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Ключевые слова: побережье Камчатки, Авачинский залив, дистанционное зондирование, цветение микроводорослей, цвет моря, температура поверхности океана, вихревые структуры.

Пичугин М.К., Гурвич И.А., Хазанова Е.С., Салюк П.А. НЕКОТОРЫЕ ОСОБЕННОСТИ ОКЕАНОЛОГИЧЕСКИХ УСЛОВИЙ ОСЕННЕГО ЦВЕТЕНИЯ МИКРОВОДОРОСЛЕЙ У ЮГО-ВОСТОЧНОГО ПОБЕРЕЖЬЯ КАМЧАТКИ // Подводные исследования и робототехника. 2020. № 4 (34). С. 70–73.

В работе демонстрируются возможности оптических наблюдений со спутников Sentinel-2, 3 для изучения связанных физических и биологических процессов в поверхностном слое океана. Рассматривается конкретный пример применения системы наблюдения для случая интенсивного осеннего цветения фитопланктона у юго-восточного побережья Камчатки в сентябре 2020 г. В Авачинском заливе цветение водорослей проявлялось в виде областей с высокой концентрацией хлорофилла-а, придавая морской поверхности соответствующий темно-зеленый оттенок. На композитном изображении с разрешением 10 м из-за выраженных спектральных различий на морской поверхности выделялись скопления водорослей, организованные в сложные системы мезомасштабных и субмезомасштабных взаимодействующих вихревых структур. По данным реанализа ERA5 установлено, что среднемесячная температура поверхности океана (ТПО) акватории Авачинского залива в сентябре 2020 г. показала положительную аномалию с максимумом ТПО (12,0°С) за последние 42 года при климатической норме 10,4°С. Допускается, что при сохранении тенденции роста в ближайшие годы этот максимум будет превышен.

ABSTRACTS

Key words: autonomous underwater vehicles, hybrid underwater vehicles, supervisory control, underwater robot deployment.

Matvienko Yu.V., Kostenko V.V., Scherbatyuk A.F., Remezkov A.V. DEVELOPMENT OF THE TECHNOLOGICAL POTENTIAL OF AUTONOMOUS UNDERWATER VEHICLES // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 4–14.

Prospects of designing autonomous and remotely operated underwater vehicles (AUV and ROV) of the new generation rely on developing hybrid autonomous and remotely-operated vehicles (ARV), which combine functions of AUV and ROV. It is necessary to expanse significantly AUV's technological capabilities by equipping it with new instruments, upgrading onboard control systems, involving operators in the technological process for real-time control of work progress, and execution order and conditions of novel technological operations. ARV is capable of performing a wide specter of contactless operations: approach the target of research according to the stated program, perform operations related to establishing a data exchange channel with control station, and then carry out contact operation in supervisory mode. Priority tasks of hybrid vehicles designing consist of the development of AUV's functional properties, including:

- intellectualization of onboard control systems;
- provision of supervisory control involving an operator in control flow;
- expansion of instrumentation and optimization of structural solutions;
- providing a network means for underwater navigation;
- providing an infrastructure for underwater deployment while carrying out long-term missions on the maintenance of underwater mining complexes.
- Work demonstrates a principal achievability of designing an ARV based on robotic complexes and their systems developed in the IMTP FEB RAS for the past years.

Key words: autonomous underwater robot, tethered retranslation buoy, radiocommunication module, satellite positioning system, ultrashort baseline underwater acoustic positioning system, information and measuring module, motion dynamic model.

Kostenko V.V., Bykanova A.Yu., Mikhailov D.N., Mokeeva I.G., Tolstonogov A.Yu. TECHNOLOGY FOR MEASURING THE MOTION PARAMETERS OF THE TETHERED SYSTEM OF AN AUTONOMOUS UNDERWATER ROBOT WITH A SURFACE RADIO COMMUNICATION MODULE // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 15–22.

The work considers the technology for measuring the navigational, control, and dynamic parameters of the specialized tethered system of an autonomous underwater robot (AUR). Its main idea is to use a towed surface retranslation buoy equipped with means of satellite positioning and radiocommunication with the vessel control station. The questions at issue are measuring the vector of communication cable tension in points of its attachment to AUR and retranslation buoy, synthesis of an integrated information-measuring system capable of efficient real-time operation. Decisions made in work provide measuring and registration of key parameters of AUR motion concerning communication cable influence. Hardware-software means of measurement complex allow merging in one file the data of movement speed and geographical coordinates of retranslation buoy with AUR movement parameters. At the same time, the AUR location is determined by an underwater acoustic positioning system. The element base of the complex provides the stated measurement accuracy of parameters in their variation range. The developed algorithm determines the projections of cable tension vector on the axes of a vehicle-buoy fixed coordinate system according to measured angles deviation from vertical position of corresponding measuring modules. The AUR onboard computer's storage records the measured parameters as a time-synchronized file with a possibility of further graphic-analytical processing and parametric identification of the communication cable dynamic model.

Key words: autonomous underwater vehicles, emergency control system, control system, diagnostic, hardware-software means of ECS.

Eliseenko G.D., Inzartsev A.V., Pavin A.M. AUV LAYERED DISTRIBUTED EMERGENCY CONTROL SYSTEM // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 23–30.

The work considers the concept and implementation of an emergency control system (ECS) to increase the survivability of autonomous underwater vehicles (AUV) of different types and functionality. The task of raising the AUV survivability can be solved in several ways: dual redundancy of software and hardware means and providing their mutual coherent (consistent) functioning. ECS is based on a hierarchal decomposition of solving tasks and includes several software layers and hardware components. The ECS software component controls the software's integrity, prelaunch diagnostic, errors, and emergency monitoring. The ECS hardware component provides capabilities of positioning and emersion of AUV in case of its computational system malfunction. The key feature of the proposed approach is the "relatively independent" behavior of the systems in different operational modes (both routine and emergency) and the capability of the ECS to perform the predetermined task (mission) to the maximum extent. Different scenarios of AUV behavior in emergencies are considered.

Key words: underwater multilink manipulator, underwater vehicle, identification, high precision, observer.

Filaretov V.F., Konoplin A.Yu., Zuev A.V., Krasavin N.A. SYNTHESIS METHOD OF SYSTEMS FOR HIGH-PRECISION MOVEMENTS CONTROL OF UNDERWATER MANIPULATORS // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 31–37.

The paper presents a synthesis method of combined systems providing high-precision movements control of multilink manipulator arm tool mounted on underwater vehicles. The proposed method allows precise identification of negative torques on the output shaft of the manipulator electric drives that emerged during its motion in a viscous medium and moments of coulomb and viscous friction in these drives. This method begins with a preliminary analytical calculation of external moments appearing in underwater manipulator axes of motion by the recurrent algorithm of solving the inverse dynamic problem. This calculation is highly coarse due to the complexity of determining parameters of the real interaction between all links of the manipulator, engaged load, and seawater medium. Additional diagnostic observers are then synthesized using dynamic models of electric drives of every axis of freedom, including analytically determined external moments. These observers can more precisely determine the values of unpredicted changes of the viscous and coulomb friction moments in drives itself using formed discrepancy signals. Then identified torques on the electric drives of all manipulator axes are compensated using self-regulated correcting devices capable of stabilizing these drives' dynamic properties on the nominal level. The paper contains numerical modeling of the system synthesized by a developed method for a multilink manipulator with a PUMA kinematic scheme, an arm tool of which was moved alongside a complex three-dimensional trajectory. The numerical modeling results showed a significant increase in the accuracy of different technological operations performed by underwater manipulators using a synthesized system.

Key words: internal waves, surface manifestations, density diagnostic.

Aleksanin A.I., Kim V., Yaroschyuk I.O. SEAWATER DENSITY ESTIMATION ON SURFACE FOOTPRINTS OF INTERNAL WAVES // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 38–44.

The problem of shallow water density estimation based on the surface images of internal gravity waves is considered. The images are used for calculation of internal gravity waves speed and wavelength. The seventeen cases of in-situ wave registration by vertical allocation temperature sensors are analyzed. The standard two-layer model and constant Väisälä-Brunt frequency model are explored. The wave speed is calculated by direct task solution using in situ data and image data separately, and the results are compared. Two kinds of direct task solutions are considered: as a solution of Sturm–Liouville problem and as a solution of Korteweg-de Vries equation. The relation between internal wave speed and the depth can help us to choose the density model. It is shown, that for the two-layer model with upper layer depth much higher than the bottom one both approaches to the solution of the direct task give significantly lower speed than the speed calculated from the image sequences.

Key words: seawater, bubbles, gas-hydrates, gas flares, scattering, sound absorption.

Bulanov V.A., Korskov I.V., Sosedko E.V. ABOUT THE USE OF NON-LINEAR SOUND SCATTERING FOR ESTIMATING THE OFFSHORE GAS FLARES STRUCTURE AND LENGTH COMPOSITION // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 45–52.

New objects in the ocean, underwater gas flares (GF) formed by gas bubbles emerging from the sea floor, are ubiquitous in areas where gases are released from the bottom sediments in various areas of the ocean, and in areas where gas is discharged during permafrost melting in the Arctic seas, and they are receiving increasing attention. The standard application of sound scattering allows detecting the presence of GF in the sea, but does not allow us to fully correctly estimate the bubble size distribution function in the flare, and therefore there are uncertainties with the estimation of the power of gas emission from the sea. The possibilities of using the method of non-stationary and nonlinear sound scattering to obtain information about the structure and dynamics of underwater gas flares formed by gas escaping from the sea floor are discussed. Nonlinear sound scattering is caused by the high nonlinearity of bubble structures in water. Non-stationary sound scattering occurs due to transient processes of bubble swinging under the action of acoustic pulses, and it was previously used to study the distribution of bubbles in near-surface layers of seawater. It is shown that the use of nonlinear non-stationary scattering on colliding beams will allow remote spectroscopy of bubbles in gas flares and correct estimates of the gas content in the flares.

Key words: acoustic ranging, impulse signal, anticyclonic eddies, group velocities, normal modes method.

Sorokin M.A., Petrov P.S., Kaplunenko D.D., Stepanov D.V., Morgunov Yu.N. ESTIMATION OF THE SYNOPTIC EDDIES

INFLUENCE ON THE ACOUSTIC RANGING ACCURACY // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 53–60.

The development of acoustic navigation and acoustic ranging systems is currently one of the most important practical problems of ocean acoustics. In this study, the influence of large-scale inhomogeneities on the sound speed field in the ocean on the accuracy of acoustic ranging problem solution is considered. As a representative example of an inhomogeneity of this kind, we chose a stable anticyclonic eddy that is observed in the southern part of the sea of Japan in summer. In this work, computational experiments are conducted in order to study the influence of this eddy on the structure of the sound field formed along an acoustic path passing through the eddy's center by a source of navigation signals (SNS) located on the shelf. In the course of these experiments, a model of a range-dependent "shallow-to-deep-sea" waveguide was constructed along this path using hydrological data obtained from NEMO and INM RAS global ocean circulation models. After that, the acoustic field produced by the SNS in this waveguide was simulated by the method of wide-angle parabolic equations. The mode structure of the field along the path is studied, localization intervals of various modal components of the signal are determined, and the effective propagation velocities of signals transmitted by SNS are calculated at various reception horizons. The influence of the synoptic eddy on these waveguide characteristics is also investigated. On the basis of this analysis, the effect of the eddy on arrival times of the signals propagating from the SNS to the reception point is estimated, as well as the additional error in the solution of acoustic ranging problem caused by the presence of the eddy. The results of the study show, that within the framework of the considered technique of acoustic ranging problem solution, even the presence of a large unaccounted synoptic eddy, with its core located directly on the acoustic path, has a relatively weak effect on the accuracy of range estimation (about 30 m for a path 300 km long, or 0,01%).

Key words: autonomous underwater vehicle, positioning system, motion control system, recognition of sonar images.

Borovik A.I. AUV POSITIONING SYSTEM BASED ON RECOGNITION OF ARTIFICIAL MARKERS ON ACOUSTIC IMAGES // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 61–65.

The work considers a positioning task, the solution of which is to increase the accuracy of the autonomous underwater vehicle (AUV) position determination by detecting the objects located on the seafloor on the sonar images. Specifically designed markers with predetermined technological characteristics were used as objects of recognition. Algorithms of marker placement in the operational aquatic areas and vehicle motion guarantees the detection of markers by the side-scanning and sector-scanning sonars. The positioning algorithm is integrated into the AUV control system and works in real-time mode.

Key words: ocean acoustics, modal-analysis method, perturbation theory, bathymetry inhomogeneities.

Zakharenko A.D., Petrov P.S., Trofimov M.Yu. ON PERTURBATION OF ACOUSTIC MODES BY INHOMOGENEITIES OF THE BATHYMETRY IN A SHALLOW SEA // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 66–69.

Modeling of sound propagation in ocean acoustics can be performed using the modal-analysis method. If solving task has bathymetry inhomogeneities, the vast majority of computational time is spent calculating modal functions and numbers in several cross-sections of the studied waveguide. An implementation of the perturbation theory to the computational process can save a significant part of this time. The work forms a theory of perturbations by solving the Sturm-Liouville problem for modal functions and numbers caused by variations of the sea depth. This issue can be narrowed down to the conventional task about a potential disturbance in the stationary Schroedinger equation by a specific change of variables. The work presents formulas of the perturbation theory of the first and second orders for modal functions and numbers in an explicit form. The example of these formulas' implementation is presented, and its accuracy is analyzed. The described approach allows to significantly increase the computational effectiveness of modeling the sound propagation in irregular waveguides of the shallow sea, securing the same accuracy level, which can be achieved by solving the Sturm-Liouville problem for every cross-section.

Key words: Kamchatka shore, Avachinsky bay, distant probing, microalgae flowering, sea color, sea surface temperature, vortex structures.

Piuchugin M.K., Gurvich I.A., Khazanova E.S., Salyuk P.A. SOME FEATURES OF OCEANOLOGICAL CONDITIONS OF THE MICROALGAE AUTUMN-FLOWERING NEAR THE SOUTHEAST SHORE OF KAMCHATKA // Underwater Investigation and Robotics. 2020. No. 4 (34). P. 70–73.

The paper demonstrates the possibilities of optical observations from the satellites Sentinel-2, 3 for studying linked physical and biological processes in the ocean's surface layer. The specific example of using an observation system for surveillance over intense autumn-flowering of phytoplankton near Kamchatka's southeast shore in September 2020 is considered. In Avachinsky Bay, the microalgae flowering manifested as areas with high chlorophyll-a concentration, coloring the sea surface into the corresponding dark green shade. On a composite image with a resolution of 10 m, significant spectral differences on the sea surface highlighted conglomerates of algae organized in complex systems of mesoscale and submesoscale interacting vortex structures. According to ERA5 reanalysis, it was found that the average monthly sea-surface temperature in Avachinsky Bay in September 2020 demonstrated a positive anomaly with a maximum (12,0° C) over the past 42 years with a climate normal of 10,4° C. It is assumed that this maximum will be surpassed if the current trends continue.