Simulation Analysis of Influence of Vibration Impact on Optics Imaging System

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Abstract. Taking a certain type of photoelectric system of armored vehicle as an example, the influence of angular vibration on the optical system image quality is analyzed. Firstly, the paper introduces the characteristics of photovoltaic system and the basic theory of imaging; Then it uses the ZEMAX to build optical system model; finally, it simulates the MTF and Spot Diagram as the change of lens angular. By making quantitative analysis of the photoelectric system influence on imaging quality of lens deflection angular, we get the relationship between geometry maximum radius and mean root square radius with the lens deflection angular, and evaluate the effects of angular vibration on image quality synthetically, which has important reference value to the design of photoelectric system.

1. Introduction

On-board sights as eyes of indirect weapons and equipment, mainly used in observable, but external vibration impact will affect sights the stability of the primary mirror, make its produce Angle disturbance, lead to the optical system transmission light deflection, unfavorable to target observation and track.

To reduce the influence on imaging quality of angular vibration, to improve the tracking of the photoelectric system, aiming and shooting accuracy and image quality is of great significance [1]. Literature [2] to airborne electro-optical pod as the research object, analysis of linear vibration and angular vibration effects on image quality and steady precision. Compare line vibration and angular vibration on the system steady precision of the size of the influence degree, put forward the reasonable vibration reduction method. Literature [3] in the MTF as evaluation function, according to various forms of vibration to quantitative analysis of the influence of image resolution, and analyzes the influence of various parameters on the MTF. Literature [4] analyzed the light level corner of vibration on the optical transfer function of the system.

At present, due to the impact of reflector offset Angle disturbance, in turn, lead to light from the study is less, and greatly influenced by the disturbance of light transmission Angle, based on the car mirror in sight as the research object, using ZEMAX simulation Angle disturbance effects on light transmission, obtained under different disturbance Angle reflector optical transfer function and the column chart, and draw some column graph geometry maximum radius and root mean square radius and the relation curve between disturbance Angle reflector.

2. A theoretical analysis

2.1 Model [5]

The on-board sights reflector, bracket and base as a multi degree of freedom spring - quality - damping system, its equivalent model is set up, and to analyze its vibration characteristics. Are motivated by the outside impact effect, the primary mirror can produce Angle disturbance, when the excitation frequency equal to the one order natural frequency of the system, the system will produce resonance, strong resonance may cause the lens in the optical system of line vibration and angular vibration, serious impact on the photoelectric system imaging quality.

The vibration transmissibility of passive vibration isolation system is

$$T = \frac{1}{\sqrt{\left[1-\left(f/f_0\right)^2\right]^2+\left(2\xi f/f_0\right)^2}} \quad (1)$$

Type, as the vibration frequency, as the natural frequency of vibration isolation system for the damping ratio of isolation system.

2.2 Basic theory of imaging [6-8]

When the beam by two smooth interface of isotropic homogeneous medium happens when the refraction and reflection. The law of refraction of the vector form

$$n'\left(\mathbf{S}'\times\mathbf{N}_0\right)=n\left(\mathbf{S}\times\mathbf{N}_0\right) \quad (2)$$

Type: and are respectively incident light in the medium and the refractive index of refraction of light in the medium; And the incident light and refracted light glass printing vector; For the direction of the interface normal unit vector.

If the incident light and refracted light respectively using vector and said

$$n'\left(\mathbf{A}'\times\mathbf{N}_0\right)=n\left(\mathbf{A}\times\mathbf{N}_0\right) \quad (3)$$

That refracted light and incident light and through the incident point of normal coplanar.

The law of refraction of scalar form

$$n'\sin I' = n\sin I \quad (4)$$

Optical path refers to the geometric distance light propagation in the medium Multiplied by the medium the refractive index, with the said,

$$S = nl \quad (5)$$

Continuous light through a variety of media, the total optical path

$$S_\Sigma = \sum n_i l_i \quad (6)$$

Set the speed of light in medium is, then

$$l = vt, n = \frac{c}{v} \quad (7)$$

Therefore,

$$S = ct \quad (8)$$

Visible, over a period of time the light propagation in the medium of optical path, equivalent to the light in a vacuum within the same interval through the path.

Optical system is composed of multiple fold, reflector, as shown in figure 1 for a single refract light path diagram below. For a point on the axis in the graph, refractor is two refractive index respectively, and the interface, as the core, for the vertices, the spherical radius. For the incident to the sphere of a light. After the refraction of light, and optical axis intersection, intercept, for content to intercept like a party, for the square aperture Angle, as the Angle.

By the geometric relationship and the law of refraction figure 1 can be a single refractive light path calculation formula as below

$$\begin{cases} \sin I = \dfrac{L-r}{r}\sin U \\ \sin I' = \dfrac{n}{n'}\sin I \\ U' = U + I - I' \\ L' = r\left(1+\dfrac{\sin I'}{\sin U'}\right) \end{cases} \quad (9)$$

The equations above, the fourth type calculation formula for practical optical path of the light. Due to the law of refraction of the nonlinear, namely the sine function is a nonlinear function, so the points from the different Angle of light, and the optical axis of the intersection point is different, as shown in figure 2.

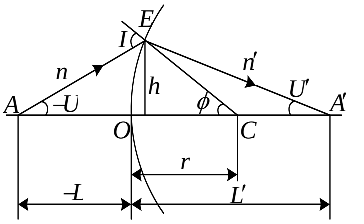

Figure 1 Single refract light path below

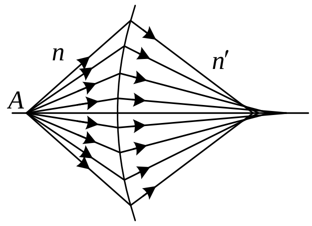

Figure 2 Different aperture Angle and the optical axis intersection

Each surface is curved surface in the system, the symmetric axis and optical axis coincidence, as shown in figure 3. Each surface in the system represented by an equation, the shape of the coordinate system is shown in figure 4.

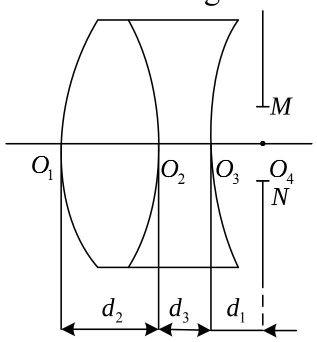

Figure 3 optical system diagram

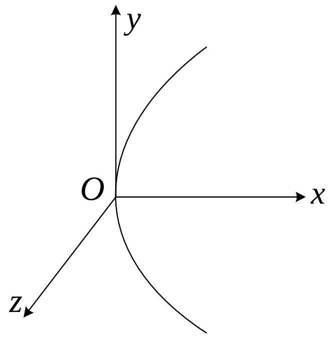

Figure 4 Optical system coordinate system

$$X = \frac{cH^2}{1+\sqrt{1-Kc^2H^2}} + \alpha_4 H^4 + \alpha_6 H^6 + \alpha_8 H^8 + \alpha_{10} H^{10} + \alpha_{12} H^{12} \qquad (10)$$

Type; For surface vertex curvature; As the quadric coefficient; For high quadric coefficient.

The above equation can be the representation of a common sphere, quadric surface and high times. Formula on the right side of the first representative benchmark quadric surface, behind each representative of higher order term. Benchmark quadric coefficient values represent different quadric surface as shown in table 1.

Table 1 quadric surface shape

K value	K<0	K=0	0<K<1	K=1	K>1
The form	hyperboloid	Parabolic	ellipsoid	spherical	oblate

2.3 Vibration analysis

A certain frequency, relative to the linear vibration angular vibration will increase the image motion of the camera system, make the image quality drop, reduce the resolution of the optical system. For the same, the Angle of vibration and line like shift diagram as shown in figure 5 to 7, the calculation method is as follows:

Disturbance of the lens image motion form shown in figure 7

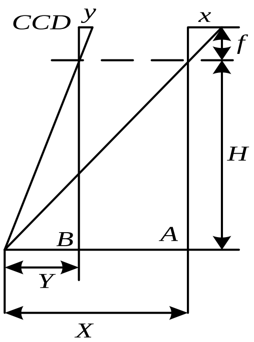

Figure 5 A linear vibration

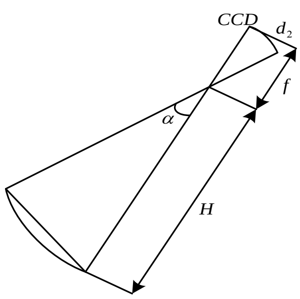

Figure 6 Angle disturbance

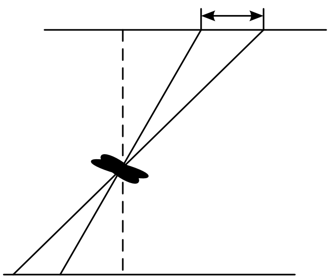

Figure 7 Angle vibration

For linear vibration, mobile location before and like to

$$\frac{X}{x}=\frac{f}{H} \tag{11}$$

After moving position and like to

$$\frac{Y}{y}=\frac{f}{H} \tag{12}$$

So for both like shift before and after vibration

$$d_1 = x - y = \frac{f}{H}(X - Y) \tag{13}$$

For Angle disturbance, before and after vibration like a shift for both

$$d_2 = f \sin\alpha \tag{14}$$

3. Simulation analysis

By using ZEMAX optical design software, the establishment of the optical system model, assuming that mirror disturbance Angle 0 ° and 0.5 ° and 1.0 ° respectively, 1.5 ° and 2.0 °, the simulation analysis under different disturbance Angle of the optical system of optical transfer function and the column chart.

3.1 Optical transfer function

Using the optical transfer function evaluation of the optical system imaging quality, reflect the different frequency components of the optical system of objects transmission capacity [9-10].

Car sight optical system model is set up as shown in figure 8.

Because the mirror is affected by the impact is bigger, and have a decisive role on the imaging quality, and so on primary mirror as the research object in this paper.

As shown in figure 9 (a - e), the disturbance Angle for 0 ° and 0.5 ° and 1.0 ° and 1.5 ° and 2.0 ° of the optical transfer function.

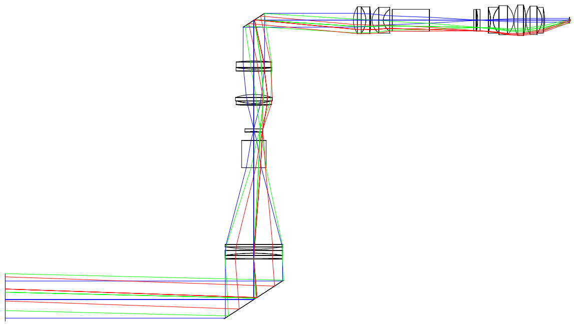

Figure 8 car sight optical system model

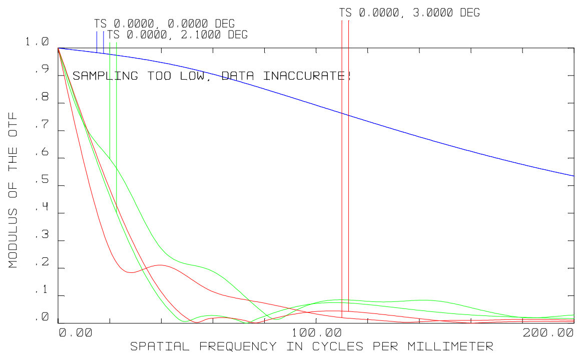

Figure 9 (a) 0 ° optical transfer function

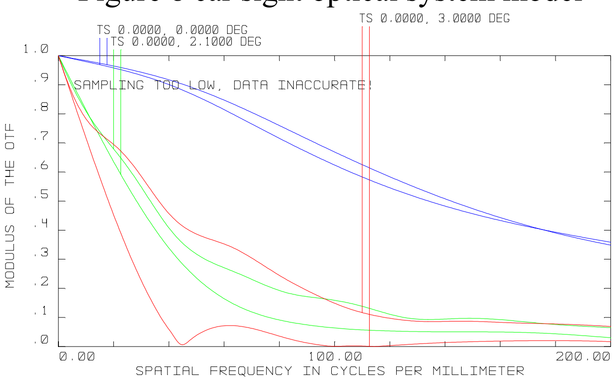

Figure 9 (b) 0.5 ° optical transfer function

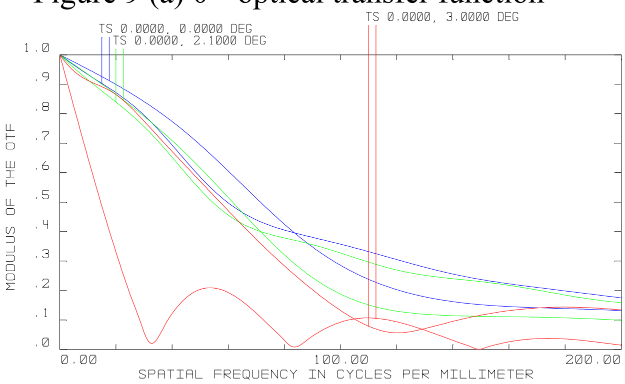

Figure 9 (1.0 ° c) optical transfer function

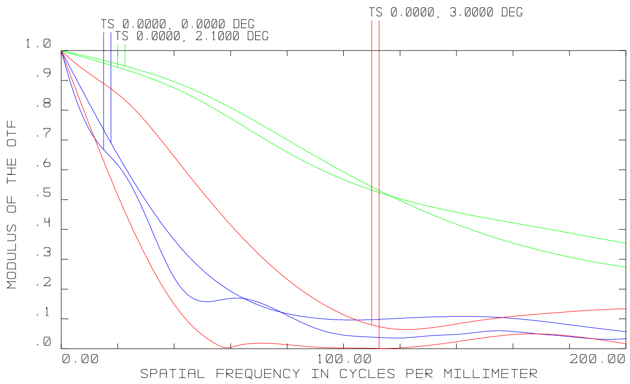

Figure 9 (d) 1.5 ° optical transfer function

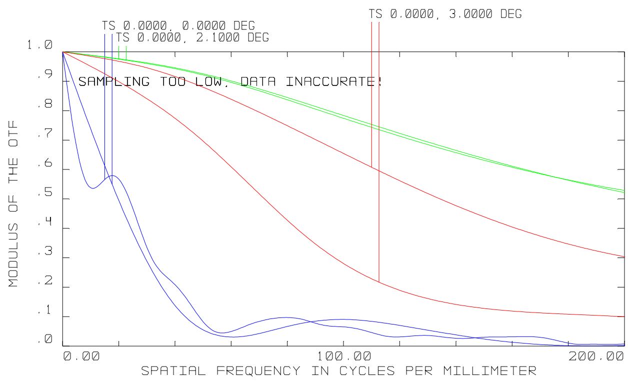

Figure 9 (e) 2.0 ° optical transfer function

From figure 9, you can see that with the increase of the disturbance Angle, 0.0 DEG field curve decreases obviously, 0.0 DEG field line is given priority to light path, with the axis surrounded by the smaller area, said lens can transfer the less the amount of information, namely for the imaging quality. Can be seen from the diagram, the low frequency (< 10lp/mm) curve represents lens contrast characteristics, high frequency (> 30lp/mm) curve represents the camera resolution features are in a recession. In addition, with the increase of Angle, the curve is more and more curved, in the middle of the edge and the consistency, the worse, edge serious descent that edge light contrast and resolution. S curve and the contact ratio of T curve (meridian curve) followed deflection Angle increase and decrease, said the greater the astigmatism of the lens.

3.2 Spot Diagram

Point column chart point can be approximately represent the distribution of energy distribution of image point, using these points intensive can measure system imaging quality. Dense column points distribution state can use geometric maximum radius value and root mean square radius of two quantities. Geometric maximum radius is a reference point to the farthest light intersection distance. Geometric maximum radius only reflect a maximum of aberration, does not really reflect the light energy concentration. RMS is each light intersection and reference points of the square of the distance from the light, after the article divided by the light of several square root. Root mean square radius value reflects the intensity of light energy, compared with the geometric maximum radius value, more can reflect the system imaging quality [6]. Simulation conclusion disturbance Angle for 0 ° and 0.5 ° and 1.0 ° and 1.5 ° and 2.0 ° points column chart, as shown in figure 10 (a - e).

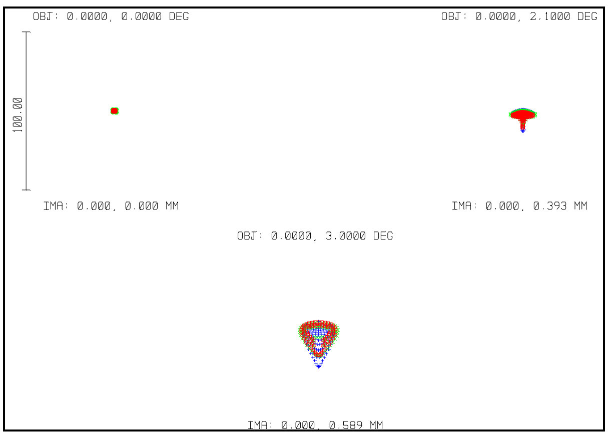

Figure 10 (a) 0 °Spot Diagram

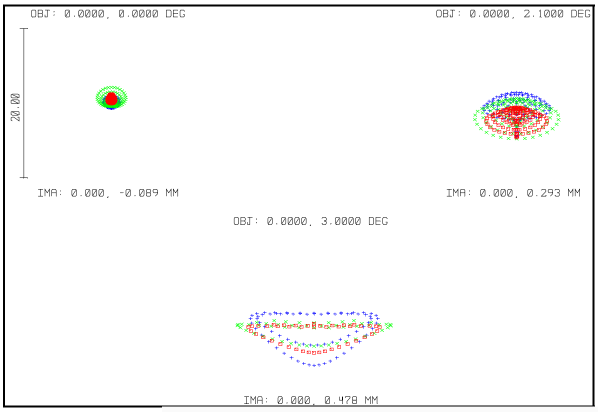

Figure 10 (b) 0.5 °Spot Diagram

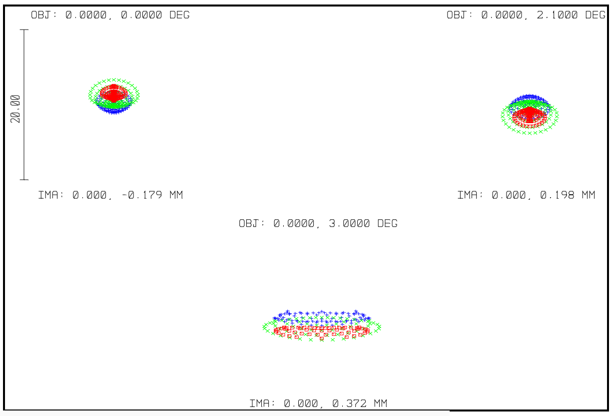

Figure 10 (c) 1.0 °Spot Diagram

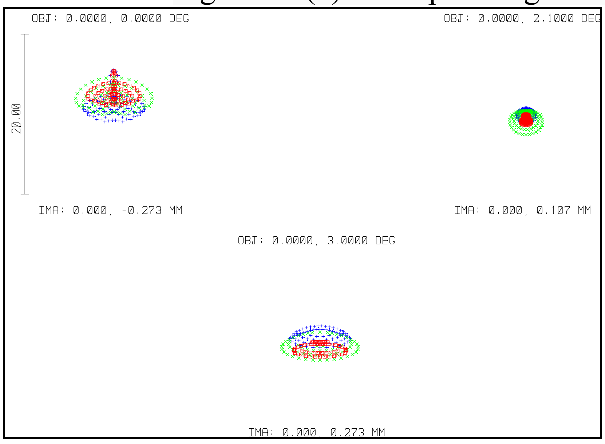

Figure 10 (d) 1.5 °Spot Diagram

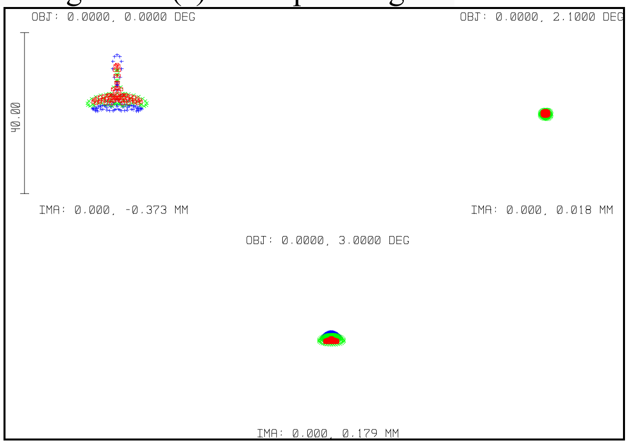

Figure 10 (e) 2.0 ° Spot Diagram

Column at different Angle disturbance, figure in the three field of root mean square radius, geometric maximum radius as shown in table 2

Table2. The root mean square radius of each field, Geometry of the largest radius

Angle variation(°)	field	Root mean square radius (um)	Geometry of the largest radius (um)
0	1	0.587	1.202
	2	4.545	12.942
	3	9.550	23.036
0.5	1	0.817	2.128
	2	2.746	5.354
	3	5.710	8.981
1.0	1	1.472	3.320
	2	1.679	3.797
	3	3.863	6.682
1.5	1	2.961	5.552
	2	0.965	2.590
	3	2.596	4.568
2.0	1	5.554	14.505
	2	0.609	1.516
	3	1.276	2.884

From figure11. A clear field of geometric maximum radius 1 field (center) and root mean square radius with the increase of Angle increased significantly, that with the increase of lens deflection Angle, light intensity of the image point weakened gradually, the energy distribution is more and more dispersed, namely a drop in the quality of imaging.

4. Conclusion

This paper, by using ZEMAX optical system simulation analysis of the impact of on-board a sight of light transmission, the following conclusions:

Optical transfer function (MTF) with the increase of Angle, the curve is more and more curved, in the middle of the edge and the consistency, the worse, edge serious descent that edge light contrast and resolution. S curve and the contact ratio of T curve (meridian curve) followed deflection Angle increase and decrease, said the greater the astigmatism of lens; Column points (Spot Diagram) geometric maximum radius and root mean square radius with the increase of Angle increased significantly, that with the increase of lens deflection Angle, light intensity of the image point weakened gradually, the energy distribution is more decentralized, namely a drop in the quality of imaging.

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