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SHORT GLASS FIBER AND FERROSILICON CONTENT'S EFFECTS ON THE MECHANICAL CHARACTERISTICS OF A FRICTION COMPOSITE MATERIAL BASED ON PHENOL

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ABSTRACT

The goal of this essay is to weigh the benefits and drawbacks of the modern composition used to make composite brake blocks at the Central Railway Workshop in Mysuru, India. The main goal is to create a composite material with the greatest ingredients for use in railway brake blocks, with a focus on replacing asbestos with ferrosilicon and short glass fiber. Glass fibers in five different quantities have been added to phenol formaldehyde matrix composites. Hardness, compression, and flexural characteristics of phenolic-based composites with glass and ferrosilicon reinforcements differed significantly, indicating that the reinforcements were more compatible with the phenolic matrix. However, as ferrosilicon loading increased, declining trends were noted in the impact strength of all the composites.

Keywords: Friction Composite Material; Glass Fiber; Ferrosilicon; Mechanical Properties; Fractograph.

I. INTRODUCTION

Brake blocks are crucial parts that regulate the vehicle's speed by using friction to transform kinetic energy into thermal energy.

The composition and microstructure of the material decides the performance of brake blocks [1]. The gradual phasing-out of asbestos used in the manufacture of brake pads due to its health issues has sparked the onset of many new unique composite compositions, as a result of which brake industries has seen the birth of different brake blocks. In order to achieve the combination of good performance properties these are necessarily a multi-ingredient system.

In accordance with the literature there are several hundreds of materials available for the formulation of these composite frictional materials. These are mainly classified into four categories such as binders to obtain good binding and compatibility with other ingredients, fibers to provide mechanical strength to the component, frictional modifiers to increase the wear resistance and frictional coefficient and fillers to mainly cut down the cost and increase the characteristics like resistance to fade [2-5].

Because they have a number of advantageous qualities, including the ability to wet most materials, good creep resistance, increased hardness, and improved temperature resistance, phenolic-based resins are frequently utilized as binding materials. The use of phenolic resin has not changed despite the identification of numerous different types of resin components in the literature [6–9]. In addition to this mix, the metallic filler components are essential since they fulfill unique roles beyond just offering strength. They efficiently transfer the heat produced at the contacts and lessen the fading in μ. Because of its high thermal conductivity, copper is an essential component of these fillers. According to studies, the use of copper has increased fade resistance [7–10].

High specific strength, modulus and good tribological properties of fiber reinforced polymer composites have sparked the interest of many researchers to carry out much experimental analysis on the wear, friction and fade behavior of such materials [14]. In the availability of numerous types of fibers used in polymer matrix composites the most widely used are the glass fibers. Glass fibers are inexpensive in comparison to other fibers such as carbon or aramid and they provide the advantage of ease of fabrication. Due to the presence of good strength with the matrix material used they exhibit better tribological and mechanical properties [15, 16].

Glass fibers (GFs) have been widely used as reinforcement materials in composite manufacturing due to their good properties such as high specific modulus, strength, stiffness and electrical properties. While thermal and chemical properties of composites mainly depend on matrix materials, mechanical properties of composites such as strength depend on properties of glass fiber and fiber/matrix interfacial adhesion strength. If there is good fiber/matrix adhesion strength, the applied load can be transferred from matrix to fiber more efficiently. Short glass fibers were mainly used as replacement to the banned asbestos. There are two types of short glass fibers namely chopped and milled which are utilized for dry mixing and hot compaction. These have been identified as the substitute due to its increased mechanical strength and heat resistance [17, 18]. The dimensional specification of short glass fibers ranges from 2-6 mm in length and in diameter a several tens of microns. There are fibers other than glass fibers that are identified as reinforcements in the composite frictional material to enhance the brake efficiency namely, metal fibers [19, 20], carbon fibers [21, 22], ceramic whiskers [23, 24], aramid fibers [25, 26], ceramic fibers [27, 28] and natural fibers [29]. In comparison to the monolithic fibers blending of glass fibers with the above mentioned fibers provide better performance properties [30, 31]. The impact of short glass fibers on tribological performance and properties of friction composites have been studied by various research people

A study by Bahadur et al. [32] revealed no relationship between the mechanical characteristics and coefficients of friction of glass fiber reinforced polymer composites. They discovered superior mechanical qualities and enhanced wear resistance. Gopal et al. [33] investigated the pull-out of glass fibers and the thermal deterioration of the matrix as a result of the development and breakdown of friction films on the surface, which were connected to the coefficient of friction at various temperatures. According to Kim et al. [18], the more glass fiber there was in the friction material, the less likely it was that vibrations would occur. Short glass fibers are also employed as abrasives to regulate the frictional coefficient of various friction materials [34]. As far as we are aware,

II. MATERIALS AND METHODS

Materials

Since phenol formaldehyde has an exceptional modulus and creep resistance, it was chosen as the matrix material. When combined with other friction compounds, it also works well as a binding agent. Eight 150 mesh friction modifiers and four different types of binders were added in accordance with the standard standards utilized at the Central Railway Workshop in Mysuru, India. As reinforcement, short glass fibers with an average length of 2–6 mm were used. Eleven elements' parent makeup (75 weight percent) remained consistent, with two exceptions: ferro-silicon and short glass fiber. Five distinct components with varying compositions were manufactured. Table 1 lists all of the additional ingredients' weight

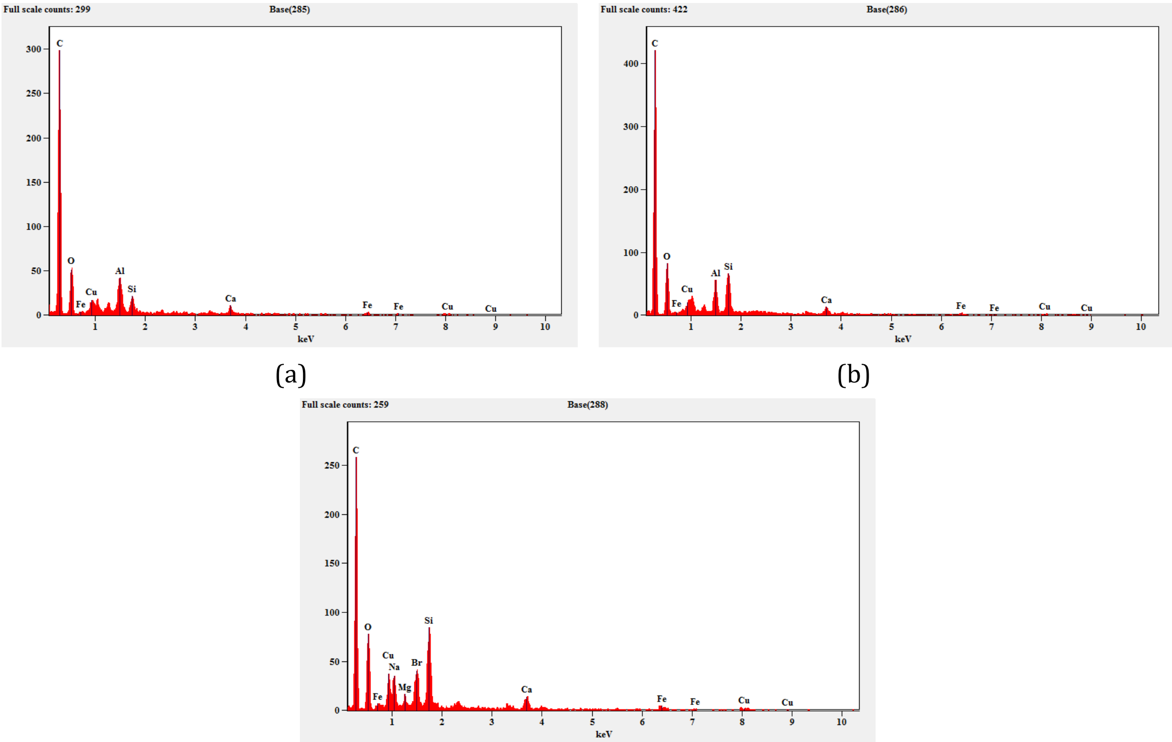
Table 1. Details of specimen composition

Composite Designation	Fibers (wt %)	Binders (wt %)	Fillers (wt %)	
Sample	Short Glass Fibers	Phenol formaldehyde powder(17), Cashew nut shell liquid (CNSL 9.5), Plaster of Paris (1.5), Carbon black(2)	Copper (Cu, 8), iron (Fe, 8), Silicon carbide (SiC,5), Alumina (Al_2O_3, 5), Cashew dust (7), Graphite (6), Nano Silicon Carbide(6)	Ferrous Silicon
C1	25	30	45	0
C2	20	30	45	5
C3	15	30	45	10
C4	10	30	45	15
C5	5	30	45	20

Fabrication

Thirteen of the elements required to create the composites are listed in Table 1. The hot compression molding technique was used to create the examples. Mixing, hydraulic pressing, curing, and post-curing were all steps in the procedure. To achieve homogeneity, the proper ratio of ingredients was mixed using a laboratory mixer. To guarantee uniform dispersion, fibers were added after the powders had first been combined using a mechanical mixer. The temperature of the mold was set to 80°C. Curing is the process by which a composite composed of multiple components hardens. Heat, chemical additives, or ultraviolet light can all do this. The remaining resin is cured after curing in order to release the frozen-in stress. Additionally, this technique improves cross-linking, chemical and mechanical qualities, and heat resistance.

The specimens were then cut according to the ASTM standards for different tests and analyzed for their mechanical strength. Sample O1 is the commercially used break block in the railway workshop whereas samples C1, C2, C3, C4 and C5 were the new formulations



(a) (b)

(c)

Fig. 1. The EDX of : (a) C1, (b) C3 and (c) C5samples

Density test

In accordance with ASTM D792, a METTLER AE 200 densometer was used to measure the densities of several manufactured samples. After weighing the sample in air, it was submerged in room-temperature distilled water. A little holder was used to make sure the sample sank completely, and its density was recorded. For every sample, three readings were obtained, and the average results are given. Every measured deviation standard was less than 0.02 g/cm3. Figure 2 displays the variability of these values.

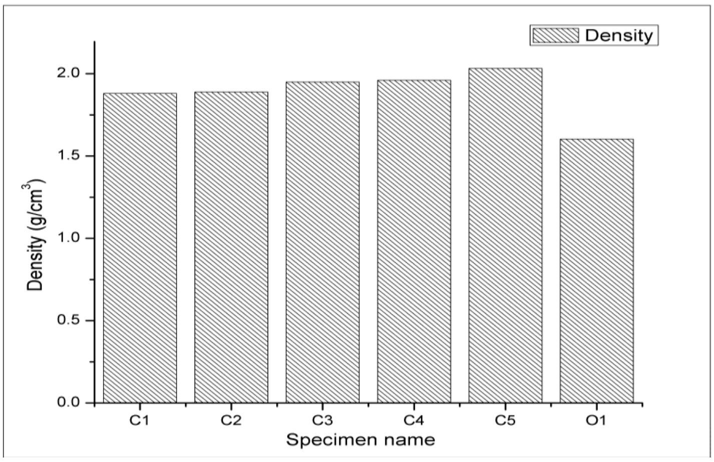


Fig. 2. Variation of density of samples

Hardness test

In accordance with ASTM D 2240, the Shore D hardness tester was used to test the hardness of the provided specimens. In accordance with the aforementioned specifications, the hardened steel rod has a 1.4 mm diameter, a 30° conical point, and a 0.1 mm radius tip. In contrast to the penetration of an indenter, the depth of penetration of the indent is utilized to describe the indentation's hardness. Five separate sites were used to collect the numbers, and Figure 3 plots the average reading.

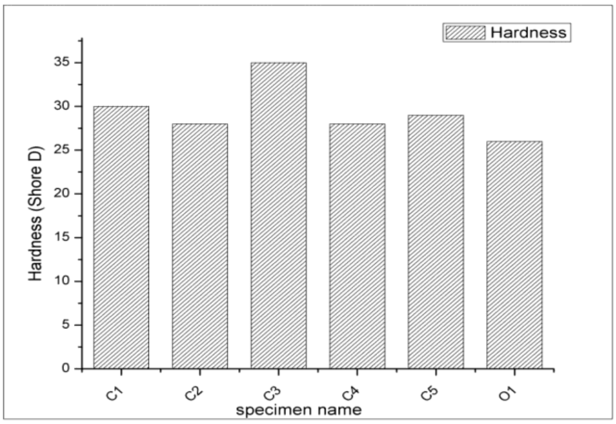


Fig. 3. Variation of hardness of samples

Compression test

With the use of KALPAK software and a fully automated Kalpak 100K Universal Testing Machine, this test was conducted in accordance with ASTM E9 requirements. The dimensions of the specimen were 12 mm x 6 mm × 5 mm. For every sample, three specimens were examined, and measurements were made. Every test was carried out at room temperature. Displacement-controlled loading was used, and data on load versus deflection was gathered. Figure 4 displays the compressive strength of several samples that were created.

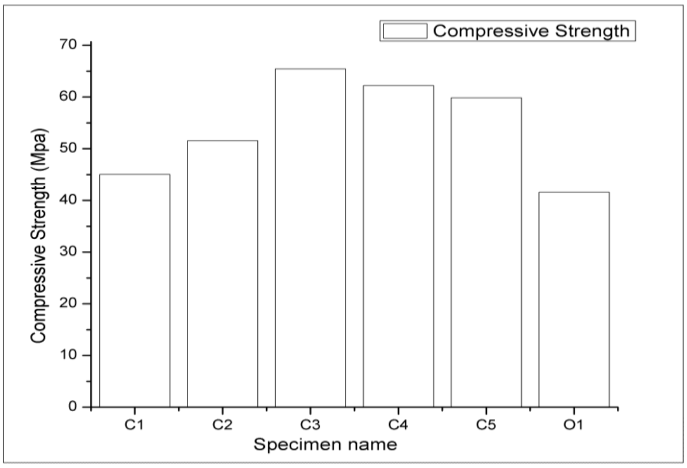


Fig. 4. Compressive strength of the samples

III. RESULTS AND DISCUSSION

Density

Plots of the measured densities of each prepared sample (C1 through C5) are displayed in Figure 2. It was found that as the ferrosilicon content rose, the density rose as well. High density ferrosilicon particles were the cause of the phenolic-based composites' increased densities. A greater quantity of ferrosilicon (sample 5) reinforced phenolic composite results in a larger density because ferrosilicon has an individual density of 5.65 g/cm3, whereas glass fiber has a density of about 2.54 g/cm3. Commercial brake friction material has a density of 1.623 g/cm3, which is lower than the samples (C1 to C5) that were manufactured..

Hardness

Figure 3 displays the findings of the room temperature hardness testing (Shore D). The figure indicates that the phenolic composite with 15 weight percent SGFs and 10 weight percent ferrosilicon had the highest hardness. The phenolic composite's homogeneous reinforcing dispersion and strong interfacial bonding may be to blame for this. Furthermore, ferrosilicon and short glass fiber reinforcements may have a higher hardness than the composite, which could explain the observed increase in hardness. Reduced inter-particle distance inside the matrix and homogeneous phase distribution were the causes of the resistance to indentation; this close atom packing increases density near the fibers and permits shorter bond lengths.

Compression strength

Good control of the interface morphology of polymer based composites is one of the most critical parameters to impart the desired mechanical properties in such materials. Good load bearing capacity of SGFs makes them important reinforcing fiber for polymer matrix composites (PMCs). On the other hand, high amount of ferrosilicon particulates increases the hardness and stiffness of PMCs. Many researchers have concluded that with the addition of the short glass fibers, the compressive strength of PMCs increases. The results of the compressive test at room temperature are shown in Figure 4 with the wt % of SGFs and ferrosilicon particles. From the figure it is observed that the compressive strength increases with increase in ferrosilicon content up to 10 wt % (sample C3). The strength increase of 31% for the sample containing 15 wt % SGFs and 10 wt % ferrosilicon was found to be the highest. Compression strength of phenolic composite did not increase further with increase in ferrosilicon (15 to 25 wt %) which may be due to inadequate interactions between composite constituents and decreases the reinforcing ability of particles. This poor reinforcing ability of ferrosilicon in phenolic composite may also due to the difficulty in achieving a homogeneous dispersion of particles in the phenolic resin. On the other hand, compression strength values of 20 and 25 wt % SGFs reinforced composites are lower than those of other composites which might be due to disorientation of glass fibers

IV. CONCLUSION

In this study, effect of short glass fibers and ferrosilicon loading on mechanical properties of phenolic composites were explored and the following results may be deduced. Short glass fibers and ferrosilicon filler altered the density and hardness of phenolic composite. The highest density was found in samples C5 (20 weight percent ferrosilicon), while the highest hardness was found in samples C3 (10 weight percent ferrosilicon and 10 weight percent SGFs). When ferrosilicon is included in the phenolic composite at the same time, these findings may be the result of a higher density ferrosilicon filler and improved glass fiber dispersion.

Compression strength increases with increasing ferrosilicon loading up to 10 wt % and then decreases with increase in ferrosilicon loading. The strength increase of 31% for the sample containing 15 wt % SGFs and 10 wt % ferrosilicon was found to be the highest. Compression strength of phenolic composite did not increase further with increase in ferrosilicon (15 to 25 wt %) which may be due to inadequate interactions between composite constituents and decreases the reinforcing ability of particles

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