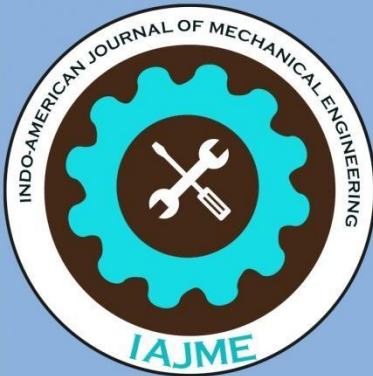


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# Using finite element analysis, we investigate jute-based composites to learn more about the synergy of natural fiber reinforcement in composite materials.

U. Santosh Kumar<sup>1</sup>, G Manikanta Rao<sup>2</sup>

<sup>1,2</sup> Department. of Mechanical Engineering, SRM Institute of Science and Technology, Tiruchirappalli Campus, Tamil Nadu, India-621105.

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## ABSTRACT

Composite components made from natural fibers and fillers are all the rage now since they are strong, lightweight, easy to acquire, and good for the environment. In this study, the tensile properties of jute-based composites at various filler content compositions (0, 2.5, 5, 7.5, 10, and 12.5 wt.%) are evaluated using Finite Element Analysis (FEA). This research uses ANSYS R121 software to correlate computational findings with experimental data, proving that FEA is effective in predicting material changes under different conditions. Research shows that jute particle composites (JPC) have an increasing tensile strength with increasing filler content up to a certain limit, but thereafter their strength drops due to reduced stress transfer efficiency. Jute has the ability to compete with synthetic fibers in applications that need lightweight and biodegradable materials, according to the study. Engineers and researchers are also able to make better material choices and constructions thanks to a fifth-order polynomial model that determines composite strength from strain rates and particle proportions. With its informative information on mechanical characteristics, this research emphasizes the significance of natural fiber composites in creating sustainable material solutions for many industrial applications.

**Keywords:** Jute particulates, Mechanical strength, FEM, ANSYS.

## I. Introduction

When it comes to improving particular strength and stiffness while simultaneously minimizing weight, the construction and automotive sectors confront the greatest obstacles. Relative to fuels, the efficacy is improved by the decrease in mass. Consequently, people may look into alternative materials that have a better strength-to-weight ratio and are suitable for their purposes, rather than traditional ones [1, 2]. Currently, the combined component, which is composed of two or more

parts joined macroscopically, came into view. Composites are becoming increasingly acceptable for use in many scientific and automotive applications due to their low bulk, resistance to corrosion, and optimum strength [3]. The extraordinary properties used throughout numerous industrial sectors are shown by the composite that incorporates synthetic fibers including glass, Kevlar, and carbon. Nevertheless, owing to a handful of characteristics, these synthetic materials still fall short of expectations in terms of recycling

and biodegradability [4]. In the creation of biodegradable goods, natural fiber-based composites (NFC) are preferred over synthetic fiber-based composites (SFC) due to their better modulus-to-strength ratio, lower production costs, and lighter weight. NFC has a lot of qualities, such as being very resistant to harm and having a lot of capacity to hold moisture.

While NFCs have been around for a while, synthetic replacements with better mechanical qualities have caused their popularity to decline, despite their continued use in industries like textiles and housing. Nevertheless, there has been a resurgence of interest in NFCs because of the growing awareness of the environmental problems caused by synthetic waste and the ongoing search for sustainable materials. The mechanical qualities of NFCs can now compete with those of SFCs, thanks to recent developments, opening the door for their use in harsher conditions [5-7].

There has been a surge in studies examining the feasibility of making polymeric materials from natural fibers. The mechanical properties of composites reinforced with natural fibers may match those of traditional synthetics, according to the research [8]. In a study conducted by Khan et al. [9], it was shown that composites consisting of bamboo fiber had significantly higher fracture toughness when the fiber lengths were longer. Rosa et al. found that quasi-unidirectional flax-fiber composites outperformed raw polymer samples mechanically. Isothalic polyester materials derived from jute were found by Ahmed et al. to possess better mechanical characteristics compared to conventional polyester jute composites [10, 11].

For many uses, jute is a great alternative to lignocellulosic fillers. It comes from the eco-friendly jute plant, which is growing rapidly. Jute has tremendous potential as a composite material and is an affordable agricultural resource. Due to their low disintegration rate, jute particles are an excellent choice for making high-quality goods [12, 13]. Jute particle composites (JPC) have proven useful in many different fields, including the fabrication of lighter automotive components, construction boards, panels, and protective clothing

[14]. A computational evaluation of NFC was carried out by Balasubramanian et al., and compared their results to experimental evidence. A little discrepancy of about 2%-6% is evidence of the excellent agreement between numerical and experimental findings, according to the authors [15]. With a little variation of around 6.6% [16], computational approaches for calculating composite mechanical strengths have also shown findings that are equivalent to experimental data, according to Cuan-Urquizo et al. When Petrone and Meruane used the model update approach to include additional variables to their numerical analysis of flax/polyethylene NFC mechanical characteristics, they found that the results may still be better after updating two factor sections [17]. Xiong et al. used the RVE simulation method to evaluate the micromechanical properties of flax/polyoxymethylene NFCs. The findings shown that the elastic characteristics of this NFC are greatly influenced by the twist arrangement of the fiber [18].

The tensile properties of jute-based composites are investigated in this study using Finite Element Analysis (FEA) with varying filler content compositions. Using ANSYS R121, this research endeavors to provide a comprehensive understanding of the effects of different jute powder weight fractions on the mechanical performance of these composites. The findings will provide researchers and engineers valuable information for material selection and design processes, and they will contribute to the ongoing conversation on sustainable materials.

## II. COMPOSITE DESCRIPTION & COMPUTATIONAL METHODOLOGY

In order to test the tensile strength of compounds with different percentages of jute particles (0, 2.5, 5, 7.5, 10, 12.5 wt. %), this study makes use of ANSYS R121. Then, the computational measurements are compared to the quantities that have been validated empirically, which were previously studied by Mahakur et al. [19]. Table 1

displays the results obtained at a single strain rate of 1 mm/min.

Table 1: Experimental outcomes of composites at varied particulate proportions [19]

| Filler wt.% | Tensile strength (MPa) |
|-------------|------------------------|
| 0%          | 36.09                  |
| 2.5%        | 41.9                   |
| 5%          | 49.54                  |
| 7.5%        | 45.25                  |
| 10%         | 41.77                  |
| 12.5%       | 24.32                  |

Probability of solution for the given border area is computed using the Finite Element Method (FEM). First, the desired geometry is mesh-separated into smaller sections; second, the right material is allocated; and lastly, the structure is subjected to the necessary boundary criteria to obtain the responses related to the parameters that have been specified [20].

The FEA on the CatiaV5R21-generated sample is carried out in this study using ANSYS R121. Figure 1(a) shows the specimen, which is 63.5 mm x 10 mm x 3.2 mm in size. The specimen has been transferred to the ANSYS workbench from the IGES format following its design. Then, the tensile test is performed using physical-type explicit dynamics. Concepts of composite processes

establish the presence of material qualities and traits such as density, Poisson's ratio, and Young's modulus [21]. The material qualities that were considered during the investigation are listed in Table 2. The statistics on Young's modulus vary with the different jute particle proportions. In boundary scenarios, one part of the object under study is held still while the other part is moved at a certain speed. Figure 1(b) displays the model's constituent parts, which consist of 21,056 elements and 50,595 nodes, and which are meshed using quadratic meshing. With quadratic meshing set to a maximum resolution of 7, we may get a better stress-gradient across components.

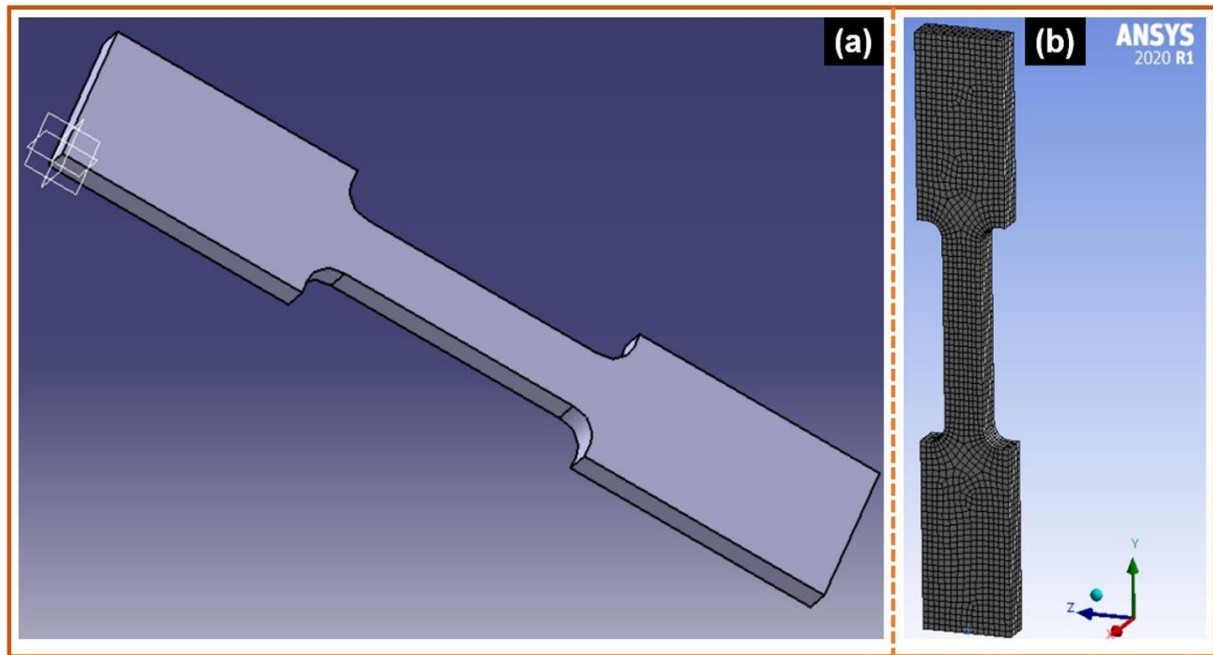


Fig. 1 (a) Specimen model drawn at CatiaV5R21, and (b) Quadratic meshing performed on the composite model specimen using ANSYS

Table 2: Material engineering characteristics at varied particulate proportions [22]

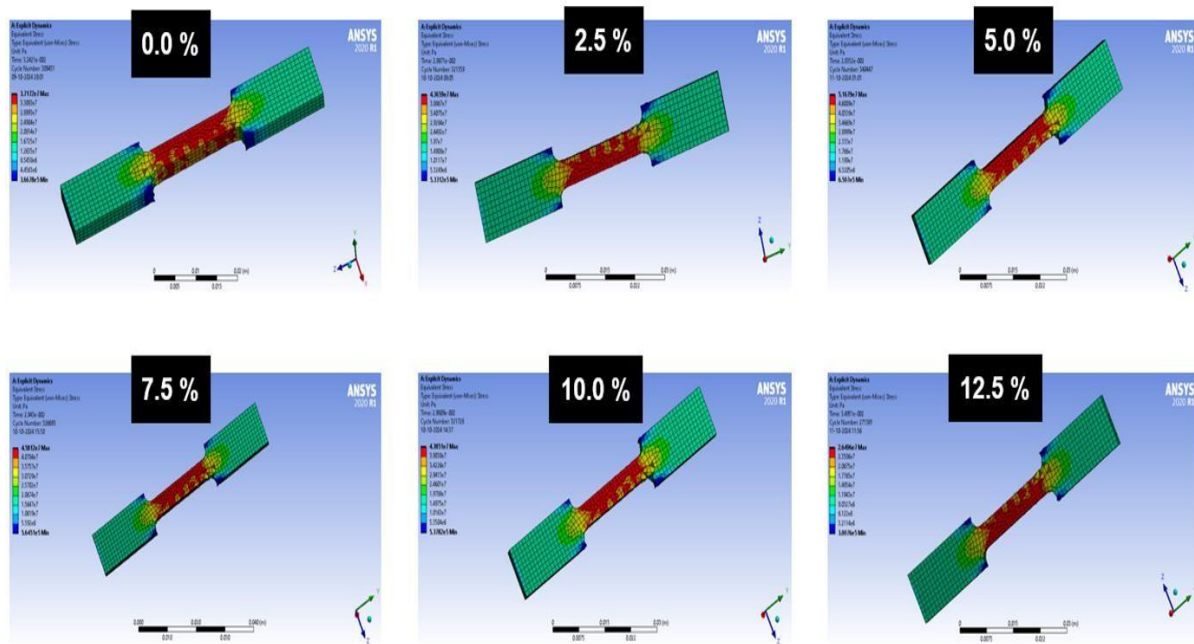
| Composite Sample | Density (g/cm <sup>3</sup> ) | Young's Modulus (MPa) | Poisson's ratio ( $\nu$ ) |
|------------------|------------------------------|-----------------------|---------------------------|
|                  |                              | @ 1 mm/min            |                           |
| 0.0 wt.%         | 1.2                          | 260                   | 0.25                      |
| 2.5 wt.%         | 1.14858                      | 380                   |                           |
| 5.0 wt.%         | 1.10138                      | 430                   |                           |
| 7.5 wt.%         | 1.05792                      | 320                   |                           |
| 10.0 wt.%        | 1.01776                      | 290                   |                           |
| 12.5 wt.%        | 0.98052                      | 190                   |                           |

### III. RESULTS AND DISCUSSIONS

In certain boundary circumstances, when the item is fixed at one end and subjected to a velocity of 1 mm/min

on one side, the tensile

The characteristics of jute particle composites (JPC) with the weight proportions 0–12.5% are examined. In order to learn how this pace affects the tensile strength of the produced materials, which might reveal its future applications in many fields. In addition, learning how to categorize them would greatly aid in comprehending their usefulness in contexts including dynamic applications.



In this case, the models are constructed supposing that the material's cross-sectional profile is uniform. Results of tensile tests conducted at a cross-head speed of 1 mm/min for composite materials at all weight proportions investigated are shown in Figure 2, using the identical boundary circumstances used in the real time evaluation.

Fig. 2 Analytical results of the modelled parts at different specifications

The mechanical properties of a composite material using jute as its foundation and varied filler weight are shown in this study. The tensile qualities of the substances fluctuate with different weight proportions, according to the experimental findings. Figure 3 shows these differences. Differences in density, boundary conditions, and other input parameters used in experimental and computational assessment may account for the observed discrepancy. After reviewing the data, one would expect that adding powder particles to the composite material increases its durability. In relation to

on the opposite side, when this particle's concentration in the epoxy rose over 10 wt.

The strength of the composite was reduced because the rate of stress transmission under the components was reduced [23].

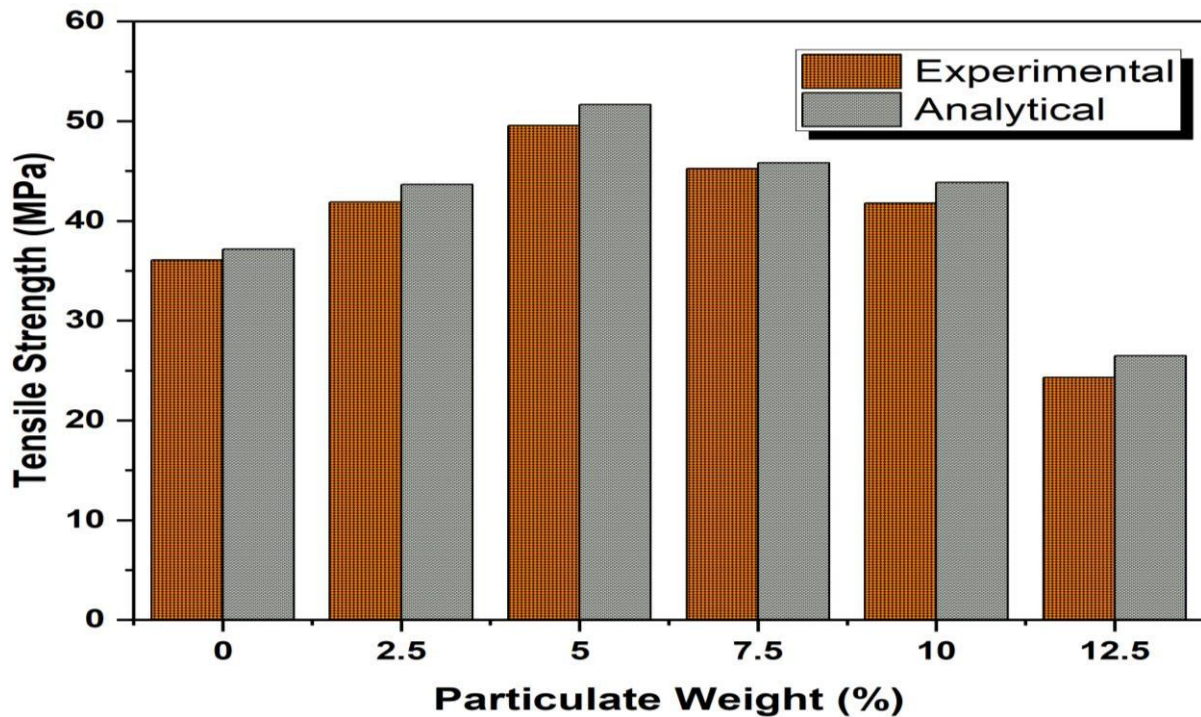


Fig. 3 Comparison of experimental and analytical results for specimens

A curve-fit strategies are implemented for assessing the coefficients for the purpose to build a homogeneous and anisotropic the material. Considering a 5<sup>th</sup>-order polynomial path, Figure 5 presents a straightforward display of the strength coefficients at various cross-head rates. By studying the above polynomial trajectory, it is obvious that the composite's strength can be estimated by contemplating the fluctuations in particulate proportions and strain rates, although the existence of an enormous disparity in inaccuracy compared to the experimental findings.

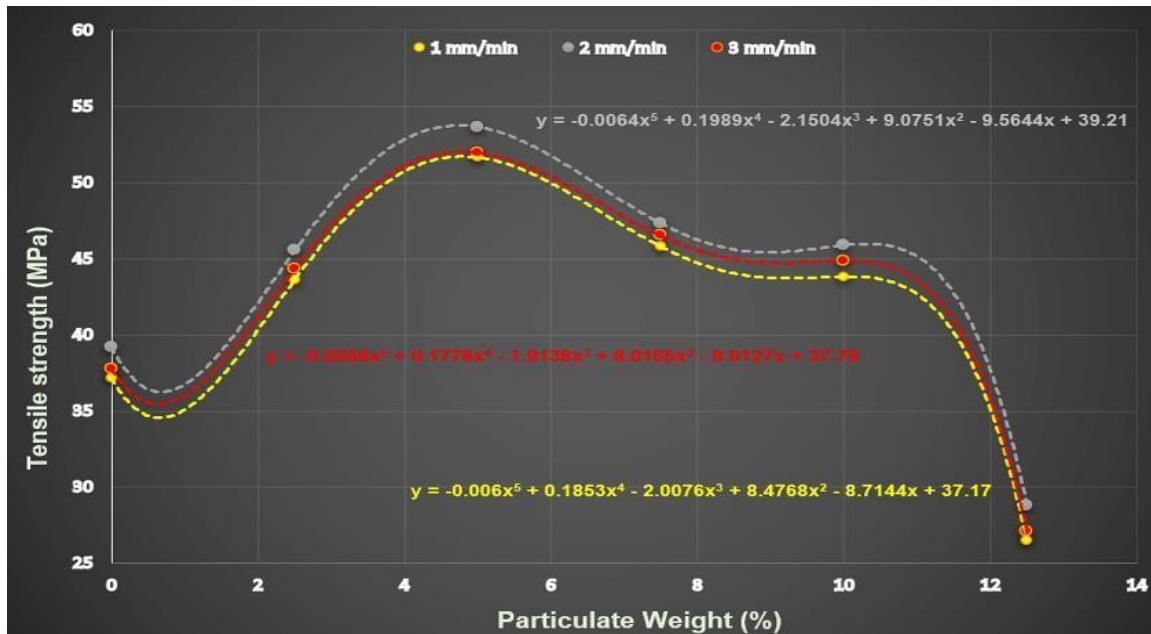


Fig. 4 Curve fitting plot for all analytical results at varied strain rate

#### IV. CONCLUSIONS

We used the finite element analysis (FEA) method to evaluate the tensile properties of JPC at a certain strain rate and compared the results to our experimental data. Among the several significant results of the study were:

- Jute-based NFCs are becoming more important in the industry because they are lightweight, environmentally friendly, and have better specific mechanical properties than synthetic alternatives.
- JPC's tensile properties were successfully analyzed using ANSYS R121 for FEA for a range of particulate proportions (0, 2.5, 5, 7.5, 10, and 12.5 wt.%).
- Computational results corroborated experimental results, demonstrating FEM's reliability in forecasting mechanical properties.

In order to predict how well a composite would work in real-world scenarios, scientists developed a fifth-order polynomial model that takes strain rates and particle proportions into account when estimating the composite's strength. Also, for all weight proportions examined, the specimen may provide the maximal strength up to a strain rate of 2 mm/min.

As a result, this method facilitates efficient material selection and design for a wide range of applications by helping researchers anticipate the mechanical properties of NFC using FEA.



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