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Impact Properties Study of Fibre Reinforced Resin Matrix Composites

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Abstract: In order to study the impact resistance of new resin-based fiber composite materials and apply them to the electric vehicle battery PACK box, the dynamic simulation for fiber composite laminates is carried out based on ANSYS ACP module and Explicit Dynamics module. In the calculation of the finite element model, the damage of the material is judged according to the change of the maximum stress and the maximum strain of the top surface about experiment samples. Calculate the difference between the stress or strain of the carbon fiber and the glass fiber at different impact heights to determine whether they have a good resistant ability to impact. Finally, compared with the results of hammer-dropping test, verify the accuracy and reliability of numerical simulation method.

Keywords: Fiber Composite Materials, ANSYS ACP, Stress and Strain, Impact Test

1. Introduction

Fiber-reinforced composites are widely used in aviation, aerospace and other fields due to their high specific strength, specific modulus and design ability. At present, electric vehicles develop rapidly, because of battery energy density constraints and other factors, more and more fiber composite materials are used in automotive lightweight projects. This paper is based on composite material battery PACK and focuses on the impact properties of carbon fiber reinforced composite polymer (CFRP) and glass fiber reinforced composite polymer (GFRP). The CFRP is a resin-based, carbon fiber reinforced composites, whose density is small, closing to magnesium and beryllium, being 0.20 ~ 0.57 times of several other metal materials [1]. The use of CFRP as a structural material can reduce the structural quality of 30% to 40%; CFRP's light and high strength performance is most significant and its specific strength is 5 times higher than that of steel, 4 times higher than that of aluminum alloy. Its specific modulus is 1.3 ~ 12.3 times of other structural materials [1]. The GFRP is superior to organic fiber in high temperature resistance, non-burning, corrosion resistance, heat insulation, high tensile strength, good electrical insulation [2].

Based on the ANSYS ACP module, the simulation of the hammer impact test of the composite laminates are carried out. According to the stress level of the laminated plate under different impact heights and the damage of the concentrated area and the strain size prediction model, the results are compared with the drop hammer impact test, contrast the difference between the material properties. According to the above several kinds of material personality, apply them to the PACK box on appropriate locations, so as to maximize the impact resistance of the box.

2. Simulation Analysis

The ANSYS ACP and Explicit Dynamics modules based on ANSYS workbench are used to simulate the impact experiment of the two kinds of fiber reinforced composites on the PACK box, including the establishment of the impact model, setting the material properties, creating the connection between components, the definition of contact properties, meshing, the application of boundary conditions and the application of load, impact control, and set the output parameters and so on. To

better guide the PACK box production process of carbon fiber and glass fiber distribution, to maximize the power battery cabinet safety performance index.

2.1. Impact Model Establishment and Meshing

Use UG software modeling a square plate with 200mm length, 200mm width and 2mm thickness, including an impact head model with 40mm diameter. Then bring it into the ANSYS software, using the ANSYS workbench software to automatically generate the grid, the grid cell size is set to 5mm. Figure 1 for the 2mm-in-thickness fiberboard impact test model grid, a total of 3973 unit points, 5902 grid cells. Define the side of the contact with the hammer is positive, the other side is negative.

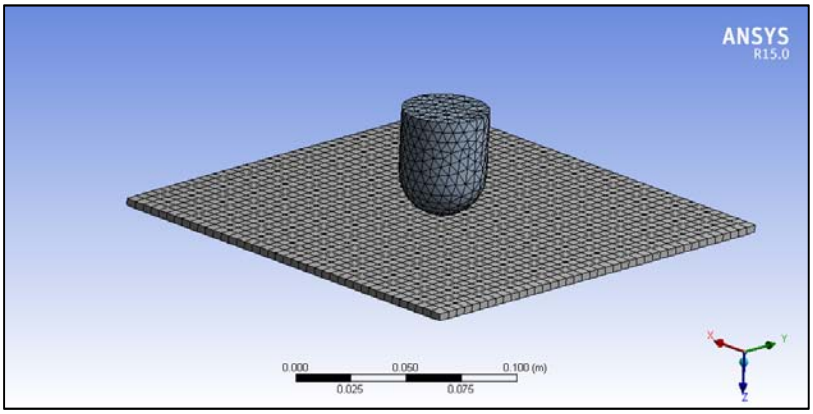

Figure 1. *Meshing model.*

2.2. Calculate Environment Setting

The basic parameters of the carbon fiber are set to density 1.7g / cm^3, elastic modulus 20GPa, Poisson's ratio 0.3, tensile strength 800MPa; the basic parameters of glass fiber is set to density 1.6g / cm^3, elastic modulus 8GPa, Poisson's ratio 0.22, Tensile strength of 320MPa. The impact hammer material is set to structural steel.

The four sides of the fiber model are all fixed by ordinary fixed, and the freedom of the impact hammer is limited. Only the impact head is allowed to be displaced in the vertical direction. The contact between the punch and the fiber board is set to No Separation. When the impact head contact the sample top surface, define the speed of impact head "V" which is determined by the impact height called "h". The impact height is 600mm, 800mm, 1000mm, 1500mm. Set the gravitational acceleration g = 9.8km / s^2 and the impact time is set to 0.0008s.

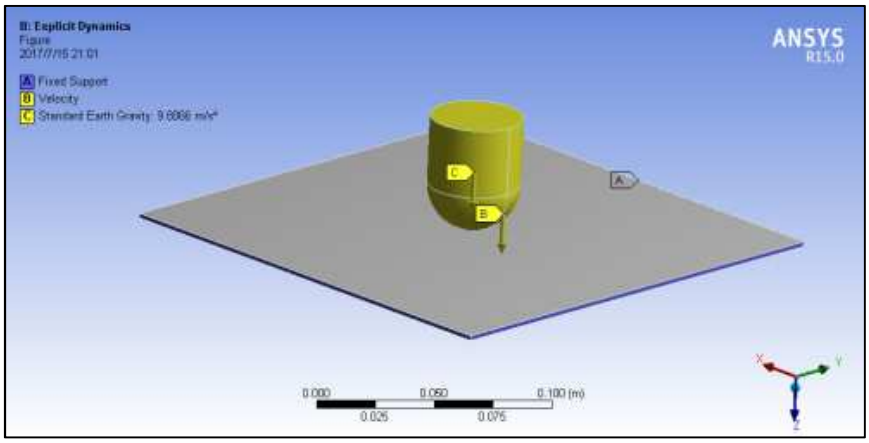

Figure 2. *Impact environment.*

2.3. Simulation Result

2.3.1. Calculation Formula

The calculation formula of stress and strain:

$$\sigma = \frac{F}{a^2} \tag{1}$$

$$\varepsilon = \frac{\Delta d}{d^2} \times 100\% \tag{2}$$

Among them:

σ-Impact stress or impact strength in units of MPa;

F-Impact load or maximum load in units of Newton;

a-Square fiber sample board side length in units of millimeters;

ε-Impact strain;

Δd-The deformation in the vertical direction of the sample in units of millimeters;

d-The thickness of the fiber test sample in units of

millimeters

According to the output of the ANSYS simulation results about the magnitude of the stress σ and the strain ε, the corresponding value of the impact load F and the vertical deformation amount Δ d of the fiberboard can be deduced according to the formulas 1 and 2.

2.3.2. Comparative Analysis

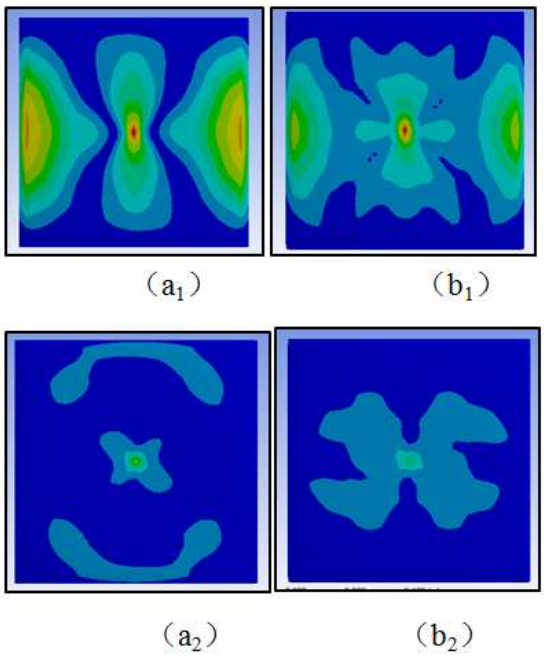

Figure 3. *h=600mm.*

In the Figure 3, Figure (a_1) is carbon fiber sheet positive impacting equivalent stress cloud figure, the stress area is dispersed, composed of three parts, the maximum stress occurred in the hammer and carbon fiber board front contact point and the stress value is 180MPa and the corresponding impact load is 7200kN, which is the biggest impact load on the board. Figure (a_2) is carbon fiber sheet positive impacting equivalent strain cloud figure, the strain area is divided into three parts, the maximum strain is 0.58%, and the corresponding vertical deformation of the amount of deformation is 11.6 μm, which is smaller than the maximum strain value of the whole test plate.

Figure (b_1) is the glass fiberboard positive impacting equivalent stress cloud figure, the stress area is continuous, where the maximum stress occurs at the point where the hammer touches the front of the glass fiberboard, where the stress value is 92MPa and the corresponding impact load is 3680KN, which is the biggest load of the whole model. Figure (b_2) is the glass fiberboard positive impacting strain cloud figure, the strain area is concentrated as one part, in which its maximum strain is 0.4%, and the corresponding vertical deformation is 8μm, deformation slightly lower than the carbon fiber board.

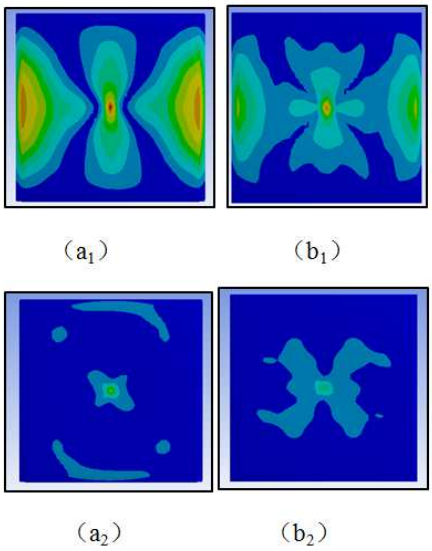

Figure 4. *h=800mm.*

In Figure 4, carbon fiber stress area is dispersed in Figure (a_1), but also consists of three parts, and the maximum stress occurred in the hammer and carbon fiber board front contact position, the stress value of 204.5MPa, and the corresponding impact load is the biggest.

In Figure (a_2), the edge strain area of carbon fiber becomes smaller, the maximum strain is about 0.73%, and the corresponding vertical deformation is 14.6 μm.

In Figure (b_1), the stress area of glass fiberboard becomes smaller. The maximum stress is in the position of the front of the hammer and the glass fiberboard, where the stress value is 107MPa and the corresponding impact load is 4280KN, which is not the biggest load value of the whole board. In Figure (b_2), the maximum strain on the glass fiberboard is 0.53%, and the corresponding deformation in the vertical direction is 10.6μm, and the deformation is close to the carbon fiber board.

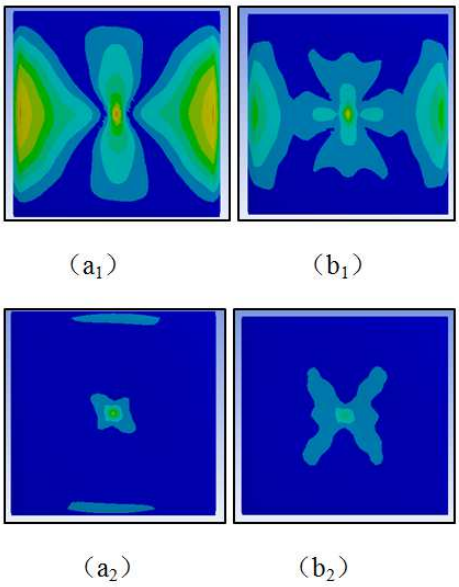

Figure 5. *h=1000mm.*

In the Figure (a_1) of Figure 5, carbon fiber sheet stress region consists of three parts, and the maximum stress occurs at the point where the striker and the carbon fiber positive contact, where the stress value is 224MPa, and corresponding impact load is 8960KN, but not the biggest on the sheet. In Figure (a_2) the carbon edge strain area becomes smaller than Figure (a_2) of Figure 4, in which the maximum strain is 1.05%, and the corresponding vertical deformation is 21 μm.

Figure (b_1) is about glass fiberboard. The stress area is more narrowed than that when the impact height is 800mm. The maximum stress occurs at the point where the hammer is in contact with the front of the glass fiberboard. The stress value is 128MPa, and the corresponding impact load is 5120KN but not the biggest of the whole sheet. In Figure (b_2), the glass fiber sheet maximum strain is 0.8%, and the corresponding vertical deformation is around 16μm, and the deformation is slightly smaller than the carbon fiber board.

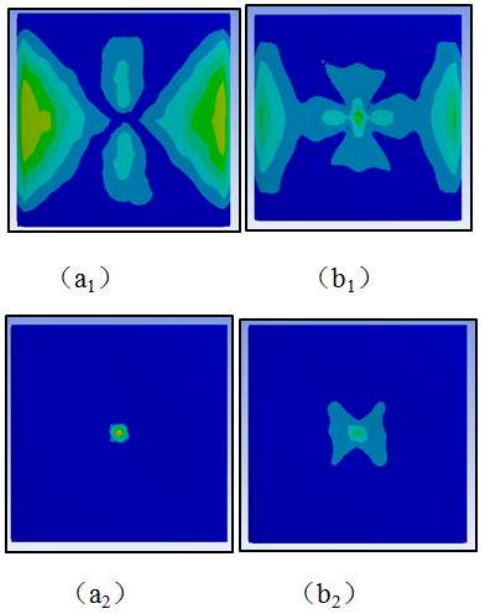

Figure 6. *h=1500mm.*

In Figure (a_1), the carbon fiberboard stress area is divided into four parts, in which the middle part of the stress section is separated into two parts; positive center stress close to 0 MPa, indicating that the front has been damaged and there must have a hole. In Figure (a_2), the maximum strain of carbon board positive surface is 4.2%, and the corresponding vertical direction is about 84μm, and the strain area is concentrated into a diameter of about 40mm circular area.

Figure (b_1) is about glass fiberboard impact positive equivalent stress, the stress area is continuous, where the maximum stress occurs at the point, at which the hammer touches the front of the glass fiberboard and the stress value is 156.6MPa, indicating that the corresponding impact load is 6264KN, but not the largest load of all the sheet. In Figure (b_2), the maximum strain of the glass board is 1.11%, and the corresponding deformation in the vertical direction is 22.2μm, and the deformation is far less than that of carbon fiber board under the same conditions.

2.4. Simulation Conclusion

2.4.1. Stress and Height

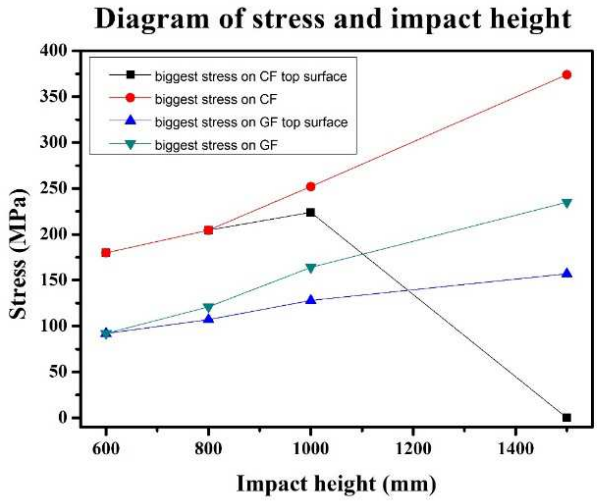

Figure 7. *Connection of stress and impact height.*

From the above figures to see, when the impact height is less than or equal to 800mm, the maximum stress present at the positive center of carbon fiber sheet is the maximum stress on the whole fiberboard, indicating this time the impact stress has not rushed through the fiber board front matrix. When the impact height is more than 800mm, the maximum stress value at the positive center of the carbon fiber sheet is gradually smaller than the maximum stress value of the whole carbon fiber sheet. It shows that the impact stress rushes through the upper substrate and gathers on the fiber structure; when the impact height is equal to 1500mm, the positive impact stress is almost zero, at this time the fiber board has been completely penetrated and becomes invalid.

When the impact height is less than or equal to 600mm, the maximum stress present at the positive center of glass fiber sheet is the maximum stress on the whole fiberboard, indicating that the impact height less than or equal to 600mm, the glass fiber front is not damaged, indicating at this time the impact stress has not rushed through the fiber board front matrix. When the impact height is more than 600mm, the maximum stress value at the center of the impact of the glass fiber sheet is gradually smaller than the maximum stress value of the whole glass fiber sheet. It shows that more than 600mm the front of the glass fiberboard starts to be damaged by impacting; when the impact height is equal to 1500mm, the maximum stress on the front of the glass fiberboard is still large, indicating the glass fiberboard has not failed.

2.4.2. Strain and Height

From Figure 8 to see, the strain value of the carbon fiber sheet is larger than that of the glass fiber at the same height. when the impact height less than 800 mm, the strain values difference between the positive and negative of carbon and glass board is relatively stable; when the impact height more than 800 mm, the strain values difference between the

positive and negative surface of the carbon fiber sheet is gradually increasing until the breakdown is broken. While the glass fiber reinforced plastic's front and back strain values difference although becomes larger, but also stable in a certain range.

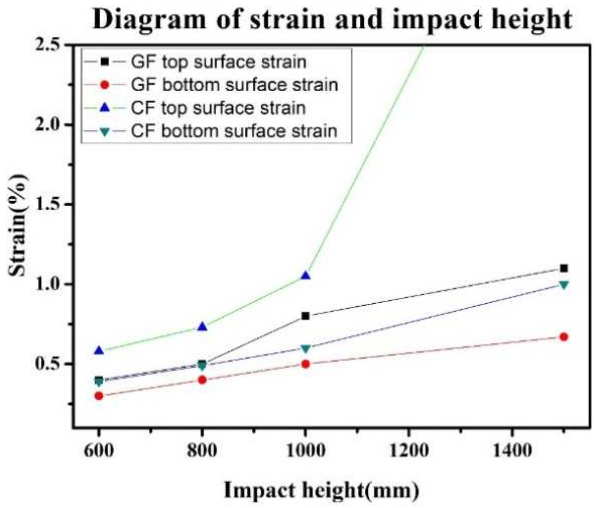

Figure 8. *Connection of strain and impact height.*

3. Impact Test

Prepare several sets of drop hammer impact tests for the above fiber materials, and then obtain the test results, compared with the simulation results, to verify the accuracy of the simulation results based on ANSYS software. Finally combine the test results and simulation results to better guide the design work of the PACK box.

3.1. Sample Introduction and Preparation

In this paper, two new fiber reinforced resin composite laminates have been prepared, including 2mm-in-thickNess carbon fiber board and 2mm-in-thickNess glass fiber board. Set the size of two kinds of boards 200mm × 200mm. Among them, the carbon fiber board made by the E51 epoxy resin matrix and two layers of T300-3K carbon fiber twill cloth; glass fiber board made by the E51 epoxy resin matrix and two layers of 06 alkali grid composition. Figure 9 shows the RTM high-pressure injection molding schematic. Figure 10 shows the shape of the mold. The mechanical properties of the two materials are shown in Table 1.

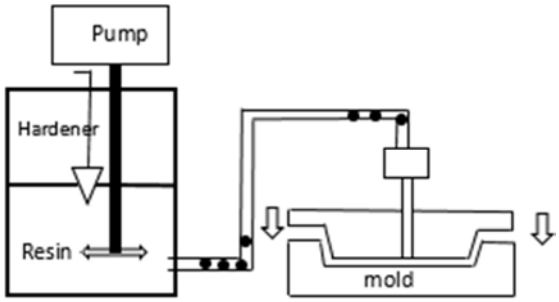

Figure 9. *RTM molding schematic.*

Figure 10. *Forming mold.*

Table 1. *Material properties.*

Materials	Density ρ/(kg·m-3)	Elastic Modulus E/GPa	Poisson's ratio v	Tensile Strength f/MPa
T300	1.7	20	0.3	800
06 glass fiber	1.6	8	0.22	320

3.2. Impact Test Conditions

The impact test is carried out in accordance with the national standard GB_T 11548-1989. The main contents of the experiment include: use the ZCJ1302-A automatic drop hammer testing machine in order to do composite laminates low-speed impact test. The experimental variables are controlled by the type of composite laminates, the weight of drop hammer and the height of drop hammer, and the composite laminates are glass fiberboard and carbon fiber sheet.

In the case of the experiment, set the positive surface of sample board for the zero potential surface to calculate the impact energy from different dropping heights.

The 2kg impact hammer is dropped from the test plane with heights of 600mm, 800mm, 1000mm and 1500mm respectively. The test objects are 2mm-in-thickNess carbon fiber sheet and glass fiber board with the same thickness.

3.3. Results and Analysis

The test results:

(1) When h = 600mm, there is no damage to the front of the carbon fiber board, there are small cracks on the back substrate; the matrix of both side of sheet have a larger crack, the crack diameter is about 15mm;

(2) When the h = 800mm, there appears a small crack on the front of carbon board matrix, the opposite matrix cracks become larger; both sides of the glass fiber matrix have a large strip cracks appear, the diameter of the largest cracks expansion is about 62mm;

(3) When the h = 1000mm, the front of the carbon fiber sheet appears about 30mm in diameter cracks, there starts appearing degumming phenomenon between the matrix and the fiber layer. The cracks in the front and back of the glass fiberboard are further expanded, and there is a slight degumming phenomenon between matrix and fiber layer, but the material does not fail;

(4) When the h =1500mm, the front of the carbon fiber sheet appears about 79mm in diameter pits, and the fiberboard is basically flushed. The degumming phenomenon between the matrix and the fibrous layer is serious for glass fiber board, but it does not fail.

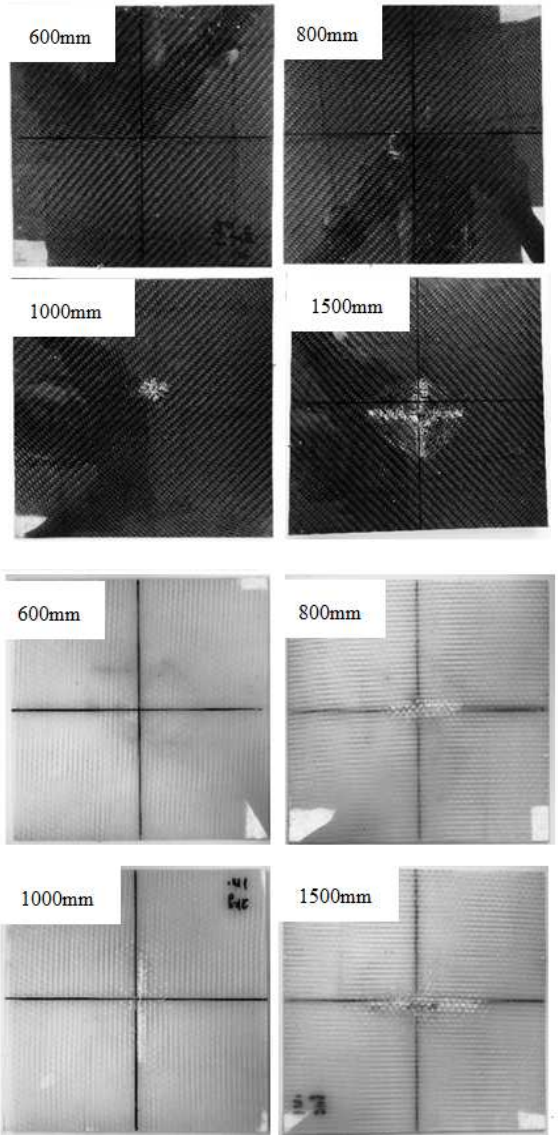

Figure 11. *Impact test phenomenon (partly).*

4. Conclusion

The experimental results are similar to the simulation results of the carbon fiber and glass fiber, indicating that the impact test can be able to verify the accuracy of the simulation results based on ANSYS software and as long as set the appropriate material parameters, dense meshing, the correct contact conditions, boundary conditions, etc., it is be OK to simulate the real dropping hammer test; The basic strength of the carbon fiber board is slightly larger than that of the glass fiberboard. When the impact energy is small, carbon fiber board has a better performance than glass fiber; When the energy grows stronger, at the same impact conditions, because the carbon fiber board deformation area is smaller and the deformation is larger, so the load capacity is weaker than the glass fiber board. In the battery PACK box, glass fiber board must be placed outside the carbon fiber board, which can improve the impact resistance of the box.

Acknowledgements

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References

[1] ZHANG J H, SHENG Z M, SUN J T. Design Guide of Composites Constructure [M]. Beijing: Beijing Yuhang Publishing Company, 1999.

[2] Yan Xiao. The Application of Glass Fiber Composite Materials [J]. Jiangmen Chemical Materials Company (Jiangmen, Guangdong 529100), 2013.

[3] Xiao Lu, Haijun Xuan, Lianfang Liao. Simulation of Ballistic Impact on Carbon Fiber Laminate Panels [J]. Material Engineering, 2009.

[4] Guozhong Tang, Weiguo Guo, Yulong Li, Fei Xu, Yao Zhao. Research on Dynamic Tensile Test and Impact Resistance of Carbon Fiber Composite Laminates [C]. School of Aeronautics, Northwestern Polytechnical University, 2008.

[5] Jianli Cai, Huan Yu, Yunying Wang. Damage Resistance of Low Velocity Impacted on Foam-core Sandwich Structure Composites [D]. Jianli Cai. Nanchang Aeronautical University, 2011.

[6] Boru Li, Guimin Qu. Research of the Impact Performance of Glass Fiber Reinforced Aluminium Laminates [D]. Boru Li. Harbin Polytechnic University, 2015.

[7] Marie-Laure Dano, Elhassania Kamal, Guy Gendron. Analisis of bolted joints in composite laminates: strains and bearing stiffness predictions [J]. Compos Struct, 2000, 79: 562-570.

[8] Peng Zhou, Deyuan Zhou. Study on Accuracy of Simulation Analysis of Guardrail Impact based on ANSYS/LS-DYNA [J]. Vibration and shock. 2008 (04).

[9] Wei Li, Quanfeng Guo. Application of carbon fiber composites to cosmonautic fields. Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130033, China.

[10] Xiuli Wang, Junjie Li, Zhigang Lv. Research on Impact Resistance Performance of New-style Debris Flow-resisting Dams with Braces Based on ANSYS/LS-DYNA [J]. Journal of Disaster Prevention and Mitigation Engineering, 2014.

[11] Bingjie Zhou, Wei Li. Research on Carbon Fiber Laminates for Impact Damage Property and Pedestrian Head Protection [D]. Bingjie Zhou. Donghua University, 2015.

[12] Xiangdong Yang, Jiaqiang Xu, Hao Tao. Study on Impact Properties of Carbon Fiber Reinforced Polymer Laminate [J]. Journal of Zhengzhou University of Light Industry, 1997.

[13] Xiaohong Zhang, Feng Zhou, Qi Feng. Design of Carbon Fiber Cabinet for Vehicle Power Battery [J]. Shanghai Vehicles, 2014.

[14] Determination of material parameters for Abaqus progressive damage analysis of E-glass epoxy laminates [J]. E. J. Barbero, F. A. Cosso, R. Roman, T. L. Weadon. Composites Part B. 2013.

[15] Standard test method for measuring the damage resistance of a fiber-reinforced polymer matrix composite to a drop-weight impact event. American Society for Testing and Materials. ASTM D7136/D7136 M-12. 2012.

[16] Mingyang Xiong, Zhong Xiang, Xudong Hu. Numerical Simulation of Low - speed Impact Failure of CCF300 Carbon Fiber Laminates Based on ABAQUS [J]. Light Industry Machinery, 2017.

[17] Finite Element simulation of carbon fibre-reinforced composite laminates subjected to low velocity impact using damage induced static load-deflection methodology [J]. Umar Farooq, Peter Myler. Thin-Walled Structures. 2015.

[18] Delamination prediction in composite laminates under low-velocity impact [J]. Shuchang Long, Xiaohu Yao, Xiaoqing Zhang. Composite Structures. 2015.

[19] Composite damage model based on continuum damage mechanics and low velocity impact analysis of composite plates [J]. Eun-Ho Kim, Mi-Sun Rim, In Lee, Tae-Kyung Hwang. Composite Structures. 2013.