THE EFFECT OF VANADIUM ON THE MICROSTRUCTURE AND TOUGHNESS OF WELD HEAT AFFECTED ZONES

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Abstract: Work on factors affecting heat affected zone toughness is summarised and includes the effects of vanadium, nitrogen and heat input on the toughness of the coarse grained HAZ and thr intercritically reheated, grain coarsened HAZ as well as the effect of vanadium on the toughness of laser weldments.

Key words: vanadium, microstructure, toughness, heat affected zone.

1. Introduction

Hannerz and Jonsson-Holmquist[(1)], in 1974, carried out one of the first systematic investigations into the effects of vanadium on weld heat affected zone microstructure and toughness. They used simulated welds in a steel containing 0.15%C – 1.4%Mn, the welds having cooling times between 800°C and 500°C of 33 secs, 100 secs and 300secs. At cooling times of 33 secs and 100 secs they observed little or no effect of vanadium on HAZ toughness up to 0.1%V, or perhaps more. Indeed, at the lower cooling time, thought to be similar to that experienced by a 20mm thick plate welded at 3.6kJ/mm[(2)], the HAZ toughness appeared to exhibit a small improvement at a vanadium level of 0.06%. Even at the longest cooling time, equivalent to welding 20mm thick plate at 10.8kJ/mm the deterioration in HAZ toughness, in steel containing 0.1%V, was small. It was only at higher vanadium levels that significant reductions in toughness occurred at any cooling time.

Since 1974 there have been many papers which have examined different aspects of the effect of micro-alloying on HAZ toughness. It is the purpose of the present paper to summarise work on factors affecting HAZ toughness which, has been carried out on behalf of VANITEC supplemented, as required, by other published material. This includes an examination of the effects of vanadium, nitrogen and heat input on the toughness of the coarse grained HAZ, the effect of vanadium on the toughness of the intercritically reheated HAZ and the effect of vanadium on the toughness of laser weldments.

2. Factors Affecting the Heat Affected Zone Toughness of Vanadium Microalloyed Steels

Among the more important factors affecting the heat affected zone toughness of vanadium micro-alloyed steels are likely to be : -

- The solubility of VN and VC and the size of any particles present.
- The austenite grain size in the coarse grained heat affected zone.
- The effects, if any of vanadium on transformation temperatures, rates of transformation and the resulting microstructures.
- The size and amount of any M-A phase which may form in the intercritically reheated heat affected zone.
- Precipitation hardening within the HAZ.

2.1 Solubility

Equilibrium solubility data for VC and VN in austenite and ferrite, as shown in the equations in Table 1, indicate significant solubility of vanadium compounds in both phases, that of the carbide being higher than the nitride. In addition their solubility in austenite is greater than that in ferrite.

Table 1. Solubility Products of VC and VN in Austenite and Ferrite

	Phase	A	B	References
VN	Austenite	-8330	3.46	3
	Ferrite	-7830	2.45	4
VC	Austenite	-9500	6.72	5
	Ferrite	-12265	8.05	6

$$Log_{10}[\%M]^{a}[\%X]^{\beta}=A/T+B$$

In welds equilibrium conditions are rarely observed. However, Easterling and his co-workers[(7)] have shown that, even under welding conditions, the greatest majority, if not all, of the VC and VN present should be in solution in the coarse grained region next to the fusion boundary. The further away from the fusion boundary the more likely will VC and VN remain out of solution and in the intercritically reheated region there will, almost certainly, be some VC and VN present. The possibility of obtaining some dissolution and/or precipitation in the sub-critically reheated heat affected zone cannot be overlooked.