Behaviour of Coconut Shell Powder Filled Polymer Composites under Impact and Bending Loads

S J Prashanth¹, K V Arun², K G Satish³
Department of Mechanical Engineering
Bapuji Institute of Engineering and Technology, Davangere, Karnataka, India¹
Government Engineering College, Haveri, Karnataka, India²
UBDT College of Engineering, Davangere, Karnataka, India³

Abstract:
The objective of this experimental investigation is to evaluate the mechanical performance of the filled polymer hybrid composites under impact and bending loads. The composite is made of epoxy as the matrix and the coconut shell powder (CSP) as the filler material. The investigation has been made by varying the percentage of the filler material, with varied grain size. The results have shown the increase in the volume fraction of the filler will increase the strength of the composites under impact loading and under bending loads it increases to certain limit only, beyond which it will decrease drastically. The specimen preparation and experimentations were carried out according to the ASTM standards.

Keywords: Filled Polymer Composites, Impact Strength, Bending Strength, Coconut Shell Powder.

I. INTRODUCTION
Epoxy resins (ER) are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives [1–6]. One of the most successful methods of improving the toughness of epoxy resin is to incorporate a second phase of dispersed rubbery particles called secondary fillers into the cross-linked polymer [7–10]. The use of natural fillers to reinforce the composite materials will offer good strength and rigidity, and are light in weight, environmental friendly, abundantly available in comparison with mineral fillers [11, 12]. On the other hand, they will be degraded by moisture, possess poor adhesion to hydrophobic polymers and the non uniform size of the filler may affect the strength. Much amount of work on the application of natural fillers and fibers in composites like pineapple, sisal, coconut coir, jute, palm, cotton, rice husk, bamboo, and wood as the reinforcements in composites have been well documented in the past literature. In the recent days much attention is being paid to coconut fiber. The incorporation of filler such as coconut shell powder into thermosetting materials is used to reduce the production costs of the molded products. Coconut shell powder is widely available at very low cost, so it is an ideal filler material in this regard. Coconut shell powder is made from the most versatile part of the coconut which is from the shell where this shell is organic in nature. High filler content, however many adversely affect the processability, ductility and strength of the composites. Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, Sri Lanka and India. Many works have been devoted to use of other natural fillers in composites in the recent past and coconut shell filler is a potential candidate for the development of new composites because of their high strength and modulus properties. Composites of high strength coconut filler can be used in the broad range of applications as, building materials, marine cordage, fishnets, furniture, and other household appliances. In view of the above facts an attempt has been made in this work to evaluate the compression, impact and bending properties of the coconut shell powder filled polymer composites.

II. MATERIALS AND EXPERIMENTAL
A. Matrix Materials
A medium viscosity epoxy resin (LAPOX L-12) and a room temperature curing polyamine hardener (K-6) used in this experiment. The epoxy used is colourless, odorless and completely nontoxic. Tensile, modulus of elasticity compressive, flexural and impact strengths are 43 MPa, 800-820 kg/mm², 90-100 MPa, 50-60 MPa, 2.5-4 kJ/cm² respectively. Density is 1.15 g/cm³.

B. Secondary Filler
Coconut shell powder (CSP) is widely available at very low cost, so it is an ideal filler material in this regard. Coconut shell powder is made from the most versatile part of the coconut which is from the shell where this shell is organic in nature. Since the size of the filler material plays a vital role on the strength aspects, the coconut shell powders of 150µm, 200µm, and 250µm are used in this experimental investigation. The table 1 gives the basic chemical composition of the coconut shell powder.

Table 1 Chemical composition of coconut shell.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lignin</td>
<td>29.4</td>
</tr>
<tr>
<td>Pentosans</td>
<td>27.7</td>
</tr>
<tr>
<td>Cellulose</td>
<td>26.6</td>
</tr>
<tr>
<td>Moisture</td>
<td>8</td>
</tr>
<tr>
<td>Solvent Extractives</td>
<td>4.2</td>
</tr>
<tr>
<td>Uronic Anhydrides</td>
<td>3.5</td>
</tr>
<tr>
<td>Ash</td>
<td>0.6</td>
</tr>
</tbody>
</table>

C. Specimen Preparation
In this experimental study the coconut shell powder (CSP) of three different grain sizes is used. From the past literature the grain size of the CSP is chosen as 150µm, 200µm and 250µm. The composite specimens were prepared for three different volume fractions as given in the table 2.

In the present investigation the specimens were prepared molding technique. Epoxy and hardener were mixed in a...
container and stirred well for 2-3 minutes. Then the filler is added to the container. Before the mixture was poured inside the mould, the inner surface of the mold will be polished and a release agent is applied to prevent the composites from adhering to the mold surface during the removal. Finally, the mixture will be poured into the mold and is allowed to cool at room temperature for 18 hours. After the curing of 18 to 24 hours the specimen will be removed from the mold. The same procedure is adopted for the preparation of specimens for compression impact and bending test specimens.

<table>
<thead>
<tr>
<th>Grain Size in µm</th>
<th>Volume Fraction in % Epoxy</th>
<th>CSP Filler</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>25</td>
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<tr>
<td>200</td>
<td>95</td>
<td>5</td>
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<td></td>
<td>85</td>
<td>15</td>
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<td></td>
<td>75</td>
<td>25</td>
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<tr>
<td>250</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>25</td>
</tr>
</tbody>
</table>

The different mold and the specimens used in the present study have been shown in figures 1 and 2.

Table 2 Composition of Composites Material.

A. Effect of filler volume and filler size on the strength of the filled composites

The coconut shell particles have significant effect on the impact strength of the composite. From Figure 3, it can be seen that the impact strength of the composites increase with increase in the volume percent of the coconut shell particles within the matrix of the composite. The composite with the highest volume fraction of filler (25%) has the highest strength. This may be due to the high impact energy absorbing capacity of the coconut shell powder.

![Graph showing impact energy vs volume of filler content](image)

Figure 3. Volume fraction / Impact Energy of the filled composites

It can be seen that the impact strength of the CSP filled composites increases with increasing filler loading. The impact strength of the composites increases due to the ability of the filler to support stress transferred from the matrix. Coconut shell as a filler has a high toughness and high lignin content. The bio-flour materials are mainly composed of a complex network of three polymers: cellulose, hemicellulose and lignin [14]. According to Kim et al. [15], lignin not only holds the bio-flour together, but also acts as a stiffening agent for the cellulose molecules within bio-flour cell wall. Therefore, the lignin and cellulose content of CSP has an influence on the strength of CSP and the impact strength of composites.

![Graph showing impact energy vs size of filler](image)

Figure 4. Impact behavior of the CSP filled polymer composites.

The effect of the filler size on the impact behavior is very clearly seen in the figure 4. When the filler size is increased, more weak interfacial regions between the filler and the matrix are formed. Thus, the crack travel more easily through the weaker interfacial regions, hence decreases the energy absorbing capacity before failure. Imperfect inter-facial bonding between the coconut shell particles and polymer matrix causes a dramatic decrease in the impact energy, even when it is present in very low amount. As filler content increased, the possibility of filler-matrix interaction has

III. RESULTS AND DISCUSSIONS

The experimentations have been carried out to analyze the effect of filler size and its volume fraction on the impact, compression and bending behavior. The experimentations have been carried out on the filled polymer composites in a computer controlled universal testing machine. The results of which have been discussed in this section.
increased which leads to the increase in the efficiency of stress transfer from the matrix to the filler phase. Thus, the increases in CSP content which having higher stiffness than polymer matrix has eventually increased the modulus of elasticity of CSP filled polymer composites. Figure 5 shows the fracture specimens of different volume fractions under impact loading.

Figure 5. Fractured specimens of Impact Test, a) 5% CSP, b) 15% CSP, c) 25% CSP

B. Effect Moisture uptake on the impact strength of the filled composites.

The composite coupons were dried at 60ºC for 24 hours and immersed in distilled water at room temperature. The water absorption was determined by weighing the samples at regular intervals. The specimens were periodically taken out of the water, wiped with tissue paper to remove surface water and weighed. It was found that the saturation of the water uptake is for 24 hours, beyond which no significant water absorption is identified. The test specimens for all the volume fractions and the grain sizes were prepared and allowed to have moisture uptake upto 24 hours and tested under impact loading. All the composite specimens have shown a similar pattern of water absorption, with a initial sharp water uptake followed by gradual increases until equilibrium water content is achieved. This equilibrium has achieved in the present study for about 24 hours. The results of which have been shown in the figure 6.

Figure 6. Impact behavior of the CSP filled composites with moisture up take of 24 Hours.

Since CSP is a natural filler, it is strongly hydrophilic materials with many hydroxyl groups (–OH) in the fiber structure. The hydrophilic nature of CSP causes the water uptake by this lignocellulosic material which is due to the formation of hydrogen bonds between filler and water molecules. It is well known that filler absorbs water by forming hydrogen bonding between water on the all cell wall of the filler. With the presence of hydroxyl groups, coconut shell powder tends to show low moisture resistance. Due to the moisture uptake the capacity of the energy absorption has been increased drastically as compared to the normal specimens.

C. Effect of filler volume and filler size on the bending strength of the filled composites.

Stress at fracture from a bend or flexure test is known as flexural stress. Figure 6 shows the typical stress/strain curves for three different epoxy/coconut filler composite materials. From the figure, it is very clear that the bending strength increases with increase in the filler content, irrespective of the grain size. The maximum bending strength is attained by the composite with 15% filler material. The minimum strength is for the composite with 5% of the filler. At lower concentration of the filler material, specimen demonstrated slightly nonlinear behavior prior to sharp failure or fracture. This means that specimen deformed plastically immediate after elastic deformation.

Figure 7. Bending behavior of the CSP filled composites with different grain sizes. CSP 150 µm, b) CSP 200 µm, c) CSP 250µm
The increase of filler content results in the steady linear increase bending strength. This increase is due to the relationship between the interface of fillers and matrix in which the fillers strengthen the composite materials. However, the resistance to deformation increases with increase in the filler content due to the fact that the materials have become harder with the increase in filler content. Therefore, the elongation decreases as filler materials reduce the ductility of matrix. Due this reason the load sustainability of the 15% CSP filled composite, before the start of deformation is found to be very high, as compared to other two.

![Fractured specimens of three point bending test](image)

Figure 5. Fractured specimens of three point bending test, a) 5% CSP, b) 15% CSP, c) 25% CSP

IV. CONCLUSIONS

From the experimental investigations made on the CSP filled epoxy composite under the impact and bending loads, it is found that the load carrying capacity in both cases of loading has been increased by increasing the filler content. It is observed that only upto 15% of the filler the bending strength is increased, beyond which it has shown drastic decrement. The impact resistance of the filled composite has been increased by increasing the filler content. Also it is found that the filler matrix interaction is satisfactory for all the tested volume fractions.

V. REFERENCES


