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ASYMMETRIC CUTS IN THE CONTOUR METHOD FOR RESIDUAL STRESS MEASUREMENT

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ABSTRACT

The standard contour method is limited to sectioning test components into two symmetric halves. In this study a new approach is developed to deal with asymmetric cuts in the contour method of residual stress measurement. The proposed approach is demonstrated using finite element (FE) simulations and is validated experimentally using a series of asymmetric contour cuts and neutron diffraction measurements.

Keywords: residual stress, finite element method, neutron diffraction measurement, the contour method.

INTRODUCTION

The implementation of the contour method (Prime & DeWald, 2013), (Hosseinzadeh, Kowal, & Bouchard, 2014) comprisescutting the test component in two parts. The created cut surfaces deform as a result of stress relaxation. The out-of-plane displacement of the cut surfaces is measured and used to back-calculate the original residual stresses acting normal to the cut plane that were present in the component prior to the cut. Like any other techniques, there are assumptions and limitations associated with the contour method one of which is that the test component must be sectioned into two symmetric halves about the cut plane. This limits the application of the contour method to simple geometries and the range of locations in a component over which contour method measurements can be made.

In the present work a new approach was investigated to deal with analyzing the measured displacements and back calculating the residual stresses when asymmetric cuts are used for the contour method. First, finite element analysis was employed to design a suitable and well-defined benchmark test specimen, simulate the entire contour method process on the benchmark test specimen using asymmetric cuts and demonstrate the proposed approach.

The designed benchmark test specimens were manufactured. A series of asymmetric cuts were conducted on the benchmark test specimens for contour method measurements. The measured stresses using the new proposed approach for asymmetric contour cuts were validated by neutron diffraction measurements.

RESULTS AND CONCLUSIONS

The benchmark test specimen used in this study was a 200 mm x 250 mm x 6mm plate made with bright steel (designated in British Standard BS 970:1991), autogenously laser welded along a 60 mm x 1 mm slot (Fig. 1a). The FE prediction of the initial residual stress state, weld induced residual stresses, is presented in Figure 1 (b). Figure 1 (a) shows the cut plane at 25 mm from the weld center line. The stresses acting normal to the cut plane in transverse direction are of interest and will be measured with the contour method.

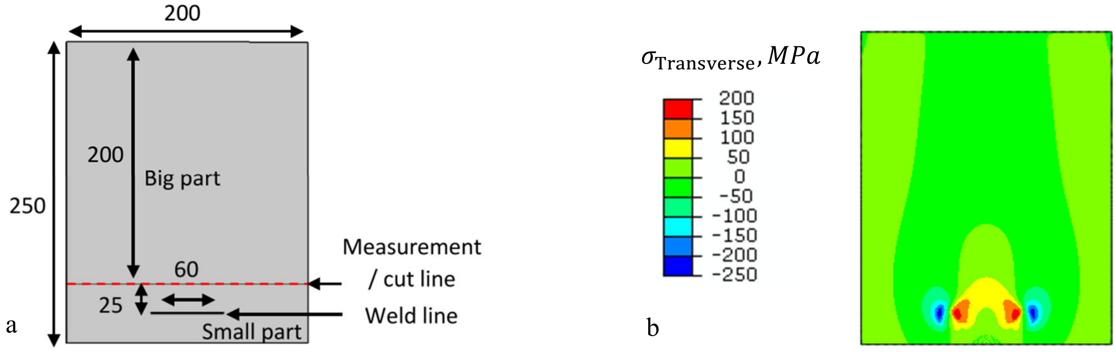

Fig. 1 - The benchmark test specimen, a laser welded plate showing the location of the measurement / cut line. Dimensions are in mm.

The results of neutron diffraction measurements conducted on the benchmark specimen show an excellent agreement with the FE predicted stresses (Figure 2 (a)). The constructed FE model for the benchmark specimen was then used to simulate the entire contour method procedure. The extracted out-of-plane displacements were used to develop a new data analysis and back-calculation of residual stress approach for the contour method using asymmetric cuts. Figure 2 (b) shows that the FE reconstructed contour stresses match closely with the FE predicted weld induced stresses with a root mean square (RMS) error less than 1%.

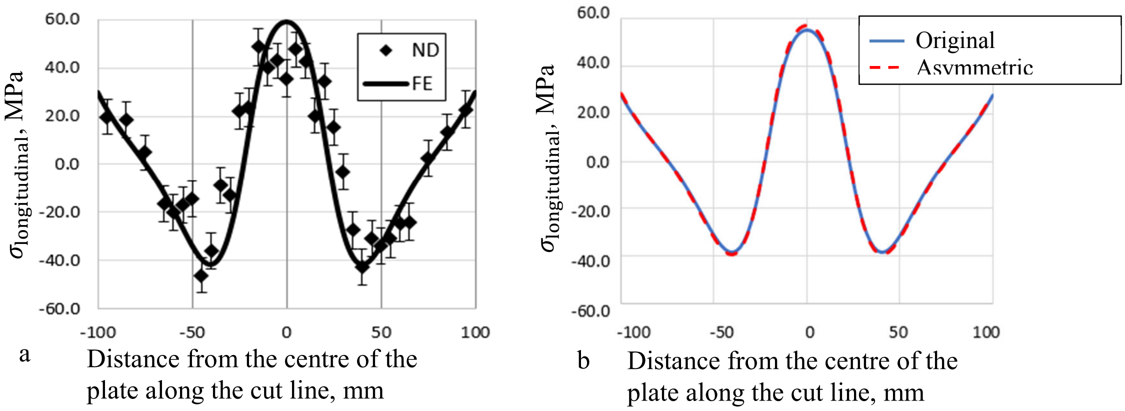

Fig. 2 - (a) Comparison of neutron diffraction stresses with FE predicted stresses, (b) comparison of FE predicted stresses with FE reconstructedcontour stresses. The stress distributions are shown for a line profile at mid-thickness of the plate.

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