Vibration factors impact analysis on aerial film camera imaging quality

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Abstract. Aerial film camera can acquire ground target image information advantageous, but meanwhile the change of aircraft attitude, the film features and the work of camera inside system could result in a vibration which could depress the image quality greatly. This paper presented a design basis of vibration mitigation stabilized platform based on the vibration characteristic of the aerial film camera and indicated the application analysis that stabilized platform could support aerial camera to realize the shoot demand of multi-angle and large scale. According to the technique characteristics of stabilized platform, the development direction are high precision, more agility, miniaturization and low power.

1. Introduction
Imaging is an important means of military reconnaissance. It is the main method for obtaining battlefield intelligence in modern war. The aerial camera is an important implement tools in imaging reconnaissance activities, electromagnetic wave radiations or reflections of the ground targets were collected through the optical system, and the lights were focusing on the focal plane and it was provide energy for recording medium. For the air film cameras, the recording medium is film. Digital imaging and digital image material has been developed rapidly since the 1990s, it has the characteristics of imaging convenient storage and real-time transmission, but the sensitive material with the characteristics of low cost, high resolution, high cost performance, high sensitivity, so it is still the most mature technology. While obtaining the target image, the vibration of the vehicle will be passed on to the aerial camera through the connection platform, so as to affect the work of aerial camera optical system, also has a great influence on the quality of imaging [1]. In the paper, by analyzing the characteristic of air film and camera vibration on the camera image quality, the domestic and foreign application situation of stabilized platform were summarized, the necessary of effective vibration reduction of the camera stable platform method was put forward, it can provide reference for the design of the vibration and stability of the aerial camera platform and the selection of film.

2. The Film Features and its Imaging Principle
The film is a kind of photographic material which can accept lights information, then after the chemical or physical process, a fixed image can be obtained. The nitric acid fiber, acetate fiber or polyester was taken as the base material, on the base coated by gelatin and suspension of photosensitive material made of silver halide particles in emulsion. When taking the photo, the lights through the camera lens illuminate on the film emulsion layer, the light reaches the silver halide crystal mass formed by the coalescence and silver halide crystals, and different intensity of illumination can make the film emulsion layer micro field have different amount of crystal structure changes and mutual coal escence, film exposure, latent image, developing the film for operation, the structure change of silver halide crystals into black metallic silver particles get nexus of contracts,
produce images; The without photo sensitive part on film, the crystals without structure change is washing out by fixative, present light grey or transparent; The result is negative as the dark parts are more exposed, and the bright part is less exposure, the transparent part is not under the light irradiation, it is the black and white film process. There are three emulsion layers in the color film, respectively in the emulsion layer can produce dye containing different color coupler. The emulsion layers are colourless, when it was developing, the color development developer oxide coupling to be colored dyes. Compared to the common film, the air film have more excellent physical and mechanical properties such as excellent resistance to impact, high tensile strength, bending strength, compression strength, small creep, size stable, and the relationship between imaging quality and its characteristic parameters depends on the material structure and properties of the film itself, so the air film imaging quality influence factors analysis has important practical significance [1-3].

3. Film Imaging Quality Influence Factors
There are many influencing factors to film imaging quality, we only focus on the photographic properties factors [1].

3.1. Contrast
Contrast is the brightness of the image contrast imaging after the degree of difference. For film it is the difference of maximum density and minimum density, it can affect the deepest and the most shallow tone differences of the image, so it is one of the factors that influencing the quality of film imaging, it is usually called contrast coefficient. The contrast coefficient of air film is larger than normal film, usually between 1.5 to 2.6.

3.2. Tolerance
Tolerance refers to the film according to the proportional relationship between the scopes of the right record scene brightness difference portion of straight line on both ends of the photosensitive characteristic curve corresponding to the exposure of the logarithmic difference. In characteristic curve, the linear part is recorded according to the proportional relationship between the image luminance differences. The bigger of tolerance, the bigger scope of brightness, the range of tolerance is larger than the brightness of the scenery, the greater the range of correct exposure scalable.

3.3. Identification Rate
The identification rate is the resolution, it is the film's ability to identify and record the scene details, also called as force. It is showed to distinguish the number of lines every mm. The major influencing factors for film materials is the silver halide emulsion particle size. Generally speaking, the higher of sensitivity of emulsion particles, the lower identification rate, and low sensitivity of the emulsion particles is small, with high identification rate.

3.4. Fog Density
The density that did not photosensitive part was called fog density. Any film has a certain fog density, mainly produced by the instability of emulsion itself, and it also had relation to the exposure in air too long and friction factor and so on.

3.5. Maximum Density
Photosensitive characteristic curve can achieve the maximum density value is called the maximum density, is also the most black that film can be achieved. In reconnaissance plan, the exposure time should require the brightest part of the density value not exceed this value.

4. Effect of Vibration to Image Quality
Camera vibration can be divided into the external and internal vibration. External vibration is generally characterized by frequent vibration, such as the change of the flight, flying in the air with a plane and the plane engine, weapons and equipment of the fire control system, can cause the vibration of plane emergency or frequent periodic vibration. In the vibration, especially when the landing impact effect on camera parts is bigger, and frequent vibration caused by engine working on image quality is bigger also, the influence of the system must be eliminated [1,4,5].
Internal vibration is generally characterized by sudden, random vibration, such as camera internal parts, the system of work, such as the rotation of the motor, the shutter open, the rise and fall of platen, the vibration of the swing seat frame and so on, also can cause camera flash or frequent vibration. It can be found that the vibration of the camera is irregular, that is to say, the camera can be moving along at any direction or around any axis reciprocating vibration, and the vibration can produce very big effect on the imaging quality of the camera.

In order to study the effect of vibration to image quality, the vibration of the camera can be decomposed into respectively along the perpendicular of x, y, z axis vibration and around the triaxial vibration, as shown in figure 1.

![Figure 1](image1.png)

**Figure 1.** The directions of the camera vibration

![Figure 2](image2.png)

**Figure 2.** The camera image point vibration along the X axis vibration

The biggest influence on image quality is the regular vibration of the camera, the vibration is a harmonic oscillator with sine law generally, and the six points of vibration can be written as the following form:

\[
x = a_x \cos(\omega t + \alpha_x)
\]

\[
y = a_y \cos(\omega t + \alpha_y)
\]

\[
z = a_z \cos(\omega t + \alpha_z)
\]

\[
\varphi_x = \psi_x \cos(\omega t + \beta_x)
\]

\[
\varphi_y = \psi_y \cos(\omega t + \beta_y)
\]

\[
\varphi_z = \psi_z \cos(\omega t + \beta_z)
\]

\[\alpha_x, \alpha_y, \alpha_z, \psi_x, \psi_y, \psi_z\] are each vibration amplitude and angle amplitude, \[\alpha_x, \alpha_y, \alpha_z, \beta_x, \beta_y, \beta_z\] are all the points in the early phase of the vibration, \(\omega\) is the angular frequency of vibration, general aircraft engine vibration angular frequency. The following concrete analysis the influence of various vibration on image quality.

### 4.1. The Vibration Along the x, y, z Direction

In the process of exposure, the camera along the horizontal axis x or y axis vibration, vibration will cause the image accordingly. Figure 2 shows the image move caused by camera along the x axis vibration.

When the exposure time is greater than the vibration period \(T\) (\(T=2\pi/\omega\)), the image point in completing a vibration plate, the length of the image point vibration is set to \(\Delta l_x\):
\[
\frac{1}{2} \Delta l_x \left( a_x \right)^{-1} = \frac{f}{H}
\]  
(7)

\[
\Delta l_x = 2a_x \frac{f}{H}
\]  
(8)

When the exposure time is less than the period of vibration, the exposure of the image point has not yet completed a vibration, the image point move less than \(2a_x \frac{f}{H}\), its length depends on the exposure time and its beginning and ending time in the process of vibration. Along the y axis vibration on image point and the influence of the above situation is the same.

When making imaging reconnaissance aircraft, \(a_x\) and \(a_y\) are small, reconnaissance height \(H\) generally greater than the camera focal length, so the absolute value of \(2a_x \frac{f}{H}\) is small; The vibration of the camera along the vertical axis z axis is equivalent to the change of the camera height. As a result, the vibration of the camera along the x, y, z axis had no real effect on image quality.

4.2. The Vibration Around the x, y Axis

In the process of exposure, the camera around the horizontal axis x or y axis vibration, will cause the image point make corresponding reciprocating movement on the plate.

Figure 3 represents the camera around y axis vibration, both sides of the fulcrum of vibration respectively. Set the same amplitude \(a_y\), phase are 180 DHH, camera around y axis vibration amplitude (the angle amplitude) \(\psi_y\) is largest:

\[
tg \psi_y = \frac{2a_y}{l}
\]  
(9)

Because the amplitude \(a_y\) in general is far less than mount fulcrum spacing \(l\), also \(\psi_y\) is very small:

\[
\psi_y = \frac{2a_y}{l}
\]  
(10)

In a vibration period, the optical axis of camera lens angle of vibration is \(2\psi_y\). If the exposure time is greater than the vibration period, the main axis of image point to complete a reciprocating movement on the plate, so the length \(\Delta \phi_y\) of the image point was as follows:

\[
\Delta \phi_y = 2\psi_y \cdot f = \frac{4a_y}{l} f
\]  
(11)

Generally the camera pivot spacing and the camera focal length roughly equal, so \(\Delta \phi_y = 4a_y\), the longer the camera focal length, the more serious the image motion. The influence of the x axis vibration is also the same.

4.3. The Vibration Around the z Axis

In the process of exposure, the camera around the vertical axis z axis vibration will cause as click to the reciprocating movement of the main focus for the center of the circle arc, as shown in figure 4.

Amplitude for each fulcrum is \(a\), and it goes around the z axis direction, around the radian of the angle of the z axis vibration amplitude value is:

\[
\psi_z = \frac{a}{l'}
\]  
(12)

In (12), \(l'\) is the distance protection from z axis and mount.

Within a vibration period \(T\), vibration Angle is \(2\psi_z\), when exposure time is more than \(T\), the image point in completing a vibration plate, arc length as follows:
\[ \Delta \varphi_z = 2 \mu_z \cdot r = 2 \frac{ra}{l'} \] (13)

In (13), \( r \) is the distance between the point and the main focus.

On that, as the size and image point position and image point outside edge, the closer the negatives as move. Usually \( l' \) is greater than \( r \). If exposure time is less than \( T \), the image motion will be smaller. So kind of vibration caused by image motion is usually close to or smaller than the vibration amplitude of the camera.

Known from the analysis of the above that in the six kinds of vibration, the vibration around the horizontal axis \( x, y \), impact on the quality of image is the largest, its influence degree and saddle point up and down is directly proportional to the amplitude of the vibration. Minimize the amplitude values, therefore, is stabilized platform vibration device to complete one of the main tasks.

5. Conclusion
Because the aerial reconnaissance is given priority to with photoelectric devices, not just the visible and infrared aerial camera, and synthetic aperture radar, laser range finder, etc., so in recent years abroad has stabilized platform to develop into a dedicated opto-electronic reconnaissance platforms, and its related technology developing rapidly, such as payload towards platform lighter, sensors, more smaller and higher stable precision in the direction of development. In recent years, the domestic aviation photoelectric reconnaissance platform also has great development, whether in the quality of platform, and precision of payload, stability, greater progress, yet there is a large gap compared with abroad, especially in terms of volume and quality, its reason mainly lies in the framework form and material, and the miniaturization of optical structure design and manufacturing technology level. According to the characteristics of modern warfare and the developing trend of the development of the aviation surveillance will be towards the three-dimensional space, intelligence information in real time, the means of diversification, reconnaissance and combat integration direction, thus determines the reconnaissance platform will be toward more accurate, more flexible, small volume, small energy consumption in the direction of development.

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