Analysis on Mechanical Properties of Wood Plastic Composite

Mr. V. Vinoth Kumar[1], Mr. D.B. Naga Muruga[2], Ms. S.P.Pooja[3], Mr. C. Rohith Kannan[4]

[1]PG Student, Dept of Manufacturing Engineering, Sriram Engineering College, Perumalpattu, Tamil Nadu, India
[2]UG Student, Dept of Mechanical Engineering, Sriram Engineering College, Perumalpattu, Tamil Nadu, India
[3]UG Student, Dept of Manufacturing Engineering, CIPET, Guindy, Tamil Nadu, India
[4]UG Student, Dept of Mechanical Engineering, Sriram Engineering College, Perumalpattu, Tamil Nadu, India

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Abstract - *Wood plastic composites (WPC) are a form of composites made by combining wood particles/flour with polymers. The Mechanical properties of Wood Plastic Composites mainly depends on the compositionof its matrix (Polymers), reinforcements (Saw dust), coupling agents and lubricants. Generally, the polymer of the matrix in WPCs is made of a single monomer such as HDPE, PP, PS, PET etc. The Objective of the project is to investigate the mechanical properties of a Wood Plastic Composite by using polymer blend (combination of two or more polymer) as a matrix and its effects on mechanical properties of WPC by varying the composition of the mixture at various proportions.*

Key Words: Matrix, Polymer Blend, Wood Plastic Composite (WPC), thermoplastics, coupling agent, lubricant.

1. INTRODUCTION

Wood is one of the earth's most versatile raw materials which play a vital role in our daily lives. Since Wood is more flexible to work with many applications such as tools, shelter, furniture, source of heat, transportation, decoration etc. In many developing countries wood is the major source of fuel supply. Over the upcoming years, 3 billion people around the world will face acute fuel wood shortages as a result of decrease in fuel wood sources. The major factor which pushes the use of wood is its low density, high toughness, non-toxicity. However, wood has the major disadvantage having low water resistance due to its natural hygroscopic characteristic. In order to reduce the usage of wood in practical applications Wood Plastic Composites (WPC) are introduced in early 1990's which is made up of wood and thermoplastic resins such as High Density Polyethylene (HDPE), Polypropylene (PP), Polystyrene (PS). In WPC both virgin and recycled thermoplastics can use but thermosetting plastics can't be used because the thermosets cannot be recycled.

From the physical properties of WPC, it is seen that it has low moisture content, thickness swelling and absorption respectively [1] makes it enable for both indoor and outdoor applications. For the conservation of wood, WPC mixture of 50% wood flour and 50% Recycled Polypropylene (RPP) provides a reasonable balance to the composite [2]. Further the use of Injection Molding suggests that wood flour content of less than 50% may be optimal in the manufacture of WPCs [3]. WPC also contributes to economy by the use of recycled thermoplastics like HDPE. Using recycled HDPE granulates from post- consumer packaging is economically feasible for WPC [4]. Through Better Processing of WPC, it is speculated that moisture absorption rate decreases when severe compounding conditions are employed because these causes the loss of hydrophilic volatile organic compounds contained in the WPCs [5] and this happens without a change in mechanical properties.

The mechanical properties of the WPC can be enhanced by the addition of additives such as silicon and the property enhancements were controlled mainly by the extension of silica agglomeration [6]. In Life Cycle Assessment of WPC, linking physical parameters with ecological parameter shows that more the secondary wood is used lower is potential environmental impacts, which results in best ecological and technical alternative [7]. The Cost of the plastics can be reduced by the use of recycled plastics but the effect of the degradation level of recycled plastics on mechanical properties and performance of WPCs needs to be identified to obtain an acceptable level of physical and mechanical properties of the final product [8]. The Major difficulty faced in the manufacture of WPC is the wood produces ash at higher temperature which violates the properties of composite the fluidity state of wood is obtained by controlling the temperature and fiber arrangements, strength properties similar to those of industrial engineering plastics such as acrylonitrile butadiene styrene could be attained for wood-plastic composites obtained by wood-flow forming [9].It was observed that from previous works as they have employed only one type of polymer. In this experiment we have introduced polymer blend as a matrix component.

2. Experimentation Material

Matrix, Lubricants, coupling agents, Reinforcements are the materials used in the fabrication of Wood Plastic Composites. Only thermoplastics like PP, PE, PVC, Polystyrene etc., are applicable in wood–plastic composites which can be processed at temperatures below 400 (about 200). The melting points of various polyolefin are shown in table 1. These limitations are due to limited thermal stability of wood. The Polymer blend of High Density Polyethylene (HDPE) and Polypropylene (PP) at the ratio of 20:80 is chosen as matrix components as they carry good range of properties and energy efficient.

Polyolefin	Melting point (℃)
LDPE	115
LLDPE	123
HDPE	130
Polyethylene(PE)	135
Polypropylene(PP)	170
Polystyrene(PS)	240

Table 1 – Melting Point Of Polymers

Treated wood is used as reinforcing agent in WPC. Among large numbers of wood species in the world, only some are frequently used in WPC namely Pine, Oak, Maple wood etc. Heat Treated Pine wood sawdust of grain size 125μm is used as the reinforcements since smaller grain size higher the strength and heat treatment prevents wood from burning at melting temperatures of Polymers. Adding the sufficient quantity of coupling agent can increases the mechanical properties and probably decreases the thickness swelling of WPC. Similarly insufficient quantity of coupling agent can increases the swelling and probably decreases the mechanical properties of the WPCs. Hence the best composition of the coupling agent and lubricant in WPCs were both 3% was referred [1]. Maleic Anhydride forms the coupling agent and Zinc Sterate is used as the lubricant. The Composition and amount of materials used is given by table 2.

SPECIMEN	WOOD FLOUR (PINE WOOD)	POLYMER MATRIX (80%PP AND 20%HDPE)	COUPLING AGENT (MALEIC ANHYDRIDE)	LUBRICANT (ZINC STERATE)
A	30%	64%	3%	3%
B	40%	54%	3%	3%

Table 2 – Composition of Materials

3. Method

The Wood Plastic Composites are fabricated by using Compression Molding Method. The saw dust is dried at 103℃ to remove the moisture content. The compositions of materials were mixed in the required ratios and temperature was erected to 180℃ and maintains same temperature throughout the process. At 180℃ temperature, a pressure of 20 barwas applied on the moldfor 400 seconds. Then the pressure was increased to 60 bars and left for about 120 seconds and finally pressure was further increased to 100 bar and maintained for about 30 seconds then remain to cool to room temperature in the same pressure. The Fabricated specimen of WPC was shown in Fig1 & Fig2

Figure 1 – Specimen A

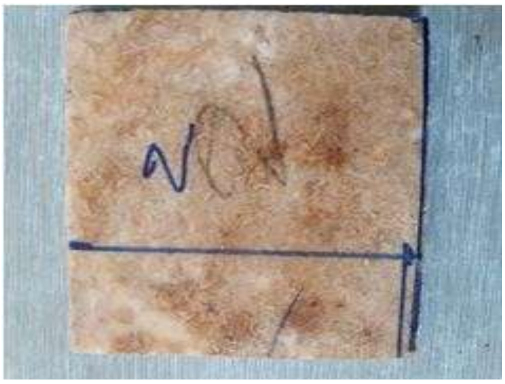

Figure 2 – Specimen B

Physical Property Tests

The Density and Water absorption test are the major physical tests carried out through the process, as these two tests determine the physical nature and environmental suitability of component can be decided.

Density Test

Density of the specimens was calculated on the assumption that the water used for immersion has a density of one gram/cm³ (1000kg/m³) and it was calculated according to the formula:

Density =

Where W_0 is oven dry mass of the specimen weight, Kg

V_0 is the Volume of the specimen, m³

Water Absorption

Water absorption of the WPC can be calculated by differing its weight for each periodic time (2, 4,6,12 and 24 hours) after total immersion into demineralized water at 25⁰C.Water absorption was calculated according to formula:

Water absorption (%) =

Where W_t is specimen weight after immersion in water, N

W_0 is oven dry mass of the specimen weight after constant mass was reached, N

Mechanical Property Tests

Mechanical testing of materials covers a wide variety of experimental approaches, ranging from a simple standard tensile test to more complex tests. The mechanical properties tested in this study where bending test, hardness test, tensile strength, impact test etc. It is used to ensure that supplied materials will perform as expected.

Tensile Test

Tensile strength was calculated according to formula:

Tensile strength (σ_t) = –

Where P is a tensile load, N

A is the cross-sectional area, mm^2

Hardness Test

Hardness test is done to measure the resistance of a material to deformation, indentation, or penetration by means such as abrasion, drilling, impact, scratching etc.The test was done on Shore Hardness on Scale D.

Impact Test

The purpose of an impact *test* is to determine the ability of the material to absorb energy during a collision. The obtained energy can be utilized to discuss the toughness exhibited, also the impact strength that can be with standed also the fracture resistance. The Impact strength was found using Izod test.

Results and Discussion

Physical Test

Through the physical tests it is found that the density of WPC is higher when the wood content of the composite increases. Table 3 shows the variation in the density of the material with respect to composition of the material.

Specimen	Wood content	Density(kg/m^3)
A	30%	141.96
B	40%	158.57

Table 3 – Density of Specimens

The Water absorption of the WPC decreases due to the use of thermoplastics and it is seen that the weight of the material is increasedwhen completely immersed for 24 hours and was shown in Table 4.The original weight of the specimen A and specimen B tested was 3.6881 N and 4.1201 N respectively.

Specimen	Water absorption		
	24hrs	48hrs	72hrs
A	0.22% (3.6966 N)	0.27% (3.6985 N)	0.32% (3.7003 N)
B	0.29% (4.1321 N)	0.37% (4.1354 N)	0.43% (4.1376 N)

Table 3 Water Absorption of Specimens Scanning Electron Microscopy (SEM)

SEM micrographs is carried out in the wood plastic composites which was manufactured by compression molding process is analyzed by coating the samples with thin gold layer.

Fig 3 shows the SEM micrographs of the Specimen A at various places and it is seen that there is an improper bonding of the components when wood content is 30% and minute craters were appeared.

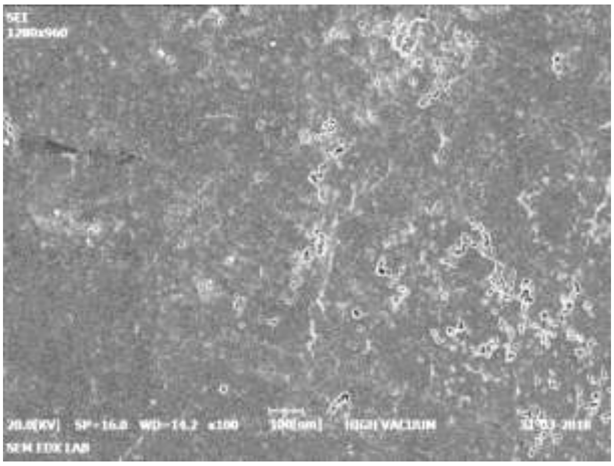

Fig 3 – SEM Image of Specimen A

Fig 4 shows the SEM micrographs of the Specimen B at various spots and it can infer from the results that unlike the Specimen A there was no crater formation in the microscopic picture. The components were bonded properly hence resulting in higher physical and mechanical strengths

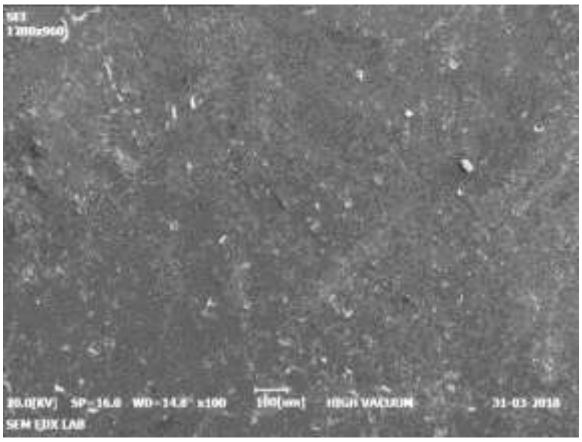

Fig 4 – SEM Image of Specimen B

Tensile Test

The tensile strength of the material is lower when compared to the wood plastic composites made of a single polymer. This shows that the polymer blend ratio has a lesser effect on the tensile strength. Hence the tensile strength of specimen A, specimen B are 1.040MPa and 1.253MPa respectively.

Hardness Test

The hardness of the composite increases with the increase in the amount of wood particles.Hardness test was conducted on both specimens at 5 points and tabulated below

Specimen	Hardness number
A	72,73,73,76,79
B	74,75,75,76,77

Table 4 Hardness of Specimens Impact test

The toughness of WPC was analyzed in detail. Hence the impact resistances of both the specimens are similar and equals to 2 joules.

Bend Test

Bend test of specimen with dimension of 130*13.5*3 mm as per ASTM D4761 with a force of 24 times of thickness at center of specimen were conducted in ANSYS analysis software of 15.0 version. Geometric results of deflections are as shown fig 5, fig 6 and fig 7.

The fig 5, fig 6, fig 7 indicates total deformation of the respective WPC specimens. The maximum total deformation of the specimen A, specimen B and reference specimen are 0.067051 mm, 0.083813 mm and 0.057738 mm respectively. It is been observed that specimen B has higher total deformation than the other two specimens.

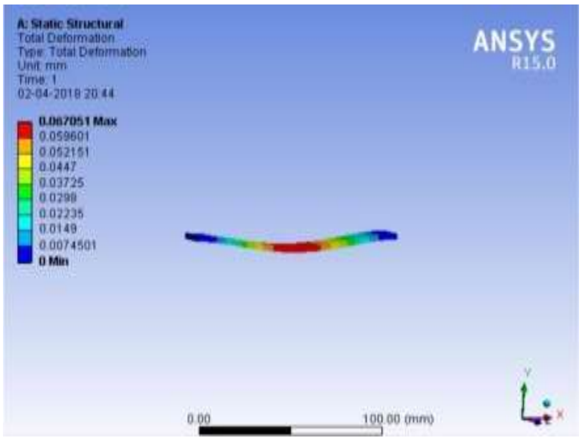

Fig 5 Total Deformation of Specimen A

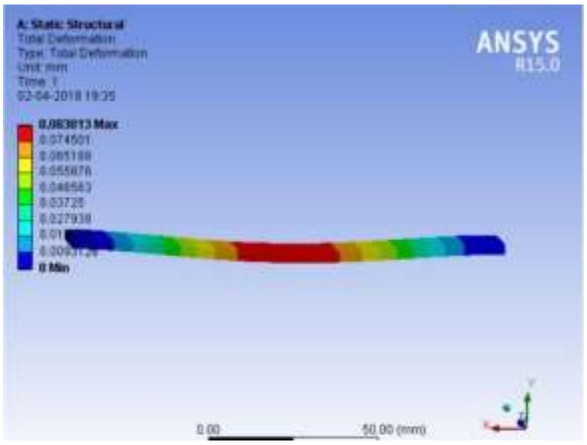

Fig 6 Total Deformation of Specimen B

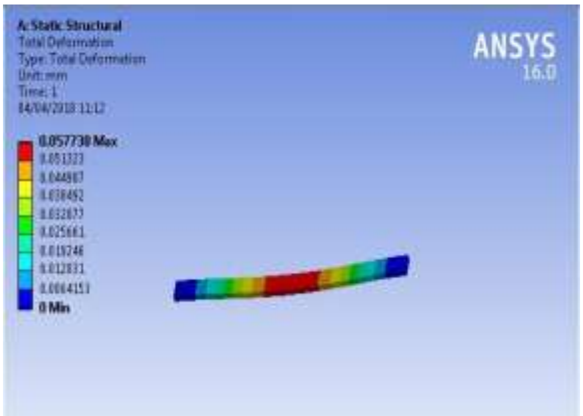

Fig 7 Total Deformation of Reference Specimen

The fig 8, fig 9, fig 10 indicates the shear stress of the respective WPC specimens. The maximum shear stress of the specimen A, specimen B and reference specimen are 8.0681 MPa, 10.085 MPa, 6.9476 MPa respectively. It is been noted that specimen B has maximum shear resistance than the other two specimens. From the tested specimens the increase in wood flour content increases shear strength of the material and the maximum shear occurs at end of the specimen. Hence the amount of wood content is directly proportional to shear strength. The maximum deflection occurs at the point of contact of load which makes it vulnerable for failure to occur.

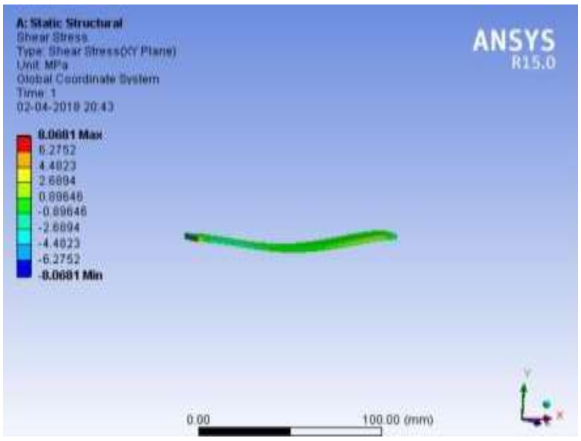

Fig 8 – Shear Stress of Specimen A

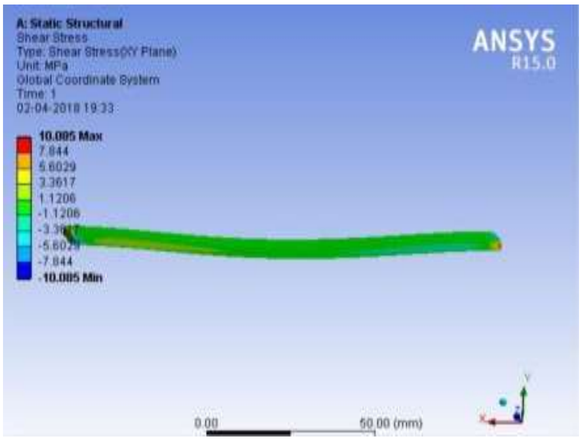

Fig 9 – Shear Stress of Specimen B

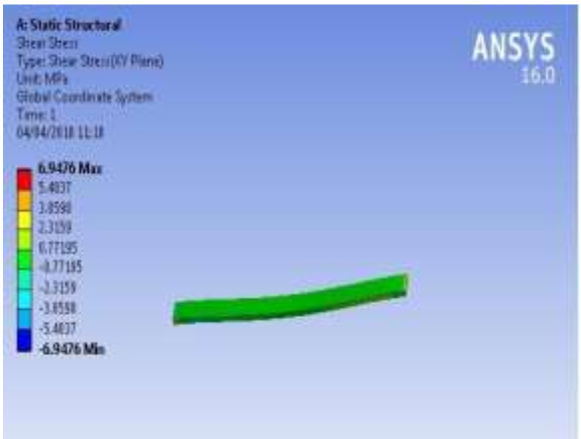

Fig 10 – Shear Stress of Reference Specimen

The fig 11, fig 12, fig 13 indicates the equivalent stress of the respective specimens. The equivalent stress of the specimen A, specimen B and reference specimens are 35.853 MPa, 44.815 MPa and 30.873MPa respectively. It is been noted that specimen B has maximum equivalent stress than the other two specimens.

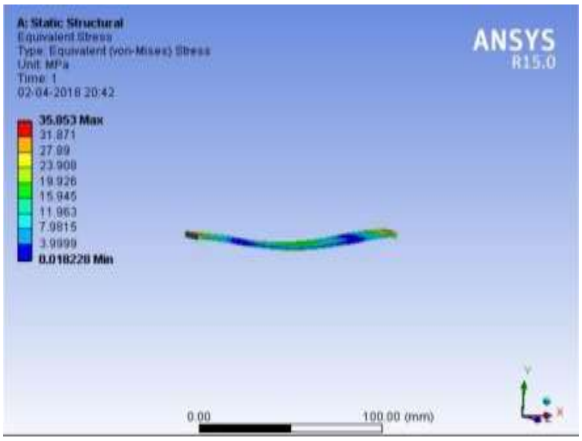

Fig 11 Equivalent Stress of Specimen A

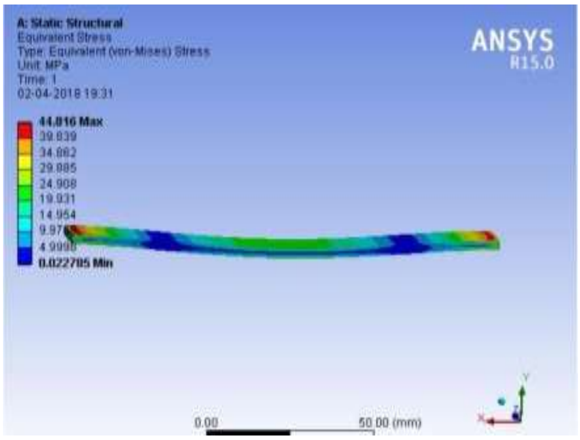

Fig 12 Equivalent Stress of Specimen B

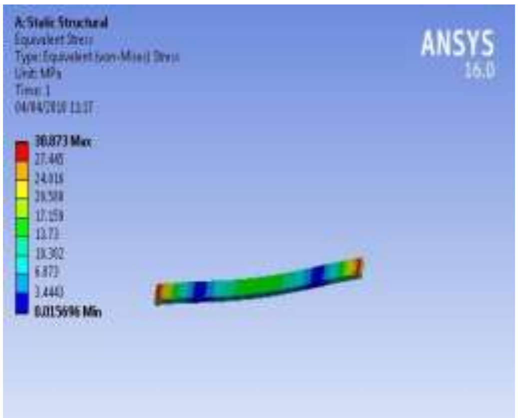

Fig 13 – Equivalent Stress of Reference Specimen

CONCLUSION

The WPC which have more than one type of polymer has the greater strength and possess the high physical strengths. The SEM image of the composites shows the proper blend of the wood particles with the polymers. It was observed that total deformation, shear stress and equivalent stress for the specimen B which has wood content of 40% was better than existing WPC material.

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BIOGRAPHIES

V. Vinoth Kumar, Dept of Manufacturing Engineering, Sriram Engineering College, Perumalpattu

D. B. Naga Muruga, Dept of Mechanical Engineering, Sriram Engineering College, Perumalpattu.

S. P. Pooja, Dept of Manufacturing Engineering, CIPET, Guindy.

C. Rohith Kannan, Dept of Mechanical Engineering, Sriram Engineering College, Perumalpattu.