Research Article

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Study on impact resistance of composite rocket launcher

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Abstract: The transient impact load during the launch of a rocket at sea threatens the safety of the launcher and the deck structure of the launch platform. In view of the impact resistance of the offshore rocket launcher system, this paper takes the real-scale rocket launcher system as the research object and establishes the analysis model of the fiber-reinforced composite rocket launcher based on the finite element method. Then, we explore the factors of the thickness by finite element simulation method and the angle and the position of IM7 fiber-reinforced composite, which influence the impact resistance property of the rocket launcher. The results show that the fiber-reinforced composite rocket launcher can effectively reduce the impact response of the structure and improve the impact resistance of the structure. The best laying scheme is to lay four layers of IM7 fiber material on both sides of the panels of the fixed bracket and the webs of the erector, respectively, with a single layer thickness of 0.75 mm and a laying angle of $[90^\circ/\mp 45^\circ/90^\circ]$.

Keywords: fiber-reinforced composites, finite element method, impact response, rocket launcher structure

1 Introduction

As a part of the cold launch platform at sea, the rocket launcher has the functions of carrying, supporting, installing, and so on. For the cold launch of the rocket, the vibration of the launcher will cause the initial disturbance of the rocket at the outlet, and the transient impact load may also cause damage to the launcher, thus affecting the accuracy and safety of launch. Therefore, the study of the impact resistance of the cold launch ejection device is of great significance for the structural performance evaluation of the launcher and the improvement of launch accuracy. Material is one of the main parameters that affect the vibration characteristics of the launcher, but in engineering applications, using a single material as a protective structure against explosion and impact, it is difficult to reduce the damage to the structure caused by high-speed impact load and effectively attenuate the shock wave. At the same time, modern engineering applications require the development of advanced materials that provide a broad spectrum of property combinations, such as: (i) high specific strength (lightweight and high strength) and ductility for aerospace, automobile, and ship applications where fuel economy and enhanced engine performance become critical; (ii) superior wear resistance, high specific stiffness and satisfactory corrosion resistance in defense applications, and so forth [1]. By laying high-performance materials on the outer layer with metal as the inner base, such as carbon fiber and boron fiber, high-performance composites with toughness, ductility, thermal conductivity, high strength, high hardness, high modulus, and so on can be effectively realized [2–4]. Through the use of high-strength materials in the outer layer and the composite structure of multilayer materials with cushioning energy-absorbing materials, the purpose of anti-explosion and impact can be achieved, that is, the anti-explosion and impact effects can be achieved through the combination of rigid materials and flexible materials [5]. The combination can give full play to the advantages of monomer materials to achieve the purpose of learning from each other and enhancing the anti-explosion effect.

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In terms of impact response of composite structures, Rajaneesh *et al.* [6] studied the high-velocity impact response of quasi-isotropic carbon fiber-reinforced polymeric laminates cured from unidirectional plies using finite element models. They used rigid steel spheres as projectiles and extended the intraply meso-model originally proposed by Ladeveze (LMT-Cachan) for the ply behavior based on continuum damage mechanics, taking ply fracture energies and in situ strengths into account. By implementing intraply and inter ply damage modes in LS Dyna, three different types of post peak degradation strategies are compared: (a) damage rate bound model, and smeared-crack formulation-based (b) linear and (c) exponential softening laws.

Dhari [7] reported the response of composite laminates under high-velocity impact by fragments. They developed a numerical model to simulate a hostile scenario of impact of fragments after their interaction with a blast wave to study the response of cross-ply laminates. The performance of laminates is discussed based on different combinations of standoff distances and angles for deformable AA7075 and rigid Steel projectiles. The damage model is based on a combined elastic-plastic response which was found to have good agreement with existing experimental and numerical results.

Liu *et al.* [8,9] used a woven five-harness satin (5HS) weave with AS4 carbon fibers and unidirectional high-strength IMS60 carbon fibers to manufacture hybrid laminates, using resin infusion, to assess their performance in low-velocity impact tests. By comparing the performance of the hybrid unidirectional/woven (U/W) laminates with the pure unidirectional (PU) carbon-fiber reinforced composite laminates with equivalent layup, the hybrid laminates were shown to yield better impact resistance.

Yang *et al.* [10] built a 3-D finite element model to investigate the high-velocity impact response of FMLs using ABAQUS/Explicit platform; the results showed that the effect of fiber stacking sequence on the impact performance of FMLs is very limited under critical penetration velocity, and the damage pattern depends on the projectile incident angle. Yang *et al.* [11] also verified their mode of inter-ply hybrid composites based on woven fabrics and polymerized cyclic butylene terephthalate resin subjected to low-velocity impact.

In addition, many scholars have carried out related research. The research on vibration characteristics and impact response of composite structures mainly includes numerical method, analytical method, and experimental

method [12–21]. Li *et al.* [22] proposed an integrated model for prediction of the dynamic behaviors involving vibration and impact on hybrid fiber-metal laminates (FMLs) embedded with a viscoelastic layer and performed the detailed experimental test. The outputs provide important references for this type of composite hybrid structures with improvement in the anti-vibration and impact resistant capabilities. Payeganeh *et al.* [23] presented several theoretical models of FMLs subjected to low-velocity impact excitation via an assumption of two degrees of freedom spring-mass system. Based on the 1st-order shear deformation theory, Shooshtari and Razavi [24] presented a novel vibration model of FMLs to predict the natural frequencies and transverse responses. Shariyat and Hosseini [25] established an impact model of composite sandwich plates with viscoelastic cores. However, the effects of failure modes such as delamination, tensile fracture of fiber and matrix on the impact contact forces, and energy absorption properties were not considered. To simulate the failure behavior of a composite sandwich plate subjected to impact loading, Long *et al.* [26] proposed a numerical model of the plate with a foam core by ignoring its fluidity. Liao and Jia [27] studied dynamic structural responses and failure mechanisms of composite pressure vessels subjected to low-velocity impact. They built a three-dimensional laminated media model to calculate the impact responses of composite pressure vessels using ABAQUS/Explicit. The outputs showed that the experimental and numerical results agreed well. Rafiee *et al.* [28,29], based on the layer-wise theory, developed a theoretical solution for predicting the low-velocity impact-induced failure in composite cylinders. And, the obtained results are validated with available experimental observations in open literature. Choi [30] investigated the transient response of composite laminated cylindrical shells with convex and concave shapes subjected to low-velocity impact and concluded that geometrically nonlinear analysis must be performed with consideration of the membrane effect of the curved shell, in order to accurately analyze its impact response. Zhang *et al.* [31] proposed a finite element model to investigate the dynamic mechanical response and damage modes in cross-ply composite laminates under transverse low-velocity impact. By adopting Hashin criterion and a gradual degradation scheme, the simulation results agree well with the available experimental data. Using the proposed model, they also investigated the effect of interface friction on the delamination response of cross-ply composite laminates under impact. In the study presented

by Evci et al. [32], different types of composites specimens; unidirectional E-Glass, woven E-Glass, and woven aramid composite specimens were tested under low-velocity impact. Based on experimental results, the damage growth in woven composites was constrained within a smaller area compared with unidirectional composites and shown to have superior damage resistance than unidirectional composites. Tsartsaris et al. [33] reported the low-velocity impact response of FMLs through testing and numerical simulations. Their results show that the FMLs are able to absorb energy through plastic deformation of the aluminum layer. Li et al. [34] investigated the influence of fiber type on the impact behavior of titanium-based FMLs and found that the use of a polyethylene fiber layer as a sandwiched element of FMLs improves their ballistic performance. More recently, Yao et al. [35] studied the influence of impactor shape on low-velocity impact response of FMLs, while Carrillo et al. [36] investigated the low-velocity impact behavior of thermoplastic-based FMLs under a set of impact energies. Lee et al. [37] fabricated carbon and glass FMLs and investigated their impact behavior under low-velocity impact loadings. The results indicated that the impact strength of FMLs is increased by the use of high-stiffness steel, achieving as well a significant reduction in weight.

It can be seen from the above literature that studies on composite materials are mostly focused on simple models such as composite plates. However, in applications of practical engineering, due to the influence of structural forms, connection modes, and other factors, the research on composite structures is still insufficient. In view of the complex structure of the rocket launcher at sea in this paper, both the analytical method and the experimental method have great limitations. At the same time, the finite element method has great advantages of high efficiency and high accuracy which have been verified by masses of scholars [38–41]. Thus, it uses the finite element method to deal with the vibration and impact response of composite structures. Moreover, the fiber-reinforced composite materials are of great interest [42–46], where the reinforcement is purposely made variable and may lead to more efficient designs [47–49]. By selecting the type of reinforcement structure and reinforcement materials, it is possible to create a structure with predetermined strength characteristics. Therefore, in this paper, the finite element method is used to compare and analyze the vibration characteristics and impact response of fiber-reinforced composite launchers with different laying modes, in order to provide reference for the practical engineering application of composite materials.

2 Finite element theory and modeling of impact response

2.1 Theory and formulation of finite element

The finite element code ABAQUS/Explicit performs dynamic analysis, using a Lagrangian formulation and integrating the equations of motion in time explicitly by means of central differences. The theory and formulation of it are discussed in the following.

2.1.1 Formulation of 4-nodes element

The type of element used in finite element simulation in this paper is three-dimensional shell element. The picture shows the motion state of the object b in the three-dimensional Cartesian coordinate system. Boundary $\partial b_j (j = 1, 2, 3)$, a is any point inside. The point a in object b is from the coordinates $X_k = (k = 1, 2, 3)$ of time zero to the coordinates $x_i (i = 1, 2, 3)$ of time t (Figure 1).

The relevant physical quantities are expressed by tensors. By using the Lagrangian coordinate method [50–55], the relationship between the coordinate x_i of point a at time t and its initial coordinate and time is as follows:

$$x_i = x_i(X_a, t). \quad (1)$$

Assuming that the moving object is divided into finite elements, the displacement of any point in the body can be expressed as

$$x_i(X_t, t) = x_i(X_k(\xi, \eta, \zeta), t) = \sum_{j=1}^h N_j(\xi, \eta, \zeta) x_i^j(t). \quad (2)$$

In the formula, N_j is the shape function in the local coordinates (ξ, η, ζ) , h is the number of element nodes, and x_i^j is the coordinate of the j th node in the i direction.

Figure 1: Diagram of 3D shell finite element.

The vector space $R^{(n)}$ is introduced, and the basis in Cartesian coordinates is $\{e'_k\}_{k=1}^n$. The moving object is discretized into m finite elements, so $\delta\pi$ can be decomposed into

$$\delta\pi = \sum_{k=1}^m \delta\pi_k = 0. \quad (3)$$

The contribution of each unit is

$$\begin{aligned} \delta\pi_k = & \int_{v_k} \rho \ddot{x}_i \delta x_i dv + \int_{v_k} \sigma_{ij} \delta x_{ij} dv - \int_{v_k} \rho f_i \delta x_i dv \\ & - \int_{\partial b_1 \cap \partial v_k} t_i \delta x_i ds, \end{aligned} \quad (4)$$

superimposing each unit to get

$$\begin{aligned} \sum_{k=1}^m \left\{ \int_{v_k} \rho \ddot{x}_i (e_i \otimes v^k) dv + \int_{v_k} \sigma_{ij}^k (e_i \otimes v_j^k) dv \right. \\ \left. - \int_{v_k} \rho f_i (e_i \otimes v^k) dv - \int_{\partial b_1 \cap \partial v_k} t_i (e_i \otimes v^k) ds \right\} = 0, \end{aligned} \quad (5)$$

where e_i is the unit base vector.

$$v^k = \sum_{k=1}^h N_i e'_{n_k(i)}, \quad (6)$$

where $n_k(i)$ represents the global node number.

$$\begin{aligned} \sum_{k=1}^m \left\{ \int_{v_k} \rho N_m^T N_m a dv + \int_{v_k} B_m^T \sigma dv - \int_{v_k} \rho N_m^T b dv \right. \\ \left. - \int_{\partial b_1} N_m^T T ds \right\} = 0. \end{aligned} \quad (7)$$

In the formula, N is the interpolation matrix, σ is stress vector, B is the stiffness matrix, a is the nodal acceleration vector, b is the physical force vector on the moving body, t is the vertical resultant force on the boundary, B , T , and σ are expressed as

$$b = \begin{bmatrix} f_x \\ f_y \\ f_z \end{bmatrix}, \quad T = \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} \quad (8)$$

$$\sigma^T = (\sigma_{xx}, \sigma_{yy}, \sigma_{zz}, \sigma_{xy}, \sigma_{yz}, \sigma_{zx}).$$

The acceleration vector at any point is

$$\begin{bmatrix} \ddot{x}_1 \\ \ddot{x}_2 \\ \ddot{x}_3 \end{bmatrix} = N \begin{bmatrix} a_x^1 \\ a_x^2 \\ \vdots \\ a_y^h \\ a_z^h \end{bmatrix} = Na. \quad (9)$$

2.1.2 Explicit integral in ABAQUS/EXPLICIT

The explicit time integral of ABAQUS adopts the central difference method, and the motion balance equation is as follows:

$$[M]\{\ddot{x}\} = [F^e] - [F^i]. \quad (10)$$

In the formula, F^e is the external force vector applied, F^i is the internal force vector, and the acceleration of any point of the body at t time is:

$$\{\ddot{x}_t\} = [M]^{-1}([F_t^e] - [F_t^i]). \quad (11)$$

The velocity and displacement of each element node at the moment $t = t + \Delta t/2$ and $t = t + \Delta t$ are as follows:

$$\{\dot{x}_{t+\Delta t/2}\} = \{\dot{x}_{t-\Delta t/2}\} + \{\ddot{x}_t\}\Delta t \quad (12)$$

$$\{x_{t+\Delta t}\} = \{x_t\} + \{\dot{x}_{t+\Delta t/2}\}\Delta t_{t+\Delta t/2} \quad (13)$$

In the formula, $\Delta t_{t+\Delta t/2} = \frac{1}{2}(\Delta t_t + \Delta t_{t+\Delta t/2})$.

The new geometry of the object is obtained by the initial configuration plus the increment of displacement, that is,

$$\{x_{t+\Delta t}\} = \{x_0\} + \{x_{t+\Delta t/2}\}. \quad (14)$$

For the nonlinear dynamic response analysis of undamped structures, the calculation time step is conditionally stable, as follows:

$$\Delta t \leq \Delta t_{cr} = \frac{2}{\omega_{\max}}, \quad (15)$$

where $\omega_{\max}$ is the highest natural frequency of the system.

2.2 Finite element modeling of launcher structure

2.2.1 Finite element model and boundary condition

The total length of the offshore launch platform is 159.6 m, the maximum ship width is 38.8 m, and the mold depth is 10.9 m. The rocket launcher is located in the middle of the launch platform deck. When the rocket launcher is erected, it is 20.5 m long, 9 m wide, and 15.5 m high. The rocket launcher is a truss structure composed of I-beam, T-profile, box profile, and pipe profile. The main structure is composed of rocket erector and fixed bracket, which are connected by rotary shaft to provide carrier for rocket installation, testing, and launch. This paper establishes the finite element calculation model of real scale with the help of ABAQUS software. The structural model of

Figure 2: Model diagram of launcher structure. (a) Structural model of offshore launch platform. (b) Finite element model of offshore launch platform and boundary condition.

the rocket launcher is simplified as shown in Figure 2. Compared with the strong impact load produced during rocket launch, the effect of wave load on the platform is negligible. Moreover, we only focus on the parameters of fiber-reinforced composite, which have influence on the impact resistance of rocket launcher structure. Therefore, the structural finite element model of simulation is simplified as the model shown in Figure 2(b). That is, the structural finite element model only contains the rocket launcher and its bottom cabin of the platform, and the flow field is not taken into account. The boundary condition of the cabin is set to be fixed at both ends.

As is shown in Table 1, by comparing the results of the modal analysis when the sizes of finite element are $100\text{ mm} \times 100\text{ mm}$, $80\text{ mm} \times 80\text{ mm}$, $50\text{ mm} \times 50\text{ mm}$, and $20\text{ mm} \times 20\text{ mm}$, it is found that the model has converged when the mesh size is $50\text{ mm} \times 50\text{ mm}$. Therefore, based

on the consideration of calculation accuracy and efficiency, the finite element mesh size is chosen as $50\text{ mm} \times 50\text{ mm}$ and the number of mesh is 354,305, and the types of the elements are S4R (Figure 3).

Table 1: Results of modal analysis

Mode		Size of element			
		100 mm × 100 mm	80 mm × 80 mm	50 mm × 50 mm	20 mm × 20 mm
Bending	1	13.723 Hz	13.701 Hz	13.687 Hz	13.687 Hz
	2	33.901 Hz	33.886 Hz	33.882 Hz	33.882 Hz
Torsional	1	27.334 Hz	27.331 Hz	27.329 Hz	27.329 Hz
	2	40.265 Hz	40.258 Hz	40.253 Hz	40.253 Hz

Figure 3: The modal of the erector: (a) 1st-order bending mode, (b) 2nd-order bending mode, (c) 1st-order torsional mode, and (d) 2nd-order torsional mode.

2.2.2 Material simulation and reference point

In the finite element calculation, the launcher material is made of T700 carbon fiber and steel material. The parameters and the simulation method of the materials used in this paper are referred to reference [56]. The material parameters of the model are shown in Table 2. The adhesive is used between the carbon fiber composite layer and the metal.

The method of cold launch is adopted for launching a rocket at sea, which is similar to that of a missile. The rocket ejects out of the cylinder first and produces thrust in mid-air. The thrust of the rocket when it comes out of the cylinder is about 5 times of its own weight. In this paper, taking the offshore launcher of a certain type of

rocket as an example, the mass of the rocket is about 100 t, and the impact load is simplified to a triangular shock wave load. According to the stability conditions, the stability is often 1×10^{-6} s. The load form and loading position are shown in Figure 4.

In order to compare the response of the launcher structure under this load more clearly, the reference points 1, 2, and 3 are respectively selected in the typical structural areas of the fixed bracket, the rocket erector, and the platform deck. Figure 5 shows the reference points location; point 1 is located in the middle of the side of the fixed bracket – the side near the launcher, point 2 is on the connection between the top of the rocket erector and the launcher, and point 3 is on the deck near the bottom of the launcher.

Table 2: Fiber layer performance parameters [56]

Material	Density ρ ($\text{kg}\cdot\text{m}^{-3}$)	Elasticity E ($\text{N}\cdot\text{m}^{-2}$)		Poisson ratio ν		Yield Stress σ_s (MPa)	
Q235 Steel	7.85×10^3	2.06×10^{11}		0.3		235	
T700-Fiber layer	Density ρ ($\text{kg}\cdot\text{m}^{-3}$)	E_{11} (GPa)	E_{22} (GPa)	μ_{12}	G_{12} (GPa)	G_{13} (GPa)	G_{23} (GPa)
	1,440	278.5	3.502	0.24	13.1	13.1	9

Figure 4: Loading form and position: (a) loading form and (b) loading position.

Figure 5: Schematic diagram of reference point selection.

3 Results and discussion

In order to explore the influence of composite materials on the impact resistance of structures, the impact response of launcher structure under the action of composite layer thickness, composite layer angle, and composite layer position is considered respectively. Taking the typical reference points of each structure as an example, the acceleration response law is analyzed.

3.1 Influence of laying thickness on impact response

It takes the scheme as an example; which four layers of fiber-reinforced materials are laid both on the top and

bottom of the steel plate. The laying angle is $[0^\circ/\mp 45^\circ/0^\circ]$, with the same thickness of sandwich metal and different thickness of monolayer as shown in Figure 6. In this case, the whole structure of the launcher bracket and the platform deck is made of composite material. It discusses the influence of the laying thickness on the structural response, and the acceleration response of the reference point is shown in Figure 7.

As can be seen from Figure 7, when subjected to impact load, the impact response law of fiber-metal sandwich composite structure is similar to that of steel structure. It shows a trend that the acceleration increases with the application of load and attenuates rapidly after the load is revoked. However, the peak value of the acceleration of the composite structure is low and so is the attenuation. The acceleration response versus time data at each reference point is transformed into the acceleration response in frequency domain by Fourier transform. It can be seen that in the frequency range of 0–200 Hz, the vibration acceleration of the composite structure at each frequency point decreases with the increase of the frequency, which is smaller than that of the steel structure as a whole. It indicates that the composite structure has a good damping effect. The vibration acceleration decreases significantly with the increase of the layer thickness when it is less than 0.75 mm, but the acceleration will not decrease any more when the layer gets thicker (Figure 8).

Figure 6: Laying mode with different laying thicknesses.

(a)

(b)

(c)

Figure 7: Curves of acceleration response under different laying thicknesses: (a) 1#, (b) 2#, and (c) 3#.

Figure 8: Diagram of acceleration response: (a) $t = 0.25$ mm, (b) $t = 0.5$ mm, (c) $t = 0.75$ mm, and (d) $t = 1$ mm.

3.2 Influence of laying angle on impact response

From the analysis of the previous section, it can be seen that when the whole structure uses fiber-reinforced composites with the same laying angle, the impact resistance

of the composite launcher with 0.75 mm-thick fiber is the best. On this basis, this section further explores the influence of the laying angle of fiber-reinforced composites on the impact resistance of the structure, which are shown in Figure 9. The acceleration response of the reference point is shown in Figure 10.

Figure 9: Diagram of laying angles.

Figure 10: Curves of acceleration response under different laying angles: (a) 1#, (b) 2#, and (c) 3#.

As can be seen from Figure 10, when the laying angle of the fiber-reinforced composite is different, the response of the structure will change. Combined with the curve of

acceleration response versus time data and in frequency domain, we can see that under each laying angle, the trend of acceleration response with time and frequency

Figure 11: Diagram of acceleration response: (a) $[0^\circ/\mp 45^\circ/0^\circ]$, (b) $[0^\circ/\mp 45^\circ/90^\circ]$, and (c) $[90^\circ/\mp 45^\circ/90^\circ]$.

Figure 12: Location of composite materials for launcher structure.

Figure 13: Curves of acceleration response under different laying positions: (a) 1#, (b) 2#, and (c) 3#.

is basically the same. When the laying angle of IM7 fiber is $[90^\circ/\pm 45^\circ/90^\circ]$, the acceleration response attenuates first, and the acceleration level is the lowest at the same

frequency point, indicating that the laying method has the best damping and impact resistance. For the launcher structure, the impact resistance of IM7 fiber at the laying

Figure 14: Diagram of acceleration response: (a) composite launcher, (b) composite faceplate, (c) composite web, and (d) composite square tube.

angle of $[0^\circ/\mp 45^\circ/0^\circ]$ is better than that of $[0^\circ/\mp 45^\circ/90^\circ]$. For the deck structure, the laying method of $[0^\circ/\mp 45^\circ/90^\circ]$ is better than that of $[0^\circ/\mp 45^\circ/0^\circ]$ (Figure 11).

3.3 Influence of laying position on impact response

From the analysis of the previous section, it can be seen that the impact resistance of the structure is the best when the thickness of single layer is 0.75 mm and the laying angle is $[90^\circ/\mp 45^\circ/90^\circ]$. This section continues to discuss the influence of the laying position of the composite material and analyzes the impact response law of the launcher panel structure (the purple part of Figure 12), the web structure (the yellow part of Figure 12), and the

riser structure on both sides of the launch tube (the green part of Figure 12) when the composite material is used alone. It should be noted that when the composite material is used in the local structure, the rest are made of steel and the acceleration response of the reference point is shown in Figure 13.

As can be seen from Figure 13, when the location of the fiber-reinforced composite is different, the response of the structure is different. When the composite is applied to the whole structure of the launcher, the overall impact resistance of the launcher structure is the best. For the fixed bracket, the impact resistance of the structure with only the fiber-reinforced composite panel is close to that when the composite is used as a whole. For the rocket erector, the impact resistance property of the composite material only for the web is similar to that of the composite structure. From the curve of reference point 3, it can

be seen that the acceleration response of the deck attenuates faster only when the composite is applied to the web. Therefore, considering the impact resistance and economy of the launcher structure, we can choose to lay fiber-reinforced composites in the local structure of the launcher. Combined with the simulation results of this paper, fiber-reinforced composites can be laid only on the panel of fixed bracket, the web of erector, and the web of platform deck to meet the structural safety and economic practicability (Figure 14).

4 Conclusion

In this paper, based on the finite element method, the real-scaled structural model of offshore rocket launch platform-launcher is established, and the impact responses of the structural model originally made of steel material and the structural model of fiber-reinforced composite are calculated respectively. The effects of IM7 fiber layer thickness, laying angle, and laying position on the impact response of the launcher are analyzed. The conclusions are as follows:

- i. IM7 fiber-reinforced composites have the advantages of greater stiffness and lighter weight than steel. When they are used in rocket launchers, the structural vibration response can be effectively reduced and the impact resistance can be improved.
- ii. When the monolayer thickness of the composite is 0.75 mm, the impact resistance of the composite launcher has been significantly improved. When the monolayer thickness of the fiber-reinforced composite is less than 0.75 mm, the structural vibration response decreases with the increase of the thickness. When the monolayer thickness is greater than 0.75 mm, the vibration response decreases with the increase of the thickness.
- iii. The laying angle has an influence on the impact response of fiber-reinforced composite structures. Among the three laying methods discussed in this paper, the impact resistance of the composite rocket launcher is best with laying angle of $[90^\circ/\mp 45^\circ/90^\circ]$.
- iv. When the composite material is applied to the whole structure of the launcher, the overall impact resistance of the launcher structure is the best. When using composite material only for panels of the fixed bracket, the webs of the erector can meet the structural safety and economic practicability, which is the best scheme of composite lamination.

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