Research Article

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Fabrication and low-velocity impact response of pyramidal lattice stitched foam sandwich composites

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Abstract: In this study, the foam sandwich panels were manufactured by integrating top facesheet and bottom facesheet with pyramidal lattice stitched core to overcome the weak interface between the core and skins of the sandwich structures. Low-velocity impact test and numerical simulation were conducted to reveal the failure mechanisms and energy absorption capacity at sandwich composite with foam core, different strut stitched foam core under different impact energy. The experimental results show showed that the strut core can improve the impact resistance of the specimen, and which is closely related to the diameter of the strut core. Compared with foam sandwich structure, pyramidal lattice stitched foam sandwich composites have comparable specific energy absorptions. The failure modes were also analyzed which is: fiber breakage, delamination, foam deformation and strut core breakage. The research presented here confirms that numerical simulation show good agreement with the experiment.

Keywords: pyramidal lattice core; low-velocity impact test; numerical simulation; failure modes

1 Introduction

Composite sandwich structures have been attracted considerable critical attention in aerospace and automobile industries due to the benefit of high strength construction with light weight [1–3]. In recent years, there has been increasing academic interest in lattice stitched foam sandwich composites which have excellent strength, stiffness and overall stability [4–11].

Due to the broad prospects of the foam lattice sandwich structure, there has been a series of methods proposed by the researchers for manufacturing specimens, such as hot press molding, weaving and sheet folding [12–14]. Finnegan [15] using waterjet cutting machine to cut the composite laminate along the fiber direction into the continuous 2-D slot-fitting strut cores and then the strut core was assembled with the top and bottom facesheets to manufacture the specimens. In Ref. [16], hot press molding was used to manufacture composite sandwich beams with lattice core. The author put the top and bottom facesheets and strut cores which were made up of carbon fiber prepreg into the rigid mold and then the sample was vacuum bagged and cured in an autoclave. Wang *et al.* [17, 18] manufactured foam sandwich structures which were reinforced by carbon fiber columns.

Impact is one of the most frequently stated problems with the composite sandwich structures [19–22]. The invisible damage caused by inadvertent impact seriously affects the strength and stiffness of the structures and there are a variety of impact failure modes, so it is essential to investigate the impact of sandwich structure. Prakash *et al.* have studied the low velocity impact behavior of the sandwich composites with honeycomb core [23]. The experimental results demonstrated that the impact response is shown to be greatly influenced by the core cell size. Wang L and Wu Z investigated the impact damage of the sandwich wall panels with glass fiber-reinforced polymer skin and a foam-web core. And the work researched the residual axial strength of the impacted panels with varying impact energies [24]. Wu Y and Wan Y conducted impact test and compression after impact test of foam core sandwich panels with shape memory alloy hybrid facesheets. It is found that the specimen have a better impact resistance performance due to the shape memory alloy added to the facesheets [25]. Wu *et al.* [26] investigated the impact damage and the residual compressive strength of impact-damaged pyramidal truss core sandwich structures, finding that the extent of damage was significantly affected by the impact site. Han *et al.* [27] established numerical model

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of the stitched foam-core sandwich composites subjected to low-velocity impact. The numerical simulation results and the experiment results are in good agreement. It is revealed that stitching could bridge the delamination crack, thereby suppressing crack propagation and raising the ultimate strength.

Up to now, stacks of research papers have been carried out in studying the impact resistance of the sandwich composite with foam/honeycomb/strut core. In this essay, the study aims to use the high-strength carbon fiber strut to reinforce a low-modulus and lightweight foam sandwich structure. The study explored a new method of manufacturing pyramidal lattice stitched foam sandwich composites to enhance the strength of the structures, and study the impact damage of the foam sandwich composites and the pyramidal lattice stitched foam sandwich composites after impact. Firstly, we explore the failure mechanisms of the structures in different impact energy and different core diameter. What's more, the impact response of the pyramidal lattice stitched foam sandwich composites have been compared with the damage of the foam sandwich struc-

ture. Last but not least, numerical simulation of the specimen was established to analyze impact damage.

2 Experiments

2.1 Specimen fabrication

Carbon fiber reinforced epoxy resin is used to fabricate the pyramidal lattice stitched foam sandwich structure. The top and bottom facesheets consisted of 16 layers of unidirectional carbon/epoxy prepreg (T700/TDE85, China Carbon Technology Co., Ltd, China), the stacking sequence is $[0^\circ/90^\circ]_s$. The mechanical properties of the T700/TDE85 composite are detailed in Table 1. The foam consists of ArmaFORM PET (Armacell International GmbH, China); the experiment parameter is listed in Table 2. The diameter of the strut core is 1mm and 1.4mm, respectively.

In this paper, a set of preparation process, as shown in Figure 1, is designed for lattice stitched foam sandwich plants. Firstly, 8 layers of unidirectional carbon/epoxy prepregged laminates, the stacking sequence is $[0^\circ/90^\circ]_s$,

Figure 1: The process for the fabrication of the pyramidal lattice stitched foam sandwich panels.

Table 1: Mechanical property of T700 / TDE85 composite materials

Property	Value
Longitudinal stiffness E_{11} (GPa)	132
Young's modulus $E_{22} = E_{33}$ (GPa)	10.3
Poisson's ratio $\mu_{12} = \mu_{13}$	0.25
Poisson's ratio μ_{23}	0.38
Shear modulus $G_{12} = G_{13}$ (GPa)	6.5
Shear modulus G_{23} (GPa)	3.91
Longitudinal tensile strength (MPa)	2100
Longitudinal compressive strength (MPa)	1050
Transverse tensile strength (MPa)	24
Transverse compressive strength (MPa)	132
Interlaminar shear strength (MPa)	75
Out-of-plane tensile strength (MPa)	65
Density ρ (kg/m ³)	1570
Fiber volume content	58±2%

Table 2: The experiment parameter of ArmaFORM PET

Material	Density (kg/m ³)	Compressive	Compression	shear strength
FORM	80	1.0	75	0.6

Figure 2: Drop-weight machine Instron 9250HV.

with the holes were fabricated as the top and bottom facesheets. Subsequently, fix the foam and the perforated panels together, and pierce the foam with a hot steel needle. The holes were drilled for sewing the foam and the facesheets, which were stitched through the Continuous carbon fiber towpreg. Then, 8 layers of carbon/epoxy prepregged laminates with the stacking sequence $[0^\circ/90^\circ]_s$ were used to cover the top and the bottom surface of the prototype structure. Finally, put the samples into a vacuum bag for sealing and vacuuming, and

then the samples are cured in an autoclave at 135°C for 2.5hours.

2.2 Low-velocity impact tests

In LIV experiment, the impact tests were performed by using a drop weight impact testing machine of which the Instron Dynatup 9250HV is given in Figure 2. The impactor has a hemispherical nose with a diameter of 12.7mm, where there is a force transducer to collect the impact data. The impact testing machine consists of steel nose, force transducer and additional weight mass which were set to 6.15kg during the test. During the impact, the test piece was fixed by a pneumatic clamp. The outer dimensions of the pneumatic clamp were 100 mm × 100 mm, and there was a circular cavity with a diameter of 76.2 mm. A pneumatic valve is provided around the pneumatic clamp. When the drop hammer rebounds, the pneumatic valve pops up to prevent the secondary impact of the drop hammer. In this paper, a variety of impact energies are gained by changing the impactor's height.

In this research, the specimens are divided into three categories which are listed in Table 3. Specimen A is a foam sandwich structure with the impact point in the center. Specimen B is a pyramid lattice foam sandwich structure with a strut core diameter of 1 mm, and the case is the

Table 3: Specifications of the sandwich composite specimens used in the study.

Specimen code	Core type	Impact site
A	Non perforated foam	SN
B	Perforated foam with 1mm strut stitched	SN
C	Perforated foam with 1.4mm strut stitched	SN

impact site located on the node (Impact site SN shown in Figure 3). Specimen C is a pyramid lattice foam sandwich structure with a strut core diameter of 1.4 mm, the case is the impact site located on the node (Impact site SN). Impact energy can be selected from 15 J, 30 J, 45 J and 60 J. In order to hold the specimen, the clamping pressure of 0.02MPa is imposed on the pneumatic clamps.

Figure 3: The impact location during impact tests.

3 Finite element modeling

In this paper, the nonlinear finite element software, ABAQUS/Explicit, is used to simulate the impact process of pyramid lattice foam sandwich structure. The finite element model is presented in Figure 4.

Figure 4: The FE model of the low velocity impact test.

3.1 The geometry model and boundary condition

In this paper, the finite element model is established according to the actual situation of impact test. The top and bottom facesheets are meshed by using S4R element, which is 4-node doubly curved thick shell, reduced integration with hourglass control and finite membrane strains. The thickness of the panel is 1mm, and the stacking sequence is $[0^\circ/90^\circ]_s$, with eight layers in total. The diameter of the strut core is 1 mm, the angle between the core and the panel is 60 degrees, and the thickness of the foam core is 15 mm. Define the Tie constraint between the strut core and the panel and between the foam and the panel for improving the computational efficiency. During the impact tests, the specimen is restrained by a pneumatic clamp with 76.2mm circular aperture. Thus, the pneumatic clamps with 76.2 mm circular aperture are also created in the model, which is 2 mm in the thickness. In the finite element model, the impactor is defined as a rigid body because of its large modulus and small deformation. Therefore, the mass and initial velocity of the impactor is defined on the rigid reference point of the impactor.

C3D8R, which is 8-node linear brick, reduced integration with hourglass control, were used for strut, foam and impactor. The foam is divided into 8 layers of meshes along the thickness direction, and each one of them is provided with a contact surface with the impactor. In order to better capture the complex stress conditions in the impact area, local mesh encryption was performed at the center of the foam and the composite panel. The size of the encryption mesh was approximately 0.8mm×0.8mm, and the mesh size in other areas was approximately 2.4mm×2.4mm. Finally, the finite element model has 63808 elements: 24000 elements for struts, 1408 elements in impactor, 12800 elements in foam, and 25600 elements in composite panels. The contact of the impactor with the composite panels, and of foam and struts is defined as general contact

3.2 The material properties

Although the impactor is set as a non-deformable rigid body in the finite element, the material properties of the impactor need to be defined in the display calculation. Its material properties are: Modulus of elasticity $E = 210$ GPa, Poisson's ratio $\nu = 0.3$.

The strut material property is set to the engineering material constant. The axis of the strut in the cylindrical coordinate system is the z-axis of it. The tensile strength and modulus of the strut are measured by compression experiments of a single strut. The measured elastic modulus along the axial direction $E = 25$ GPa and the yield strength $\sigma_f = 260$ MPa were tested through experiments.

Foam is defined as an elastic-plastic material, and the elastic partial response is defined as * ELASTIC ISOTROPIC, its properties are provided by the manufacturer: the modulus of elasticity $E = 75$ MPa and the Poisson's ratio $\nu = 0.3$; Plastic response behavior is defined as * CRUSHABLE FOAM and * CRUSHABLE FOAM HARDENING. The hardening behavior of the foam can be obtained through a set of uniaxial compression experiments. The data of uniaxial compression test on foam material made sure the relationship between stress and strain of foam during the plastic part, which was shown in Figure 5. The foam is in the stage of elastic deformation at the initial region, and the slope of the curve is described by Young's modulus. Then, the yield plateau stress remains almost constant while the strain increase, which is due to the fact that the cell of foam begins to lose the stability when the stress reaches the yield stress. As the load increasing, Cells continue to compress and collapse, resulting in densification of the foam and increasing stress. Foam material density: $\rho = 80$ kg/m³. The impactor is set as a non-deformable rigid body with the Young's modulus of 210 GPa and the Poisson's ratio of 0.3.

The composite panels are defined as an elastic material, and the carbon fiber material properties are given in Table 1. The cross-sectional properties of the composite panel are defined as the laminated structure of the composite element shell, and the stacking sequence is $[0^\circ/90^\circ]_s$. A progressive damage model based on the Hashin failure criteria and Yeh delamination failure criteria is implemented in ABAQUS/Explicit for the composite facesheets by means of a user subroutine VUMAT. The Hashin failure criteria and Yeh delamination failure criteria are written as follows:

Tensile fiber failure:

$$\left(\frac{\sigma_{11}}{X_T}\right)^2 + \frac{\sigma_{12}^2 + \sigma_{13}^2}{S_{12}^2} = \begin{cases} \geq 1 & \text{failure} \\ < 1 & \text{no failure} \end{cases} \quad \sigma_{11} \geq 0$$

Figure 5: Stress-strain curve for a compression test on foam.

Compressive fiber failure:

$$\left(\frac{\sigma_{11}}{X_C}\right)^2 = \begin{cases} \geq 1 & \text{failure} \\ < 1 & \text{no failure} \end{cases} \quad \sigma_{11} < 0$$

Tensile matrix failure:

$$\left(\frac{\sigma_{22} + \sigma_{33}}{Y_T^2}\right)^2 + \frac{\sigma_{23}^2 - \sigma_{22}\sigma_{33}}{S_{23}^2} + \frac{\sigma_{12}^2 + \sigma_{13}^2}{S_{12}^2} = \begin{cases} \geq 1 & \text{failure} \\ < 1 & \text{no failure} \end{cases} \quad \sigma_{22} + \sigma_{33} > 0$$

Compressive matrix failure:

$$\left[\left(\frac{Y_C}{2S_{23}}\right)^2 - 1\right] \left(\frac{\sigma_{22} + \sigma_{33}}{Y_C}\right) + \frac{(\sigma_{22} + \sigma_{33})^2}{4S_{23}^2} + \frac{\sigma_{23}^2 - \sigma_{22}\sigma_{33}}{S_{23}^2} + \frac{\sigma_{12}^2 + \sigma_{13}^2}{S_{12}^2} = \begin{cases} \geq 1 & \text{failure} \\ < 1 & \text{no failure} \end{cases} \quad \sigma_{22} + \sigma_{33} < 0$$

Delamination failure:

$$\left(\frac{\sigma_{33}}{Z_T}\right)^2 + \left(\frac{\sigma_{13}}{S_{13}}\right)^2 + \left(\frac{\sigma_{23}}{S_{23}}\right)^2 = \begin{cases} \geq 1 & \text{failure} \\ < 1 & \text{no failure} \end{cases} \quad \sigma_{33} > 0$$

where X_T, X_C denote the longitudinal tensile and compressive strength of unidirectional laminates, Y_T, Y_C represent the transverse tensile and compressive strength of unidirectional laminates, S_{12}, S_{13} and S_{23} denote the shear strength of unidirectional laminates in corresponding directions; Z_T represents the out-of-plane tensile strength of unidirectional laminate. The finite element ABAQUS software model calculation is based on the element integration point to calculate the element stiffness, stress

and strain. In finite element model calculations, when the stress of element integration point meet the Hashin failure criteria or Yeh delamination failure criteria, it will be considered that the material has been damaged, and then the material properties will degrade.

4 Results and discussion

4.1 Low-velocity impact tests

The impact historical process, peak value and absorbed energy of simulation are consistent with the experiment which can examine the accuracy of the model. Figure 6-9 represents the load-time curves and absorbed energy of different specimens at 15J, 30J, 45J and 60J, which indicates that there exists a good agreement between experiment and simulation.

As seen in Figure 6, the load-time curves of the three types of specimens under the impact energy of 15 J. When

the drop hammer contacts the top surface of the specimen, it is obvious that the impact load rapidly increases to the peak. Then the impact force decreased to zero which indicates that the damage only occurs in the top facesheet. Compared with the three curves, it is found in Figure 6(a) that the curve between the impact load and contact time curve is smooth due to without the strut core. Owing to the support of the lattice core, there is fluctuation at the peak value during impact, and some damages will occur in the facesheet. The maximum impact load of specimen C is 4.89kN, which is higher than the maximum impact load of specimen B (4.61kN) and specimen A (4.28kN), which is proved that the strut core can improve the stiffness and strength of the foam sandwich structure. The larger the strut core density is, the more obvious the impact resistance increases. Figure 6 also shows the energy-time curves for three specimens. The specimen A had been impacted by 15.1J, only 14.2J (94.03%) were absorbed by the specimen A. However, the specimen B and specimen C have the higher absorbed energy rate, respectively

Figure 6: Response of specimens impacted under the impact energy of 15 J.

Figure 7: Response of specimens impacted under the impact energy of 30 J.

98.63% and 98.88%, which is due to the fact that the energy was converted to many failure mechanisms. The load-time curves and the energy-time curves of numerical simulation are in good agreement with the experimental value. But the element is set to be deleted in the simulation, thus the load curve will fluctuate obviously in the loading process.

As shown in Figure 7, the load-time curves of the three types of specimens under the impact energy of 30 J. When the impactor contacts the top surface of the specimen, it is obvious that the impact load rapidly increases to the peak, where the maximum impact load is 4.39 kN for specimen A, where the maximum impact load is 4.77 kN for specimen B, where the maximum impact load is 5.08 kN for specimen C. After the impact force decreased to the minimum value, a prolonged plateau region are observed in Figure 7a and b, which indicate that the top facesheet has been punched through and the drop hammer has reached the core of the specimen. Conversely, it is found that the curve in Figure 7c at the peak has a longer fluctuation due to the higher strut core density, which mean that stronger strut core has bet-

ter resistance at peak load and the top facesheet of specimen C is not perforated. Due to the low impact energy, the impactor does not contact the bottom facesheet. From the energy-time curves of the three specimens in Figure 7, it is different from the impact with 15 J that the impact energy was fully absorbed by the specimen because the top facesheet of specimen A and specimen B have failed at the 30 J impact energy.

When impact energy increased 45 J, there are two peaks in the impact-time curves, which indicate that the drop hammer contacts the top facesheet and the bottom facesheet respectively (shown in Figure 8). From Figure 8, it is quite noticeable that the impact process can be divided into three stages under high impact energy: In the first stage, the impactor contacts the top facesheet of the specimen and penetrates the top facesheet. In this stage, the load-time curve is the initial rising part, reaching the first peak and continuous wave comes into being, the top facesheet starts to damage, and then the curve rapidly drops and the impactor penetrates through the top facesheet. It is found that the energy absorption curve

Figure 8: Response of specimens impacted under the impact energy of 45 J.

shows a rapid upward trend. In the second stage, the punch squeezes the foam and deforms it plastically. At this stage, in the pyramid lattice foam sandwich structure, the load is about 400N higher than that of the foam sandwich structure due to the presence of the strut core. In the last stage, a secondary peak load was observed, showing the impactor contacts the bottom facesheet until the kinetic energy of the impactor is exhausted or the impactor penetrates the bottom facesheet. The impact energy was also fully absorbed by three specimens due to the high impact energy.

As seen in Figure 9, the load-time curves of the three types of specimens under the impact energy of 60 J. And the impact result at 60J for three types of specimens can be seen in Figure 10. From Figure 10a, the slope of initial stage of the curve gives the dynamic rigidity of the specimen against drop hammer impact. Compared with the foam sandwich specimen, it is quite noticeable that the stitched core specimens have the steeper slope, which means that the foam sandwich specimens have higher dynamic rigidity and first peak force. This improvement can be attributed to the existence of the strut in the core of

perforated core specimens as this is the only difference between the compared specimens. When the specimen B and specimen C are compared, it is found that specimen C is observed to have highest values, and the advantage becomes more obvious due to the increase in strut diameter. In addition, specimen C has the largest region at the prolonged plateau area than specimen A and specimen B (as shown in Figure 9a), indicating the core of specimen C absorbs more amount of energy than specimen A and specimen B during impact.

4.2 Failure analysis

The cross-sectional view about the top facesheet and the bottom facesheet of foam sandwich structures (specimen A) and pyramid lattice stitched foam sandwich structures (specimen B) under 30J, 45J and 60J impact energies are shown in Figure 11-16. The left side is the profile of the experiment results, and the right side is the profile of the simulation results. Compared with the experimental and numerical results, it is found that there are good agreements in the failure morphology.

Figure 9: Response of specimens impacted under the impact energy of 60 J.

Figure 10: The load displacement curve (a) and impact response (b) under the impact energy of 60 J.

Figure 11: Impact damage of experimental and FEM simulation of foam sandwich composite at the impact energy of 30J.

From Figure 11, the impactor leaves a clear dent in the top facesheet. At the impact energy of 30 J, the top facesheet completely penetrated by the impactor, and matrix crack, fiber fracture as well as delamination are observed. The foam suffered significant damage in the form of plastic deformation. It is noticed in Figure 11f that the bottom facesheet have suffered impact and stress distribution occurred, but there was no damage at the bottom facesheet of specimen as shown in Figure 11e.

At impact energy of 45J, the top facesheet completely failed, which was penetrated by the impactor and a dent as shown in Figure 12c was caused after impact at the top surface. From Figure 12a, we can see that the damage of the top facesheet comprises: fiber breakage, matrix crack and delamination. The impactor penetrates the foam and contracts the bottom facesheet which causes significant damage as shown in Figure 12 in the bottom facesheet and consists of delamination. The slight damage: ply splitting in the bottom surface as seen in Figure 12e.

When the impact energy is increased to 60J, it is obvious that the top and bottom facesheets are penetrated by the impactor and damages consist of delamination, fiber breakage as well as matrix crack can be seen in Figure 13a. The foam is deformed in the direction of impact as shown in Figure 13a. Compared with Figure 11, 12 and 13, the larger the impact energy, the more severe the damage, and the larger the damage area formed on the back surface of the foam sandwich specimen.

Figure 12: Impact damage of experimental and FEM simulation of foam sandwich composite at the impact energy of 45J.

Figure 13: Impact damage of experimental and FEM simulation of foam sandwich composite at the impact energy of 60J.

Figure 14 shows the damage between the experiment and simulation of the pyramidal lattice stitched foam sandwich composite at the impact energy of 30J. From the cross-sectional views for the pyramidal lattice stitched foam sandwich composite, it can be seen that the top facesheet were penetrated and the damage consist of fiber breakage and matrix cracking. The foam suffered significant dam-

Figure 14: Impact damage of experimental and FEM simulation of foam sandwich composite stitched by 1mm diameter strut at the impact energy of 30J.

Figure 15: Impact damage of experimental and FEM simulation of foam sandwich composite stitched by 1mm diameter strut at the impact energy of 45J.

age in the form of plastic deformation and the strut core were broken caused by the impact. From Figure 14f, it is quite noticeable that the impactor contract with the bottom facesheet, but the remaining energy does not exceed the damage threshold of the bottom facesheet of the pyramidal lattice stitched foam sandwich composite, so there

Figure 16: Impact damage of experimental and FEM simulation of foam sandwich composite stitched by 1mm diameter strut at the impact energy of 60J.

was no damage in the bottom surface as shown in Figure 14e.

Figure 15 showed the cross-sectional views, the top facesheet views and the bottom facesheet views of experiment and simulation of the pyramidal lattice stitched foam sandwich composite at the impact energy of 45J. It is found that the impactor penetrated the top facesheet and the core which leaf a dent on the top surface and delamination, fiber breakage and matrix cracking were observed in Figure 15a. The core suffered significant damage in the form of plastic deformation of foam and breakage of strut. When the impactor contract with the bottom facesheet, delamination was formed in the bottom facesheet. Compared with the damage on the bottom surface between the foam sandwich composite and the pyramidal lattice stitched foam sandwich composite at the impact energy of 45J, the damage in the form of ply splitting was observed but no damage was on the bottom surface. This can be explained that pyramidal lattice stitched foam sandwich composite can improve the ability to resist impact.

Figure 16 showed the cross-sectional views, the top facesheet views and the bottom facesheet views of experiment and simulation of the pyramidal lattice stitched foam sandwich composite at higher impact energy of 60J. As seen in Figure 16a, the damage in the form of fiber breakage, matrix cracking and delamination were obvious at both the top facesheet and the bottom facesheet. The core

was completely failure and consists of plastic deformation of foam and breakage of strut. Compared with the damage on the bottom surface between the foam sandwich composite and the pyramidal lattice stitched foam sandwich composite at the impact energy of 60J, serious damage in the form of ply splitting and fiber breakage was observed on the bottom surface of the foam sandwich composite but lighter damage in the form of delamination was on the bottom surface of the pyramidal lattice stitched foam sandwich composite. It is obvious that, at the same impact energy level, stitched foam sandwich structure have less damage than foam sandwich structure. This can be explained that the pyramidal lattice stitched foam sandwich composites can improve the ability to resist impact.

5 Conclusions

In this paper, the pyramidal lattice foam sandwich structure was fabricated by weaving and interleaving technology. The impact resistance of pyramid lattice foam sandwich structure and foam sandwich structure were tested and simulated. The following conclusions are obtained:

1. At low impact energy levels, the impact load of the foam sandwich structure stitched by 1mm diamant strut is more than 10% higher than that of the foam sandwich structure. Moreover, the strut core reduces the damage area of the specimen, which indicates that the strut core has the toughening effect;
2. Under different impact energy, the damage degree of pyramid lattice stitched foam sandwich structure under impact load is analyzed. It is found that the damage degree increases with the augment of impact energy;
3. Based on the Hashin failure criterion, a low-velocity impact model is established. The load time curve and energy absorption curve are obtained by numerical calculation and checked with the experimental value. The damage diagram and impact profile diagram of the specimen are compared, and the failure mode and process are analyzed. The theoretical value is in good agreement with the experimental value.

On the basis of this research, the author thinks that further research is needed: It is necessary to analyze the CAI of pyramid lattice foam sandwich structure, and study on toughening effect of different cores on foam sandwich structure.

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