



MODELLING SIMULATION ON MECHANICAL PROPERTIES OF FIBRE REINFORCED COMPOSITES

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Abstract— A thorough investigation into the modeling and simulation of fiber-reinforced composites' (FRCs') mechanical characteristics is presented in this project. Because of their improved durability and superior strength-to-weight ratio, these materials are being used more and more in a variety of industries. Therefore, it is essential to comprehend their mechanical behavior in order to maximize their applications. The impact of fiber orientation, volume fraction, and matrix parameters on the overall performance of FRCs is examined in this study using a mix of finite element analysis (FEA) and micromechanical modeling approaches. Our objective is to forecast the failure and elastic properties under various loading scenarios by creating a comprehensive computational model. The correctness and dependability of the models are ensured by experimental validation using tensile and flexural tests, which supplement the simulation results. The results of this study open the door for the improved use of fiber-reinforced composites in the structural, automotive, and aerospace engineering sectors by offering insightful information for their design and optimization.

Keywords— Fiber-reinforced composites, mechanical properties, modeling, simulation, finite element analysis, micromechanical modeling, fiber orientation, volume fraction, matrix properties, tensile tests, flexural tests, material optimization.

1. INTRODUCTION

Since they are lightweight and offer remarkable mechanical qualities, fiber-reinforced composites, or FRCs, have become essential materials in contemporary engineering. These composites, which are made of a polymer matrix reinforced with fibers like glass, carbon, or aramid, have several advantages over more conventional materials like metals and ceramics. They are perfect for applications in a variety of industries, including as sports equipment, automotive, aerospace, and construction, due to their ability to combine high strength and low weight.

Numerous parameters, such as the type of fiber, fiber orientation, volume percentage, and matrix material qualities, have a significant impact on the mechanical performance of FRCs. Optimizing the functionality and design of composite materials requires an understanding of these relationships. A move toward more effective modeling and simulation techniques is

required since traditional experimental methods for evaluating mechanical properties can be expensive and time-consuming.

The goal of this project is to model and simulate the mechanical behavior of fiber-reinforced composites using sophisticated computational approaches. Through the use of micromechanical modeling and finite element analysis (FEA), we want to clarify the ways in which different design parameters impact the overall performance of FRCs. A strong framework for forecasting mechanical properties will be made possible by the combination of computer modeling and experimental validation, allowing the creation of composites that are suited for particular uses. By supporting innovations that depend on improved material performance and efficiency, our research will help progress FRC technology.

EASE OF USE

2. Literature Review

1. Garrett W. Melenkaa, Benjamin K.O. Cheunga, Jonathon S. Schofielda, Michael R. Dawsonb, Jason P. Careya Study say that utilizing an Average Stiffness (VAS) method to forecast elastic properties and evaluate the fiber-reinforced 3D printed constructions' elastic qualities. The volume proportion of fibers in the 3D printed constructions was varied to create the samples examined in this study (4.04, 8.08, and 10.1%, respectively). Fiber volume percentages of 4.04, 8.08, and 10.1% were found to have experimentally determined elastic moduli of 1767.2, 6920.0, and 9001.2 MPa, respectively. It was discovered that the anticipated elastic moduli were 4155.7, 7380.0, and 8992.1 MPa. For the 4.04, 8.08, and 10.1% fiber volume fractions, the model results deviated from the trials by 57.5, 6.2, and 0.1%, respectively. The elastic qualities of fiber-reinforced 3D printed components are supported by the prediction model. With the help of the model, designers will be able to forecast the elastic qualities of fiber-reinforced 3D printed parts that will be utilized for functional components that need particular mechanical characteristics.

2. Heyuan Huang, Meiyong Zhao, Yonghui Dai, Wenzhi Wang study say that addresses the problems with the microstructure of fiber-reinforced composite materials and offers a novel numerical technique based on the represent volume element (RVE) for creating random fiber distributions and forecasting the macroscopic mechanical properties of composite materials. The technique, known as the random sequence generation algorithm (RSGA), efficiently creates a statistical equivalency RVE by using image processing to acquire fiber radius distributions and positional connections. For micromechanical study of composite materials, the technique for fiber distributions in composite materials offers a practical substitute for creating random numerical models.

3. Prabhakaran, R.T. Durai; Gupta, Mohit; Mahajan, Puneet study say in order to comprehend how the orientation and layups of flax fibers impact the mechanical behavior of layered laminated composites. One-way [0]Cross-ply, 4S [0/90][+45/-45], angle-ply, 2S2S and [0/90/45/-45] quasi-isotropic To investigate the tensile, flexural, and stress distribution of individual laminae, S laminates composed of flax fiber reinforced epoxy composites are taken into consideration. The stress-strain response of a layered composite is predicted using a numerical simulation approach based on finite element modeling (FEM) and a classical

laminate plate theory (CLPT), which takes into account the elastic behavior of the laminae. Additionally, the quasi-isotropic flax/epoxy laminate outperforms angle-ply and cross-ply laminates, according to the analytical results and numerical projections.

4. Timothy K. Mulenga, Albert U. Ude and Chinnasamy Vivekanandhan study say that In recent years, the study of natural fiber-based composites using computational methods to model and optimize their properties has become a rapidly expanding field. The use of natural fibers as reinforcing material in composites has become widespread due to ecological concerns about synthetic fibers. Many researchers now use computational tools as a key tool to simulate and examine the factors that affect the mechanical properties of natural fiber composites.

5. Gyu-Wol Lee, Tae-Hyun Kim, Jong-Hwan Yun, Nam-Joo Kim, Ki-Hwan Ahn¹ and Min-Soo Kang study say that assesses the mechanical strength of composite-material products that are 3D printed. With glass fiber and carbon fiber serving as internal reinforcements, onyx serves as the basis material for the composite material under consideration in this study. Fiber reinforcements are typically laminated as layers inside the produced part when 3D printing with composite materials. Specimens were created by altering the reinforcement's layer count and layout to examine the impact of such reinforcements on the printed parts. According to the analysis, the effect of the fibers on the longitudinal direction and a greater bonding surface between the internal Onyx and the fibers cause the composite's tensile strength to grow with the number of reinforcing layers.

6. Sri chandana Buddi, P Phani Prasanthi and P Srikanth study say that accurately investigates the average mechanical characteristics of composite materials. Any composite material's characteristics are influenced by its constituents, loading, geometry, interphase region, and environmental factors. The proposed effort focuses on evaluating the fiber reinforced composite material's properties under various loading scenarios with varying volume fractions. In order to assess engineering constants such as longitudinal modulus, transverse modulus, major Poisson's ratio, and minor Poisson's ratio of the fiber reinforced composites for various fiber volume fractions while taking into account uniform and random distribution of reinforcement, a 3D finite element model with governing boundary conditions was created from the unit cell of square pattern of the composite.

7. T. Raja, Dr. P. Anand, M karthik, M. Sundaraj study say In order to create a mat layer comprising one or more layers of flat sheets, natural fiber is made by assembling long or short fiber bundles. Abaca, cotton, jute, flax, hemp, and coir are among the natural fibers used in many industrial processes. Natural fiber composites research and innovation have grown rapidly in recent years. Natural fiber composites have the following qualities: they are long-lasting, inexpensive, lightweight, have a high specific strength, are non-abrasive, have rather good mechanical qualities, are environmentally benign, and biodegrade. These materials show promise for a variety of industries, including the automotive and aerospace sectors.

8. Sandeep Kumar study say that According to research conducted throughout the previous era, fiber reinforced polymer composites, or FRPC, have proven to be a highly

valuable and appropriate new construction material. The use of natural fibers as reinforcement in polymer composites to create low-cost building materials has garnered a lot of attention from structural scientists and engineers worldwide, despite the fact that natural fibers currently receive a lot more attention. The use of fiber reinforced composite increased the researcher's or scientist's curiosity because of the drawbacks of using synthetic and fiber glass as reinforcement. Although natural fibers have served many practical functions, there has been an increasing demand in recent years to use them as fortification in polymer matrices.

9. S. Lakshmi Narayana and Venkatachalam Gopalan study say that This study aims to investigate the mechanical properties of a composite made of jute fiber polymer loaded with silicon carbide (SiC), boron carbide (B₄C), and aluminum oxide (Al₂O₃) particles. To create the various combinations of process variables needed to create the necessary polymer composites, the response surface methodology (RSM) with three levels/three factors is employed. In this context, a detailed analysis is conducted of the impact of process variables on tensile characteristics, weight percentage increase, and flexural properties.

10. Hamad Hasan Zedan Khalel and Muhammad Khan study say that The suggested model predicts compressive and flexural strengths with errors of less than 6% and 15%, respectively, but it is simple to implement. The assumption made regarding the fiber material input during model creation is largely represented by this inaccuracy. It ignores the fiber's plastic behavior because it is based on the material's elastic modulus. Future studies will examine a potential model adjustment to account for the fiber's plastic behavior.

11. Yesong Wang , Jiang Liu , Yipeng Yu , Qing Zhang , Hongfu Li and Guokun Shi study say that The conventional continuous fiber-reinforced polymer (CFRP) production process is being revolutionized by the quick development of additive manufacturing technology (AM). Continuous fiber reinforced thermoplastic composites (CFRTPC) 3D printing technology was created by combining FDM and CFRP technologies. This method allows for the fabrication of parts with intricate structures and superior performance. However, printing tools, materials, and mechanical property enhancement are the primary areas of present CFRTPC printing research. The polytetrafluoroethylene (PTFE) tube in the printer head's nozzle is frequently obstructed, according to this paper's investigation of CFRTPC 3D printing track errors during the printing process. A line-following mathematical model that takes into account the CFRTPC printing track's variations is developed through in-depth investigation. A modified line-following model without the minimum curvature point is further suggested based on the property of the fiber and its track during actual laying. This model is used to reproduce the real printing track for the theoretical path, conduct process tests on the printing track at various corner angles, and derive the pertinent laws between the model's parameters and various corner angles. Theoretically, the logical fiber track design in CFRTPC printing is supported by experiments that validate the mathematical model and eliminate the printer head clogging issue brought on by the fiber track mistake.

12. Juan Leon-Becerra, Octavio Andrés González-Estrada and Heller Sánchez-Acevedo study say that Composites made using continuous fiber-reinforced additive manufacturing

(cFRAM) enhance the mechanical characteristics of polymer parts. This paper attempts to compare the prediction skills for the mechanical properties, stiffness constants, and strength of cFRAM using two different predictive models and discuss the primary failure processes in light of the recent interest in their mechanical performance and failure mechanisms. Experimental tensile testing of continuous carbon fiber AM composites with different reinforced fractions, printing directions, and fiber angles are presented in this paper. The first predictive model forecasts the macroscopic response of stiffness and strength using a micromechanical model. In the second section, data-driven models are trained to predict stiffness and strength based on crucial characteristics utilizing various machine learning methods for regression. The accuracy, usability, and capacity for generalization of both models are evaluated. Additionally, a qualitative assessment of the parameters and their impact on the macroscopic response and failure surface topology is conducted using microstructural pictures. Lastly, we draw the conclusion that, despite the complexity of the task, it is possible to predict the mechanical properties of cFRAM using a micromechanical model and a Gaussian process regression, with good accuracy that can be expanded onto specimens with varying process parameters.

13. P. Phani Prasanthi · V. Raghavender · V. V. Venu Madhav, Pankaj Sonia · Ch. Sri Chaitanya · Din Bandhu · Ashish Saxena · Sherzod Shukhratovich Abdullaev study say that aims to examine the mechanical characteristics of a composite made of jute fibers reinforced with a mix of non-cellulose and cellulose particles. Aloe vera gel is added to these fibers, which are then strengthened in an epoxy matrix. Aloe vera gel is applied to the jute fibers, and then they are allowed to cool for 48 hours. The epoxy matrix is then strengthened with these treated jute fibers. The composite's tensile and flexural strengths were assessed by experimental testing. Aloe vera gel-coated jute fiber composites, which contain both cellulose- and non-cellulose-based particles, are used to reinforce the epoxy matrix. Groundnut shell powder and teakwood powder are the cellulose-based fillers used in this study, while graphene is the non-cellulose-based filler. In comparison to a jute composite without particle reinforcement, the aloe vera gel-coated jute fibers' tensile strength increased by 11.11%, 8.46%, and 53.43%, respectively, when graphene, teakwood powder, and crushed groundnut shell powder were added. Using finite element methods, the study also investigates the behavior of a composite material with two pre-existing cracks positioned differently. Transverse fractures consistently produced larger von Mises stresses and shear stresses than longitudinal cracks in all materials studied.

14. Chensong Dong, Ian J. Davies study study is a computational and experimental investigation of the mechanical characteristics of continuous glass fiber-reinforced composites made by the material extrusion process. Using a MarkForged Mark Two printer, specimens with different amounts of reinforcing layers are 3D printed. The performance of these specimens is assessed using both tensile and flexural tests. Furthermore, a finite-element analysis (FEA)-based numerical modeling technique is created to model the composites' tensile and flexural characteristics. There is a fair amount of agreement between the experimental findings and the model predictions. The results of this study offer significant insights into the developing field of continuous fiber-reinforced 3D printing technology, allowing users to confidently design and create parts that satisfy the particular needs of their applications.

CONCLUSION

We may infer from the thorough literature review of fourteen research publications that the study of the mechanical properties of the composite material is aided by the modeling and simulation of the material. Different packings of materials provide us with information that will aid in the development of the necessary mechanical qualities. To determine whether a material is providing the required qualities, FEA analysis is utilized. Since no physical model is needed for testing, FEA analysis lowers the cost of material testing.

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