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Development of Hybrid Coconut Shell Powder-Wood Dust Polyester Resin Based Composites

D.Ravindran, T.Sornakumar , D.S Prithvirajadurai, V.Varadharajan

Abstract— The wood dust particles are left to degrade in many wood cutting industries. Coconut shells are one of the important agriculture waste products and they are left to degrade of its own. In the present work, polyester resin based composite laminates are manufactured by filling the mixed solution consisting of polyester resin with wood dust and coconut shell powder fillers into a mould. The weight percentages of the fillers are systematically varied to study its effect on the mechanical properties of the laminates. The tensile test was conducted in a Universal testing machine as per ASTM: D638 standard. The flexural test was conducted in a Universal testing machine as per ASTM: D790. The double shear test was conducted in the Universal testing machine as per ASTM: D5379 standard.

Keywords— Wood dust, coconut shell powder, Tensile strength, Flexural strength, Shear strength.

I. INTRODUCTION

Due to the global demand for fibrous materials, worldwide shortage of trees in many areas, and environmental awareness, research on the development of composites prepared using various waste materials is being actively pursued. Among the possible alternatives, the development of composites using agricultural residuals (including stalks of most cereal crops, rice husks, coconut fibers, bagasse, maize cobs, peanut shells, and other wastes) is currently at the center of attention (Ashori and Nourbakhsh, 2010) [1]. In recent years, significant efforts have been directed to investigating the use of natural fibres as reinforcement in thermoplastics. Natural fibres, such as wood fibre, wheat straw, jute fibre and bagasse fibre have several benefits: low cost, low density, high toughness, acceptable specific strength properties, enhanced energy recovery and biodegradability. The use of natural fibres in plastic matrix includes many benefits, such as low volumetric cost, increase of heat deflection temperature, increase of stiffness of thermoplastics and improvement of ‘‘wood’’ surface appearance. So natural fibres reinforced plastic composites have achieved applications in decking, furniture components, door moldings, packing pallets and interior panels of automobiles (Zheng et al, 2007) [2]. Natural fibres/polymer composites (NFPC), defined as polymer matrix reinforced with wood or other natural fibres, are principally produced from commodity thermoplastics. Due to the advantages of low cost, good mechanical and thermal properties, low density, water resistance, availability of renewable natural resources and biodegradability, NFPC are widely used in various purposes such as construction materials, decorative parts, aerospace components, and vehicles’ compartments. With the worldwide shortage of trees, increased wood costs and competition of wood resources from traditional wood sectors, developing environmentally friendly natural fibre sources for plastic composites is being actively pursued. Currently, the use of agricultural residues (including stalks of most cereal crops, bagasse, rice husks, and other wastes) for the production of composites has been at the centre of attention (Huang et al, 2012) [3]. The mechanical and thermal properties of polymers and composite structures can be altered through the use of various kinds of fillers. The dimensions of these fillers typically fall on a macroscopic (1 μm–1 mm) length scale. Fillers of this type increase the stiffness and heat distortion temperature of a polymer, primarily because the filler makes up a significant proportion of the total mass. However, macroscopic fillers usually cause decreases in strength, impact resistance, and processability (Timmerman et al, 2002) [4].

Wood plastic composites (WPCs) have experienced steady growth over the pevious years in response to consumer demands for low maintenance and durable timber construction materials, and increased global ecological concern about preservative-treated lumber (Ashori, 2008) [5]. The wood plastic composites are produced by combining thermoplastics with wood/natural fibers, and complex structural sections can be formed using conventional plastics processing techniques. Most WPC product applications to date including residential deck boards, rails and balusters, window lineal, door components, boat hulls, and automotive components have modest structural requirements. However, these bio-composite materials do not have adequate mechanical properties required in typical structural applications. The industry has opportunities to expand into a host of new products, including structural components for low-rise buildings, marine, and transportation structures (Lei and Wu, 2012) [6]. Wood plastic composites (WPCs) are becoming attractive because of their unique properties such as low cost and versatility in processing. They are nowadays categorized as ‘‘green materials’’ due to the possible usage of recycled materials in their compositions and also their ability to be recycled. The main role of wood component in WPC is acting as the filler, rather than the reinforcement, to reduce cost (although it causes an increase in stiffness). Hence, the primary application of WPCs, in their current state, is in building industry such as

D.Ravindran, Department of Physics, Thiagarajar College of Engineering, Madurai-625015, India
T.Sornakumar , D.S Prithvirajadurai, V.Varadharajan , Department of Mechanical Engineering, Thiagarajar College of Engineering, Madurai-625015, India. (E-mail id: sornakumar2000@yahoo.com)

decking, roofing, door and window frames where a high strength is not demanded. In general, WPCs exhibit low strength and toughness (or impact strength) which hinders their usage in the load bearing applications (Zolfaghari et al, 2013) [7].

Natural fibers, such as flax, cordenka, hemp, jute, ramie, kenaf, bamboo, caraua and sisal, have been employed as reinforcement to prepare green composites and are basically composed of cellulose, hemicelluloses and lignin. The resulting composition of those elements varies depending on the harvesting area and agricultural conditions. Cellulose and hemicelluloses comprise polysaccharides, whereas lignin consists of amorphous polyphenolic macromolecules (i.e., three kinds of phenylpropanes). Coconut (Cocos nucifera), a member of the palm family, grows broadly in tropical and sub-tropical regions and is employed for a range of applications including decoration, culinary, and non-culinary uses. Coconut encompasses coir (mesocarp or husk), shell and inner stone (endocarp), among which the husk is made into the form of fibers and the shell is crushed into chips. Annually, approximately 33 billion coconuts are harvested worldwide with only 15% of these coconuts being utilized for fibers and chips (Jang et al, 2012) [8]. The use of residues as filler in polymer composites is not new in scientific and technological circles, but the innovation is in creating productive alternatives using various current residues to generate employment, income, and economic and social development, mainly in third world countries. In this sense, the use of lignocellulosic materials has provided a new field of analysis and experimentation in recent years. Forest-based residues have not been fully explored and their application still requires an economic feasibility study. This is the case of dry coconut endocarp, whose properties have not been widely discussed and about which there are few published studies. Cocos nucifera Linn, a material that needs more investigation and well defined applications, considering its characteristics, is extremely hard, resistant to the action of microorganisms, lustrous and most importantly, abundant in the coastal regions of many countries (Silva et al, 2011) [9] .

Coconut (Cocos nucifera) is a member of the palm family. The coconut palm is used for decoration as well as for its many culinary and non-culinary uses; virtually every part of the coconut palm has some human use. Coconut shell is non food part of coconut which is hard lignocellulosic agro waste. Coconut shell is 15–20% of coconut. The final properties of composite materials depend on fibre properties (morphology, surface chemistry, chemical composition and crystalline contents) as well as matrix properties (nature and functionality). The adhesion between the reinforcing fibre and the matrix in composite materials plays an important role. The wetting of the fibre is a main step in the adhesion process. Fibre properties, i.e. components, surface roughness and surface polarity have important contribution to fibre wettability and adhesion in composites. However surface chemistry of the fibres has influence on the mechanical properties of the composites. So it is important to define the fibre physical, chemical and thermal properties before it is using as reinforcement. Wood fibre is the most widely used lignocellulosic natural fibre for reinforcing plastics. Considering economic and ecology, wood fibre plastic was established itself as standard material but unfortunately raw wood fibre price increased 25–30% compared to last year price. Therefore, scientist are searching new source which could be the proper alternative of wood fibre. The abundance of agro by-product is eco-friendly, available, cheap and which is complicated in term of cell geometry, morphology and chemical composition. It also has created an environmental issue such as fouling and attraction of pests. Agro by-products, i.e. barley husk, coconut shell are waste product of food processing and have sufficient fibre value. So proper utilization of those waste materials will provide cheap engineering materials as well as help to waste management (Bledzki et al, 2010) [10].

The toughening mechanisms due to the addition of particles to polymers are localised inelastic matrix deformation and void nucleation, particle debonding, crack deflection, crack pinning, crack tip blunting, particle deformation or breaking at the crack tip (Battistella et al, 2008) [11]. Mwaikambo and Ansell (2003) reported that alkali treatment with NaOH concentrations between 4-6% yield stiffness and maximum stress on hemp fibre (Mwaikambo and Ansell, 2003) [12]. The NaOH treatment removes the hemicelluloses, lignin and other impurities on the surface of the rice husk (Guilbert-Garcia et al, 2012) [13]. Alkalization caused a better interfacial bonding between rice husk fiber and polyester matrix and improve the mechanical properties (Wayan Surata et al, 2014) [14].

II. EXPERIMENTAL

The wood dust (WD) materials namely, Indian elm wood dust (IWD) (Holoptelea Integrifolia) was used in the present work. The wood dust particles were dried in air and used after cleaning process. The coconut shell powder (CSP) was used after chemical treatment. Figure 1 and Figure 2 presents the Indian elm wood dust (IWD) and coconut shell powder (CSP) fillers used in the present work. The minor scale is in mm and major scale is in cm of the upper scale. The coconut shell powder (CSP) were dried in air and used after cleaning process. The binding properties between the matrix and particle can be enhanced with chemical treatment. The CSP were dried in air and used after cleaning process. The binding properties between the matrix and particle can be enhanced with chemical treatment. The CSP were immersed in 5% NaOH solution for 4 h. The CSP were then thoroughly washed in deionised water several times and then dried at 50^0 C for a period of 6 h in a hot air oven to remove the adhering moisture.

In the present work, polyester resin based composite laminates are manufactured by filling the mixed solution consisting of polyester resin with Indian Elm wood dust and coconut shell powder fillers into a mould. The weight percentages of the fillers are systematically varied to study its effect on the mechanical properties of the laminates. A mould release agent was thoroughly applied over the surface of the mould for easy removal of the polyester composite specimen. The hardener (methyl ethyl ketone peroxide) and the accelerator (cobalt naphthenate) was mixed with unsaturated polyester resin and stirred slowly. The Indian elm wood dust (IWD) particles and coconut shell powder (CSP) particles were taken in appropriate weight ratio and slowly poured in the polyester resin solution and the mix is stirred to disperse the IWD and CSP in the matrix. The gel like solution consisting of polyester resin with the IWD and CSP was then filled into a pre-cleaned mould. The polyester composite was cured under a load of about 50 kg for 24 hours before it was removed from the mould. Then it was post cured in the air for another 24 hours after removing out of the mould. The polyester resin with IWD particles and CSP particles were used for preparation of polyester composites. The weight percentage of polyester resin was kept at 80 (wt%) and different polyester composite specimens were fabricated by varying the composition of IWD particles and CSP particles. The thickness of the polyester composite specimen is 6 mm.

Fig.1. Indian elm wood dust (IWD)

Fig.2. Coconut shell powder (CSP)

Results and discussion

Figure 3 and figure 4 presents the polyester composite specimens for tensile tests and flexural tests respectively.

Figure.3.Specimen for tensile test

Figure.4.Specimen for flexural test

The tensile test was conducted in a Universal testing machine as per ASTM: D638 standard. The flexural test was conducted in a Universal testing machine as per ASTM: D790. The double shear test was conducted in the Universal testing machine as per ASTM: D5379 standard. Figure 5, figure 6 and figure 7 presents the polyester composite specimens during tensile test, flexural test and shear test respectively.

Figure.5.Tensile test

Figure.6.Flexural test

Figure.7.Shear test

The tensile strength (TS), flexural strength (FS) and shear strength (SS) of the different compositions of GFRP are presented in table 1.

The type of filler, the interface adhesion between fillers and matrix, and the extent of load-sharing mechanisms determine the strength quantitatively (Bhagyashekar and Rao, 2010) [15]. The quality of the interface in composites, i.e. the static adhesion strength as well as the interfacial stiffness, usually plays a very important role in the materials capability to transfer stresses and elastic deformation from the matrix to the fillers. If the filler matrix interaction is poor, the particles are unable to carry any part of the external load. In that case, the strength of the composite cannot be higher than that of the neat polymer matrix. If the bonding between the fillers and matrix is instead strong enough, the yield strength of a particulate composite can be higher than that of the matrix polymer (Abdul Khalil et al, 2013) [16].

Table.1.The composition and mechanical properties of the specimen

Specimen Code	Polyester Resin (PR) (wt %)	Indian elm wood dust (IWD) (wt %)	Coconut shell powder (CSP) (wt %)	Tensile strength, MPa	Flexural strength, MPa	Shear strength, MPa
FRP 1	80	20	0	3.58	4.05	2.14
FRP 2	80	15	5	7.48	8.42	4.52
FRP 3	80	10	10	12.38	14.78	8.12
FRP 4	80	5	15	17.82	23.46	12.63

The mechanical properties of tensile strength, flexural strength and shear strength of the polyester composite specimen FRP4 (80 % wt PR, 5 % wt IWD and 15 % wt CSP) are higher than that of FRP3 (80 % wt PR, 10 % wt IWD and 10 % wt CSP), which are higher than that of FRP2 (80 % wt PR, 15 % wt IWD and 5 % wt CSP) , which are higher than that of FRP1 (80 % wt PR , 20 % wt IWD and 0 % wt CSP). The mechanical properties increased with addition of coconut shell powder filler particles. The mechanical properties improve with addition of coconut shell powder filler particles because of higher resistance to forces, due to good distribution of coconut shell powder filler particles and decrease of Indian Elm wood dust particles in the polyester matrix reveals that the stresses are efficiently transferred via interface. The synergistic effect of coconut shell powder filler particles, India Elm wood dust particles and polyester resin results in enhancement of the mechanical properties

III. CONCLUSION

In the present work, polyester resin based composite laminates are manufactured by filling the mixed solution consisting of polyester resin with the wood dust fillers and coconut shell powder into a mould. The mechanical properties of tensile strength, flexural strength and shear strength of the polyester composite specimen FRP4 (80 % wt PR, 5 % wt IWD and 15 % wt CSP) are the highest. The development of hybrid coconut shell powder–wood dust polyester resin based composites revealed that these materials can be used to the advantage for many applications.

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