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CHAPTER 3: ADVANCED MATERIAL SCIENCE AND MECHANICAL ENGINEERING

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Adaptive Drive for Space Engineering

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Abstract. Control of the orbital spaceship procures its orientation and stabilization. Only the centre of masses is keeping the prescribed trajectory of ship, and all ship can change a position concerning the axes connected with the centre of masses under the influence of various disturbing forces. The stabilization system procures a motionless position of the ship body concerning the centre of masses. Orientation is necessary for the telescopes directed on space objects, for solar batteries, antennas and other devices. After performance of orientation it is necessary to execute stabilization for conservation of the received position. Expenses of energy for orientation and stabilization should be minimal as power resources are onboard restricted. Adaptive electric drives are effective remedies of transfer of motion in space engineering.

Introduction

Control of the orbital spaceship procures its orientation and stabilization. Only the centre of masses is keeping the prescribed trajectory of ship, and all ship can change a position concerning the axes connected with the centre of masses under the influence of various disturbing forces. The stabilization system procures a motionless position of the ship body concerning the centre of masses. Expenses of energy for orientation and stabilization should be minimal as power resources are onboard restricted.

Orientation is carried out rather simply. It is enough to put the corresponding short-term turning moment. Stabilization demands constant force. The regular and irregular perturbations of various sorts are opposing to conservation of the received orientation. Their compensation makes a stabilization problem.

The stabilization system should work continuously and to be sensitive to a variable disturbing moment. Magnitude of the disturbing moment driving the orbital spaceship in rotation round the centre of masses can be changing in a wide range.

Sources of a disturbing moment can be as in the ship, and outside.

The reasons of possible external perturbations are forces of aerodynamic resistance, gravitational and magnetic terrestrial fields, pressure of solar radiation, collision with small objects and space refuse. Some external affecting, for example, light pressure of the Sun, can be useful and be used as stabilising factors.

Internal perturbations can be called not only by work of moving parts of the equipment, but also by a moving of members of crew.

External perturbations of a natural origin (aerodynamic, gravitational or magnetic) are characterised, on the one hand, by rather small values of a disturbing moment, on the other hand, the big duration of their act. For example, the gravitational field of the Earth will act on the orbital spaceship continuously though the disturbing moment originating thus will be rather small. This moment should be compensated constantly, otherwise the moment pulse can be very big, and angular velocities of rotation will grow beyond all bounds, and the spaceship can be uncoiled till the big speed.

Disturbing moments, which can take place at ship mooring to a space station board, have the big magnitude, but they are short-term.

Methods of stabilization of not rotating station can be divided on passive and active.

In passive methods the compensation of disturbing moments is carried out at the expense of the energy, coming from the outside. Sources of the compensating moments can be either the external rotational moments of affecting of potential terrestrial fields (gravitational or magnetic), or superposed forces of an aerodynamic resistance or light pressure.

Active methods of stabilization are more effective. Active methods of stabilization create a restoring moment at the expense of the energy received or reserved onboard of the orbital spaceship. Stabilization refers to such methods by means of rotating flywheels and by jet nozzles.

In the system of stabilization by flywheels, offered by Tsiolkovskiy for space vehicles, the use of the inertia property of a rotating body to keep invariable orientation takes place. It is known, that the more angular velocity of rotation of a body and the more its moment of inertia, the more stabilization position of this body in space. Such three flywheels with the axes, which have mutual-perpendicular directions, provide full three-axial stabilization of the ship on pitch, hunting and roll.

But possibilities of system with flywheels on a maximum of magnitude of a restoring moment are not boundless and are defined by rotation speed limits of flywheels. Therefore reaction of such stabilization system to very big perturbations can appear insufficient.

The active system of stabilization by jet nozzles is the most effective and is already used in practice. But it demands the big energy resources.

Selection of Drive

The inertia control system and the stabilization, based on use of flywheels, is the most effective on a power demand. This system allows reacting rapidly and precisely to any external or internal perturbations, it allows rapidly and reliably to change station orientation.

The production engineering of work of the drive with flywheel is that the greatest power expenses takes place at the start (the motion beginning). Power of an engine is defined on its starting loading. The adaptive electric drive with the inbuilt adaptive gear variator [1] has simplicity of a design and allows overcoming starting loading by the low power engine.

Besides the use of the adaptive electric drive in attitude control systems and stabilization, it can be applied in following devices of space vehicles:

- Systems of turn of antennas,
- Devices of turn of solar batteries,
- Devices of turn of engines of correction,
- Systems of reflector adjustment,
- Mechanism of a mast outlet,
- Electromechanical executive element (manipulator).

The listed systems are working in a free space at a range of operating temperatures ±100^{0}C and in the conditions of vacuum to 10-13 mm hg

Adaptive Drive for Space

The drive for space should have the minimum possible weight and sizes.

The drive weight depends on power of an engine. Power of an engine should match to the maximum loading. Researches of drives of manipulators have shown that the maximum loading is connected with overcoming of the maximum inertial force [2]. In the article [2] it was offered to use the adaptive drive of the manipulator with the variable transfer ratio depending on loading.

The adaptive gear variator (Figure 2) brand differs from the gear transfer mechanism. The kinematic chain of an adaptive gear variator has two degree of freedom and only one input link. The variator contains the input carrier H_1, the closed contour containing toothed wheels 1, 2, 3, 5, 6, 4 and the output carrier H_2. Wheels 1, 4 and 3, 6 are joined in blocks of the central wheels 1-4 and 3-

6. The variator has two external links and the structural group of Assur with zero mobility placed between them. This structural group represents closed four-bar contour with toothed wheels 1-2-3-6-5-4.

Between them with zero mobility. This structural group represents closed four-bar contour with toothed wheels 1-2-3-6-5-4.

As it has been proved [1, 2] the closed four-bar contour imposes an additional constraint on motion of the kinematic chain with two degree of freedom, provides definability of motion at presence only one input link and power adaptation to a variable output loading.

The adaptive gear variator has a preset value of the maximum transfer ratio $u_{\max}$ ($u_{\max} = 3 \ldots 10$) and the maximum output moment of resistance M_{H2} on an output link H_2. It is required to determine the constant parameters of an engine power ω_{H1}, M_{H1} on an input link H_1, power and kinematic parameters of a variator.

Definition of power of an engine:

1) It is defined the minimum output angular speed

$$\omega_{H2} = \omega_{H1} / u_{\max},$$

where ω_{H1} - nominal angular speed of engines of the set type.

2) It is defined the moment of the engine $M_{H1} = M_{H2} / \eta \cdot u_{\max}$,

where - η efficiency of a variator ($\eta = 0.9$).

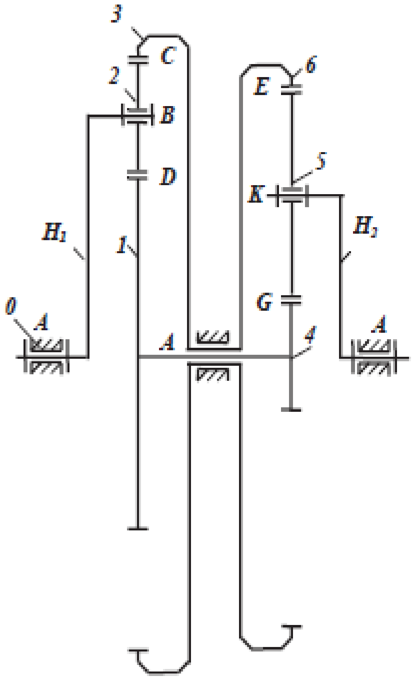

Figure 1. Gear adaptive variator.

3) It is defined power of an engine $N = M_{H1} \cdot \omega_{H1}$.

Initial data: constant parameters of power of an engine ω_{H1}, M_{H1} on the input link H_1, the set maximum value of a variable output moment of resistance M_{H2} on a output link H_2 : $\omega_{H1}, M_{H1}, M_{H2}$;

$z_1, z_2, z_3, z_4, z_5, z_6$ - numbers of teeth of wheels; m - the engagement module.

It is required to define the kinematic and power parameters of the mechanism: $\omega_{H2}, \omega_1, \omega_3, M_{12}, M_{32}, M_{45}, M_{65}$.

The solution.

1) Radiuses of toothed wheels $r_i = mz_i / 2, \quad i = 1, 2, 3, 4, 5, 6$.

2) Radiuses of the input and output carriers $r_{H1} = (r_1 + r_3)/2, r_{H2} = (r_4 + r_6)/2$.

3) Transfer ratio of wheels 1 and 3 at the motionless carrier H_1: $u_{13}^{(H1)} = -z_3 / z_1$.

4) Transfer ratio of wheels 4 and 6 at the motionless carrier H_2: $u_{46}^{(H2)} = -z_6 / z_4$.

5) Output angular speed $\omega_{H2} = M_{H1}\omega_{H1} / M_{H2}$.

6) Intermediate angular speed of a link 3

$$\omega_3 = \frac{\omega_{H2}(1 - u_{46}^{(H2)}) - \omega_{H1}(1 - u_{13}^{(H1)})}{u_{13}^{(H1)} - u_{46}^{(H2)}}.$$

7) Intermediate angular speed of a link 1

$$\omega_1 = u_{13}^{(H1)}(\omega_3 - \omega_{H1}) + \omega_{H1} .$$

8) Reactive moments on toothed wheels:

$$M_{12} = 0.5M_{H1}r_1 / r_{H1}, M_{32} = 0.5M_{H1}r_3 / r_{H1},$$

$$M_{45} = 0.5M_{H2}r_4 / r_{H2}, M_{65} = 0.5M_{H2}r_6 / r_{H2}$$

9) Check of reliability of the gained results

$$(M_{21} - M_{54})\omega_1 = (M_{56} - M_{23})\omega_3 .$$

Thus all required parameters are defined.

Conclusion

The adaptive electric drive with the build in adaptive gear variator is capable to fulfil all listed demands, has simplicity of a design, allows to overcome effectively a starting loading by the low power engine, has small dimensions and weight.

Adaptive electric drives are effective means of motion transfer in space engineering.

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