

## Study of Residual Stress Field in a Stainless Steel Bead-on-Plate (BOP) Simulation Benchmark Sample

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**Background:** Welds in reactor pressure vessel and surrounding heat exchangers are the primary sources of structural integrity problems in nuclear power plants. Weld joints are susceptible to original fabrication defects which can grow during service. Welding also introduces a complex residual stress field which has significant influence on the crack propagation behavior. Therefore, improved understanding is needed of the residual stress surrounding welds and how they can be modeled accurately. The presented work aimed to study the 3-dimensional residual stress field in a single weld bead on a rectangular stainless steel specimen. The work carried out forms a part of an international round robin exercise of parallel measurement and simulation in order to develop a residual stress validation benchmark.

**Specimen Manufacture:** A single weld bead of 60 mm nominal dimension was laid on the top surface of a AISI 316L type stainless steel base plate of 180×120×17 mm dimension. Fig. 1 shows the bead-on-plate photograph and schematic measurement points along the AA' longitudinal-normal plane. The bead was laid by an automatic TIG welding process.

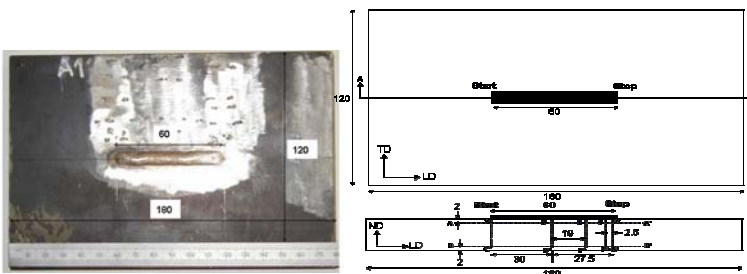
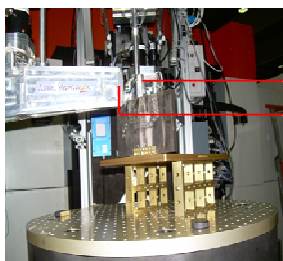


Fig.1- BOP specimen photograph & measurement points

**Measurement Technique:** The measurements were carried out at the SALSA diffractometer at the ILL reactor neutron source. A monochromatic neutron beam of 1.494 Å was used to measure the internal strain using the crystallographic lattice plane spacing as an atomic strain gauge. The d-spacing of the {311} crystallographic plane was measured as it is known to follow the macroscopic strain behaviour for FCC lattice systems. Strain was measured in the longitudinal, transverse and normal strain directions and stress is then calculated using Hooke's law with the assumption that the measured directions are the principal strain directions. Fig. 3 shows the SALSA measurement set-up and table 1 gives the important parameters



Parameter	Value
Wave length (λ/Å)	1.494
Crystallographic Plane	{311}
Gauge vol. (mm <sup>3</sup> )	2×2×2
Measurement time	
Longitudinal (min)	10
Transverse (min)	10
Normal (min)	10-30

Table 1 – Measurement parameters

Cubes of 3×3×3 mm dimension machined out from the parent material were used as a stress free reference material.

**Results :** Stress calculated 2 mm below the bead-on-face along line AA' and 2 mm above back face along line BB' is shown in fig. 3.

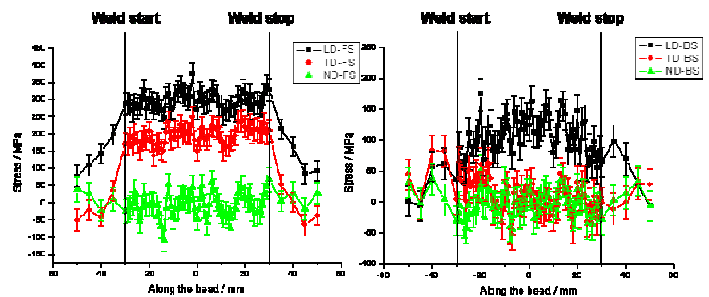


Fig. 3 – 3-dimensional stress distribution. Stress contour maps plotted in the principal directions with the result obtained from the different through thickness lines measured along the AA' plane

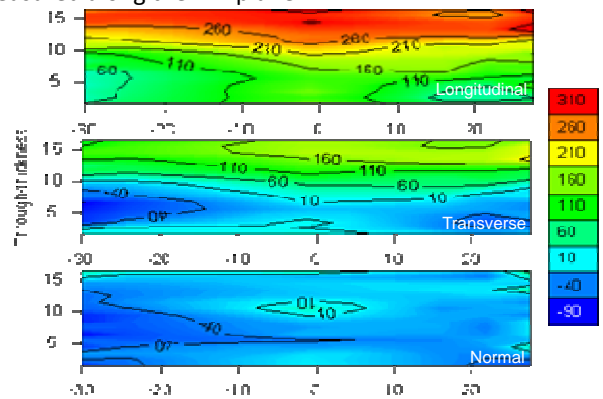


Fig. 4 – Through thickness stress maps

### Conclusion:

- The 3-dimensional stress distribution in a BOP was accurately characterised.
- For validation, data compared with measurements carried out at pulsed neutron source show excellent agreement on the stress distribution.

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