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Phil. Trans. R. Soc. Lond. A 1980 **295**, 123
doi: 10.1098/rsta.1980.0083

Phil. Trans. R. Soc. Lond. A **295**, 123 (1980)
Printed in Great Britain

The effect of alloying and residual elements on the strength and hot ductility of cast cupro-nickel*

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A high strength, corrosion resistant cupro-nickel casting alloy having good intermediate temperature ductility and controlled corrosion behaviour has been developed for use in sea water cooling systems.

Welding for repair and fabrication may be required with such components and this property is related to hot ductility behaviour. The latter was assessed by using a modified Gleeble apparatus which enabled specimens to experience a simulated weld thermal cycle followed by fracture at a high strain rate during cooling. These alloys usually show a reduced ductility at intermediate temperature (600 °C) associated with intergranular failure.

Tests on binary Cu–Ni alloys indicated that Ni enhanced the ductility dip behaviour by delaying recovery processes and thus should be kept below 15 % (Chubb & Billingham 1978). Other alloying elements are required to improve corrosion resistance, castability and strength and the effect of Al, Si, Fe and Mn on hot ductility of a binary Cu 10 % Ni alloy was evaluated. Whereas 0.1 % additions had little effect on the hot ductility, increased amounts of Al (5 %) Si (0.5 %) and Fe (more than 1 %) caused a severe reduction in intermediate temperature ductility, modified the grain boundary region by precipitation or segregation and thus enhanced grain boundary fracture processes. Corrosion experiments indicated an optimum Fe level of 2 % for combined resistance to jet impingement and immersion attack. Fe at levels above 3 % gave rise to dendrite centre corrosion. The detrimental effect of Fe additions on the hot ductility of the cupro-nickel was counteracted by the inclusion of Mn. The Cu–Ni–Fe–Mn alloy was then strengthened by the addition of 3 % Al, which formed an Ni_3Al type precipitate. The best combination of properties was achieved in an alloy containing Cu 13 % Ni 2 % Fe 5 % Mn 3 % Al. The room temperature strength was 400 MPa with 17 % elongation, and the elongation at 600 °C in the high strain rate Gleeble test was 24 %.

A commercial purity material was compared with an identical alloy produced from high purity melting stock. The commercial alloy, containing 440 μg/g of trace impurities gave almost zero ductility in the mid-temperature range whereas the laboratory alloy (194 μg/g impurities) had an intermediate temperature ductility of 20 %. From this and other associated work (Gavin *et al.* 1979), impurity limits have been set which ensure satisfactory hot ductility. These limits are (in micrograms per gram) Bi $<$ 10, Te $<$ 50, Pb $<$ 100 and Se $<$ 100.

References (Chubb *et al.*)

Chubb, J. & Billingham, J. 1978 *Metals Technol.* **5**, 100.
Gavin, S. A., Chubb, J. P., Billingham, J. & Hancock, P. 1979 To be published.

* Extended abstract; the full paper appears in *J. Metals* **30**, 20 (1978).