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DESIGN AND DEVELOPMENT OF BIO-LATTICE STRUCTURE BY USING nTOPOLOGY SOFTWARE AND 3D PRINTING TECHNOLOGY

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Abstract: The goal of this article is to design and develop bio-lattice structures utilizing 3D printing technology with ABS carbon fiber and nTopologysoftware, which are inspired by the fibrous pattern of foxtail palm seed fiber. The aim is to replicate the complex structure of foxtail palm seeds while maximizing biocompatibility and mechanical robustness. ABS carbon fiber will be incorporated into the lattice structures using cutting-edge manufacturing processes to increase their durability. Tests for tensile strength and compression will be performed to assess the bio-lattice structures' mechanical characteristics. This study intends to promote the knowledge and implementation of bio-mimetic structures in diverse engineering domains, such as biomechanics and sustainable materials development, by fusing bio-inspired design with state-of-the-art materials and testing procedures.

Keywords: Bio-lattice structures, Foxtail palm seeds, microstructure, nTopology,3D printing

1. **Introduction:** Biomedical applications as well as engineering have shown a great deal of interest in the design and development of biomimetic structures. The objective of this study is to investigate the complex fibrous pattern found in the fibers of foxtail palm seeds and uses it as a model for bio-lattice constructions[1], [2]. With additive manufacturing methods like 3D printing and sophisticated design tools like nTopology software, the project aims to create these bio-lattice structures out of ABS carbon fiber. An interesting model for the creation of bioinspired materials with improved mechanical qualities and biocompatibility is provided by the distinctive fibrous arrangement of foxtail palm seed fibers. By utilizing nTopology software, parametric design techniques will be used to replicate the structural features of foxtail palm seed fibers while maximizing for specific mechanical requirements[3]–[6]. A potential approach for easily and stably constructing these complex lattice structures is the use of 3D printing technology with ABS carbon fiber reinforcement. Evaluating the performance of the produced bio-lattice structures by extensive mechanical testing, such as tensile and compression tests are one of the main goals of this study[6]–[8]. These tests will offer essential data about the strength, stability, and mechanical behavior of the structures under various loading scenarios. To verify the

effectiveness of the bio-inspired design methodology and evaluate the possible uses of these structures in the engineering and biomedical domains by carefully analyzing the test results. In general, this project is an example of an integrated effort that connects advanced design tools, additive manufacturing processes, mechanical testing, and biomimicry[1], [9]. The author contributes to the development of bio-inspired materials with customizable properties for a range of engineering applications by creating and analyzing bio-lattice structures patterned after the seed fibers of the foxtail palm, vide in Figure 1. In the realm of botany, the intricate lattice structure of seeds plays a crucial role in seed dispersal, protection, and germination. One compelling example of such a botanical marvel is found in the seeds of the foxtail palm (shown in Figure 1(c)).The only known toxic palm fruit is the seed of the foxtail palm, which makes it special. When fully grown, the seeds are orange-red, and they must be removed from the seed pod while still inside the crown shaft. Because the seeds are poisonous if consumed, it's critical to handle them carefully. Using foxtail palm seed fibers as inspiration for creating lattice structures is one of the main points of the literature review. The researchers want to mimic the complex pattern of the seed fibers using parametric design tools and additive manufacturing techniques. In order to further the development of biomimetic materials, this strategy aims to improve mechanical qualities and biocompatibility[10], [11]. The usefulness of this bio-inspired engineering process is investigated through extensive testing.

(a) (b) (c)

Figure 1: (a) foxtail palm tree (Wodyetiabifuracate) (b) Palm tree fruit (c) foxtail palm dry seed

2. MATERIAL:

The combination of ABS (Acrylonitrile Butadiene Styrene) carbon fiber composites makes such a potential material for 3D printing. This is toughness, heat resistance and impact resistance is just a few of the characteristics that make ABS a popular thermo plastic. When compared to conventional ABS, the resulting composite can bear larger loads and stresses since carbon fibers are known for having high tensile strength and modulus. For applications demanding structural integrity and longevity, ABS carbon fiber composites are therefore perfect[2], [12], [13]. During 3D printing, the carbon fibers enhance the material's flow characteristics, producing prints that are smoother, more accurate, and experience less shrinkage and warping. This allows high dimensional accuracy production of complicated designs.

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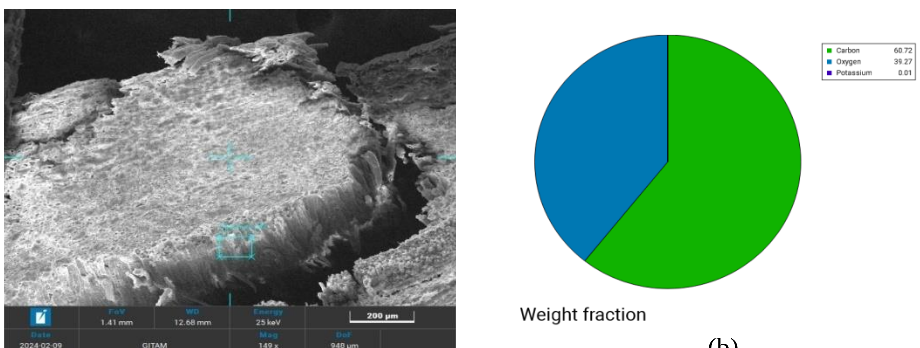
3. RESULTS AND DISCUSSION:

3.1.1. FE-SEM Analysis on foxtail palm seed fiber:

Field Emission Scanning Electron Microscopy (FE-SEM) is used to analyze the structure and properties of the fiber in foxtail palm seed fiber, shown in Figure 2. This research offers comprehensive insights into the fiber's shape, content, and surface characteristics. The efficacy of utilizing foxtail palm fruits to produce activated carbon for water purification applications is demonstrated by the study on foxtail palm fruits as prospective activated carbon for eliminating pollutants like metamifop and methylene blue. The study highlights the value of using natural resources, such as foxtail palm fruits, to create environmentally friendly solutions for problems facing the environment and highlights the potential uses of these materials in long-term projects.



(a) (b)

Figure 2: (a) SEM of foxtail palm seed fiber(b) Atomic Fraction of foxtail palm seed fiber

Examining the foxtail palm seed's composition and physical attributes is part of the structural analysis process, shown in Figure 3. The surface of the foxtail palm seed fiber was closing like iso-truss and fluorite lattice structures. These lattice structures are designed and developed with the help of nTopology software. Furthermore, Figure 4 showed that they might be used to make activated carbon, which would be utilized to clean up pollutants like metamifop from water sources. Studying the morphology of the seed, which entails assessing its dimensions, form, and surface characteristics, is a popular strategy. Furthermore, the seed's interior components the embryo, endosperm, and seed coat offer clues into the seed's growth and possible germination process. At high magnification, the seed's surface can be seen using methods like scanning electron microscopy (SEM), enabling a thorough analysis of its morphology and texture[8], [14]. Additionally, examining the seed's histochemistry can provide important insights on the cellular components and chemical makeup of the seed, which can help comprehend the processes involved in its germination and growth. Researchers can examine the structure of foxtail palm seeds in detail to learn more about their traits and germination behavior by combining various analytical techniques.

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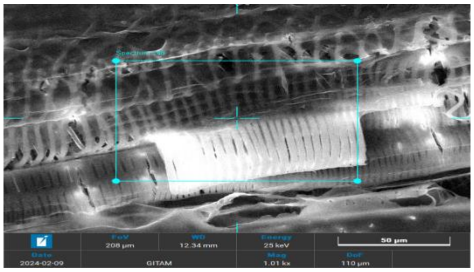


Figure 3: Structure analysis of foxtail palm seed.

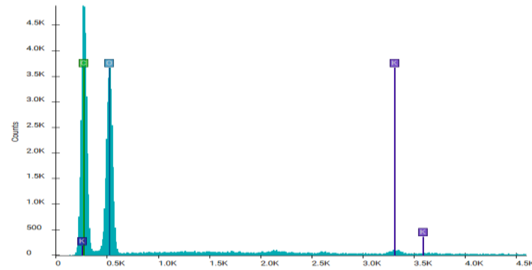
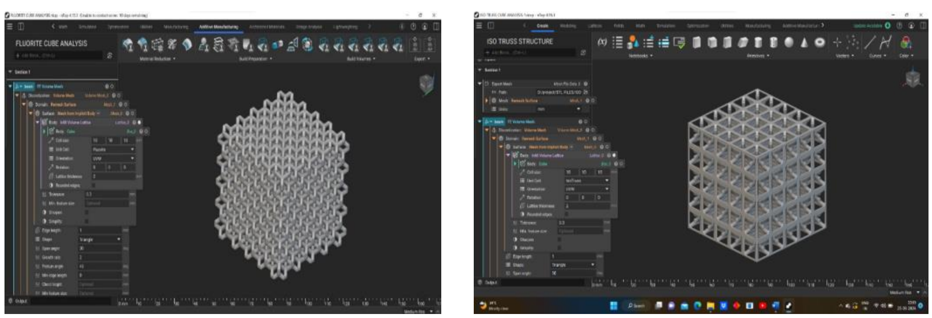


Figure 4: EDX Analysis of foxtail palm seed fiber.

3.1.2. Design and Analysis of Lattice Structures:

Making intricate models to examine the structure and properties of foxtail palm seeds can be a part of the design and analysis process utilizing nTopology software[15], [16]. These workflows can be used to model numerous situations pertaining to the behavior and structure of the seed, assisting in the comprehension of its performance in various circumstances[17]. With nTopology software's sophisticated functionalities, scientists may do comprehensive design and analysis of foxtail palm seeds, thereby augmenting their comprehension of the seeds' morphology and its uses. To fully grasp the features and actions of materials that have fluorite structures, it is necessary to carefully study their structures (Vide in Figure 5a), investigation is essential. It entails examining how crystal defects, lattice factors, and ion coordination affect the structural stability and functional characteristics of fluorite compounds. The utilization of nTopology software in the design and analysis of Iso-Truss structures entails employing sophisticated tools for geometric morphometric analysis and simulation operations. Iso-Truss structures are distinguished by its lattice-like configuration shown in Figure 5b, which provides exceptional strength-to-weight ratios and structural efficiency.



(a) (b)

Figure 5: Design of bio lattice structures (a) Fluorite (b) Iso-Truss

4. Result Analysis

4.1.1. Discussion of Static Analysis on Lattice Structure:

The Displacement result has shown the model deformed under the given boundary conditions as displacement resistant and load 100N in z- axis. The obtained maximum and minimum of total deformation, as shown in figure 6(a) and 6(b).

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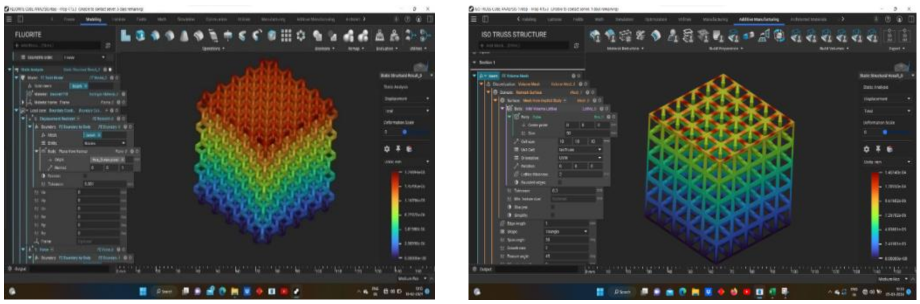
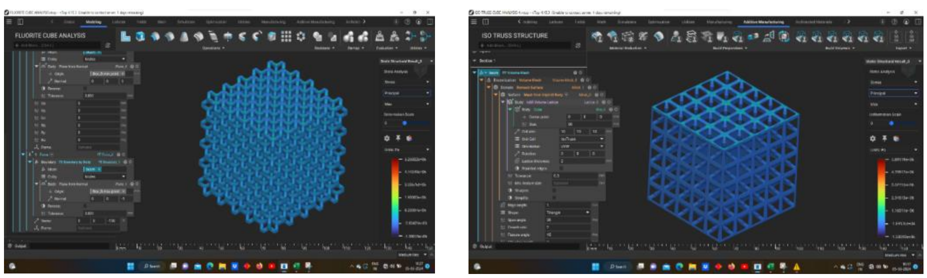


(a) **(b)**

Figure 6: Displacement in Static analysis (a) Fluorite (b) Iso-Truss

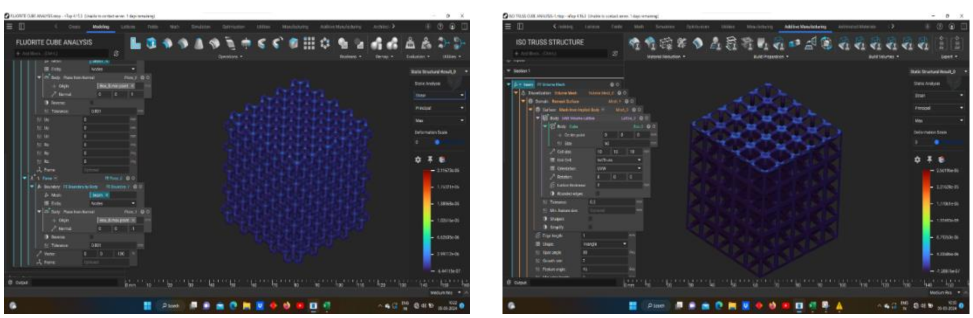
The Stress results has shown, the model stressed under the given boundary conditions as displacement resistant (0,0,0) and load (0,0,-100).Here the principal stresses are developed as shown in figure 7(a) and 7(b).



(a) (b)

Figure 7 Principal stress in Static analysis(a) Fluorite (b) Iso-Truss

The strain results has shown, the model deformed under the given boundary conditions as displacement resistant (0,0,0) and load (0,0, -100). The maximum and minimum values of strain developed as shown in figure 8(a) and fig 8(b).



(a) (b)

Figure 8: Strain in Static analysis(a) Fluorite (b) Iso-Truss

The results are summarized in Table 1 of lattice structures. It clearly representing the maximum displacement occurred in Iso-Truss. Similarly found the maximum Stress and maximum Stain in Fluorite lattice structure.

Table1: Analytical Analysis of lattice structure

S.NO	STRUCTURE	DISPLACEMENT		STRESS		STRAIN	
		MAX	MIN	MAX	MIN	MAX	MIN
1	ISO TRUSS	1.45140e-04	2.41901e-05	7.48879e+06	1.20706e+01	2.66196e-05	-1.20876e-07
2	FLUORITE	1.54122e-04	2.56870e-05	4.83732e+06	1.67139e+04	2.11673e-05	-6.44115e-07

5. Conclusion:

In this work, nTopology software is used to create lattice structures, drawing inspiration from the complex microstructure of foxtail palm seeds. The foxtail palm seed fibers' microstructure using FE-SEM analysis, revealing their amazing intricacy. Next, two lattice structures were created that mirrored the fundamental design principles of the seed: fluorite and iso-truss. Based on the data designed lattice shapes that were optimized for strength and resilience by utilizing the adaptability of nTopology. By bridging biomimicry and computational design, this multidisciplinary method opens upnewavenues for solving engineering problems. The research highlights how biomimetic-inspired design can be used to develop cutting-edge materials and structures. By working on this work, support innovation at the nexus of nature and technology by advancing computational tools and biomimetic design processes.

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