Design of zero position movement control and damping structure in infrared gun sight

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Abstract. In this paper, starting from the key technical indicators of the infrared gun sight mirror, through the analysis of the cause of zero movement, on this basis, the design of zero movement control is carried out, and on the basis of ensuring that the zero movement momentum meets the index, the design of multiple damping structure is carried out. Through the field shooting test, the design method meets the requirement of zero movement momentum of 0.5mil. In terms of shock absorption, twenty thirty bad elements are reduced to 1-2 after the shock absorption, and obvious results are obtained. The feasibility and effectiveness of the design method mentioned in this paper in the design of zero position motion control and damping structure of infrared gun sight mirror are illustrated.

Keywords: infrared detector zero position momentum local damping global damping

1. Introduction
In the performance index of infrared gun aiming, a very key index is zero position walking momentum. Generally speaking, it means the offset of aiming point when the aiming point is greatly impacted by the gun. If the aiming point is greatly offset, the shooter will not be able to hit the target accurately, and the gun sight will not be used, so it must be controlled in the design. It is a key control point in the design of infrared gun aiming.

In addition, in order to improve the image quality, reliability and service life of the infrared gun sight mirror, it is necessary of design of the domestic infrared detector for shock absorption. At present, when the domestic uncooled infrared detector is impacted, a large number of bad elements will appear. When the domestic uncooled detector is used in the infrared gun sight glass, the number of bad elements will increase with the increase of shooting times, which will affect the image observation. If the existing infrared gun does not take shock absorption measures, when the infrared detector is used on the gun, the performance and working life of the detector will inevitably be reduced after experiencing multiple shooting shocks. At present, the buffer mechanism used in the infrared gun sight mirror is generally to increase some springs. By increasing the impact force, the instantaneous energy can be reduced. If the increase is not suitable, the zero position movement will be large, which affects the shooting accuracy of the infrared gun sight glass. Therefore, for the design of the infrared gun sight mirror, it is based on the zero position walking amount to meet the target, the shock absorption of uncooled infrared detector is considered.
2. Factors that affect the zero position momentum

In order to effectively control the zero position momentum, we should first analyze the factors that affect the zero position momentum. There are mainly the following:

1) Optical axis offset of infrared objective lens

In the design of infrared gun sighting lens, the infrared objective lens generally has a focusing structure (linear forward and backward movement or spiral forward and backward movement). One is to realize the non-thermal technology of infrared objective lens, and the other is to meet the clear imaging of targets at different distances. The optical axis offset of the objective lens in the process of focusing will lead to the change of zero position momentum. Let \( x \) denote the lateral offset of the optical axis, and \( y \) denotes the longitudinal offset of the optical axis, \( \delta_1 \) represents the zero position momentum caused by the optical axis in the transverse coordinate, and \( \delta_2 \) represents the zero position walking momentum caused by the optical axis in the longitudinal coordinate, then the relationship is as follows:

\[
\delta_1 = \tan(x/f') \\
\delta_2 = \tan(y/f')
\]

Where, \( f' \) is the focal length of the infrared objective.

2) Displacement in installation plane of infrared detector

Because the infrared detector is connected to the printed circuit board by welding, and the printed circuit board is fixed on the detector bracket by screws. If the detector moves slightly, that is, the imaging target plane is offset, it will directly affect the infrared movement of the gun sight.

Let \( X' \) denotes the lateral offset of the detector target after impact, and \( y' \) denotes the longitudinal offset of the detector target after impact. \( \delta_3 \) represents the zero position momentum caused by the optical axis in the transverse coordinate, and \( \delta_4 \) represents the zero position momentum caused by the optical axis in the longitudinal coordinate, then the relationship is as follows:

\[
\delta_3 = \tan(x'/f') \\
\delta_4 = \tan(y'/f')
\]

Where, \( f' \) is the focal length of the infrared objective.

3) The displacement between the gun mirror connecting base and the fixed detector parts

Because this factor will have a great impact on the overall zero position momentum, the design here must adopt the rigid connection to ensure that the two parts are completely fastened, and there is no looseness or offset. Therefore, we will not consider the influence of zero position momentum in this calculation.

From the above analysis, it can be concluded that the zero position momentum of gun sight in the abscissa and ordinate directions is as follows:

Zero walking momentum in abscissa direction

\[
\delta_x = \delta_1 + \delta_3
\]

Zero walking momentum in ordinate direction

\[
\delta_y = \delta_2 + \delta_4
\]

3. Design method of zero position movement momentum control

3.1 Technical index requirements of zero position movement momentum

In the domestic gun sight products, the index of zero position movement is usually required to be less than 0.5mil, so we will design the zero position movement control of infrared gun sight based on this index.

3.2 Specific design methods

In the design of a gun aiming lens, we choose the focal length of the infrared objective lens as 40mm and the pixel size of the infrared detector as 20μm. It can be calculated that the combined displacement of the optical axis of the objective lens and the displacement of the detector in the installation plane at 0.5mil shall not exceed:
\[
\tan^{-1} \delta \times f' = \tan^{-1} 0.5 \text{mil} \times 40 \text{mm} = 0.020 \text{mm}
\]

It is the size of one pixel of the detector.

According to the above calculation and analysis, we take the following measures to control the zero movement momentum.

1) Adopt passive non-thermal lens

After using passive non-thermal lens, there is no focusing ring. The optical axis will not move, and the optical axis will not cause the zero position walking momentum. Although the cost of using passive non-thermal lens is slightly increased, it is very worthwhile to completely solve the zero position walking momentum caused by it. In addition, the designed passive non-thermal lens can meet the imaging of the target from 10m to infinity (for the experimental results of the target being human), and fully meet the design requirements of the focusing range of the overall infrared gun lens.

2) Directly restrict the detector target surface

The main influence of zero position moving is mainly concentrated on the fixing of detector after passive non heating lens is adopted above. Because the detector is welded on the printed board, the transverse and longitudinal displacement will occur if the welding pin is not fixed firmly when it is impacted; Moreover, the printed board with fixed detector will not improve the zero position momentum, so directly fixing detector will be the best way to solve the target offset. So in this design, we design four grooves on the detector bracket. By making the four corners of the detector fit with the grooves, it is equivalent to insert the detector into the structure of the detector bracket and make it one, so that there will be no deviation at all, as shown in the following figure 1:

![Fig. 1 Location of limit groove](image1)

After embedded in the detector bracket, the detector is pressed on the detector bracket by fixing the printed circuit board, as shown in Figure 2 below:

![Fig. 2 Fixed structure of detector](image2)

Connection design of gun mirror connection base and fixed detector parts:
The design of gun mirror connecting base and fixed detector parts adopts the method of multi-directional screw fixation combined with keyway to ensure that the two parts are combined into a whole, so that it does not affect the zero position movement. The specific design method is shown in Figure 3 below. A stop block is designed on the gun mirror connecting base to form an interference fit with the detector bracket. Two M3 screws are installed in the longitudinal direction, and two M2 screws are fixed in the transverse direction. Figure 4 shows the designed keyway position on the detector bracket.

4. Shock absorption structure design
The difficulty of shock absorption design is not only to achieve the effect of shock absorption, but also to ensure the technical index of zero walking momentum. Through analysis, we use the method of multiple shock absorption combining local shock absorption with overall shock absorption to achieve the shock absorption requirements of infrared gun lens.

4.1 Local shock absorption
Local shock absorption is to make shock absorption for the infrared detector that directly produces bad elements. The specific method is to install a heat-conducting paste at the place where the infrared detector contacts the mounting base, which can not only reduce the impact of hard contact, but also play the role of heat conduction, making the temperature around the detector stable. As shown in Figure 1, a heat-conducting pad is placed at the limit groove;
In addition, nylon pad is added between the screw of infrared detector and detector to reduce the impact force caused by hard contact between detector and printed circuit board and screw. As shown in Figure 5 below:

![Fig. 5 Installation position of nylon pad](image)

4.2 Overall shock absorption
The whole shock absorption is to reduce the impact on the whole gun lens, which is realized by the connecting seat of the gun lens.

The damping gun mirror connecting seat adopts the Z-type damping method. When the infrared gun sight mirror is impacted, the Z-type connecting seat deforms to alleviate the instantaneous impact force, so as to achieve the overall damping effect. It consists of Z-shaped connecting seat, spring plunger, locking screw, locking nut, wrench and lock ring, as shown in Figure 6 below:

![Fig. 6 Composition of damping gun mirror connecting seat](image)

The Z-shaped connecting base bracket is composed of an upper plate, a lower plate and an inclined plate; The angle between the plane of inclined plate and the plane of upper plate and lower plate is 77°~79°(The angle is the result of finite element simulation design); The intersection of the inclined plate, the upper plate and the lower plate is processed as a fillet transition; The upper flat plate of the Z-shaped bracket is provided with a mounting hole connected with the parts of the detector bracket; The bottom surface of the lower flat plate of the Z-shaped bracket is provided with a dovetail groove connected with the external rifle; The inclined plate of the Z-shaped bracket is provided with a threaded hole which is consistent with the direction of the upper plate; The position of the lower plate near the inclined plate is provided with a stepped threaded hole, which is perpendicular to the axis of
the threaded hole on the inclined plate;

The external thread of the stop screw and the internal thread of the check nut are both M7×1.5. The purpose of using the non-standard thread is to obtain greater vertical displacement at a limited angle. The sight can be locked and fixed by only pulling the wrench about a quarter of a turn, which is convenient and fast.

The locking screw is processed with circumferential teeth, and the spring plunger collides with the circumferential teeth of the stop screw, which further enhances the locking effect.

The Z-type integral damping seat has two main effective functions:
1) Reduce the impact of the infrared objective lens and eyepiece lens of the infrared gun sight lens to prevent the infrared glass from breaking or cracking;
2) Reduce the impact of domestic uncooled infrared detector of infrared gun sight mirror to reduce the bad element number generated when the infrared detector is subjected to greater impact.

5. Test results and data analysis

After the completion of the zero position control and shock absorption design, we will verify the feasibility and effectiveness of the above design through the field target shooting experiment.

In the experiment, it must be noted that the shock absorption experiment should be tested first, because it is to reduce the vibration on the basis of meeting the zero position walking momentum. If it only meets the shock absorption requirements and the zero position walking momentum is not up to the standard, then the shock absorption design is invalid.

5.1 Shock absorption effect test

Before the shock absorption measures are taken, many bad elements will appear in the infrared gun sight after shooting, and the bad elements will disappear after non-uniform correction. We will test the damping effect by comparing the number of bad elements before and after adopting damping measures.

The test results are shown in Table 1 below (the test results are the data of continuous firing of 30 rounds):

| Items                               | 1# gun sight | 2# gun sight | 3# gun sight |
|-------------------------------------|--------------|--------------|--------------|
| Number of bad elements without damping measures | 23           | 37           | 32           |
| Number of bad elements with damping measures    | 1            | 2            | 1            |

It can be seen from the above table that the number of bad elements has been significantly improved after taking the damping measures, and only 1~2 of them appear after 30 shots in a row. Therefore, it will be proved that the damping measure is feasible and effective as long as the zero position walking momentum test is passed.

5.2 Zero position walking momentum test

On the basis of the good damping effect mentioned above, the zero position walking momentum is tested. Before shooting, the coordinate position of the aiming point in the current state is determined and recorded. After shooting, the coordinate position of the aiming point is rechecked and recorded, so as to make a difference to get the zero position walking momentum. The test results are shown in Table 2:
Table 2 Record of zero position walking momentum test

| Items                           | 1# gun sight | 2# gun sight | 3# gun sight |
|---------------------------------|--------------|--------------|--------------|
| Zero value before shooting(mil) | X:+2.07      | X:+2.76      | X:-0.69      |
|                                 | Y:-5.75      | Y:-10.35     | Y:-8.05      |
| Zero value after shooting(mil)  | X:+2.07      | X:+2.76      | X:-0.46      |
|                                 | Y:-5.52      | Y:-10.81     | Y:-8.28      |
| Zero position walking           | X:0          | X:0          | X:0.23       |
| momentum(mil)                   | Y:0.23       | Y:0.46       | Y:0.23       |

In the above table, the zero momentum of 0.23mil is the offset of 0.5 infrared detector pixels (1 OLED display pixel), and 0.46mil is the offset of 1 infrared detector pixel (1 OLED display pixel). As can be seen from Table 2, 1# gun sight lens moves 0.23mil in Y direction, 2# gun sight lens moves 0.46mil in Y direction, and 3# gun sight lens moves 0.23mil in both X and Y directions, both of which are less than 0.5mil. Therefore, it can be concluded that this gun sight lens meets the technical requirements of zero movement.

6. Conclusion

Based on the analysis of the causes of zero position walking, the corresponding design of zero position walking control is carried out. On the basis of ensuring that the zero position walking meets the index, the local and overall multiple damping structure is designed. Through the field shooting experiments, it is verified that the three gun sighting mirrors can meet the requirements of the zero position walking momentum less than 0.5mil. In the aspect of shock absorption, the number of bad elements produced after the impact is reduced from 20 or 30 to 1 or 2, and the obvious effect is also achieved. The design method mentioned in the paper has feasibility and effectiveness in the control of the zero position walking momentum and the design of the damping structure of the infrared gun sight lens.

However, in the design control of the zero position movement, the theoretical zero position movement is 0, that is, the zero position movement is controlled according to the zero position immobility. However, 0.23mil and 0.46mil zero moving momentum appear in some directions in the test, and some have no zero position movement. Which aspect should be identified as the cause of this part? Whether it is in the damping measures or in the assembly of some link should be thoroughly analyzed, so that the theoretical results and practical results are consistent.

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