

Synthesis of Silicon Carbide Based Composite Material for Industrial Applications

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Abstract-Silicon Carbide is a leading material for components and devices operating at high temperature, high power and under harsh environments. Micro-sized SiC particles and whiskers are commonly used as reinforcement materials for ceramics, metals and alloys for various structural and tribological applications. This work of the composite materials are synthesized containing fibrous reinforcing constituents, friction imparting additives, wear resisting additives, fire retarding constituents and phenolic resins as binder. The composites are heated to moderate temperature for few hours to make the constituents intact further. The composite materials are tested for wear rate and coefficient of friction using pin on disc wear testing machine. Apart from synthesis, the synthesized composite material characterizations were performed with the wear tests to find the generation of voids on the wear surface.

Keywords: Silicon carbide, Composites, Binders, Iron fibers, Epoxy resins.

1. INTRODUCTION

Clutches & brakes are frequently subjected to high temperature due to friction between clutch disc & flywheel. The frictional heat generated leads to high temperature rise as high as 540°C for a very short duration of the order of 10⁻⁴ sec and this causes thermal deformations, thermal crack & wear eventually leading to premature failure of the sliding system.

Thus, there has been a long felt need to find alternative reinforcing materials for the production of frictional materials used in Automobile brakes, clutch plates to withstand at high temperature without deformation and also to radiate and conduct the heat to the atmosphere at sufficiently fast rate.

Silicon carbide (SiC) is a material with outstanding physical and mechanical properties. It has high mechanical strength, high hardness, low density, high thermal conductivity, low thermal expansion coefficient, large band gap and excellent oxidation and corrosion resistances. Silicon carbide (SiC) is highly resistant to heat. The material is stable up to temperatures near 1,600 °C in air and its decomposition temperature is 2,545°C. Silicon carbide fibers, added as reinforcement to plastics or light metals to impart increased strength and stiffness. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics which are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates.

2. SYNTHESIZING SILICON CARBIDE COMPOSITE

Composite materials signify that two or more constituents are combined on microscopic scales to synthesize a useful material. A variety of materials can be combined on a microscopic scale. The advantage of the composite materials is that their individual constituents retain their characteristic unlike alloys. As a result, various combinations of useful properties, usually not attainable by alloys, can be obtained through composite materials by suitable tailoring the matrix and reinforcement.

3. MAJOR CONSTITUENTS OF SIC COMPOSITE

Phenol formaldehyde resin

Phenol formaldehyde resin composites offer superior fire resistance, excellent high-temperature performance, long-term durability, and resistance to hydrocarbon and chlorinated solvents. [14].

Epoxy resin

Epoxy resins are routinely used as adhesives, coatings, encapsulate, casting materials, potting compounds, and binders. Some of their most interesting applications are found in the aerospace and recreational industries where resins and fibers are combined to produce complex composite structures. [14].

Epoxy hardeners:

Epoxy hardeners are not catalysts and they react with the epoxy resins, greatly contributing to the ultimate properties of the cured epoxy resin system. Mechanical properties of the epoxy resin system such as

tensile, compressive, flexural properties, etc., are also influenced by epoxy hardeners.

Cashew Nut Shell Liquid:

The major by-product of cashew nut is the liquid from the pericarp known as cashew nut shell liquid (CNSL). CNSL is one of the sources of naturally occurring phenols. CNSL is amber-colored, poisonous, viscous oil obtained from the by-product shells of the cashew nut by extraction. It is often considered as the better and cheaper source of unsaturated phenols. [19]

Silicon carbide:

It is used in abrasives, refractories, ceramics, and numerous high-performance applications. The material can also be made an Electrical Conductor and has applications in Resistance Heating, Flame Igniters and Electronic Components. Structural and Wear applications are constantly developing [20]

Typical mechanical properties of Silicon Carbide:

Properties	Value	Units
Tensile Strength	2.8	GPa
Elastic Modulus	400	GPa
Compressive Strength	1.3	GPa
Poisson's Ratio	0.19	
Flexural Strength	550	MPa
Fracture Toughness	4.0	MPam ^{1/2}
Hardness	2700	HK

Table 1: Mechanical properties of SiC

Iron fibers:

Iron of sufficient purity so that its properties are essentially those of the element is commonly called high-purity iron. Such iron is not an article of commerce; instead, it is employed almost exclusively in research. Iron of very high purity can be prepared by a variety of methods, but the last stage of the process is purification by floating-zone refining, often combined with treatment in oxidizing and reducing atmospheres. In order to maintain this purity, it is essential to avoid contamination of the iron, which can occur by reactions with the atmosphere or with containers [21].

Shellac:

Shellac is a natural polymer and is chemically similar to synthetic polymers, and thus can be considered a natural form of plastic. It can be turned into a molding compound when mixed with silica flour or wood flour and molded under heat and pressure method, so it can also be classified as thermoplastic.[22]

Graphite

Graphite are used in frictional materials for heavier (nonautomotive) vehicles, and became important with the need to substitute for asbestos. Graphite increases

the efficiency of the frictional materials in terms of lifetime, electrical and thermal conductivity, lubricity and hardness, mechanical strength and resistance to corrosion and reduction of noise.

Silica flour:

Excellent resistance to oxygen, ozone and UV light (sunlight). This has led to widespread use in the construction industry, and automotive industry. Good thermal stability.

4. MATERIALS AND EXPERIMENTAL PROCEDURE

Procedure for the preparation of silicon carbide reinforced composite material:

1. Apply releasing agent to the ceramic bowl in which the constituents are mixed and wait till the ceramic bowl is dried.
2. The releasing agent is also applied to the die so that the composite billet can be easily removed from the die after pre-sintering process. Sufficient time should be allowed for the die to dry.
3. Weight 7 gm of of epoxy resin and, 0.4 grams of epoxy hardener [resin to hardener ratio is 10:1] mix it thoroughly until the homogenous mixture is obtained. Add the epoxy resin mixture to the phenol formaldehyde and mix both the resins, during mixing a little amount of heat and fumes are generated this is an indication of proper polymerization of both resins.
4. Now add 1 gm of CNSL to the polymerized resin it helps proper condensation of the formaldehyde from the phenol formaldehyde solution so as to prepare the phenolic polymers.
5. Add 0.8 gm of graphite, 0.8 gm of silicon carbide and 2.2 gm of iron fiber to the polymerized phenolic adhesive resin which results in a semi solid compound of composite.
6. Add 0.5 gm of shellac, 1.5 gm of silica flour and 0.4 gm of silicon resin to the composite prepared since shellac with silica flour and silica resin result in the adhesive material for the proper binding of the composite and mix it thoroughly.
7. Add 1 gm of rubber solution and 0.6 gm of trisphenol hardener to the homogenous semi solid composite and mix it well until a sticky semi solid composite is obtained.
8. Take the mould apply the releasing agent to the mould top, bottom support and plunger for easy removal of composite billet and wait till it is dried.
9. Once the composite is ready, pour the semi solid composite material in the mould and apply weight of 5kg on the top of mould for proper compaction and to remove the voids and air vents form the mould for a period of 5 to 6 hours.

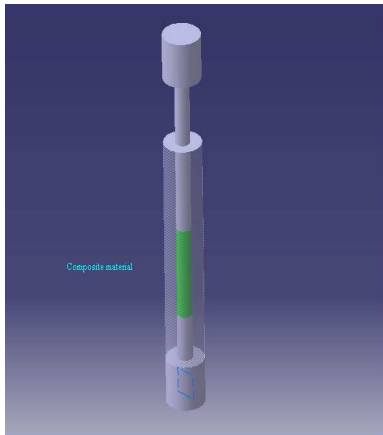


Fig.1 Die with composite material.



Figure 2: Sintering Furnace

a. Pre sintering stage:

During this stage the composite billet along with the die is placed inside the sintering furnace at a temperature of 60°C for a period of 3 hours. Before placing the composite billet in the furnace sufficient time is allowed till the temperature inside the furnace reaches 60°C. Once the pre sintering is completed the billet is removed from the die.

b. Post sintering process:

During this stage the temperature of the furnace is adjusted to 180°C. The composite billet which is pre sintered is placed in the ceramic bowl and kept inside the furnace for a period of 2 and half hours. Once the post sintering is completed remove the billet from furnace and allow it to cool in room temperature. Once room temperature is achieved the composite billet is ready for the future processing and testing. The below

figure 3 shows the specimen after subjected to the sintering process.



Figure 3: Post Sintered Model

5. RESULTS AND DISCUSSIONS

The friction materials is made up of fibrous materials, abrasive particles, anti-wear materials, fillers and binders, curing agents and heat and wear resistance additives. The binder phenolic resin is a critical one in the whole component. The limits of heat resistance and strength of the frictional material are governed largely by the heat resistance and strength of the resin binder. Phenolic resins are highly brittle by nature, thus to reduce the brittle nature of the composite, specific ratios of epoxy resin and rubber particles are used. This improves the toughness of the resin-bonded mixture. The composite thus consists of phenolic resin and epoxy resin that function as the base matrix. The matrix is strengthened by reinforcing materials of Fe fibers. Graphite and silica flour are added to act as anti-wear additives and the addition of silicone resins acts as a fire retardant. The cashew nut resin is added to improve the temperature resistance of the composite. Shellac is a natural, organic resin that comes from an insect, used to improve the hardness of the composition. The rubber solution helps reducing the brittle nature of the phenolic base. A curing agent in the form of tris phenol is used to improve the curing time. The percentage of each component has been selected by trying various permutations and combinations in the percentages for the phenolic and epoxy levels. The same has been done to select the percentages of other filler materials, hardener and the like. For example, a higher percentage of phenolic content created a composite which was extremely brittle. Higher percentages of shellac resulted in a composite which was very hard but with reduced friction characteristics. Similarly, higher percentages of tris phenol resulted in composites which hardened extremely rapidly and lost its workability and hence, made it increasingly brittle. Increasing the percentage of graphite content increased the wear resistance but at the cost of friction coefficient. The filler contents were chosen at percentages which were optimum for blending and at the same time provided the desired

characteristics. Thus, the appropriate composition as indicated have been obtained after a number of iterations and trials and errors associated with them, thus optimizing the process requirements. The friction material synthesized was subjected to a wear test by making use of a pin on disc tribometer which is shown in below figure 1.

The tribometer is coupled to a computer to generate the results for the plot as shown in



Figure 4: Pin on disc tribometer

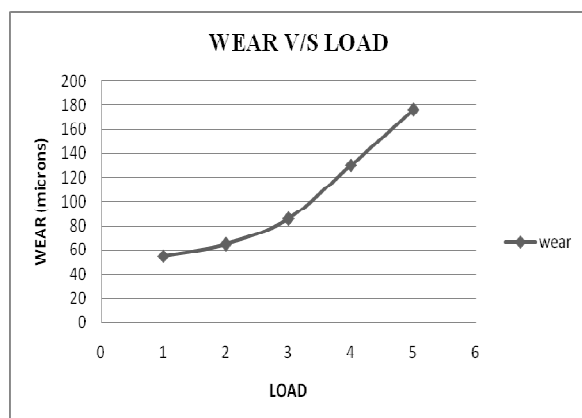


Figure 5: Variation of wear with load.

The sample used for the test was of 8 mm diameter and is slid against a rotating steel disc. Initially a load of 1.0 kg is applied on the sample against a speed of 500 rpm of the rotating disc for a period of 300 seconds. The next load is applied after every 300 seconds with the increment of 1.0 kg upto 5.0 kg against the same speed. From the graph it is observed that the wear increases as load increases and varies from 55 to 176 microns. The graph clearly shows that the friction material has exemplary resistance to wear under different loading conditions.

The same setup was used to determine the coefficient of friction of the composite friction lining. The prepared sample was found to exhibit excellent coefficient of friction as illustrated by the plot of coefficient of friction vs load in figure 6.

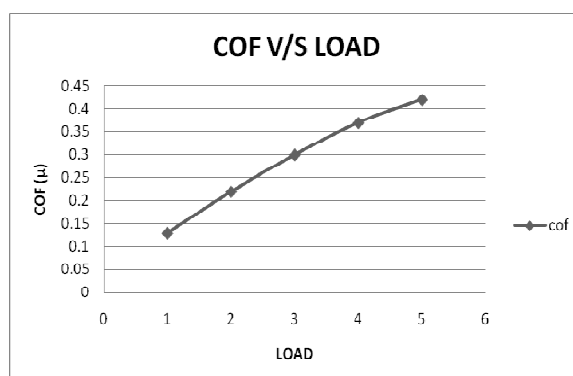


Figure 6: Plot of coefficient of friction vs load.

From the graph it is clear that the coefficient of friction was found to be varying between 0.13 to 0.42 for varying load conditions.

6. CONCLUSION

The friction material composite for brake liner is synthesized which contains fibrous reinforcing constituents, friction imparting and controlling additives, elastomeric additives, fire retarding components and a thermosetting resin. The samples were subjected to tests like wear test and friction tests. It was also found to exhibit exemplary friction and anti-wear characteristics. The constituents used in the composite are extremely economical and are hence appropriate for industrial applications. The composite becomes even more economical when manufactured in bulk for industrial applications.

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