NFL THE STUDSVIK NEUTRON RESEARCH LABORATORY

Experimental report

Instrument: REST	Experiment Number: 154

Residual Stresses in Welded Specimens of High Strength Steel and the Effects of TIG Dressing and Mechanical Loading

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Preliminary studies of welding residual stresses were carried out in 1996 on a welded and then TIG dressed fatigue specimen of high strength steel. The through thickness distribution of residual stresses, which was presented in NFL's annual report of 1996, showed good agreement with X-ray diffraction measurements at the surface and ultrasonic measurements at the mid-thickness. In the present work, more detailed mappings of residual stress distribution were made in the same specimen and in an as-welded specimen. In addition, the evolution of residual stresses due to the Spectrum Fatigue (SF) loading was followed in both specimens by measuring residual stress after loading to 500,000 (SF 1) and 2 million (SF 2) cycles, respectively. The effect of static loading with 250 MPa tensile stress, corresponding to the peak stress in the spectrum fatigue loading, was also investigated on other two specimens. The aim of the present work, which was involved in an inter-Nordic project concerning spectrum fatigue of improved welded component, was to understand welding residual stresses in high strength steels and to provide accurate stress data for optimising fatigue design of welded structure of high strength steels.

The fatigue specimens under investigation were made from 12 mm thick sand blasted plates of steel DOMEX 590XPE. Two flanges of 140 mm long and 40 mm wide were attached by one-pass fillet weld to the centre of a 80 mm by 700 mm plate, see Fig. 1. By neutron diffraction measurement, residual stress distributions were obtained at three through-half-thickness sections, indicated by letters A, B, and C in Fig.1. While the A-section intercepted the weld toe and the B section was at the edge of the TIG dressing track, the C-section was located at the mid-width of the plate. Using monochromatic neutrons of wavelength 1.76 Å, residual strains were measured with the Fe (211) reflection. The size of the incident beam slit was 2 mm by 2 mm and that of the diffracted beam slit was 2 mm by 40 mm. Small specimens cut from different locations of the plate were used as reference specimens for measurement of the stress-free lattice spacing.

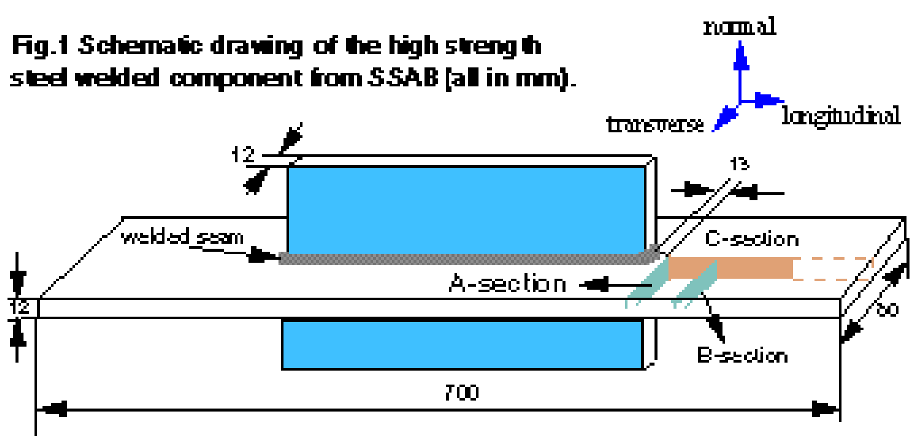

Fig.1 Schematic drawing of the high strength steel welded component from SSAB (all in mm).

Fig.2 (a)

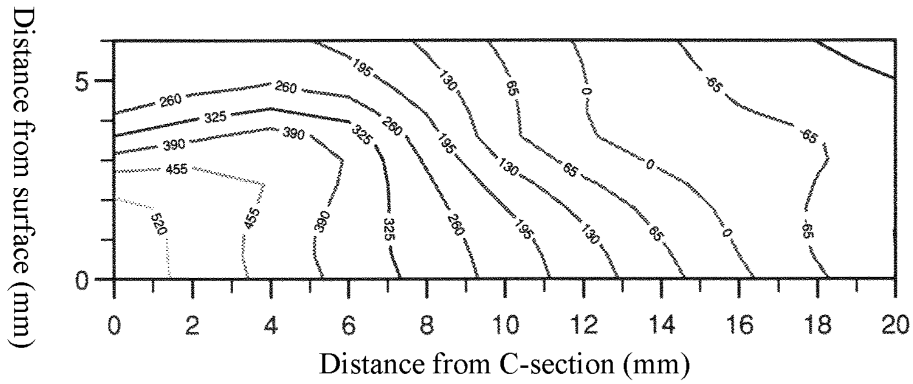

Fig.2 (b)

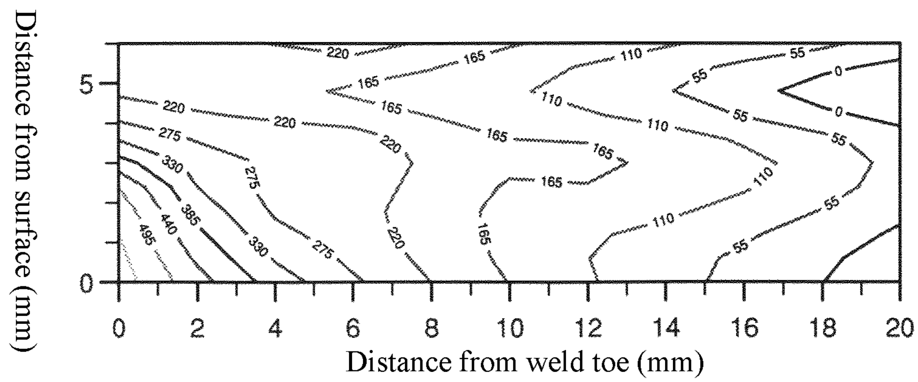

Fig.2 (c)

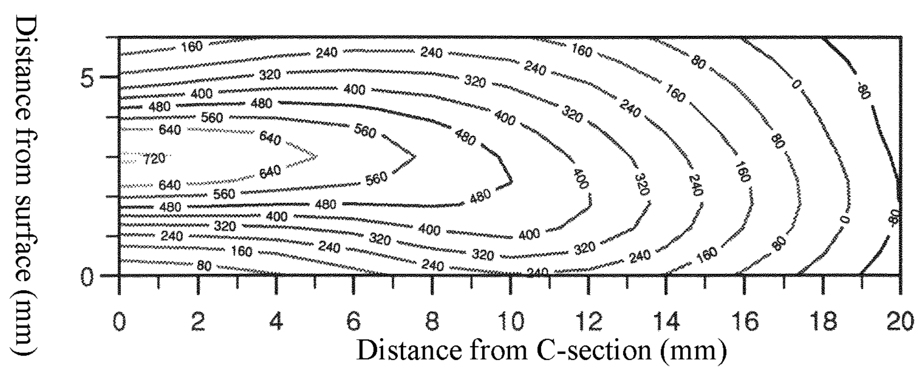

Fig.2 (d)

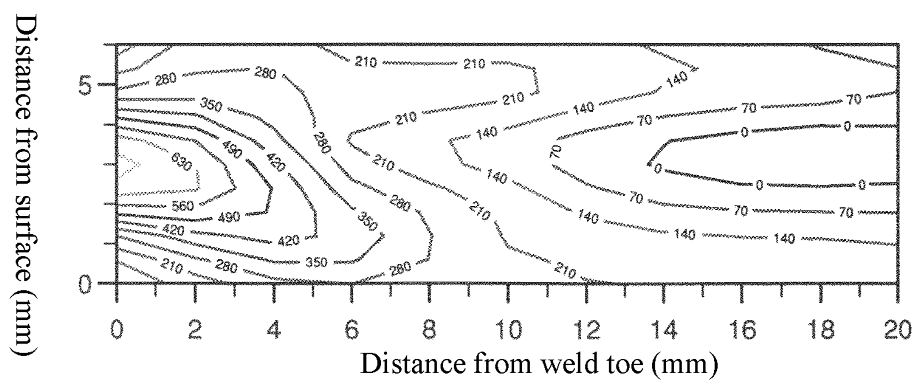

Fig.2 Longitudinal stress distribution in the as-weld (a, b) and in the TIG dressed (c, d) components. (a) and (c) are in A-section. (b) and (d) are in C-section.

Fig.3 (a)

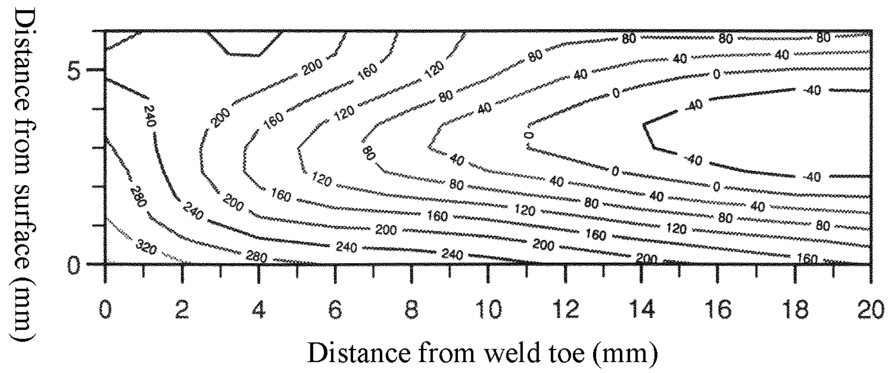

Fig.3 (b)

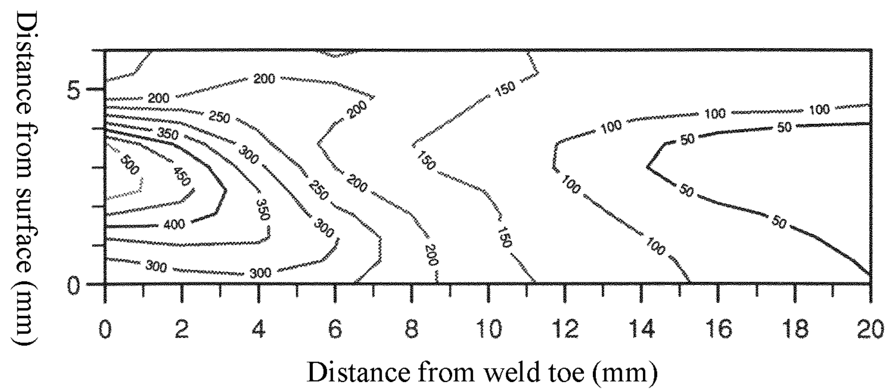

Fig.3 Longitudinal stress distribution in the as-weld (a) and the TIG dressed (b) components after subjected to a static fatigue loading.

Fig.4 (a)

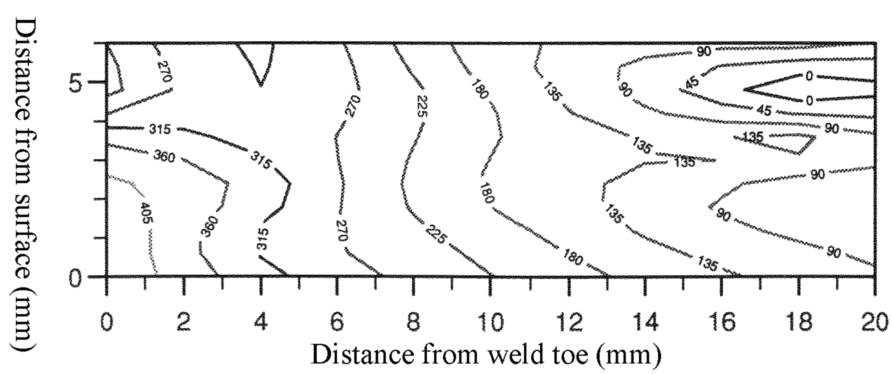

Fig.4 (b)

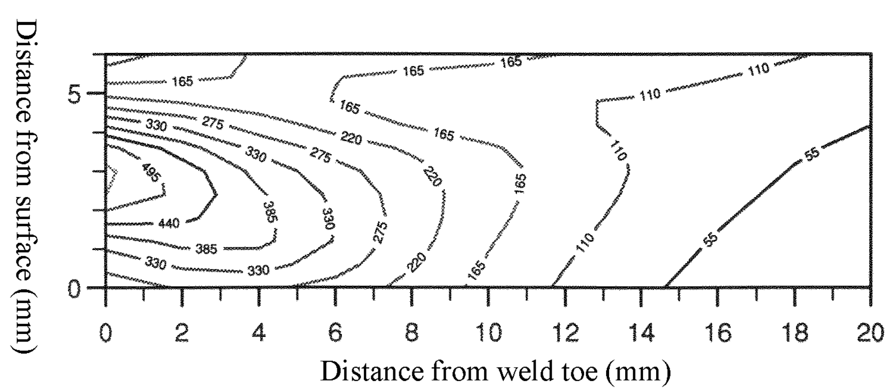

Fig.4 (c)

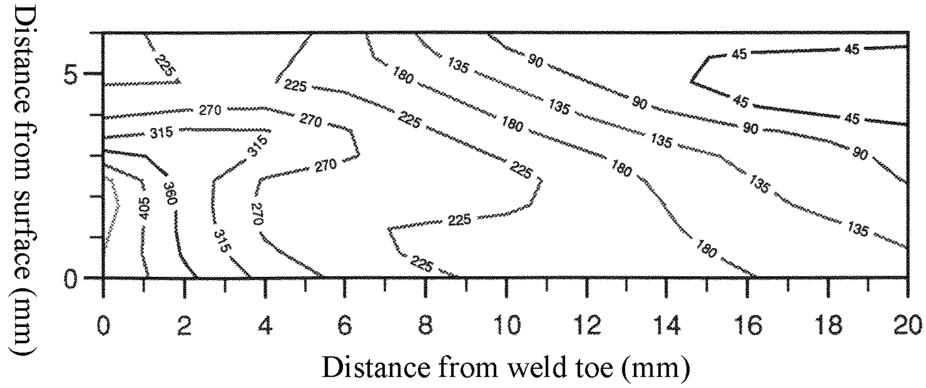

Fig.4 (d)

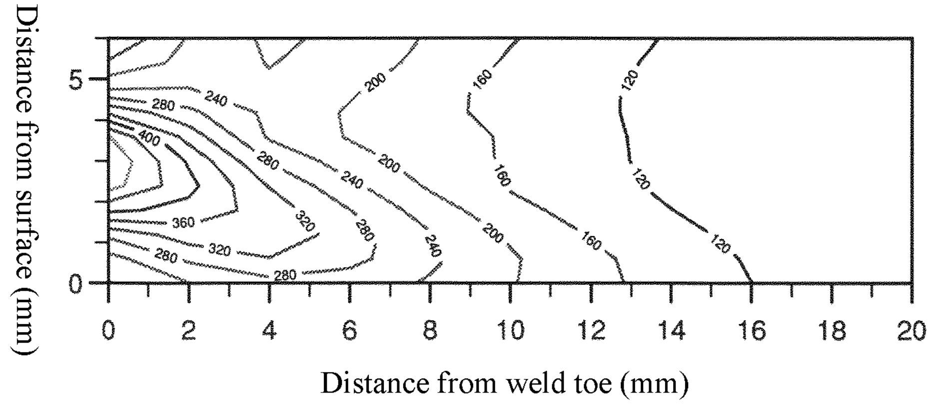

Fig. 4 Longitudinal stress distribution in the as-weld (a, c) and the TIG dressed (b, d) after subjected to the SF 2 loading (a, b) and SF 3 loading (c, d).

Some of the obtained distributions of longitudinal stress were presented as contour plots in Fig.2 to Fig.4. High tensile residual stresses, up to 600 MPa, were found at the weld toe as can be seen in Fig. 2 (a) and (b) for the A and C-sections of the as welded specimen. The application of TIG dressing increased the maximum tensile stress to 750 MPa but at the same time shifted it into the depth of the plate (Fig. 2(c) and (d)). It was also found that mechanical loading had a marked effect on relaxation of the residual stresses. Static loading to 250 MPa decreased markedly the tensile peaks in both the as-welded specimen and the as welded and TIG dressed specimen, see Figure 3. So did the SF loading (Figure 4), with most significant relaxation occurring within the first 500,000 cycles. As the residual stress distributions after static and spectrum fatigue loading are similar, it is reasonably to conclude that the peak loading stress (sum of the applied and the residual stress) was the controlling factor in the relaxation of residual stresses.