Design process - satellite hinge

[School] Number] September 10, Preliminary design process to select an optimal hinge for a small satellite panel deployment.

Problem Statement

The primary goal for this design process is to select an optimal hinge for a small satellite panel deployment. The satellite has 8 solar panels with the inner panels held by a 90o hinge to the satellite while the outer panels are held to the inner panels by 1800. The solar panels in this case are usually stowed during the launch and are normally deployed when the satellite is in a stable orbit.

Hinge Constraints

The principle behind functionality of the hinge is an arrangement of joints that have been selected and are aimed at providing a quasi-center-pin guiding behavior coupled by a high twist stability. Its thickness and positioning are adjusted so as to tune the final design in terms of motorization torque, stability, stiffness. Therefore, the selected hinges have to meet certain constraints for the satellite to work since the movement of panels has to be controlled without any damage and should be brought to rest and locked when fully deployed. These constraints are also very important since if they fail, then the whole satellite becomes unusable. (Givois, 2001)

The hinges must have a maximum panel acceleration and deceleration of 200 deg/sec/sec and a maximum angular velocity of 400 deg/sec. Individual panels should not exceed a weight of 200 grams while the cost of each hinge should be approximately £400. Figure 1 below shows the relationship between angle versus time, velocity versus time, acceleration versus time and torque versus time for both hinges. (Donzier, 1997)

Figure 1: Graphs of Graphs of angle-time, velocity-time, acceleration-time, torque-time for both hinges

Design Criteria

According to Pellerin, Mazoyer and Givois, the design process to select an optimal hinge for a small satellite panel’s deployment is guided by the following criteria:

1. The best possible first natural frequency
2. The lowest mass of about 85g
3. Reliability of the components used and ease of deployment
4. Flatness i. e. less than 1/20th of the panel’s wavelength
5. The packaging efficiency i. e. approximately 1. 4m by 1. 2 stowed to 4m by 11m when deployed
6. Holding torque of about 4. 5N. m/rad
7. The mechanical stability of the whole system
8. Compatibility of the material used for design with launch and Low Earth Orbit (LEO) space environment
9. A low energy consumption
10. Temperature range; -85oC to +1150C

The Design Solutions

The three design solutions proposed for this design include;

1. A powered Hinge system

This comprise of two components i. e. a powered drive hinge and a multiple degree-of-freedom floating hinge. Powered deployment is a result of High Output Paraffin (HOP) linear motor that is acting through a redundant metal band. Deployment is initiated by provision of power to the actuator. One the panel is deployed in position, a bar latch gets into position hence locking the panel in a fully deployed position. (Starsys, p. 51)

2. Torsion Spring System

It comprises of two hinges i. e. a spring powered drive and a multiple degree-of-freedom floating hinge. This provides exceptional stiffness for vibration loads without need of for a high tolerance alignment. Deployment energy is provided by a double coil torsion spring on the drive hinge. (Starsys, p. 53)

3. Constant Torque Spring Hinge

The hinge mechanism consist of a passive and powered constant torque hinge. The powered hinge is deigned to take axial and radial loads while the passive hinge has axial play to allow panel thermal displacements. This system provides a near constant torque for any deployment up to an angle of 180o. Each hinge consists of an axle, a precision spherical bearing, two spacers and springs for both low powered hinge and passive hinge. (Starsys, p. 55)

Analysis

In the table below, the most desirable characteristics of the three solutions are compared with the ‘ support structure complexity and mass category’ being the most important of all.

Support

structure

complexity

and mass

Electronic

complexity

Smoothness

and

controllability

Space

heritage

Powered Hinge

HIGH

LOW

LOW-MEDIUM

HIGH

Torsion Spring

MEDIUM

LOW

LOW

HIGH

Constant Torque Spring

LOW

LOW

LOW

LOW

In terms of Support structure complexity and mass, the powered hinge has need to attached to the structure of the frame and also the devices for motion transmission need to be inserted to ensure its power is properly coupled to the frame for an aligned deployment hence providing a challenge in terms of weight increase and mechanical complexity. However, the two springs have low weight and are small in size hence can be easily be integrated to the frame. (Donzier, 1997)

Powered hinge systems function with the help of current pulses hence increase in system’s weight. They however provide a smooth and controllable motion as compared to the spring’s; which has a mechanism to control the elastic energy stored internally. On the other hand, very large displacements could lead to a high inertia imparted in to the frame hence making it difficult to control compensation for the satellite’s attitude. (Givois, 2001)

Decision

In conclusion, the constant torque spring offer weight savings but presents a challenge of finding an acceptable mechanism to control the release strain energy in order to minimize the effects of inertia during deployment. Therefore, based on the above analysis, the design process to select an optimal hinge for a small satellite panel deployment will be based on the constant torque spring.

Works Cited

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