УДК 531.383

METHOD OF DETERMINING THE POSITION OF THE GEOGRAPHIC MERIDIAN THREEFOLD PENDULUM GYROCOMPASS DURING NATURAL STOP ITS ROTOR

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A method for determining the position of the geographic meridian three-stage pendulum gyrocompass during the process of natural stop its rotor. An algorithm identifying the initial position of the rotor axis, which are based on the properties of the motion differential equation gyrocompass and the equation itself. The results of the simulation of the corresponding algorithm of information processing. These advantages of the proposed method is compared to traditional.
Keywords: geographic meridian, three-stage pendulum gyrocompass, a natural process stops the rotor, identifying the initial position of the rotor axis.

Formulation of the problem. In carrying out geodetic, topographic, marksheyderskih and other activities connected with the definition of reference direction relative to the Earth, is a topical issue of increasing accuracy and reducing the time spent on carrying out one measurement. This article discusses how to determine the direction geographic meridian ground threefold pendulum gyrocompass with torsion suspension unmanaged sensor equipped with high-precision digital sensor azimuth angle position sensor and processing unit. During data processing indirect method is used to obtain data on the initial deviation of dynamic systems.

Analysis of recent achievements and publications. In the process of improving the device revealed that a further increase in accuracy is due to the need to consider the following factors. During the measurement around the vertical axis of the sensor operates a permanent uncontrolled moment due to operational reasons, different from meas-

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urement to measurement. This shifts the center point of the azimuthal oscillation sensor, which, in accordance with the procedure identified azimuth northerly direction, a constant value. For the self-compensation of this error have been proposed several methods, based on measurements of different but fixed device parameters. However, these measures are more than twice lengthened measurement process.

The article [2] proposed to determine the geographical position of the meridian based on the analysis of the azimuthal motion sensor gyro during ramp-up of its rotor. The proposal brings a double win in the issue of reducing the measurement time: firstly, the rotor acceleration mode becomes the «staff» rather than ballast operation mode gyro, as it was before; secondly, there is no need for special measures to combat the harmful vertical moments, since the displacement of the equilibrium position, due to the action of the latter, is variable in time, which allows to determine the value of harmful torque during one measurement.

In [3] is the next step in determining the geographic meridian plane threefold pendulum gyrocompass mode changes the speed of rotation of its rotor. We consider the work gyro mode when before the measurement process it instantly rotor (Pulse, for example, with the help of the cutter) reported nominal angular velocity of rotation, after which it is given to itself and its rotational speed is reduced in a natural way – by law exponent.

The purpose of the article. The aim is to build an information processing algorithms on the movement of three-stage pendulum gyrocompass mode in the natural stop its rotor.

Main part. The equations of motion of the device is stationary relative to the base of the Earth, taking into account the current around the vertical axis of the sensor harmful uncontrolled moment M = const, have the form:

$$H\dot{\alpha} + HU_{\Gamma}\beta + mgl\beta + HU_{в} = 0$$

$$H\dot{\beta} + \dot{H}\beta - HU_{г}\alpha = M, \qquad (1)$$

где H – the angular momentum of the gyroscope,

$U_Г$ and $U_в$ – the horizontal and vertical components of the Earth's angular velocity at the point of measurement

α and β – the current angle of the rotor axis gyro deviations from the meridian and the plane of the horizon, respectively,

mgl – pendulum gyrocompass.

The system of equations (1) in the case of a reduction of the angular momentum according to the law:

$$H = H_m e^{-\lambda t}, \ (3)$$

where H_m – the maximum angular momentum, λ – an indicator of decay exponential function, t – the current time $t = \lambda^{-1} ln(H_m \cdot H^{-1}) = \lambda^{-1} ln(e^{\lambda t})$ taking into $В = mgl \cdot {H_m}^{-2}$,, account and refer to the equation of motion is given by the azimuthal coordinate α type

$$\ddot{\alpha} - 2\lambda\dot{\alpha} + U_{г} mglH_m{}^{-1} e^{\lambda t} \cdot \alpha = 2\lambda U_{в} - M \cdot Be^{2\lambda t}. \ (4)$$

By introducing a new independent variable

$$z = 2\lambda^{-1}\sqrt{U_{г} H_m^{-1} mgle^{\lambda t}},$$

and denoting $Д = 8U_в \lambda^{-1}$; $A = 0.25\lambda^2 H_m^2 U_г^{-2}(mgl)^{-2}$, a derivative of the unknown function on the new independent variable through α' and α'', the equation (4) can be written as

$$Д = 8U_в \lambda^{-1}; \quad A = 0.25\lambda^2 H_m^2 U_г^{-2}(mgl)^{-2},$$

$$z^2\alpha'' - 3z\alpha' + z^2\alpha = \mathcal{D} - BAz^4 \cdot M \qquad (5)$$

The homogeneous equation corresponding to (5), is a special case of the Bessel equation and has a solution [4]:

$$\alpha = C_1 z^2 I_2(z) + C_2 z^2 Y_2(z),$$

where C_1 и C_2 – arbitrary constants, $I_2(z)$ and $Y_2(z)$ – Bessel functions of the second order of the first and second kind, respectively.

With the notation

$$\int_0^z z^{-3}\, Y_2(z)dz = F(z); \qquad \int_0^z z^{-3}\, I_2(z)dz = E(z),,$$

Equation (5) has a solution

$$\alpha = [\alpha_0 + (z_0^2+4)BAM]\frac{\pi z^2}{2z_0}[Y_1(z_0)I_2(z) - I_1(z_0)Y_2(z)] +$$
$$+\left[\frac{\lambda}{4U_г}\left(\frac{U_в H_m}{mgl} + \beta_0\right) + BAM\right]\cdot \pi z^2[Y_2(z_0)I_2(z) - I_2(z_0)Y_2(z)] - BAM(z^2+4) + \qquad (6)$$
$$+\frac{\pi\mathcal{D}}{2}z^2\{Y_2(z)[E(z) - E(z_0)] - I_2(z)[F(z) - F(z_0)]\}$$

As seen from the equation (6), in the last two brackets integral with the recorded limits of integration and z:

$$\int_{z_0}^{z} z^{-3}\, Y_2(z)dz = F(z_0,z); \ \int_{z_0}^{z} z^{-3}\, I_2(z)dz = E(z_0,z); \ (7)$$

Taking into account the expressions (7) and introduced below the designations for the known functions of the parameter z

$$f_1(z) = \frac{\pi z^2}{2z_0}[Y_1(z_0)I_2(z) - I_1(z_0)Y_2(z)] - 1;$$

$$f_2(z) = 0.25\lambda U_г^{-1}\pi z^2[Y_2(z_0)I_2(z) - I_2(z_0)Y_2(z)]$$

$$f_3(z) = BA\{(z_0^2+4)\frac{\pi z^2}{2z_0}[Y_1(z_0)I_2(z) - I_1(z_0)Y_2(z)] +$$
$$+\pi z^2[Y_2(z_0)I_2(z) - I_2(z_0)Y_2(z)] - (z^2+4)\}$$

$$f_4(z) = \alpha - \alpha_0 - \frac{\pi D}{2}z^2[Y_2(z)E(z_0,z) - I_2(z)F(z_0,z)] -$$
$$-\ 0.25\lambda U_г^{-1} U_в H_m (mgl)^{-1}\pi z^2[Y_2(z_0)I_2(z) - I_2(z_0)Y_2(z)]$$

can be written

$$f_4 = \alpha_0 f_1 + \beta_0 f_2 + M f_3. \qquad (8)$$

Picture 1 shows a graph of the angular momentum from time to time in accordance with (3) the following numerical data: H_m = 1 N*m*s; λ = 1.068*10⁻³, rad/s, and Figure 2 is a graph of the corresponding azimuthal motion sensing element at a time $U_г$ = 3.65*10⁻⁵ rad/s; $U_в$ = 6.32*10⁻⁵, rad/s, which corresponds to the latitude of 60°, mgl=4.1, N*m; M = 7*10⁻⁷, N*m; $\dot{\alpha}$ = 0; α_0= П/180, rad.

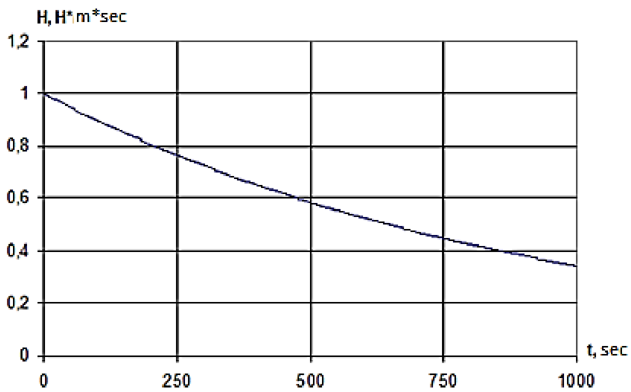

Fig. 1. Schedule changes in the angular momentum of the law of time $H=H_m e^{-\lambda t}$.

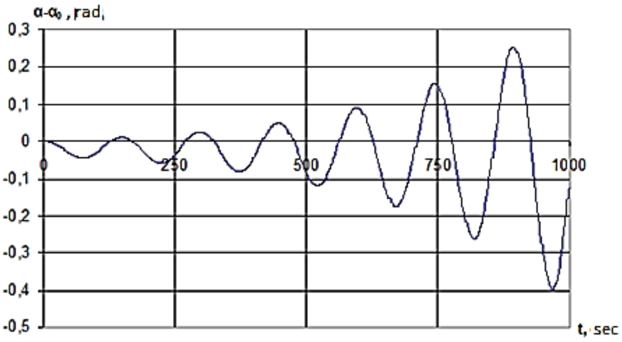

Fig. 2. Schedule changes azimuthal coordinates of the time when you change the angular momentum by law

Making changes in the discrete time points can, using the processing information, such as the least squares method in its analytic form, to find the best estimate, unknown from the system

$$\begin{aligned}
&\hat{\alpha}_0\sum_{i=1}^{n}(f_{1i}f_{1i})+\hat{\beta}_0\sum_{i=1}^{n}(f_{1i}f_{2i})+\hat{M}_0\sum_{i=1}^{n}(f_{1i}f_{3i})=\sum_{i=1}^{n}(f_{1i}f_{4i}),\\
&\hat{\alpha}_0\sum_{i=1}^{n}(f_{1i}f_{2i})+\hat{\beta}_0\sum_{i=1}^{n}(f_{2i}f_{2i})+\hat{M}_0\sum_{i=1}^{n}(f_{2i}f_{3i})=\sum_{i=1}^{n}(f_{2i}f_{4i}),\quad (9)\\
&\hat{\alpha}_0\sum_{i=1}^{n}(f_{1i}f_{3i})+\hat{\beta}_0\sum_{i=1}^{n}(f_{3i}f_{2i})+\hat{M}_0\sum_{i=1}^{n}(f_{3i}f_{3i})=\sum_{i=1}^{n}(f_{3i}f_{4i}).
\end{aligned}$$

Evaluation provides clear information on the status of the plane of the geographic meridian.

If the analytical solution of the equation of motion can not be represented by a linear combination of the unknown, to find them you can use an algorithm based on the actual characteristics of the differential equations of motion gyrocompass [5]. The scheme for obtaining solutions in this case is shown in Figure 3.

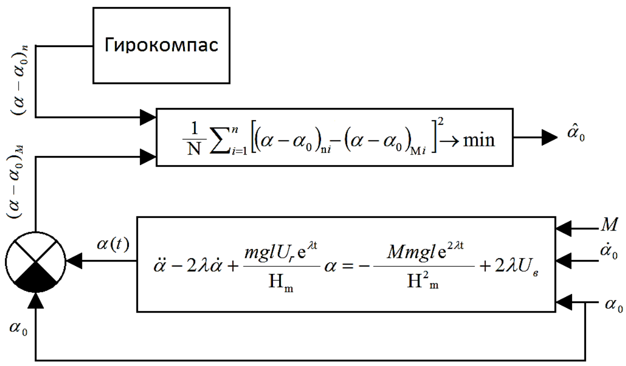

Fig. 3. The scheme of calculating the «best» assessment of initial position gyro axis with exponential «freewheel» rotor

According to this scheme, resulting from the gyro array of information about the azimuthal motion sensor in the «coasting» of the rotor is compared with the result of the integration of the differential equations of motion of the device, produced for arbitrary but permissible in terms of the operation of the unit, the initial conditions and perturbations. It then computes the sum of the squares of the differences of the real instrument readings and machine model (called the sum «residuals» squares), reduced to one dimension, and implemented search engine minimum of this amount. Rank, corresponding to the minimum sum of squares «residual» and is the «best» estimate of the initial position of the axis gyro.

With computer simulation algorithm block «gyrocompass» in Figure 3 has been replaced by a block of integration of the differential equation (4), to the output of the random noise is added a predetermined intensity. Driving machine experiment is shown in Figure 4.

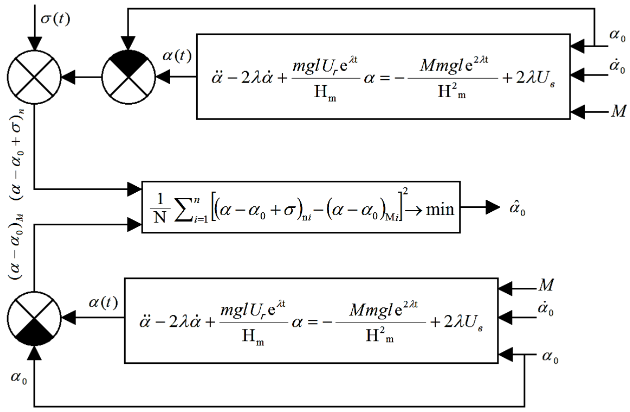

Fig. 4. The scheme of computer experiment

Computer modeling of the proposed algorithm for determining the meridian confirmed its efficiency. Figure 5 shows the estimation error of the initial position of the rotor axis gyro from the time of collection of information for different values of the intensity of the «noise» measurement.

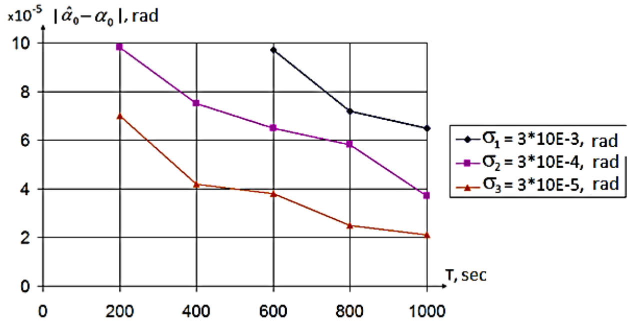

Fig. 5. The dependence of the estimation error of the initial position of the gyro axis of observation time

Conclusions. In the article the technique [6] determining the position of the geographic meridian threefold pendulum gyrocompass based on an analysis of the azimuthal motion sensor mode exponential overrun its rotor. The scheme of identifying the «best» assessment of the initial position of the rotor axis gyro, which is based on the properties of differential equations of motion of the device.

Assuming that after the acceleration pulse gyro rotor to rated speed is no need for a mechanical connection between the housing and the gyro sensor, the proposed method has two significant advantages compared to the methods applied until now:

– An opportunity to «non-contact» hanging the sensor, which greatly reduce the level of disturbances transmitted from the gyrocompass housing on the sensing element, and as a consequence – increase the accuracy of measurements;

– As a gyro sensor can use a device whose rotor and stator do not carry electrical coils that greatly reduce the cost of the device.

Further studies that improve the use of this technique, there may be in the direction of algorithmic accounting and other compensation (except DC) types of uncontrolled moments that arise during the operation of the gyrocompass.

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МЕТОДИКА ВИЗНАЧЕННЯ ПОЛОЖЕННЯ ГЕОГРАФІЧНОГО МЕРИДІАНА ТРИСТУПЕНЕВИМ МАЯТНИКОВИМ ГІРОКОМПАСОМ ПІД ЧАС НАТУРАЛЬНОЇ ЗУПИНКИ ЙОГО РОТОРА

Анотація
Запропоновано метод визначення положення географічного меридіана триступеневим маятниковим гірокомпасом в процесі природної зупинки його ротора. Отримані алгоритми ідентифікації початкового положення вісі ротора, в основу яких покладені як властивості рішень диференційних рівнянь руху гірокомпаса, так і саме рівняння. Розглянуті результати моделювання відповідних алгоритмів обробки інформації. Показані переваги запропонованої методики у порівнянні з традиційними.
Ключові слова: географічний меридіан, триступеневий маятниковий гірокомпас, природний процес зупинки ротора, ідентифікація початкового положення вісі ротора.

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МЕТОДИКА ОПРЕДЕЛЕНИЯ ПОЛОЖЕНИЯ ГЕОГРАФИЧЕСКОГО МЕРИДИАНА ТРЕХСТЕПЕННЫМ МАЯТНИКОВЫМ ГИРОКОМПАСОМ ВО ВРЕМЯ ЕСТЕСТВЕННОЙ ОСТАНОВКИ ЕГО РОТОРА

Аннотация
Предложен метод определения положения географического меридиана трехстепенным маятниковым гирокомпасом во время процесса естественной остановки его ротора. Получены алгоритмы идентификации начального положения оси ротора, в основу которых положены как свойства решений дифференциального уравнения движения гирокомпаса, так и само уравнение. Рассмотрены результаты моделирования соответствующих алгоритмов обработки информации, Указаны преимущества предложенной методики по сравнению с традиционными.
Ключевые слова: географический меридиан, трехстепенной маятниковый гирокомпас, процесс естественной остановки ротора, идентификация начального положения оси ротора.