EXPERIMENTAL ASSESSMENT OF LOCOMOTIVE BRAKE BLOCKS - CASE OF BOTSWANA RAILWAYS

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The brake blocks employed on Botswana Railways locomotives have been found to fail frequently resulting in increased maintenance and operational costs. The paper presents the metallurgical and mechanical properties of two different types of brake blocks (referred to in this paper as "Type A" and "Type B"). These have been observed to fail differently in service. Type A fails normally while Type B fails at a faster rate and usually prematurely. Analysis carried out on the brake blocks material include mechanical testing, optical microscopy and electron dispersion spectroscopy (EDS). The elemental compositions of the materials differ among others, in: carbon, sulphur, phosphorus and manganese. EDS results show that elemental composition of the materials influences the behavior of the material under loading conditions. Finally it was concluded that porosity content in the materials contributes significantly to premature failure of the blocks. Therefore the manufacturing process of brake blocks should be monitored to ensure high quality products and enhanced service life of the brake blocks.

Key words: porosity, rate of wear, EDS analysis, mechanical properties

1 INTRODUCTION

There are different mechanisms of braking systems on automobiles such as trains, cars, and other locomotives. There are different kinds of braking systems used in locomotives; the pneumatic, dynamic, and brake blocks. The Botswana Railways uses brake blocks made from cast iron, which is a rigid molded friction material, grey black in color. While brake blocks used in locomotives are made from cast iron, there are others made from composite materials like asbestos for those used in rail wagons/cars [2-3]. The material used for brake blocks should have the ability to withstand the heavy braking forces of electric multiple units (EMU). This project was aimed at carrying out an investigation failure behavior of cast iron brake used in locomotives by BR. The study involved characterization the mechanical properties of materials used for brake blocks by performing mechanical tests, optical microscopy, and electron dispersion spectroscopy.

2 EXPERIMENTAL PROCEDURE

2.1 Mechanical Tests

Materials used in the investigation were prepared form samples obtained from Botswana Railways. Two types of samples were investigated, type A for the standard block material type And type B for the brake blocks that failed prematurely. Mechanical tests carried out included impact and hardness tests. Test specimens were prepared as per ASTME23 and ASTME92 standards, respectively. Several specimens were prepared from both types A and B. Impact test was performed using the Charpy impact testing machine. The purpose of the test was to determine the average energy absorbed by materials, as the brake blocks are subjected to impact loading when in service. The results were analyzed using a bar chart [5, 6, 7]. Hardness measurements were determined by using the Vickers hardness indenter. Test specimens were mounted on epoxy, followed by polished progressively on grin paper until 600 grit. The hardness indentations were performed using a Vickers micro indenter. On wear resistant different forces were applied on the specimens and the depth of wear was recorded as the difference between the original length and the final length of the specimen [8]. A plot of wear rate vs. applied force was constructed from the results.

2.2 Energy Dispersive Spectrometry (EDS) Analysis

Two identical specimens from material type A and material type B were prepared. Electron displacement analysis was performed on the materials to determine the microstructures composition. Scanning Electron Microscopy housed at University of Botswana in Science Faculty was used [9]. The specimens were polished before they could be taken for EDS analysis. Three different areas were spotted on material type B and material type A specimens, bulk analysis was done

on each one of them and the electron dispersive x-ray spectrometer was captured for each material. Backscattered and Secondary Electron modes were used. Backscattered electrons are generated when a beam of electron collides with or passes close to the nucleus of an atom of the specimen while the secondary electrons are generated when a beam of electrons interact with the atoms of the specimen to produce low energy or secondary electrons[10]. Different parameters were also recorded together with the ZAF correction factors;
Z is used to designate the effects of atomic number, as the atomic number increases the x-ray intensity also increases [11].

A is used to designate the absorption effects within the specimen. For light elements and low accelerating voltages absorption is minor and for heavier elements absorption is high [11].
F is used to designate the fluorescence effects of X-ray within the specimen. All these effects are mainly referred to as the ZAF correction factors [11].

Other parameters such as K, At and Wt were also recorded during the EDS analysis. Wt which is the weight or elemental composition and At which is the atomic percentage. K which is the sensitivity factor, K-ratio are a comparison of peaks intensity between an element in pure form and the same element in a multi element compound with all analytical conditions the same [9,10,11].

3 RESULTS AND DISCUSSION

3.1 Mechanical Properties

The impact test results show that the average energy absorbed by type A and type B materials are 11 joules and 8.8 joules, respectively. Brake block material in type A requires more energy to brake than the type B material. It is important that a material should be able to withstand high impact loads, especially big loads like in the case of a locomotive. If the material fails or breaks prematurely, the braking will not be effected, and subsequently, an accident is likely to occur.

The wear resistance tests performed on both material types show that wear rate is proportional to load applied. Material type B showed higher wear rate than type A. For applied force of 20 *N* material type A exhibits an average wear rate of 120 μm of wear/s and material type B exhibits wear rate of averaging 250 μm of wear/s. At higher applied load of 40 N, the material type exhibit wear rate of 450 μm of wear/s and 500 μm of wear/s, respectively. This observation is consistent with the observation made on the premature failure of the type B material. Type B material was observed to have high porosity content, although the Vickers hardness measurements show similar results for both Type A and Type B materials. The surface hardness measurement is about 3675 VHN in both cases.

3.2 Energy Dispersive Spectrometry (EDS) Analysis

Energy-dispersive spectrometry analysis was performed on samples prepared from both material types. The following Figures show spectra obtained, together with corresponding scanning electron microscopy (SEM) images. EDS spectrum gives elemental composition of the brake block material.

Figure 1 shows EDS spectrum obtained from material type A, while Figure 2 shows EDS spectrum for material type B. The spectra show that there is little carbon content compared to iron content in both material types A and B. The presence of other elements like silica, sulphur, phosphorus and manganese is also indicated.

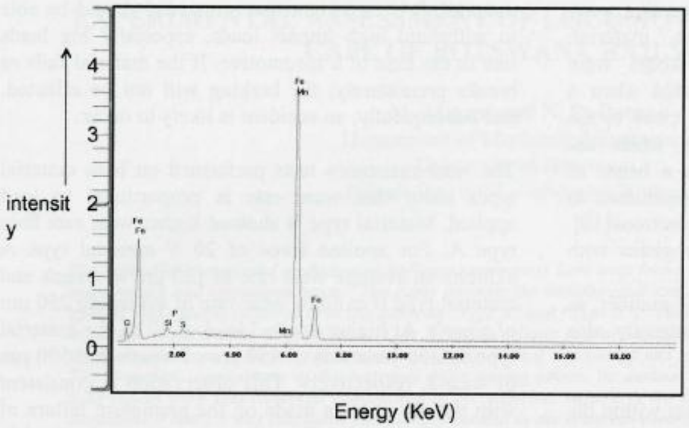

Figure 1: EDS spectrum of material type A showing 0.3C, 1.4Fe and 3.7Fe, 0.1Mn and 3.6Mn, 0.6Fe, 0.24Si, 0.21S and 0.2P counts according to the scale.

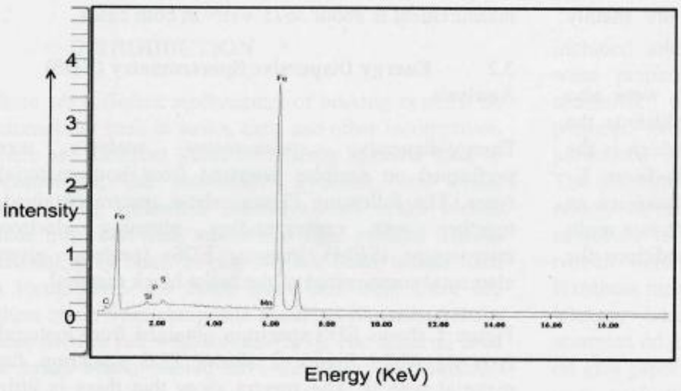

Figure 2: EDS spectrum of material type B showing 0.15C, 1.5Fe and 3.8Fe, 0.1Mn, 0.2Si, 0.21S and 0.2 P counts according to the scale.

The EDS show that material type A has more carbon content in its composition as compared to material type B. It can further be observed that material type B exhibits slightly higher iron content as compared to material type A, about 0.1Fe difference. There is also high composition of manganese in material type A than in material type B.

Figure 3 shows the scanning electron microscopy images obtained from the brake block materials. Figure 3 (a) reveals a higher volume graphite flakes and shrinkage porosity, while in Figure 3 (b) the presence of cracks is shown. From the SEM images the carbon content is observed to be dicey and further analysis can be made accurately with calibration against a certified standard, e.g. certified grey cast iron. Graphite flakes appear clustered together in small pockets resulting in a variation of the C content. The sample is not homogeneous and a very bad example of a "good grey cast iron "An uneven distribution of the other elements can clearly be seen from the LM photos. The material type A appears to be a two phased matrix. The Graphite (light in element - C) is black in BSE mode. Some MnS appears to be a dendritic shape indicating they formed early during the casting process. While porosity appears to present in material type A as shown by associated graphite flakes, it is not to the extent observed in type B material. The high volume of pores in the B type material is attributed mainly to the casting defects.

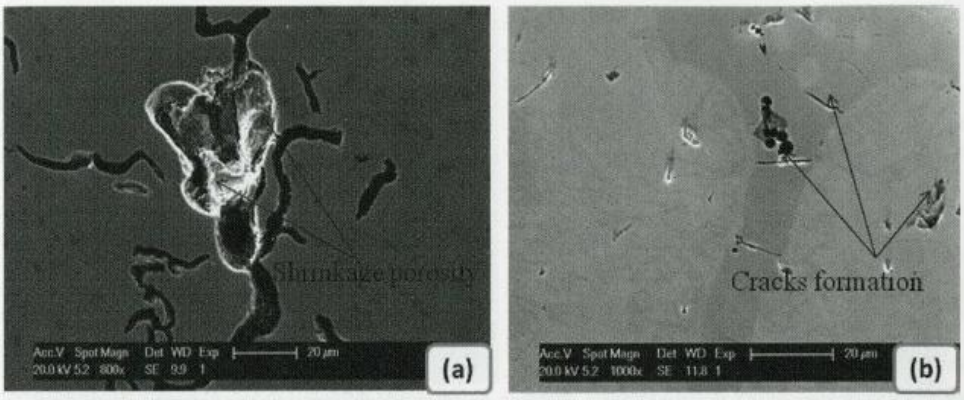

Figure 3: Electron microscopic images for (a) material type A showing shrinkage porosity and (b) material type B showing the formation of cracks.

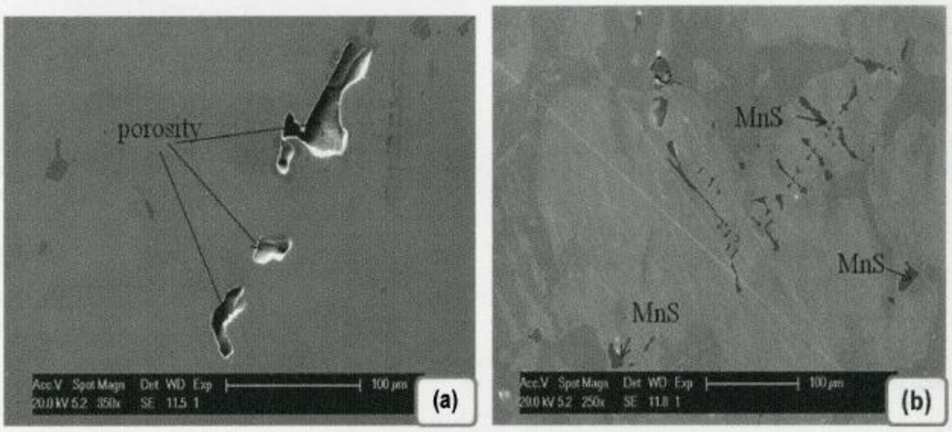

Figure 4: Electron microscopic of material type B showing (a) porosity and (b) the formation of dentritic MnS due to solidification.

From the SE image can see a possible dendritic structure due to casting, no clear graphite flakes and the porosity is more evident as shown in Figure 4. Some micro pores which appear to be pronounced in material type B, as indicated in Figure 4 (a), are likely to link up under stress and subsequently lead to formation of cracks. These cracks in turn, contribute significantly to premature failure of the brake blocks.

Some MnS and FeS islands are also shown in the materials. It also shows that there are no clear graphites on material type B.

The microstructures shows the graphite flakes on the material type A and there are no graphites on material type B. Material type B shows more ferrite which is a composition of iron with other elements which is a soft matrix [12]. The high volume fraction of graphites in type A material reduces the material's superplasticity and improves its brittleness, hardness and strength. The graphite flakes improves the damping characteristics of the material [12], which ensure that the material is able to withstand high impact loads. The deficiency in graphites observed in material type B compromises the brittleness of the material, thus the binding effect of the brake blocks during braking of the locomotives.

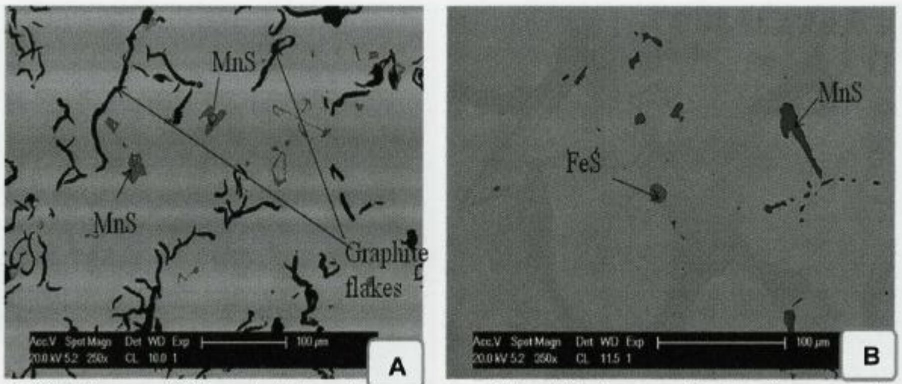

Figure 5: SEM images of (a) material type A showing graphite which improves the damping properties of the material, and (b) material type B showing no evidence of graphite.

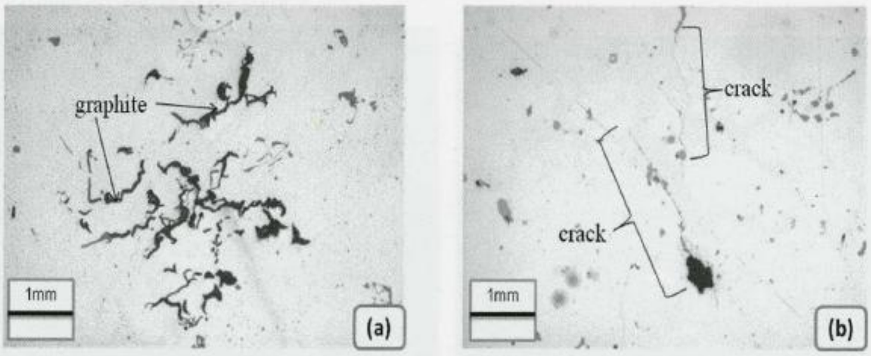

Figure 6: Light microscopic photos of (a) material type A showing uneven distribution of the graphite flakes and (b) material type B showing the cracks.

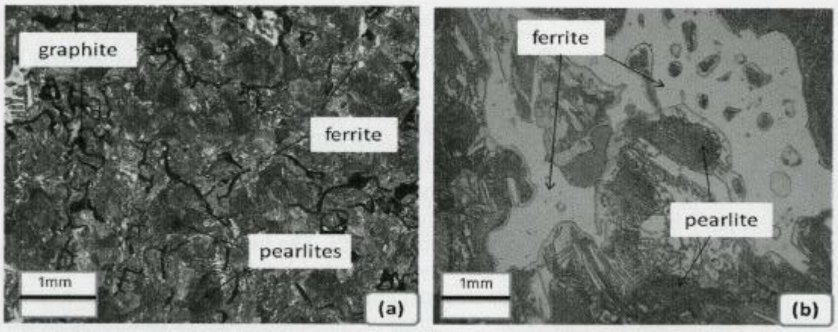

Figure 7: Scanning electron microscopy images from: (a) material type A, and (b) material type B.

4 CONCLUSIONS

Results show that material type A exhibits higher impact energy than material type B, and therefore, it is likely that material type B will fail first on impact loading. The EDS spectra show that carbon content is higher in Material type A than that observed in type B material, thus material type A will have a higher wear resistance as compared to material type B. The volume fraction of pores is higher in type B material than in type A. The high porosity content weakens the structure and as a result, further contributes to premature failure of the type B brake block material. The SEM images reveal the presence of graphites in material type A but not in type B. Graphites enhance mechanical properties of the material, like hardness, strength and brittleness. Material type A on the one hand posseses damping characteristics due to the presence of graphite flakes [12]. On the other hand, the high wear rate, the binding effect and premature failure of the brake blocks associated with material type B may be attributed to the low graphite content in the material.

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