Research on Airborne Active and Passive Composite Vibration Isolation Optoelectronic Stabilization Platform System

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Abstract. According to the vibration isolation requirements of a certain type of optoelectronic stability platform, an active-passive composite vibration isolation system based on the hierarchical vibration isolation idea is designed. The system uses the active and passive hybrid vibration isolator as the outer frame damper, and the two-axis four-frame optoelectronic system. The stable platform has a reasonable layout. The system realizes the three-way stiffness, removes the line vibration coupling in the three directions of the system, establishes the three-dimensional model of the vibration reduction system in UG, and uses the Altair HyperMesh/OptiStruct software for finite element analysis. The results show that the vibration isolation system meets the design requirements.

1. Introduction
Airborne optoelectronic stability platforms are currently widely used in civil, aerospace and military applications. The core competitiveness of UAVs in industrial applications is the function that can be realized by task load. The payload of airborne opto-stabilization platform as a widely used UAV has attracted the attention of scholars at domestic and abroad [1]. During the flight, the UAV will be subjected to vibrations from the abdomen position of the drone, the internal load of the optoelectronic stability platform, and the wind resistance received during the flight. The displacement and angular displacement are applied to the optoelectronic stability platform [2], a large number of studies by domestic and foreign scholars have shown that the angular vibration generated by angular displacement has a much greater influence on the imaging quality of the optoelectronic stability platform than the line vibration generated by the linear displacement on the imaging quality of the optoelectronic stability platform [3]. Therefore, when designing the vibration isolation system of the optoelectronic stability platform, it is necessary to eliminate or control the coupling of the line vibration into angular vibration. Other paragraphs are indented (BodytextIndented style).

Because drones require high accuracy over a wide frequency range, the commonly used passive damping has been limited by performance. Therefore, a large amount of research has been recently conducted on active dampers to overcome the limited performance of passive dampers. Active
dampers typically attenuate unwanted vibrations by using external energy provided by electromagnetic or hydraulic servo actuators [4]. However, electromagnetic and hydraulic servo actuators are composed of many components, have a large design and require relatively large power consumption, and are too cumbersome to be applied to drones. Due to its fast response time and easy control characteristics, many materials have been studied by many scholars for their application to vibration reduction [5]. Therefore, an effective active-passive hybrid isolator can be manufactured by combining a piezoelectric actuator with a rubber member [6].

According to the existing two-axis four-frame optoelectronic stability platform [8], a non-angular displacement active-passive composite vibration isolation system was designed. The existing two-axis four-frame optoelectronic stability platform is improved, and the active-passive hybrid vibration isolator is used as the outer. The damping mode of the platform is analyzed, modeled in UG, and finite element analysis is performed with Altair HyperMesh/OptiStruct. The results show that the designed new vibration isolation platform meets the design.

2. Structural design and vibration reduction analysis of the amount

2.1. Structural design of the external frame active damper

Figure 1 shows the structure of an active-passive hybrid isolator consisting of a rubber element, a piezoelectric column actuator and an inertial mass. The rubber element supports the weight of the photovoltaic stabilization platform. The piezoelectric column actuator has one end fixed to the rubber member and the other end connected to the inertial mass. By exciting the piezoelectric actuator, the inertial force can be generated as an actuation force. The structure also provides fail-safe functionality; even if the piezo driver breaks due to unexpected excitation with high amplitude and force, the damper will work properly [9]. The optoelectronic stability platform designed in this paper is a two-stage vibration isolation system, and the mechanical model of the first stage vibration reduction is shown in Fig. 2. From the mechanical model, the governing equations of motion are derived as follows:

\[ m_c \ddot{x}_c + c_r (\dot{x}_c - \dot{x}_b) + k_r (x_c - x_b) = -m_i \ddot{x}_i \]

\[ m_r \ddot{x}_r = k_p (x_c - x_i) - F_a \]

(1)

Where \(x_b\), \(x_i\) and \(x_c\) are the displacement of the susceptor, inertial mass and support mass, respectively. \(m_i\) and \(m_c\) are inertial mass and support mass, respectively. \(k_r\) and \(k_p\) are the stiffness constants of the rubber component and the piezoelectric stack actuator, respectively.

![Figure 1. The structure of active and passive hybrid damper](image-url)
2.2. Selection of inner frame damper
The inner frame damper is shown in Figure 3. The inner frame damper uses the JGZ type dry friction high damping damper of Liaoning Tongze Shock Absorber Co., Ltd., which has wide dynamic range and large damping. Features such as bearing direction limitation, can safely pass through the resonance zone to achieve vibration isolation in any direction. The product quality and technical indicators have reached the domestic leading level, and were widely used in the buffer vibration isolation system of aviation and aerospace equipment.

![Figure 3. JGZ dry friction high damping damper](image)

3. Main passive composite vibration isolation system design and principle analysis

3.1. Design of active and passive composite vibration damping system
The three-dimensional model of the optoelectronic stability platform and the installation position of the damper is shown in Fig. 4. Part1 is equivalent to the outer frame, part3 is the base of the body, part4 is the inner frame base, part6 is the inner frame, and the optical device load is inside. Part4 of the same outer frame active and passive hybrid dampers part2 are arranged symmetrically with respect to the center of gravity of the nacelle in the plane of the base of the moving carrier; eight identical inner frame dampers part5 are arranged symmetrically with respect to the center of gravity of the inner frame.
A coordinate system as shown in Fig. 5 is established: the X-Y plane is parallel to the plane of the base, and the Z axis is perpendicular to the plane of the base. The following problems should be noted during installation: the axis in the active-passive hybrid damper in Figure 2 is parallel to the Z-axis; the axis of the JGZ-type dry-friction high-damper damper in Figure 4 is parallel to the X-axis. At the same time, it is guaranteed that each set of dampers is installed in the same plane, and the joints of the shaft ends are also in one plane.

3.2. Analysis of the principle of angular displacement of active-passive composite vibration isolation system

The principle of active-passive composite vibration isolation of two-axis four-frame optoelectronic stability platform is shown in Figure 5. It consists of two layers of frame structure: outer azimuth, outer pitch and inner azimuth and inner pitch. The outer isolators are actually susceptor isolator, optoelectronic the stable platform was installed on four evenly distributed active and passive hybrid isolators. The outer frame isolators are installed on the aircraft to achieve overall vibration isolation of the optoelectronic stability platform. The good active vibration isolation performance can be well isolated. Low frequency vibration of the body. The inner frame isolator is mounted on the outer pitch frame, and the inner azimuth and inner pitch frames are mounted on the inner isolator. The outer frame isolator isolates the Z-direction vibration, the X, Y degrees of freedom are limited, and the rotational motion around the X, Y, Z directions is also limited. The inner frame isolators isolate the vibrations in the X and Y directions, the Z-direction degrees of freedom are limited, and the rotational motion around the X, Y, and Z directions is also limited. Through the two-stage vibration isolation, that is, the combination of the inner and outer frame dampers, the vibration of the vibration along the triaxial line is realized, and the angular vibration around the three axes is limited. The active-passive composite damping system designed in this paper relieves the three-way vibration coupling between the base and the load, and avoids the influence of angular vibration on the load caused by the vibration coupling of the base.
4. Finite element analysis of 4 active and passive composite optoelectronic stability platform

According to the vibration isolation theory, the vibration isolation system of the stable platform is designed. The UAV ejection process, the parachute process and the flight process all need to experience the harsh mechanical environment. Therefore, the mechanical performance of the stable platform is stable and high precision stability. Therefore, the finite element analysis of the structure of the stable platform must be carried out to determine whether its stiffness and strength can meet the overload requirements. At the same time, establish a finite element model of the stable platform to determine the overall modal information of the system. This topic uses Altair Hypermesh/OptiStruct software for finite element analysis.

4.1. Stable platform finite element model

The model established in UG is imported into Altair Hypermesh/OptiStruct for finite element analysis. The specific setting method is as follows:

Material: Aluminum alloy, its modulus of elasticity is 71000 MPa, Poisson's ratio is 0.33, density is 2.770 g/cm³, and does not change with temperature and time.

Model simplification: Ignore some small structures such as rounded corners and bosses, and replace the structures that are not affected during the stress process with mass points such as cameras, motors, sensors, and housings.

Meshing: In the Hypermesh software, the manual partitioning method is used to divide the tetrahedral mesh with a minimum cell size of 5.

The connection between the structural components: the overlapping faces between the merged structures, the RBE2 rigidly joins the non-contact faces, and the RBE3 connects the equivalent masses to their loads.

Constraint: Apply a fixed constraint at the outer frame bolt hole.

Load: Study the stress and strain of a stable platform with 1x gravity load.

The final simplified finite element model of the stable platform is shown in Figure 6:

![Figure 6. Finite element model of optoelectronic stability platform](image)

4.2. Modal Analysis of Stable Platform

The free modal analysis of the finite element model of the main framework obtained in Section 4.1 is carried out. The analysis results are shown in Figure 7:

![Figure 7. Modal analysis results of the optoelectronic stability platform](image)

(a) 1\textsuperscript{st} mode of optoelectronic stability platform (b) 2\textsuperscript{nd} mode of optoelectronic stability platform
It can be seen from Fig. 7 that the modalities of the various frames can meet the design requirements, but the natural frequency is too low, which needs to be improved, and the rigidity of the structure can be improved by reducing the shaft hole or local thickening.

4.3. Static analysis of the stable platform
The static analysis of the finite element model of the optoelectronic stability platform obtained in Section 4.1 is carried out. The analysis results are shown in Figure 8:

![Stress cloud diagram of the platform](image1) ![Train cloud image of the platform](image2)

Figure 8. Static analysis results of the optoelectronic stability platform

From the results of the overall static analysis of Figure 9, it is seen that the static performance of the stable platform meets the design requirements, indicating that the model simplification and the joint constraint method are feasible in the overall static analysis. In addition, the static of the whole platform is stabilized. Well performance and meet design requirements.

5. Conclusion
According to the design requirements of a certain type of optoelectronic stability platform, a principal-passive composite vibration isolation optoelectronic stability platform is designed, which adopts the idea of hierarchical vibration isolation. The external frame damper selects the active and passive hybrid isolators based on the piezoelectric column actuator, which can effectively attenuate the low frequency vibration from the body. The inner frame damper adopts the JGZ type dry friction high damping damper, two the vibration damping system effectively cancels the line vibration coupling in the three directions of the system. The 3D model established in UG is imported into Altair HyperMesh/OptiStruct software for finite element analysis. The static and modal analysis results show that the designed composite vibration isolation system meets the design requirements, but there is still a lack of rigidity, which needs to be in the subsequent work. Optimize to apply the system to real engineering problems as quickly as possible

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627

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