Characterising the Brake Blocks of a Freight Rail Container Wagon

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***Abstract*—Society has become dependent on trains to provide the means for freight and transport services and with so many people being dependent on these services safety must be taken as the utmost priority. The aim of this research project is to characterise the Brake block samples of a Freight Rail container wagon using tribological properties for the effect of friction and wear, hardness tests to investigate the mechanical property and microstructure analysis and material composition in different environmental conditions using Scanning Electron Microscopy (SEM), Energy Dispersive Spectrometry (EDS.**

***Index Terms*—Brakes block, friction, hardness test, test, wagon, wear test, microstructure**

I. Introduction

Trains provide a very important service to society, not only do they help numerous people get to work every day, they also use in transport of raw materials and goods [1]. Many industries depend on trains in order to survive in the economy [2]. With so many people being dependent on these services in order to provide society with the necessary goods and services to enable growth, safety must be taken as the utmost by ensuring that the braking systems of these locomotives are up to standard [3, 4].

The air braking system is used around most parts of the world as the standard braking system for trains. The basic operation of the air braking system is that compressed air is used as a means to drive brake blocks into contact with a wheel [5].The brake blocks provide a retarding force on the train which provides a means for dissipation of energy through a conversion of kinetic energy to heat energy. The compressed air that is used for braking is transferred through brake pipes to the various components of the brake system [6]. Currently, braking systems have only been analysed in a two dimensional plane and are thus somewhat not an accurate representative of the actual system [5]. Thus the braking system must be completely analysed and modelled in order to recognize any problems and make corrections thereafter. Friction materials such as brake blocks are to decelerate a vehicle by converting kinetic energy to heat via friction [7]. Brake blocks are generally required to possess certain qualities such as resistance to corrosion, light weight, long life, low noise, stable friction, low wear rate and acceptable cost versus performance [8].

The brake blocks are designed according to a type and thickness such that they can fit onto the brake head used on the particular wagon. Typically there are two types of brake blocks available: cast iron brake blocks and composite brake blocks. Cast iron brake blocks were often used on older cars whereas composite blocks are now employed for newer braking systems. The newer high friction composite brake blocks have about twice the stopping ability of cast iron blocks [9].

The brake blocks are selected such that they satisfy the requirements of the user as best as possible. They are selected so that a balance can be achieved between certain characteristics such as: The braking characteristics; the wear and service life of the blocks; Wear on the running surface of the wheel; the effect on adhesion between the rail and the wheel [10]. Brake blocks Materials can be classified as one of four different types of additives. Abrasives help maintain the cleanliness of mating surfaces and control the build-up of friction films. They are also used to increase the amount of friction in a particular brake block during a braking process [11, 12]. Typical abrasives are shown in Table 1. Friction modifiers lubricate, raise the friction or react with oxygen and help control interfacial films. Typical friction modifiers are shown in Table 2. Fillers are used to maintain overall composition of the friction material while some have other functions too. They can be metals, alloys, ceramics or organic materials and typical filler materials are shown in Table 3.Typical binder materials are composed of phenolic resins mostly used in automobile and truck brake pads but sometimes used in trains as well. These are common materials such as sintered, carbon-carbon and organic materials. Typical binder materials are shown in Table 4

Therefore, Brake blocks serve a very important purpose in society and as such, a lot of time and effort goes into researching, the purpose of this research project is to characterisation the Brake blocks of a Freight Rail container wagon to further increase the accuracy to which the brake force system is represented which will further explain the brake force behaviour. The Brake block samples will be analysed through Scanning Electron Microscopy (SEM), Energy Dispersive Spectrometry (EDS), Microstructure analysis, tribological properties for the effect of friction and wear and hardness tests. This will give an indication of brake wear and its life cycle

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Table 1: Typical abrasives in brake blocks [13]

Material	Description/Comment
Aluminium oxide	(1)Hydrated form added as a polishing agent for wear resistance, but can produce fade, (2) Anhydrous form is still more abrasive, (3)fused is very hard and is the most abrasive form.
Iron oxide	Hematite (Fe_2O_3) can act as a mild abrasive, magnetite (Fe_3O_4) is also mildly abrasive
Quartz	Crushed mineral particles (SiO_2)
Silica	May be naturally or synthetically produced (SiO_2)
Zirconium silicate	($ZrSiO_4$)

Table 2: Typical friction modifiers used in brake blocks [13]

Material	Description
Antimony trisulphide	Solid lubricant added to enhance frictional stability; lubricates >450°C; Sb_2S_3 is potentially toxic
Brass	Typ. 62% Cu – 38% Zn, sometimes used as chips or machine shop cutting swarf, said to improve wet friction and recovery, common additive
Carbon (graphite)	Cheap and widely used; but there are forms and sources, some of which can contain abrasive contaminants; burns in air at 700°C, friction level is affected by moisture and structure
Copper	Used as a powder to control heat transport but can cause excessive cast iron wear
"friction dust"	Commonly consists of processed cashew resin, may have a rubber base; some additives used to reduce spontaneous combustion or help particle dispersion
"friction powder"	May consist of Fe sponge, e.g. for semi-metallic brake pads; number of different particle grades (sizes) are available depending on the requirements for surface area, light-medium-heavy duty vehicle applications
Metals – fluxing compounds	Pb, Sb, Bi, Mo, as fluxing compounds serve as oxygen getters to stabilize friction-induced films and help to keep them from getting too thick.
Molybdenum disulphide	(MoS_2), a typical layer lattice type lubricant
Petroleum coke	Low cost, can lower friction, low ash

Table 3: Typical filler and reinforcement materials used in brake blocks [13]

Material	Description
Anti-oxidants	Help to maintain the proper oxide film thickness on aircraft brakes- too much oxide leads to unstable friction (high at low speeds) and thick films that can wear off too readily; graphite is a common one in metal ceramic composites brakes
Asbestos	Most common filler in early brake materials (No longer used due to health implications)
Barium sulphate ("barytes")	($BaSO_4$) basically inert, but increases density and may aid in wear resistance, stable at high temperatures
Calcium carbonate	$CaCO_3$ is a lower cost alternative to barytes, but not quite as stable at high temperatures
Cashew nut shell oil	Improves resilience in the binder system and reduces brake noise
Cotton	Reinforcing fibre for the matrix
Fibres – mixed oxides	Reinforcement fibres, produced from a base slag mineral wool, can contain for example, a mixture of silica (40-50 wt.%), alumina (5-15 wt.%), calcia (34-42 wt.%), magnesia (3-10 wt.%), and other inorganics (O-7wt.%); function is to control fade and increase braking effectiveness
Lime	$Ca(OH)_2$ is used to avoid corrosion in Fe-additives, helps in processing , helps raise fade temperatures
Potassium titanate	Inert filler material; also, an insulator and structural participant to replace the role of asbestos
Rubber – diene, nitrile	Used as stabilizers to promote cross-linking and increase wear resistance in polymer composite brake materials containing asbestos fibres, rubber also modifies the compressibility (modulus/stiffness)
Rubber scrap	Ground up tires ("tire peels"), decrease costs, must not contain road dirt
Zinc oxide	ZnO imparts some wear resistance, but can polish drums.

Table 4: Typical Binder materials used in brake blocks [13]

Material	Description/comment
Phenolic resin	Common binder; too little-material weakness; if too much is used, there is a friction drop-off at high temperatures; the degree of polymer cross-linking affects behaviour
Metallic alloys of Cu, Fe, Ni	Affect brake matrix materials
Modified resins	A variety of modified resins is available; modifications to alter bonding Characteristics and temperature resistance includes cresol, epoxy, cashew, PVB, rubber, linseed oil and boron.

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II. Experimental Material and Procedures

A. *The brake blocks material*

The brake blocks used for these experiments is a low-friction composite material shown in Figure 1.

Fig. 1: The new low friction brake blocks being used from a wagon company to replace cast iron brake shoes [14]

Fig. 2*: Used low friction brake blocks from a wagon company*

The brake blocks were cuts to obtain the required specimens for testing. Two sets of specimens were cut both from the new low friction brake blocks and used low friction brake blocks a wagon company for the wear tests, SEM/EDS, microstructure and hardness tests. The first set of samples for the wear tests were cut to a size of roughly 20mm×20mm×10mm samples. The second set of samples for the SEM/EDS, microstructure and hardness tests were cut to a size of roughly 15mm×15mm×15mm.

Microstructure analysis was performed to analyse on a microscopic level to be able to make judgement based on material composition, structure and layout using Optical Microscope. The SEM/EDS analysis is used to analyse a materials microstructure as well as the constituting elements found within the samples. The EDS analysis however yields the results of the elemental composition of a sample by looking at the different X-ray emissions given off by different elements. Hardness test was performed to testing the hardness properties of a material by using a micro hardness testing machine. The wear rate and friction coefficient for both samples were tested using the ball-on-flat machine. The wear tests are used to generate the behaviour of the brake pads under wear conditions [15, 16, 17]. Two different tests were conducted to investigate the effect of a changing frequency of oscillation for the sample and a change in load applied to the sample.

III. Results and Discussion

Fig. 3 shows the microstructure image that reveals the structure of the materials on the surface. From the figures it is clear that there is no set structure for the composite material that the brake block is composed of (i.e. it was not of a homogenous composition). The microstructure reveals that the brake block is composed of a number of materials, some of which appear to be metallic in nature while others appear to be minerals. Using the EDS. Certain common elements was found to occur in the composite material. The most common elements found were, C, O, Al, Si, S, P, Ti, K, Ca and Zn. the microstructure shows a number of darker materials (assumed to be a carbon based composite) which are surrounded by a binder like material. It is also apparent from the structure that a number of pores exist in the material. This can be attributed to the fact that phenolic resin decomposes or evaporates which leaves a material highly porous and also decreases the density of the material at the wear surface.

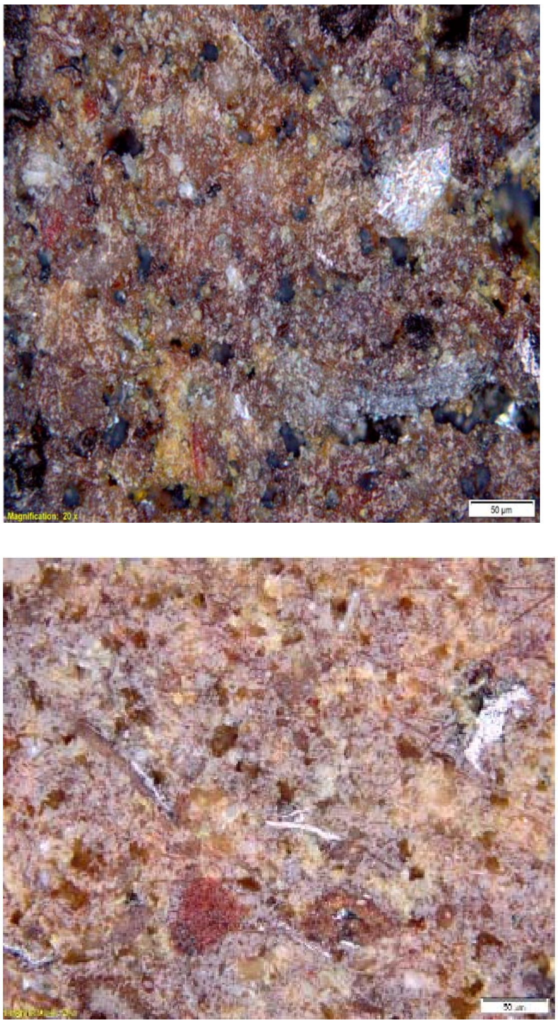

Fig. 3: Two different locations of the same sample from the same brake block

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The scanning electron microstructure for the used sample brake block is shown in fig.4 and Fig. 5 show the SEM analysis of virgin sample. 500µm portion area of both samples was analysed. It is clear from the microstructure of the sample shows that there is formation of carbon based compounds has taken place. This is due to the high temperatures that the brake block is subjected to during application of the brakes.

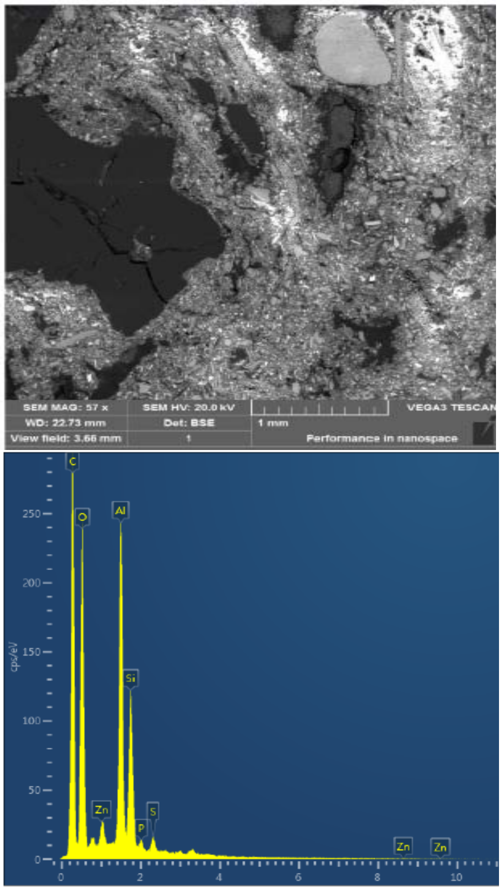

Fig.4: SEM analysis of used Sample

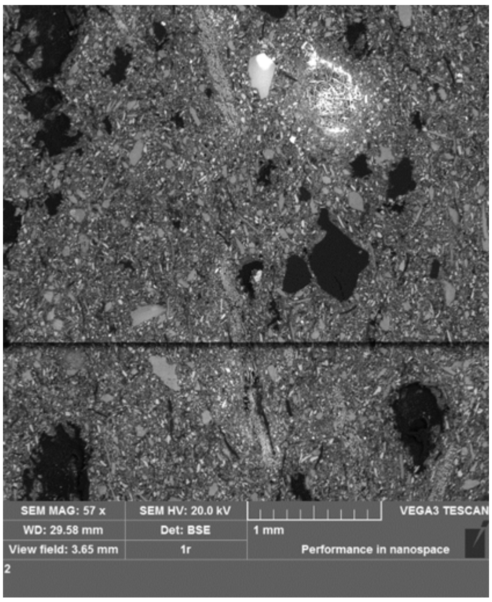

Fig. 5: SEM analysis of unused Sample

The apparent concentrations of the elements found as well as the wt% of the elements are shown in table 5. The suggested materials are once again SiO2 as well as Al2O3. IT should be noted that the oxygen concentration is large in the material which could suggest the possibility of trapped air in the material at this point. Other trace elements found in this sample are P and Fe

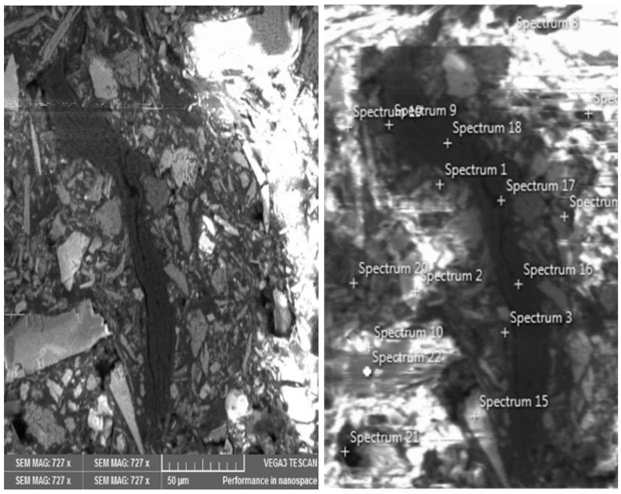

Fig.6: Points to be analysed on the EDS spectrum

Table 4: Spectrum 22 Wt%

Element	Apparent Concentration	Wt%	Standard Label	Factory Standard
O	67.90	51.13	SiO2	Yes
Al	37.14	31.13	Al2O3	Yes
Si	13.67	16.24	SiO2	Yes
P	1.47	1.26	GaP	Yes
Fe	0.24	0.24	Fe	Yes
Total		100.00		

Table 5: spectrum 9 wt%

Spectrum 9	Apparent Concentration	Wt%	Standard Label	Factory Standard
O	55.40	54.81	SiO2	Yes
Al	15.38	14.97	Al2O3	Yes
Si	17.43	19.03	SiO2	Yes
P	1.18	0.99	GaP	Yes
K	3.00	2.72	KBr	Yes
Ti	2.75	2.92	Ti	Yes
Fe	0.43	0.44	Fe	Yes
Zn	0.79	0.85	Zn	Yes
Mo	2.49	3.26	Mo	Yes
Total		100.00		

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The hardness results are shown in fig. 7. Tests were performed on both the samples (Sample A and Sample B) and plotted for the comparisons between the hardness close to the surface and the hardness of the material close to the backing plate. It is clear from these results that the hardness value for both materials varies quite substantially over the surface of the material.

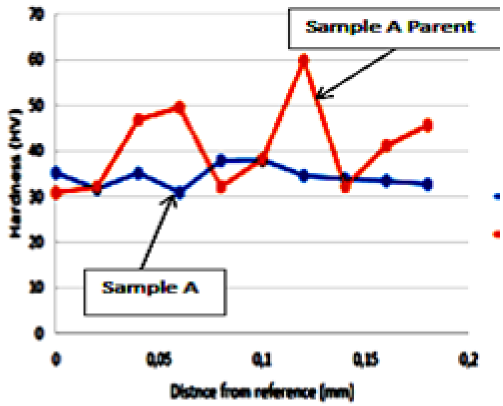

Fig. 7: The hardness test results

Graphical representations of the results for the wear tests are shown in fig 8. From the result, there is a clear relationship between the wear rate and the frequency of the oscillation which represents the speed of the friction material against the ball. The results indicate that as the frequency of oscillations increase, so too does the wear on the brake block. This is in line with expectations as one would expect the brake block to wear away faster the faster it moves in contact with the wheel. The other relationship that one can derive from the results of the wear test is that the greater the force applied to the sample, the greater the wear rate of the brake block. Again, this makes sense as an increase in the force applied would result in an increase in the abrasive force between the wheel surface and brake blocks thus resulting in a greater rate of removal of brake block material per unit time frame.

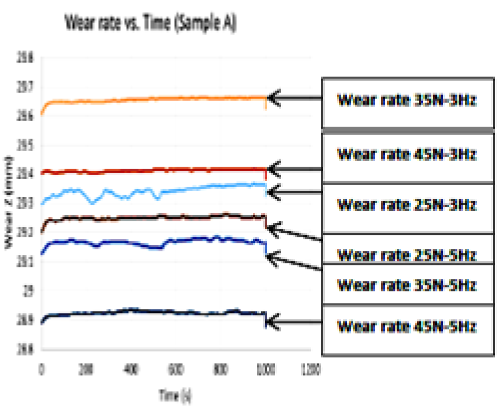

Figure 8: Wear results of Sample A

IV. Conclusion

Brake block testing was performed on two brake blocks of the same composition but with different amounts of wear. It was found that the brake blocks were composed of a vast number material. Each material was found to add a different aspect to the braking characteristics. The SEM/EDS test results of this test showed that the main constituents of the brake blocks was silicon, aluminium, carbon and a fibre called wollastonite. The main material used to bind the brake block was a phenolic resin. The resin is designed to evaporate or disintegrate instead of breaking off of the brake block. Micro hardness testing was found to be an ineffective test for the brake blocks as the brake block is composed of different materials therefore, the hardness values obtained were inconsistent as the indenter encounters different materials of different harnesses,

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