PULMONOLOGY

Sustainable Epoxy Composites Using Delonix regia Biomass and CD/DVD E-Waste Reinforcement

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ABSTRACT
In this paper work a cheaper and ecofriendly artificial wood for domestic application is developed by mixing waste compact discs (CDs) and digital versatile discs (DVDs) an e-waste and Delonixregia fruit (DRF) with epoxy as a matrix. This artificial wood composite uses 1:1 ratio of *Delonixregia* fruit particle and CDs /DVDs flakes .*Delonixregia* fruit powder to evaluate its effect on the mechanical properties. The percentage water absorption, density, hardness, tension, impact strength, and flexural strength of both *Delonixregia* fruit particles epoxy (DRF) and *Delonixregia* fruit particles and CDs/DVDs flakes (DRFP) composite were determined. The result showed that the use of CDs/DVDs flakesas a filler material has improved these properties.The physical properties,percentage water absorption, density and hardnessDRFand DRFP composite are compared with the reported natural wood.

INTRODUCTION
Scientist and engineer are in constant search of cost effective, waste reducing, byproduct composite materials to reduce the burden on the conventional materials. Composite material found its application in almost all sectors such as transportation,construction, domestic[1]. Glass fiber reinforced composite constitutes about 95% and 97% by volume in European and UK market respectively. In year 2010 the market value of carbon reinforced composite £658 million[2]. The high cost and high environmental impact of this high technology, synthetic fiber composite as forced the researchers to shift towards natural, eco-friendly, waste reducing, cheaper, lightweight composite materials for lower technology application to resists these environmental hazardous synthetic composites from lower technology application .*Delonixregia* (Gulmohar) is a traditional medicinal tree whose leaves, barks and seeds are used for treatment of pneumonia, bronchitis, stomach disorder and rheumatism. The fruit of *Delonixregia* is flaccid and green when young but turns into dark brown hard woody pod, which is a bio waste.[3]Obam[4] used sawdust, waste paper and starch for manufacturing of composite for ceiling board. Non -biodegradable, the limited lifetime;CDs and DVDs, widely used for storing music, text, videos and software's is an electronic waste (e-waste). Among other storage devices like floppy disc, cassettes and video tapes, CDs and DVDs are widely used. As per the United States Environmental Protection Agency (EPA), millions of CDs are thrown away and 5.5 million go as landfill[5]. The heterogeneous polymer combination and multi-layer metal coating of the CDs/DVDs causes its recycling problem. The paper work is aimed to produce environmentally friendly, Delonixregia fruit powder- epoxy composite material and at the same time to evaluate the effect of CDs/DVDs flakes, on its mechanical properties.

EXPERIMENTAL
2.1 Materials
The *Delonixregia* fruit, hard woody pod is used as reinforcement in the composite was collected from the *Delonixregia* trees at, Arya Institute Of Engineering And Technology, Kukas, Jaipur. The *Delonixregia* fruit was crushed to small pieces, dried in sunlight and ground to mesh size range of 80 and 100. The powdered *Delonixregia* fruit was dried at 105°C for about 24 hours until constant weight was reached to insure the removable of moisture, and then stored in the polyethylene bag to be used conveniently [6].
The waste CDs and DVDs used as a filler material for improving the mechanical properties of the developed composite was collected together from our houses. These collected CDs and DVDs were cleaned with disinfectant, dried and crushed**.** Epoxy resin with the density of 2.25 g/m^3 was used as a polymer matrix.

2.2Manufacturing
The traditional hand lapping process at ambient temperature was used to develop the composite. The two combination of composite reinforcement was used; one with *Delonixregia* fruit, powdered particles (DRF) and other with *Delonixregia* fruit, powdered particles and glass powdered particles (DRFP)in aratio of 1:1 by weight. The reinforcement and the matrix (Epoxy) were mixed in a ratio of 1:1 by weight and stirred uniformly for insuring proper mixing. The mixtures were then placed in a wooden mold with releasing paper and allowed

to cure for 24 hours. The specimens for testing the different mechanical properties were cut from the molded composite according to ASTM standard**.**

Fig 1 Cross sectional view of DRP composite

Fig 2 Cross sectional view of DRFP composite

2.3 Testing of Samples

The tensile, flexural and impact test was carried at Microlab-Metallurgical Test House, Ambattur Industrial Estate, Chennai-600058. The moisture absorption and the hardness test were carried out at the Department of Mechanical Engineering, Strength of Material Lab, Arya Institute of Engineering And Technology, Kukas, Jaipur. Mass and the volume of the developed composite were used to calculate the density of the composite.[6]

2.3.1 Water Absorption

Four replicates samples for both DRF and DRFP composites of dimension 40 mm X 10 mm X 4.1 mm were manufactured for percentage water absorption test. The samples were dried in oven at 60^0c till the constant weight was reached. The digital weighing machine of precision of 0.000 g was used for weighing the sample. These samples were then placed in deionized water at ambient temperature. The samples were taken out periodically from the water, wiped to remove surface water, reweight and immediately kept in the water till constant weight was reached. The following formula was used to calculate the percentage water absorption of the composite,

Water absorption (%) $= [(W2 - W1)/W1] * 100$

Here W2 is the sample weight after keeping in water and W1 is the initial weight of the sample[7].

2.3.2 Hardness Test

The hardness test of DRF and DRFP composites were performed according to ASTM D785-98 on the Rockwell Hardness Testing Machine. Four replicates samples for each test were tested and the average values were reported.

2.3.3 Tensile Test

The tensile test of DRF and DRFP composites were performed according to ASTM D638, on Universal Testing Machine (Model: WDW-100, China).Four replicates samples for each test were tested and the average values were reported.

2.3.4 Flexural Test

The flexural test of DRF and DRFP composites were performed according to ASTM D790-00.Four replicate samples for each test were tested and the average values were reported.

2.3.5 Impact Test

The Charpy impact test of DRF and DRFP composites were performed according to ASTM D256.·Four replicate samples for each test were tested and the average values were reported.

RESULTS AND DISCUSSION

3.3.1Water absorption& Density

The maximum percentage water absorption for DRF and DRFP composites were observed as 14.45% and 10.2% after 16 and 20 days respectively. The water absorption primarily depends upon the nature of the individual input ingredients (*Delonixregia* fruit, powdered, CDs/DVDs flakes and epoxy). The decrease in the component of the cellulose and hemicellulose which are hydrophilic, the percentage of water absorption is reduced by 4.25% with the CD/DVD flakes incorporation.

The density of any composite depends upon the specific gravity, the interaction and the proportionate formulation of its individual components.The density of DRF and DRFP composites measured to be 2414kg/m^3

and 3179.2 kg/m^3 respectively.The presence of voids could be also the possible reason for higher densities of these developed composites.

3.3.2Hardness

The measured hardness of the DRF and DRFP composites were 45 and 68 on the Rockwell scale respectively. The better dispersion between the CDs/DVDs flakes (filler) and the epoxy (matrix) thereby reduction in void could be the possible reasons for the improvement of DRFP composites. Rahman[7] reported that hardness properties could be enhanced by increasing stiffness and decreasing flexibility. As per Mohammed [8], the well-polished surface has better hardness. DRFP composites had a better surface finished, showed better hardness.

Table 1 Characteristic of DRF and DRFG composites

Sample	Density (kg/m3)	Water absorption (%)	Hardness (Rockwell Scale)	Tensile strength (Mpa)	Flexural strength (Mpa)	Impact strength (kJ/m2)
DRF- Epoxy	2414	14.45	45	5.5	18.06	10.61
DRFP- Epoxy	3179.2	10.2	68	11	21.01	10.61

3.3.3Tensile strength

The presence of CDs/DVDs flakes has improved the interfacial strength between the CDs/DVDs flakes and the matrix (epoxy) leading to an improvement in the tensile strength of the DRFP composites by 5.5 Mpa. The calculated tensile strength of the DRF and DRFP composites were 5.5and 11Mpa, respectively.

3.3.4Flexural strength

The result obtained from the flexural test showed that the flexural strength increased by adding the CDs/DVDs flakes (filler).Flexural strength of the DRF and DRFP composites were 18.06 and 21.01Mpa, respectively. The addition of CDs/DVDs flakes (filler) had increased the stress transfer between the filler and matrix.

Fig. 3 Cracked DRF composite specimen under flexural strength test.

Fig. 4 Cracked DRFP composite specimen under impact test.

3.3.5 Impactstrength

The impact strength of both DRF and DRFP composites were 10.61kJ/m^2. There is no improvement in impact strength by addition of CDs/DVDs flakes as filler. The higher impact resistances are demanded by the composite that are subjected to impact stresses and recurrent vibrations.

CONCLUSION

Delonixregia fruit (bio-waste) powdered and CDs/DVDs flakes (e- waste) were recycled and composite material was developed which is ecofriendly, innovative, effective and cheaper. Comparing the physical properties with the natural soft wood and natural hard as evaluated by Mohammed [8], the present developed DRF and DRFP composites have similar properties. The density of the present developed composites is higher than natural wood which resist their applications, but the other physical and mechanical properties could be used for specific applications such as flooring and doors. The table 2 shows the comparison of physical properties of natural wood evaluated by Mohammed[8] with the present developed composites

Table 2 Comparison of physical properties of natural wood evaluated by Mohammed [8] with the present developed composites

Sample	Density (kg/m3)	Water absorption (%)	Hardness(Rockwell Scale)	Refs.
Natural hard wood	660	29.2	85.46	8
Natural soft wood	470	42.4	56.1	
DRF- Epoxy	2414	14.45	45	Present work
DRFP- Eooxy	3179.2	10.2	68	

The addition of CDs/DVDs flakes as a filler material has made the composite dense. The water absorption is inversely proportional to the density of the composite. The hardness of DRF composite is less than DRFP. The glass powder has improved the tensile strength of the composite as well as its flexural strength. The impact strength of the composite is same for both DRF and DRFP composites.

Considering the environment, the recycling of CDs/DVDs would save much pollution and power at the same time using *Delonixregia* fruit would save forest resources and tree thereby promoting green environment. Considering economics, these are the cheapest raw material that could be a valuable asset in the construction industry.

The use of other both biodegradable and non-biodegradable polymer is suggested as future work

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