Based on the lattice structure of the sandwich structure of 3D printing

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Abstract. Lattice structure materials have great advantages in thermal, electrical and optical properties, and as a potential lightweight materials have attracted much attention. The inherent complexity of lattice structure makes 3D printing technology and its manufacturing have a natural junction. One of the advantages of 3D printing is that its flexibility and printing cost are insensitive to the complexity of products, so complex lattice structure has become a hot research direction in the field of 3D printing. In this project, we proposed a new lattice sandwich structure, and further studied its mechanical properties, explored its mechanical properties in three-point bending experiment, and prospected its specific application in engineering.

1. Introduction
As a potential multifunctional composite structure, lattice structure has a broad application prospect in energy absorption, electromagnetic scattering and absorption, heat transfer, structure control and intelligent materials. In product design, the mechanical performance of lattice, such as large surface area, excellent shock absorption performance, impact protection, can overcome the limitations of traditional manufacturing, to create new, higher performance products. Lattice design can reduce weight by reducing material in both non-critical areas and critical areas of the part. This sometimes does reduce the overall strength of the part, but it can increase the strength to weight ratio. Lattice structure materials are not only light in weight, but also can release a large amount of surface area, such structures can promote heat exchange and chemical reactions. In addition, different lattice mesoscopic structures will achieve different mechanical properties. Excellent shock and impact protection lattice can also protect products by better absorbing energy. For example, the middle sole of sports shoes with lattice structure and the buffer structure of football helmet can absorb the impact force to play a role of safety protection when subjected to external force. Strengthening lattice can also reduce mechanical noise and vibration. Because of its low stiffness and strong ability to withstand and recover large strain, lattice is very effective in suppressing vibration.

The lightweight structure composed of panel and sandwich core is widely used in aerospace, transportation, civil and military fields, with high stiffness ratio, good thermal insulation performance and other multi-functional characteristics. The lattice structure is simulated by finite element simulation, and the cross section of body - centered cubic diagonal beam is variable. Wu ZL et al. studied the topology design, preparation method, mechanical properties, failure mechanism and
analysis model of the new lattice truss composite sandwich plate. In recent years, many lattice structures with 3D lattice structures have been designed.

This project aims to find has the light quality high strength characteristics of dot matrix composites reinforced polymer structure, using modelling software to design a lattice structure and a series of mechanical properties of the structure analysis, considering the lattice composites reinforced polymer mechanics performance optimization, study the effect of lattice structure of composite sandwich structure are studied.

2. Materials and experiments

2.1. Physical design

In this study, we designed a lattice sandwich structure as shown in figure 1. The sandwich structure consists of two aluminum face sheets and a lattice core. The core is a composite structure composed of body core structure and face core structure. Its overall size is 160 mm × 40 mm × 10 mm.

Lattice structure elements are shown in Figure 2.

Figure 1. The proposed sandwich structure.

Figure 2. Cutaway view and outside view.

The lattice cores were fabricated using a Stereo lithography (SLA) 3D printer (Nanotech RS6000) with a low-viscosity stereo lithography resin (Somos® GP plus 14122). The face sheet is aluminum.
alloy (AA) 1060-O with a thickness of 1.0mm. The sandwich structures were made by gluing two AA1060-O face sheets and one core together with adhesive (3M Scotch-Grip 1357). The parameters of relevant materials used in the experiment are shown in Table 1.

| Physical properties table |
|---------------------------|
| Face-sheet(AA1060-O)      |
| Young’s modulus (GPa)     | 50   |
| Yield strength (MPa)      | 110  |
| Ultimate yield strength (MPa) | 138.3 |
| Poisson’s ratio           | 0.33 |
| Core material(Somos® GP Plus 14122) |
| Tensile modulus (GPa)     | 2.51 |
| Tensile strength (MPa)    | 37.0 |
| Flexural modulus (GPa)    | 2.20 |
| Flexural strength (MPa)   | 67.3 |
| Elongation at break       | 7.5% |
| Poisson’s ratio           | 0.41 |

2.2. Three-point bending tests
Three-point bending tests were performed in a universal testing machine (Model: DNS-100, Sinotest Equipment Co., Ltd.). The transverse quasi-static load was applied by a central roller with 15 mm diameter. The support span length between two outer cylindrical rollers was 80 mm. The data acquisition rate for tests was set as 10 Hz for loads and displacements. According to GB-T1456-2005, the sandwich samples were loaded up to material failure at a displacement rate of 2 mm/min with a preload of 5 N.

The 3d-printed samples in this experiment should be kept in a dry environment, with less direct contact with the air during storage, so as to avoid changing the mechanical properties of the samples due to moisture absorption in the air

3. Results and analysis

3.1. The experimental results
The following data were obtained by three point bending experiment.

Experimental three-point bending load-deflection curves for sandwich structure are presented in Figure 3.

![Figure 3. Cutaway view and outside view.](image)
As can be seen from the figure, the load and deflection curves of lattice sandwich structure can be roughly divided into three stages. In the first stage, the curve is similar to a straight line, and the bearing capacity increases linearly with the increase of deflection. In this stage, the damage resistance of the structure can be reflected, that is, the bending stiffness. In the second stage, the curve slows down. In this stage, the damage of materials has begun, but the sample has not completely cracked, so the bearing capacity continues to rise. The long duration of this stage indicates that the bearing capacity is good and more energy is absorbed. In the third stage, the bearing capacity decreased sharply and the sample cracked, but there was still some residual bearing capacity due to its structure.

3.2. Failure mechanisms
When the load is increased, two aluminum face sheets can disperse the stress on the core surface of the lattice, thus reducing the stress concentration damage to the core of the sample. The fracture of the sample basically starts from the center of the bottom, and the tensile stress will first cause the bottom of the core structure to fracture. Meanwhile, the fracture will spread from the bottom to the unloading of the bearing capacity.

There are three possible failure modes of sandwich structures in three point bending experiments. The first is panel failure, including panel collapse, panel folding, panel fracture, panel indentation; the second is core structure failure, including core structure pillar distortion, pillar fracture; the third is the panel and core degumming separation, resulting in mechanical properties decline.

In the process of this experiment, there were no panel collapse and panel folding phenomena. Although the aluminium plate was deformed, it had good elastic properties, and no fracture occurred, which resulted in indentation on the upper and lower surfaces of the aluminium plate. At the same time, under the action of glue, there is no separation of core and panel, and the failure of sample mainly occurs in the interior of lattice sandwich structure. Diffusion from the local to the whole.

3.3. Energy absorption
The three stages are shown in Figure 4. The energy absorbed is shown in Table 2.

![Figure 4. Three theoretical stages](image)

### Table 2. The first two stages of energy calculation (J)

| Energy absorbed | Stage I | Stage II | Total |
|-----------------|--------|---------|-------|
| First           | 1.17   | 3.60    | 4.77  |
| Second          | 1.55   | 4.59    | 6.14  |
4. Conclusion
In this paper, a novel lattice sandwich structure model is proposed, the sample is made by 3D modeling and 3D printing, and the three-point bending mechanics test is carried out. Experiments have proved that the structure has good mechanical properties and can bear a large load. Meanwhile, the core mass of the sandwich structure is greatly reduced compared with that of the solid structure. While realizing the lightweight structure, the structure can still maintain a large bearing capacity, anti-bending capacity and energy absorption capacity. If the structure is applied to the field of actual production and manufacturing, it may have a broader application prospect. The combination of traditional lattice structure and 3D printing technology will also attract more researchers' attention. The impact resistance of the structure needs to be further studied and the topology optimization needs to be developed.

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