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Microscopic Identification of Strength and Durability of Rail Steels

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Pearlitic steel accounts for most of the steel tonnage that is produced today [1]. Bainitic rail steel properties offer more additional features than pearlatic. The most visible microstructural features of the single-phase alloy Bainitic are the austenite grain boundary. Austenitic manganese (AM) Steel toughness, resistance to wear, and heavy impact loading make them favored for railway frogs [2]. Austenite has a soft, low-strength phase that can be hardened [3], and grain size in AM varies according to the amount of superheat in the liquid metal during casting. This study compared the microstructure-properties and fatigue crack growth of a premium Pearlitic, AM and J6 Bainitic rail steels with optical and SEM**.**

The microstructure of Pearlitic rail steel showed characteristic lamellae of ferrite and cementite (Fig.1a) that contributed to crack propagation from left to right in Fig. 1b. By comparison, the microstructure of Bainitic rail steel showed thinner grain boundaries (Fig. 2a). Primary laths formed at the grain boundaries of primary and secondary lath contributed to crack deceleration probably through high-energy absorption (Fig. 2b). The AM rail steel showed grain boundaries and dislocations (Fig. 3a), but more Twinining than in Pearlitic and this explains its higher strength and higher ductile fracture features (Fig. 3b).

Pearlitic grain has its own orientation with lamellae of ferrite and Cementite. The lamellae are aligned in the single direction within the grains. The mechanical properties of the Pearlitic steel are determined by the interlayer spacing of the lamellae of the ferrite and Cementite. This microstructure resembles a mixture of upper and lower Bainite. The bright parts with some dark spectral within is ferrite and upper Bainite are evident. The dark portion as indicated by the arrows is lower Bainite. The low carbon and the large amount of alloying elements is the main contributor to the intricate structure within the Bainitic steel.

Fracture surface morphology examination was performed by optical and SEM on typical fatigue-failed specimens of each material. The fracture surface is mainly divided into two regions; slow and fast crack regions. The slow crack region reflects the crack deceleration and indicate a considerably high-energy absorption process associated with the crack propagation in both Bainitic and manganese rail steels. Hence, Bainitic rail steel displayed more ductile fracture features in the first region than the Pearlitic steel. The creation of these fractures consumes more energy, and probably reduces crack speed propagation in Bainitic rail steel.

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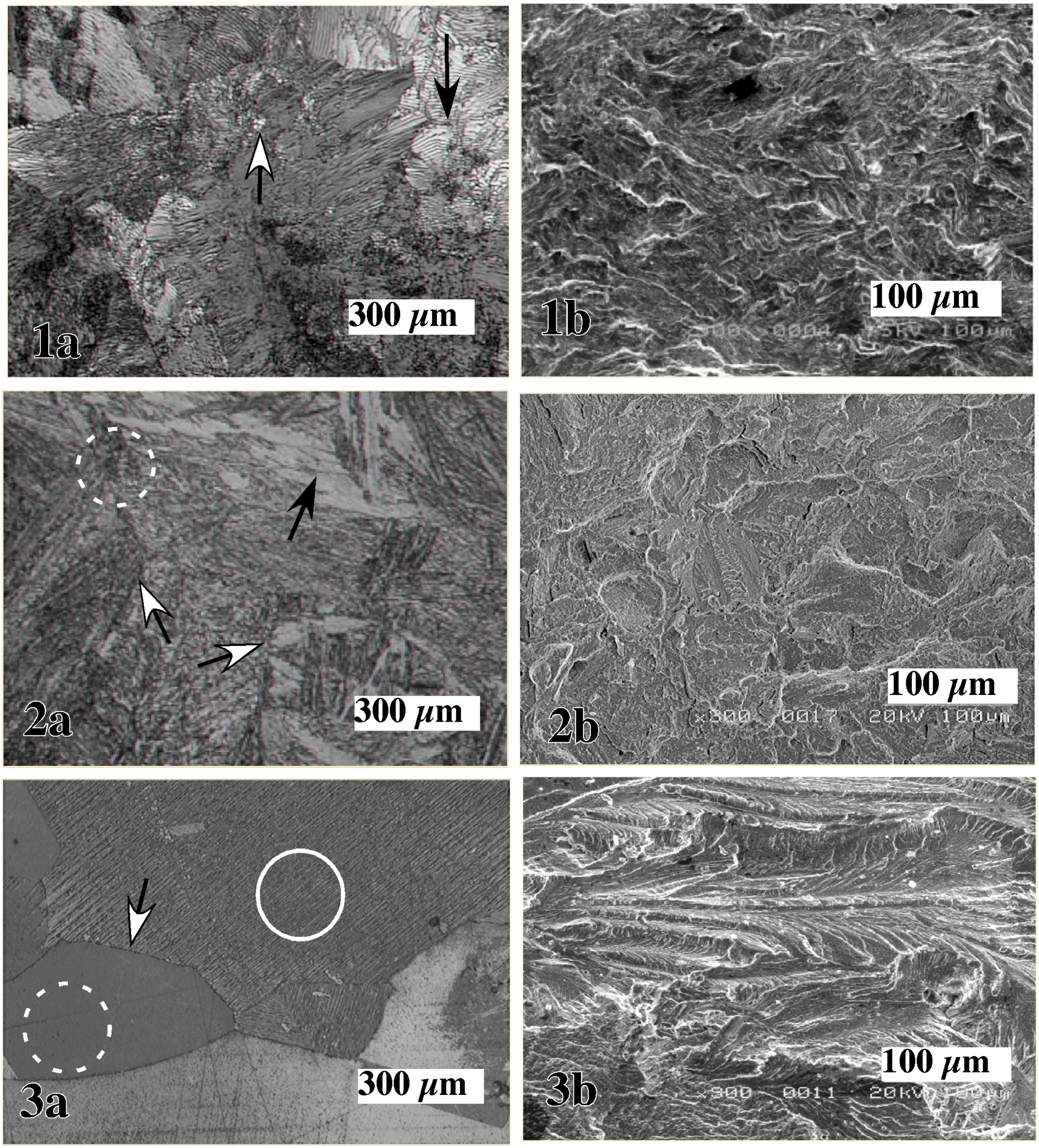

Fig. 1a. Optical microstructure of the Pearlitic rail steel with ferrite and cementite lamella (black arrow), & Pearlite (white arrow). **Fig. 1b.** SEM at beginning of the stable crack propagation (LT - RT) region in the pearltic rail steel.

Fig. 2a. Bainistic rail steel with lower Bainite grains (circle), Ferrite and upper Bainite (black arrow), with characteristic thin grain boundary lines (white arrows). **Fig. 2b**. SEM at beginning of the stable crack propagation with deep ridges.

Fig. 3a. AM rail steel with wide Twinning grain area (solid circle), showing pitting (doted circle) in the parent Austenite grain (arrow). **Fig. 3b**. SEM of AM with ductile fracture and tearing and limited micro-voids coalescence.

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