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Microstructural Evaluation of Welded Pearlitic Rail Steel

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The number of trains traveling over railway tracks and the cargo carried is increasing yearly [1]. Therefore, rail tracks undergo tremendous amount of loading accompanied by friction and a harsh working environment such as corrosion and heat changes over a lifetime [2]. The excessive loads on the rail tracks cause deformation of the railhead (few microns to 5 – 10 mm) [2]. Once the materials' ductility is exhausted, cracks will propagate, which may lead to rail failure if not detected and repaired. Derailment, loss of lives and high repair costs to the railroad industry may be associated with rail failures. Improvements in the performance of rail steels and rail steel welds are imperative in order to meet the challenges of increased traffic density and heavier axle loads. Current rail welding techniques, such as thermite and flash-butt welding, are very expensive and time consuming [3]. Development and evaluation of alternative repairs has great economical importance, but present great technical challenges. Slot welding, using gas metal arc welding (GMAW), is a promising method that could address these issues. Prior to repairs, the defects in the railhead are accurately mapped and removed via machining.

The focus of this research was to evaluate the microstructure of slot welded pearlitic rail steels using two different commercially available filler wires (LA-100 and ESAB-140), that are manufactured by Lincoln Electric and ESAB Welding and Cutting, respectively were used. Slots were machined in each rail head to simulate the removal of defects. Slot welding using GMAW was performed to fill the slots using the filler wire with multiple passes. Any excess weldment was removed from the sample and specimens were cut for microstructural analysis and were polished to a mirror-like finish. They were then etched with 2% nital (2% nitric acid & 98% methanol) for approximately 10 seconds. The etched specimens were examined using a measuring laser confocal microscope.

The microstructure of the parent pearlitic rail steel is shown in Fig. 1(a) and 2(a). Both micrographs display a typical pearlitic microstructure that consists of fine lamellar aggregates of very hard cementite (orthorhombic, Fe_3C) and a very soft ductile ferrite (body centered cubic crystal structure and is considered pure iron) phases. The lamella spacing between the cementite and ferrite structure is very evident. Fig. 1(b) shows the microstructure at the center of the welded region of the rail steel welded with the LA-100 filler wire. The microstructure consists of a mixture of pearlite (darker) and ferrite (lighter) regions. The microscopic cracks (circled in the image) will have a negative impact on the properties of the welded joint. The weld's microstructure for the rail steel welded with the ESAB-140 filler wire is shown in Fig. 2(b). This micrograph consists of mostly ferrite with small amounts of pearlite. The ferrite grains observed are very small, which are associated with higher strength and ductility. The microstructural features indicate that the rail steel welded with ESAB-140 filler wire will have better mechanical properties than that welded with LA-100 filler wire.

The ESAB-140 wire showed greater feasibility to have a better mechanical properties (greater ferrite content) when compared to the filler wire LA-100 (mixture of pearlite and ferrite in equal amounts). Microscopic cracks in the weld region of LA-100 filler wire are another indication of poor weld joint in comparison to better welded joint with no chance to cracks for the ESAB-140 filler wire.

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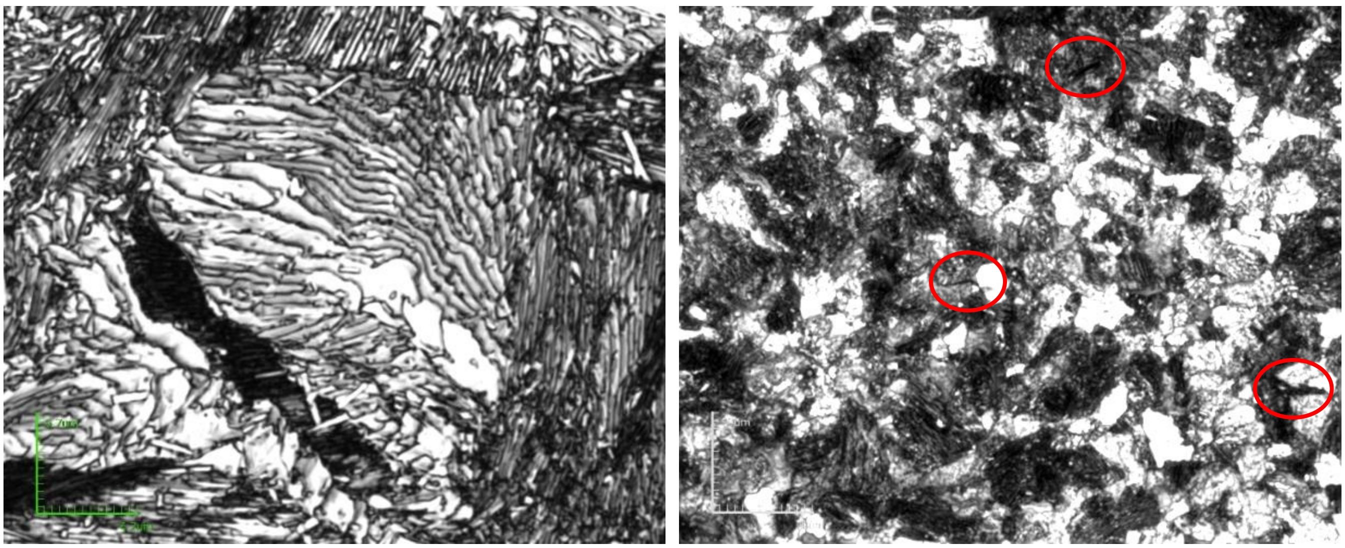

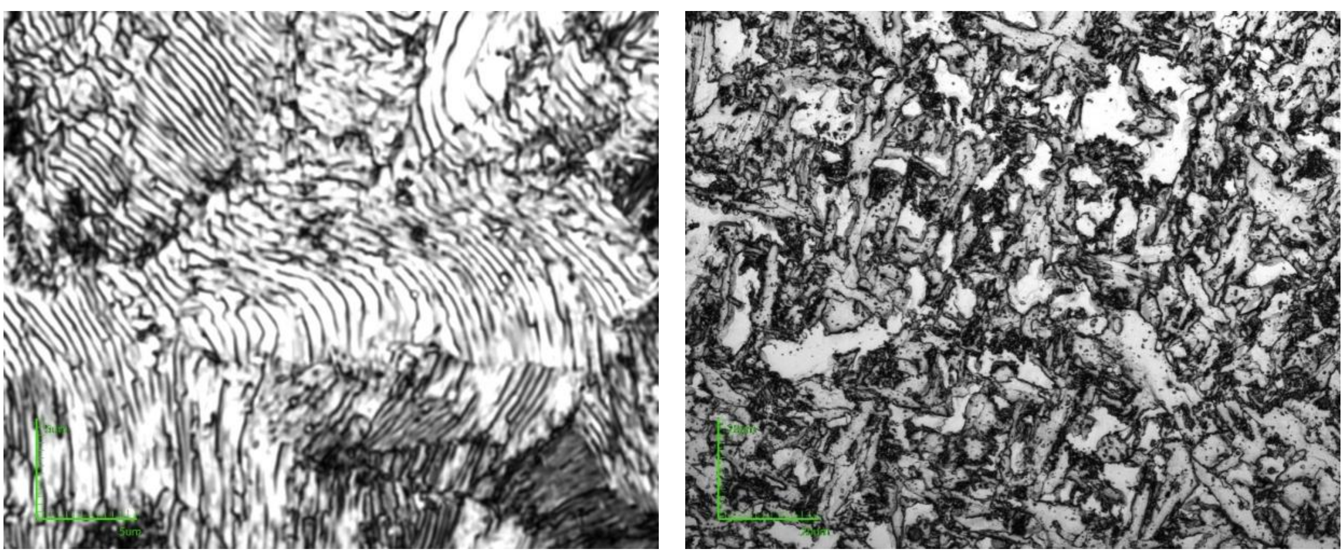

Fig. 1. Micrographs of rail steel welded with LA-100 wire: **(a)** the parent pearlitic rail steel, and **(b)** the center of the slot welded region.
Fig. 2. Micrographs of rail steel welded with ESAB-140 wire: **(a)** the parent pearlitic rail steel, and **(b)** the center of the slot welded region.

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