stainless-steel (SS) parts made by Powder bed fusion – Laser Beam (PBF-LB, SLM) technologies. During the PBF-LB process, it is not possible to avoid stress and pore formation in the built part. To ensure the satisfactory material performance of SS parts made by PBF-LB it is therefore common practice to undergo a series of post stress and porosity removal operations. Hot Isostatic Pressing (HIP) is one of the most effective material densification processes and is often included in the PBF-LB manufacturing chain. Quintus Technologies is a world leader in high-pressure technology and has strong expertise in the HIP treatment of SS. To reduce the manufacturing cost and shorten the lead time of PBF-LB parts, it is desired to combine the stress relaxation operation with other treatments, such as the HIP. However, the effect of such post-processing combination possibilities on stresses is still not known.

WHY USING A LARGE SCALE FACILITY

Because of the resulting rough as-built surfaces, the anisotropic stress state and microstructure, it is challenging to characterize stress in PBF-LB built SS by conventional analytical techniques such as hole drilling. Neutron diffraction/imaging and high-energy synchrotron x-ray diffraction (XRD) are the only techniques that allow to non-destructively measure/map macro and micro residual stress/strain at any part of a large SS sample, including all important strain components.

HOW THE WORK WAS DONE

Austenitic SS (316L) samples with size 20x20x40 mm^3 were manufactured using the PBF-LB and HIP treated by Quintus. The residual strain was then mapped in all parts of seven samples (including a reference), using both neutron Bragg-edge imaging setup at the IMAT and neutron diffraction setup at the Engine-X beamline at ISIS (UK). The measurements were performed by Dr. G. Burca and J. Kelleher from ISIS. To capture the stress gradient at the near surface (7-150 µm) with improved special resolution, complimentary synchrotron XRD-based stress measurements were performed at P61A beamline at the Petra III synchrotron in Germany. The residual strains were evaluated by examining the diffraction peaks and Bragg-edge shifts.

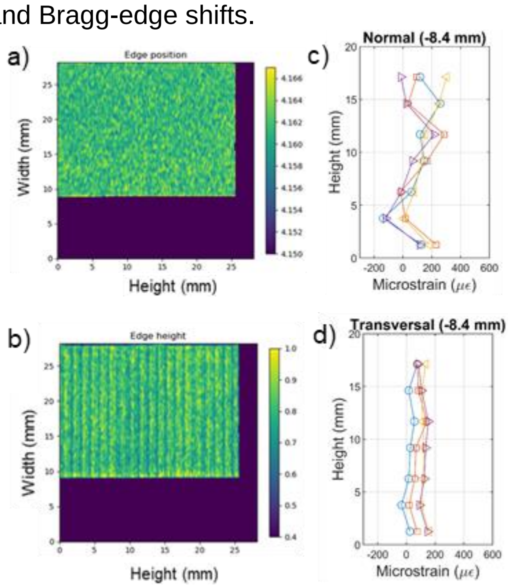

Figure 1.a) and b) display the variation of Bragg-edge and height in given sample area from neutron imaging; c) and d) shows the variation of normal and transversal strains from neutron diffraction.

THE RESULTS AND EXPECTED IMPACT

All measurements show similar results, and the work display the advantage and disadvantages of different neutron and synchrotron-based stress measurement techniques for characterizing phase and grain-specific residual stress in large metallic materials at different length scale. The results showed that it is possible to remove or reduce the stress in SS that originated from PBF-LB printing only by adjusting HIP condition without adding another stress relaxation operation (Fig.1). High-quality data and detailed strain maps from the project were also used for validation of a previously developed numerical model aimed to simulate the stress in SS built by PBF-LB related to the subsequent HIP. Results of the work are expected to deepen Quintus' understanding which might help the industry to cut one step out from the PBF-LB manufacturing pipeline.

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