PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Hot Ductility and Sulphur Segregation in 1%C-1%Cr Steels

C. Lea, R. Sawle and C. M. Sellars

Phil. Trans. R. Soc. Lond. A 1980 **295**, 121
doi: 10.1098/rsta.1980.0081

Phil. Trans. R. Soc. Lond. A **295**, 121 (1980) [121]
Printed in Great Britain

Hot ductility and sulphur segregation in 1 %C–1 %Cr steels*

By C. Lea,† R. Sawle‡ and C. M. Sellars§

† *National Physical Laboratory, Teddington U.K.*
‡ *Superform Metals Ltd, Worcester, U.K.*
§ *Department of Metallurgy, University of Sheffield, U.K.*

Hot torsion tests have been carried out at 800–1300 °C on vacuum melted 1 %C–1 % Cr steels containing *ca.* 0.005 % S with Mn:S ratios of 72, 11 and 1 by mass. These steels (A, B and C) had similar hot strengths but the ductility depended markedly on Mn:S ratio. In the single phase austenite range above about 910 °C, steel A had high ductility, which decreased systematically with increasing temperature to about 1270 °C, after which it fell precipitously to nearly zero at 1300 °C. In contrast, steel C had low ductility, which increased with increasing temperature to attain a similar value to steel A at 1270 °C. Steel B showed an intermediate behaviour. Also, the ductility of steel A was independent of grain size whereas increasing the grain sizes of steels B and C by pretreatment at 1250 °C resulted in a significant decrease in ductility.

Thermodynamic data for (Mn, Cr, Fe) S inclusions indicate greatly increased solubility of sulphur with decreasing Mn:S ratio. Thus in steel A the sulphur is not entirely in solution even at 1300 °C, whereas complete solution is expected at 1110 °C in steel B and at 1040 °C in steel C.

Samples of steels A and C were quenched from 950, 1050 and 1150 °C and fractured *in situ* in the high vacuum of an Auger electron analyser. Fracture was predominantly intergranular on the prior austenite grain boundaries. Elemental analysis of these surfaces showed the sulphur concentration in steel C to be significantly higher than in steel A, but the fractional areas occupied by sulphur were less than 0.015.

Scanning electron images revealed a distribution of fine precipitates on the intergranular fracture surfaces. Further analysis combined with ion sputtering gave a gradual decrease in both the sulphur and manganese signals as a function of etching depth, implying an association as (Mn, M)S. The thermodynamic data and the high diffusivity of sulphur indicate that this precipitation had occurred on quenching. The sulphur coverage on grain boundaries at the high temperatures was therefore calculated from the total sulphur content of the precipitates. In steel A this coverage increased from 0.14 to 1.1 monolayers with increasing temperature, whereas in steel C it was around 1.5 monolayers at all temperatures. When the solubility exceeded the bulk sulphur content, these figures give values of grain boundary enrichment ratios in accord with that predicted by the Seah & Hondros solid solubility correlation.

The segregated sulphur levels correlate closely with the hot ductility results, indicating that the major effect of Mn:S ratio on hot ductility arises from the embrittling influence of sulphur. When sulphur solubility is high and a monolayer or more of sulphur is segregated to austenite grain boundaries, grain size also becomes of importance.

* Extended abstract.