The Research about Composite Square Shell Fillet

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Abstract. The Carbon Fiber Reinforced Plastics (CFRP) is one of the most popular materials for the impact attenuator. This is because that it has small density, high strength and high stiffness, which are required for crashworthy structure. In this paper, the CFRP square shell is the research object, the effect of fillet is analyzed by the software ANSYS Workbench/LS-DYNA. The results shows that the fillet is an important effect factor for square shell failure mode and crashworthiness, the failure mode change from unstable to stable when the fillet radius increases, meanwhile the SEA and mean crash load increase.

1. Introduction

In recent years, the research on the energy absorption property of composite materials has been paid more and more attentions [1-3]. Compared with traditional materials such as metal, the composites have the advantages of light weight, high strength and high crashworthiness, so the application of composite material in the field of automotive is more and more extensive. A reasonable design can lead to stable failure mode to achieve good energy absorption efficiency [4, 5].

In the study of composite materials, the cylindrical tube is main research object, and many research aiming at wall thickness, material type, ratio of height to diameter and so on[6-8]. However, the study about composite square tube is little. In this paper, the composite square shell will be the research object to explore the influence of the fillet on the energy absorption characteristics of square shell.

2. Element Analysis

2.1 Geometric Modeling.

In order to ensure the accuracy of the analysis, the fillet of the square shell will be the only variable in the model establishment process. The geometrical model was established by CATIA. The range of the square fillet is 0mm-15mm, and a square shell is established every 3mm. All the square shells height of 120mm and a side of length 80mm, such a variable control can ensure that the initial contact area of square is same when the load applicator begins to contact, and ensure that the compression stroke and compression ratio .

2.2 Element Modeling.

In the analysis process, the load applicator and support plate is set as rigid body to improve the efficiency of analysis. The body interaction of support plate and the square shell are Single Surface, and the contact between the square shell and the indenter is also set to Single Surface. In LS-DYNA, there are three types of contact, which are: Single Surface, Nodes to Surface and Surface to Surface. After setting the Single Surface contact, the object can touch its own surface or the surface of other objects. The program will automatically find the contact surface for Single Surface, do not need to set the additional contact surface and target surface. Surface to Surface contact is a very common contact, it can be used to set the contact between different surfaces, Surface to Surface contact is very suitable for the surface of the object has a large slip of the occasion, and the contact surface can be any shape. Nodes to Surface contact will be used for various points through the plane.

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In the numerical analysis process, when the object occurs a large deformation, the object can be exposed to their own, and the contact area is often not predictable. Single Surface contact allows the program to automatically detect all contact surfaces. For explicit analysis, calculation efficiency of Single Surface contact is highly-efficiency. For this paper, the square tube may be folded or bended, so the use of Single Surface contact is the best choice.

Although there is no need to focus on the loads of support plate and the load applicator, etc., there is still a need for the two to mesh, because it is requested to analyze the force between thin-wall tubes and load applicator. The mesh of the load applicator and the support plate adopts the Solid Mesh, the mesh length is 25mm. The square shell is set with Mapped Face Meshing and the mesh size is 5mm. Fig. 1 is the diagram of mesh model.

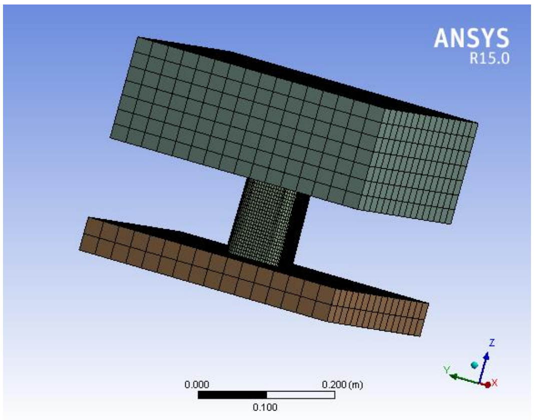

Fig. 1 Mesh Model

Fix the six degrees of freedom of the support plate with Fix Support. The initial speed of load applicator is 4 mm/s and the direction is perpendicular to the support plate and downward. Add Rotation Displacement to the load applicator, fix the degree of freedom of translation in the x and y directions, and fix the degree of freedom in the x-axis, y-axis, and z-axis directions to ensure that the bottom plane of the load applicator is always parallel to the support plane.

In this paper, Woven T300 Prepreg Carbon Fiber is adopted. The trigger geometry is required for square shell. The square shell is divided to several parts along the axis, just as shown in Fig. 2. The first ply zone is the whole square shell, the second ply zone is from the second line of top to the bottom line, which means the second ply zone contains all of part except the top blue part, and so on. According to the ply number, the square shell will be divided to 8 parts.

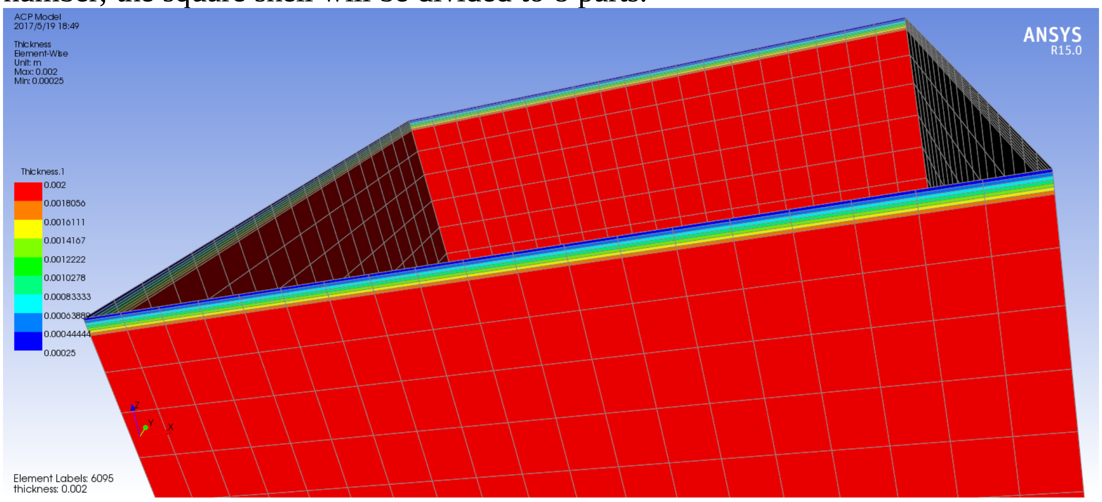

Fig. 2 Trigger geometry

In the ANSYS / ACP module, the T300 carbon fiber epoxy prepreg will be stacked in the order of eight zones which are divided in advance, which mean there are eight layers for each square shell. Analyze the energy absorption property when the fillet is changed from 3mm to 15mm. The ply schedule is shown as Table1.

Table 1. Square fillet analysis schedule

Item	1	2	3	4	5	6
Fillet radius/(mm)	0	3	6	9	12	15

Fig. 3 shows the force-displacement curves obtained by the element analysis of above six schemes. The failure modes and energy absorption characteristics of each scheme are shown in Table 2. Comparing the SEA (Specific Energy Absorption), the force-displacement curve of a square shell with 0mm rounded corners fluctuates greatly and the load varies greatly, and this failure mode is not suitable for energy absorber.

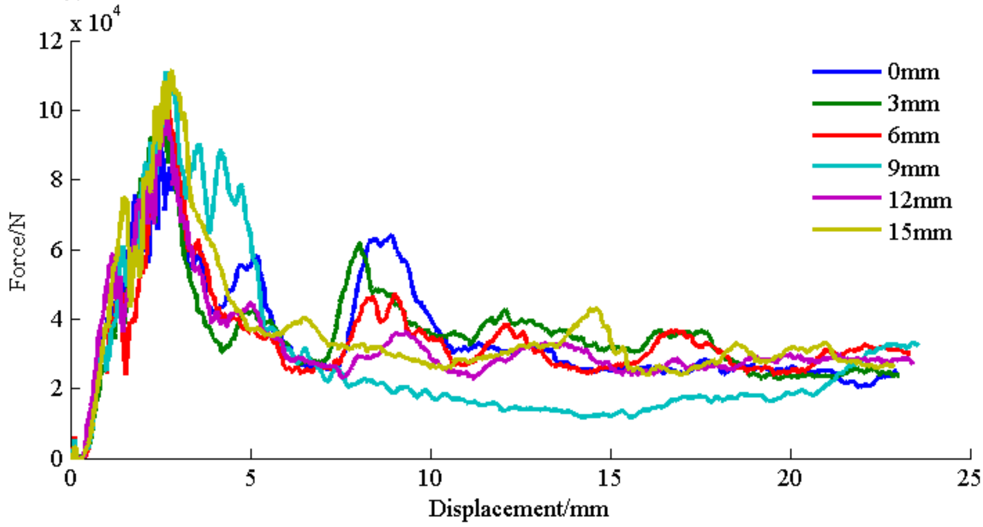

Fig. 3 Force-Displacement curve using various semi-apical angle

Table 2. Energy absorption property using different semi-apical angle

Item	1	2	3	4	5	6
Fillet radius/(mm)	0	3	6	9	12	15
SEA/(J·g-1)	44.38	45.32	46.11	41.29	44.97	46.23
Mean Crash Load/(kN)	34.36	35.41	33.82	30.38	34.54	37.53

The crashing process of carbon fiber composite square shell is unstable. When the tube is subjected to a compressive load, the wall protrudes outward, and when the protrusion reaches a certain deformation, the wall of the tube breaks and the fracture tissue presents large pieces of fragments. The stress distributing graphs of square shells with 0mm fillet radius and 15mm fillet radius are each shown in Fig.4 and Fig.5. When the fillet radius of the square shell is 0mm, that is the square shell has no fillet radius, the crashing load fluctuates greatly. Because when the load reaches the limit of the square shell during the compression process, the wall of the square shell is cracked and the square shell is local unstable, which results in plummeting of the load. With the increasing of the fillet radius, the crashed part of the square shell gradually appears palm leaves like tissue, that is, part of the wall began to appear buckling phenomenon, and the appearance of this phenomenon makes the cracked phenomenon in the compression process to reduce and the crashing process gradually becomes smooth.

The relationship between specific energy absorption and fillet radius is nonlinear, and there is a turning point during the fillet radius gradually increases, which can make it gradually transit from the unstable crashing mode to the stable crashing mode, which is identical with the changing condition of the crashed part of the cracked experimental samples, the fillet radius becomes larger, the crashed parts gradually transform from large fragments into a kind of continuous palm leaves like buckling fragments, and the crashing process gradually become stable. Similarly, with the fillet radius increases continuously, the mean load gradually increases and the total absorption of energy increases, that is, the energy absorption property of the square shell gradually increases.

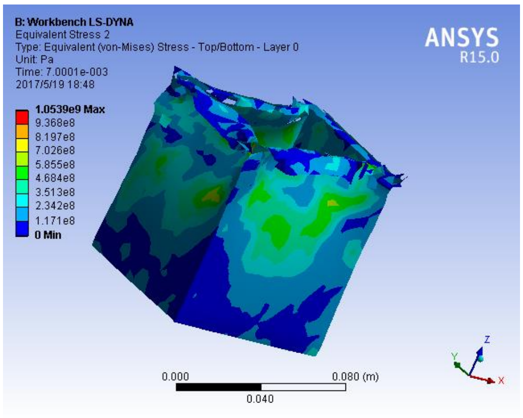

Fig. 4 0mm square shell

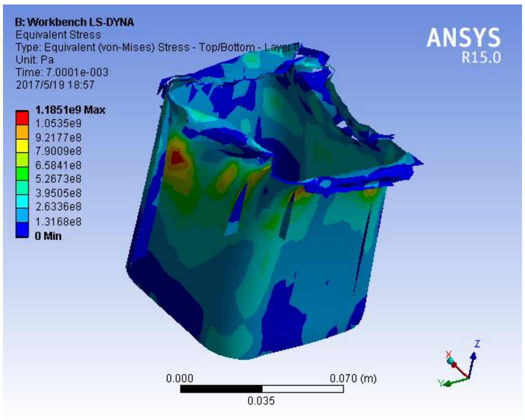

Fig. 5 15mm square shell

3. Summary

Through the experiment, it is found that the setting of fillet radius is of great significance to the failure form of the square shell. By setting the fillet radius and increasing the fillet radius, the square shell gradually changes from an unstable local brittle fracture pattern to a stable progressive crashing mode, which makes the produced during the crashing process gradually become stable and ensure the square shell to achieve sustained and stable energy absorption. As the crashing force gradually becomes stable, the difference between the crash load decreases gradually, the mean load increases gradually, the total energy absorption increases, and the energy absorption property of the composite square shell is improved. But the effect of the fillet radius size on the specific energy absorption of the composite square shell is not very obvious and there is no clear change rule.

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