Experimental report

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Proposal: **1-02-182**

Council: 4/2015

Title: Triaxial residual stress states for multipass welds processed using novel LTT filler materials under variation of the alloy composition

Research area: Engineering

This proposal is a new proposal

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Samples: steel

Instrument	Requested days	Allocated days	From	To
SALSA	5	5	20/11/2015	25/11/2015

Abstract:

Low transformation temperature (LTT) filler materials offer an attractive alternative to cost intensive postweld treatments to generate compressive residual stresses over the weld joint in the course of the welding procedure itself. To study this stress built-up triaxial residual stress analyses will be carried out for the three mean stress components for multipass weld lines processed by MAG welding. The project aims at the determination of local phase-specific residual stress distributions introduced in multipass welding with respect to the local amount of retained austenite. Neutron residual stress analysis will be carried out at the weld centerline on a path in depth direction to determine the depth distribution within the weld. Further a path over the final pass in a distance of about 2 mm to the nominal surface will be measured. Three different LTT filler materials will be analyzed. Further, the residual stress built up in a multipass weld will be studied for different conventional weld fillers in combination with a final pass of LTT filler material. By this means, the suitability of LTT filler materials to be applied for repair welds of high strength steel will be studied.

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Triaxial residual stress states for multipass welds processed using novel LTT filler materials under variation of the alloy composition

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Welding using novel low transformation temperature (LTT) filler materials is an innovative approach to mitigate detrimental welding residual stresses without cost-intensive post weld-treatments. The alloying concept offers an attractive alternative to generate compressive stresses over the complete weld joint in the course of the welding procedure. The volume change induced by the transformation affects the residual stresses in the weld and its vicinity. LTT fillers exhibit a rather low transformation temperature and therefore a martensitic transformation, which leads to a strong volume expansion, resulting in compressive residual stresses in the weld area. The resulting high strength of these filler materials makes them potentially applicable to high-strength steels as well as for a large amount of requested repair works in low strength steel structures. Due to the local generation of compressive residual stresses in the weld line by means of a delayed martensite transformation a significant enhancement of the cold cracking resistance of highly stressed welded components can be expected. However, the currently used LTT alloys mostly based on the Cr/Ni-alloys (e.g. 10%Cr + 10%Ni) show a relative high susceptibility to hot cracking phenomena. For this reason the alloying composition was altered and Mn-containing LTT are going to be established as filler materials for high strength steels. In this respect the residual stresses induced during welding using different welding parameters must be analyzed non-destructively to optimize the welding process on bases of weldability and stress engineering.

The aim of this experiment was to investigate the effect of different LTT-alloys on the residual stress state after welding of multilayer joints using the SALSA instrument. The samples are steel cuboids of high strength fine grained construction steel S960 with dimension 30 mm × 100 mm × 50 mm (W × L × H). The multipass weld was processed by MAG welding in a machined U-shaped grove using 3 successive weld passes.

Measurement setup:

We used neutron diffraction at the SALSA instrument with the area detector set to approximately $2\Theta = 80 - 96°$. In this position the α-Fe (211) peak at approximately $2\Theta = 90°$ using a wavelength $\lambda = 1,64$ Å was studied for the three mean stress components (longitudinal, transversal and normal to the weld direction). Radial collimators were used on the primary and secondary side (FWHM = 2 mm). For the longitudinal measuring direction the gauge volume was defined to $2 \times 2 \times 2\ mm^3$ and in transversal and normal direction to $2 \times 2 \times 10\ mm^3$. In Figure 1 the experimental setup is shown. Neutron residual stress analysis was carried out at two different LTT weld filler materials with mean compositions (i) 10wt%Cr/10wt% Ni and (ii) 7wt%Mn/11wt%Cr. For comparison and final assessment of the results similar measurements were carried out using a conventional weld filler material. Residual Stress depth profiles were determined at the centerline of the weld pass at six measuring positions from 2 – 12 mm depth. Further, for the 10wt%Cr/10wt%Ni weld filler material a total of five different paths in depth direction with a distance of 3 mm from each other were measured to obtain a residual stress map of the whole weld joint. For the measuring positions additional scans at stress relieved cuboids, sectioned by EDM from similar samples, were carried out. These measurements were needed for the local d_0-determination and thus are necessary for the residual stress calculation.

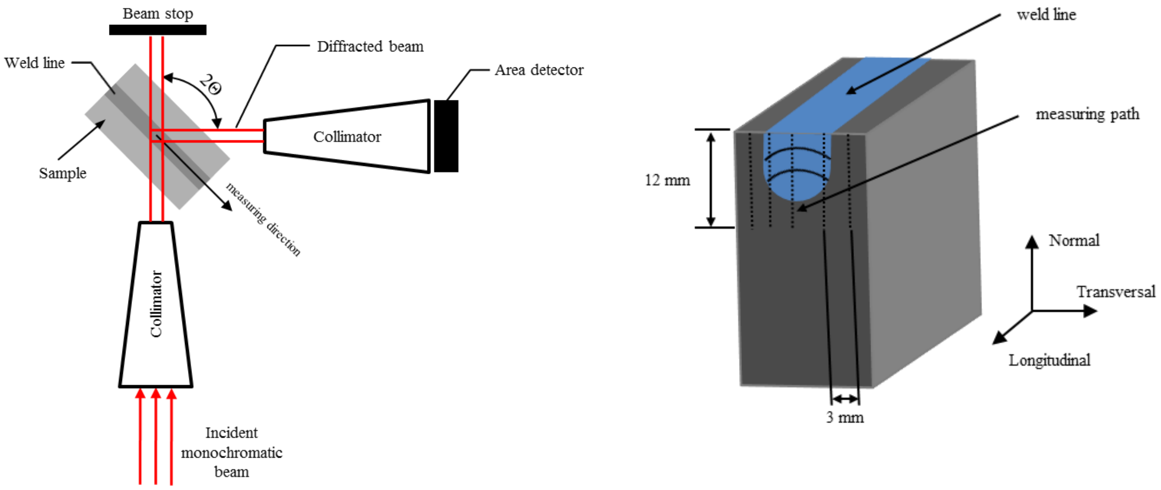

Figure 1: *Left: Schematic illustration of the experimental setup for determination of the α-Fe(211) peak exemplarily in longitudinal direction to the weld line, Right: Multipass weld sample with 3 weld passes. The five measuring paths for the residual stress map are shown.*

Preliminary results

Figure 2 displays the measured longitudinal interplanar lattice spacing distribution and its associated stress relieved lattice spacing values (determined from stress relived cuboids for identically welded samples) in the weld for the 10%Cr/10%Ni LTT weld filler material.

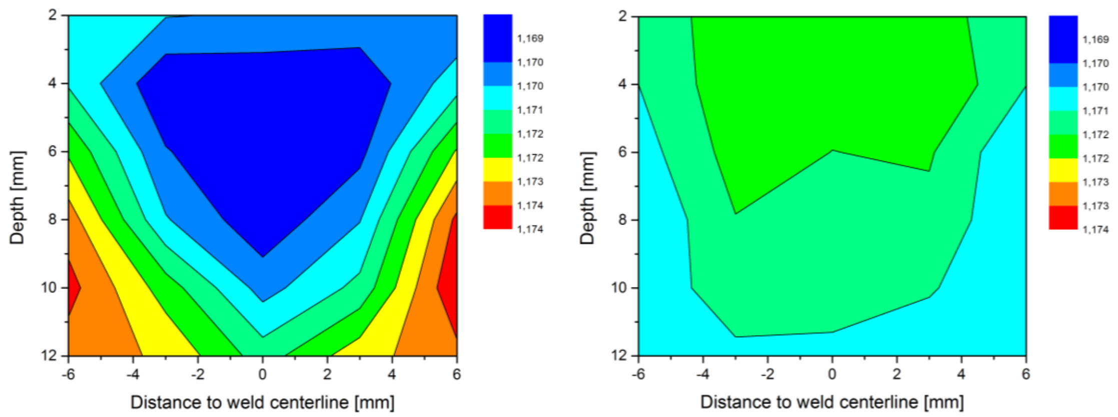

Figure 2: *Left: Determined interplanar lattice spacing (Å) in longitudinal direction for the 10%Cr/10%Ni LTT weld filler material, Right: reference interplanar lattice spacing (Å) from stress relieved cuboids sectioned from a similar 10%Cr/10%Ni LTT sample.*

The LTT-alloy weld displays smaller interplanar lattice spacings d compared to the reference data d_0 in the weld centreline and heat affected zone (Distance to weld centerline ± 3 mm). In the base material (Distance to weld centerline ± 6 mm) higher values for d than for d_0 are measured. These data indicate that compressive residual stress is present in the weld joint and the heat affected zone, while balancing tensile residual stresses are expected in the base material. Same observations can be made in the centreline of the 7wt%/11wt%Mn LTT-alloy. In the conventional weld filler material minor differences between d and d_0 are observed. Therefore it appears that compared to the LTT-alloys less compressive residual stress is generated during the welding of the conventional filler material. Hence, the first results clearly confirm the effectiveness of the LTT idea. So with this experiment a data basis has been established to calculate the final three dimensional residual stress states for different weld filler materials. However, complementary analysis indicated that the inhomogeneous crack network being present in the LTT welds might affect the d_0 values. Hence, to assess this effect, prior to calculation of the ´final´ residual stress results complementary analyses of the stress independent lattice parameter is currently determined by means of lab X-ray residual stress analysis on identical weld lines. The data will be compared to the neutron results and finally meaningful data for the reference interplanar spacing will be determined and used for residual stress analysis. The first data evaluation already indicates that the results are very helpful to explain the residual stress generation and the crack susceptibility in novel LTT welds. Currently, the beamtime results will be prepared for publication in a relevant journal.