Experimental study on impact characteristics of composite plate based on falling ball method

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Abstract

In order to study the multiple impact variation of the composite material by the drop ball impact method, the low velocity impact test was carried out on the glass fiber plate by using the drop ball impact device. The pressure sensor was used to record the impact load time curve during the drop of the ball, the displacement time curve and the energy time history curve were calculated. The test results show that the damage form of the composite plate caused by the drop impact is not consistent with that of the drop hammer impact. More damage forms such as the matrix cracking and the plate fracture are produced, and the multiple impactproduces cumulative damage to the composite plate. After many impacts, the peak load of the plate decreases, the rebound velocity becomes smaller and the absorption energy increases. The experimental results show that it is reasonable to evaluate the impact resistance of the composite plate by the drop ball impact method, and in some respects it is more consistent with a certain kind of actual situation.

Keywords

Composite material; Cumulative damage; Falling ball impact; Destruction form.

1. Introduction

The fiber reinforced composite material is a composite material formed by a reinforcing fiber material, such as glass fiber, basalt fiber, carbon fiber, etc., and a matrix material is subjected to a forming process such as winding, molding or pultrusion, and has high specific strength and large specific modulus; The performance can be designed to be strong; the corrosion resistance and durability are good; the thermal expansion coefficient is similar to that of concrete. The impact test can study the ability of the material to resist dynamic loads. Compared with the static load, the contact time between the dynamic load and the material is very short, and the instantaneous impact force is much larger than the static load. It can be difficult for the material to be exposed under the action of static loading. Features and defects. Therefore, the dynamic and static properties of composite materials often vary greatly. In order to study the mechanical properties of fiber composites, domestic and foreign scholars have carried out a lot of work and achieved some fruitful results.

Yang Bin et al [1] studied the impact damage resistance of glass fiber-carbon fiber hybrid composite laminates under low velocity impact; Zhang Xia et al [2] simulated the mechanical properties of glass-carbon fiber reinforced polymer under impact; Ying et al [3] studied the mechanical analysis of aramid-polyethylene fiber composite sheets under low velocity impact; Haibao Liu et al. [4] predicted the impact strength of damage resistant hybrid unidirectional/woven carbon fiber reinforced composite laminates; MAEMAli et al [4] studied hybrid fiber reinforced cement-based composites under tensile and impact loads; Chen Yong et al [5] studied the impact failure morphology and mechanical properties of glass fiber reinforced aluminum alloys under low temperature; Shi Baohui

et al [6] studied the impact resistance of hybrid composites under low-speed impact; Ahmad Rafiq et alstudied the impact resistance of hybrid glass fiber reinforced epoxy resin / nano-clay composites; Wei Jun et al The energy absorption characteristics of composite sheets subjected to low velocity impact were analyzed.

The above studies provide a broad theoretical basis for the analysis of fiber reinforced composites under impact, but most of the studies are based on the drop impact test. The hammer head of the drop hammer impact test is sharper, and it is easy to cause the fiber laminate to penetrate and break during the impact process, so it is easy to study the mechanical properties and morphological changes of the laminate in the event of damage. However, in the field of practical engineering, another common form of impact is the surface impact load generated on the fiberboard. The back side of the fiberboard is tensioned, causing cracking of the matrix, and then tearing of the fiber to cause the laminate. Loss of protection. The drop hammer impact test method does not directly reflect the impact resistance of the material in the actual engineering field. For example, road crash barriers have the effect of facial force when the car collides. Therefore, in order to meet the actual project and better simulate the actual impact shape, this paper uses the falling ball impact test method instead of the drop hammer impact test method.

2. Experimental Method

2.1 Impact Test Piece.

The reinforcing fiber used in the impact test piece is glass fiber, and the fiberglass cloth is a plain cloth provided by Suzhou Zhengtian Composite Material Co., Ltd., and the weight is 160g/m^2. The thickness is 0.15 mm. The structural adhesive used for preparing the composite board is a mixture of epoxy resin glue E44 (6101) and low molecular weight 650 polyamide curing agent in a ratio of 1:1, and the impact composite material test board has a size of 200 mm×200 mm, wherein The fiber woven fabric is layered according to 0°/90° so that the upper layer of the fiber cloth is orthogonal to the layer of the next layer of the fiber cloth. The preparation method of the composite material plate is a manual wet method, and for the molded test piece, the thickness is controlled to ensure that the amount of glue is kept substantially the same. In this impact test, three layers of fiber cloth are used for layering, and finally the total thickness deviation of the composite board is not more than 6%, which is qualified [1], and the thickness of the glass fiber board for preparing multiple impact plates is 1.46.mm.

2.2 Falling Ball Impact Tester.

The impact equipment used in this low-speed impact test uses a self-assembled impact test device; the main body of the impact test machine is the LX-5621 falling ball impact tester developed by Guangdong Dongguan Lixin Instrument Co., Ltd. according to the relevant standard [2].

A special impact pressure sensor is installed between the base and the top plate, and the maximum acquisition frequency can reach 10000HZ. The V1.2 high-speed data acquisition card produced by Hengkai Electronic Technology Co., Ltd. was used to collect the pressure signal, and the corresponding upper computer was used to store the pressure data and process it accordingly.

2.3 Experiment Method.

The impact tester is equipped with a movable lifting bracket and a suction head for electromagnetic suction. The power supply can be controlled to open and close by controlling the switch. Above the tip is equipped with a laser head for impact point calibration, disconnecting the power supply, and the steel ball is free to fall and hit the center of the board. The impact energy can be adjusted according to the quality of the test steel ball and the height of the steel ball drop. Since this test is to investigate the damage of the composite plate under multiple impacts, the impact energy pre-experiment is set to ensure that the plate body is not damaged by a single impact and cannot be completely obscured. Impact damage. After several impact pre-experiments, the impact steel ball was determined to be 1kg, and the drop height was 1.8m, that is, the impact energy was 18J. According to the SACUA standard, the impact ratio is determined according to the thickness of the test piece, wherein the energy

coefficient is 4.45 J/mm. Therefore, this impact energy is significantly larger than the impact energy of the current drop hammer impact. During the impact process, the acquisition software automatically records and stores the pressure values received by the test piece, and obtains a time history curve of the impact force. After the failure mode of the first impact was recorded, the damage of the board surface after every 10 impacts was photographed, and the numerical values of the long axis and the wide axis of the damage area were recorded by a digital vernier caliper. Each composite panel impacted 100 stops.

3. Results and Discussion

3.1 Time Damage Pattern.

After the first impact and after every 10 low-speed impact tests, the composite panel was inspected for impact damage on the impact surface (front) and bottom surface of the composite panel. According to the relevant research, the damage pattern of the fiberglass board under impact can be approximated by an ellipse, and the surface of the board with obvious damage changes is photographed, and the change of the long and short axes of the crack in the damaged area is measured to calculate the cumulative impact energy. The area under the impact damage (Figure 1). In fact, the main deformations of the plate body under different impact times are shown in Figure 2.

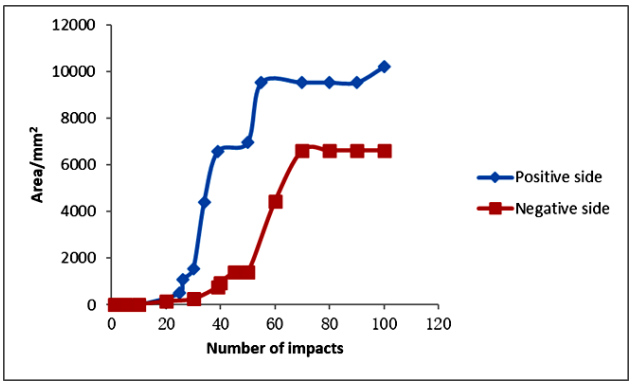
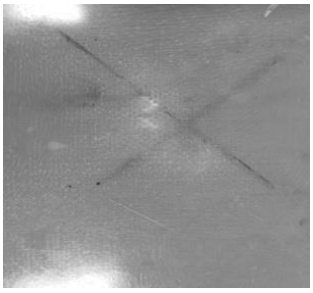
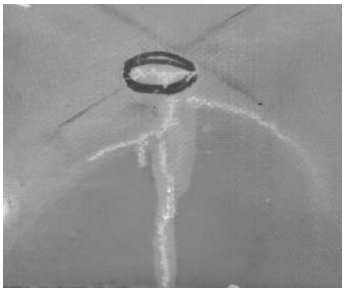


Fig. 1 Panel impact damage area under different impact times

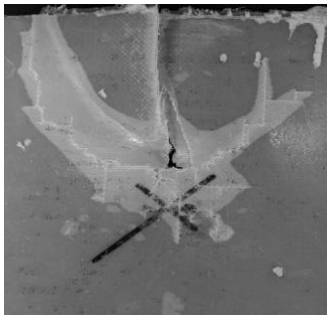


(a) Single impact (negative side)



(b) 50 times impact (negative side)

(c) 100 times impact (negative side)



(b) 100 times impact (positive side)

Fig.2 Damaged form of fiberglass board under different impact times

According to the damage form, the impact of the impact damage caused by the low-speed impact test of the composite board based on the falling ball impact method is different from that obtained by the

drop weight impact test. The main difference is that the falling ball impact damages the board in the impact board. The back is first deployed and the damage develops faster. According to the impact form, the damage forms of the composite sheet in the case of falling ball impact can be divided into three categories: the first type is the continuous depression of the impact surface and the large number of surface cracks caused by the matrix fracture caused by the huge pressure. The second type is the crack at the bottom of the plate due to fiber breakage and extraction, and the third type is the occurrence of extensive delamination and large collapse.

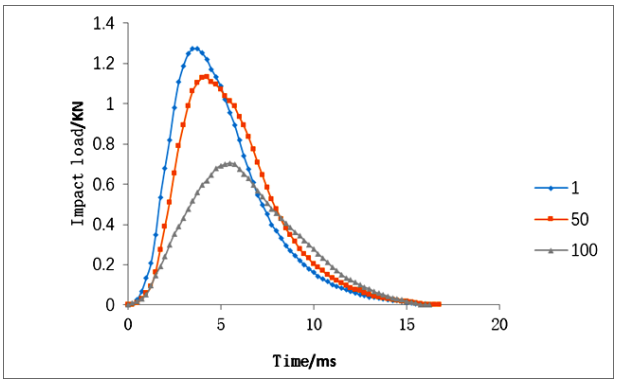


Fig.3 Composite material plate impact load time history curve

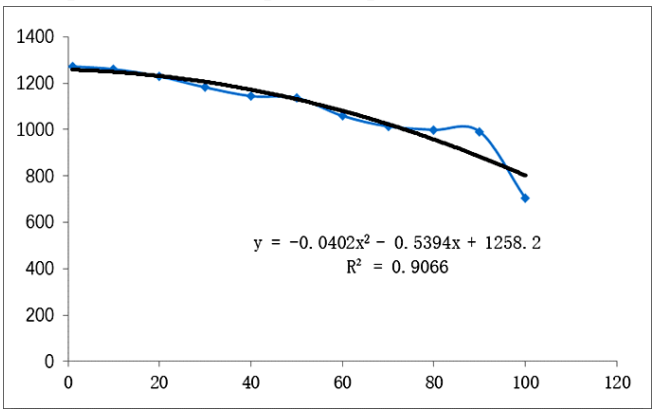


Fig.4 Peak load shock trend

According to Figure 3, the glass fiber reinforced plastic sheet has undergone three types of failure modes under different impact times. The damage form of the glass fiber reinforced board in the single impact is almost the same as that of the basalt fiberboard, and the damage area at the bottom is called basalt fiberboard is smaller. As the number of impacts increased, the cracks at the bottom of the fiberglass board continued to develop, and at the 25th time, the impact surface of the fiberglass board suddenly appeared a crack extending from the impact point to the boundary, and three cracks appeared on the back of the fiberglass board to The shape of “mountain” continued to expand toward the boundary. At the 65th impact, the crack completely extended to the boundary, and the crack on the impact surface also extended to the boundary. When the impact occurred again, the glass fiber slab began to show large-scale delamination. With the increasing number of impacts, the change trend of the impact damage area of the fiberglass board is basically consistent with the trend of the basalt fiberboard, which is the rapid growth in the early stage and the change of the damage area in the later stage is small. However, after 5 times of ball impact, the damage area of the fiberglass board is larger than that of the basalt fiber board under the same number of impacts. This is because the middle fiber layer is not broken and the damaged boundary appears local stress concentration under the next impact, further expanding. The damaged area. When a certain number of impacts is reached, the crack extends to the constraint boundary, and at this time, the plate body can be completely failed, and the damage area is no longer increased.

Based on the above-mentioned multiple impacts, the impact change of the glass fiber reinforced plastic sheet shows that the glass fiber reinforced plastic sheet exhibits good impact resistance under the surface impact.

3.2 Impact Load.

According to the voltage signal fed back by the pressure sensor, the time history curve of the impact load can be plotted. Figure 4 shows the time history curve of the impact load of the two composite plates under different impact times. The maximum impact load in the time history curve of the impact load is selected as the impact peak. The variation trend of the impact load peak under different impact times is shown in Figure 5.

Under the impact of falling ball, the trend of the time-history curves of the two types of composite plates is consistent. At the initial stage of the falling ball impact (t<0.2ms), the falling ball and the composite material plate begin to contact, the falling ball presses the fiber and the resin, and the plate body undergoes compression deformation and depression during the compression process, and the inside of the plate body is opposite. The stress redistribution is carried out by the impact load; as the falling ball continues to fall, the load time history curve rises continuously due to the boundary constraint. After the impact load maximum is reached, the falling ball rebounds together with the composite plate, and the subsequent load time history The curve continues to drop until the ball falls out of the plate so that the impact load returns to zero.

Compared with the drop hammer impact, the impact load history curve of the ball impact is consistent in the general trend, but since the force surface gradually becomes larger as the impact process changes, it does not appear at the tip of the hammerhead. The resulting initial curve region fluctuates drastically and the load appears to fall significantly. In addition, the load based on the falling ball method is relatively fluctuating due to delamination damage and severe fiber drawing during the drop hammer impact process. The time history curve is smoother throughout the impact history.

With the increase of the number of impacts, the peak load trend of the glass fiber laminates is parabolic decline, and the change trend of the impact load peak is first large and then small, and the magnitude of the decrease is large. This shows that the fiberglass laminate has a large loss of stiffness under continuous falling ball impact.

3.3 Impact Load-displacement Curve.

The acceleration time history curve can be calculated by the load time history curve obtained by the pressure sensor. The acceleration time history curve can be integrated to obtain the speed time history curve, and the speed time history curve can be integrated to obtain the displacement time history curve. Impact load time-history curve can obtain the impact load-displacement curve of two composite plates (Figure 5)

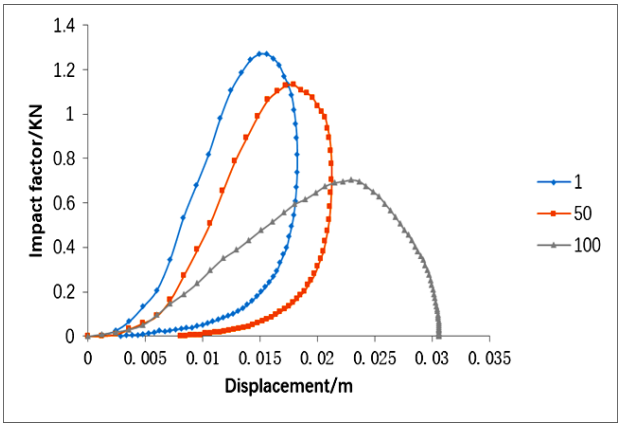


Fig.5 Glass fiberboard impact load-displacement curve

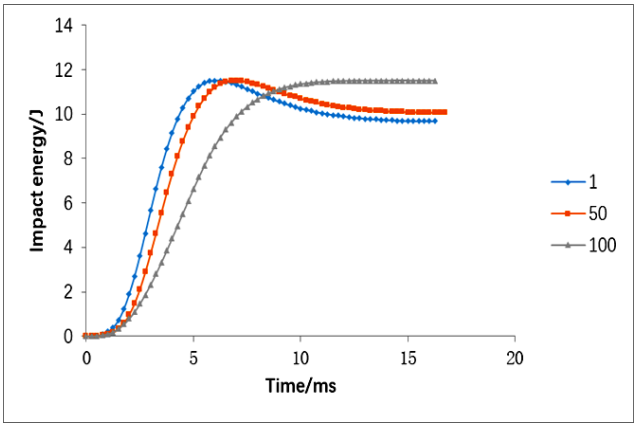


Fig.6 Glass fiber board impact energy time history curve

According to the impact load-displacement curve, when the falling ball impacts the fiberboard, the displacement of the fiberboard gradually increases until the impact load reaches the maximum, and then the impact load and the displacement value decrease continuously. When the impact load is zero, the ball falls and At the moment when the fiberboard is separated, the plate body will still recover a part of the deformation under the action of inertia. If it cannot return to the original position, the permanent deformation of the pit will cause damage to the plate body. When the number of impacts is small, the two types of fiberboards mainly produce elastoplastic deformation under the impact of falling ball, and no large-area plate fracture damage occurs. Therefore, the impact load-displacement curve has a large displacement recovery in the later stage.

For the fiberglass board, the peak value of the impact load decreases as the number of impacts increases, and the corresponding displacement peak gradually increases. When the number of impacts is only one, the plate body damage is small, so the displacement of the contact point can return to the original position after the ball is separated from the fiberboard in the later stage. As the number of impacts increases, the cumulative damage of the plate increases. The substrate on the surface of the plate is cracked, and the plate body is compressed and depressed when the ball plate is separated. When the number of impacts reaches 100, the displacement of the fiberglass board hardly recovers, and the plate body appears as a whole fracture.

Figure 6 is the energy time history curve of two types of composite laminates. After the initial contact, the curve is in the continuous rising phase until the maximum impact energy is reached. Then the impact energy time history curves under different impact times are different. Change form. The energy time history curve of the falling ball impact is basically consistent with the energy time history curve of the drop hammer impact. According to the relevant literature, the energy absorption time history curve can be divided into three main regions: the first region has a shorter time, compound The material plate absorbs less energy. After entering the second region, the impact energy curve rises rapidly. At this time, the fiber plate and the falling ball are in the elastic energy absorption region, which is also the main stage of energy absorption. The energy time history curve of the third region has The obvious difference is that some of the energy absorption remains almost unchanged, but the energy absorption curve of the other part shows a significant drop, indicating that energy rebound occurs. This part of the impact energy is not absorbed by the fiberboard and converted into the elastic strain of the plate. can.

Since part of the energy is converted into elastic strain energy during the impact process, this part of the energy is the energy required for the deformation of the fiberboard to rebound, and the other part of the energy is absorbed by the fiber. This part of the energy can be stratified by the fiber laminate, plastic deformation and Matrix cracking and fiber extraction and fracture are absorbed. Therefore, it can be seen from the figure that when the number of impacts is only one, the fiberboard body is damaged lightly and the matrix is not completely cracked. Therefore, the impact energy of the fiberboard rebounds more, and after multiple impacts, the fiber absorption More energy, energy rebound is not obvious.

4. Conclusion

(1) After the pressure data is collected by the pressure sensor, after a certain data processing, various time-course stress curves of the composite plate can be obtained under the impact of the falling ball. The time-course stress curve obtained by the analysis can be used to know the damage of the fiberboard. This method is simple, straightforward and more in line with the requirements of actual engineering. This is a better way to react the composite under damage at low speeds.

(2) The impact of the drop hammer is different. The damage of the composite plate caused by the drop hammer is mainly caused by the cracking of the base when the number of impacts is small. When the number of impacts is large, the integral fracture of the plate is caused by the cumulative damage. Less damage such as fiber drawing and delamination occurs.

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