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Extraction procedure and tensile properties of Dharbai and Christmas palm natural fibres

S Kalyana Sundaram[a] & S Jayabal

Department of Mechanical Engineering, A C College of Engineering and Technology, Karaikudi 630 004, India

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A new variety of natural fibres has been extracted from Dharbai and Christmas palm for their use as reinforcement in polymer matrix composites. The tensile properties and cross-section area of Dharbai and Christmas palm fibres have been evaluated experimentally and compared with natural fibres such as sisal, banana and coir which are already used as reinforcement in polymer composite. Monofilament test has been used to study the tensile properties of the fibres and Rapid-I machine vision system is used to determine the diameter of the fibres. Density of the fibre is determined using picnometric procedure. The investigation confirms that Dharbai and Christmas palm fibres could be effectively used as reinforcement materials in the natural fibre reinforced polymer composites.

Keywords: Christmas palm, Dharbai, Fibre composite, Monofilament test, Rapid-I machine vision system

Among the various synthetic materials that have been developed, plastics claim a major share as wood substitutes. Plastics are used for almost everything from articles of daily use to the components of complicated engineering structures and heavy industrial applications. But, the study of plastic composites has simulated immense interest in meeting the future shortage of plastic materials. Also, plastic composite materials are expensive and non-renewable. Due to the high price of this petroleum based products, there is a need to identify suitable alternative for this goods[1]. Some of the best alternates for these synthetic materials are agricultural and plant fibre based materials[2, 3]. Natural plant- based fibres are available abundantly and have high specific mechanical properties. The progress in development of natural fibre reinforced composites has witnessed the increasing interest in demonstrating the efficient use of renewable resources[4]. Many kinds of textiles, ropes, canvas and papers are produced using natural fibres[5, 6]. Different parts of plants such as the stem, leaf, seed and fruit have been found to be viable source for this raw material.

The reinforcement of coir fibres in the polyester matrix results in low density and high electrical resistance and the composites are likely to be useful as electrical and acoustic insulators[7, 8]. Several attempts have been made to study and improve the thermal and mechanical properties of natural fibre reinforced polyester composites[9, 10]. The surface topography study of banana fibre shows wood like appearance and poses good mechanical properties and better surface finish[11]. The mechanical properties evaluation of sisal fibre reinforced composite proves their application as a commercial products[12]. The fatigue and damage characterization study on abaca fibres reinforced polymer composites has established their significance as light weighted materials[13]. The extraction and tensile properties study on vakka and date fibres results in possible usage of this fibre as reinforcement in composite materials[14]. This work is mainly focused on introducing Dharbai and Christmas palm fibre as effective natural fibre reinforcement in polymer matrix composites.

Experimental

Fibre Extraction

Banana, coir and sisal fibres were collected from the local source at Pollachi, Tamilnadu, India. Dharbai and Christmas palm fibres were extracted from Dharbai and Christmas palm plants respectively.

Dharbai (*Eragrostis cynosuroides*) is widely cultivated in both southern and northern part of India. These fibres belong to Grass family and do not require much water for higher yield. The Dharbai leaves are chopped off with the knife and dried in the shade for three days. The resultant fibre was water retted for 8 days and rinsed with water for removing the foreign impurities formed during retting process. The fibre is than dried at a room temperature for 2 days to remove the moisture content from the fibre.

[a]Corresponding author.
E-mail: kalyan.Int@gmail.com

Adonidia merrillii popularly known as Christmas palm is a native of Philippines, cultivated in India. The source of Christmas palm fibre is the foliage of the Christmas palm tree, which falls on to the ground as it ripens. The sheath collected was immersed in a water-retting tank for 15 days to segregate fibres from the sheath. The fibres were cleaned by means of water rinsing and dried at room temperature for 3 days to remove the moisture content. The gums present in the sheath dissolved in water completely and excess hard impurities present over the surface of the fibre were removed by means of combing.

Mechanical Testing

The diameter of the fibres was measured with the help of Rapid-I machine vision inspection system. The Rapid-I software was used to measure the fibre diameter, the lighting control in the software was utilized to illuminate the component to be inspected, the coarse/fine adjustment knobs was used to bring the component under the camera and magnification was adjusted to desired setting, Appropriate cross-hair type and geometric entities were selected to measure the fibres diameter. The density of banana, coir, sisal, Dharbai and Christmas palm fibres was calculated by means of picnometric procedure.

The fibres were subjected to single filament test for evaluating their tensile properties. The monofilament of each fibre was tested using the Instron (Model: 5500 R) testing machine at the loading rate of 5 mm/min until the fibre fractures at 21 ± 1°C temperature and 55 ± 2 % RH. To obtain a statistically significant result, 20 fibres from each family were tested to evaluate the average tensile strength and average tensile elongation.

Results and Discussion

Fibre Extraction

The Dharbai fibre was extracted by a simple and economical water retting process. The quality of fibre depends on number of times the fibres are scrapped. The Christmas Palm fibre extracted using simple water retting process helps in dissolving and separating foreign matter (lignin, gums, etc.) in water within 15 days. Since the leaf sheath contains about 70% of fibre and 30% foreign matter, processing the fibres is simple and results in an excellent quality of fibres. The fibres are continuous and 15– 25ft long. The fibres are slightly glazed and brown in color. Both Dharbai and Christmas Palm fibre exhibits a rough fibre surface and the fibres are expected to have better adhesion property with matrix when reinforced in polymer composites.

Fibre Diameter

The cross-section area of fibre measured using Rapid-I machine vision system is shown in Fig. 1. It is observed that the cross-sections of all the fibres are circular approximately. The cross-section area of

Fig. 1—Diameter measurement of natural fibres

Dharbai fibres is dissected to vary widely, while the diametric variations of other fibres are considerably small. But this problem could be diluted by proper scrapping of fibres during the extraction process. The average diameter of banana, coir, sisal, Dharbai and Christmas palm fibres are 0.1307, 0.1196, 0.1271, 0.1168 and 0.2517 mm respectively. The surface of Christmas palm fibre is found to be rough and exactly circular; it is found at par with other exploited fibres such as banana, coir and sisal. The circular shape and outer surface of the Christmas palm fibres are expected to enhance the interfacial bonding between fibres and matrix materials when used as reinforcement in polymer composites.

Density of Natural Fibres

The density of fibres measured by Picnometric procedure are listed in the Table 1.The density of fibre depends up on various factors such as process of fibre extraction, age of the plant, soil condition in which the plant has grown, etc. However, the table gives a relative measure of the densities between the fibres considered. The density of banana, coir, sisal, Dharbai and Christmas palm fibres are 1290, 1100, 1380, 1150 and 1060 kg/m^3 respectively. It is observed that the density of new fibres namely Dharbai and Christmas palm are comparable with those of established natural fibres and can be effectively used as reinforcement in natural composites.

Tensile Strength of Natural Fibres

The cross-section area of the fibre is determined with the help of optical micrometer for consistency purpose. The fibres are subjected to single filament test as per ASTM D 2256 standard. The diameters of banana fibres are ranged between 0.13 mm and 0.16 mm and that of coir fibres are between 0.112 mm and 0.142 mm. The diameters of sisal, Dharbai and Christmas palm fibres are ranged as 0.120–0.156 mm, 0.116–0.145 mm and 0.251–0.285 mm respectively. The tensile properties of the investigated natural fibres are listed in the Table 1.

The tensile properties of Christmas palm fibre are found to be better than banana, Dharbai and coir fibres. The ultimate tensile stain of different fibres increases in the order Christmas palm < coir < Dharbai < banana < sisal. The strain rate in Christmas palm fibre is found to be lower than all other fibres. The low strain rate in Christmas fibres witness the superior restriction offered by the fibres to the applied load. The percentage elongation of Dharbai fibres is also found to be good than the banana and sisal fibres. The specific tensile strength of Christmas fibre is found to be excellent than all other fibres examined. This maximum value of specific tensile strength and specific modulus substantiates that the Christmas palm fibre reinforcement in polymer matrix can offer better strength to weight ratio than all other fibres investigated. The tensile properties of Dharbai fibres are at par with coir fibres and can be used for manufacturing low load bearing products. The tensile properties are well comparable with the work carried out by previous researchers[15-17]. Since the tensile properties and density of the newly introduced fibres are well within the range, this fibre could be successfully used as reinforcement with natural fibre reinforced polymer composites.

Dharbai and Christmas palm natural fibres extracted from the Dharbai plant and Christmas palm tree respectively are inexpensive and their extraction process is simple. The water retting process adapted results in excellent quality of fibres and is comparable to any of the presently exploited natural fibres. As far as extraction process is concerned, cost and length of fibres extracted are excellent, compared to those of coir and banana fibres. The density of newly introduced fibres is comparable to the established fibres. The tensile properties of Dharbai and Christmas palm fibres are found as good as fibres that are already recognized as reinforcement materials in

Table 1—Tensile properties of natural fibres

Fibre	Density kg/m^3	Average diameter mm	Mean breaking strength gf	Average tensile strength MPa	Average tensile elongation %	Average tensile modulus GPa	Specific tensile strength MPa/kg m^{-3}	Specific modulus MPa/kg m^{-3}
Banana	1290	0.1307	882.41	601	2.17	24.87	0.4568	19.27
Coir	1100	0.1196	500.00	507	1.61	13.56	0.4609	12.32
Sisal	1380	0.1271	937.21	710	2.49	28.51	0.5144	20.66
Dharbai	1150	0.1168	527.50	541	1.80	16.53	0.4704	14.37
Christmas Palm	1060	0.2517	3798.39	680	1.55	22.68	0.6415	21.39

natural fibre reinforced composites. Hence, it can emphatically be stated that the fibres considered herein deserve to be included in the list of natural fibres used as reinforcements in polymer composites for designing lightweight engineering materials.

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