INDUSTRIAL PILOT PROJECT

In-situ SAXS and WAXS synchrotron Xray diffraction investigations of additive manufacturing parts for Ni-base superalloys.

THE INDUSTRIAL CHALLENGE

Gas turbine components produced by powder bed fusion laser beam (PBF-LB) additive manufacturing are gaining large industrial interest. Component and turbine performance can be significantly improved if features such as lattice structures, surface modifications and novel cooling design concepts can be produced. However, final properties of Ni-based superalloys required to produce these parts rely on post processing steps. For Ni-based superalloy components produced by PBF-LB technique, heat treatment (HT) steps in terms of hot isostatic pressing, solution heat treatment and ageing are required to tailor the mechanical properties. The group of superalloys which meet the mechanical properties, i.e., precipitation hardened superalloys, are difficult to process by powder bed fusion techniques. Gamma-prime precipitation and built-in residual strain and stresses play roles in a phenomenon called strain-age cracking. It is already known that high temperature exposure during post-processing will trigger strain age cracking. Improving alloy processability requires investigation of these phenomenon at relevant conditions in situ.

WHY USING A LARGE-SCALE FACILITY?

Home lab Xray diffraction (XRD) measurements have shown residual tensile stresses exceeding 900 MPa in alloy 247. This indicates the importance of reducing stresses in the HT cycle. The phase transformations during heating can be observed from dilatometry experiments, where various temperatures, heating and cooling rates can be applied. However, only the high brilliance and beam penetration at high energy synchrotron source coupled with in-situ dilatometry capabilities would allow for monitoring the introduction of residual stresses or the secondary phase precipitation in-situ, at a time scale necessary.

HOW THE WORK WAS DONE

Material of the Ni-base alloy 247 type was PBF-LB printed at Siemens Energy AB in Finspång. From these prints hollow dilatometer samples (OD 4mm / ID 2mm x 10mm) were prepared by electric discharge machining. Samples were produced as hollow in order to improve the signal response. Combined wide angle (WAXS) and small angle (SAXS) scattering were performed at the P07 (High Energy Materials Science) Beamline of Helmholtz-Zentrum Hereon and DESY at Petra III, Hamburg. P07 also allows in-situ thermal cycles (programmed to mimic the industrial processes used in the tempering steps of the PBF-LB production step). Seven thermal cycles of the material were done in order to study precipitation and growth of γ', dissolution of the precipitates together with the associated stress development. during heating and cooling.

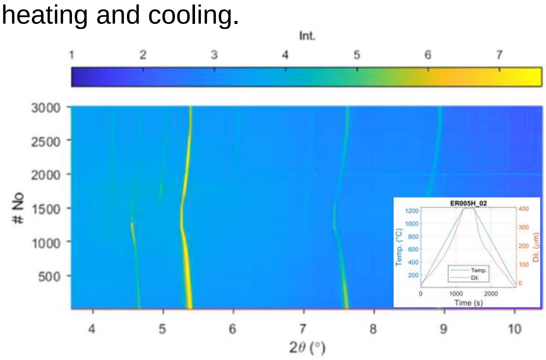

Figure. During the thermal cycling diffraction patterns were recorded and analyzed based on precipitation and micro stress evolution.

THE RESULTS AND EXPECTED IMPACT

The performed in-situ experiments gave valuable insights in the response of thermal cycling on stress development. The measurement results are, however, not conclusive and separate test series for SAXS and WAXS would improve data quality for a better determination of the development of stresses. Especially continued WAXS experiments are needed for a better understanding of how the thermal treatments can be optimized for improved component quality.

"The use of LSI in-situ techniques will help industry R&D to optimize process parameters in the AM field."/ Håkan Brodin, Siemens Energy AB

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