Solute profiles in the region of weld bead/parent metal interface of a welded Al–Zn–Mg alloy

Flemings [1] has discussed solute profiles that may result during solidifcation when there is a sudden increase in the growth velocity of the solid/liquid interface. This situation is shown schematically in Fig. 1 in which it is predicted that excess solute initially in the liquid boundary layer will appear as a solute-rich band in the region where the velocity change occurred. A more rigorous treatment is given by Smith *et al* [2].

Sudden changes in the rate of solidification may occur during fusion welding and solute banding has been recognised in the microstructure of aluminium alloy welds [3-5]. This phenomenon has been related to the cyclic characteristics of the power source, or to arc instabilities, both of which influence heat input. Such banding has also been associated with surface undulations or ripples on welds [4, 5]. The present note reports some observations of composition transients in a welded Al–Zn–Mg alloy which seem to have different origins.

The investigation has been concerned primarily with the effects of filler wire composition and post-weld heat treatments on the resistance of welded sheets to intergranular fracture under conditions of combined stress and a corrosive environment [6, 7]. 4 mm thick sheets of the German alloy AlZnMg1 (Al–4.9% Zn–1.2% Mg) were welded by the TIG process resulting in a weld bead of mid-section thickness 5 to 6 mm. The filler wires were Al–5% Mg and Al–3% Zn–4% Mg with additions of 0, 1, or 2% and 0.3 or 1% of silver respectively. Particular attention was paid to the region of the weld bead/parent metal interface since cracking in susceptible alloys normally occurs in the parent metal adjacent to this interface in what has been termed the "white zone" because of its etching characteristics [6].

The welded plates were sectioned and polished to allow metallographic examination and for composition traverses to be made by microprobe analysis using an X-ray energy dispersive system coupled to a scanning electron microscope. Solute profiles were determined for zinc, magnesium, and silver, the interest in silver being stimulated by reports that its presence in the filler wire (i.e. in the weld bead) increases the resistance of welded components to stress-corrosion cracking [8, 9]. Analysis for silver presented difficulties because the peak for silver in the X-ray spectrum coincides with a pile-up peak for aluminium, and it was necessary to modify the analysing system [10].

Fig. 2a shows composition traverses taken across the mid-section of a welded specimen which was prepared using the filler wire Al–5% Mg–2% Ag and given only a post-weld ageing treatment. It will be seen that there is a significant sharp peak in the silver content in the weld bead close to the interface with the parent metal. Such a peak was found in all specimens welded with filler wires containing 1 or 2% silver, and the maximum values were as much as double the average silver contents of the weld beads. The silver-rich band was quite narrow and ranged from 0.3 to 0.7 mm; it occurred

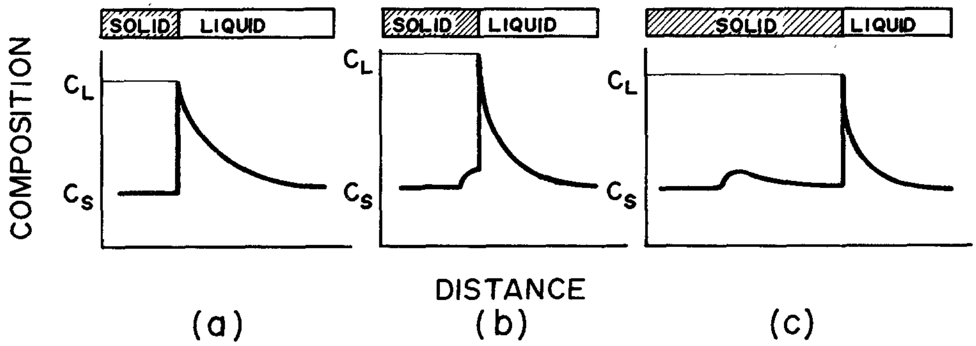
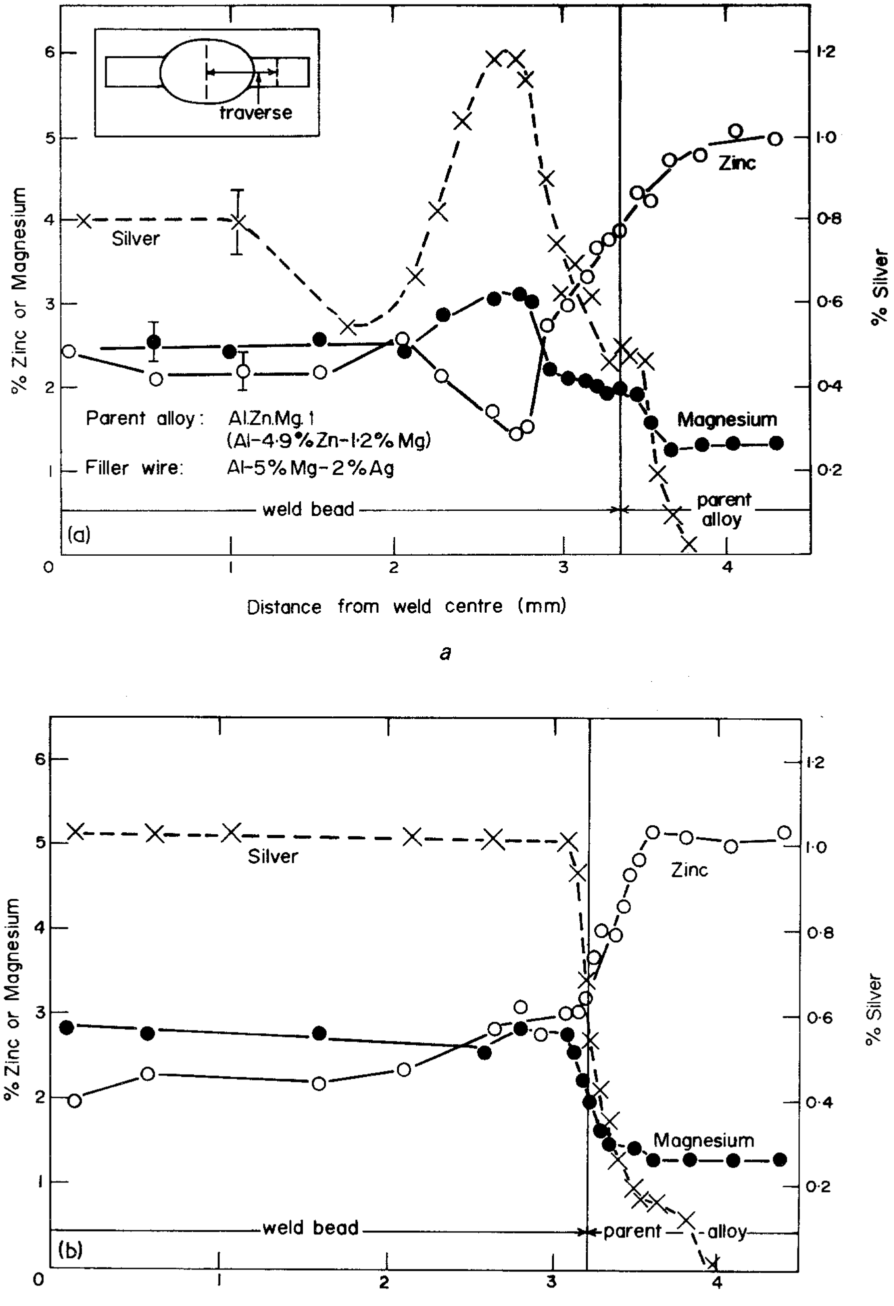


Figure 1 Proposed formation of a solute-rich band in an alloy due to an increase in solidification velocity; C_S = composition of solid, C_L composition of liquid at interface. (a) Steady state solidification. (b) Growth rate increases. (c) Steady state solidification resumed at new growth rate (after Flemings [1]).



a

b

Figure 2 Composition traverses for silver, zinc, and magnesium in the region of the weld bead/parent metal interface in a welded AlZnMg alloy. (a) Welded and aged. (b) Welded, solution treated at 480° C, air-cooled, and aged.

at an average distance of 0.6 mm from the interface with the parent metal. A similar but smaller peak was commonly noted in the magnesium content, whereas the zinc content usually showed a minimum value, all values being recorded at the same distance from the interface. Solution treatment of the specimens at 480° C after welding effectively removed these transients in the composition profiles of silver, magnesium, and zinc (Fig. 2b).

The variations in the solute contents that have been described are not periodic in character and it is suggested that the peak values in silver and magnesium arise from a sudden increase in the solidification rate that is to be expected when the welding electrode retreats from a molten zone. The greater magnitude of the peak in silver content when compared with that observed for magnesium is presumed to arise from preferential segregation of the higher melting point element at the solid/liquid interface. The minimum value in zinc content in the same region is a curious result and may perhaps be due to localized volatilization of zinc during arc-welding.

Reference has been made to the possibility of solute banding having an influence on the mechanical properties of welds [5]. The presence of such bands would also be expected to alter the local electrochemistry of a region. Accordingly it has been proposed that this may be one reason why the addition of silver to filler wires has been found to increase the resistance of adjacent regions in the parent metal to intercrystalline cracking [7].

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References

1. M. C. FLEMINGS, "Solidification Processing", (McGraw-Hill, New York, 1974) p. 37.
2. V. G. SMITH, W. A. TILLER, and J. W. RUTTER, *Canadian J. Phys.* 33 (1955) 723.
3. D. L. CHEEVER and D. G. HOWDEN, *Weld. J.* 48 (1969) 179S.
4. J. G. GARLAND and G. J. DAVIES, *Metal Construction* 2 (1970) 171.
5. J. G. GARLAND and G. J. DAVIES, *Int. Met. Rev.* 20 (1975) 83.
6. H. CORDIER, M. SCHIPPERS, and I. J. POLMEAR, *Z. Metallk.* 68 (1977) 280.
7. H. CORDIER and I. J. POLMEAR, Proceedings of the 6th European Congress on Corrosion (Soc. Chemical Industry, London, 1977) p. 77.
8. S. LINDGREN, *Metallen* 22 (1966) 109.
9. E. LINDSTRAND, Select Conference on Weldable Al–Zn–Mg Alloys, (The Welding Institute, Abington, U.K. 1969) p. 94.
10. B. A. PARKER and I. J. POLMEAR, *J. Aust. Inst. Metals* 21 (1976) 169.

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Determination of the effective size of germanium particles in an Al–Ge alloy with small- and wide-angle X-ray methods

Precipitation phenomena in Al–Ge alloys have been recently studied by X-ray and hardness methods [3, 4]. These studies show that the mean size and shape of Ge precipitates depends on the solution treatment and ageing temperatures. Thus, the quenched-in vacancies play an important role in the formation of Ge nuclei and the subsequent growth of the Ge precipitates. The considerably larger atomic volume of the precipitate phase (22.5 Å^3/atom), as compared with that of the matrix (16.6 Å^3/atom), is responsible for the stressed condition both of the Ge precipitates and of the matrix [4, 5]. It is known that the shape of a X-ray diffraction line profile depends on the particle size and the microstrain components, too.

In the present work Ge precipitates in an Al–4.0 wt % Ge alloy have been studied by small- and wide-angle methods. The specimens were prepared from super-purity aluminium and germanium (99.999%, Koch Light Laboratories, UK). The specimens were homogenized at 450 and 480° C, and then quenched in ice-water. The ageing temperature was 160° C, and ageing times were 390, 1200 and 3000 min. The percentage of germanium