Structural Design and Simulation of Ejection Device with Pulley Block

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***Abstract*—The catapulting device is widely used in the aerospace field. In the process of simulated impact test of a certain type of missile, a design method of the pulley group ejection device is proposed for the test system with large load mass, large impact speed and short acceleration time, which elaborates The design idea of the catapult device with pulley group. Based on UG, the structural design of each part of the ejection device was carried out, and the composition of each part was elaborated. Based on AMESim, the mathematical model of the pulley block is established, and the offset load force generated by the pulley block model is obtained. Based on Nastran, the finite element analysis of each part of the ejection device is carried out, and the structural deformation of each part of the ejection device is obtained. At the same time, it provides a good idea for the design of high-speed catapults.**

Keywords—pulley group; catapult; structural design; finite element analysis

I. INTRODUCTION

The structure of pulley block is applied to a certain type of missile ejection system, which was used in impact and test, which is suitable for load test with high speed and high quality [1]. It was simulated the motion state of the missile in the launching cylinder of the missile, by giving a certain speed of 100 kg of the measured load, so that the measured load moves at a high speed in the vertical direction, and the simulated load collides with the relative speed of the tested product [2]. The impact process is monitored by the measurement and control system to analyze the interaction between the simulated load and the tested product during the impact process [3]. The main performance indicators proposed by the project is that the action speed is not less than 45m/s, and the maximum stroke is not less than 5 meters, and the action stroke is not more than 6 meters.

II. WORKING PRINCIPLE OF PULLEY BLOCK STRUCTURE

A. Catapulingt Status

The traditional methods of ejection at home and abroad are mainly divided into pneumatic ejection, electromagnetic ejection and hydraulic ejection [4]. Electromagnetic ejection is an emerging linear dynamic technology, which has broad application, but it has strong interference in magnetic field and high cost [5]. However, although the pneumatic ejection method has faster response speed, its speed controllability is poor [6]. The output of hydraulic ejection method is large and the rapidity is good, but its speed is slow, and the maximum can only reach about 10 m/s [7]. This test system is a difficult transient accelerating process that is difficult to implement. It is necessary to accelerate the load to 45 m/s within 3 meters of the stroke,

B. Working Principle

Any of the ejection methods alone cannot be satisfied. Therefore, the hydraulic cylinder has the characteristics of large output force, low speed and short stroke, and is combined with the speed increasing and force reducing characteristics for the pulley block. The working principle is shown in Figure I.

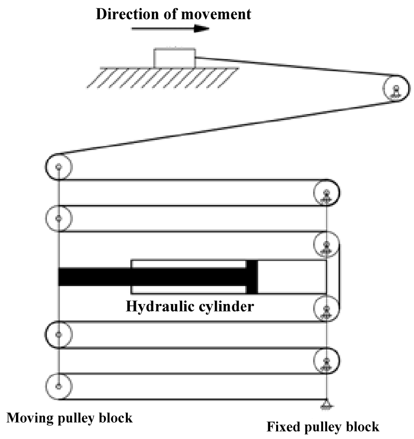

FIGURE I. WORKING PRINCIPLE

According to the test performance requirements, the four sets of moving pulleys are used to enlarge the stroke and speed of the hydraulic cylinder by 8 times [8]. At this time, the stroke of the hydraulic cylinder is only 700 mm, and the speed is only 6 m/s. When the load is accelerated to 45 m/s, its acceleration is shown in equation (1).

$$a = \frac{v^2 - {v_0}^2}{2x} = \frac{45^2}{2\times 3} \approx 33g \tag{1}$$

In equation (1), v is the final speed, v_0 is the initial speed, and x is the stroke of acceleration. Then the maximum driving force of the hydraulic cylinder output is shown in equation (2).

$$F = 8ma = 8\times 100\times 330 = 26.4T \tag{2}$$

In equation (2), m is the load mass, a is the acceleration, and the force of the hydraulic cylinder output is $26.4T$, which is relatively easy to realize.

III. STRUCTURAL DESIGN OF EJEVTION DEVICE

The three-dimensional model of the pulley block ejection device based on the UG software is shown in Figure II, which are mainly composed of an actuator, a traveling mechanism, a pulley block, a buffer mechanism and a platform.

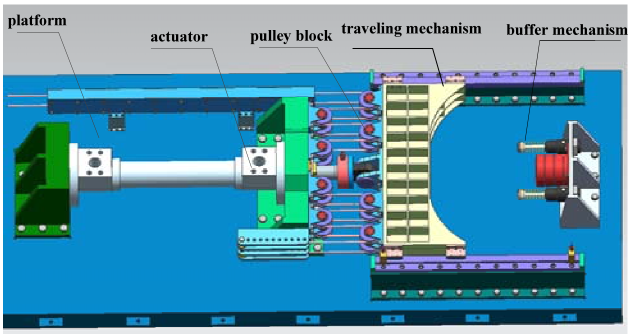

FIGURE II. THREE-DIMENSIONAL MODEL OF EJECTION DEVICE

A. Actuator

As shown in Figure III, the actuator is mainly composed of a hydraulic cylinder, a fixed seat, a force sensor and a support base. The hydraulic cylinder is fixed to the support base and the fixed seat by bolts, and the hydraulic cylinder piston rod passes through the shaft and the ear seat. It is coupled to the walking frame.

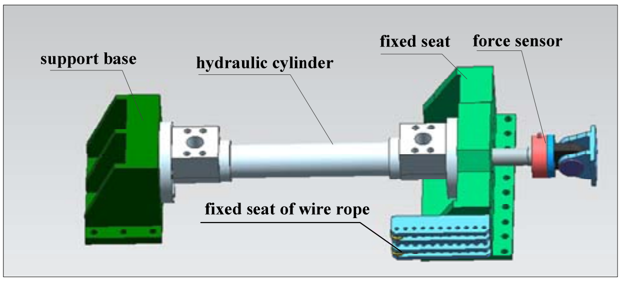

FIGURE III. THREE-DIMENSIONAL MODEL OF ACTUATOR

The working principle is that the hydraulic cylinder acts on the hydraulic source power, and the moving rod block is driven by the piston rod to realize the linear motion, thereby providing power to the simulated load through the wire rope. The force sensor is used to test the output force of hydraulic cylinder in real time.

B. Traveling Mechanism

As shown in Figure IV, the traveling mechanism adopts a wheeled walking mode, which is mainly composed of a traveling frame, a roller slider, a linear guide and a travel switch. The working process is that the hydraulic cylinder pushes the traveling frame through the ear seat to perform a straight line along the linear guide. Movement, thereby moving the movable pulley to achieve linear motion, wherein the travel switch is electrically limited. Six precision roller sliders are used on both sides of the walking frame to ensure the walking of the walking frame and improve the anti-rolling ability of the walking frame.

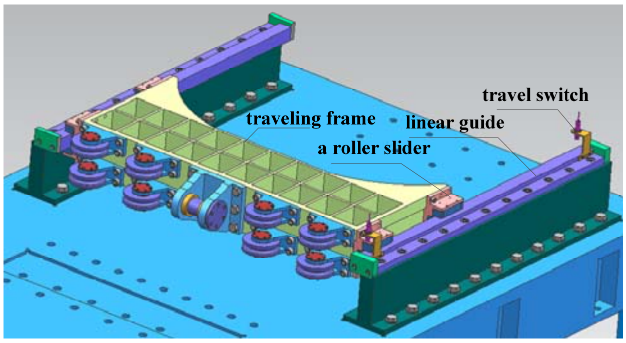

FIGURE IV. THREE-DIMENSIONAL MODEL OF TRAVELING MECHANISM

C. Pulley Block

The pulley block is shown in Figure V. The structure of the pulley block is mainly composed of four fixed pulleys and four movable pulleys. The wire rope is used to drive the object to be tested, and is mounted on the fixed seat for amplifying the output displacement of the hydraulic cylinder by 8 times.

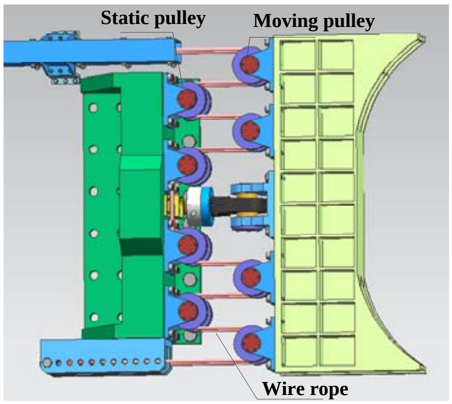

FIGURE V. THREE-DIMENSIONAL MODEL OF PULLEY BLOCK

Since the motion device is driven by a double wire rope, the double pulley structure is used to drive the wire rope. The pulleys are fixed to the pulley block using shaft and angular contact ball bearings.

D. Buffer Mechanism

As shown in Figure VI, the buffer mechanism is mainly used for buffer braking of the actuator and the traveling mechanism. A combination of a specific type of hydraulic damper and a polyurethane damper is used to achieve mechanical limit buffer braking for both.

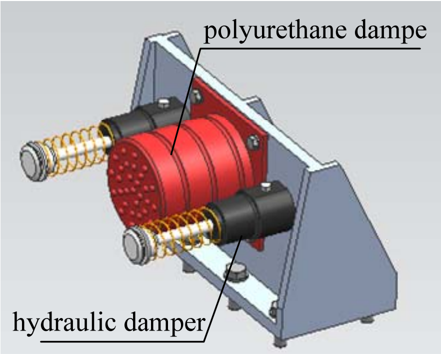

FIGURE VI. THREE-DIMENSIONAL MODEL OF BUFFER MECHANISM

IV. SIMULATION AND ANALYSIS

According to the working principle and operating characteristics of the ejection device, the hydraulic cylinder piston rod provides the thrust to push the walking device to realize the translation, and provides the pulling force for the wire rope in each moving pulley.

Based on AMESim, the mathematical model of the pulley block is established, and it were shown in Figure VII.

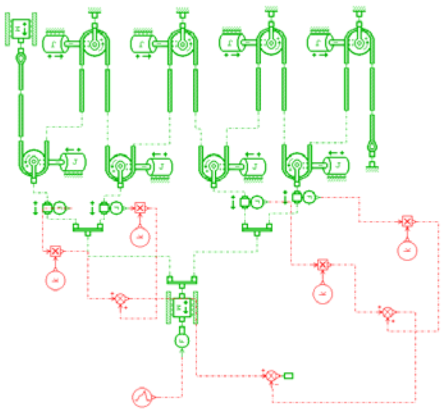

FIGURE VII. MATHEMATICAL MODEL

It is found that the inertial load of pulley and the wire rope were the main cause of the eccentric load. When the mass is 100 kg and the final speed is 45m/s, the maximum load is generated on the pulley block.

The maximum, through simulate and analysis, the force of the four moving pulleys is shown in Figure VIII. The tensile forces on the four moving pulleys are 68156N, 69726N, 70786N and 82318N.

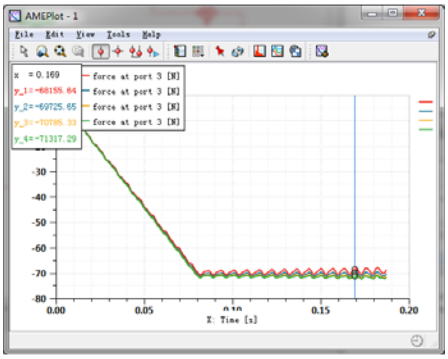

FIGURE VIII. THE RESULT OF SIMULATION

A. *Finite Element Analysis*

As shown in Figure IX and Figure X, the traveling mechanism and actuator are pre-processed respectively, and the material characteristics and mesh division are set for each part. According to the force characteristics of the moving device, a fixed constraint is applied at the working position of the hydraulic cylinder, and the pulling force is added to the four moving pulleys, which are 68156N, 69726N, 70786N and 82318N respectively, and applying linear slider constraints at both ends of the traveling device.

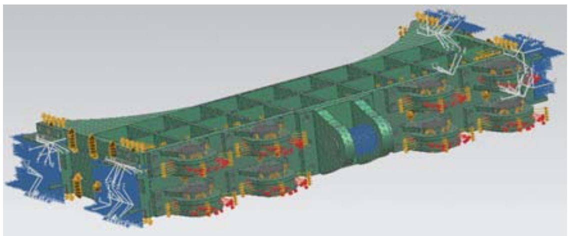

FIGURE IX. PRETREATMEN OF TRAVELING MECHANISM

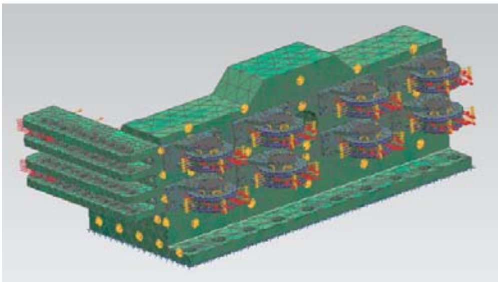

FIGURE X. PRETREATMEN OF ACTUATOR

The finite element analysis of traveling mechanism are shown in Figure XI and Figure XII, in which the maximum deformation is 0.35 mm and the maximum stress is 117.2 Mpa, which meets the design requirements of mechanical properties of the product.

The finite element analysis of are shown in Figure XIII and Figure XIV, in which the maximum deformation is 0.127 mm and the maximum stress is 95.08 Mpa, which meets the design requirements of mechanical properties of the product.

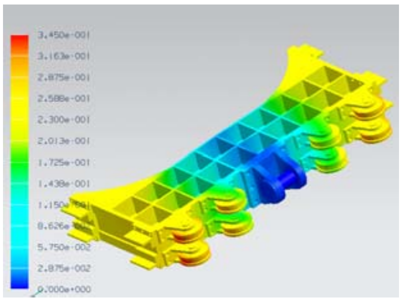

FIGURE XI. STRAIN DISTRIBUTION

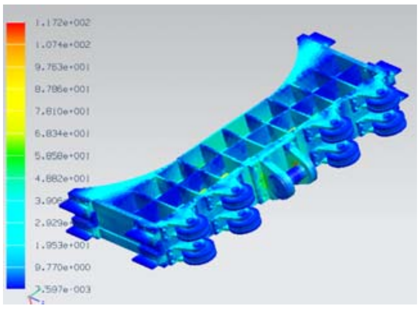

FIGURE XII. STRESS DISTRIBUTION

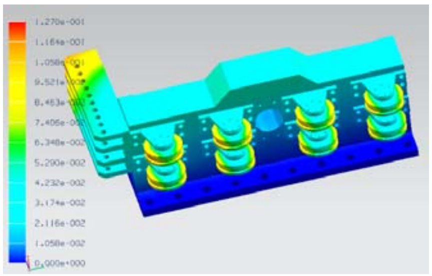

FIGURE XIII. STRAIN DISTRIBUTION

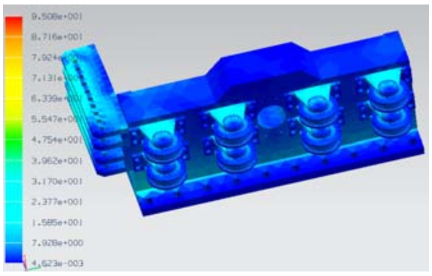

FIGURE XIV. STRESS DISTRIBUTION

V. CONCLUSION

At present, the ejection device with pulley group has completed the assembly and debugging process, and its load mass is about 130 kg. It can instantaneously accelerate to 47m/s in the 3.5m stroke, and complete the braking process in the 6m action stroke. The strain and stress performance are consistent with the simulation. The ejection device has good safety and high control precision.

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