ТЕХНІЧНІ НАУКИ

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IMPROVEMENT OF THE NAVIGATION DEVICES CHARACTERISTICS BY ALGORITHMIC METHOD

Introduction. The navigation devices based on fiber-optic gyroscopes (FOG) and pendulum accelerometers (PA) for use in aircraft and spacecraft control systems of different types are developed at the Research and Production Enterprise (RPE) HARTRON-ARKOS LTD (Kharkiv, Ukraine). The integrated universal navigation complex (UNC) is one such device. Fiber-optic gyroscopes become a serious alternative to mechanical, laser and other gyros. They have rather high accuracy of measurements, relatively small dimensions, mass, energy consumption and low readiness time [1]. That is what determined their use in the UNC.

The goal of development. The basic set of UNC consists of an inertial measuring unit (IMU) and a navigation computer connected with the equipment of the consumer of the satellite navigation system. In navigation computer the additional links on-board computer control system are provided. The IMU consists of three FOGs and three PAs, which operate in the mode of measurements of angle and speed, accordingly. FOG and accelerometers are installed on the base platform in accordance with the orthogonal scheme.

The basic principle of functioning the UNC is the principle of a strapdown inertial navigation system, adjusted by external information sensors. The goal is to create an accurate universal navigation device with stable precise characteristics that do not depend on the temperature of the environment and other factors, while the characteristics of these sensors are closer to the middle class precision sensors.

The applying FOG as an angular velocity meter has put a number of new tasks to the developers. The main ones are the problems of studying the influence of temperature, including the PA, the magnetic field and radiation, on the error of measurement of the FOG, as well as the question of improving the technology of testing and methodology for determining the technical characteristics, the development of mathematical models [2].

To achieve the above-mentioned goal, the following tasks were set:

– study of the heat sensitivity of FOG and PA and the construction of a mathematical models of sensors temperature error;

– carrying out calibration works to determine the systematic errors of the FOG and PA, which are independent of the temperature factor, and technological errors in the manufacture of the IMU;

– assessment of the effectiveness of the developed methodology to achieve the exact characteristics of the device.

Solving set tasks. The step-by-step solution of the above-mentioned tasks is the technology of creating an integrated UNC based on a free-form inertial navigation system on FOG and PA.

It should be specially noted the follows. The enterprise has created technology of conducting thermal tests of separate sensors (FOG, PA) and technology of thermal testing of the device as a whole. Approximate polynomial mathematical models of thermal errors of FOG and PA (bias of zero, and scale factors) were constructed. These models allowed algorithmically compensate the thermal errors of sensors in the UNC. This ensured the stability of the exact characteristics of the device [3; 4].

Mathematical model of thermal FOG drift:

$$W_T(T,G,t) = K_0^W + K_1^W T_{FOG}(t) + K_2^W G_{FOG}(t) + K_3^W T_{FOG}(t) G_{FOG}(t) + \\ + K_4^W G_{FOG}^2(t) + K_5^W T_{FOG}(t) G^2_{FOG_{FOG}^2}(t) + K_6^W G_{FOG}^3(t).$$

Mathematical model of thermal PA errors:

$$\tau_T(T,\ t) = K_0^\tau + K_1^\tau T_{PA}(t) + K_2^\tau T_{PA}^2(t),$$

$$K_T(T,\ t) = K_0^K + K_1^K T_{PA}(t) + K_2^K T_{PA}^2(t) + K_3^K T_{PA}^3(t),$$

where $K_i^W,\ K_j^\tau,\ K_k^K\ \ (i, j, k = 0, 1, 2, ...)$ – the parameters of mathematical models of thermal FOG drift, bias of zero and error of scale PA coefficients; $T_{FOG}(t),\ G_{FOG}(t),\ T_{PA}(t)$ – centered and normalized temperature and sensors temperature gradient.

The FOG of this party has small errors due to temperature changes of the device. The developer of FOG provides compensation for its programmatic errors in the controller of the most sensitive element. However, software in the computer of the UNC in the absence of such temperature self-compensating FOG allows its temperature compensation. Thermal tests require a lot of time. For its reduction, software was developed that allows automation of tests on the ACUTRONIC stand and to carry them out continuously for 63 hours. On graphs Fig. 1 are the output signals of the PA during their thermal tests in the UNC when the ambient temperature changes in the range -40 ... +50°C and the base temperature +10°C. From the graphs shown in Fig. 1, it can be seen that PAs have a marked thermal sensitivity.

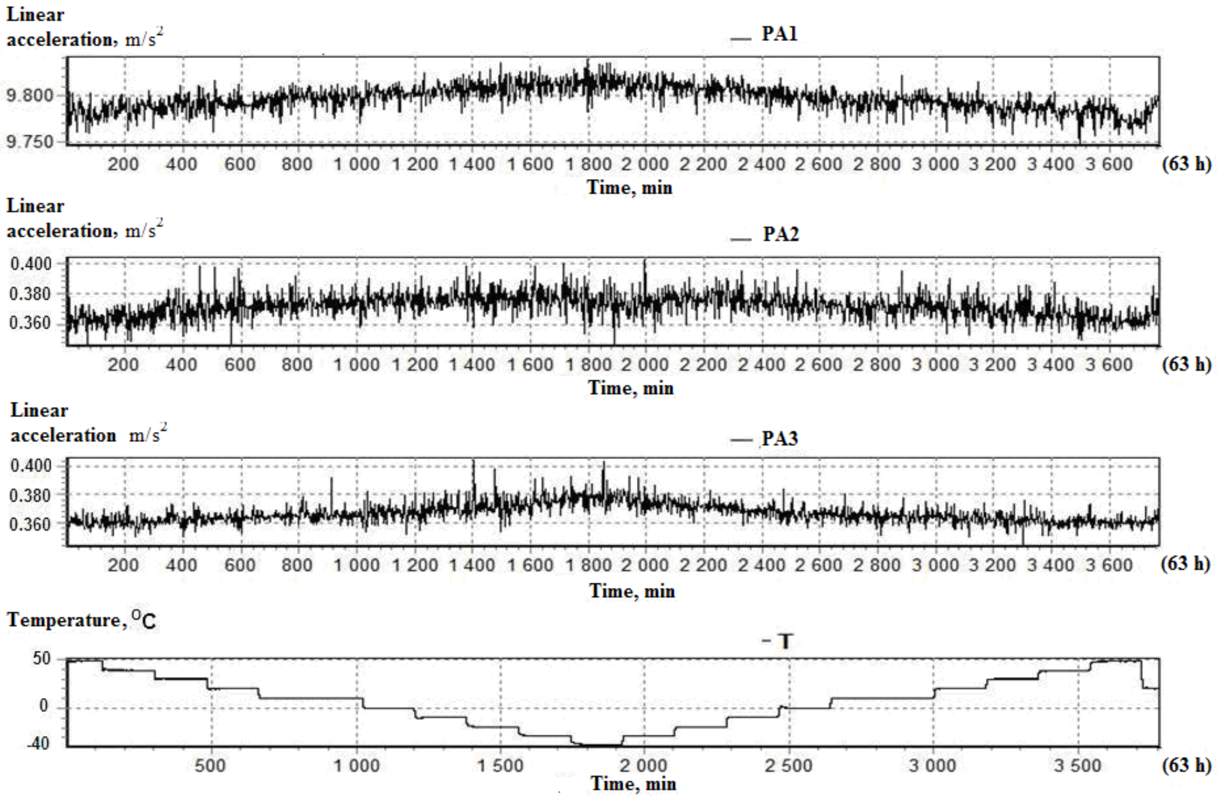

Fig. 1. Measurement of PA as the part of the UNC

When carrying out the calibration of the device, the systematic errors of the sensors at the base temperature are determined:

– bias of zero FOG and PA;

– errors of scale factors;

– angles of actual orientation of the sensitivity axes of the FOG and PA after placement of them in the construct of the IMU.

The method of calibration is based on the direct measurements of the sensors and their comparison with the reference values. For the implementation of the method, the following data is required: measurement of sensors; value of the azimuth of the angle of the device; the value of the latitude of the place; reference value of the angular velocity of the platform for each gauge turn; reference value of the measured angle of the platform turn. The conditions for conducting experiments are as follows: horizontality of the axes of the IMU; absence of precession of the axis of rotation; high accuracy of the original exhibition of the IMU axes; high accuracy of fixing the time to reach the measured angle of the platform turn [4].

After calibration of the UNC and taking into account the systematic values of temperature compensation, an array of formular parameters that correspond to this device was formed. The key in evaluating the results of experimental research of the device is the conclusion that the random variances correspond to the range and the side from the design values. As a result of the research, the main characteristics of the UNC were obtained [4; 5].

Conclusions. In the RPE HARTRON-ARKOS LTD the technology for the creation of integrated navigation devices based on the FOG and PA for use in the control systems of aircraft of various types was developed.

The research have shown that the navigation device – a universal navigation complex created with this technology – integrates with the satellite navigation system as well as in the autonomous inertial modes, provides characteristics that meet the requirements for modern control systems for rocket carriers, objects of aviation technic, unmanned aerial vehicles of medium and heavy class.

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