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Investigations of Mechanical Characteristics of Chicken Feather-Teak wood Dust Filled Epoxy Composites

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ABSTRACT: The present research has been undertaken with an objective to explore the potential of wood dust and chicken feather as reinforcing material in epoxy composites and to investigate the mechanical behaviour of the composites. Composites of teak wood dust (450 µm size) in 10,15 and 20 percentages of weight mixed with epoxy along with 5 % of chopped chicken feather have been prepared by hand lay up technique. The metallic mould developed in house was used to cast ASTM standard specimens. All the three samples have been tested in UTM for tensile strength and it is observed that composite with 15 % teak wood dust is having highest strength of 8.93 MPa. From water absorption tests in 24 hours the weight gain is very little and negligible for all the composites. Hence these composites can perform very well in moist atmosphere.
Keywords: Chicken feather-teak wood dust-epoxy composites, tensile, water absorption tests

I. INTRODUCTION

In the past few decades, research and engineering interest has been shifting from monolithic materials to fiber-reinforced polymeric materials at macroscopic level or even nano level. The quest for light weight and high strength materials is never ending for due consideration owing to their wide applications. Therefore a polymeric composite material has its importance in the applications of light structures. These composite materials (notably aramid, carbon and glass fiber reinforced plastics etc.) now dominate the aerospace, automotive, construction and sporting industries. However, these fibers have serious drawbacks such as non-renewability, non-recyclability, non-bio-degradability etc. These shortcomings have been highly exploited by proponents of natural fiber composites. Though mechanical properties of natural fibers are much inferior to those of artificial fibers, their specific properties, especially stiffness, are comparable to the stated values of artificial fibers. Various kinds of polymer matrix composites reinforced with metal particles, fibres, whiskers and particles have a wide range of industrial applications. These engineering composites are desired due to their low density, high corrosion resistance, ease of fabrication and low cost. Further the waste products of poultry like chicken feathers are available in million tonnes per day polluting the environment. Similarly effective utilization of wood dust as waste from saw mills may be thought of for developing natural fibre reinforced composites. Therefore an attempt has been made to prepare composites taking chopped chicken feather and teak wood dust as reinforcements in epoxy matrix in this investigation. The strength characterization and water absorption capacity of these composites are tested as per standards so that proper conclusions can be drawn for their use in structural applications. The various applications of such composites may be in automobiles like seat frame, doors and interior lining etc. They can also be used as packing materials in transportation of delicate articles and household decorating products.

II. LITERATURE REVIEW

Much of published work as regards to mechanical characterization of chicken feather composites is not available. However recent published works of a few researchers have been referred here as under. Barone and Schmidt [1] worked on composites of polyethylene reinforced with keratin fibers obtained from chicken feathers. In the experiment fibers of similar diameter but varying aspect ratio were mixed into low-density polyethylene (LDPE) using a Brabender mixing head. Scanning electron microscopy revealed some interaction between the fiber and polymer without the need for coupling agents or chemical treatment of the fibers. The density of the composite upon introduction of keratin feather fiber is not increased, but reduced by 2%.The results obtained from mechanical testing are compared to theoretical predictions based on a simple composite material micromechanical model. Kock and Jeffery [2] studied the physical and mechanical properties of chicken feather materials and recommended that materials derived from chicken feather could be used advantageously in composite building material application. Results describing the moisture content, aspect ratio, apparent specific gravity, chemical durability, Young's modulus and tensile strength for processed CFM specifically their fibre and quill component was studied and presented by them. Fibre fraction has greater Young's Modulus than quill fraction. It is comparable to that of other fibres such as jute and flax. Quill fraction has lower tensile strength than fibre fraction. Evans and Vance [3] recommended that the physical properties of most of the feather fiber-containing greenhouse root substrates differed from the 0% feather fiber control substrates, but the total pore space and the water-holding capacity values were within recommended ranges for greenhouse crops. Air-filled pore space was higher than recommended levels, but this did not result in suboptimal water-holding capacities. Feather fiber could be used at rates up to at least 30% with peat and perlite substrates without negatively affecting the physical properties of the substrate. However, at 30% feather fiber with peat and bark, aggregation or clumping of the feather fiber occurred during mixing of the final substrate. Anandrao et al. [4] studied behaviour of polymer composites reinforced with short fibres obtained from poultry feather. Although poor tensile and flexural strength was exhibited but erosion wear performance showed significant improvement with reinforcement of short fibers. Erosion resistance was successfully analysed using Taguchi experimental design .impingement angle, erodent size and impact velocity affected the erosion behaviour of these composites. Martinez-Harnandez et al. [5] studied dynamical–mechanical and thermal analysis of polymeric composites reinforced with Keratin bio fibres from chicken feathers. Hydrophobic nature of keratin fiber allowed even distribution within and exhibited good adherence to polymer. From measurement of transition temperature T_g and decomposition temperature it was clearly observed that PMMA composites had good thermal stability. Composites with 1 wt% and 2 wt% of bio fibre showed higher storage modulus and elastic behaviour (E) at higher temperatures. A study on development of an eco-friendly chicken feather fiber/poly lactic acid bio composite was conducted by Lam et al. [6]. Flight feather fiber and down feather fiber were separated from chicken feather and added to PLA matrix to fabricate bio composite. It was found that down feather reinforcement improved the stiffness of PLA. Various tests on samples containing different CFF wt% (2 to10) were conducted. Tests revealed that Young’s modulus and ductility increased significantly. Interfacial bonding was also improved. Acda [7] worked on waste chicken feather as reinforcement in cement-bonded composites. Study showed that waste chicken feather could be used as reinforcement in cement bonded composites but only up to about 10% feather content. Boards containing 5% to 10% fiber and/or ground feather were comparable in stiffness and strength properties to commercial wood fiber cement board of similar thickness and density. Increasing the proportion of chicken feather above 10% resulted in significant reduction of elastic modulus, rigidity modulus and decreased dimensional stability. Krystyna et al. [8] prepared composite of chicken feather, cotton linters, synthetic fibres and resin by blending all of them. Mechanical properties, water absorption tests and organoleptic tests were carried out. It was observed that with higher content of feather (70%) the wet strength increased. Technology for manufacturing paper like composites has been developed through this process. Uzun et al. studied the mechanical behaviour of chicken quills and chicken feather fibres reinforced polymeric composites. Study showed that impact properties of CFF reinforced composite were significantly better than control composites. For 10% CFF reinforced vinyl composite, impact value was found to be 4.42 kg/mm^2 which was 25% higher than control vinylester composite. However tensile and flexural properties had poorer value compared to control composites. Chinta et al. [10] examined the application of chicken feather in technical textiles. Feathers of chicken possessing properties like- good thermal insulation, porosity and light weight used in production of erosion control fabrics utilizing latex bonding were found to be suitable for fabricating technical textiles. Ganesh and Rekha. [11] made a comparative study on tensile behaviour of plant and animal fiber reinforced composite. Hybrid composite samples were prepared using rice straw, chicken feather and polyester resin matrix with different volume proportions. It was observed that tensile property of hybrid composite exhibited higher value than individual. Further proper orientation of fibre yielded better tensile strength. It was concluded that increase in tensile strength of the order of 28% and 85% of hybrid composites made it suitable in manufacture of automobile components. Kiew et al. [12] worked on comparative study of dielectric properties of chicken feather-Kenaf fibre reinforced unsaturated polyester composites It was judged that the chicken feather fibre composites would be suitable for application as high speed printed circuit board material basing on the result that the dielectric value increments were high at low frequencies and they gradually reached significantly lower values at higher frequencies. The chicken feather fibre unsaturated polyester composite exhibited an overall lower dielectric constant, dissipation factor and loss factor compared to the Kenaf fibre unsaturated polyester composites. Arun kumar et al. [1314studied recycling of chicken feather and wool fibre waste reinforced in multilayer composite. Tensile and flexural strength could be enhanced with increasing percentage of chicken feather and different resin. Oladele et al. [14] studied the mechanical properties of chicken feather and cow hair fibre reinforced high density polyethylene composites. Fowl feather and cow tail hair were sourced from poultry and abattoir respectively. Various tests were carried out and the results showed that fowl feather reinforced samples at 1-2 wt % gave a promising results in flexural properties while 3 wt % gave a promising result in tensile property. It was concluded that the strength decreases as the fibre content increases. However, the strength was mostly enhanced by chicken feather than cow hair. Naggireddy et al. [15] evaluated performance of Emu feather fiber reinforced composite materials. The specimens were produced by varying the weight percentages 0%, 2%, 4%, 6%, 8% of fiber loadings. The mechanical properties such as tensile strength, impact strength and flexural strength were evaluated. Its resistance to chemicals such as HCl, NaOH, NaCl, and H_2O was also tested and compared with epoxy and polyester resins. It was revealed that as the fiber loading is increased from 0 to 8%, the tensile strength was reduced from51.21MPa to 26MPa. The Flexural strength is also reduced from 79.6MPa to18.71MPa, but the impact strength increased from 8J/mm^2 to 18 J/mm^2. The samples were immersed in water for 24hrs.It is observed that the moisture absorption capacity is increased along with swelling thereby decreasing the water resistance strength. Thermo gravimetric analysis (TGA), Differential Scanning Calorimeter (DSC), Degradation Temperatures Gradient (DTG) properties of epoxy composites reinforced with feather fiber of 'emu' bird was studied by Chandrasekhar et al. [16]. Transition temperature T_g of pure epoxy was found to be 140.4 °C, but in composite T_g value was lowered. With fibre length of 1 cm to 3 cm T_g value was found to be 96 °C to 73.3 °C and for length of 5 cm, it was further reduced.

III. THEORETICAL FORMULATION

The composite is usually prepared based on calculation of weight fractions or Volume fractions. The density and other properties of the composite are found out by rule of mixtures as mentioned below.

Weight fraction of the reinforcement: $\mathbf{w_r = W_r / (W_r + W_m + W_f) * 100}$,

Weight fraction of the matrix: $\mathbf{w_m = W_m / (W_r + W_m + W_f) * 100}$

Weight fraction of the chicken feather: $\mathbf{w_f = W_f / (W_r + W_m + W_f) * 100}$

where $\mathbf{W_r}$= Weight of reinforcement, $\mathbf{W_m}$ = Weight of matrix, $\mathbf{W_f}$ = Weight of chicken feather .

Weight of the composite = $\mathbf{W_c = W_r + W_m + W_f}$

Further as per rule of mixtures, the density of the composite is obtained by

$$\rho_c = \rho_m v_m + \rho_r v_r + \rho_f v_f \quad \text{.....(Eqn.1)}$$

where ρ_c= Density of the composite, ρ_m = Density of the matrix, ρ_r= Density of the reinforcement, ρ_f = Density of the chicken feather.

$\mathbf{v_m}$ = Volume fraction of the matrix, $\mathbf{v_r}$ = Volume fraction of the reinforcement,

$\mathbf{v_f}$ = Volume fraction of the chicken feather

Further

$$\mathbf{v_m = V_m / (V_m + V_r + V_f + V_v) * 100},$$

$$\mathbf{v_r = V_r / (V_m + V_r + V_f + V_v) * 100},$$

$$\mathbf{v_f = V_f / (V_m + V_r + V_f + V_v) * 100},$$

Volume of the composite = $\mathbf{V_c = V_m + V_r + V_f + V_v}$

Where $\mathbf{V_m}$ = Volume of the matrix, $\mathbf{V_r}$ = Volume of the reinforcement, $\mathbf{V_f}$= Volume of the chicken feather and $\mathbf{V_v}$ = Volume of voids.

Assuming modulus reinforcing efficiency as unity and as per rule of mixtures:

Modulus of elasticity of the composite,

$$\mathbf{E_c = E_r v_r + E_m v_m + E_f v_f} \quad \text{…. (Eqn.2)}$$

Where $\mathbf{E_r}$ = Modulus of elasticity of reinforcement, $\mathbf{E_f}$ = Modulus of elasticity of chicken feather and $\mathbf{E_m}$= Modulus of elasticity of matrix

Strength of the composite,

$$\sigma_c = \sigma_r v_r + \sigma_m v_m + \sigma_f v_f \quad \text{….. (Eqn.3)}$$

Where σ_r = Strength of the reinforcement, σ_m= Strength of the matrix, σ_f= Strength of the chicken feather.

Table 1. Properties of Teak wood dust

Properties	**Value**
Density (g/cc)	0.8
Young's modulus of elasticity(GPa)	10.5
Tensile Strength(MPa)	95

Table 2. Properties of Epoxy

Properties	**Value**
Density (Kg/m^3)	1.2*10^3
Young's modulus of elasticity(GPa)	20
Tensile Strength(MPa)	75

Table 3. Properties of Chicken Feather

Properties	**Value**
Density(g/cc)	0.89
Young's modulus of elasticity (GPa)	3
Tensile strength (MPa)	70

Table 4. Properties of Composite with 5 % chicken feather and 450 µm Teak wood dust

Type of composite	Density(g/cc)	Modulus of elasticity(GPa)	Strength(MPa)
Sp-A (10%)	1.13	17.89	77.19
Sp-B (15%)	1.11	17.46	78.22
Sp-C (20%)	1.10	17.08	79.14

Specimen A – Sp-A-10 % teak wood dust
Specimen B – Sp-B-15 % Teak wood dust
Specimen C – Sp-C- 20 % Teak wood dust

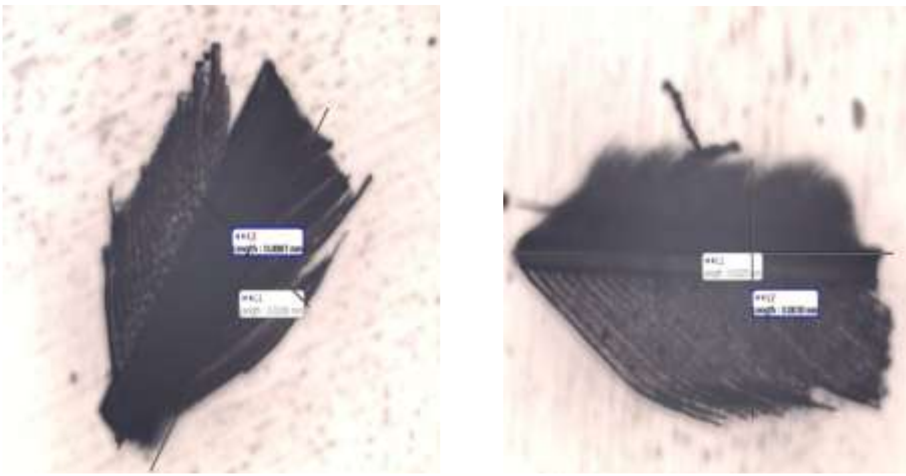
IV. EXPERIMENTAL WORK

Specimen preparation:

At the outset teak wood saw dust has been collected from Sharma Furniture, Bhubaneswar (Fig.1). The dusts so collected were separated by sieve shaker depending on their mesh size (450 microns). Chicken feathers (Fig. 2) were collected from Mayurbhanj District of Odisha. The chicken feathers were separated from the stem (quill) by using scissors. Different sizes of chicken feather dust have been prepared by grinding as shown in the Fig. 3(a,b,c and d).

Fig. 1. Teak wood dust

Fig. 2. Chicken feather



(a) **(b)**

(c) **(d)**

Fig.3(a,b,c,d). Sizes of chicken feather and dust

After measuring four samples of chicken feather sizes the average size considered is 18µm.Metallic mould was prepared out of aluminium for casting the standard specimen as per ASTM. The dimensions of standard specimen are given in Fig. 4.The metallic mould so prepared has been shown in Fig 5. Shrinkage allowance as per norms has been provided in the moulds taking epoxy as the matrix material.

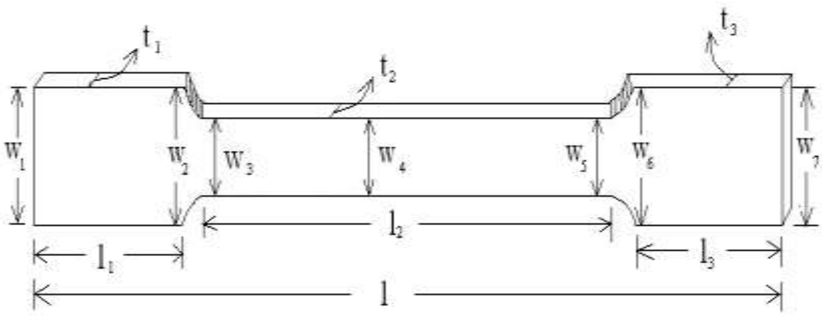


Fig.4. ASTM standard specimen

Table 5. Recommended dimensions of the specimen

Specimen	l_1	l_2	l_3	l	w_1	w_2	w_3	w_4	w_5	w_6	w_7	t_1	t_2	t_3
Standard	**42**	**100**	**42**	**204**	**25**	**25**	**13**	**13**	**13**	**25**	**25**	**-**	**-**	**-**

Fig.5. Metallic mould with ejector for standard specimen

Fig. 6. Mould with specimen

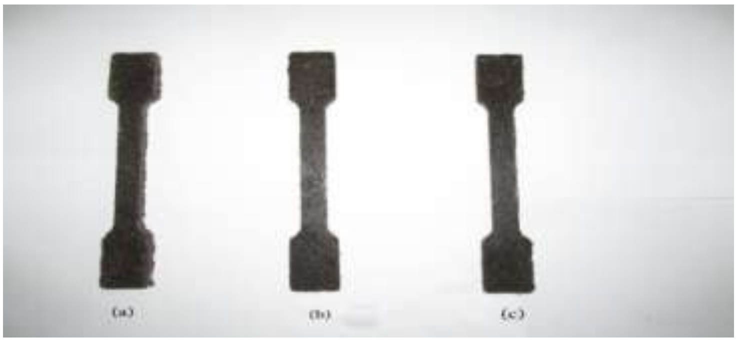


Fig. 7. *Cast specimens , (a) 10%, (b) 15 % and (c) 20 % teak wood dust and 5% constant chicken feather*

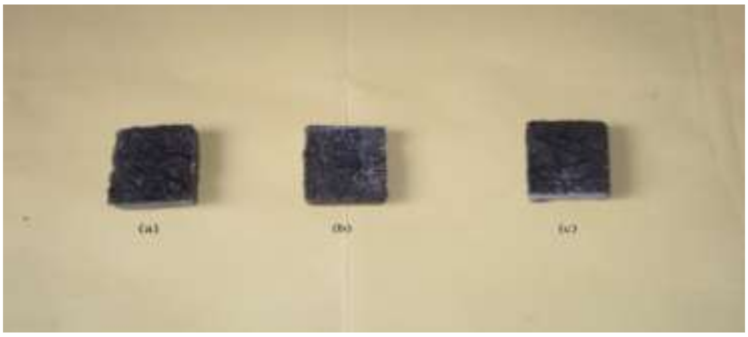


Fig. 8. Sample for water absorption test,(a) 10%, (b) 15 % and (c) 20 % teak wood dust and 5% constant chicken feather

The recommended dimensions of the specimen as per standard are shown in Table 5. The mould with ejector (Fig. 5) specimen in cast condition (Fig..6) and the ejected specimens are shown in Fig. 7. The deviations in dimensions with respect to standard are also given in Table 6.

Table 6. Comparison of dimensions with respect to standard

Specimen nomenclature	l_1	l_2	l_3	l	w_1	w_2	w_3	w_4	w_5	w_6	w_7	t_1	t_2	t_3
Standard	42	100	42	204	25	25	13	13	13	25	25	-	-	-
Cast specimen	41.5	100	40.5	204	25.5	25.1	13.9	13.1	13.3	25.3	25.2	13.1	13	13.1
Deviation	-0.5	-	-1.5	-	0.5	0.1	0.9	0.1	0.3	0.3	0.2	0.1	-	0.1

For water absorption test the rectangular specimens having size 40x25x10 mm for each composite are shown in Fig. 8.

Tensile test

The standard tensile test specimens so prepared were tested in Universal Testing Machine (**TINIUS OLSEN, model no.- H50KS, 50 KN** capacity-Fig. 9) and the Stress- Strain curves are plotted.

Fig. 9. UTM for tensile test (TINIUS OLSEN, model no.- H50KS, 50 KN capacity)

V. RESULTS AND DISCUSSION

The results obtained from tensile tests are interpreted in Table 7. Further the stress-strain curves so obtained are also shown in Fig. 10 to 12 for Specimen A, B and C.

Table 7. Results of tensile tests

Speci-men	Rate (mm/ min)	Width (mm)	Thick-Ness (mm)	Area (mm^2)	Length (mm)	Max. Load (N)	Tensile Strength (MPa)	Extension at Break (mm)	Tensile Strain at Break (%)
A	2	13.8	8.7	120.06	115	474	3.95	0.35	0.33
B	2	14.4	7.45	107.28	115	958.17	8.93	0.85	0.74
C	2	14.3	8.95	127.98	115	1070.29	8.36	0.88	0.77
	2	14.17	8.37	118.44	115	834.15	6.44	0.7	0.61

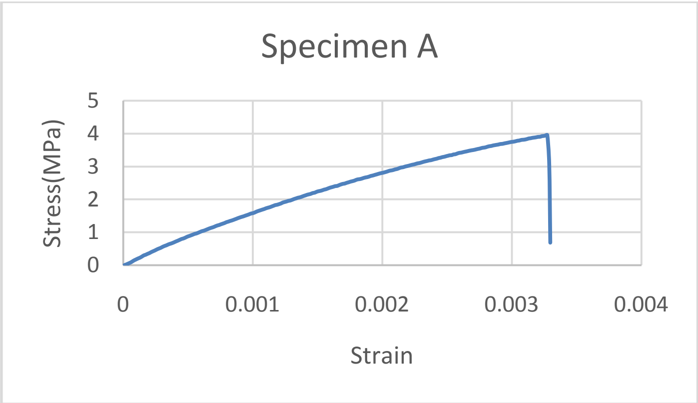


Fig. 10. Stress-strain curve for 10 % teak wood dust composite

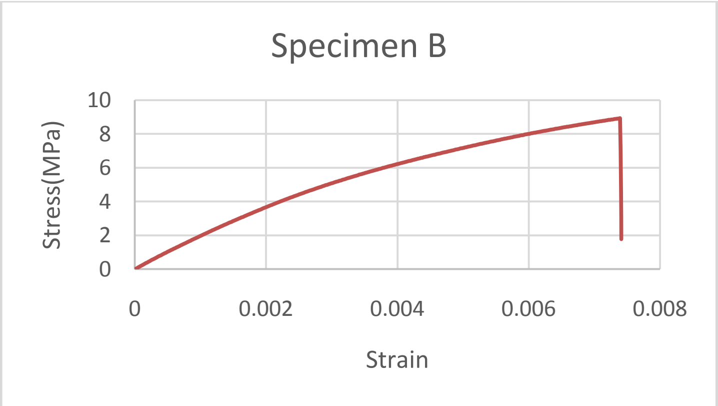


Fig. 11. Stress- Strain curve for 15 % Teak wood dust composite

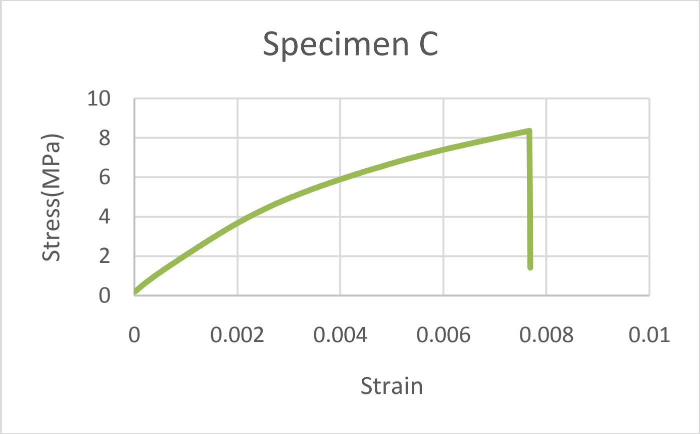


Fig. 12. Stress- strain curve for 20 % teak wood dust composites

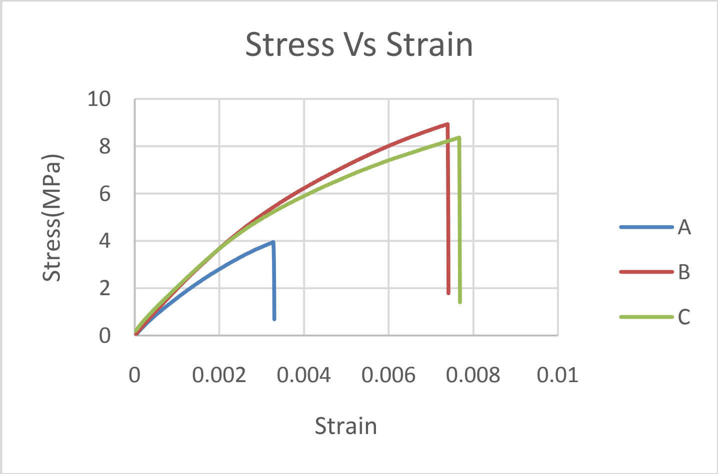


Fig. 13. Superimposed curves for comparison

The superimposed curves are also shown for comparison in Fig. 13.

Water absorption tests

The specimens of the required sizes were immersed in water for 24 hours for checking the moisture absorption capacity. The difference in final weight after soaking and initial dry weight gives the weight gain. These results are give in Table 8.

Table 8. Results of water absorption tests

Specimen	Length x width(mm)	Thickness in mm	Initial dry weight in gm	Final Weight after soaking for 24 hours in gm	Gain in weight in gm	Moisture absorption capacity in %
A	39 x 26	11	11.240	11.280	0.040	0.356
B	39x 25	08	8.070	8.130	0.060	0.744
C	39 x 25	9.5	10.110	10.180	0.070	0.692

It is seen from the results that strength is increasing up to 15 % teak wood filler composite but decreases with 20 % dust composite. Further the composite with 15 % teak wood dust has exhibited highest strength of 8.93MPa.More addition of dust has resulted in decrease in strength. Similarly from the moisture absorption tests it is revealed that all the composites have excellent properties as far as water absorption capacity is concerned. Very little moisture is absorbed in 24 hours of test.

VI. CONCLUSIONS

During these investigations it has been seen that the composite with 15 % teak wood dust and 5 % chicken feather is a good proposition for application as packing materials, instrument casings, light decorative fittings and other such applications as it has shown highest tensile strength amongst all the materials considered. From moisture absorption test all the composites under consideration can be used in moist atmosphere as gain in weight is negligible.

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