Application of 3D Printing Technology for Designing Light-weight Unmanned Aerial Vehicle Wing Structures

Dr. Arun Kumar Marandi, Assistant Professor

Department of Computer Science, Arka Jain University, Jamshedpur, Jharkhand, India

Email Id-dr.arun@arkajainuniversity.ac.in

ABSTRACT: Unmanned Aerial Vehicles (UAVs) have been created for a variety of military and civilian purposes, including reconnaissance, attack missions, pipeline monitoring, and interplanetary exploration. The goal of this study is to create rapid adaptive UAV design technologies for nimble, fuel-efficient, and flexible structures that can adapt and operate in a variety of situations. The goal of this study is to investigate existing design techniques and understanding of deployable technologies in the field of engineering design and manufacturing in order to create adaptive design technologies. According to the Hashin & Shtrikman theoretical limits, this study aims to find one truss lattice with the best elastic performance for deployable UAV wing design. Three lattice structures are proposed: a 3D Kagome structure, a 3D pyramidal structure, and a hexagonal diamond structure. The suggested lattice structure designs are printed on an Objet 350 3D printer with a polypropylene-like photopolymer named Objet DurusWhite RGD430 as the material. The suggested inflatable wing design, based on compression testing, would combine the benefits of compliant mechanisms and deployable structures to enhance movement flexibility in UAV design and development.

KEYWORDS: Aerial vehicle, 3D Printing, Manufacturing Industry, Structure, Unmanned Aerial.

1. INTRODUCTION

By progressively adding material to a geometrical representation, 3D printing may produce actual things. In recent years, this 3D technique has grown in popularity. Charles Hull was the first to commercialize 3D printing in 1980. 3D printing is currently mostly utilized to make man-made objects. 3D printed corneas, PGA rocket engines, steel bridges in Amsterdam, heart pumps, jewelry collections, PGA rocket engines, steel bridges in Amsterdam, and other aviation and culinary-related goods 3D printing (3D) is a layer-by-layer technique of producing three-dimensional objects. Directly from a CAD design, structures are built. 3D printing is a cutting-edge technology that has proven itself as a flexible and adaptable technological stage. It expands the range of options available to businesses seeking to increase efficiency. Materials made of graphene, thermosets, and ceramics Metal and materials are among the materials that can currently be produced utilizing 3D printers.

3D printing is a technique for creating three-dimensional objects. Industry and industrial processes may be changed by technology. 3D Printing's Acceptance Thanks to technological advancements, manufacturing will be expedited while expenses are lowered. At the very same time, consumer demand is increasing. will have greater production control Consumers have a greater say in the final product and may make specific requests. It was created especially for them. In the meanwhile, 3D printing technology facilities will become more interconnected. providing for more flexibility and responsiveness in the production process, as well as better quality control Furthermore, the use of 3D printing technology reduces the requirement for worldwide shipping. This is due to the fact that when production facilities are closer to the final destination, all distribution may be handled locally. This was accomplished by using fleet monitoring technology, which conserves both energy and time. Finally, the technology of 3D printing has the potential to be beneficial. The company's logistics should be restructured. Businesses' logistics departments may be able to oversee the whole process and offer additional options. There are services accessible that are comprehensive and finished. 3D printing is now extensively utilized all around the world.

Unmanned Aerial Vehicles (UAVs) have been created for a variety of military and civilian purposes, including reconnaissance, attack missions, pipeline monitoring, and interplanetary exploration. Due to a broad variety of possible applications with sophisticated operations and greater flexibility for smaller transportation containers and storage, tiny and deployable UAVs have recently garnered interest. Although the concept of integrating inflatable structures into flight has been around for a long time, inflatable wing technology has only recently been developed. The Goodyear inflatoplane, created in the 1950s, was one of the first successful demonstrations. Goodyear Aerospace developed and built a number of aircraft prototypes using inflatable components during this time.

The GA-468 Inflatoplane was one of their last designs. The inflatoplane was created as a military rescue plane that could be dropped behind enemy lines near fallen pilots in order to assist them in escaping. NASA's Dryden research facility has created the 12000 micro UAV, which has wings composed of inflated tubes enclosed by crushable foam. The UAV was launched from a bigger UAV "mother ship" at approximately 300 meters height during its test flight, and its inflatable wings expanded from a compressed condition in about one-third of a second. Vertigo, Inc. designed the wings as a gun-launched observation vehicle for the US Navy. The I2000 is considerably smaller than the inflatoplane, having a wingspan of 1.63 m and a chord length of 0.18 m. Improved portability via decreased volume/weight ratio may be achieved by altering the wings of a UAV from a rigid to an inflatable design. Another benefit of utilizing an inflatable wing is that the shape of the wing may be readily modified to meet mission needs, such as from conventional wing spans to high-aspect ratio designs. The stiffness and yield strength of high-strength light-weight materials can be achieved at low densities. They aid in the achievement of fuel economy objectives in the aerospace and automobile sectors, among other industries. High-strength light-weight materials include honeycombs, foams, and truss lattice constructions.

The three architectures have been thoroughly researched and refined to offer distinct performance advantages in a variety of applications. In terms of elastic modulus, 3D truss lattices outperform both metal foams and honeycombs, according to published findings. Furthermore, unlike closed cell metal foams and honeycombs, which are only open in one direction, truss lattices have an open structure that allows for multi-functional applications such as heat transmission. The goal of this study is to investigate existing design techniques and understanding of deployable technologies in the field of engineering design and manufacturing in order to create adaptive design technologies. We look at the apparent strengths of truss lattices in order to find the truss lattice with the best elastic performance. For deployable UAV wing design, we examine the compressive strength of three lattice structures with excellent elastic performance. For compression testing, we suggest three lattice designs: 3D Kagome structure, 3D pyramidal structure, and hexagonal diamond structure.

The suggested lattice structure designs are printed on an Objet 350 3D printer with a polypropylene-like photopolymer named Objet DurusWhite RGD430 as the material. The suggested inflatable wing design, based on compression testing, would combine the benefits of compliant mechanisms and deployable structures to enhance movement flexibility in UAV development. The rest of this paper is laid out as follows. The second section of the paper goes through some background information and relevant research on lattice structures. There are several alternatives for mass-producing lattice structures, however they are restricted when producing one-offs or small numbers. Complex designs with undercuts and overhanging elements exacerbate the issue since only a few traditional production methods can manufacture them. Multiple variations for various geometric characteristics of the design, such as truss diameter, unit cell size, and density of structure, may be required for testing reasons, implying that additional tooling is necessary.

The layer-by-layer method enables any forms, including lattice structures, to be readily generated directly from computer-aided design (CAD) files, making AM a less costly and more flexible design and production alternative. Furthermore, whether the machine produces one component or hundreds, the cost per unit of an AM part remains the same. Objet Geometries Ltd is a company that sells the technique that was selected. To create 3D components, it combines ink-jet technology with the usage of photopolymers as raw materials. The Objet 350 3D printer was used, and the photopolymer used was Objet DurusWhite RGD430, which is a polypropylene-like substance. The printer works by depositing liquid photopolymer in the form of 3D objects and then subjecting the liquid to ultra-violet radiation to harden it, according to at least one US patent document issued to the firm. The CAD model of the different structures is created in accordance with industry standards.

All test specimens had their relative core density adjusted to 0.04 since the original relative density of 0.02 caused postprocessing issues during manufacturing. Instead of following a predetermined number of unit cells in any direction, we chose to set the height of all the specimens at 33.68 mm. The thickness of the face sheet was maintained consistent throughout at 5 mm. To reduce the impacts of the layer-by-layer manufacturing method, such as anisotropic characteristics of the finished components during testing, the parts were constructed from the bottom up with the face sheet positioned orthogonally to the built direction. components that have been finished . Component and production design flexibility are unmatched thanks to 3D printing technology.

In the aircraft industry, 3d printing allows for the production of lightweight materials with more complex forms while using less energy and resources. Simultaneously, 3D printing technology has the potential to conserve fuel by decreasing the quantity of material required to produce aeronautical components. Furthermore, 3D printing has been widely utilized to produce spare parts for aviation elements such as engines. The component of the engine is easily damaged and requires replacement on a regular basis. As a consequence, 3D printing technology has emerged as a feasible alternative for obtaining such replacement parts. Because of their tensile properties, oxidation/corrosion resistance, and damage tolerance, nickel-based alloys are used in the aerospace industry.

1.1 Additive Manufacturing:

AM refers to a set of technologies for creating physical models, prototypes, patterns, tooling components, and final production parts using computer data, three-dimensional scanning systems, or video games. 8Unlike conventional subtractive manufacturing methods such as machining, AM builds things layer by layer via the combining of liquid, powder, or sheet materials. AM is used to make components that would be difficult or impossible to make using other methods. Stereolithography, selective laser melting (SLM), three-dimensional printing (3DP), and fused deposition modeling are examples of these technologies (FDM). Each technology has its own set of advantages and disadvantages. The number of AM technologies is steadily increasing as designers, engineers, and other professionals become more aware of, embrace, and use these technologies.

1.2 Structures for High-strength Light-weight Materials:

A honeycomb is made up of hollow cells that are divided by thin vertical walls. Columnar and hexagonal cells are the most common, although rectangular and triangular forms are also conceivable. Sandwich composite panels for use in aviation constructions are a typical use of honeycomb[1]. Metal foams are sponge-like materials made by pumping an inert gas into molten metal. The outcome is a solid that is filled with voids of all sizes and shapes. A closed cell metal foam is produced when individual voids are completely enclosed by the solid. Similarly, an open cell metal foam is produced when the voids overlap and form an interconnected network[2].

Repeating units of similar skeletal structures of geometric three-dimensional forms such as a polyhedron are placed in a regular manner to form lattice structures. Lattice structures are now easier to construct than ever before thanks to new manufacturing techniques. The techniques developed allow for the creation of complete lattice structures of unit cells ranging in size from millimeters to centimeters[3]. The mechanical characteristics of honeycombs, metal foams, and truss lattices have been thoroughly researched, with many papers available. The elastic moduli of honeycombs, metal foams, and truss lattices are compared to the Hashin-Shtrikman (HS) limits using data from the literature.

Honeycombs are likened to foams in certain cases, while truss lattices are compared to honeycombs in others[4]. For a particular phase volume percentage, the HS upper limit reflects the highest effective elastic moduli of isotropic two-phase composites. Rank-6 laminates are known to achieve the HS limits on the bulk and shear moduli in 3D applications[5]. Rank laminates are created via a sequential procedure in which the preceding laminate is laminated again in a different direction with a single lamina at each step. A rank laminate, on the other hand, is a multi-length-scale construction that cannot be manufactured. As a result, a single-length-scale replacement in honeycombs, foams, or truss lattices with the best microstructure is required[6].

One study found that closed cell foams may outperform honeycombs in terms of shear strength and shear modulus, according to relevant research. Closed cell foams also have compressive strengths that are isotropic yet similar to honeycomb compressive values in the thickness direction[6]. Closed cell foams, on the other hand, do not seem to reach the HS top limits, according to the research[7]. The bulk and shear moduli of an octet-truss lattice material with singlelength-scale microstructure were compared to the HS upper limit and found to be approximately half of what could be achieved. The stiffness and strength of the octet-truss lattice were compared to metal foams in the research, and the lattice was found to be 3 to 10 times stiffer[4].

1.3 Description of 3D Lattice Structures:

3D Kagome lattice structure the 2D Kagome structure began as a traditional bamboo basket weave pattern and was found as an optimum structure for a variety of fraction volumes via topology optimization. A recent study looked at whether the better characteristics found in the 2D version were transferred over to the 3D variant. Both tetrahedral and pyramidal truss core panels were shown to be inferior than 14 3D Kagome core panels. The 3D variant's reduced susceptibility to plastic buckling was ascribed to its higher load bearing capacity and lower softening rate after the peak load in both analytical and empirical tests[8]. The 3D Kagome structure is evaluated as a truss core panel sandwiched between two solid face sheets in this experiment, as illustrated in Figure 1. This is the same setup as in previous trials. Pairs of tetrahedrons are vertically inverted and rotated 60 degrees away from each other to create the 3D Kagome structure.

The hexagonal diamond structure is a hexagonal variation of the cubic diamond structure. It was discovered imbedded in meteorites and created in the lab at high temperatures and pressures. This structure is also seen in carbon films produced by chemical vapor deposition, which have a high density of (111) microtwins and stacking faults. The hexagonal and cubic diamonds have comparable local atomic configurations. Both feature six-membered rings of bonding and covalent tetrahedral links. The arrangement of their (111) atomic layers is the primary distinction (each pair labeled as A, B or C). Each succeeding layer in the cubic diamond is pushed laterally from the preceding, with the fourth layer returning to the same location as the first, resulting in the ABCABC stacking pattern.The hexagonal diamond stacking sequence, on the other hand, is of the form ABAB.... More significantly, research has revealed that hexagonal diamonds are 58 percent tougher than cubic diamonds and can withstand indentation pressure of up to 152 GPA. We're interested in assessing the performance of hexagonal diamond as a macro-sized lattice structure because of its unique characteristics. Figure 2 depicts the hexagonal diamond's unit cell structure. Structure in the form of a cross pyramid - Four inclined trusses connect at a sheet node to form a pyramidal lattice structure. The benefit of this design is that the inclination of the trusses may be changed to sustain more compressive or shear stress depending on the structure's needs. We changed the original design and derived an alternative structure created by placing two pyramidal structures against each other in order to get a design that can be more readily transformed into a multi-layered structure. Figure 3 depicts an alternative design.

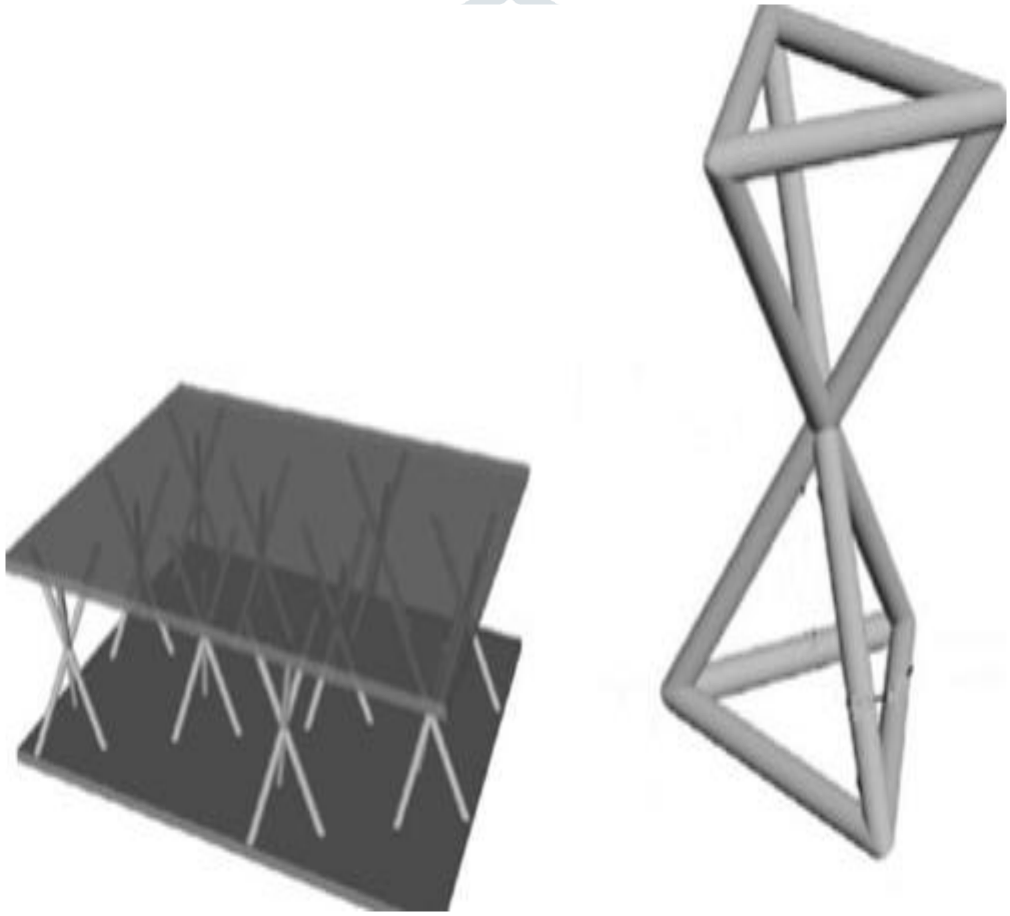

Figure 1: 3D Kagome truss core panel and unit cell of 3D Kagome structure16

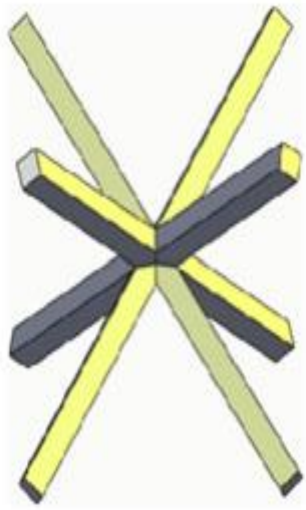

Figure 2: Hexagonal diamond structure.

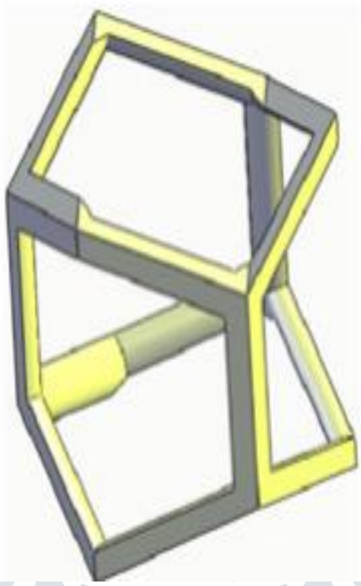

Figure 3: Cross pyramidal structure.

Three-dimensional (3D) printing is an additive manufacturing technique that involves laying down successive layers of material to create a three-dimensional object. 3D printers are machines that create models of objects that have been designed with CAD software or scanned with a 3D scanner. Printing is a technique for reproducing text and images using ink on paper. Different methods, such as selective laser sintering (SLS), stereolithography, fused deposition modeling, and laminated object manufacturing, can be used to print different dental pieces. Individual impression trays, orthodontic models, gingiva masks, and various prosthetic objects can all be printed with the materials. The material's flexural strength is more than 80 MPa. Digital projects are now more effective in the manufacturing phase thanks to 3D printing. Using a combination of oral scanning, 3D printing, and CAD/CAM design, dental laboratories can create crowns, bridges, stone models, and various orthodontic appliances. For several years, modern 3D printing has been used to develop prototypes, and it is now finding its way into the manufacturing world [9]. Using custom surgical guides and improving the quality and accuracy of dental work, digital technology and 3D printing have significantly increased the rate of success in dental implantology [10]. Propose that Unmanned Aerial Vehicles (UAVs) have been created for a variety of military and civilian purposes, including reconnaissance, attack missions, pipeline monitoring, and interplanetary exploration. The goal of this study is to create rapid adaptive UAV design technologies for nimble, fuel-efficient, and flexible structures that can adapt and operate in a variety of situations. The goal of this study is to investigate existing design techniques and understanding of deployable technologies in the field of engineering design and manufacturing in order to create adaptive design technologies. According to the Hashin & Shtrikman theoretical limits, this study aims to find one truss lattice with the best elastic performance for deployable UAV wing design. Three lattice structures are proposed: a 3D Kagome structure, a 3D pyramidal structure, and a hexagonal diamond structure. The suggested lattice structure designs are printed on an Objet 350 3D printer with a polypropylene-like photopolymer named Objet DurusWhite RGD430 as the material. The suggested inflatable wing design, based on compression testing, would combine the benefits of compliant mechanisms and deployable structures to enhance movement flexibility in UAV design and development. The Korean Society for Precision Engineering was founded in 2014[4].

2. DISCUSSION

The compression strength of the suggested three lattice constructions was evaluated. The experimental data was used to plot the stress-strain curves, which are displayed. The Kagome structure is shown to be able to resist the maximum compression stress of 0.65 MPa at a strain of 3.8 percent before softening. The 3D pyramidal structure softened at a lower stress of 0.2 MPa before softening, while the hexagonal diamond structure did not soften at all, even at strains of more than 8% - the equivalent stress being about 0.1 MPa. The hexagonal diamond's test was halted before the start of plastic buckling at 9 percent strain, unlike the other forms. With the exception of the hexagonal diamond structure, all of the constructions examined show signs of plastic buckling. The compression test parameters were transformed to non-dimensional units consisting of compressive forces to ensure that the findings were legitimate. This research delves into the landscape of 3D printing in the industrial sector. Individuals, companies, and governments all benefit from 3D printing technology, which is now gaining momentum in the industrial sector. As a consequence, more data is needed to advance techniques for improving 3D printing usage. Companies and governments will benefit from more understanding of 3D printing technology as they upgrade and improve the technology's infrastructure. As a consequence, the objective of this report is to give an overview of the many types of 3D printing technologies, as well as the materials used in 3D printing technology in the manufacturing sector and 3D printing technology applications. Researchers may look at the many kinds of 3D printing machines as well as the suitable materials for each type of machine in the future. Mandible contouring osteoplasty is a procedure that is used to improve the appearance of the mandible.

3. CONCLUSION

We used the principles of compliant mechanics to inflatable wing design for tiny and deployable UAVs in this study. The apparent strengths of truss lattices were studied in order to determine which truss lattice had the best elastic performance according to the Hashin and Shtrikman limits. The compressive strength of their lattice structures with good elastic performance were compared using 3D Kagome lattice, hexagonal diamond, and cross pyramidal structures. Although the hexagonal diamond showed the perfect characteristics of energy absorbers, the findings indicated that the 3D Kagome had the greatest load capacity. We created a prototype wing section for UAVs using 3D printing technology to show and verify the utility of the suggested inflated design. Other characteristics of the constructions, such as tensile and shear strengths, will be investigated in the future, as well as numerical simulations. To reduce the impact of boundary conditions, the structures will be extended to at least 5-7 unit cells in each direction. 3D printers is a quick, simple, and fairly priced method. Currently, a wide range of materials and technologies with various characteristics and parameters are available (the scope of the following article is extremely restricted, consisting solely of a selection of typical popular technologies). This enables a potential researcher to choose the technology that best meets his demands while still fulfilling the experiment's requirements. Thin-walled models with tough exteriors have been successfully manufactured. It is possible to 3D print holes with a high length-to-diameter ratio, as well as very small objects (like measurement holes of 0.4mm diameter). However, not all of the 3D printing techniques on exhibit are perfect. The method and materials used have a direct bearing on the final product's quality.

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