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Optical Lens Anti-High Overload Design Technology

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Abstract. In view of the problem that the optical lens is difficult to withstand the impact of high overload, on the basis of the optical imaging function, measures in many aspects such as selecting the appropriate lens material, designing the appropriate diameter-to-thickness ratio and designing the colloidal vibration damping structure are adopted to improve the optical lens anti-high overload capability. The ANSYS simulation analysis and hammering test verify that the optical lens designed by this method can withstand overloads above 20,000g, and the optical imaging ability does not change before and after the hammering.

Keywords. High overload, optical lens, structural design

1. Introduction

With the development and application of information technology, a number of new types of ammunition such as TV reconnaissance shells, laser terminal guided shells, and TV terminal guided shells have emerged. The seeker contains various photoelectric sensors and microelectronic components. During the launch of the artillery, the shell will be subjected to the pressure in the chamber, and the projectile body will produce a large acceleration, making the seeker to withstand huge instantaneous, high-energy and strong impact load [1]. With the development of shells, the requirements for the range of the shells are getting higher and higher, so the firing overload that the shells need to bear is also increasing [2], This high overload environment will cause deformation of the internal support structure of the seeker and damage to various electronic components, and even cause the guidance system to fail[1]. In the face of high overloads of 10,000g or even more than 20,000g, how to withstand the optical lens is the most critical and difficult one [3]. This paper proposes a high-overload resistance design scheme for optical lens, which can meet the requirements for use in an overload environment of more than 20,000 magnitude after simulation analysis and experimental verification.

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2. Optical lens anti-high overload design

2.1. Material selection

Since the system has certain requirements on the related parameters of mechanical mechanics of the lens, in addition to the optical properties of the lens such as refractive index, absorptivity, thermal deformation and other parameters, the mechanical related properties of the lens such as stability, impact resistance, hardness and weight, should also be considered when selecting the lens material.

In combination with the above material selection criteria, the lens materials to be used in this project are lanthanum crown glass, heavy flint glass and lanthanum flint glass, because these lens materials have good mechanical stability, suitable weight, and can prevent the lens from chipping due to its own material in the case of high overload or large impact.

The optical lens has a simple structure and small volume, but the mechanical and thermal environment is harsh. The optical lens needs to withstand an overload of more than ten thousand orders under working conditions. Therefore, considering the mass-strength ratio, the main structure material chooses low-density and high-stiffness super-hard aluminum alloy material 7A09 for aviation.

2.2. Anti-high overload structure design

The structure and fixation of the lens are the core of whether the lens can withstand high overload. In the optical design, the curvature of the lens should be as large as possible to improve its anti-overload ability; Comprehensive imaging design and lens strength simulation, the diameter-thickness ratio of the lens is not more than 3 to prevent the lens being unable to bear its own weight and broken under high impact.

The optical lens structure adopts optical centering and edge-taking process design. By adding a layer of mechanical frame to the lens, the outer diameter of each lens is consistent and the installation tolerance requirements are met through centering and edge removal processing. At the same time, because the lens is equipped with a mechanical frame, there is no direct contact between the lens and the lens, the lens depends on the positioning of the mechanical frame. Due to the high strength and processing accuracy of the mechanical metal material, the problem of positioning and force transmission between the lenses is solved. The boss for positioning the lens of each edge removal frame is on the side opposite to the acceleration direction, that is, the bearing side, which ensures that the lens does not fall out under the structural limit of the edge removal frame under working conditions. The appearance of the optical lens structure is shown in **Figure 1**.

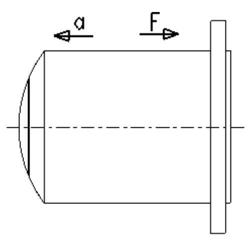

Figure 1. Schematic diagram of optical lens structure design.

The components of the optical system in this optical lens are installed in order from left to right, and the positioning of the first lens is ensured during installation, and then the rear lens is installed in sequence, and glue is applied to the gap between the lens and the frame, and finally the pressure ring is tightened.

3. Finite element analysis and test verification

The optical lens working normally in a high-overload environment must have sufficient strength and rigidity, so that the lens will not be broken and the relative positional relationship between the lenses will not change. From these two aspects, perform finite element analysis [4-6] and experimental verification on the optical lens.

3.1. Finite element analysis

In order to verify the strength of the optical lens in a high overload environment, a finite element analysis was performed on the optical lens[7].

3.1.1. Force model

The optical system accelerates from the stationary state and shoots out along the rifling of the barrel. At this time, the projectile is in a linear acceleration state, and the projectile is subjected to a force F opposite to the direction of acceleration a. The kinetic energy of the projectile gradually decreases after it exits the chamber. The force of the optical lens is shown in **Figure 2**.

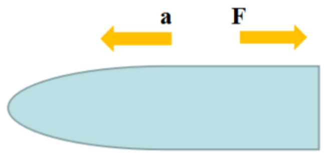

Figure 2. Optical lens force diagram.

3.1.2. Material parameters

The material parameters used in the structural finite element analysis are shown in **Table 1**.

Table 1. Material parameters in analysis

Material name	Density (kg/m^3)	Young's modulus (GPa)	Poisson's ratio	Thermal expansion coefficient 1/°C×10^{-6}
H-K9L	2520	79.2	0.211	7.6
H-ZF88	3520	108.81	0.243	6.0
H-FK61	3700	70.07	0.3	13.1
H-ZF4	4510	52.95	0.245	9.6
H-ZF4	4510	52.95	0.245	9.6
H-ZF88	3520	108.81	0.243	6.0
Aluminum alloy	2770	71	0.33	23
PTFE	2170	0.47	0.45	120

3.1.3. Finite element analysis results

The lens, lens holder, and threaded connection are set according to Frictional; The friction coefficient is set to 0.2; Restrict the flange connection of the shell. The overall stress distribution cloud diagram of the structure is shown in **Figure 3**.

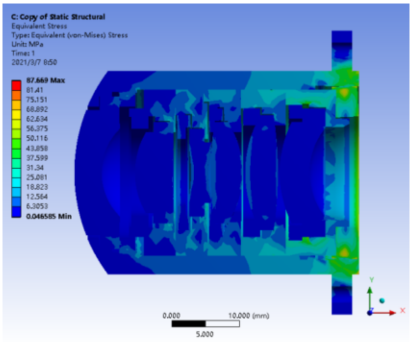

Figure 3. Lens stress cloud

The stress distribution cloud diagram of each lens is shown in **Figure 4.**

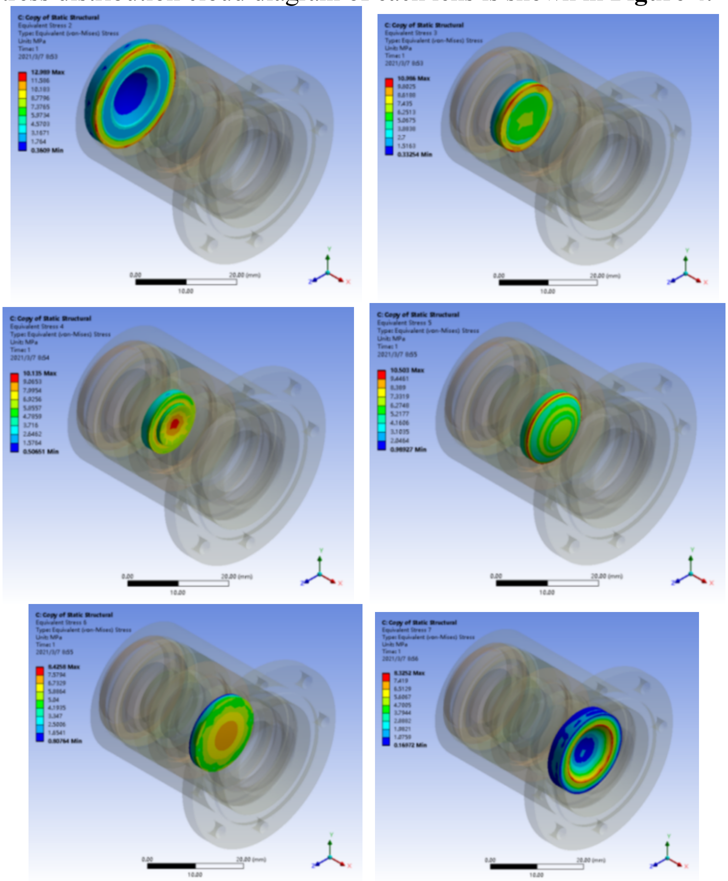

Figure 4. Stress cloud diagram of each lens

The stress cloud diagram of the threaded connection is shown in **Figure 5**.

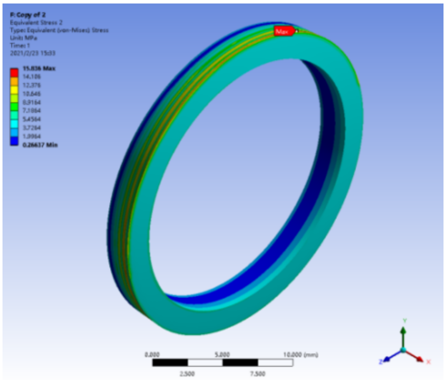

Figure 5. Stress cloud diagram at threaded connection

The analysis results show that under the target overload condition, the maximum stress position is at the connecting flange on the lens base, the size is 87.669Mpa, and the maximum stress at the threaded connection is 15.836Mpa.The maximum stress of each lens is shown in **Table 2**.

Table 2. Maximum lens stress table

	Lens 1	Lens 2	Lens 3	Lens 4	Lens 5	Lens 6
Stress (MPa)	12.989	10.986	10.135	10.503	8.4258	8.3252

In summary, the stress of each part of the optical lens is much smaller than the allowable stress of the material, and the analysis result meets the requirements of use.

3.2. Hammer test

A Marshall hammer test system[8] was used to conduct a high overload resistance test on the optical lens, and the test magnitude was close to and greater than the target overload magnitude.The same scene was imaged before and after the test, and the imaging comparison is shown in **Figure 6**.

Figure 6. Imaging comparison chart

It can be seen from the figure that after three hammering tests, the optical lens is intact, and the imaging effect is basically unchanged before and after the test.

4. Conclusion

This article adopts measures such as selecting the appropriate lens material, designing the appropriate diameter-to-thickness ratio, and designing the jelly damping structure to improve the high overload resistance of the optical lens.The ANSYS simulation analysis and hammering test verified that the optical lens designed by this method can withstand overloads above 20,000g, and the optical imaging ability does not change before and after hammering, which can meet the requirements of high overload environment.

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