INDUSTRIAL DEVLOPMENT PROJECTS

Neutron diffraction residual stress measurements in automotive components with complex geometry

THE INDUSTRIAL CHALLENGE

Residual stresses are important for automotive components, as they affect the structural integrity. Accurate stress measurements at critical locations are required for both process validation and component life calculations.

WHY USING A LARGE SCALE FACILITY

Currently, Volvo Group use in-house X-ray diffraction (XRD) for residual stress measurements, but this technique suffers from geometrical constraints, as well as limited spatial resolution and penetration depth. This causes limitations when addressing local stresses in samples with complex geometry, or in locations deep within metallic parts. For the largest components even high energy synchrotron-based XRD cannot reach sufficient penetration depths, and cannot offer the required cubic or near-cubic gauge volumes necessary for mapping of internal gradients with arbitrary stress states. Neutron diffraction (ND), on the other hand, allows for non-destructive measurements of stresses in small internal near-cubic gauge volumes deep within metallic components. ND can thus be used to capture local stresses and stress gradients inaccessible to laboratory methods or synchrotron-based XRD.

HOW THE WORK WAS DONE

Within the project, two representative case studies were performed, aimed at demonstrating the capability and versatility of neutron diffraction for local residual stress measurements in complex automotive components:

(1) The weld toe in post-processed fillet welds between two 10 mm thick 100x200 mm aluminium alloy plates, and in particular differences in stress level and spatial stress distribution from two different surface treatments (shot-peening and high-frequency mechanical impact [HFMI] treatment).

(2) The internal locations along lubrication channels in case-hardened truck crank shafts made of case-hardened steel.

Measurement were performed at the SALSA strain scanning instrument at Institut Laue-Langevin (ILL) Grenoble. Specific attention was given to the near surface stresses, which require careful correction of so-called “pseudo stresses” which arise when the neutron gauge volume is only partially immersed in the sample. SALSA and the associated instrument scientist team have well-established correction methods available for this. To access all three principal stress components the samples had to be rotated, remounted and remeasured in three different orientations. The small gauge volume (0.5x0.5x2 mm^3) combined with pseudo-stress corrections allowed spatial gradients to be resolved while maintaining sufficient statistics for reliable stress measurements.

THE RESULTS AND EXPECTED IMPACT

Stress measurements for both cases were successfully completed. The effect of shot-peening and HFMI treatment on the residual stress profiles at the aluminum weld toe (case 1) revealed clear differences between the stress levels and affected depths between the two surface treatment methods. This is being combined with fatigue testing at Volvo to provide input to the continued process development and optimization. The measured stress profile at the crank shaft cooling channel (case 2) is currently being implemented by Volvo in finite element models to allow fatigue life calculations to account for residual stresses.

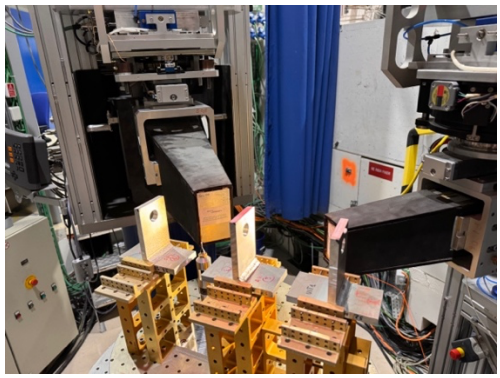


Figure. Welded aluminum samples mounted for stress measurements at SALSA, ILL.

Contacts: Krste Cvetkovski – Volvo Group Trucks Technology, krste.cvetkovski@volvo.com
Magnus Hörnqvist Colliander –Chalmers University of Technology, magnus.colliander@chalmers.se

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