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The effect of process efficiency on the calculation of weld shrinkage forces

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A study of welding residual stresses has been in progress at Cambridge in which efforts have been made to relate the weld shrinkage force to the welding parameters. Several commonly used welding processes have been studied experimentally but it has not been possible to investigate the electro-slag process.

43. I should like to comment on the positions selected for measuring strains on the two specimens described in the Paper. Some of the stations appear to be too close to the weld. In this area the material yields in compression as it is heated during welding and longitudinal compressive plastic strains are present in the plate when it has cooled to room temperature. These strains are usually substantially larger than the elastic strains present in the plate so that, if the non-sectioning method is used, compressive strains are recorded in this area even though the residual stress may be tensile (see, for example, reference 8). Consequently, the tensile stresses measured on plate B are unexpected. Was a sectioning technique used on this specimen? It is shown later that the strains measured at stations 1 and 2 on plate A may also have been affected by the presence of residual compressive strains.

44. A theoretical method has recently been developed at Cambridge[9] to find the stress distribution in flat plates when a weld bead is deposited along their centre lines. The weld is modelled as a moving line source of known power. This has led to the following empirical relationship between the shrinkage force and the heat input for the bead on plate problem

$$F = HpE_1 = pE_1(0{\cdot}192 - 0{\cdot}0207pE_1/vbt\sigma_y) \quad . \quad . \quad . \quad . \quad (11)$$

where b is the specimen half width in mm, σ_y is yield stress in kN/mm^2 and other quantities are as defined in the Paper. Equation (11) holds for $pE_1/vbt\sigma_y < 2{\cdot}2$. If it is assumed to apply to the two specimens described in the Paper, the results given in Table 4 are obtained.

45. For plate A the agreement with experiment (Fig. 4) is good. It is difficult to comment on plate B in view of the measured stress distribution. In deriving equation (11) the weld was modelled as a moving line source which gives rise to sharp temperature gradients in the immediate vicinity of the weld, whereas in electro-slag welds the material in the gap is at a constant (and high) temperature and will be stressed to yield when it has cooled to room temperature. Thus, the shrinkage force predicted is likely to be an underestimate of the actual shrinkage force and a better estimate of the latter will be obtained by adding the contribution of the material in the gap to the calculated force (i.e. $F_{actual} = F + A\sigma_y$). The shrinkage forces for plates A and B will

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Table 4

Plate	pE_1/v, kN/m	H	F, kN	σ_r, N/mm²
A	9550	0·136	1300	55
B	13500	0·109	1460	68

increase by approximately 13% and 23% respectively, giving approximate values of σ_r as 65 N/mm² and 90 N/mm² for the two plates.

46. From the values of the shrinkage forces it follows that approximately 120 mm and 72 mm of material will yield on each side of the weld centre line for plates A and B respectively so that measurements at stations 1 and 2 on plate A and at station 1 on plate B are likely to be unreliable if they are made using the non-sectioning technique.

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Mr Kamtekar raises a problem concerning the use of the non-sectioning technique for the measurement of welding residual stresses. If stations are chosen within the region where plastic strains have occurred during heating, measured strain changes will not give a true indication of the existing residual stresses. When station positions were being selected for plates A and B it was thought (because of the extremely slow welding speed) that temperature differences in the plates would not be large and that therefore residual stresses would be small. This was not the case, and Mr Kamtekar is correct in mistrusting the stress values shown close to the weld. However, the stresses in those regions of the plate which have remained elastic are not in dispute, and it is these values which lead to the conclusions drawn in the Paper.

48. It would be misleading to attach too much importance to equation (11) in the present circumstances because it was developed for a line source on the edge of a semi-infinite plate. The electro-slag weld would be better described as a block source and the plates used were decidedly finite.

References

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