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Cavitation control in steels of high residual element content*

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The cavitational mode of failure of prior austenite grain boundaries in bainitic creep-resisting low alloy steels is now well established as a principal factor in the high incidence of cracking problems which has developed on modern power plant in recent years.

The microstructural features dominating the cavitation process at the reheat temperature in a ½CMV bainitic steel of high classical residual level have been determined. The prior austenite grain boundaries become zones of comparative weakness *ca.* 1 μm thick at 700 °C and are incapable of sustaining significant shear loads. Deformation is therefore initiated by a relaxation of load, through a process of prior austenite grain boundary zone shear, from inclined to transverse boundaries such that a concentration of normal stress develops across the latter. The overall deformation is thereafter determined by cavitation of the transverse boundary zones, the necessary inclined boundary displacements being accommodated by further grain boundary zone shear. Transverse boundary cavitation is shown to be an essentially time-independent process of localized ductile microvoid coalescence resulting from the plastic deformation of the boundary zone.

Under these conditions the overall ductility is determined directly by the maximum cavity size and therefore by the cavity density. Cavities were found to nucleate on a dispersion of sub-micrometre manganese sulphide particles precipitated some 1–5 μm apart on the austenite boundary during the simulation welding cycle. The sulphides are chemically unstable in ferrite at 700 °C and therefore act as pre-existing nuclei.

Residuals appear to exercise their detrimental effects predominantly by influencing the austenite boundary precipitate density. Conversely, in the absence of prior austenite grain boundary MnS, additions of high levels of Sb, P, Sn and As in combination are totally innocuous. A background level of boron of no less than 1 μg/g is shown to be necessary for sulphide precipitation, this being less than the natural level of electrolytic and industrial steels. With this condition satisfied, residuals have complex interactive effects at 700 °C on the sulphide and therefore cavity densities; e.g. tin added alone results in a density some 10^2 times greater than when in combination with P, Sb and As.

Reheat cracking susceptibility is shown to be dependent on the attainment of a critical reheat cracking temperature in analogous fashion to overheating and is largely independent of grain size. Effective control can be exercised by a process of chemical sulphur stabilization which modifies the prior austenite grain boundary sulphide dispersion. Titanium and zirconium additions are shown to be beneficial, but additions of rare earths can suppress sulphide precipitation entirely and promise a viable means of cavitation control with associated improvements in resistance to temper embrittlement and improved isotropy in steels of high residual level. The process should be equally beneficial for weld metal cracking.

Chromium additions are also shown to counteract residual effects, but through a combination of a reduction in the degree of grain boundary zone shear as well as matrix sulphide modification.

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* Extended abstract; the full paper has been submitted to *Metal Sci.*