SYSTEM FOR OUTDOOR LIGHTING OF A LARGE SURFACE AREA BASED ON A SOLAR REFLECTOR IN THE TURKESTAN REGION

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ABSTRACT

The lack of advanced solar panel technology and the heavy dependence of electric power generation on ambient temperature, as well as the low operating reliability of solar panels in the field do not facilitate the widespread introduction of this type of electrical generation system into the general energy supply system of the Turkestan region. A design of a solar reflector is proposed, which allows reorientation in a shorter time with less energy consumption than a design without a compensating flywheel. An algorithm for the spatial rotation of the solar reflector by changing the angle between the vectors of kinetic moments has been developed. The limiting values of the change in the angle between the vectors of the angular momenta of the flywheel and the frame-film system, as well as the limiting value of the angular velocity of the solar reflector turn, are found. As an external control effect on the solar reflector, you can use the change in the reflectivity of the film. To change the reflectivity of the solar reflector, you can use the energy obtained by reducing the kinetic energies of the flywheel and the frame-film system. The use of a solar reflector of such a design will allow illuminating a given area of the earth's surface for a long time without its continuous maintenance, conducting remote monitoring of the solar reflector equipment.

Keywords: solar reflector, vector imbalance, liquid crystal panel, vector, angular momentum, frame, film.

INTRODUCTION

The widespread introduction of solar energy technologies in the Turkestan region is constrained by the fundamental limitations inherent in these technologies. These include the inability to use solar energy facilities at night, a significant loss of power from solar power plants and thermal solar power plants during fogs, rains and other atmospheric precipitation, including dust storms, snow, hail, etc. Despite the fact that according to the solar cadastre data in the Turkestan region there are 340 days a year sunny days and the development of solar energy is favorable, but its use is only 5% of the total electrical power generated by other types of power plants. The main factor in this case is the extremely low efficiency. semiconductor solar panels, which are the backbone of solar energy. It should be noted that due to the imperfect technologies for the production of solar panels and the strong dependence of the generation of electrical energy on the ambient temperature, as well as the low reliability of the performance of solar panels in the field, it does not contribute to the widespread introduction of this type of power generation systems into the general energy supply system of the Turkestan region.

Bringing such systems out of the Earth's atmosphere into near space would eliminate many of the limiting factors inherent in such systems on the Earth's surface. For a long time, the scientific press has published articles on projects of numerous solar, space power plants of increased power, the main problem of which is the implementation of methods for transferring large powers of electrical energy to the Earth, to the main consumers.

One of the promising topics for space solar energy's development is external illumination of large areas of the Earth's surface using an orbiting mirror solar reflector. The essence of the idea is that the design of a solar reflector can be represented in the form of a thin mirror film, the shape of which is supported by centrifugal forces arising from the rotation of a rigid openwork frame and a flywheel that compensates for the kinetic moment of the frame-film system. In this version of the design, the reorientation of the solar reflector is possible by changing the angle between the vectors of the kinetic moments of the flywheel and the frame-film system, which will make it possible to do without the consumption of the working fluid. When an undesirable angular velocity of a solar sail occurs with a nonzero sum of the angular momentum vectors of structural elements, an external control torque can be created by changing the reflectivity of the film. One of the advantages of this design of the solar reflector is that it does not require propellant consumption for its movement [1]. To achieve the required orbits, in this case, it is necessary to change the orientation of the sail, therefore, the problem of controlling its spatial turn without the consumption of the working fluid seems to be urgent. [2, 3].

MATERIALS AND METHODS

The design of a solar reflector in the form of a circular mirror film of a large area is considered in this article, the shape of the surface of which is formed and maintained by the rotation of the openwork frame [10, 12]. To compensate for the angular momentum of the frame-film system, a flywheel is designed, the axis of rotation of which is opposite to the direction of the axis of rotation of the rigid frame [3,5]. This allows the spatial rotation of the solar reflector without the consumption of the working fluid due to the change in the angle between the vectors of the kinetic moments of the flywheel and the frame-film system. Equality to zero of the total angular momentum of the structure will lead to the fact that the solar reflector will begin to rotate around an axis that coincides with the sum of these vectors [10].

The imbalance of the angular momentum vectors arising during the long-term operation of the solar reflector in orbit can be compensated by changing the reflectivity of the solar reflector film or its individual sectors [5, 6]. This technology can also be used to change the angle between the vectors of the kinetic moments of the flywheel and the frame-film system during the spatial rotation of the solar reflector and change the direction of its movement. It should be noted that the change in reflectivity has already been used to control the orientation of the IKAROS solar sail. In the Japanese project, liquid crystal panels located along its edges made it possible to regulate the amount of light pressure on individual parts of the sail, as a result of which the spacecraft was turned [5]. However, it will take a lot of time and energy to reorient a solar reflector with a high moment of inertia alone by the pressure forces of sunlight [12]. The proposed design of the solar reflector makes it possible to reorient in less time with less energy consumption than the design without a compensating flywheel [8]. The direction of the kinetic moments vectors of the solar reflector in its spatial reversal is shown in Fig. 1.

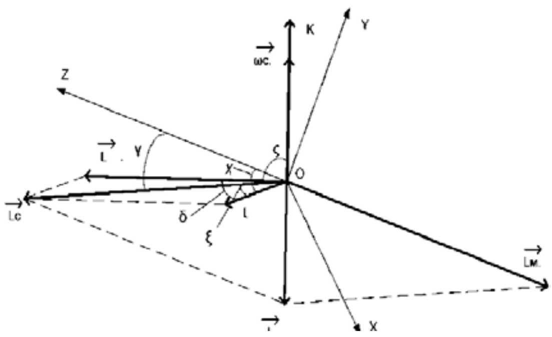

Fig. 1. Direction of the kinetic moment vectors of the solar reflector when it is spatially rotated.

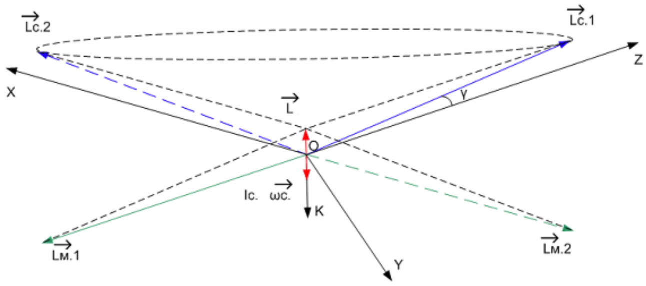

Fig. 2. Position of the torque vectors of the flywheel and the frame-film system if they are modulated

Fig. 2 shows the possible positions of the kinetic moment vectors of the flywheel and the frame-film system in case of their modular equality in magnitude during the spatial rotation of the solar reflector. In order to prevent the surface of the film from being unduly deflected from the plane of the frame, it is necessary to impose a limit on the turning rate of the solar reflector, and therefore on the change of angle between the vectors of the kinetic moments of the flywheel and the frame-film system. The ratio for the limiting value of the angular velocity of rotation of the solar reflector is defined as:

$$\omega_{\max s.s} = \frac{\delta_{\max} \cdot \omega_{s.z1}}{K_1} \quad (1)$$

To ensure the stability of the control during the spatial rotation of the solar reflector, the following condition must be observed:

$$\frac{K_1 \cdot L}{I_{s.s.} \cdot \omega_{s.z1}} < 1 \quad (2)$$

The angle between the current position of the coordinate systems and the desired one is related by the relation

$$\alpha = \arccos\left(\frac{y_Y}{z_Z}\right) \tag{3}$$

The angle at which the solar reflector needs to turn will be determined by the ratio:

$$\vartheta = \arccos\left(\frac{1}{2}\left[x_X + y_Y + z_Z - 1\right]\right) \tag{4}$$

To stop the solar reflector, it is necessary to create a control torque, the vector of which is oppositely directed to the ON axis. It will return collinearity to the kinetic moments vectors of the flywheel and the rigid frame-film system.

The solar reflector spatial rotation algorithm includes the following steps:

Step 1. To compare the current spatial position of the solar sail with the desired spatial position and find the required rotation angle of the solar reflector.

Step 2. To calculate the limit value of the angular rate of the turning rate by ratio (1).

Step 3. To calculate the position of the ON axis using the relation (3).

Step 4. To change the angle between the vectors of the angular momenta of the flywheel and the frame-film system.

Step 5. To rotate the solar reflector around the OK axis, which coincides with the sum of the angular momentum vectors.

Step 6. To return the zero sum of the vectors of the angular momenta of the flywheel and the frame-film system.

Step 7. To stop overlay positions.

RESULTS AND DISCUSSION

The turning time of the solar reflector will be determined by the limit of its angular velocity, which is determined by the ratio (1) and the time at which the angle changes between the vectors of the kinetic moments of the flywheel and the frame-film system corresponding to that angular velocity.

If a film with a different coefficient of reflectivity is applied, these areas of the surface are exposed to different light pressure [9]. At a non-zero angle of installation (the angle between the direction of incidence of the sun's rays and the normal to the solar reflector), the thrust force is the sum of the projections onto the normal and tangential directions. With the help of the difference in the normal component of the light pressure force acting on different parts of the film, it is possible to change the direction of the angular momentum vector of the frame - film system. The difference in the tangential components of the light pressure forces will affect the angular velocity of the frame - film system. In considering the spatial rotation of the solar sail, this value may be neglected, as shown in [12]. Suppose that the rate of change in the coefficient of reflectivity of the film is equal to the rate of rotation of the frame-film system. Then the moment due to differences in normal constituents of the light pressure will be determined by the following ratio [1, 12]:

$$\Delta M_{n.} = \frac{2S\cdot\left(N_2 - N_1\right)\cdot\left(R_{pl}^3 - R_{krk}^3\right)}{3c}\cdot\lambda\cdot\cos^3\theta \tag{5}$$

The moment due to the difference in the tangential components of the forces of light pressure will be determined by the following relationship [1, 4, 7]:

$$\Delta M_{k.} = \frac{2S \cdot (1 - N_2) \cdot \left(R_{pl}^3 - R_{krk}^3\right)}{3c} \cdot \lambda \cdot \cos^2\theta \cdot \sin\theta \qquad (6)$$

For maximum performance, the sector angle λ should be equal to π. In order to save energy, this angle can be reduced [9], but this will entail an increase in the time of the reflector turn. If we impose a restriction on energy consumption, then based on it, we can choose the optimal value of λ, taking into account the maximum speed.

Changes in reflectivity can be used, inter alia, to make a spatial turn of the solar sail. Given the modular equivalence of the kinetic moments of the flywheel and the frame-film system and the small change in angle between them, the angle of the sail will be determined by the ratio:

$$\theta = \arccos\left(\cos\theta_{k.}\cos\theta_o + \sin\theta_o \sin\alpha \sin\vartheta\right) \qquad (7)$$

The spatial rotation of the solar reflector will be described by the following system of equations:

$$\begin{aligned} &\frac{d\chi}{dt} = \omega_\chi \\ &\frac{d\omega_\chi}{dt} = \frac{S\left(N_2 - N_1\right)\left(R_{p.}^3 - R_b^3\right)}{3cI_{c.z}}\pi\cos^3\theta \\ &\frac{d\vartheta}{dt} = \frac{L_\chi}{I_{c.p.}} \end{aligned} \qquad (8)$$

With the non-zero sum of the kinetic moment vectors of the flywheel and the frame-film system, an undesirable angular rate of rotation of the solar reflector may occurr. Also, with modular inequality of the kinetic moments vectors of the elements of design, the limit value of the turning angle of the solar reflector will decrease. To do this, it is necessary to develop a system that eliminates the imbalance in the vectors of the angular momenta of structural elements. For this purpose, it is proposed to use a change in the reflectivity of the surface of the sail, as this would not require the consumption of a working medium.

When the reflectance of the solar reflector changes, a large amount of energy, and therefore a large area of solar panels, will be required to create external moment. I propose that when the solar reflector is turned or if the imbalance of the kinetic moment vectors is corrected, the kinetic energy of the flywheel and the frame film system should be converted into an electric film, thereby reducing the necessary area of the solar panels. It should be borne in mind that the angular velocity of the frame-film system» shall not fall below a value sufficient to orient the surface of the reflector when it is turned.

CONCLUSION

An algorithm for the spatial rotation of a solar reflector by changing the angle between the kinetic moment vectors was developed in this article. Limit values of change of angle between the kinetic moment vectors of the flywheel and the frame-film system were found, as well as limit value of angular rate of turning of the solar reflector. Changes in the reflectance factor of the film can be used as an external control on the solar reflector. This will allow the return of the zero sum of the angular momentum vectors of the rotating parts of the reflector structure to ensure the immobility of the instrument compartment. The change in the reflectance coefficient can also be used to change the angle between the vectors of the kinetic moments of the flywheel and the frame-film system during the spatial rotation of the solar reflector. To change the reflectivity of the solar reflector, you can use the energy obtained by reducing the kinetic energies of the flywheel and the frame-film system. The use of a solar reflector of this design will allow illuminating a given area of the earth's surface for a long time without its continuous maintenance, conducting remote monitoring of the solar reflector equipment.

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