THE EFFECTS OF TiN PARTICLES ON THE HAZ MICROSTRUCTURE AND TOUGHNESS IN HIGH NITROGEN TiN STEEL

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ABSTRACT

In the coarse grain HAZ adjacent to the fusion line, most of the TiN particles in conventional Ti added steel are dissolved and austenite grain growth is easily occurred during welding process. To avoid this difficulty, thermal stability of TiN particle is improved by increasing the nitrogen content in steel. In this study, the effect of high nitrogen TiN particle on preventing austenite grain growth in HAZ was investigated. Increased thermal stability of TiN particle is helpful for preventing the austenite grain growth by pinning effect. High nitrogen TiN particle in simulated HAZ were not dissolved even at high temperature such as 1400℃ and prevented the austenite grain growth in simulated HAZ. Owing to small austenite grain size in HAZ the width of coarse grain HAZ in high nitrogen TiN steel was decreased to 1/10 of conventional TiN steel. Even high heat input welding, the microstructure of coarse grain HAZ consisted of fine polygonal ferrite and pearlite and toughness of coarse grain HAZ was significantly improved.

KEYWORDS

TiN particle, HAZ, Austenite grain size, microstructure, toughness

1. Introduction

Recently the construction of welded structure is required for large-sized scale and high heat input welding is employed from an economic point of view. However the toughness of welded joint tends to deteriorate with increase in welding heat input. This is caused by austenite grain growth in HAZ during the welding thermal cycle. Many studies have shown that addition of Ti is one of effective ways to improve HAZ toughness[1~3]. But in the coarse grain HAZ adjacent to the fusion line, most of the TiN particles in conventional Ti bearing steel are coarsened or are dissolved and austenite grain growth easily is occurred during weld thermal cycle[4,5]. Coarse grain HAZ toughness of steel is improved by austenite grain refinement. However experience has shown that austenite grain size in coarse grain HAZ is the most difficult to control due to the very high peak temperature reached.

The austenite grain growth in coarse grain HAZ can be prevented from increasing the thermal stability of TiN particles at high temperature. The growth of the pinning particles will be minimized with a small value of the metal solute in the matrix in equilibrium with the pinning particles. An increase of nitrogen content to give a hypostoicheometric Ti:N ratio in TiN steel is beneficial in decreasing the dissolved amount of Ti in the austenite. Fig.1 shows how move towards hypostoichiometry by increasing the nitrogen content greatly decrease the dissolved amount of Ti in the austenite matrix[6].

In this study the effect of high nitrogen TiN particles on the HAZ microstructure and HAZ toughness of high nitrogen TiN steel was investigated.

2. Experimental Procedure

Conventional TiN steel and high nitrogen TiN steel were investigated for this study. The chemical compositions of materials used are shown in Table 1. Simulated HAZs were produced by induction heating in a computer controlled weld thermal cycle simulator. Prior austenite grain size of simulated HAZ with peak temperature was measured using conventional light microscopy. TEM studies for precipitate were carried out using carbon extraction replicas taken from the simulated HAZ. The amount of Ti combined as precipitate was analysed by ICP-AES using precipitates residue obtained by selective potentiostatic etching by electrolytic dissolution method(SPEED). The HAZ toughness of welded joint was investigated by depositing a single-pass SA weld with a heat input of 100kJ/cm obtained with parameter of 1050A, 40V and 25cm/min. To compare the width of coarse grain HAZ, microstructure of coarse grain HAZ in SA welded joint(60kJ/cm heat input) was also investigated.

3. Results and Discussion

Fig.2 shows the ratio of Ti content in simulated HAZ to Ti content in base metal as precipitate with peak temperature from 1200℃ to 1400℃ by analysis of the extraction residue. In conventional steel Ti content as precipitates was greatly decreased with increasing peak temperature and only 40% of TiN precipitates of base metal was existed at peak temperature 1400℃. But in high nitrogen steel Ti content as precipitates was almost the same and 90% of TiN precipitates of base metal was existed at 1400℃. This fact indicated that TiN particles in conventional steel were dissolved at high temperature but TiN particles in high nitrogen TiN steel were very fine and stable at high temperature up to 1400℃. Fig.3 shows TEM micrographs of extraction replica of TiN particles in simulated HAZ with peak temperature 1400℃ and $\Delta t_{800\text{-}500}$ = 40sec. In conventional TiN steel, very few TiN particles existed in simulated HAZ, whereas high nitrogen TiN steel had a large number of fine TiN particle size of 10 to 20nm in simulated HAZ. Variation of austenite grain size with peak temperature in simulated HAZ at peak temperature 1400℃are shown in Fig.4. The austenite grain size of simulated HAZ in high nitrogen TiN steel was much smaller than that of conventional TiN steel. Especially austenite grain refinement remarkably occurred in high nitrogen TiN steel at high temperature up to 1400℃. From these observations it was inferred that high nitrogen TiN particles were very stable at high temperature up to 1400℃ and were effectively pinning austenite grain boundaries in simulated HAZ, so that austenite grain growth was inhibited at high temperature.

Conventional TiN steel and high nitrogen TiN steel were cooled from 1350℃at various cooling rates and CCT diagram shown in Fig.5 were obtained. High nitrogen TiN steel (thick line) had ferrite nose pronounced towards the short time side and high temperature side than conventional TiN steel. Fig.6 represents the microstructure of weld metal/HAZ junction in SA welded joint of heat input 60kJ/cm. In high nitrogen TiN steel no grain coarsening was evident near the weld fusion boundary whereas significant austenite grain growth was occurred in this region of conventional TiN steel. The microstructure of coarse grain HAZ in high nitrogen TiN steel was consisted mostly of fine ferrite and pearlite, while those in conventional TiN steel exhibited an upper bainite and grain boundary ferrite. The width of coarse grain HAZ in high nitrogen TiN steel was measured as 0.2mm wide and this width was approximately 1/10 of coarse grain HAZ width of conventional TiN steel.

Fig.7 shows the toughness of welded joints made through one-pass SAW process(100kJ/cm heat input) in the two TiN steels measured at various locations through 2mm V-notch Charpy impact tests at –20℃. High nitrogen TiN steel showed better toughness at all HAZ locations than the conventional TiN steel. Free nitrogen level of simulated HAZ of high nitrogen TiN steel was measured as 20ppm and this level was almost the same level of conventional TiN steel.

4. Conclusion

High nitrogen TiN particles in simulated HAZ were very stable at high temperature and were found to be effective in preventing austenite grain coarsening. Besides the austenite grain growth inhibition effect, ferrite transformation in coarse grain HAZ was remarkably promoted for high nitrogen TiN steel compared to that of conventional TiN steel. A marked improvement of toughness in coarse grained HAZ of high nitrogen TiN steel was accomplished through a refinement of coarse grained HAZ, where fine ferrite-pearlite microstructure were produced in place of the ordinary coarse bainite microstructure.

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Table 1 Chemical composition of materials used (wt.%)

Materials	C	Si	Mn	Ti	B	N	Ti/N	Ceq*
Conventional TiN steel	0.13	0.43	1.1	0.012	-	0.0035	3.4	0.31
High nitrogen TiN steel	0.09	0.12	1.48	0.019	0.0010	0.0130	1.5	0.34

* *Ceq(%) = C + Mn/6 + (Cr+Mo+V)/5 + (Cu+Ni)/15[IIW]*

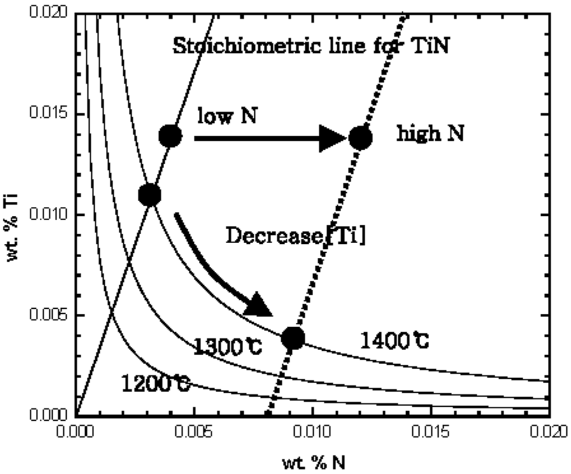

Fig.1 Solubility product of TiN in austenite temperature range.

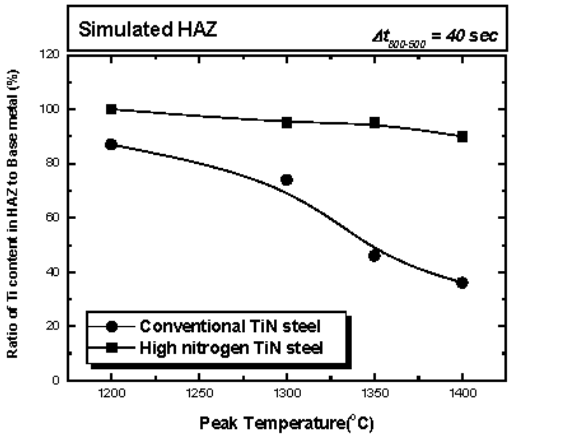

Fig.2 Ratio of Ti content in HAZ to Ti content in base metal as precipitate with peak temperature

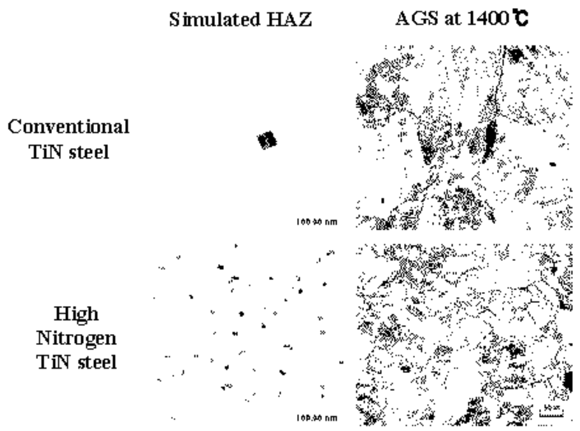

Fig. 3 TEM micrographs of TiN particles in simulated HAZ

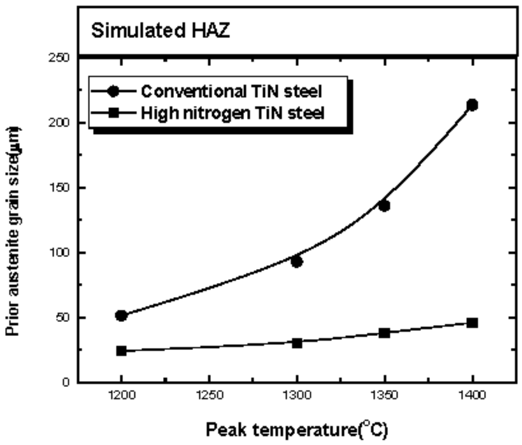

Fig. 4 Variation of austenite grain size with peak temperature

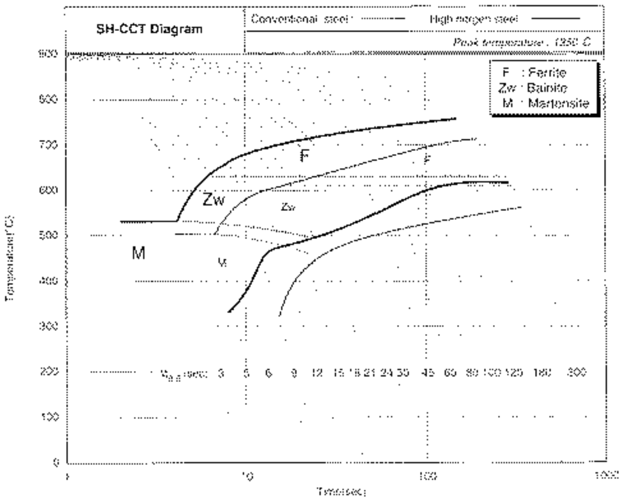

Fig. 5 SH-CCT diagram of conventional TiN steel and high nitrogen TiN steel

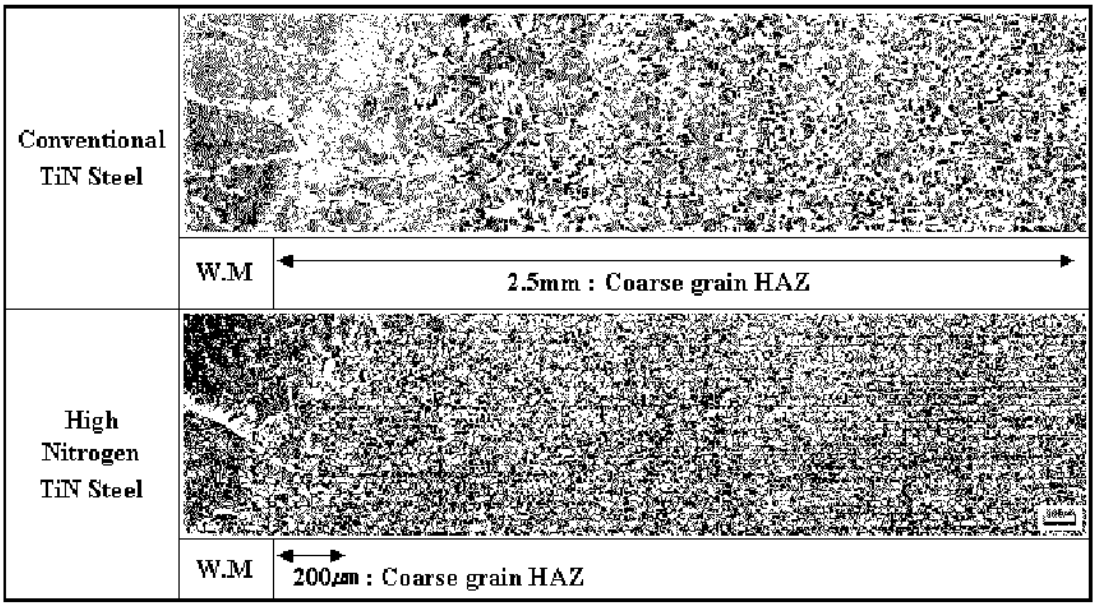

Fig. 6 Microstructure of weld metal/HAZ junction in SA welded joint of conventional TiN steel and high nitrogen TiN steel

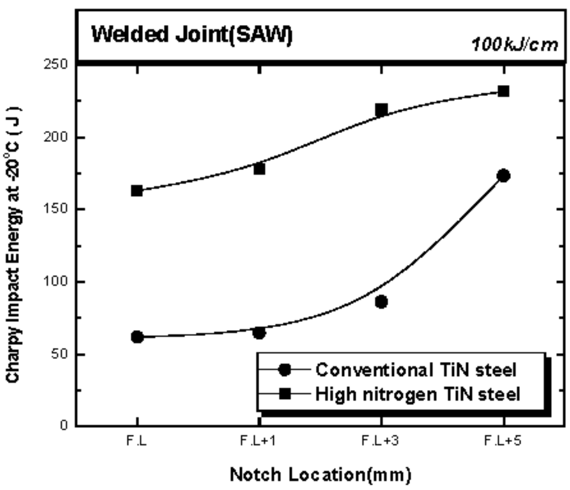

Fig. 7 Charpy test results at various notch locations of one-side, one-pass SAW(100kJ/cm)