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# Mechanical Characteristics of CSP Filled Glass-Epoxy Composites

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***Abstract*: Composite materials are the combination of two or more materials which are different in form and chemical compositions. These are gradually gaining more importance as structural materials in the present day engineering design and development activity; this is because they offer very attractive physico-mechanical properties. Hence composite materials can be used in automobile brake, aircraft and marine components, wind turbine blades, heat insulators, sporting equipment etc.,**

***Brake is a very important part of an automobile which causes safe emergency stop with certain predetermined distance and it was made of asbestos and continuous use of asbestos leads carcinogenic and lung disorders due to these causes use of asbestos was banned during 1990's.***

***Hence attempts are made to develop new eco-friendly brake friction materials for automotive applications using Glass-Epoxy FRP composites filled with Coconut Shell Powder (CSP) to estimate mechanical characteristics.***

***Keywords— Eco-friendly Brake Friction Material, Coconut Shell Powder, Mechanical Characteristics.***

## I. INTRODUCTION

Brake is a mechanical device which restrains motion the motion of a moving object. The core purposes of a braking system are:

- During emergency stops the vehicles safely in shortest possible distance.
- Controlling the vehicle when it is sliding down the hills.
- Keeping the vehicle in desired position after bringing it at complete stationary position.

Figure:1 illustrate the working principle of a braking system. When brake pedal is pressed the brake fluid is forced into a wheel cylinder. This fluid pushes the pads $S_1$ and $S_2$ out which causes the surface of the brake drum and brake pad to come into contact with each other due to the friction between them stops the vehicle.

*Brakes are classified as:*

- Hydraulic brakes
- Electric brakes
- Mechanical brakes

The hydraulic and electric brakes are used to reduce or control the speed of automobiles. These cannot bring the vehicle to rest effectively. Hence these brakes are extensively used in laboratory dynamometers and electric locomotives. Further, the mechanical braking system is extensively used in automotive braking applications.

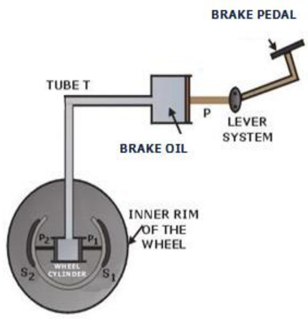


**Figure 1. Working Principle of an automobile brake**

## II. LITERATURE REVIEW

In a braking system, the brake pad is the most important component. Commonly used brake pad materials are Woven Cotton, Woven and molded asbestos lining and Sintered metal pads etc. It is evident from the medical reports that continuous use of asbestos causes lung cancer and adverse respiratory problems in human beings due to these reasons in 1986, the Environmental Protection Agency (EPA) announced a ban on use of asbestos which resulted in a major shift away from the use of asbestos by most of the friction material suppliers and vehicle manufacturers [1, 2, 3].

Hence it becomes imperative to develop composite friction material without asbestos. In the present context many researchers have worked towards the development of new brake pad frictional lining formulations which comprised of four different categories of materials, which include fibers, binders, fillers, and friction additives to meet the desired properties of the brake pad [13, 14, 15]. To understand the concepts of brake material systems an extensive literature perusal has been carried out for evaluating the mechanical and tribological properties of polymer composites.

Rao et al., [2] reviewed and developed environment friendly brake friction materials using various agricultural wastes to replace the asbestos brake pad and study the physical and Tribological properties by varying filler, fiber, binder compositions.

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It was observed from the results that increase in Phenolic Resin percentage in banana peels, increased the frictional properties and addition of excessive banana peels causes reduced life.

Bao et al., [3] developed non-asbestos mining brake friction material to evaluate the wear properties. Minimum wear rate was noticed at increased temperature. The braking surface reach thermal decomposition point, failure occurs due catastrophic friction phenomenon.

Thiyagarajan et al., [4, 16] developed alumina fiber filled with different weight fractions of synthetic barites to study the mechanical, physical and thermal properties as per IS2742 standards. From the thermo gravimetric analysis it was seen that increase in the fiber weight fraction led to higher thermal stability, better wear properties and good fade resistance.

Aranganathan et al., [5] developed brake-friction material using treated rock wool fibers to investigate mechanical, physical and tribological properties to replace copper. It was noticed that developed brake friction materials showed better performance such as higher thermal conductivity, lower density, and minimum rise in temperatures.

Zhang et al., [6] fabricated SCF and long carbon fibers-ER composites to investigate sliding performance under dry sliding conditions using POD experiments. It was noticed from SEM micrographs that peel-off of SCFs from the matrix were difficult. As the contact pressure and temperature were increased, slight decrease in the COF and better wear resistance of SCF composites compared to long carbon fibers were observed.

Pihtili et al., [7] developed GF-ER and GF-PE resin composite materials to investigate the effect of dry sliding wear characteristics by varying load and the speed along with worn surface morphology. It was clear from the results that GF-ER composites revealed better and mechanical wear behavior when compared with GF-PE resin composites.

Shivamurthy et al., [8] developed E-glass fabric or epoxy laminated composite materials by adding graphite particles to estimate different properties such as flexural, tensile, impact, hardness and density with wear characteristics. From the results, 3 wt. % of graphite showed the minimum specific wear rate and the highest mechanical performance. With Increase in graphite content the specific wear rate enhanced and depreciated mechanical properties respectively.

Bijwe et al., [9] fabricated NAO based Brass and Barite FRP composites to study the effect of mechanical, physical and chemical properties along with fade and recovery tests by varying amount of brass and barite. It was observed that mechanical properties decreased with increase in brass content. Density, voids, absorption of water, specific heat, conductivity and thermal diffusivity increased. With increased brass composition friction performance increased.

Ganguly et al., [10] developed AFBFM using fibers, matrix, fillers and friction additives to conduct wear, thermo gravimetric and SEM analysis. It was evident from the test results that frictional properties, thermal stability and wear resistance were improved on synthesized composites.

U.D. Idris et al., [11] fabricated banana peels reinforced with PF resin eco-friendly asbestos free brake-pad by varying 5 to 30 wt. % of the resin to study morphology, mechanical and Tribological characteristics. It was noticed from the results that hardness, compressive strength and specific gravity increases with addition of resin and it was also observed that 25 wt.% of uncarbonized and 30 wt.% carbonized banana peels exhibited improved properties.

From the available literature it was observed that many researchers have worked towards the development of new brake friction material formulations for automobile brake liner using different fibers, matrix, fillers and frictional additives to investigate mechanical and tribological characteristics.

## III. DEVELOPMENT OF ASBESTOS FREE BRAKE FRICTION MATERIAL

### A. Reinforcing Fibres

Strength of composite mainly depends upon the nature of reinforcing fiber which are available in different forms The fibers like Glass, Aramid, Kevlar, Carbon etc. are popular for load bearing applications. Glass fiber is commonly used in Polymeric Matrix Composites (PMC) because of its low cost, high tensile strength, high chemical resistance, and excellent insulating properties due to these reasons E-glass fibers are used in this research.

### B. Matrix

Matrix holds the fibers and other constituents together and protects the constituents from mechanical degradation. Epoxies and other polyesters resins are extensively used in the manufacture of fiber reinforced composites because of their flexibility, low contraction and exceptional adhesive properties with minimum cost. Hence in this research work epoxy LY- 556 along with hardener is used to manufacture FRP composites.

### C. Fillers

Fillers are induced into a polymer matrix to minimize cost, enhance modulus, diminish mold shrinkage, controls the viscosity and to produce good surface roughness. In this research Barium Sulphate, Calcium Carbonate and Coconut Shell Powder (CSP) are used as fillers in the development of eco-friendly brake friction material.

### D. Frictional Additives and Lubricants

Frictional additives and lubricants are used in the manufacture of brake friction materials in order to alter the friction coefficient and wear rate. In the present research work, aluminum oxide ($Al_2O_3$) and Antimony Sulphide as an abrasive materials and *Graphite* as lubricant to manufacture brake friction material.

The various Fibers, Fillers, Matrix and Frictional additives used to fabricate asbestos free brake friction materials and their volume fraction are shown in Table I

### E. Process Plan

The sequence of processes and process flow chart used to fabricate asbestos free brake friction material shown in Figure. 2.

In the present work, a 200 x 160 x 3 mm thick composite sheets were fabricated using compression molding process for different volume fractions of fiber and the matrix. Specimens for impact, hardness, density, water and oil absorption and wear tests were cut using band knife cutting machine as per respective ASTM standards.

**Table I. Materials and their Volume Fractions**

| Materials | | Density (g/cm$^3$) | Volume Fraction Samples A | B | C |
|---|---|---|---|---|---|
| Fiber | E-Glass | 2.55 | 5 | 10 | 15 |
| Matrix | Epoxy Resin | 1.56 | 60 | 55 | 50 |
| Fillers | Barium Sulphate | 4.5 | 8 | 8 | 8 |
| | Calcium Carbonate | 2.71 | 4 | 4 | 4 |
| | Coconut Shell Powder | 1.6 | 10 | 10 | 10 |
| Frictional Additives | Aluminum Oxide | 3.95 | 9 | 9 | 9 |
| | Graphite | 2.26 | 2 | 2 | 2 |
| | Antimony Sulphide | 4.64 | 2 | 2 | 2 |

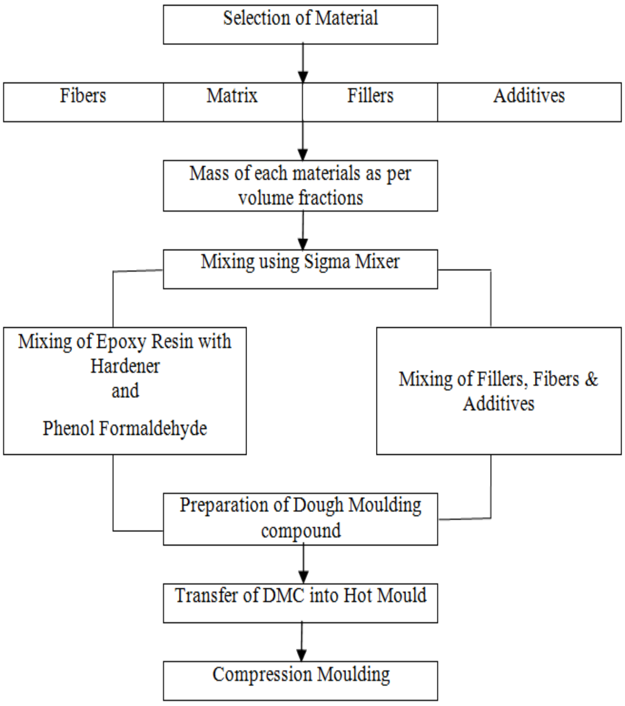


**Figure 2. Process flow chart**

## IV. RESULTS AND DISCUSSION

### A. Compressive Strength

Tests were conducted on universal testing machine as per ASTM D 650 standard to determine the compressive strength of Glass-Epoxy Resin reinforced asbestos free brake friction composite material with different volume fractions.

**Table II. Compressive Strength of various Brake Pad Materials**

| Percentage Reinforcement | | 5 | 10 | 15 |
|---|---|---|---|---|
| Compressive strength of asbestos free brake friction composite material, MPa | ER+GF | 87.6 | 90.3 | 105.2 |
| Compressive strength of Commercial asbestos based brake pads, MPa | ABBPM-1 | 104.3 | | |
| | ABBPM-2 | 112 | | |
| Compressive strength of Commercial brake pads (Literature), MPa CABBPM | | 110 | | |

It is observed from the Table II. That compressive strength of the non-asbestos based brake pad friction materials increased with increase in the percentage of reinforcement. This is due to uniform dispersion of the filler, fibers and frictional additives along with the binder which results in good interaction between particles and binders [17, 18,19].

### B. Impact Strength

Impact strength of the asbestos free brake friction composite material enhances with increase in the percentage of reinforcement. This is due to better bonding between fibers, binders and additives. Further, it is also noticed that impact strength of 15% volume fraction of GF+ER based composites exhibit equal impact strength compared to commercial asbestos based brake pad materials ABBPM-1.

### C. Hardness

The hardness of composite materials was measured using Shore- Durometer (Shore-D) test. It is a measure of resistance offered by materials for indentation which is depicted as hardness number. Experiments were conducted for different volume fractions of GF and ER based friction materials which are tabulated in Table IV. shows the hardness number for 15% volume fraction of GF and ER composites and asbestos based commercial brake pads. It is observed that, Epoxy Resin based composites have higher hardness compared to commercial brake pad materials. This is due to better interfacial bonding of fiber, filler and frictional additives with ER.

**Table III. Impact Strength (J/mm2) of various Brake Pad Materials**

| % Reinforcement | Asbestos free brake friction material | Commercial brake pad C-1 | Commercial brake pad C-2 | Commercial brake pad (Literature) |
|---|---|---|---|---|
| 5 | 0.066 | | | |
| 10 | 0.068 | 0.083 | 0.09 | 0.11 |
| 15 | 0.0810 | | | |

**Table IV. Hardness Number of various Brake Pad Materials**

| Percent Reinforcement (%) | ER+GF | **C-1** | **C-2** | CABBPM (Literature) |
|---|---|---|---|---|
| 5 | 85 | | | |
| 10 | 87 | 82 | 83 | 82 |
| 15 | 90 | | | |

### D. Density

Densities of different volume fractions of GF and ER based asbestos free brake friction composite material as per ASTM D 792-86 using Mettler Toledo's density tester. The density of samples A, B and C of composite specimen compositions varied from that of the conventional brake pad by 6.47%, 6.14% and 5.58% respectively. It is noticed that due to the addition of CSP in the development of asbestos free brake pad composite materials led to the decrease in density because CSP particles are light in weight and dispersed uniformly in more volume. Hence CSP can be used as alternate organic filler in brake friction material [20,21].

**Table V. Densities of various Brake Pad Materials.**

| Material/Composition | Percent Reinforcement | | |
|---|---|---|---|
| | 5% | 10% | 15% |
| ER+GF (Sample-A) | 1.7419 | 1.7583 | 1.7751 |
| ER+GF Sample-B) | 1.5914 | 1.7360 | 1.7806 |
| ER+GF (Sample-C) | 1.6633 | 1.7441 | 1.7901 |
| C-1 | 1.6189 | | |
| C-2 | 1.8109 | | |
| CABBPM | 1.89 | | |

## E. Water and Oil absorption

Water and oil absorption characteristics of different volume fractions of GF and CF reinforced with PF and ER friction composite materials filled with CSP are tabulated in the Tables-VI.

From Table VI. it is seen that the percentage of volume fraction of the fibers increases with decrease in volume of the GF. During fabrication, the melt behavior of GF affects the interfacial bonding negatively between the fibers and matrix. Hence, voids were developed in the composite which resulted in increase of water and oil absorption. Further, it is found that with increase in reinforcement the quantity of Epoxy Resin decreases which leads to reduced binding between fibers and fillers which intern led to void formation. Thus, percentage of water and oil absorption increased. It is also evident that, water absorption of the CSP based composites is less than commercial brake pad materials.

**Table VI. Water Absorption Behavior of various Brake Pad Materials.**

| % of Reinforcement | Water absorption | | |
|---|---|---|---|
| | Initial Weight ($W_1$), g | Final weight ($W_2$), g | Absorption, % |
| 5%, Sample-A | 1.0272 | 1.0328 | 0.54 |
| 10%, Sample-B | 1.0324 | 1.0383 | 0.57 |
| 15%, Sample-C | 1.0378 | 1.0443 | 0.62 |
| ABBPM-1 | 1.3479 | 1.3578 | 0.73 |
| ABBPM-2 | 1.3308 | 1.3399 | 0.68 |
| CABBPM, (Literature) | | | 0.9 |

**Table VII. Oil Absorption Behavior of various Brake Pad Materials.**

| % of Reinforcement | Oil absorption | | |
|---|---|---|---|
| | Initial Weight ($W_1$), g | Final weight ($W_2$), g | Absorption, % |
| 5%, Sample-A | 1.0272 | 1.0318 | 0.45 |
| 10%, Sample-B | 1.0324 | 1.0376 | 0.51 |
| 15%, Sample-C | 1.0378 | 1.0439 | 0.58 |
| ABBPM-1 | 1.3479 | 1.3529 | 0.37 |
| ABBPM-2 | 1.3308 | 1.3352 | 0.33 |
| **CABBPM, (Literature)** | | | **0.3** |

## V. CONCLUSION

- Eco-friendly brake friction material was successfully developed using Glass Fiber-Epoxy resin and CSP filler.
- Compressive strength of composites developed are comparable with the results of other researchers and commercial brake pads.
- Impact strength of ER-GF composite is 0.081 J /mm$^2$ which is almost equal to equal to impact strength of ABBPM-2.
- Hardness of ER+15% $V_f$ GF is 92 which is higher than 10.86% and 9.78% as compared to ABBPM-1 and ABBPM-2 respectively.
- Density, Water and oil absorption capacity of GF-ER composites is less as compared to commercial brake pads.

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