

Application of cascade-connected regulation in the implementation of the software of weight component compensation system

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Abstract. The paper considers the necessity to develop specialized technological equipment (a weight component compensation system) for ground-experimental testing of the functioning of high-technological large-size transformable reflectors for a spacecraft and their components. A simplified block diagram of the module layout of the weight compensation system with one carriage is presented. A mathematical model of cascade-connected regulation of a control system of a weight component compensation system was developed. An adaptive model has been presented. It determines the more appropriate settings for proportional–integral–derivative (PID-controller) through a fuzzy inference system applicable to test technological large-size transformable reflectors for a spacecraft.

Nowadays, one can note a rapid growth in the market for broadband communication services in the field of civil space all over the world. It is the fastest growing sector in the global telecommunications industry and represents a huge potential interest for investors. Large-size antenna systems provide the direct access of personal consumers to the information resources of the spacecraft (SC), bypassing ground-based operators. The cost of information services is continuously reduced due to the operation of energy-power platforms. New markets for mobile communication services, broadcasting, the Internet access are being improved and the occurrence of personal television, for instance, etc. is possible in future [1-3].

In the defense application field of large-size transformable reflectors (LTK), as a key element, will provide the development of technical facilities for communication and space surveillance systems that allow for continuous monitoring of satellite earth stations, radio relay and troposphere communication lines, radiation from telemetric ballistic missile and spacecraft transmitters. Current trends in the development of LTK of a spacecraft cover the expansion of the operating frequency range, the reduction in specific weight and the increase in the overall dimensions of their components.

As a result, radical measures are required to mobilize resources for this sphere of space activities. The development of manufacturing and testing technology of LTK is actively developing at the JSC



To solve the problem of testing and evaluating the reliability parameters of the operation of high-technological LTKs and their components, both in terrestrial conditions and in orbit under zero-gravity conditions, the development of the specialized technological equipment is required. It will be a high-precision active automated multi-channel weight component compensation system (WCCS) [5,6].

A simplified block diagram of the layout of the WCCS module with one carriage is given as an example in figure 1.

The adjustment of the main cable tension parameter (P_T) is carried out by an external circuit. It includes an input signal (1), correction signal from the internal regulator (6), and the main signal from the external regulator (3). The parameter's change in the tension of the cable is ensured by a signal from the proportional-integral-derivative (PID) controller of the cable winding mechanism with the help of the cable reducer motor.

The adjustment of carriage movement depending on the angle sensor is carried out by the internal circuit. It includes a dead zone of the sensor and an internal regulator (6). The impact is provided by the motor of the carriage reducer on the object with the help of an analog signal determined by the PID-law of the control of the carriage movement mechanism.

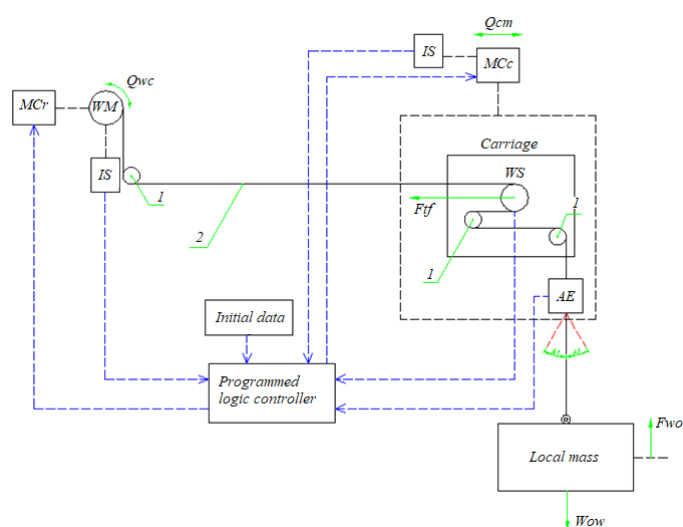


Figure 1. Block diagram of the layout of the WCCS module with one carriage: 1-roller; 2-cable; MCr- motor - cable reducer, MCc - motor - reducer of the carriage; WM - the winding mechanism of the cable; WS - weight sensor; AS - angle sensor; IS-incremental sensor; AE - absolute encoder (angle sensor); Qwc -winding speed of the cable, provided with a cable reducer; Qcm - speed of carriage movement, provided by the motor-reducer of the carriage; Fwo - internal force of the local mass of the object to be weighed; Ftf - cable tension force, measured by a weight sensor; Wow -weight of the object to be weighed.

The determination of the dependence of the LTK weight on the cable length is a minimum quadratic polynomial:

$$P(L) = A \cdot L^2 + B \cdot L + C, \quad (1)$$

where L is the current cable length; A , B , C are the calculated coefficients of the polynomial.

For the current value taken from the weighing sensor, the current misbalance of the error is determined:

$$e(t) = F_{\text{td}} - P(L), \quad (2)$$

where F_{td} is the cable tension force measured by the weight sensor is equal to the total force on the different sides of the roller of the weighing sensor.

It is necessary to use the theory of automatic control to develop a mathematical model of the PID controller of the cable winding mechanism, according to which the standard PID controller formula has the form [7]:

$$u(t) = P + I + D = Kp \cdot e(t) + Ki \cdot \int_0^t e(t)dt + Kd \frac{de(t)}{dt}, \quad (3)$$

where $u(t)$ is a control function; P is a proportional component; I is an integral component; D is the differential component; $e(t)$ is a current error; Kp is a proportional coefficient; Ki is an integral coefficient; Kd is a differential coefficient.

Consequently, the mathematical model of the PID controller of the cable winding mechanism is as follows:

$$Wm(t) = Kp \cdot (F_{\text{td}} - P(L)) + Ki \cdot \int_0^t (F_{\text{td}} - P(L))dt + Kd \frac{d(F_{\text{td}} - P(L))}{dt} \quad (4)$$

It is necessary to develop an adaptive model based on the developed model. It determines the more suitable PID controller settings through the fuzzy inference system depending on the control error and its derivative (figure 2).

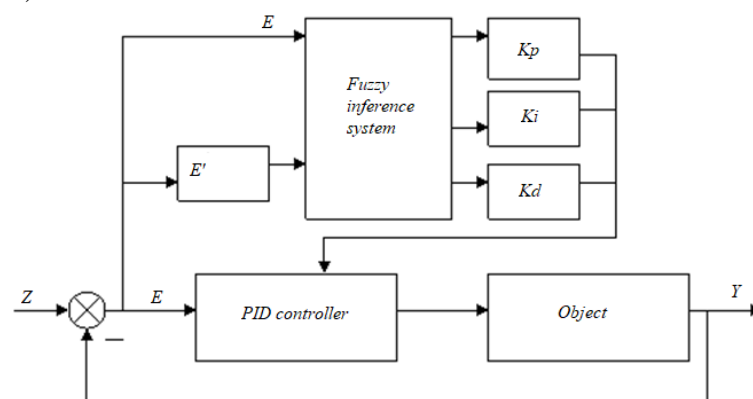


Figure 2. Structure of the PID controller with the automatic tuning unit based on fuzzy logic where E - error; E' - error derivative; T - task; V - output value; Kp , Ti , Kd - PID controller settings.

In order to exclude self-oscillations and ensure a smooth increase in the speed of carriage movement, the system of insensitivity of the angle sensor is introduced into the system - τ - hysteresis. Determine

the current error of the error for the current value from the angle sensor:

$$e(t) = \alpha_{av} - \tau, \quad (5)$$

where α_{av} is angle value measured by the angle sensor; τ - hysteresis.

Consequently, the mathematical model of the PID controller of carriage movement is as follows:

$$Wm(t) = Kp \cdot (\alpha_{av} - \tau) + Ki \cdot \int_0^{\tau} (\alpha_{av} - \tau) dt + Kd \frac{d(\alpha_{av} - \tau)}{dt} \quad (6)$$

Moreover, the controller of the internal circuit influences the controller of the external circuit about the output signal with its integral component, thereby ensuring the shock-free operation of the external controller at the moment when the auxiliary parameter of the cable inclination angle enters the dead zone and the precise adjustment of the control action to the load value of the object.

Then, the parametric equation of the main control loop is as follows:

$$P_T(t) = Wm(t) + Ki \cdot \int_0^{\tau} (\alpha_{av} - \tau) dt \quad (7)$$

The program implementation based on the calculations given above has been realized. It allows solving all these tasks and to carrying out information and software-instrumental support for the preparation and conduct of LTK tests applying WCCA. This technical solution provides testing of physical characteristics of LTK and methods for analyzing the logic of its operation under constant monitoring. It represents information about the real state of the equipment [8-10].

The developed software is implemented into the hardware and software complex developed to perform LTK tests using WCCS. The introduction and development of these kind systems ensure compliance with the current world level of the technology of conducting ground-experimental development (GED) of LTK. It contributes to the competitiveness of home LTK.

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