**"Gyroscopy and Navigation" №1 (32), 2001**

**CONTENTS**

|  |  |  |
| --- | --- | --- |
| **B.E.Landau, V.D.Aksenenko, S.S.Gurevich, S.M.Dyugurov, V.I.Zavgorodny, S.L.Levin, S.G.Romanenko, V.N.Tsvetkov** | **A gimballess attitude control system for a space vehicle on the basis of the electrostatic gyro with the solid rotor** | **3** |
| The outcomes and the state of the development of an electrostatic gyroscope (ESG) with a solid rotor and a gimballess attitude control system of a space vehicle are considered. Physical principles and design solutions which are fundamentals of the development and production of gimballess ESG are described. The main parameters of suspension systems of rotor, the run up of the rotor, the readout of the angular information, and also the changes of the parameters when applied on the Earth and in space are shown. The means of improvement of the gyro design are shown with the purpose of increase of the gyro accuracy and reliability.The model of gimballess electrostatic gyro drift under the effect of the conservative and nonconservative moments generated by different physical fields is analyzed. The interaction of unbalanced and nonspherical rotor with the electrical field of anisoelastic suspension, and also the influence of the quasistationary residual magnetic field is taken into account in the model. The conclusion that the maximum degree of the accuracy of gimballess ESG can be reached in space vehicles is confirmed on the basis of the model analysis. The equations of the apparent motion of the rotor of free ESG are obtained. A detailed analysis of these analytical solutions is made for initial conditions conforming to polar and equatorial orientations of a rotor.Methods of identification of drift model parameters, including analytical solutions of equations of motion and the method of least squares are suggested. Their comparative analysis is made. A number of outcomes of experimental investigations confirming the obtaining of the required precise parameters of ESG with a solid rotor and rather good agreement between the practical implementations and programmatic motion is depicted. The structure of a gimballess inertial system of orientation (GIS-ESG) constructed (based) on three ESG is presented. The functions of basic elements and units of the structure of the GIS-ESG are described. The requirements to computing facilities of the system and their realization are considered in more detail. The schematic and design solutions permitting to maintain high requirements of accuracy and reliability of attitude orientation system are represented. |  |
| **V.I.Kremer, A.M.Osipov, E.F.Polikovsky** | **Compensation of laser gyro errors caused by effect of the vibrating frequency dither** | **14** |
| The filtration of a signal of a laser gyroscope, founded on usage of polynomial approximating of an envelope of oscillations of its resonator is esteemed. The outcomes of experimental check of a way are resulted and the capabilities of its application are analysed. |  |
| **B.A.Blazhnov, L.P.Nesenyuk, V.G.Peshekhonov, L.P.Staroseltsev** | **Miniature integrated orientation and navigation systems for hydrographic vessels and inshore survey boats** | **20** |
| Integration of Inertial Measurement Units (IMU) with Satellite receivers gave the opportunity to use low performance and thus low cost and miniature inertial sensors for high precision Integrated Reference and Navigation Systems.Besides traditional high precise gyros and autonomous INS development, design of miniature strapdown IMU is carried out at CSRI "Elektropribor" during last years. Till nowadays some types of miniature IMU on the base of micromechanical, dynamically tuned and fiber-optic gyros have been designed and the results of the inertial sensors laboratory examination are presented. These results were taken into account while designing IMU for different applications: in strapdown magnetic compass, in reference and heading system for oceanographic and cost guard vehicles, in gyrocompass and attitude reference system. For the first one Murata GyroStar™ and Analog Devices ADLX solid state gyros and accelerometers were used. Fiber-optic gyros of the Fizoptica company were used for the last two systems. As the performance of the chosen fiber-optic gyros does not satisfy the requirements for gyrocompass, modulation of gyros output signal by IMU rotation is provided. The results of IMU modeling and laboratory tests are discussed. Taking into account cost and performance of the above mentioned IMU, two types of onboard microcomputer have been designed. Microcontroller Siåmens SAK-C167 is chosen for IMU with micromechanical inertial sensors and boards of PC-104 standard are used in microcomputer for fiber-optic gyros. Unified program simplified for micromechanical sensors has been designed for onboard computers. The developed systems can use either a built-in or exterior satellite receiver. A set of different receivers has been examined in laboratory, driving and marine tests. The results of integrated systems tests are presented. |  |
| **B.V.Dudnitsyn, O.L.Mumin, L.P.Ryabova** | **Application of microacceleration measurement system "SINUS" for determination of speed projection increments onboard a space vehicle** | **31** |
| The problem is considered for spaceship apparent velocity increments determination, when the corrective engine brake operates during the descending phase, according to data of the acceleration sensor rigidly bounded with the space vehicle and being a part of "Sinus" system. The aim of consideration is to obtain an algorithm for calculation of apparent velocity increments which is acceptable for realisation in Sinus" system as well as to analyse the accuracy of problem solution and influence of measuring procedure duration and of different disturbing factors over it.Capabilities of the system computing device, high level of spaceship mechanical vibrations during the descending phase, and requirements to the definition accuracy for apparent velocity increments in real-time mode result in necessity of extra processing of acceleration sensors output signals before integrating acceleration. Processing method is proposed for output signals of each measuring channel of acceleration sensor. It includes accelerometer output signal processing by low-pass second-order analog filter for the purpose of high-frequency cutoff conditioned by the mechanical vibrations, signal processing by digital restoring filter, and signal processing by fifth-order digital Bessel filter with linear phase characteristic and constant slowing-down time within the considered frequency band. Numerical integration algorithm for the processed signal of acceleration sensor is based on Simpson method. The experimental check results are given for the presented method of apparent velocity projection increments determination by "Sinus-12KU" system placed on board of spaceship "Foton-12", in orbital flight. |  |
| **E.V.Freiman, S.V.Krivosheyev, V.V.Losev** | **Peculiarities in constructing orientation algorithms of gyroinclinometers based on a monoaxial gyrostabilizer** | **36** |
| For the present-day oil production inclined wells and in separate areas - horizontal wells - are drilled. In order to use drilling equipment effectively it is necessary to determine with a specified accuracy zenith  and azimuth  well angles and coordinates of the well's symmetry axis trajectory. Such problems are basically solved by gyroinclinometers. Here principal difficulties are concerned with determination of  and a well-logging cable length. The paper discusses the gyroinclinometer with the gyroinertial unit designed by the scheme of monoaxial indicator gyrostabilizer. On its stabilized platform a three-component accelerometer and a two-channel (two-degree-of-freedom) gyro are mounted. One gyro's channel is used for indicator stabilization, and the second one - for measurement of angular rate relative to the axis perpendicular to the stabilization axis. Application of the monoaxial indicator gyrostabilizer allows the gyroinclinometer's measuring unit to be isolated from rotation of the well device relative to the longitudinal axis. That makes it possible to use output characteristics of the accelerometer and the gyro with maximum accuracy. Actually, the gyroinclinometer is a sui generis strapdown system with incomplete input measurement data, in which two types of intermediate orientation parameters are used. The paper discusses a structure of iteration algorithms for generating  and , which include: initial alignment of the monoaxial indicator gyrostabilizer platform in azimuth (gyrocompassing); measurement of three components of free-fall acceleration and one component of angular velocity; analytical construction of matrix of orientation (MO) at an instant step as a product of MO increment and MO at a previous step; standard procedure of translating MO elements to and . The basic peculiarity of the algorithm consists in: (a) constructing the increment of MO whose elements are functions of finite turn vector projections. Determination of these elements results from solution of the inverse problem for discrete representation of Poisson's equation using accelerometer signals at two adjacent steps and a signal from an angular-rate sensor; (b) variability of algorithm structure depending on angle . In addition to basic functional algorithms, accuracy increase algorithms are presented including algorithms of temperature error compensation; algorithms of gyro error model in two channels. Here the angular momentum of the gyro is levelled to the horizon plane, because with this calibration coefficients are more reliable. |  |
| **V.N.Ilyin, Yu.L.Smoller, S.Sh.Yurist** | **Results of development and testing of the mobile land gravimeter** | **47** |
| The article presents the basic results of development of a small-sized relative gravimeter intended for measuring gravity increment from board of a land vehicle in the mode of short-term stops. A gravity sensor has the axial configuration with a test-mass in a joint flexure assembly, a photoelectric position sensor and a magnetoelectric feedback force sensor. The bandwidth of the gravity sensor is about 100 Hz. The gravity sensor is mounted on the gyrostabilized platform enclosed in the biaxial gimbal suspension. The gravimeter is completely automated. Stated are the basic principles of design, the software peculiarities, the results of laboratory and full-scale tests. At present on the basis of this gravimeter a wide-application mobile gravimeter is under development, including air and marine applications. |  |
| **O.K.Epifanov, A.B.Oskin, I.A.Salova, V.V.Khrushchev** | **Development of small-sized module-type brushless torque motors for modern digital gearless servo systems of navigational equipment** | **50** |
| The article presents the main results of examining the evolution of domestic flat brushless dc torque motors (BTM) with permanent magnet excitation; magnets are located in an air gap on the rotor surface. Principal design of BTM is described, their basic advantages and deficiencies are considered. Described is the principal |  |
| **A.Yu.Zadorin, G.B.Zakharova** | **Automation system for optical check of photomasks and printed circuit boards using a standard scanner** | **62** |
| The paper deals with the automated optical inspection (AOI) system that uses a flatbed scanner to obtain the images of printed circuit boards (PCB) and phototools. This solution is very cost-effective but it requires some special processing which is discussed in the article. The system is based on the method of full comparison with a standard. This method provides the most reliable inspection results but the images, which are to be compared, should be superposed. The problem of superposing is completely solved. APLITE (the name of the inspection system) provides both visual and automatic superposing methods. After the images have been superposed, the report containing all mismatches exceeding the specified size is generated (fig. 1). Finally, APLITE checks the PCB topology for gaps, shorts and line/space violations (fig 1). It also finds misplaced and wrong-sized holes in the PCB. The paper discusses all basic algorithms and mathematical models used in the system. |  |

**Papers presented at the 7th St. Petersburg International Conference on Integrated Navigation Systems**

|  |  |  |
| --- | --- | --- |
| **P.Westphal, O.Wagner** | **Flight safety improvement via fuzzy logic based flight control systems** | **75** |
|   |  |
| **D.Accardo, G.Rufino** | **Innovative solution for initial acquisition by an autonomous star sensor: algorithm, implementation, and tests** | **87** |
| This paper presents an innovative approach to reliably achieve initial altitude acquisition with an autonomous star sensor. In particular, the following topics are considered: problem analysis, algorithm development, software implementation in an hardware prototype of the sensor, and functional tests. Firstly, the generation of the on-board reference catalog of stars is presented. Indeed, this is a crucial component in order to achieve an adequate initial altitude acquisition performance and its development cannot be carried out independently of the algorithm. The catalog organization in triplets is also introduced, which is aimed at efficient browsing. Subsequently, an original algorithm for star field identification is described in details. It is based on the recognition of three-star patterns, avoiding the use of any information about the brightness of the observed stars. Finally, the results of the tests are reported, which have been performed by means of a star sensor model and a laboratory validation facility. Non-misleading outputs are in the percentage of 99.8% being 96.0% the probability of successful attitude acquisition. |  |
| **J.Beschnidt, R.Barthel, E.Gilles** | **Practical application of an integrated navigation system on inland ships** | **101** |
| This paper presents functionality, features and practical application of an integrated navigation system, developed at the Institute for System Dynamics and Control (fSR) at the University of Stuttgart. The tasks of this autonomous on-board system comprise on one hand the real-time determination of the ships current dynamic state, including its position, heading and velocity, with high precision and availability. On the other hand, the system guides the vessel automatically and with high accuracy along predefined tracks. The project is aimed at a substantial improvement of the safety on waterways. For this purpose, measurements of different independend sensor devices, like radar, GPS, and inertial systems, and a-priori knowledge about the waterway are combined to obtain reliable information on the ships dynamic state. In the course of the project the system has already been installed on various commercial vessels. The paper gives an overview about intention and results of the projects and concludes with an outlook on current research topics at the ISR. |  |
| **T.Routhier, J.Ryan** | **An integrated C2 navigation system for the joint maritime services** | **115** |
| To effectively carry out search and rescue, drug enforcement, fisheries enforcement, alien interdiction, and defense operations, the U.S. Coast Guard's Famous and Reliance classes of medium endurance cutters require a robust electronic navigation system fully integrated with the ship's command and control (C2) system. Since 1994, the Command and Control Engineering Center (C2CEN) has developed the COMmand Display and Control Integrated Navigation System (COMDAC INS). COMDAC INS is a fully integrated C2 navigation system built upon the Department of Defense's (DOD's) Defense Information Infrastructure - Common Operating Environment (DII-COE) and its Global Command and Control System - Maritime (GCCS-M) extensions. The Coast Guard's requirements for an integrated navigation system are based on existing mission needs, the international standards for Electronic Chart Display and Information Systems (ECDIS), and additional standards for warships developed by the U.S. Navy and the North Atlantic Treaty Organization (NATO). The Navy has joined the Coast Guard in this development effort and will use the same software for the Navigation Sensor System Interface (NAVSSI) scheduled to be installed on over 130 surface ships and for the Navigation Data Distribution and Display (ND3) system of the new Virginia class attack submarines. Over 170 Coast Guard cutters and Navy vessels will potentially be using this C2 navigation system by 2003. |  |

**Information**

|  |  |
| --- | --- |
| **Russian and international conferences, symposiums and exhibitions** | **137** |
| **V.M.Korchanov. Review of the book by D.A.Skorokhodov "Motion control systems for high-speed vessels"** | **138** |