

Experimental report

11/09/2025

Proposal: 1-02-368

Council: 4/2023

Title: Effect of transformation induced plasticity on residual stresses: application to the welding repair of ferritic steel

Research area: Materials

This proposal is a new proposal

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Samples: ferritic steel plate

Instrument	Requested days	Allocated days	From	To
SALSA	8	6	04/12/2023	10/12/2023

Abstract:

he proposed experiments aim to firstly, measure the distribution of residual stress generated in a 30 mm thick ferritic steel plate with one weld bead in order to calibrate a thermo-metallurgical-mechanical (TMM) simulation (with a focus on the TRIP effect on the residual stresses); secondly steel plates with up to 3 weld beads made according the TBW technique. The position and welding parameters of each weld beads have been defined with the help of thermal TMM. This will allow us to observe the evolution of residual stresses along the regular TBW procedure. The measurement of these residual stress fields will be related to the physical phenomenon under investigation: LTT and TRIP. These experimental data are crucial for validating our TMM simulations and for proposing a multipass welding procedure that may reduce the high tensile stresses in the welded part.

Effect of transformation induced plasticity on residual stresses: application to the welding repair of ferritic steel

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1 Summary of the neutron diffraction campaign

This campaign aimed to characterize the residual stresses in several welded specimens in order to evaluate the effect of the welding procedure named : “temper bead welding” (TBW) on both residual stresses and phase transformations (martensite in particular). These TBW techniques produce beneficial metallurgical transformations during in-situ modification or repair of thick pressure vessel equipment [1,2]. The specimens are made in P355NL steel of size 300x100x30 mm³. Seven specimens were investigated with 1, 3, 4, 5, 6 and 7 welds (welds 6 and 7 were deposited on top of 1 to 5). Specimens with 3, 4 and 5 welds are shown in figure 1.

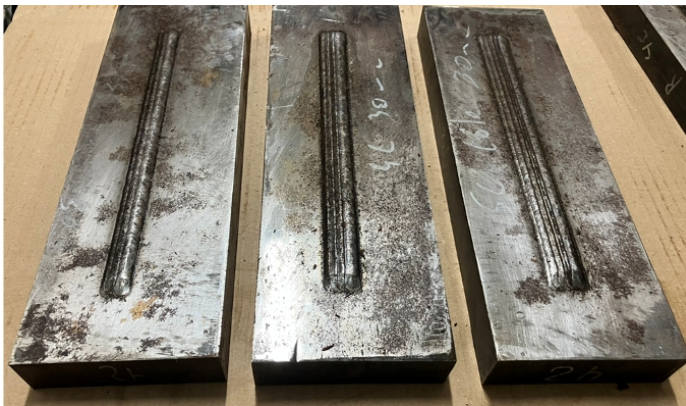


Figure 1 : P355 specimens with 3, 4 and 5 welds.

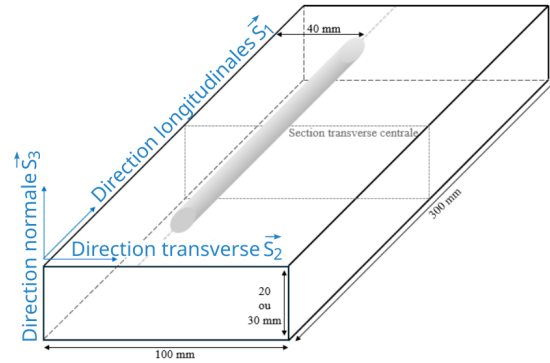


Figure 2 : the studied section is in the middle of the specimen.

2 Neutron diffraction settings and measured section

The following parameters have been set on SALSA diffractometer :

- neutron wavelength was set to 1,66 Å,
- incident diffraction angle : 92,8°,
- cristallographic plane : Fe-211
- gage volume : 2 x 2 x 2 mm.

3 “Measured” micro-strain and computed residual stresses in specimens

Firstly, dedicated specimens (combs-like) were used to determine the appropriate reference diffraction angle. This value was measured to 89,849° for the three diffraction angles : longitudinal, transverse and normal.

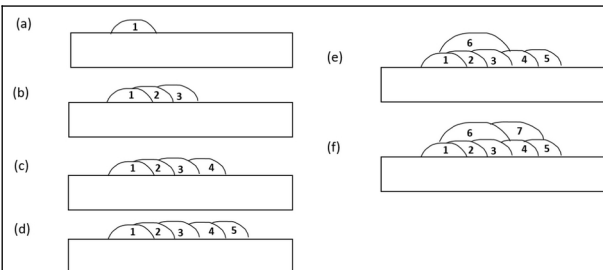


Figure 3 : welds deposition order.

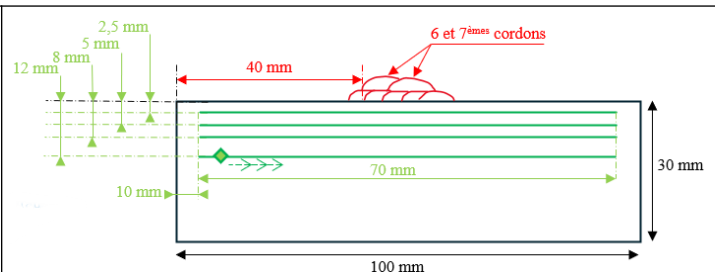


Figure 4 : position of measured lines (green) with neutrons.

Secondly, we always assumed that the three directions : longitudinal, transverse and normal as shown in figure 2 are the principal directions even with the specimens with several weld beads. The section of interest is located in the middle of welded specimen (about 150 mm). The order of deposition of the welds is displayed in figure 3.

The first bead is always started at 40 mm from the left side as presented in figure 4. The length of the welds is about 220 mm .

Neutron measurements were done along 4 lines positioned at different left. 20 points of measure were located along the 2 lines close to the weld / parent interface. Only 11 points was measured on the top deepest lines. The three strain components were measured along the longitudinal, transverse and normal directions. Stress fields were reconstructed from these measurements. The longitudinal and transverse stress fields are reported in figure 5 and 6.

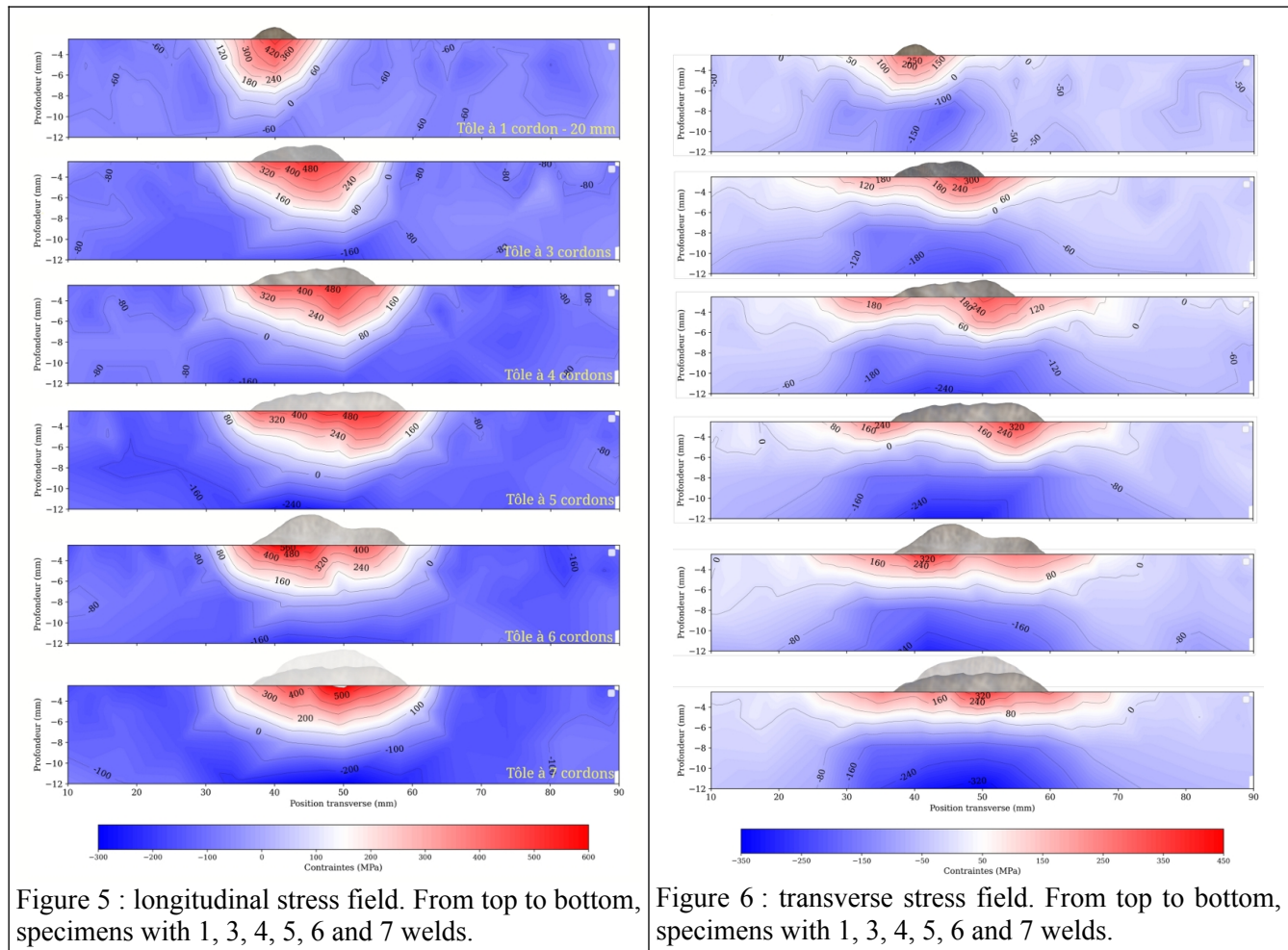


Figure 5 and 6 report, respectively the longitudinal and transverse stress fields reconstructed from micro-strains at the 4 lines of neutron measurements. The zone under the weld: fused and heat affected zones are both tensile. The longitudinal stress is almost twice the transverse in the tensile zone. The core of the parent develops compressive stresses for longitudinal and transverse components. The compressive stress is quite important for the transverse stress due to the long size of the welds with regards to specimen length and thickness.

4 Conclusion

This neutron campaign was totally successful. All the specimens have been characterized without loss of data and with an excellent accuracy (± 15 MPa for the worst case). These measurements are highly valuable for the setting up of thermal-metallurgical and mechanical simulations as it will help understanding the effect of phase transformations in the development of residual stresses.

- [1] WTIA, 2006, *Temper Bead Welding*, TGN-PE-02, Welding Technology Institute of Australia.
- [2] Lundin, C. D., Wang, Y., and Batten, G., 2005, "Literature Survey of Half-Bead, Temper-Bead, Controlled Deposition Techniques for Improvement of Fabrication and Service Performance of Cr-Mo Steels," Weld. Res. Counc. Bull., (499).