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The influence of microalloying elements on the hot ductility of thin slab cast steel

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The Influence of Microalloying Elements on the Hot Ductility of Thin Slab Cast Steel

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CANDIDATE'S CERTIFICATE

This is to certify that the work presented in this thesis is original and was carried out by the candidate in the Department of Materials Engineering, the University of Wollongong and has not been submitted to any other university or institution for a higher degree.

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Kristin Carpenter

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Synopsis

Experiments were performed on a Gleeble 3500 Thermomechanical Simulator to study the hot ductility behaviour of C-Mn-Al steel and the influence of Nb, Ti and Nb-Ti additions. The simple hot tensile test has been shown to correlate well to the problem of transverse cracking. Therefore, the principle aim of this research is to gain a greater understanding of transverse cracking during the straightening of continuously cast slabs. In particular, attention was paid to thin slab casting conditions.

Hot tensile test specimens were either solution treated or melted *in-situ* (direct cast) and cooled to the deformation temperature. Solution treatment tests simulated conventional casting, where slabs are cooled to room temperature then reheated prior to rolling. Direct cast tests simulated hot direct rolling conditions, where slabs are rolled directly after casting without being cooled below the austenite to ferrite transformation. Specimens were cooled to the deformation temperature at two cooling rates, 100K/min and 200K/min. The cooling rate of 100K/min corresponds to the average cooling rate experienced for a conventionally cast slab, 250mm in thickness. The cooling rate of 200K/min corresponds to the average cooling rate for thin-cast slabs, 50mm in thickness.

The development of the combination of thin slab casting with hot direct rolling requires hot ductility work to be performed under direct cast conditions and at higher cooling rates. Surface quality is of the utmost importance in thin slab casting so the elimination of transverse cracking is of prime economic importance. There are significant differences between as-cast (direct cast) and reheated (solution treatment) microstructures. In particular, changes in precipitate behaviour, austenite grain size, and the relationship between segregation and the position of austenite grain boundaries was investigated. An attempt has been made to determine what influence these differences in microstructure have on hot ductility.

Niobium bearing steels were selected for the reason that there are still problems with Nb steels regarding transverse cracking. Furthermore, there have been contradictory reports on the effects of Ti additions on the transverse cracking behaviour of Nb steels. There is

evidence from commercial practice that indicates that small additions of Ti improve the transverse cracking susceptibility of Nb steels. However, laboratory results generally show Ti additions have little influence or even a detrimental effect on hot ductility. Disparities in the thermal history simulated in laboratory tests to actual conditions near the surface of a continuously cast slab is the most likely reason for this discrepancy. Therefore, the influence of more closely simulating the thermal history conditions near the surface of a continuously cast slab was evaluated for the Nb-Ti steel.

Experimental work involved metallographic and scanning electron microscopy examination of the fracture surface. Transmission electron microscopy was used to determine precipitation characteristics. Tensile tests were conducted to determine mechanical properties, where reduction in area (RA) was used as a measure of ductility. The dendritic structure for direct cast and solution treatment specimens was revealed using a heat treatment procedure (normalising). Particle size was correlated to reduction of area for precipitates in the single-phase austenite temperature region. It was shown that particles below 15nm were detrimental to hot ductility. The relationship between interparticle spacing and reduction of area was also determined.

Microalloying additions to C-Mn-Al steels significantly widen the ductility trough but the depth remains similar. Low ductility was found at higher temperatures in the microalloyed steels due to intergranular failure as a result of grain boundary sliding in the austenite. Grain boundary sliding was favoured by the slow strain rate and was enhanced by fine microalloyed nitrides and/or carbides. Fine particles can pin austenite grain boundaries, allowing sufficient time for cracks to link together, ultimately causing intergranular fracture. Increasing the cooling rate generally lowered ductility further by promoting finer precipitation. The trough depth is similar in all steels as the formation of thin ferrite films controls ductility at the minimum trough position. The formation of thin films of ferrite allowed strain to concentrate in the softer ferrite phase and intergranular failure occurred due to microvoid coalescence.

Direct cast conditions always led to lower ductility compared to solution treatment conditions. This is explained in terms of differences in the microstructure, namely, grain size, segregation and precipitation. It is recommended that direct cast conditions should be used to determine hot ductility behaviour as it more accurately simulates continuous casting conditions.

It was found that simulating the thermal history near the surface of a continuously cast slab, as opposed to cooling directly to the deformation temperature, improved ductility of the Nb-Ti steel. This improvement in ductility was attributed to the thermal history providing favourable conditions for coarsening of NbTi(C,N).

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