INVESTIGATION ON THE MECHANICAL CHARACTERISTICS OF SAWDUST AND CHIPWOOD FILLED EPOXY

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ABSTRACT

In furniture and paper industries, huge amount of wood flakes and wood flours in the form of chip wood and sawdust are always found as waste. This is known as natural fiber, a renewable source that available at low cost. This study was carried out for three different sizes of fiber which categories into "soft", "rough" and "coarse" particles that derived from chip wood (CW) and sawdust (SW). The SW and CW fiber were blended with epoxy by using hand tools machine respectively, which then open molding was employed to form a fiber composite and specimens' accordance to the ASTM standards. It was found that the strength of tensile value for the rough size particles of SW were higher than the CW. The works presented a good quality of SW and CW fiber composite had been produced which can be used for home furniture utilities.

KEYWORDS: *Sawdust and chip wood, wood composites, tensile and flexural properties.*

1.0 INTRODUCTION

Polymer composites have replaced conventional engineering materials such as metals, plastics and ceramics in many engineering applications in the recent years. Nowadays, composite materials are chosen as materials in engineering products for a variety of reasons, including lightweight, high stiffness, high strength, low thermal expansion, corrosion resistance, and long fatigue life. In recent years, natural fibre composites are used in many non-structural and semi-structural applications due to their low cost, being renewable and abundance and the examples include coconut, oil palm, pineapple leaf and wood fibre reinforced polymer composites. In the past there were numerous work have been conducted in the area of natural fibre composites using different types of fibres such as bamboo (Chen *et.al*., 1998, Ismail *et.al*., 2002), oil palm empty fruit bunch (Rozman *et.al.*, 2003) and wood (Jayaraman and Bhattacharyya, 2004, Elinwa and Mahmood, 2002).

In furniture and paper industries, huge amount of wood flakes and wood flours in the form of chip wood and sawdust are always found as wastes. Because of high accessibility and low cost of the chip wood and sawdust, they can easily be incorporated with polymers by compounding process in order to improve the properties of reinforced polymers such as high strength and ease of processing compared to wood or neat polymer. Wood is a unique material that has many characteristics such as aesthetics and light weight compared with man-made materials such as concrete and brick. Wood can be used in conjunction with polymers to forms glued laminated members and can be used alone in the form of a sheet of paper or to make a toy (Jozsef,1982). Wood continues to be the raw material for the large number of products in the modern time, even thought other materials such as metals, cement and plastics are highly used as raw materials to produce consumer products (George, 1991).

Wood fibre reinforced polymer composites have been known for many years. Historically, most of woods are used in the form of wood flour to produce filled composites. The wood flour reduces the cost of composite materials, but was not usually intended to substantially improve the performance of composites. More recently, the use of wood fibers to provide a reinforcing mechanism in thermoplastics has been of substantial interest. In fact, several companies have manufactured wood fibre reinforced thermoplastic composite materials for use as synthetic lumber in applications such as decking and window frames (Susan *et.al*., 2004). The demand from the end user for furniture especially in modern furniture design, required the use of wood composites with high strength (Eckelman ,1997). Moreover, the use of natural fibre in furniture is not just limited to wood fibres but also in other plant based fibres such as banana pseudo-stem faibres (Sapuan and Maleque, 2006).

In this paper, a study on mechanical properties of chip wood and sawdust fibre reinforced epoxy composites is presented. Mechanical properties studied include tensile strength, flexural strength, modulus of elasticity and modulus of rapture.

2.0 METHODOLOGY

Materials and methods

The waste wood fibers used in this study were collected from a saw mill in Sungai Buluh, Selangor, Malaysia. In all cases waste woods were dried overnight to remove moisture at room temperature and were kept in the polyethylene bags to prevent fungus growth. Both sawdust and wood chip were sieved using three different sizes of sieves. The timber species dominant in the sawdust and chip woods was not known to the authors and perhaps they were simply a blend of various hardwoods. Chip wood (CW) fibres collected from each sieve were separated into three different sizes namely, "coarse" for 150 meshes, "rough" for 100 meshes and "soft" for 50 meshes. The sawdust (SW) were divided "coarse" for 1.0 mesh, "rough" for 0.5 meshes and "soft" for 0.3 meshes (See Figure 1). The sieving process was carried out manually and the whole process was carried out in 30 minutes. The resins used in the study were epoxy type ASASIN 142 A used as matrix and ASASIN 142 B used as hardener. The mixing ratio was for 100 parts of ASASIN 142A there was 40 parts of ASASIN 142B. The amount of SW/epoxy and CW/epoxy composites was determined by their weight ratios. Different amount of SW, CW and epoxy liquid were blended using hand tool machine. The fibre of the size classified as 'coarse', 'rough' and 'soft' with 14 % ratio by weight each was loaded to epoxy with the weight of 100 gm and together with hardener with the weight of 40gm were prepared. The material used to prepare tensile test specimen was plaster of Paris and for flexural test was glass. The parts to be molded were coated with release agent to prevent them from sticking to the mould.

The test specimens were prepared using ASTM D 638 (TAHUN) for tensile testing and ASTM D 790-97 (TAHUN) for flexural testing. The stress-strain plots and moduli of elasticity the composite were obtained using an Instron Universal Testing Machine, model 6566 during the tensile and flexural testing. The load applied was specified at 10kN at 2.5 mm/min cross-head speed. The thickness of both tensile and flexural testing specimens was 6 mm. The experiment was conducted at room temperature. The specimens prepared took 24 hours to dry. Six specimens were tested for both tensile and flexural testing.

(a) CW Coarse fibre

(b) CW Rough fibre

(c) CW Soft fibre

(a) SW course fibre

(b) SW Rough fibre

(c) SW Soft fibre

Figure 1: Fibre used in the study

3.0 RESULTS AND DISCUSSIONS

The results of measurement of the tensile properties and flexural properties of the composites for different particle sizes in the case of sawdust and chip wood are shown in Tables 1 and 2 respectively. The comparison of the mean of each property of three categories of fibres is analyzed using T-test. The analysis of variance (ANOVA) is used to compare the mean scores for all properties of during the tensile and flexural tests for each category of fibres.

Table 1: Tensile properties of waste wood fibre reinforced epoxy composites

Property	**Sawdust (SW)**			**Chip wood (CW)**		
	Soft	Rough	Coarse	Soft	Rough	Coarse
Displacement at Peak mm	8.626	12.968	12.037	1.906	11.447	11.086
Strain at Peak (%)	17.030	26.103	24.407	3.846	22.893	22.256
Stress at Peak (MPa)	10.921	28.917	24.767	14.224	19.867	17.922
Young’s Modulus (MPa)	386.873	889.988	860.116	594.453	902.331	737.815
Load at Peak (kN)	0.852	2.297	1.932	1.117	1.550	1.398

From Table 1, it is shown that the tensile strength of rough SW is higher than the chip wood CW with a maximum reading of 29.917 Mpa. The mechanical properties for both composites (SW and CW) revealed an optimum values at rough particle size. Moreover, by comparing SW and CW, it is found that the tensile strength for rough and coarse SW is higher than the rough and coarse of CW. On the other hand, for soft chip wood the tensile strength is higher than the soft sawdust. It is believed that the material properties differences might originate from the compositions and active surface areas for the sawdust and chip wood.

Table 2: Flexural test results for SW and CW

Property	Sawdust (SW)			Chip wood (CW)		
	Soft	Rough	Coarse	Soft	Rough	Coarse
Maximum Load (N)	102.550	121.145	62.395	78.827	102.740	145.755
Extension at compression Load (mm)	4.408	6.215	14.552	4.225	4.083	8.548
Energy at Compression Load (J)	0.247	0.395	0.625	0.180	0.218	0.757
Strain at Compression Load (mm)	0.102	0.167	0.145	0.043	0.040	0.192
Stress at Compression Load (MPa)	21.910	25.891	13.333	16.843	21.952	31.141

In term of flexural properties, the highest and lowest properties between sawdust and chip wood can be found in Table 2. Stress compression load (MPa) is found decreased with the increments of the particles sizes for SW but a vise versa behavior is shown by the chip wood composite. The results in flexural test for both composites can be ascribed because of the differences in particles sizes and fiber surfaces.

A three-point bend configuration was employed for the determination of modulus of rupture (MOR) and modulus of elasticity (MOE). Equations for MOR and MOE are as shown in equation 1 (1) and equation 2 (2).

where *P* is the maximum load carried by the specimen, *l* the support span, *b* and *d* are the specimen breadth and depth, respectively, measured at the nearest undisturbed location to the region of failure, and *m* is the slope of the load–deflection curve during elastic deformation Savastano *et.al.* (2000).

$$\mathrm{MOR}=3Pl/2bd^2 \quad (1)$$

$$\mathrm{MOE}=ml^3/4bd^3 \quad (2)$$

where P is the maximum load carried by the specimen, l the support span, *b* and *d* are the specimen breadth and depth, respectively, measured at the nearest undisturbed location to the region of failure, and *m* is the slope of the load–deflection curve during elastic deformation Savastano *et.al*. (2000).

Table 3: The Means of MOR for Sawdust and Chip wood

Fiber	Mean	SD	Particle Size	Mean	SD
			COURSE	19.998	3.364
SAW DUST	30.565	8.669	ROUGH	38.829	1.534
			SOFT	32.869	4.421
			COURSE	46.716	3.543
CHIPWOOD	34.970	10.403	ROUGH	32.930	5.309
			SOFT	25.265	6.607

Table 3 shows the means of mechanical properties for the particle sizes in modulus of rupture (MOR) according to the fiber types. It can be indicate that the mean of CW is higher than SW, at 34.970 kgf/mm^2 and 30.565 kgf/mm^2 respectively.

Further test was done using Turkey's Honestly significant difference with a significant level of 0.05 in identifying the lies. The p value and the significant level of physical properties of the composite are listed in Tables 4 and 5.

Table 4: Independent T-test for Mean MOR between types of fiber

Variable	t-value	p-value
Fiber	-1.380	0.177

Significant level, α = 0.05

From the independent T-test the p-values are greater than α = 0.05 (refer to Table 4). This indicates that there is no significant difference in the mean of MOR between SW and CW.

Table 5: The Means of MOE for SW and CW

Fibre	Mean	SD	Particle Size	Mean	SD
			COURSE	324.3288	44.0466
SAW DUST	4254.195	874.771	ROUGH	10185.66	14675.49
			SOFT	2252.595	450.6688
			COURSE	1373.762	337.5417
CHIP WOOD	1993.023	421.217	ROUGH	2682.045	354.8565
			SOFT	1923.25	1075.615

Table 5 shows the means of mechanical properties in modulus of elasticity (MOE) according to fiber respectively to the particle sizes. The means and the test direction used multiple comparison of Tukey's Studentized Range Test. From Table 5 indicates that the mean of SW (4254.195 kgf/mm^2) is higher than CW (1993.023 kgf/mm^2).

Table 6: Independent T-test for mean MOE between types of fiber

Variable	t-value	p-value
Fiber	1.05	0.301

Significant level, α=0.05

The comparison of MOE between SW and CW were used an independent T-test, shows that all the p-values are greater than α = 0.05 (refer to Table 6).This indicate that there is no significant difference in the mean of MOE between chips wood and saw dust.

4.0 CONCLUSION

Based six epoxy composite that reinforced by chip wood and sawdust, the rough sawdust composite exhibit greater mechanical properties compared to chip wood. Mechanical properties data were subjected to two-way analysis of variance using Tukey's multiple comparison method to determine the significance of differences in sample means at the 95% confidence level (P=0.05). From the tests results, evidence shows that the factors influenced the natural composite are depending on the fiber source, size, shape, processes, separation in matrix, bonding in matrixes. The other potential factor is defects that have in the fiber.

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