GIET UNIVERSITY JOURNAL, Engineering, Science, Agriculture & Management 2024, SPECIAL ISSUE **"Sustainable Engineering, Technology and Management (NSETM-2024)"**

PP. – 16-22, Manuscript Received: 20th March 2024; Revised 28th June2024, Accepted: 30th July, 2024

Study on Mechanical and Thermal Characteristics of Wood Dust Filled Polyester Composites

[1]Rajashree Mohapatra, rajashreemohapatra1008@gmail.com

[2]Chetana Tripathy, tripathy.elina@gmail.com

[3]Chitta Ranjan Deo*, crdeo_me@vssut.ac.in

[4]Deepak Kumar Mohapatra, dkmohapatra_phdme@vssut.ac.in

[5]Chandrakanta Mishra, dips.mishra@gmail.com

Department of Mechanical Engineering, Veer Surendra Sai University of Technology, Sambalpur 768018, India,

Abstract: The present investigation is focused on developing an eco-friendly composite material by integrating waste wood dust (WD) as a bio-filler into a polyester matrix. The study delves into exploring the effects of different proportions of WD filler on the mechanical and thermal attributes of the composites. Results indicate that optimal tensile strength of 47.39 MPa and micro-hardness of 16.6 HV are achieved at 15wt% WD loading, while superior impact of 18.8 KJ/m^2 and flexural strength of 57.39 MPa are observed at 10 wt% of WD loading. However, exceeding WD filler loading beyond 15 wt%, leads to a decline in all mentioned mechanical properties, notably at 20 wt%. Furthermore, the inclusion of WD filler enhances the thermal stability of the composite. These experimental outcomes suggest that the composite reinforced with WD can be effectively utilized in the automotive and construction industries.

***Keywords*— wood dust, polyester, mechanical attributes, TGA,**

1. Introduction

In recent decades, polymeric composite materials have supplanted traditional metals and emerged as a highly promising field of study for researchers. The WD-filled composites (WDCs) are gaining traction in the construction, automotive, and infrastructure sectors due to their recyclability, superior stiffness, affordability, lightweight nature, environmentally friendly characteristics, and advantageous mechanical attributes. In a study, Pérez et al. [1] studied the mechanical attributes of polypropylene/WD composites. As the filler content increases, there is a decrease in strength and strain, while toughness data remains consistent. Pradhan et al. [2] found that upsurge element size enhances the tensile and thermal performances of the composites. Again, the consequence of a compatibilizer on the performance of composite is also deliberated by Dairi et al. [3]. The results indicated that the addition of a compatibilizer agent led to notable amplify in tensile strength while decreasing the elongation at break. Likewise, the impact of filler loadings and chemical modification of

ISSN NO – 2583-5955 (Online)

PP. – 16-22, Manuscript Received: 20th March 2024; Revised 28th June2024, Accepted: 30th July, 2024

filler on mechanical performances of WD filled polystyrene composites is proposed by Adeniyi et al. [4]. The experimental findings reflected that, the sample reinforced with 4% NaOH treated WD fillers with 30% wt.% and particle size 841µm possessed higher mechanical performances than that of other. Similarly, Jain et al. [5] also examined the influence of wood powder (teak and sal) on the mechanical and thermal performances composite along with water absorption characteristics. The hybrid composite with an equal percentage of teak and sal woods demonstrated a highest mechanical property amongst all combinations. In sight of the above context, this research mainly confined to determine the influence of the locally available WD inclusion on mechanical performance of the WD polyester composite.

2. Materials and Methods

2.1. Materials used

The Matrix system was made by combining unsaturated polyester and methyl ethyl ketone (MEKP) peroxide along with cobalt naphthenate accelerator. The materials were procured from Avanti Enterprises, Odisha, India. Wood dust is collected from the local sawmill.

2.2. Fabrication of composite

A stainless-steel mold having dimensions 180×180×5 mm^3 was used to fabricate polymer composites. To fabricate composite laminates, the usual hand lay-up technique was adopted. Before fabrication, the mold was cleaned by removing any foreign material present over it. After cleaning, silicone spray (grade 8082) was sprayed on the mold surface area to facilitate easy removal of the sample after casting. The matrix was prepared by combining the unsaturated polyester resin and catalyst in 10:1 ratio with 2% accelerator. After that, the required amount of oven drayed WD was thoroughly mixed with the polyester mix. Then the filler-matrix mix was poured into the mold and a little pressure was applied at the top to squeeze out the excess amount of polymer that present. Then the casting was cured for 48 hours at ambient temperature. The different types of composite samples is presented in Table 1.

ISSN NO – 2583-5955 (Online)

PP. – 16-22, Manuscript Received: 20th March 2024; Revised 28th June2024, Accepted: 30th July, 2024

Table 1. Types of WD-Polyester composites

Sl. No.	Nomenclature	wt.% of WD	wt. % of Polyester	Thickness
1	WD-0	0	100	5.0
2	WD-5	5	95	5.0
3	WD-10	10	90	5.0
4	WD-15	15	85	5.0
5	WD-20	20	80	5.0

2.3 Mechanical Characterization

2.3.1. Tensile and Flexural testing

A UTM; model INSTRON 3382 having maximum capacity of 10 KN was used to perform tensile and bending tests. According to ASTM standards, the test specimens were cutting from the composite slab. The crosshead speed was kept at 2 mm/min for both tests. Five specimen of each type were evaluated, and their average values were documented.

2.3.2. Impact testing

A digital Izod impact tester measured the impact energy of the composite samples. The specimens were prepared following ASTM D 256 standards, with the notched specimens sized at 63 mm × 12.7 mm × 5 mm.

2.3.3. Hardness Test

A Matsuzawa MMT-X7B micro-hardness tester from Japan assessed the micro-hardness of the fabricated laminates. Test samples were prepared according to the ASTM E384. A diamond indenter with 1000 HV and a 136° apical angle was used, applying a load of 100 gf for a 15-second dwell period.

2.3.4. Thermo-gravimetric Test

A thermo-gravimetric analysis was used to examine the thermal stability of WD filled composite. The amount of weight lost due to rising temperature was assessed using the Mettler-Toledo Thermo-gravimetric Analyzer, following the ASTM D3850 standard. The

ISSN NO – 2583-5955 (Online)

PP. – 16-22, Manuscript Received: 20th March 2024; Revised 28th June2024, Accepted: 30th July, 2024

analysis was done at temperature range 30^0C to 700^0 C at rate of 30^0C /min under nitrogen environment.

3. Results Analysis

3.1. Tensile Strength

The variation of tensile strength with respect to content of WD filler is presented in Figure 1(a). A rising trend of tensile strength from 13.594 MPa to 47.396 MPa due to the increase of wood dust filler inclusion from 0 wt% to 15 wt% is clearly noticed. However, the tensile strength is reduced with further increase of WD filler content (20 wt %). A maximum value of 47.396 MPa is retained at 15 wt% of WD, which is around 239.66% higher than WD-0 sample. This may occur due to the agglomeration of fillers at higher percentage. Similar growing trend is also observed by García et al. [6] while dealing with wood-plastics composites.

3.2. Flexural Strength

Flexural strength with respect to WD content is presented in Figure 1(b). The bending strength is enhanced from 18.64 MPa to 57.39 MPa by the inclusion of WD up to 10wt% which is about 207.88% higher than that of WD-0. This is due to the higher flexural stiffness of wood dust filler. However, the subsequent addition of WD above 10% lead to decline in strength due to inadequate wetting of WD. A similar growing trend of variation of flexural characteristics is while studying with wood-plastics composite [7].

3.3. Impact strength

From figure 1(c) it is noticed that, the impact value is improved with increase of WD concentration up to10 wt.% and subsequently reduces with further increase of WD content. A maximum impact strength of 18.8 KJ/m^2 is found for WD-10 which is corresponding to an increment of 126.23%. This attribute to the potential WD in impact strength as well as preventing fracture formation in the composite [8].

3.4 Micro Hardness

The outcomes of the hardness test on the composite samples are illustrated in Figure 1(d). Due to the incorporation of wood dust filler, the micro-hardness is improved, which is maximum (16.6 HV) at 15 wt% of WD. Several researchers have reported similar trend of increase in the hardness of composites with different wt.% of wood dust composition [9].

3.5 Thermo-gravimetric Analysis

ISSN NO – 2583-5955 (Online)

PP. – 16-22, Manuscript Received: 20th March 2024; Revised 28th June2024, Accepted: 30th July, 2024

Figure-2 illustrates the TGA analysis of neat unsaturated polyester composite and wood dust filler polyester composite. The first phase of degradation of neat polyester sample occurs in the range of 80ºC to 180ºC and weight loss is restricted to below 10% is noticed. However, in the second phase i.e. 180ºC to 265ºC, major degradation is observed due to decomposition and degradation of polymer network structure. Again, at temperatures of 265ºC- 600ºC, the polyester sample begins to decompose very slowly with weight loss below 5%. But, the addition of WD to polyester resin is significantly improving the thermal degradation rate. The maximum thermal degradation encountered at temperature 308ºC, 316ºC and 320ºC for 5 wt%, 10 wt% and 15 wt% WD filled polyester composite respectively. Whereas for 20 wt% WD filled polyester composite shows a maximum degradation at 310ºC. This improvement of thermal stability is due to the barrier effect of decomposition products by the distribution of the WD particles in the polyester resin.

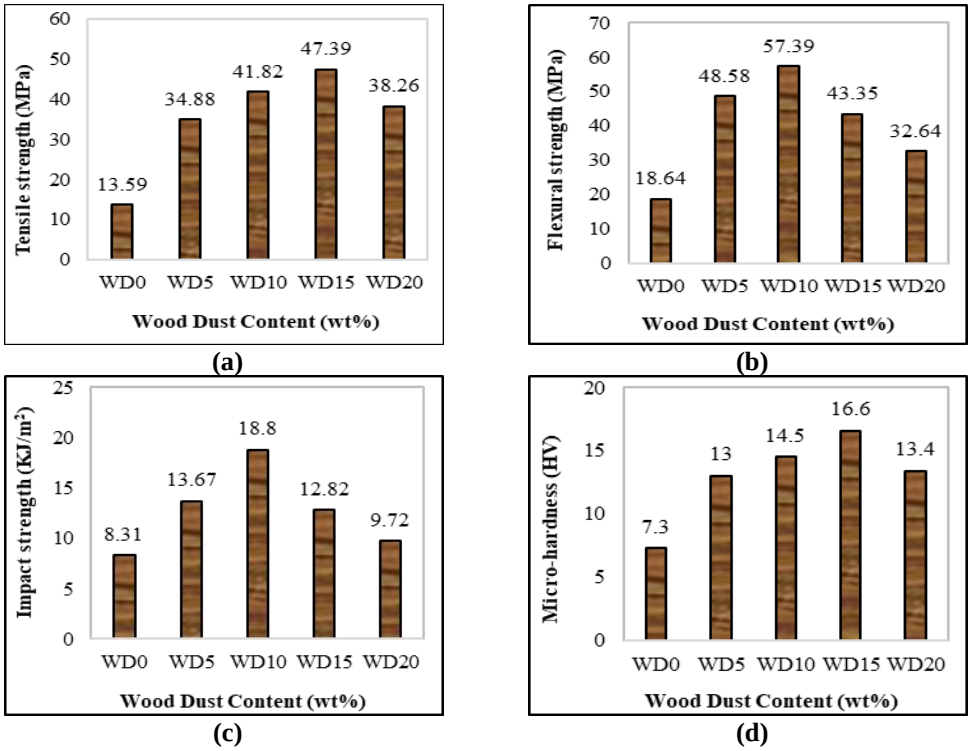

Figure 1: Mechanical attributes **of** WD/polyester composites

ISSN NO – 2583-5955 (Online)

PP. – 16-22, Manuscript Received: 20th March 2024; Revised 28th June2024, Accepted: 30th July, 2024

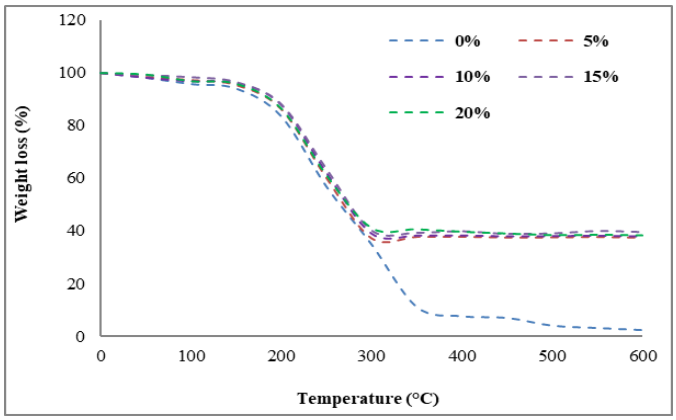

Figure 2: Analysis of TGA curves WD filled polyester composite

4. Conclusion

From the outcomes of the ongoing experimental study, the following conclusions have been drawn:

- The incorporation of WD fillers into polyester composites enhances tensile strength, flexural strength, impact resistance, and micro hardness. Specifically, adding 15% filler increases tensile strength by 239.66% compared to the resin without fillers.
- Flexural strength is about 39 MPa at 10% filler, which is 207.88% greater than unreinforced polyester composite. Similarly, the composite sample with 10wt% reinforcement of WD composite exhibited a higher impact strength value of 18.8 KJ/m^2, which is 126.23% more than neat matrix.
- Due to the greater weight percent of WD filler, the WD-15 composite (16 HV) exhibits a substantial improvement in micro-hardness.
- The inclusion of WD filler in to polyester has significantly improved the thermal stability and maximum temperature of degradation was observed at 320ºC for WD-15 composite.

In view of the above conclusion, WD can be effectively employed to prepare composites with polyester resin. As per the experimental result, this wood dust filled polyester composite can be used in different fields, such as the automobile and construction sectors.

Reference

1. E. Pérez, L. Famá, S. G. Pardo, M. J. Abad, and C. Bernal, "Tensile and fracture behaviour of

ISSN NO – 2583-5955 (Online)

PP. – 16-22, Manuscript Received: 20th March 2024; Revised 28th June2024, Accepted: 30th July, 2024

PP/wood flour composites," *Compos. Part B Eng.*, vol. 43, no. 7, pp. 2795–2800, 2012, doi: 10.1016/j.compositesb.2012.04.041.

2. P. Pradhan *et al.*, "A computational investigation for the impact of particle size on the mechanical and thermal properties of teak wood dust (TWD) filled polyester composites," *Mater. Today Proc.*, vol. 63, pp. 756–763, 2022, doi: 10.1016/j.matpr.2022.05.136.

3. Dairi, B., Djidjelli, H., Boukerrou, A., Migneault, S., and Koubaa, A., "Morphological, mechanical, and physical properties of composites made with wood flour-reinforced polypropylene/recycled poly(ethylene terephthalate) blends" Polymer Composites, 38(8): 1749–1755, 2017.

4. A. G. Adeniyi, S. A. Abdulkareem, S. A. Adeoye, and J. O. Ighalo, "Preparation and properties of wood dust (isoberlinia doka) reinforced polystyrene composites," *Polym. Bull.*, vol. 79, no. 6, pp. 4361–4379, 2022, doi: 10.1007/s00289-021-03718-6.

5. N. K. Jain and M. K. Gupta, "Hybrid teak/sal wood flour reinforced composites: Mechanical, thermal and water absorption properties," *Mater. Res. Express*, vol. 5, no. 12, 2018, doi: 10.1088/2053-1591/aae24d.

6. M. García, J. Hidalgo, I. Garmendia, and J. García-Jaca, "Wood-plastics composites with better fire retardancy and durability performance," *Compos. Part A Appl. Sci. Manuf.*, vol. 40, no. 11, pp. 1772–1776, 2009, doi: 10.1016/j.compositesa.2009.08.010.

7. S. Agayev and O. Ozdemir, "Fabrication of high density polyethylene composites reinforced with pine cone powder: Mechanical and low velocity impact performances," *Mater. Res. Express*, vol. 6, no. 4, 2019, doi: 10.1088/2053-1591/aafc42.

8. D. D. P. Moreno and C. Saron, "Low-density polyethylene waste/recycled wood composites," *Compos. Struct.*, vol. 176, no. May, pp. 1152–1157, 2017, doi: 10.1016/j.compstruct.2017.05.076.

9. A. Singh and A. Muniappan, "Experimental investigation on the mechanical properties of wood sawdust and plaster of paris reinforced composite," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 992, no. 1, 2020, doi: 10.1088/1757-899X/992/1/012009.

ISSN NO – 2583-5955 (Online)