Tribological and Mechanical behaviour of reinforced polymer composite material for clutch facing in automobile application

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Abstract. In current applications, the conductive composite polymers are investigated by filling up the polymer matrixes along with different Carbon blacks. The carbon black is considered as particulate filler in all the polymer industry. The most available carbon blacks are used from thermal cracking of natural gas and furnace black which are generated by incomplete combustion of oil filled stocks. Hence, it is necessary to implement and develop the alternative best source of the fillers from the renewable resources like wastes in agriculture units, oil palms, bamboo stem and coconut shells. The coconut shell which consists of 70.5% Carbon, 0.99% ash, 31.75% lignin and 19.5% cellulose and 70% hemicelluloses are considered compare to the agricultural waste. In this work, the investigation is made on mechanical properties and tribological behaviour of polymer matrix composite with coconut shell char.

1. Introduction

Abrasive The natural available fibers and the utilization of the fibers as composite material for automobile industry for clutch facing gives the good reinforced polymer composite with the low cost and high end mechanical properties since they are good renewable and biodegradable to the commonly used synthetic reinforce like glass fiber [1-3]. The preparation from polymer matrix composite replacing with the help of synthetic fiber like sisal, jute, accordingly extensive studies on preparation and properties of polymer matrix composite (PMC) replacing the synthetic fiber with natural fiber like Jute, Sisal were carried out [4-6]. These kinds of plants fibers have much more benefits against carbon fiber in form of they are renewable, eco friendly, very low cost and some times freely available, light in weight and also they have high specific mechanical performance over others. The synthetic filler materials like thermoplastic polymers were used in the previous days in epoxy resin composites to function as filler materials [7-9]. In our present research work the main effectiveness of the coconut shell particles as a source of natural material were reinforcing epoxy resins and their mechanical, impact, flexural and wear behaviour were investigated.
2. Materials used for Experimental work

Materials used in this experimental work are listed below:

1. Araldite Epoxy resin LY 556
2. Hardener HY951
3. Coconut shell
4. Jute

2.1 Epoxy resin

The Epoxy resin which is called by grade LY 556 which is an unmodified epoxy resin based on Bisphenyl-A purchased from Roto polymers and chemicals, Chennai.

2.2 Hardener

Hardener HY951 is aliphatic Primary amines which has a viscosity of around 11-25 MPa at $30^\circ$C which was used along with the matrix material was purchased from S&S Polymers, Bangalore.

2.3 Coconut shell powder

The shell powder of coconuts was prepared locally. They were first cut into small pieces with the help of hammer. Then these pieces were ground with the help of crushed and made in the form of fine powder. The size of the particle was around -80 to +50 microns selected from the different mesh sizes from 50 to 70.

3. Experimental work

![Figure 1](image)

Figure.1 Procedure of making raw coconut shell powder

3.1 Preparation of coconut shell char

The coconut powder is set up by the carburization temperature chose was 650°C till 800°C. The required amounts of coconut shell powder were taken in pots and were set in the heater. It took around three to four hours to achieve the required temperature. At this temperature one hour drenching time was permitted [10]. After this 24 hrs cooling was permitted with the goal that the heater comes to room temperature. At that point the carburized coconut shell powders were taken out from the heater for reuse.
3.2 Jute fiber

The Jute filaments were acquired from the Linum usitatissimum stems and they are utilized essentially to make cloth, the specific plant utilized for fiber generation. Be that as it may, the structure is increasingly crystalline in nature and make more grounded and stiffer to deal with at any conditions [11]. The Jute strands are in the range long up to 90cm and the normal measurement is around 13 to 15 microns. Since they assimilate and discharge water immediately they are valuable and have no erosion.

A wood made mould was used for preparation of composite sheet for casting purpose. For the fast removal of composite sheet a separate sheet called mould release sheet was placed above the glass plate. And also the spray for mold release was also used at the inner surfaces. The different weight percentage of coconut shell powder, jute and char and flax are about 5, 15, 20 and 25% in weight were mixed with the matrix material which consisting of epoxy resin and also the hardener HY951 in the proportion of 10:1. Proper care was taken in order to avoid the formation of air bubbles during the process of pouring is shown in Figure 1.

Now the pressure was gradually applied from the upside and the mold was allowed to cure about 3 to 4 days at 300°C. During the application of pressure some polymer squeezes out from the mould. For this, care has already been taken during pouring. After 72 hrs the samples were taken out of the mold, after curing the laminate was cut into required size of erosion and other mechanical tests by diamond cutter [12]. In the present case the composites prepared for raw coconut shell and the carbonized char at 650°C and 800°C. The density of epoxy resin, coconut shell fiber and char is found respectively. Tables 1 and 2 show the particle size and density of the shell powder and tensile test specimens are represented in Figure 2.

| Sample | Mesh number | Size in Microns (Min) | Size in Micron (Max) | Weight (Grms) | Spacing inches | Weight (%) |
|--------|-------------|----------------------|----------------------|---------------|----------------|------------|
| 1      | 40          | -                    | 410                  | 129           | 0.0172         | 20%        |
| 2      | 65          | 400                  | 218                  | 156           | 0.0056         | 35%        |
| 3      | 110         | 212                  | 150                  | 44            | 0.0034         | 10%        |
| 4      | 140         | 145                  | 105                  | 31            | 0.0031         | 7%         |
| 5      | 190         | 101                  | 75                   | 34            | 0.0024         | 12%        |

Figure 2 (a) Specimen for Tensile test and (b) Flexural Test
4. Micro-Hardness test

The micro-hardness test was done with the help of a Lecco Vickers Hardness -LV 700 equipment. A indenter called diamond which is in the shape of a right pyramid and base is in the form of square and at an angle 1350 between the two opposite faces, load (P) was applied on material is shown in Figure 3. The both the X and Y diagonals of the indentation left on the on the above surface area of the sample were measured and noted and further their mean of X was calculated and noted.

| Sample | Density(gm/cm³) For Raw Fiber | Density(gm/cm³) For 650⁰c carbonized char | Density(gm/cm³) For 950⁰c carbonized char |
|--------|-------------------------------|------------------------------------------|------------------------------------------|
| 5%     | 0.500                         | 1.940                                    | 1.20                                     |
| 15%    | 0.621                         | 1.234                                    | 1.00                                     |
| 20%    | 0.645                         | 1.243                                    | 1.00                                     |
| 25%    | 1.621                         | 1.050                                    | 1.04                                     |

5. Mechanical Properties of Composite Material

The different mechanical tests like tensile, flexural and hardness of the prepared composite material were conducted and results were noted with the help of ASTM Standard.

5.1 Tensile Strength

The tensile test was conducted for 5 different composite samples as per ASTM D 3039-76. The total length of the sample piece was 120 mm and the test was performed with the help of UTM TFUN-400 at the speed of 10mm/min is shown in Figure 3 and the mechanical properties of raw coconut shell powder fiber with flax and epoxy composite is shown in Tables 3 to 6 respectively.

![TFUN-400 Testing Machine](image)
5.2 Flexural testing

The Flexural test was also performed on the above machine as per the ASTM standard. The standard size was taken 150x20mm as length by width were tested in the 3-point bending with a span depth ratio 15:1. The tensile test was also performed with the help of same machine with 2mm/min at a load of 15kN. The flexural stress was determined with the help of following relation is shown in Figure 4.

| Fiber volume % | Tensile Strength in MPa | Flexural Strength in MPa |
|----------------|-------------------------|--------------------------|
| Neat epoxy     | 13.49                   | 13.46                    |
| 5              | 6.8                     | 20.34                    |
| 15             | 24.32                   | 65.53                    |
| 20             | 10.31                   | 51.34                    |
| 25             | 9.46                    | 46.68                    |

![Figure 4. Strength Vs Load](image_url)

Table 4 Mechanical properties of raw coconut shell powder fiber with flax and epoxy composite

| Fiber volume % | Tensile Strength in MPa | Flexural Strength in MPa |
|----------------|-------------------------|--------------------------|
| Neat epoxy     | 14.73                   | 19.26                    |
| 5              | 15.75                   | 45.54                    |
| 15             | 17.25                   | 48.21                    |
| 20             | 30.73                   | 59.28                    |

Table 5 Carbonized coconut shell char mechanical properties of epoxy composite at 650°C.
Table 6 Carbonized coconut shell char mechanical properties of epoxy composite at 800°C.

| Fiber volume | Flexural Strength in MPa | Tensile Strength in MPa |
|--------------|--------------------------|-------------------------|
| %            |                          |                         |
| Neat epoxy   | 19.46                    | 14.25                   |
| 5            | 69.25                    | 23.76                   |
| 15           | 35.26                    | 25.72                   |
| 20           | 31.14                    | 17.48                   |

6. Results and Discussions

![Figure 5](image1.png)

**Figure 5.** Histogram showing the density of all composites at different carburized temperature.

![Figure 6](image2.png)

**Figure 6** Histogram showing the hardness of all composites at different carburized temperature.
The density test results for various specimens which were prepared with raw coconut and char powder particles with different volume fraction were plotted in figure 5. The plot shows that, the density of the composite prepared with char is less when compared to the raw coconut particulate composite. It is also noticed that with increase of fiber concentration the density goes on increasing and samples with 20% fiber volume fraction of fibers and suddenly decreases to some extent because void formation.

**Figure 7** Histogram showing the tensile properties at different carburized temperature

**Figure 8** Histogram showing the flexural properties at different carburized temperature
7. Conclusions

The effectiveness of the coconut shell particles with reinforcement of epoxy resins are effectively studied on their mechanical, impact, flexural and wear behaviour of the composites.

- The density of the prepared composite with char is less when compared to the raw coconut particulate composite.
- The increase of fiber concentration, the density goes on increasing and samples with 20% fiber volume fraction of fibers and suddenly decreases to some extent because void formation.

8. References

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