Flash-but welding (FBW) is one of the primary types of rail welding techniques. The FBW technique is used for continuous welded rails in about 80% of all rail welds worldwide because of the weld quality [1]. The primary goal of this research is to examine the relationship between the microstructure and hardness in flash-but welded rails. In this research, a Phase II 900-356 Brinell Hardness Tester with an applied force of 3000 kg was used to generate indentations in the uppermost layer of a flash-but welded railhead. This was done for the calculation of the hardness values. The hardness of a particular region was calculated from the diameter of each indentation as measured by a Brinell Microscope. The hardness values obtained from each region were used to determine the base metal (BM), heat affected zone (HAZ), and weld zone (WZ). After acquiring the hardness values and identifying the correlated regions, the hardness profile was then constructed by plotting the hardness values in relation to their corresponding distance from the weld centerline (WC). The hardness profile is shown in Figure 1. For the microstructural analysis, samples were taken from the BM, HAZ, and WZ. These samples were metallographically prepared, etched with a 2% nital solution, and analyzed with an Olympus GX 51 Inverted Optical Microscope (Figure 1).

In Figure 1(a), a combination of pearlite and cementite can be seen in the optical micrograph of the WZ. The pearlite microstructure is discernable by its dark grains and is comprised of soft, ductile ferrite, and hard, brittle cementite lamellae that are aligned alternately and parallelly [2]. The cementite found in the WZ is termed pro-eutectoid cementite; this is developed cementite on the prior austenitic grain boundaries when the carbon content of steel is higher than the eutectoid composition [3]. The dense pearlite colonies enhance the ductility in the WZ, whereas the cementite grains are responsible for the high hardness value of about 404 BHN in this zone. Figure 1(b) represents the optical micrograph of the HAZ. This zone consists of spheroidized pearlite and cementite and is located roughly 15 mm from the WC. In the HAZ, there is noticeable spheroidization of pearlite and a decrease in the cementite grain size. Due to the spheroidized pearlite, the hardness is reduced in this zone. Similar findings have been noted in [4], [5]. Figure 1(c) shows the micrograph of the BM, consisting of cementite and pearlite. This region had a similar hardness value to the WZ, approximately 400 HBN. Since both the BM and WZ are pearlitic and have similar colony sizes and interlamellar spacing, the obtained similar hardness values in these zones are expected [5].

Rectangular samples were cut longitudinally from the flash-but welded rail; the samples had average dimensions of 3.68 mm thickness, 16.18 mm width, and 93 mm gauge length. An 810-material test system (MTS) was used to carry out tensile testing on these samples. A Hitachi S3400N scanning electron microscope (SEM) was used to examine the fractured surface from the tensile test. The rectangular samples broke under tensile testing at the HAZ with an average strain of about 6.26%, which is more than brittle fracture and less than ductile fracture. The SEM images of the fractured region (Figure 2) demonstrate the mixed mode of ductile fracture and brittle fracture, which is validated by [6].
Figure 1. Hardness profile for the top surface of the flash-butt welded railhead; related optical micrographs are for the (a) WZ, (b) HAZ at 15 mm from centerline, and (c) BM, each at 50x magnification.
Figure 2. SEM images of the tensile tested flash-butt sample showing (a) brittle fracture at 450x magnification and (b) ductile fracture at 4500x magnification

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