References

1. T. HASE, H. SUZUKI and T. ISEKI, *Yogyo-Kyokai-shi* 87 (1979) 576.
2. F. F. LANGE, *J. Mater. Sci.* 10 (1975) 314.
3. T. ISEKI and H. TAGAI, *J. Amer. Ceram. Soc.* 53 (1970) 582.

Received 26 July
and accepted 13 September 1979

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Microstructure of the weld region in resistance-welded zircaloy 4

An important factor determining the properties of zircaloys is microstructure. This is affected by heat treatment and cold work. The zircaloys owe their good mechanical properties to a large extent to their fine α-grain size. During fabrication, zircaloy tubes are subjected to certain stages for developing these mechanical properties. The different welding and brazing processes used to attach some parts to the fuel sheathing involve heating of these parts (or some localized areas of them) into the β-phase field (above 975° C). This can be harmful to some of the properties which have been achieved during the fabrication process. But there are some welding processes which are so rapid that only very fine β-grains are produced: one of these is the resistance welding process. This process takes place in a time shorter than 1 sec and to this time corresponds the heating and cooling rates in the range of 10^{3}° C $\sec^{-1}$ [1]. The resistance welding process leaves the thermomechanical properties of the tubes unaffected practically right up to the joint [2]. The rapid heating and cooling cycles, together with the intimate contact of the parts to be welded, avoid the formation of brittle or rapidly corroding surface layers during welding of the zircaloys.

Zircaloy, when welded, is locally heated above 975° C. This induces phase transformations during heating and cooling cycles. The result of the temperature cycle is a structure dependent on cooling rates. On cooling from the β-phase field at moderate rates (oil quenching to furnace cooling) zircaloys transform to give widmanstätten-type structure, but increasing the cooling rate produces finer widmanstätten plates to a quenched martensitic structure [3–5].

An attempt was made to characterize the microstructure obtained in resistance (projection) welded zircaloy 4. The samples chosen for this study came from a production zircaloy 4 tubing. The specimens were prepared for metallographic examination by mechanically polishing on progressively finer emery papers finishing on 600-grit paper. This was followed by chemical polishing using the following solution: $H_2O:HNO_3:HF$ (50:47:3). Fig. 1 is an optical micrograph showing the transition of the welded zone, heat-affected zone and the base material. The heat-affected zone of a zircaloy spot (or projection) weld is very narrow because of its low thermal conductivity. The non-random grain orientation of the base material is due to the plastic deformation during fabrication of zircaloy fuel sheathing. Higher magnifications of the welded zone gave a similar structure to that of a specimen cooled at 2×10^{3}° C $\sec^{-1}$, which was named a marensitic-type structure [3]. Fig. 2 is a scanning electron micrograph at higher magnifications of the welded zone. Electron

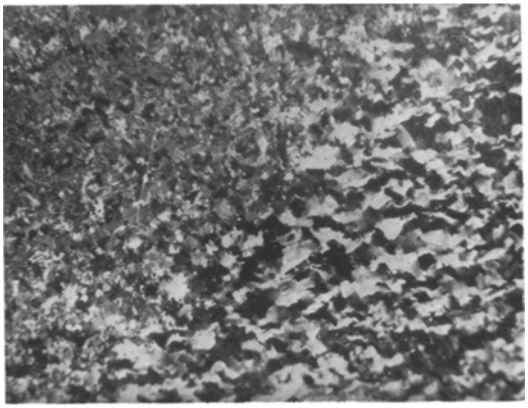

Figure 1 Optical micrograph of the transition zone between the welded part, heat-affected zone and base material. Polarized light, × 245.

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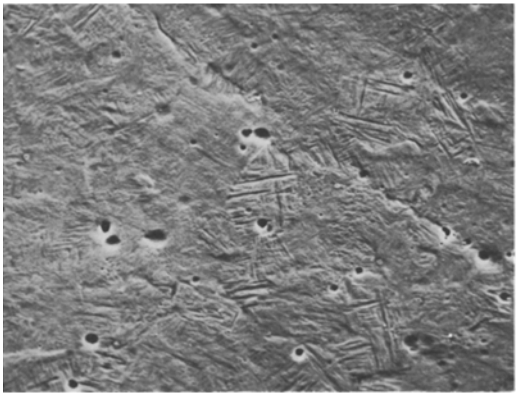

Figure 2 Scanning electron micrograph of the interface between the welded parts. × 865.

microprobe analysis gave no segregation of iron, chromium and tin in the welded zone.

As a result of this investigation the microstructure in a resistance (projection) welded of zircaloy 4 seems a martensitic-type structure or a very fine widmanstätten structure (with a plate thickness less than $0.5\,\mu$m). Bodmer *et al.* [6] reported the presence of a martensitic structure in fast-cooled electron-beam welded zircaloy 2. A careful study must be continued.

References

1. J. A. GREENWOOD, *Brit. Weld. J.* 8 (1961) 316.
2. S. DE BURBURE, *Weld. J.* 57 (1970) 322.
3. R. A. HOLT, *J. Nuclear Mater.* 35 (1970) 322.
4. *Idem, ibid* 47 (1973) 262.
5. O. T. WOO and K. TANGRI, *ibid* 79 (1979) 82.
6. E. BODMER, J. J. CHÉNE, R. O. ERIKSON and R. FERRARINI, Proceedings of the 3rd International Conference on the Peaceful Uses of Atomic Energy, Geneva, Set 1964, United Nations (United Nations Publications, New York, 1965) Vol. 9 p. 173.

Received 3 August
and accepted 20 September 1979

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Planar interfaces in Cr$_2$O$_3$-doped calcium aluminoferrite

Incorporation of chromium ions into the crystal structure of calcium aluminoferrite increases the early hydraulic activity of the respective ferrite phase. This has been observed by Sakurai *et al.* [1] who consider the beneficial effect of chromium to be associated with the semiconductivity phenomena. When investigating the Ca$_3$SiO$_5$–Cr$_2$O$_3$ solid solutions the same authors concluded that chromium-induced screw dislocations act as starting points of the hydration process. The same has been proposed for hydration of Cr$_2$O$_3$-doped aluminoferrites, although in this case experimental evidence of the presence of screw dislocations has not been given.

In order to verify whether the crystal imperfections in Cr$_2$O$_3$-doped calcium aluminoferrite are of an analogous type and density as in the case of Ca$_3$SiO$_5$-solid solution, we have examined a sample of Cr$_2$O$_3$-doped calcium aluminoferrite by transmission electron microscopy. The sample was synthesized as described by Sakurai *et al.* [1]; for preparation of the raw mixture containing 47% CaO, 29% Fe$_2$O$_3$, 18.5% Al$_2$O$_3$ and 5.5% Cr$_2$O$_3$, analytical grade chemicals were used. The mixture was fired for 2 h at 1300° C and cooled at a rate of $50^\circ\,\mathrm{C\,h^{-1}}$. The product of synthesis was checked by X-ray diffraction; the diffraction pattern showed no other reflections than those ascribable to calcium aluminoferrite. The average unit cell parameters are: $a = 5.36$ Å, $b = 14.50$ Å and $c = 5.58$ Å, which are in general agreement with the literature data for Ca$_2$Fe$_{0.5}$Al$_{0.5}$O$_5$ [2–4].

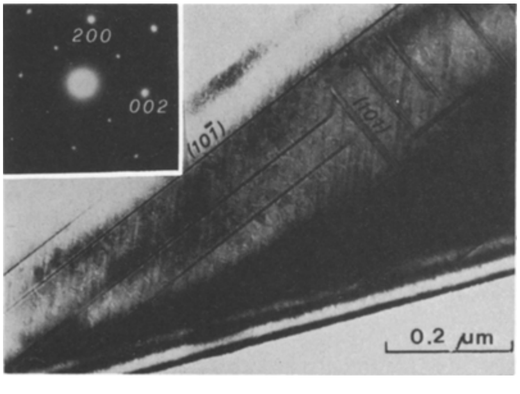

Figure 1 TEM and *h* 0 *l* electron diffraction pattern of Cr$_2$O$_3$-doped calcium aluminoferrite.

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