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Effect of Preheating Temperature and Cooling Rate on the Microstructure Development of Welded Pearlitic Rail Steel

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The heat affected zone (HAZ) formed due to vigorous heat treatment and recrystallization during welding is the most critical zone. Failure at the HAZ has been reported to be as a result of change in microstructure and reduction of mechanical properties [1]. Variation in preheating temperature and cooling rate has a significant effect on microstructure and mechanical properties of the HAZ of welded pearlitic rail steel and formation of martensite at higher cooling rates has been reported [2]. Slow cooling rates increased both the grain size and interlamellar spacing of the pearlite colony in the HAZ of welded rail [3]. Narrow interlamellar spacing resulted in higher hardness as more of the cementite phase was present there. However, toughness depends only on grain size, with a smaller grain size producing higher toughness [4]. For these reasons, retention of the pearlitic structure in the HAZ after gas metal arc weld (GMAW) finishing is highly desirable and understanding the effect of cooling rate on microstructure needs attention.

Evaluating the microstructure of HAZ of GMAW pearlitic rail steel through controlled cooling is the prime focus of this research. Multipass GMAW has been performed on one sample without preheating, two 300 °C preheated samples, and one 500°C preheated sample to fill the slot of the rail head with Postalloy 2892-SPL hardfacing filler wire. A continuous cooling transformation (CCT) diagram for the working rail steel composition was obtained using JMatPro V11 software. The cooling rate was controlled using insulating materials. One 300 °C preheated sample was cooled at the rate of 8 °C/s and another 300 °C preheated sample was cooled at the rate of 2 °C/s. The sample without preheating was cooled in open air and the 500°C preheated sample was cooled at the rate of 2 °C/s. The controlled cooling rate was measured using an infrared thermocouple. Samples were cut for microstructural analysis and were polished and etched with 2% nital. Optical micrographs of the etched samples were evaluated using the Olympus GX51 inverted metallurgical microscope.

Figure 1(a) represents the micrographs taken from the fast cooled HAZ, while the slower cooled HAZ micrographs are shown in Figure 1(b). Figure 1(a) exhibits an appearance of bainite in the microstructure. Due to the faster cooling rate, cementite (orthorhombic, Fe_3C) layer could not be formed there because the carbon was still dissolved in the austenite. The microstructure of the slower cooled HAZ in Figure 2(a) consists of fine grained pearlite, which is highly desired.

Figure 2(a) represents the micrographs taken from the no preheated sample, while the 500°C preheated sample micrographs are shown in Figure 2(b). Figure 2(a) exhibits an explicit appearance of martensite in the microstructure. The microstructure of the 500°C preheated sample HAZ with slow cooling in Figure 2(b) consists of coarse grained pearlite. The grains of pearlite in 500°C preheated sample in Figure 2(b) are a larger than those of the 300 °C preheated sample in Figure 1(b).

The cooling rate obtained from JMatPro to attain pearlitic microstructure in the heat affected zone of a pearlitic rail steel after GMAW has been achieved experimentally. Since a higher cooling rate can form bainite, even martensite, in the HAZ, 2 °C/s is the recommended cooling rate for GMAW of pearlitic rail steel to get desired pearlitic structure in the HAZ with 300°C preheating.

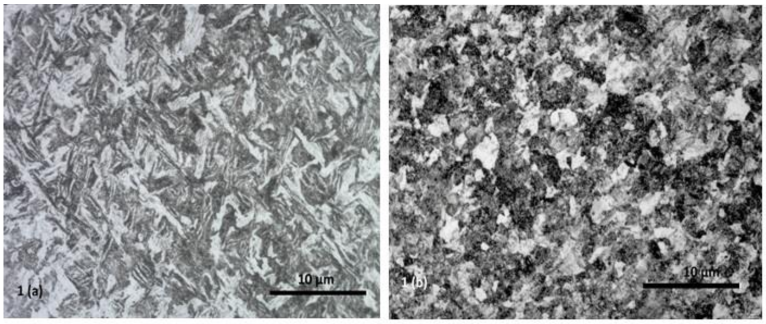

Figure 1. Optical micrographs of (a) fast cooled HAZ and (b) slow cooled HAZ with 300°C preheat

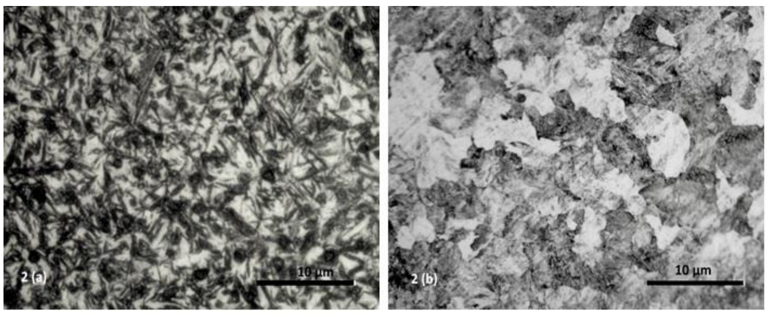

Figure 2. Optical micrographs of (a) fast cooled HAZ with no preheat and (b) slow cooled HAZ with 500°C preheat

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