FIBER-OPTICAL GYROCOMPASS BASED ON STRAPDOWN INERTIAL SYSTEM OF ORIENTATION AND NAVIGATION*

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Abstract

Key words: gyrocompass, algorithm, Schuler condition, error, drift

The analyse of state of problem is done, also is showed that the considerating gyrocompass has the precissional composition for strapdown inertial system of orientation and navigation. The approach to the forming of algorithms of functioning is considerated, the results of mathematical modeling of GC FOG composing the known FOG and accelerometers are done too.

Purpose

Today some firms make the gyrocompass based on triad FOG (GC FOG), composing SISON which, as usually, has three components meter of specific force, board computer, interface and others devices. The gyrocompass Octans (France), KVH Industries (USA), SFIM Industries (Deutschland, GmbH), gyrohorizoncompass (ЦНИИ «Электроприбор», Россия) and others [1-3] placed on hydrographic and other ships compose the same system. In this work are stated the results of studies by creation of gyrocompass having the instrumental structure, analogous to the structure of higher indicated systems, but by technical and economical characteristics no yielding to them. As the errors of elements and also of algorithms of functioning, the calculated errors and the moving of vehicle influence on the precision of GC FOG, the forming of algorithms of functioning and its parameters has an important significance for the descent of errors of GC FOG.

Solution of problem

The theory of strapdown inertial navigation systems [4] and the theory of one variety of strapdown inertial system of orientation present the base of solution of problem of construction of algorithms of functioning of GC FOG.

The combination of the principle of computer modeling of place vertical with the using of conditions of Schuler undisturb to the action of horizonal absolute accelerations [4-7] with simultaneous execution of conditions of one from horizontal axes of modeling in board computer (BC) of triad with north direction has allowed to realize in BC the model of gyrohorizoncompass. Let's note that this system is intended for the application on vehicle with limited angles of pitch, that's why in quality of algorithms are adopted the kinematic Euler equations with members of horizontal and azimuthal correction including in them. The quaternion algorithms with members of horizontal and azimuthal correction including in them are considerated in comparative plan. The algorithms with correction members including in them have the feedback connections in contrast to the known disconnecting algorithms that's why they have the asymptotic stability and the limitation of errors. The trigonometrical algorithms of initial align, guaranting the autonomity of its realization in connection with the using of signals of only inertial sensors present the special group.

The varieties and parameters of horizontal and azimuthal correction, its switching in different regimes of moving of vehicle, (the initial align, the working regime) are determined, also are applying Schuler conditions guaranting the invariance of GC FOG to the action vehicle accelerations. In particular, is done the comparative analyze of algorithms corresponding both to the direction gyroscope and to the gyrocompass. The both types of algorithms are characterised by the same structure by two axes of horizontal correction [5] and are differed only by types of azimuthal correction. In direction gyroscope which doesn't possess the selectivity to the north direction, is allowed one from varieties of angular rate of azimuthal correction as $\omega_{\zeta 2}^{K}$:

$$\omega_{\zeta 2}^{K} = -U \cdot \sin\varphi - \frac{\upsilon_{\zeta 3}}{R} tg\varphi,$$

where U, R, φ - angular rate of rotation and radius of Earth and also the latitude of place; $\upsilon_{\zeta 3}$ - eastern component of relative speed of vehicle. The regime of gyrocompass was guaranteed by including of open scheme of correction course $\Delta\psi_C$ in exit signal, analogously to [8]:

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$$tg\Delta\psi_C = \omega_{\zeta 3} / \omega_{\zeta 1},$$

where $\omega_{\zeta 1}$, $\omega_{\zeta 3}$ - northern and eastern components of angular rate of horizontal trihedron determined by correction of angular rate.

The realization of system is reached by application of FOG's model ПНСК 40-002 of own development of firm "Optolink" having the angular rate of drift in order 0,02% and the upper limit of measuring $10\,^{\circ}/_{s}$ of accelerometers type KCA-100 or AK-6. The mathematical modeling of functioning of GC FOG installed on vehicle doing the angular and progressive movements has showed:

- error by course angle with the using of FOG type ПНСК-40-002 and accelerometers type KCA-100 has composed 9 angular minutes after 5,5 hours of unbroken work (in KCA-100 – shift of zero 10^{-2} m/s^2, error of scale factor 0,01%);
- error of course angle has composed 1,8 angle degree under the using of accelerometers type Analog-Devices (zero shift 0,28 m/s^2, error of scale factor 0,2%) instead of accelerometers KCA-100. Error in the determination of course has reduced to 0,6 angle degree after 5,5 hours of work under the temperature stabilization.

The time of initial align of GC FOG composes the value 200 sec, what is compared with the time of align in french gyrocompass Octans.

Reference

1. **Пешехонов В.Г., Несенюк А.И., Старосельцев Л.П., Багенов Б.А., Буравлев А.С.** Гирогоризонткомпас на волоконно-оптических гироскопах с вращением блоков чувствительных элементов // Гироскопия и навигация. - 2002. -№1(36). -С. 52-63.
2. **SR 2100** Fiber Optic Gyrocompass & Attitude Reference System. KVH Industries. 2002.
3. **T. Gaiffe, Y. Cottreau, N. Faussot, P. Simonpietri, H. Lefevre, H. Ardity.** Marine fiber optic gyrocompass with integral motion sensor, Symposium Gyro Technology. 1999, Stutgart, p.p. 15.0-15.7.
4. **Strapdown** Inertial Navigation Technology. D.H. Titterton & J.L. Weston. Peter Peregrinus Ltd, London, 1997, 455 p.
5. **Плотников П.К.** Элементы теории работы одной разновидности бесплатформенных инерциальных систем ориентации // Гироскопия и навигация. -1999. -№4. -С. 23-24.
6. **Анучин О.Н., Емельянцев Г.И.** Интегрированные системы ориентации и навигации для морских подвижных объектов. – СПб; ЦНИИ «Электроприбор», 1999. -357 с.
7. **Дмитриев С.П.** Инерциальные методы в инженерной геодезии. –СПб; ЦНИИ «Электроприбор», 1997, -209 с.
8. **Патент** РФ №2167716. Способ выработки навигационных параметров. Автор В.А. Беленький, 2001.