EFFECT OF THE HOLE POSITION ON COMPOSITE LAMINATES UNDER LOW VELOCITY IMPACT

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ABSTRACT

This paper investigates the effect of the different hole positions on composite laminates under low velocity impact. The distance from hole to impact position of the specimens is 25 mm and 10 mm in this paper. The low velocity impact tests of the specimens with and without hole were carried out by drop weight impact test system. The impact force curves and energy curves for the three types of specimens were obtained. This paper compares the average force peak value, average absorbed energy and average back damage area of the three types of specimens. The results have shown that the average maximum impact force of the specimen without hole is largest and that of the specimen which has a circle hole at 10 mm from the impact position is smallest. The average absorbed energy of the specimen which has a circle hole at 10 mm from the impact position is largest and that of the specimen without hole is smallest. The average back damage area of the specimen which has a circle hole at 10 mm from the impact position is 1398.1 mm^2, that of the specimen which has a circle hole at 25 mm from the impact position is 334.8 mm^2 and that of the specimen without hole is only 94.6 mm^2. It can be seen that the hole position of composite laminates seriously affect the specimens' properties under low velocity impact.

1. INTRODUCTION

Composites are becoming more and more popular with industrial designers due to their superior properties, such as high specific strength, high specific stiffness, and outstanding designability. Nowadays, composites are increasingly used in automobiles, ships and aircrafts, etc. However, due to its own characteristics, usually there will be some invisible damage in composites; the low velocity impact is one of the important forms of causing the invisible damage, the damage are matrix cracking, fiber fracture and delamination, etc. Peng et al. [1] used a high-order displacement mode to analyze the stress of the composite laminates under low velocity impact and verified the correctness of the model. Wen et al. [2] developed a new delamination criterion according to delamination mechanism and developed a progressive cumulative model of low velocity impact to predict the low velocity impact damage for three types of laminates with three different layers; and the results were good agreement with the test data. Zhang et al. [3] used the user subroutine VUMAT and VUINTER in commercial finite element software ABAQUS/Explicit to analyze the interlaminar and inter-layer damage of the composite under low velocity impact, which was in good agreement with the experimental results. Yazdani Nezhad et al. [4] investigated the low velocity impact response of laminated composite panels by test and simulation. The three-dimensional finite element model was built on the ABAQUS simulation platform, and the low velocity impact resistance of the laminated composite panels under different energy was studied. Wei et al. [5] investigated low-velocity impact damage and CAI strength of composite laminates by a high-fidelity three-dimensional composite damage model which was developed as a user material subroutine in the commercial finite element package, ABAQUS/Explicit. And the results correlated well with experimental testing.

In order to connect, it need to machine some holes on composite structure during the production and assembly process, but the high stress area can be formed around the hole structure, and the local high stress will cause a complex failure mechanism. So the performance of some hole structure has also been the attention of the majority of scholars. Roy et al. [6] analyzed the response of laminates under low velocity impact, the delamination was first observed at the edge around the hole, and the delamination formed by the two holes can spread out to form a large delamination region. Amaro et al. [7] evaluated the influence of holes on delamination of glass/epoxy composite laminates subjected to low velocity impact. Laminates containing one and two holes were tested and the resulting damage was compared with the laminate without hole. Results showed that presence of holes increases the energy absorbed by damage and delaminated areas. Saleem et al. [8] studied the effect of different hole machining methods on the mechanical behavior of composite laminates subjected cyclic loading. The two hole machining methods are conventional machining and abrasive water jet machining. Du et al. [9] used different energies to investigate the damage evolution and the relationship between the damage mechanism and the impact energy of the Carbon/Epoxy composite laminates under low velocity impact.

In this paper, the effect of different hole positions on composite laminates under low velocity impact was studied by test.

2. MATERIALS AND METHODS

The drop weight impact tests were performed in accordance with ASTM Standard D7136 / D7136M-05 [10]. The size of the specimens is 100 mm in width and 150 mm in length (Fig. 1). The stacking sequence of the specimen is $(45/-45/90/0)_{3S}$, each layer thickness is 0.15 mm and the total thickness of the specimen is 3.0 mm.

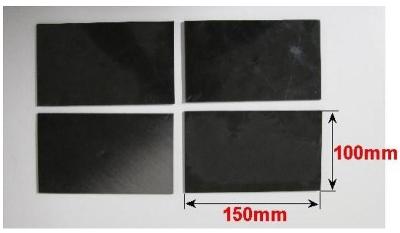

Fig. 1. The shape of laminates

There are three types of specimens, specimen without hole, specimen which has a circular hole at 10 mm from the impact position and specimen which has a circular hole at 25 mm from the impact position, the diameter of the holes is 6 mm. The low velocity impact tests of the three types of specimens were carried out by drop weight impact test system. A 25 mm impactor diameter with a mass of 4.2 kg was used. The impact energy used was 41.16J, which corresponds to an impact velocity of 4.42 ms^{-1}. The drop weight impact test system includes a drop weight impact machine, a force sensor (PCB 208C05), and a data acquisition device (Fig. 2). And the drop weight impact machine includes an impactor, a preventing secondary impact unit and a specimen clamp, etc (Fig. 2). The force data were obtained by data acquisition device, and the energy data can be calculated by the formulas in Fig. 3.

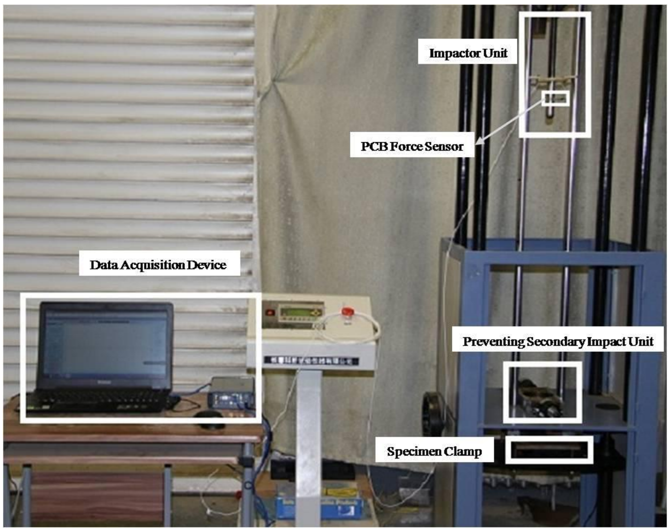

Fig. 2. The drop weight impact test system

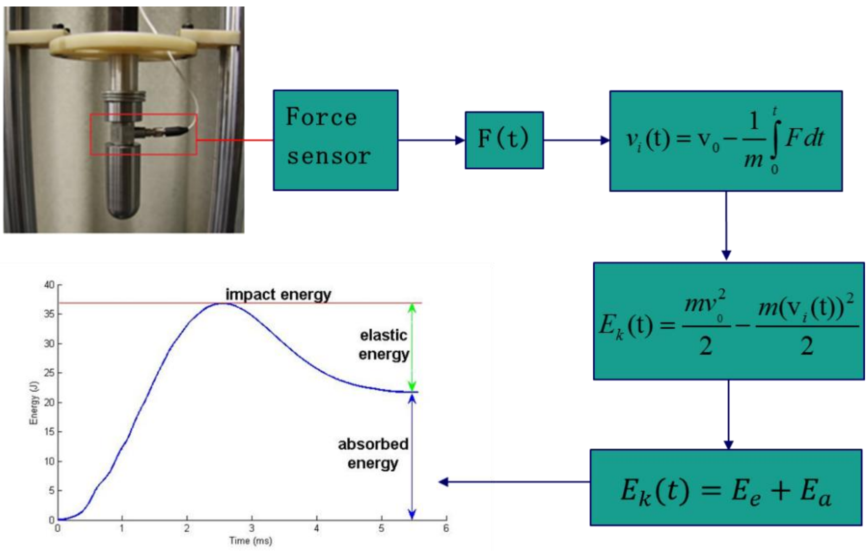

Fig. 3. The formulas for obtaining energy data

3. RESULTS AND DISCUSSIONS

Fig. 4 shows the force-time curves of the three types of specimens during the impact process. It can be seen that the force of the specimen which has a circle hole at 10 mm from the impact position has a rapid decline when it reaches the peak value; it indicates that there is great damage in the specimen. However, the tendency of the force-time curves of the specimen without hole and specimen which has a circle hole at 25 mm from the impact position are similar, the oscillations of the force-time curves are small. It can be seen from Table 1 that the average force peak value of the specimen without hole is largest, and that of the specimen which has a circle hole at 25 mm from the impact position is smallest. The presence of holes can reduce the load carrying capacity of the laminates.

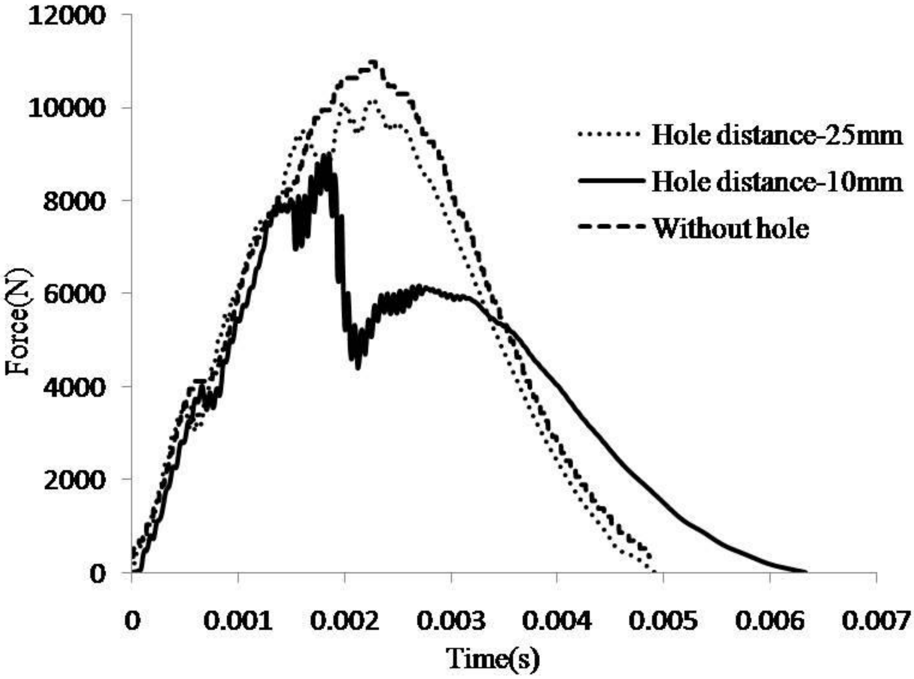

Fig. 4. The force-time curves for the three types of specimens

Specimen	Average force peak value(N)	Average absorbed energy(J)	Average back damage area(mm^2)
Hole distance-10mm	8992.31	37.30	1398.1
Hole distance-25mm	10163.40	33.97	334.8
Without hole	10977.70	29.79	94.6

Table 1. Test results for the three types of specimens after impact

Fig. 5 represents the energy-time curves of the three types of specimens during the impact process. The curve represents the energy transferred from the impactor to the laminate during the impact process, and the final energy value represents the final energy absorbed by the laminate. At the end of the impact, the average absorbed energy of the specimen which has a circle hole at 10 mm from the impact position is largest and that of the specimen without hole is smallest (Table 1).

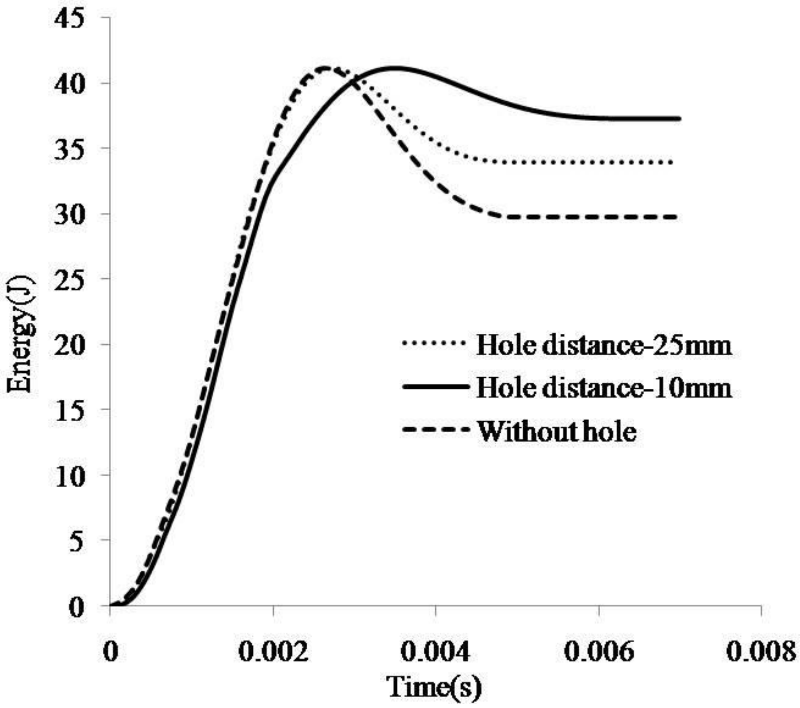

Fig. 5. The energy-time curves for the three types of specimens

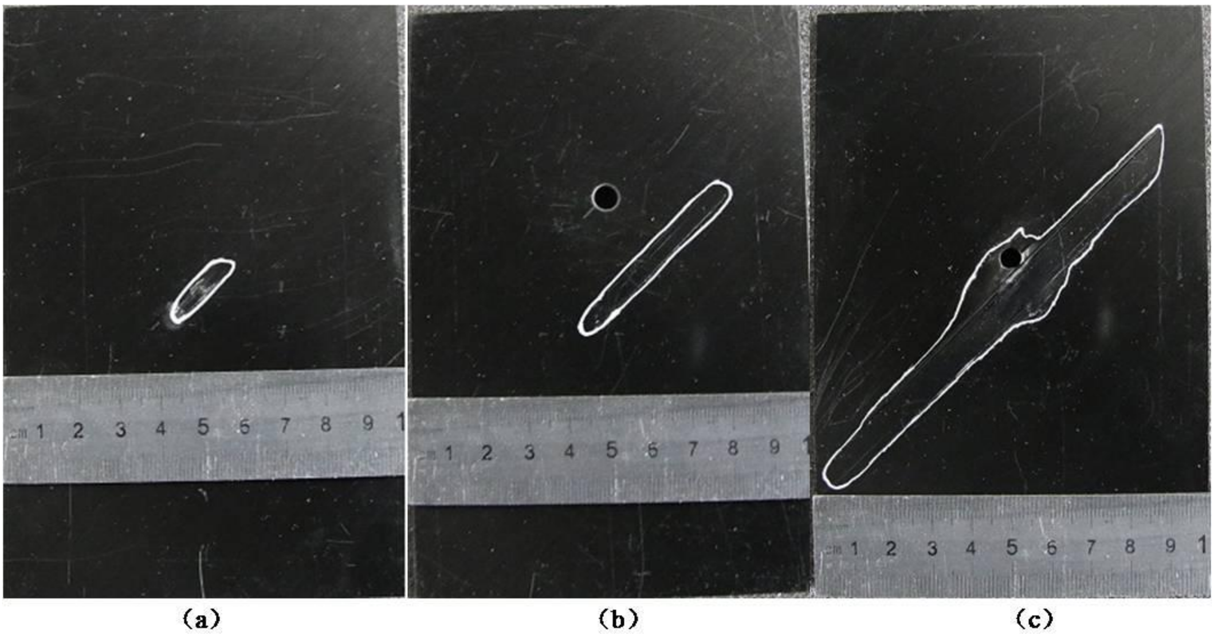

Fig. 6. The back damage areas for the three types of specimens (without hole (a), hole distance-25 mm (b), hole distance-10 mm (c))

The back damage areas of the three types of specimens after impact are shown in Fig. 6. It can be seen that the back damage area of the specimen which has a circle hole at 10 mm from the impact position is much larger than the other two types of specimens. In the Table 1, the average back damage area of the specimen which has a circle hole at 10 mm from the impact position is 1389.1 mm^2 and that of the specimen which has a circle hole at 25 mm from the impact position is only 334.8 mm^2. Therefore, it is important to reasonably choose the distance from the hole to the impact area when machining the hole.

4. CONCLUSIONS

This paper used the drop weight impact test system to study the effect of holes' positions on composite laminates under low velocity impact. The low velocity impact tests were carried out on specimens with and without hole. The force data were obtained by data acquisition device, and the energy data can be calculated by the formulas. The average back damage areas of the three types of specimens were calculated.

The results show that the hole will significantly affect the carrying capacity of the laminate. The force of the specimen which has a circle hole at 10 mm from the impact position has a rapid decline when it reaches the peak value; it indicates that there is great damage in the specimen. The average force peak value of the specimen without hole is largest, and that of the specimen which has a circle hole at 25 mm from the impact position is smallest. The average absorbed energy of the specimen which has a circle hole at 10mm from the impact position is largest and that of the specimen without hole is smallest. It can be seen that the holes' positions on specimen will seriously affect the damage area from the pictures of the back damage area. The average back damage area of the specimen which has a circle hole at 10 mm from the impact position is 1389.1 mm^2 and that of the specimen which has a circle hole at 25 mm from the impact position is only 334.8 mm^2. The more energy absorbed, the greater the area of damage. Therefore, it is important to reasonably choose the distance from the hole to the impact area.

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