Global Journal of Engineering and Technology [GJET].
ISSN: **2583-3359** (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjet-home/

AUTONOMOUS REDUCED GYRO PLATFORM DRIFT IDENTIFIER

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Article History

Received: 29/05/2023
Accepted: 06/05/2023
Published: 08/05/2023

Vol –2 Issue – 5

PP: - 01-04

Abstract
The article considers a method of learning the asymptomatic identifier (observation) of the drift-gyro platform with the minimum order using the internal generalized measurement information. The conditions for the asymptomatic stability of the identification process are determined and the structure of the perturbed identifier matrices is established. A simulation given shows the effectiveness in use of the identifier for estimating and compensating for the drift of the gyronamform while it is operating under the conditions of the action of uncertain (off-design) disturbances.

Keywords: *Gyro, Drift Identifier, Measuring system, Kalman filter, High-dimensional filtering algorithms*

1. Introduction

The accuracy of the angular stabilization of the gyronamform depends significantly on the nature and the level of air moments acting on the platforms and gyroscopes in the operating conditions of moving objects. High stabilization accuracy is ensured by the development of appropriate design and technological measures and the use of various methods of algorithmic compensation for the influence of disturbing moments. At the same time, significant efforts are spent on compensating for the influence of constant and slowly changing component moments relative to the gyroscopes' precession axes, which ultimately lead to errors in object control.

Algorithmic compensation is based on various methods of determining the expected drift of the gyronamform under operating conditions. The implementation of these methods, as a rule, is associated with the use of a priori information about the nature and the level of uncertain disturbances. Several available statistical methods of identification (estimation) have been applied gyroscopy to deal with this problem. However, the effectiveness of those applications largely depends on the ability to receive adequate information on the operating disturbances in the models of measuring systems. Furthermore, the implementation of identification algorithms is so complex. When using statistical methods for identifying system states (for example, optimal Kalman filter method and its modifications), there are some difficulties arise in obtaining static characteristics of the disturbances occurring during operation, including their complex modelings, the inconveniences associated with the formation of a measuring system and high-dimensional filtering algorithms

2. Autonomous measuring system based on a gyrostabilizer

We are more interested in the possibilities of developing simpler algorithms which can autonomously identify the gyroplatform drift operating under the conditions of the action of disturbances occuring with indefinite (off-design) characteristics. Indeed, under real operating conditions, the statistical characteristics of uncertain disturbances and their levels cannot always be reliably determined. Moreover, it is usually possible that some kinds of disturbances may not have obvious statistical properties, for example, when operating under difficult conditions in relationship with short time intervals. In these cases, the appearance of an additional (off-design) gyro platform drift should be considered. In fact, the possibility of using state identifiers for estimating such kind of drift by autonomous means (i.e., using only the current internal information of the output signals measured in the gyro platform stabilization system) has not yet been sufficiently studied.

There is a known method for constructing a state identifier based on the wave representation of uncertain disturbances, which does not require knowledge of their statistical characteristics. However, in this case, to model the disturbances, it is necessary to experimentally determine the

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form of the basis functions, which additionally leads to an increase in the dimension of the problem.

In article [5] an attempt is made to use the autonomous asymptotic identifier (observer) of the states to estimate the drift of the gyro platform under the action of stepwise and slowly changing moments. The possibility of estimating the drift with an acceptable accuracy for one of the channels of the stabilization system is shown. The difficulty in constructing the identifier consisted in the choice of its optimal parameters, which simultaneously provide a high estimation accuracy and an acceptable quality of the identification process with a high dimension of the problem.

As studies have shown, these difficulties can be overcome by building a modified identification system of the minimum dimensions. When developing a model of an autonomous measuring system based on a gyrostabilizer, we proceed from the possibility of using information about the nature of the motion of gyroscopes relative to the axis of precession. In order to simplify the problem, from the stabilization system of a triaxial gyro stabilizer with a classical (orthogonal) arrangement of gyroscopes on the platform, we will single out two interconnected (in terms of gyroscopic moment) channels (P and B), independent of the third channel.

The dimensions of the measuring system in this case can be reduced as much as possible if the order of its equations of state is made equal to two. For this purpose, we first transform the initial equations of moments with respect to the axes of stabilization and the procession and then represent them in the following vector-matrix form:

$$\dot{\omega} = A_{11}\omega + m_\alpha + I_\alpha M_\alpha \quad (1)$$

$$\dot{\omega} = B_{11}\omega - m_\beta + I_\beta M_\beta \quad (2)$$

with

$$\omega = \begin{bmatrix}\omega_P\\ \omega_B\end{bmatrix};$$

$$A_{11} = \begin{bmatrix}0 & H_P I_X^{-1}\\ -H_B I_Y^{-1} & 0\end{bmatrix};$$

$$B_{11} = \begin{bmatrix}0 & H_B I_B^{-1}\\ -H_P I_P^{-1} & 0\end{bmatrix};$$

$$I_\alpha = \begin{bmatrix}I_X^{-1} & 0\\ 0 & I_Y^{-1}\end{bmatrix};$$

$$I_\beta = \begin{bmatrix}0 & I_B^{-1}\\ I_P^{-1} & 0\end{bmatrix};$$

$$M_\alpha = \begin{bmatrix}M_{\alpha P}\\ M_{\alpha B}\end{bmatrix};$$

$$M_\beta = \begin{bmatrix}M_{\beta P}\\ M_{\beta B}\end{bmatrix};$$

$$m_\alpha = \begin{bmatrix}m_{\alpha P}\\ m_{\alpha B}\end{bmatrix}$$

$$m_\beta = \begin{bmatrix}m_{\beta P}\\ m_{\beta B}\end{bmatrix}$$

$$m_{\alpha P} = I_X^{-1}[\lambda_P K_{P1}\beta_p + (H_P + \lambda_P K_{P2})\dot{\beta}_P]$$

$$m_{\alpha B} = I_Y^{-1}[\lambda_B K_{B1}\beta_B + (-H_B + \lambda_B K_{B2})\dot{\beta}_B]$$

$$m_{\beta P} = \beta_P \ddot{+} d_P I_P^{-1} + C_P I_P^{-1}\beta_P$$

$$m_{\beta B} = \beta_B \ddot{+} d_B I_B^{-1} + C_B I_B^{-1}\beta_B$$

Here, ω_P, ω_B–angular velocities of the gyro platform drift.

β_P, β_B– gyro precession angles.

I_X, I_Y –moments of inertia of the platform relative to the stabilization axes.

I_P, I_B–the same gyroscopes relative to the axes of the procession.

H_P, H_B – kinetic moments of gyroscopes.

$M_{\alpha P}$, $M_{\alpha B}$–disturbing moments with respect to the stabilization axes.

$M_{\beta P}$, $M_{\beta B}$- the same with respect to the axes of the procession.

d_P, d_B–damping coefficients.

C_P, C_B–cruelty coefficients.

K_{P1}, K_{P2}, K_{B1}, K_{B2}–amplification factors of signals representing, respectively, the precession angles and their derivatives in the channels P и B;

λ_P, λ_B - overall gains for channels P and B, relative to.

The representation of the motion equations in the form of (1) and (2) makes easier to obtain a model of the measuring system and the drift identifier. Terms of m_α and $m_\beta$characterize a known part of the constituent moments acting on the platform and gyroscopes and depending on the parameters of the gyroscopes movement $(\beta, \dot{\beta}, \ddot{\beta})$. In principle, they can be determined from the results of measurements and used as measuring information when constructing the identifier. In what follows, without reducing the generality of the problem statement, we assume that the errors in determining these terms are insignificant.

From equ. (1) and (2), the equations of the measuring system are obtained in the following form

$$\begin{cases}\dot{\omega} = A_1\omega + 0{,}5(m_\alpha - m_\beta) + 0{,}5(I_\alpha M_\alpha + I_\beta m_\beta)\\ z = C_1\omega + (I_\alpha M_\alpha - I_\beta m_\beta)\end{cases}$$

Here, $z = -(m_\alpha + m_\beta)$; $A_1 = 0{,}5(A_{11} + B_{11})$; $C_1 = 0{,}5(A_{11} - B_{11})$.

These equations can be written in both the usual and standard forms

$$\dot{\omega} = A_1\omega + BU + GM_B \quad (3)$$

$$z = C_1\omega + DM_B \quad (4)$$

Here

$$U = [\dot{\beta}_P \quad \dot{\beta}_B \quad \beta_P \quad \beta_B]^T;$$

$$M_B = [M_{\alpha P} \quad M_{\alpha B} \quad M_{\beta P} \quad M_{\beta B}]^T;$$

$$B = \begin{bmatrix}b_{11} & b_{12} & b_{13} & b_{14}\\ b_{21} & b_{22} & b_{23} & b_{24}\end{bmatrix};$$

$$G = \begin{bmatrix}0{,}5I_x^{-1} & 0 & 0 & 0{,}5I_B^{-1}\\ 0 & 0{,}5I_Y^{-1} & 0{,}5I_P^{-1} & 0\end{bmatrix};$$

$$D = \begin{bmatrix}I_x^{-1} & 0 & 0 & -I_B^{-1}\\ 0 & I_Y^{-1} & -I_P^{-1} & 0\end{bmatrix};$$

$$b_{11} = 0{,}5\,(H_P + \lambda_P K_{P2})I_x^{-1};$$

$$b_{12} = -0{,}5 d_B I_B^{-1};\; b_{13} = 0{,}5\lambda_B K_{B1} I_x^{-1};$$

$$b_{14} = -0{,}5 C_B I_B^{-1};$$

$$b_{21} = -0{,}5 d_P I_P^{-1};$$

$$b_{22} = -0{,}5\,(H_B - \lambda_B K_{B2})I_Y^{-1};$$

$$b_{23} = -0{,}5 C_P I_P^{-1};$$

$$b_{24} = 0{,}5\lambda_B K_{B1} I_Y^{-1}$$

Vector z represents generalized measurement information (observation). Uncertain moments M_B and known controls U act at the inputs of the measuring system. Disturbances M_B

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are also directly included in the observations z. In the measuring system (3), (4), information on the second derivatives of the procession angles is not used, since it does not significantly affect the identification accuracy.

Before constructing the identifier, wedetermine the observability conditions of the measuring system. Anunperturbed systemin the form of $\begin{cases}\dot{\omega} = A_1\omega \\ z = C_1\omega\end{cases}$ can be fully observable if the rank of the observability matrix $N = \begin{bmatrix} C_1 \\ C_1A_1 \end{bmatrix}$ is equal to two. Indeed, for the usual relations for a gyrostabilizer $H_P=H_B=H$; $I_P=I_B$, $I_x \neq I_Y$ determinant of a matrix C_1 not equal to zero. Consequently, on the basis of the measuring system (3), (4), it is possible to construct an identifier (observer) that ensures the asymptotic stability of the identification process.

In our case, the equation of the reduced identifier takes the following form

$$\dot{\widehat{\omega}} = A\widehat{\omega} + BU + Kz \quad (5)$$

Here $\widehat{\omega}$ – vector of estimates of the gyro platform drift velocity;

K-identifier coefficient matrix $K = \begin{bmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{bmatrix}$;

$A=A_1-KC_1$

The identifier equation can be written in a more compact form

$$\dot{\widehat{\omega}} = A\widehat{\omega} + B_0U \quad (6)$$

$$B = \begin{bmatrix} b_{11}+c_{11} & b_{12}+c_{12} & b_{13}+c_{13} & b_{14}+c_{14} \\ b_{21}+c_{21} & b_{22}+c_{22} & b_{23}+c_{23} & b_{24}+c_{24} \end{bmatrix}$$

$c_{11} = k_{11}d_{11} + k_{12}d_{21}$,
$c_{12} = k_{11}d_{12} + k_{12}d_{22}$,
$c_{13} = k_{11}d_{13} + k_{12}d_{23}$,
$c_{14} = k_{11}d_{14} + k_{12}d_{24}$,
$c_{21} = k_{21}d_{11} + k_{22}d_{21}$,
$c_{22} = k_{21}d_{12} + k_{22}d_{22}$,
$c_{23} = k_{21}d_{13} + k_{22}d_{23}$,
$c_{24} = k_{21}d_{14} + k_{22}d_{24}$,
$d_{11} = -(H_P + \lambda_P K_{P2})I_X^{-1}$,
$d_{12} = -d_B I_B^{-1}$,
$d_{13} = -\lambda_P K_{P1} I_X^{-1}$,
$d_{14} = -C_B I_B^{-1}$,
$d_{21} = -d_P I_P^{-1}$,
$d_{22} = (H_B - \lambda_B K_{B2})I_Y^{-1}$,
$d_{23} = -C_P I_P^{-1}$, $d_{24} = -\lambda_B K_{B1} I_Y^{-1}$

Under the action of disturbing moments along the axes of stabilization and procession, the estimation will be carried out with errors $\overline{\omega} = \omega - \widehat{\omega}$ insofar as $\dot{\overline{\omega}} = \dot{\omega} - \dot{\widehat{\omega}}$ then taking into account (3) - (5), we can obtain the equation $\dot{\overline{\omega}} = A\overline{\omega} + D_0M_B$ for estimation errors, where

$$D_0 = \begin{bmatrix} (0.5-k_{11})I_X^{-1} & k_{21}I_Y^{-1} & k_{12}I_P^{-1} & (0.5+k_{11})I_B^{-1} \\ -k_{21}I_X^{-1} & (0.5-k_{22})I_Y^{-1} & (0.5+k_{22})I_P^{-1} & k_{21}I_B^{-1} \end{bmatrix}$$

If the elements of the mairitsa K are chosen so that the asymptotic stability of the identification process is ensured, then $\vec{\omega}^* \to 0$ and in steady state

The minimum order of the obtained reduced identifier makes it possible to analyze its properties by not only modeling on a computer, but also by establishing analytical dependencies. Small dimensions of matrix K and rather simple structure of matrices D_0 and $A^{-1}D_0$ facilitates the selection of optimal values of the coefficients k_{ij} identifier providing minimum (or practically acceptable) values of estimation errors $\vec{\omega}^*$, as well as acceptable quality of transients in the identifier.

In order to determine the relationship between the coefficients of the identifier and the parameters of the gyro platform, ensuring its stable operation, we find the conditions of asymptotic stability for the reduced identifier (6) with the matrix

$$A = \begin{bmatrix} a_1k_{12} & a_2 + a_3k_{11} \\ a_4 + a_5k_{22} & a_6k_{21} \end{bmatrix}$$

Here:

$a_1 = -(H_P I_P^{-1} - H_B I_Y^{-1})$,
$a_2 = 0.5(H_P I_X^{-1} + H_B I_B^{-1})$,
$a_3 = -(H_P I_X^{-1} - H_B I_B^{-1})$,
$a_4 = -0.5(H_P I_P^{-1} + H_B I_Y^{-1})$
$a_5 = -(H_P I_P^{-1} - H_B I_Y^{-1})$
$a_6 = -(H_P I_X^{-1} - H_B I_B^{-1})$

For asymptotic stability, it is necessary and sufficient that $(a_1k_{12}+a_6k_{21})<0$ and $[a_1a_6k_{12}k_{21}-(a_2+a_3k_{11})(a_4+a_5k_{22})]>0$ (7)

With the relations usual for the gyro platform between the design parameters from (7), it is easy to establish a simpler stability condition $k_{12}>k_{21}$

Based on the analysis of the matrix structure $A^{-1}D_0$ and the obtained ratios, as well as by joint computer simulation of the equations of motion of the gyro platform and the reduced identifier, the acceptable values of the identifier coefficients were determined, which ensure high accuracy in estimating the components of the gyro platform drift when simulating rather complex operating conditions. At the same time, it was found that one identifier can be most efficiently used to estimate the drift along only one of the two channels. Obviously, with the help of two identifiers with different settings of the coefficients, it is possible with high accuracy and simultaneously to estimate the drift of the gyro platform in two channels, as well as to construct an appropriate compensation system for the action of undefined disturbances.

Some of the simulation results related to the P channel are shown in Figures 1, and 2,3. Figures 1 and 2 show the perturbing moments set during the simulation along the stabilization axes of the gyro platform and the gyroscope procession. At the same time, simultaneously include constant, time-varying, and random components. The nature of these moments was chosen quite arbitrarily and had to simulate the situation with abrupt changes in perturbations acting on the gyro stabilizer that arose in real conditions. Figure 3 shows the estimation process in the situation of the gyro platform drift with the optimally selected identifier coefficients k_{11}=-0,5008, k_{12}=0, k_{21}=-0,2, k_{22}=-0,501; $H_P=H_B=H=500$[g.cm.s]. Analysis of the simulation results for various variants of the action of disturbing moments along the

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precession and stabilization axes shows that at identification time intervals of up to 100 s, the errors in estimating the gyro platform drift do not exceed 1%.

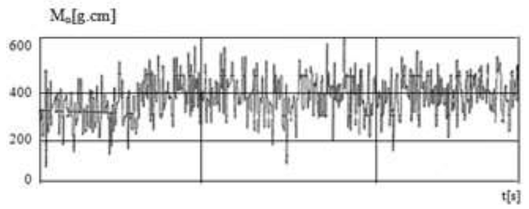

Figure 1. Disturbing moment about the stabilization axis

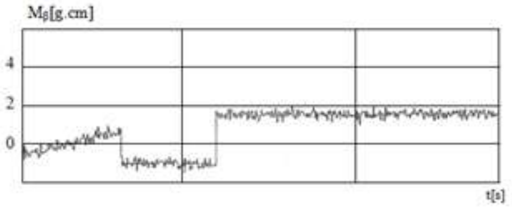

Figure 2. Pertubing moment about the axis gyro precessional

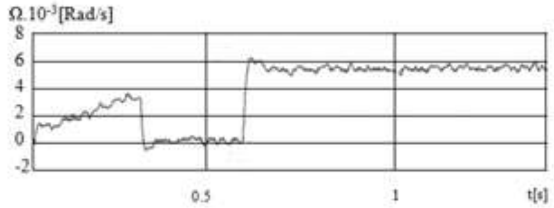

Figure 3. Gyro platform drift identification process

3. Conclusion

Thus, found the dependence of the dynamic priorities of each page on its relative importance, that is, on the number of new dangerous changes in the stress state, on the delay time in the presentation of the page on the screen, as well as on the expected degree of reliability of a structural element, or an a priori estimate of its safety margin.

The resulting dependence can be used to form examples of training a neural network that controls displaying pages during tests. The same network can be trained to recognize the stress plots of elements and diagnose failures during strength tests.

References

1. Basaca-Preciado, L.C.; Sergiyenko, O.Y.; Rodríguez-Quinonez, J.C.; Garcia, X.; Tyrsa, V.V.; Rivas-Lopez, M.; Hernandez-Balbuena, D.; Mercorelli, P.; Podrygalo, M.; Gurko, A.; et al. Optical 3D laser measurement system for navigation of autonomous mobile robot. Opt. Lasers Eng. 2014, 54, 159–169.
2. Garcia-Cruz, X.M.; Sergiyenko, O.Y.; Tyrsa, V.; Rivas-Lopez, M.; Hernandez-Balbuena, D.; Rodriguez-Quiñonez, J.C.; Basaca-Preciado, L.C.; Mercorelli, P. Optimization of 3D laser scanning speed by use of combined variable step. Opt. Lasers Eng. 2014.
3. Noureldin, A.; Karamat, T.B.; Georgy, J. Fundamentals of Inertial Navigation, Satellite-Based Positioning and their Integration; Springer: Berlin/Heidelberg, Germany, 2013.
4. Wang, X.; Xiao, L. Gyroscope-reduced inertial navigation system for flight vehicle motion estimation. Adv. Space Res. 2017, 59, 413–424
5. Groves, P.D. Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems; Artech House: Norwood, MA, USA, 2013; pp. 580–800

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