Effect of Magnesium Addition on the Rolled Microstructure of a Kind of HSLA Steel

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Abstract. A new technology to obtain a fine-structured and high-toughness HAZ of HSLA steel for high heat input welding is developed using metallurgical thermodynamics, physical chemistry of metallurgy and material processing methods synthetically in this study. The thermal stability second phase particles which would not be dissolved or aggregated at high temperature will be expected by means of adding magnesium into the steel in the form of Mg-Zr alloy. A kind of HSLA steel containing Mg was prepared by means of the vacuum induction melting and controlled rolling and controlled cooling experiments. The effect of magnesium addition on the rolled microstructure of HSLA steel was analysed. The results show that the cast microstructure has been changed after rolling and the deformed austenite. The rolled microstructure of the experimental steel mainly consists of polygonal ferrite and granular bainite and small amount of pearlite. Compared with the original steel, there is bainite presenting in the experimental steel after adding 5 wt% Mg, which is favorable to the mechanical properties of the rolled steel.

Introduction

When the steel plates use the high heat input welding, the strength and toughness of the welding heat affected zone (HAZ) decreases with the increase of the heat input welding [1-3]. In such a situation, further enhancement of HAZ toughness and strength in structural steel plates has come to constitute important development subjects in order to insure the safety of steel structures [4-6]. Therefore, a new technology to obtain a fine-structured and high-toughness HAZ is developed in this study. This is a technology whereby thermally stable oxides and sulfides containing Mg are dispersed in steel as fine particles. Magnesium inclusions have high temperature stability, high melting point, ultra-fine, evenly distributed and controllable composition [7].

Magnesium was added into molten steel in the form of Mg-Zr alloy using the special process in the experiment. A kind of HSLA steel containing Mg was prepared by means of the vacuum induction melting experiments and controlled rolling and controlled cooling experiments, and the effect of magnesium addition on the rolled microstructure of the HSLA steel was analysed. The study can provide a reliable theoretical basis and technical support for the development and application of high heat input welding HSLA steel which has good strength and toughness.

Experiments

Experimental Materials. A kind of HSLA steel was designed in this experiment. The components of the steel were obtained by smelting pure iron and adding the corresponding alloy. The components of pure iron and main alloy were shown in Table 1.

Magnesium was added in the form of Mg-Zr alloy. Other alloys included electrolytic manganese (99.9%), ferrovanadium (78.6%), ferrotitanium (99%), ferroniobium (65.6%), ferronickel (78.6%), ferrochromium (85.5%) and molybdenum (76.3%).

We designed a kind of HSLA steel, based on the above principle and absorbing predecessors's research experiences. The BJ-VIM-5 vacuum induction melting furnace was used in the smelting test of HSLA steel. The four furnaces in the test were accomplished in the order of no magnesium addition, 1 wt% Mg addition, 3 wt% Mg addition and 5 wt% Mg addition.

Table 1 Components of pure iron and main alloys (wt%)

Alloy	C	Si	Mn	P	S	Al	Fe	Ca	Mg	Zr	Ni	Cu
Pure iron	0.0013	0.01	0.05	0.007	0.0044	0.0013	92.6	/	/	/	/	/
Fe-Si	0.024	78.96	0.058	0.0093	0.0037	0.24	20.24	/	/	/	/	0.049
Mg-Zr	/	0.0053	0.0061	/	/	0.0053	0.029	/	69.68	30.12	0.15	0.0014

Process of Rolling and Cooling. The experiment of rolling and cooling used the Φ450 hot rolling machine group and controlling cooling system. Its main performance parameters were shown in Table 2.

Table 2 Main performance parameters of Φ450 hot rolling experimental machine group

Performance Parameters	Values
Roll sizes (mm)	Φ450×450
Roll speed (m/s)	0~1.5
Maximum rolling force (KN)	4000
Maximum opening degree (mm)	170
Maximum dimension of billet (mm)	150×150×200
Main motor power (kW)	400

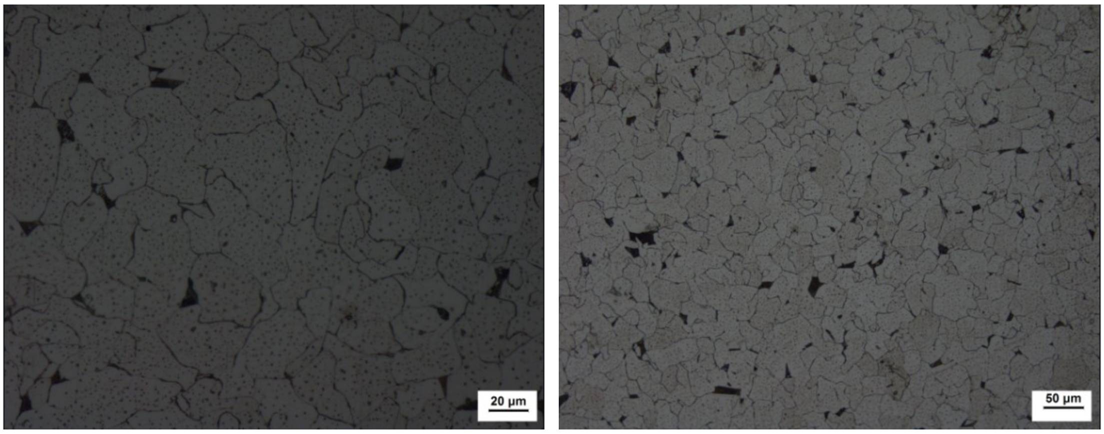
The specific process was as follows. In the heat treatment furnace, the billet was heated to 900°C for 35min. Then the billet was placed into the heating furnace with the temperature of 1220°C for 1h. After 7 passes controlled rolling, the rolling reduction was 70mm→50mm→35mm→25mm→20mm→16mm→13mm→12mm, respectively. The deformation amount of each pass was 28.6%, 30.0%, 28.6%, 20.0%, 20.0%, 18.6% and 7.79%, respectively. The total deformation of rough rolling was 87.2%, and the total deformation of finishing rolling was 66.39%. Finally, the steel plate with the thickness of 12.0 mm was produced. The start rolling temperature was 1200°C. The fourth pass rolling temperature was controlled at about 950°C ~Ar3, and the final rolling temperature was controlled at 950 ~ 700°C. After rolling, the temperature was reduced to 380°C by water cooling, then air cooling [8]. The rolling temperature of the pass steel plate was measured by the infrared thermometer, and the cooling time was determined by the stopwatch, so the cooling rate could be calculated.

Effect of Magnesium Addition on the Cast Microstructure of the HSLA Steel

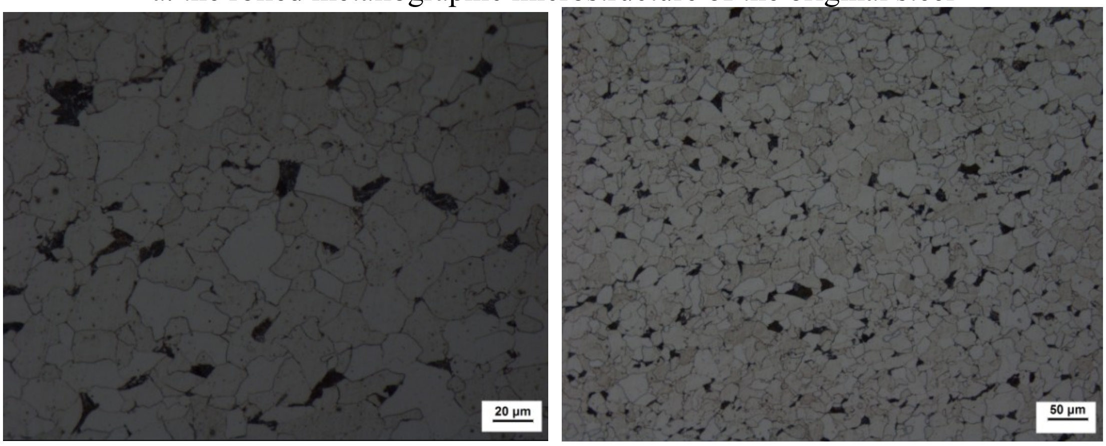
The prepared metallographic samples zoomed in 200 and 500 times were respectively observed using the OLYMPUS-CK40M optical metallographic microscope. The diagrams of cast microstructure of the X80 pipeline steel were obtained.

The contrast diagrams of the rolled microstructure at the bottom of the samples of the HSLA steel were shown in Fig. 1 (a-d), including no magnesium addition (the original steel), 1 wt% Mg addition, 3 wt% Mg addition and 5 wt% Mg addition.

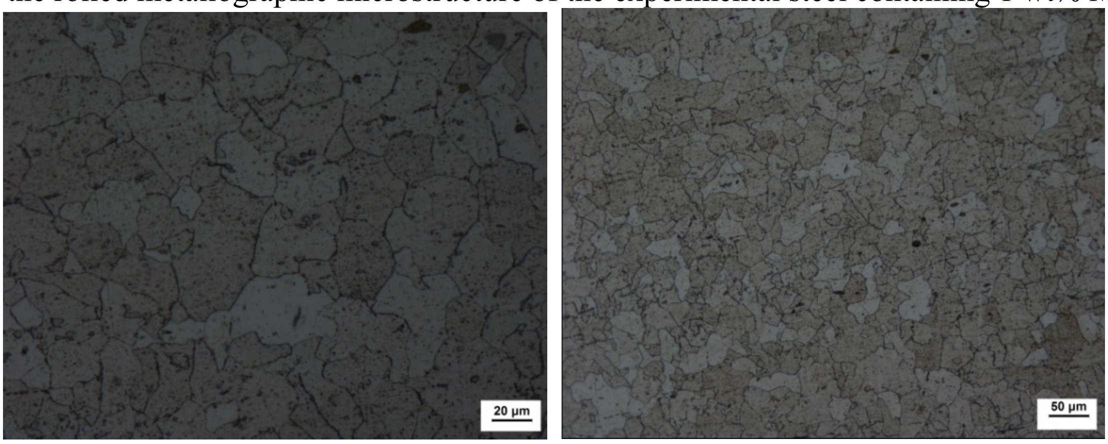
The microstructures that often can be found in the common steel are bainite, martensite, pearlite, ferrite, and so on. We can find that there are some differences in the microstructure among each experimental steel. The observation results of rolled microstructure were tabulated and shown in Table 3.



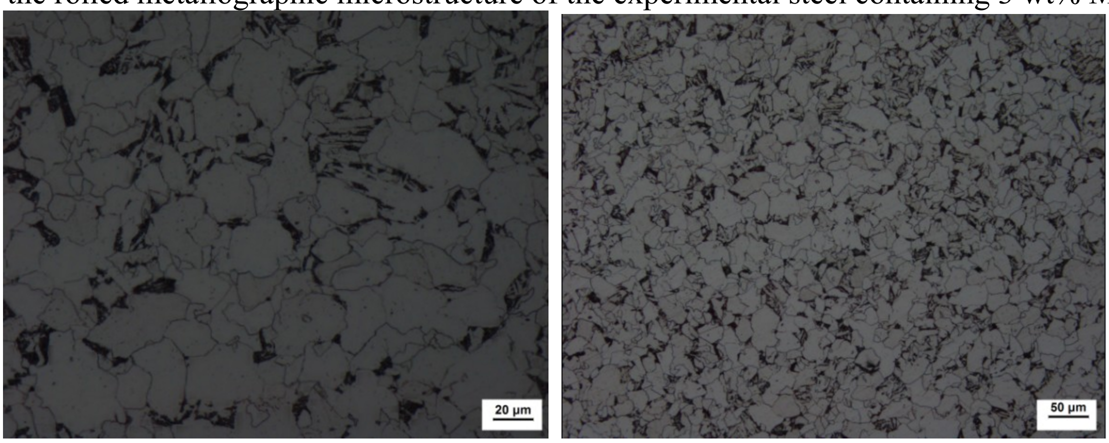
a. the rolled metallographic microstructure of the original steel



b. the rolled metallographic microstructure of the experimental steel containing 1 wt% Mg



c. the rolled metallographic microstructure of the experimental steel containing 3 wt% Mg



d. the rolled metallographic microstructure of the experimental steel containing 5 wt% Mg

Fig. 1 Rolled microstructure comparison diagrams of each sample containing Mg

Table 3 Microstructure observation results of rolled steel containing Mg

Experimental steel	The observation results of microstructure
The original steel	polygonal ferrite + small amount of quasi-polygonal ferrite + small amount of pearlite
Mg1%	polygonal ferrite + quasi-polygonal ferrite + small amount of pearlite
Mg3%	polygonal ferrite + quasi-polygonal ferrite
Mg5%	polygonal ferrite + quasi-polygonal ferrite + bainite + small amount of pearlite

From the above analysis results, it can be seen that the samples are rolled after melting and austenitizing, and the cast microstructure has been changed after rolling and the deformed austenite. The rolled microstructure of the experimental steel mainly consists of polygonal ferrite and granular bainite and small amount of pearlite. Compared with the original steel, there is bainite presenting in the experimental steel after adding 5 wt% Mg, which are the microstructure that we hope to get. The bainite will have a good effect on the mechanical properties of the rolled steel.

Conclusions

Magnesium was added into molten steel in the form of Mg-Zr alloy using the special process in the experiment. A kind of HSLA steel containing Mg was prepared by means of the vacuum induction melting experiments and controlled rolling and controlled cooling experiments, and the effect of magnesium addition on the rolled microstructure of the HSLA steel was analysed.

(1) The samples are rolled after melting and austenitizing, and the cast microstructure has been changed after rolling and the deformed austenite.

(2) The addition of Mg elements has a significant effect on the microstructure of the rolled steel. The rolled microstructure of the experimental steel consists of polygonal ferrite and granular bainite and small amount of pearlite.

(3) Compared with the original steel, there is bainite presenting in the experimental steel after adding 5 wt% Mg, which is favorable to the mechanical properties of the rolled steel.

Acknowledgments

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