Redistribution of the Residual Stresses Generated by a Overload at a High Temperature

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1. Introduction

Residual stresses may be generated by not only welding but also an excessive deformation under an overload, machining or forming. In this study the redistribution of the residual stresses distributions for a T-plate generated by overload at four point T-plate bend beam was compared with those for the welded residual stresses [1,2]. A comparison has been made for the case of plane strain and plane stress for the residual stress profiles and redistributed residual stresses at a temperature of 550°C for up to 10,000. Here the material is 316H stainless steel which is used mainly in advanced gas cooled reactor in the UK.

2. Residual Stresses by Overload

The residual stress profile generated in the T-plate structure under a four point bend overload is shown in Fig.1. The residual stresses can be induced by an overloading and unloading as follows;

- Load step 1 : Apply the concentric forces at two points as shown in Fig. 1 at the locations so that a pure bending may be induced at the mid-part of the T-plate beam.
- Load step 2 : Unload the applied load. Then the residual stresses would be obtained
- Load step 3 : Expose the T-plate structure with residual stresses at a high temperature. In the present analysis, 10,000 hours of hold time was given at 550°C. The redistribution of the residual stresses can be obtained by using a finite element analysis with creep properties for the material of the T-plate. Here the creep properties for Norton's power law suggested in French RCC-MR[3] and the British Energy [4] were used.

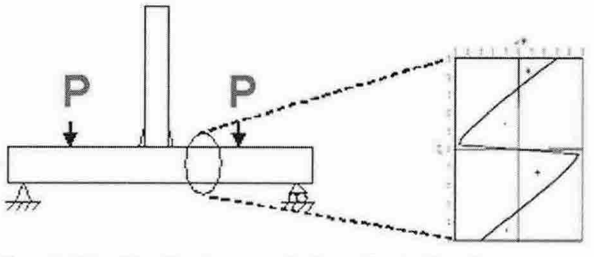


Fig. 1 Residual stresses induced at the beam cross section of the T-plate under an overload

In addition, the T-plate was simplified as a cantilever beam as shown in Fig. 2 in order to generate the residual stresses.

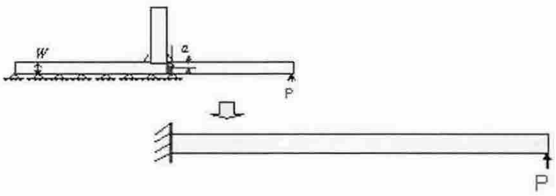


Fig. 2 Simplification of the T-plate as a cantilever beam

The residual stresses generated by an overload for the four point bend beam model(Fig. 1) and the cantilever model(Fig. 2) are shown in Fig. 3 and the calculated results using ABAQUS are shown for the plane strain and plane stress case.

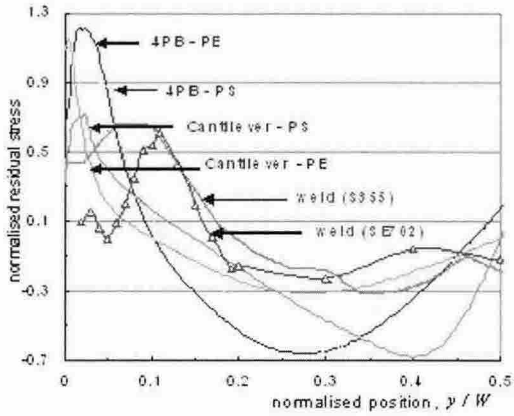


Fig. 3 Simplification of the T-plate as a cantilever beam

It is interesting to see that the profiles of the residual stresses due to an overload are similar to those of the weld residual stresses as shown in Fig. 3. Since the areas of the tensile stress regions for the residual stresses by an overload are smaller than the area of the weld residual stresses in Fig. 3, the comprehensive residual stress profiles suggested in [1] could cover these cases of residual stresses due to overstresses.

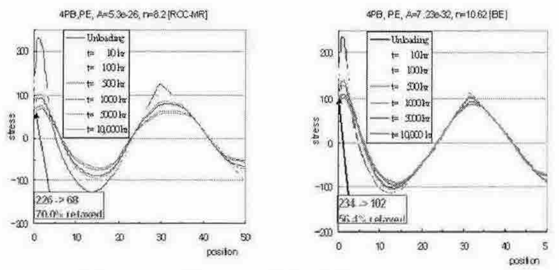
3. Analysis of the Residual Stress Redistribution

The redistribution of the residual stresses due to an overload can be analyzed for each case as follows; First the creep properties for the RCC-MR and British Energy are given below;

$$\varepsilon = A\sigma^n$$

- RCC-MR : A=5.3e-26, n=8.2
- British Energy : A=7.23e-32, n=10.62

The redistribution characteristics of the residual stresses were found as follow



(a) RCC-MR (b) British Energy

Fig. 4 Relaxation behaviour for different creep properties (Four point bend, plane strain)

The redistribution analysis of the T-plate under a four point bending (shown in Fig. 4) was carried out for the many cases covering a plane stress vs. a plane strain, and different creep properties. The exposure time at the temperature of 550°C was 10,000 hours which is slightly longer than one year.

It was shown that the peak residuals stresses for the RCC-MR creep properties relaxed at about 70% while that for British Energy was 56.4% for plane the strain, four point bend(4PB) loads.

The direct comparison of the redistribution behavior for the plane strain vs. the plane stress and creep properties showed that after 10,000 hours of exposure at a high temperature, more relaxations were observed for the plane stress than for the plane strain and for the RCC-MR creep property than British Energy's.

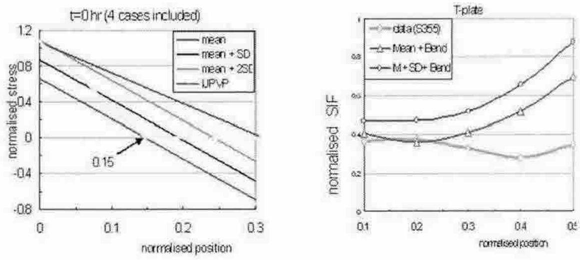


Fig. 5 Statistical analysis data lines and the SIFs for T-plate

A comprehensive residual stress distribution covering a range of welded structures(T-plate, Y-tubular, T-tubular, pipe-butt and pipe-on-plate) and bent pipe was proposed in [1]. Since it was shown that the residual stress distributions induced by a mechanical overload were similar to a weld residual stress, the residual stresses by an overload were added in to the collected data set in [1]. The collected data were analyzed statistically as was done for the range of the data set in [1].

4. Conclusion

Redistribution analysis for the residual stresses induced by an overload was carried out for the T-plate. The residual stress distribution after an unloading was obtained from the ABAQUS analysis for various cases of the plane strain and plane stress for a four point bend model and a cantilever model. The progressive relaxation behaviors for the tubular T-joint are shown in Fig. 11 and Fig.12. The degree of relaxation for each hold time (1,000hr and 10,000hr) shows that the RCC-MR creep properties cause more relaxation for the case of the T-plate. The mean linear regression line, mean + SD(Standard deviation), mena+2SD and Mean+Bend in Fig. 5 shows that the 'mean + SD' line gives better results than the existing design guideline of R6[5] and BS7910[6].

Acknowledgements

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