Mechanical Characterization of Woven and Random Jute-Palm (JP) Hybrid Composites

R.Thamilarasan¹, D.Kumar¹*, P.Muthusamy², B. Senthil Kumar³, Rajasekaran Saminathan⁴

¹Department of Mechanical Engineering, Arjun College of Technology, Coimbatore - 642120, Tamil Nadu, India
²Department of Mechanical Engineering, Pollachi Institute of Engineering and Technology, Pollachi - 642205, Tamil Nadu, India.
³Department of Mechanical Engineering, Sri Ramakrishna Engineering College, Coimbatore - 641 022, Tamil Nadu, India.
⁴Department of Mechanical Engineering, College of Engineering, Jazan University, Saudi Arabia

*Corresponding author: kumar7577@gmail.com

Abstract. This article presents the research outcomes in Jute-Palm (J-P) fibers reinforced with polymer resin. ASTM standards were followed in preparing the composites of Woven and Random J-P. The tensile, impact and flexural strengths, and hardness properties were studied using the standard test setup. The results have evidenced that the woven fiber reinforcement polymer composite gives the better mechanical characteristics compared to the random fiber arrangement. The tensile characteristics, flexural strength, impact strength and hardness of the woven composite were enhanced by 6.26 MPa, 14.27 MPa, 6 J/cm and 11 RHN, respectively.

Keywords: Polymer composite; woven JP; ASTM; SEM; mechanical characteristics.

1. Introduction

The natural fiber is a collection of cells, where diameter is very small when compared to their length. It can be classified into two types namely cellulose base and protein base. The jute, cotton, sisal, wheat, maize and wool, silk are examples of natural fiber and synthetic fibers respectively [1, 2]. The natural fibers are preferred over synthetic fiber due to their eco-friendly nature, cost effective, good insulator, and better formability [3, 4]. They are also strong, anti-bacterial quality, and renewable source. The natural fibers are used in many industries like automobile, building materials, furniture [5, 6].

Fiber treatment, length, orientation and arrangement of fibers will vary the mechanical properties of composites. Natural fibers are being preferred for its exceptional friendly property towards environment, demand of raw material, and disposal issues. The study of tensile, flexural and impact tested result shows that the palm fiber based composite is superior to coir fiber based composite and the jute laminar composite has best tensile, flexural, and impact properties when it is aligned in mat type [7, 8]. The mechanical qualities of the developed composite have shown good strength comparing to the single fiber composite. The use of hybridization and lamination of layers improves the desired mechanical qualities of the developed composite significantly [9]. NaoH treatment with 5% of natural fibers at 300C gives significant improvement in tensile property, flexural and impact properties of jute, palm and sisal fibers [10, 11]. The more the volume fraction of fibers, higher is the composite strength [12, 13]. Present study investigates the woven and random Jute-Palmyra hybrid composite by Hand
Layup Technique. The Mechanical behaviors of automotive components which are made by jute and palm fibers are discussed

2. Hand Layup Process
Hand layup procedure is explained for Jute-Palmyra (JP) composite [14]. The prepared resin is applied on the base of the mat. The mat is positioned on the resin layer in unique direction and the mat is coated with a coat of resin. Figure 1 shows the setup of the hand lay-up process.

![Figure 1. Process of lay-up.](image)

The fibre was reduced to size and the required numbers of plies were collected, after which the fibres were weighed, followed by the hardener and resin. Epoxy and hardener are mixed in a basin. It was important to avoid the production of bubbles because if air bubbles are trapped in the matrix, the material could collapse [15]. The application of a releasing film to the mold's surface is the following step in the fabrication process. The sheets were then given a second polymer covering. Finally, the adhesive was reapplied, and another type of fibre ply was placed and rolled next to it [16, 17]. The cylindrical mild steel rods were used for rolling.

2.1. Woven composite
Firstly, the resin is spread in a layer on the polythene sheet, then the jute mat is placed on top, and then the resin is applied with a brush to the mat. Second, in the same unique orientation as the first mat, a palm mat is placed on the resin layer. A coating of resin is put to the pad. A soft plastic layer was laid on resin once more, and roller force was used to eliminate the air bubbles. It was decided to leave the setup for 48 hours. For the test, this J-P woven composite (Figure 2) is cut to the ASTM specification [18].

![Figure 2. Woven fabric composite.](image)
2.2. Random composite
A layer of resin is applied to the polythene sheet, and pressed. Random jute fibre is placed on top of the resin layer. On the palm fibre, a second layer of resin is placed. Second, the pressed random palm fibre is inserted in a unique direction on the resin layer. Two layers of resin are applied to the jute fibre. Using roller force, a soft plastic sheet is placed on the material which will relieve away the air bubbles. For the next 48 hours, the setup will be left alone. For the test, this J-P random composite (Figure 3) is cut to the ASTM standard [19].

3. Mechanical tests

3.1. Tensile test
The developed composite cut to the desired dimensions and the edges are polished with emery paper for mechanical testing. The dog-bone shaped sample is employed as the testing specimen [20]. The ends of the specimen with dimensions are (150x10x5) mm undergoes uniaxial load in the Universal Testing Machine (UTM).

3.2. Flexural test
The ASTM D791 was trailed in the preparation of the flexural specimens. The most common test for composite is the three-point test. The crosshead position is used to determine the deflection of the specimen. The testing technique entails placing the test specimen in a universal testing machine and exerting force to it until it fractures and breaks. Flexural strength refers to a material's capacity to resist deformation under load [19]. ASTM standards are followed which working with UTM. The specimen's dimensions are (20x150x5) mm.

3.3. Impact test
The samples for the test were built to the ASTM standard, with the required dimensions. The specimen must be inserted into the testing equipment and the pendulum is allowed to swing until it fails. The power required to shatter the test specimen is quantified using the impact test, which can also be used to determine the material's toughness and yield strength.

3.4. Hardness test
In Rockwell superficial tests a diamond tip is forced into the surface of a test piece. The depth of indentation of the tip in the tested specimen gives the measure of hardness. A reading on the D scale is noted. A material is tested for its hardness in a Rockwell testing machine. Harder the material, lesser will be the amount of indentation. Hard materials have a shadow impression, while soft materials with low hardness levels have a deep indentation.
4. Results and discussion

Tensile, flexural, impact, and hardness parameters of random and woven Jute – Palm hybrid (JP) composites are shown in Figure 4. The randomly oriented variety has tensile characteristics of 12.86 MPa, flexural characteristics of 17.73 MPa, impacting characteristics of 10 J/cm, and hardness of 28 RHN. Tensile strength was 19.12 MPa, flexural strength was 32 MPa, impact strength was 16 J/cm, and hardness was 39 RHN for the woven form. The hardness, tensile, flexural, and impact properties of the random composite’s tensile, flexural, impact, and hardness values were lower than the woven composite’s values in the quantity of 6.26 MPa, 14.27 MPa, 6 J/cm, and 11 RHN. The presence of a palm fiber layer with jute improves characteristics, and the woven matrix outperforms the random matrix due to superior fiber grip.

Figure 4 shows the tensile property, impact property, flexural and hardness properties of the selected composite of random and woven type. The random oriented type shows the tensile property of 12.86 MPa, flexural characteristics of 17.73 MPa, impact value of 10 J/cm and the hardness value as 28 RHN. The woven type shows the tensile value of 19.12 MPa, flexural value of 32 MPa, impact value of 16 J/cm and the hardness values as 39 RHN. The tensile, flexural, impact and the hardness values of random composite are lesser than 6.26 MPa, 14.27 MPa, 6 J/cm and 11 RHN of the values of the woven composite. The presence of palm fibre layer with jute give better properties and the woven matrix provides higher values than the random one due to good grip between fibres.

5. Conclusion

The values of tensile, flexural, impact and hardness properties are compared between the woven and random composites of jute-palm. The woven type shows the tensile characteristics of 19.12 MPa, which is 6.26 MPa greater than the random one. The flexural strength of woven composite is 32 MPa which is 14.27 MPa more than random composite, and the impact strength has found as 16 J/cm, which is 6 J/cm higher than random composite. The hardness values are 39 RHN, which is also 11 RHN higher than random composite. Hence, the results evidenced that the woven composite gives better strength and bonding between the fibres, thus resulted in better mechanical strength.

References

[1] Prakash, K.B., Fageehi, Y.A., Saminathan, R., Manoj Kumar, P., Saravanakumar, S., Subbiah, R., Arulmurugan, B. and Rajkumar, S. 2021. Influence of fiber volume and fiber length on
thermal and flexural properties of a hybrid natural polymer composite prepared with banana stem, pineapple leaf, and S-glass. Advances in Materials Science and Engineering, 2021. https://doi.org/10.1155/2021/6329400

[2] Mohan Kumar, A., Rajasekar, R., Manoj Kumar, P., Parameshwaran, R., Karthick, A., Mohanavel, V., Sathi, T. and Muhibullah, M. 2021. Investigation of Drilling Process Parameters of Palmyra Based Composite. Advances in Materials Science and Engineering, 2021. https://doi.org/10.1155/2021/4222344

[3] Thirumalai, R., Prakash, R., Ragunath, R. and SenthilKumar, K.M. 2019. Experimental investigation of mechanical properties of epoxy based composites. Materials Research Express 6(7):075309.

[4] Nandhakumar, S., Kanna, K.M., Riyas, A.M. and Bharath, M.N. 2021. Experimental investigations on natural fiber reinforced composites. Materials Today: Proceedings 37:2905-2908.

[5] Mohan Kumar, A., Rajasekar, R., Manoj Kumar, P., Parameshwaran, R., Karthick, A. and Muhibullah, M. 2021. Comparative analysis of drilling behaviour of synthetic and natural fiber-based composites. Advances in Materials Science and Engineering 2021. https://doi.org/10.1155/2021/9019334

[6] Kishore, P., Kumar, P.M. and Dinesh, D. 2019. Wear analysis of Al 5052 alloy with varying percentage of tungsten carbide. In AIP Conference Proceedings 2128(1):040003. https://doi.org/10.1063/1.5117965

[7] Vigneshwaran, S., Sundarakannan, R., John, K.M., Johnson, R.D.J., Prasath, K.A., Ajith, S., Arumugaprabu, V. and Uthayakumar, M. 2020. Recent advancement in the natural fiber polymer composites: A comprehensive review. Journal of Cleaner Production 277:124109.

[8] Prakash, K.B., Amarkarthik, A., Ravikumar, M., Kumar, P.M. and Jegadheeswaran, S. 2021. Optimizing performance characteristics of blower for combustion process using Taguchi based grey relational analysis. In Advances in Materials Research 155-163. doi.org/10.1007/978-981-15-8319-3_17

[9] Anand, P., Rajesh, D., Senthil Kumar, M. and Saran Raj, I. 2018. Investigations on the performances of treated jute/kenaf hybrid natural fiber reinforced epoxy composite. Journal of Polymer Research 25(4):1-9.

[10] Karthi, N., Kumaresan, K., Sathish, S., Gokulkumar, S., Prabhu, L. and Vigneshkumar, N. 2020. An overview: Natural fiber reinforced hybrid composites, chemical treatments and application areas. Materials Today: proceedings 27:2828-2834.

[11] Rinawa, M.L., Pitchandi, P., Vigneshkumar, N., Sharma, R., Singh, M.K., Subbiah, R. and Kumar, P.M. 2021. Experimental analysis of the metal roofed industrial building using nano-silica disbonded crude wax (NDCW). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.12.253

[12] Yashas Gowda, T.G., Sanjay, M.R., Subrahmanya Bhat, K., Madhu, P., Senthamaraikannan, P. and Yogesha, B. 2018. Polymer matrix-natural fiber composites: An overview. Cogent Engineering 5(1):1446667.

[13] Kumar, P.M. and Mylsamy, K. 2020. A comprehensive study on thermal storage characteristics of nano-CeO₂ embedded phase change material and its influence on the performance of evacuated tube solar water heater. Renewable Energy 162:662-676. doi.org/10.1016/j.renene.2020.08.122

[14] Satthees Kumar, S. 2020. Effect of natural fiber loading on mechanical properties and thermal characteristics of hybrid polyester composites for industrial and construction fields. Fibers and Polymers 21(7):1508-1514.

[15] Prasad, V., Muhammed Hunize, C.V., Abhiraj, R.I., Jospeh, M.A., Sekar, K. and Ali, M. 2019. Mechanical properties of flax fiber reinforced composites manufactured using hand layup and compression molding—a comparison. In Advances in Industrial and Production Engineering (781-789). Springer, Singapore.
[16] Pereira, T.G.T., Mendes, J.F., Oliveira, J.E., Marconcini, J.M. and Mendes, R.F. 2018. Effect of reinforcement percentage of eucalyptus fibers on physico-mechanical properties of composite hand lay-up with polyester thermosetting matrix. Journal of Natural Fibers.

[17] King, M.F.L., Rao, P.N., Sivakumar, A., Mamidi, V.K., Richard, S., Vijayakumar, M., Arunprasath, K. and Kumar, P.M. 2021. Thermal performance of a double-glazed window integrated with a phase change material (PCM). Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.09.099

[18] Sarikaya, E., Çallioğlu, H. and Demirel, H. 2019. Production of epoxy composites reinforced by different natural fibers and their mechanical properties. Composites Part B: Engineering 167:461-466.

[19] Jariwala, H. and Jain, P. 2019. A review on mechanical behavior of natural fiber reinforced polymer composites and its applications. Journal of Reinforced Plastics and Composites 38(10):441-453.

[20] Balaji, M., Dinesh, S.N., Vetrivel, S.V., Kumar, P.M. and Subbiah, R. 2021. Augmenting agility in production flow through ANP. Materials Today: Proceedings. doi.org/10.1016/j.matpr.2021.06.053