INDUSTRIAL PILOT PROJECT

Investigating strain age cracking in precipitate hardening nickel-based alloys using in-situ diffraction and tomography

THE INDUSTRIAL CHALLENGE

The next generation precipitate hardening nickel-based superalloys will be used for producing more efficient and lighter jet engines. This will not only reduce the fuel consumption but the amount of NOx emission as well. However, strain age cracking (SAC) caused by heat treatments or reheating in multi-pass welds is of major concern when designing high-performance components from precipitate hardening nickel-based alloys. The problem becomes even more pronounced for alloys that precipitate rapidly and have an elevated volume fraction of precipitates. Some alloys are even treated as "non-weldable". Hence, it is of high interest to increase knowledge and improve lifetime predictions for components susceptible to strain age cracking.

WHY USING A LARGE SCALE FACILITY

Strain age cracking is a phenomenon that appears where multiple length scales are active simultaneously at elevated temperatures, however the main mechanism is not known. The capacity of synchrotron facilities where it is possible to perform high-temperature in-situ experiments that can be analyzed for multiple length scales is vital in increasing the understanding for the phenomenon. These kinds of multiple length scale in-situ experiments are hard, or if possible, at all, to do using traditional investigation techniques such as SEM or TEM.

HOW THE WORK WAS DONE

Experiments designed to understand the strain age cracking mechanisms were done at the Swedish materials science beamline, P21.2, at the Petra III synchrotron, Germany. Small Angle X-ray Scattering (SAXS), 3D X-ray Diffraction (3DXRD), and tomography were utilized in the experiments during the in-situ heating and loading of the sample using a for the project developed compact load frame. This setup covers length scales from the nm-range to the mm-range. From the results, it is possible to study the misfit strains that occur during the precipitation, but also the change in stiffness of the grains because of heat treatments. The scripting to perform the analysis of the tomography data was done by Emanuel Larsson, Lund University, and the 3DXRD analysis by Johan Hektor, Malmö University.

THE RESULTS AND EXPECTED IMPACT

The conclusions drawn from the SAXS, 3DXRD and tomography data are that an increase in grain stiffness because of precipitation is not an alone mechanism for SAC to occur. Rather it is suggested that several mechanisms at various length scales are responsible for the phenomena.

Prior to finding a suitable sample that ends within a good signal for 3DXRD analysis, numerous manufacturing techniques, and sample preparation techniques were tested out before a good signal was achieved. This means that the deformation of grains from a turning operation is detrimental for the single-crystal diffraction needed in the 3DXRD analysis. The experimental results will serve as support in a larger campaign where the aim is to understand the SAC phenomenon using a combination of experiments and modeling efforts by, e.g. crystal plasticity modeling.

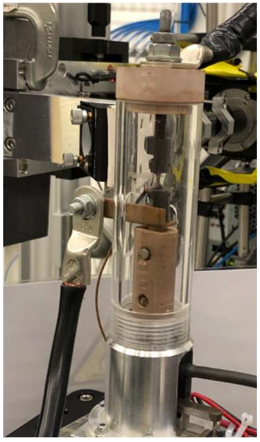

Figure. Compact load frame used to for the in-situ loading and heating 3DXRD, SAXS and tomography experiments. Joule heating are utilized for heating the sample.

"This project has increased the overall knowledge about synchrotron facilities and its possibilities to perform chall-enging in-situ experiments at various length scales" /Ceena Joseph, Materials Application Engineer, GKN Aerospace Sweden AB

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