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On the features of the progressive movement of the solid body, controlled by two propulsion devices

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On the features of the progressive movement of the solid body, controlled by two propulsion devices

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Abstract. A calculation scheme and a mathematical model of the translational motion dynamics of a solid body, simulating the movement of the underwater platform with the help of anchor-cable thrusters, are proposed. Features of motor control, DC and stepper in the structure of the actuators of the anchor-rope propulsion have been set.

1. Introduction

The development of new hydrocarbon fields on the continental shelf requires the introduction of advanced technologies for their production and exploration. It is shown [1] that the use of heavy self-lifting bases of underwater drilling complexes with a significant number of drilling points (more than a hundred) is economically impractical, and light self-lifting bases are characterized by insufficient safety. The process of drilling from a self-propelled vessel is also fraught with difficulties, the main of which are pitching and drift.

One of the promising technologies for the production and exploration of new hydrocarbon fields on the continental shelf is the use of an autonomous underwater robotic complex with anchor-cable propulsion devices. The anchor-rope mover can be used to move an autonomous underwater or surface robotic complex (figure 1) due to the thrust arising from the tension of the cables going to the anchor [6, 7, 8].
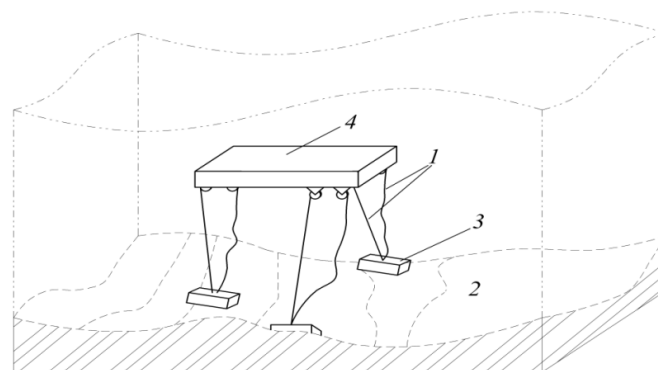
**Figure 1.** Moving the underwater platform with positive buoyancy.

The engine is an anchor. Together with two cables 1 it is associated with two flywheels, rotating in accordance with the relevant laws of motion. In the initial position, the cable 1 is weakened, the anchor in the absence of current occupies a position on the same vertical with the flywheel. When the flywheel is rotated, the cable 1 is stretched, and in the absence of slippage of the anchor along the bottom, the mobile robot is moving. The work of such an engine is similar to the work of a walking mover, and the difference is that the robot does not rely on mover, but clings to the support surface with its help.

A feature of such robotic systems is the use of excessive in terms of providing a given motion of the robot platform, the number of movers, which is explained by the need for reliable interaction of anchors with difficult to predict the bottom relief and its physical and mechanical properties. Indeed, if for an unambiguous description of the motion of an absolutely rigid body requires a minimum of 6 control actions (for the robot platform – 6 anchor-cable movers), then in the absence of reliable interaction of at least one anchor with the ground, the movement of the robot becomes unpredictable. Therefore, due to the excess of the number of control actions over the number of generalized coordinates, there is a dynamic uncertainty.

However, in solving the technical problem, this uncertainty is useful. It allows you to impose additional conditions on the control actions, optimal in one sense or another.

2. Statement of the model problem

The introduction of various additional conditions, the study and analysis of the results is convenient to carry out on a simple mechanical system with one degree of freedom, shown in figure 2.
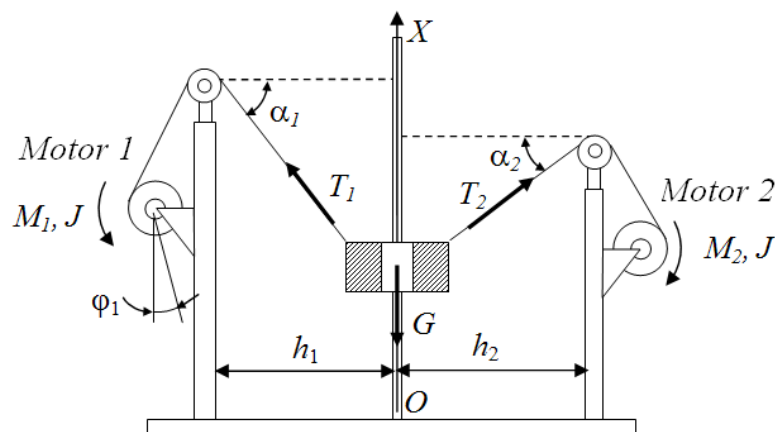
Figure 2. The settlement scheme of studies of the motion modes.

One drive is sufficient to move the load G along the vertical guide (figure 2). When using two drives, the task of the control system is to implement a given distribution of effort between these drives, as well as providing the required law of translational movement of load.

The control is reduced to the search for control actions on electric motors, in particular, to the determination of the voltage applied to the armature windings of a DC motor, to provide the required moments, or the determination of the switching frequency of windings for stepper motors.

To study the control system of anchor-cable thrusters in the translational motion of the underwater platform is considered a calculation scheme, which is shown in figure 2, where motor 1and motor 2 – electric motors; M_1, M_2 – the torque, developed by these electric motors; α_1, α_2 – the angles, formed by cables with a horizontal axis; φ_1, φ_2 – the angles of rotation of the flywheels of electric motors; T_1, T_2 – the tension force in the cables; J – the moment of inertia of the same flywheels drives; h_1, h_2 – the distance from the center of mass of the load up to flywheel axes; G/g – mass of the transported load; x (t) - movement of the load.

The mathematical model, describing the movement of the load is based on geometric equations with simultaneous operation of electric motors 1 and 2 on the one hand, and on the equation of the dynamics

of the forward movement of the load – on the other. The peculiarity of the solution of the control problem is the need for the subjective introduction of an additional ratio, both in the case of DC motors and in the case of stepper motors.

The control system can be implemented by software motion control, or using feedbacks to improve control accuracy. The block diagram of the control system is shown in the figure 3.
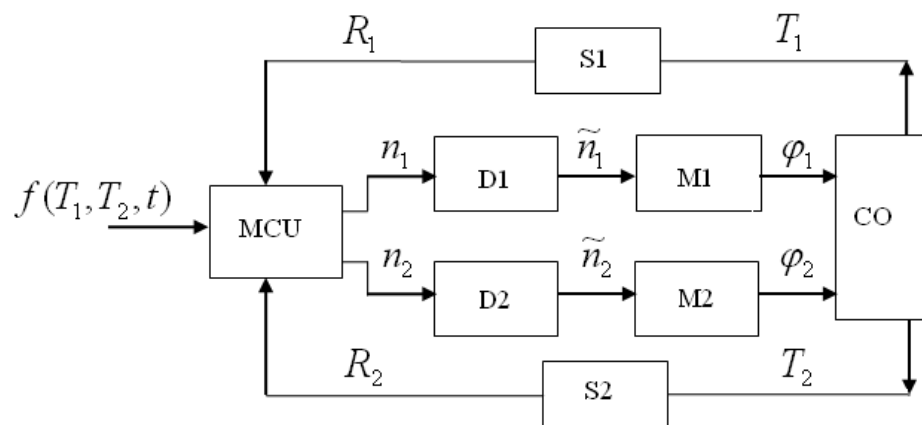
Figure 3. The block diagram of the control system: MCU – microcontroller; D1, D2 – DC-motor drivers; M1, M2 – DC-motors; S1, S2 – sensors; CO – control object.

The required ratio of the tension forces in the cables in the form of a set value is fed to the input of the control device, in this case the microcontroller (MCU). Control actions n_1, n_2 from the microcontroller are fed to the motor drivers *D1* and *D2*. Under the influence of control actions, electric motors *M1* and *M2* are installed at the appropriate angle φ_1 and φ_2. By adjusting the speed of electric motors, the necessary difference of angular accelerations calculated by the microcontroller according to the mathematical model and providing a given ratio of the tension forces of the cables are established. The determination of the engine for which the control action is required can be carried out by the value of the angle of rotation of its rotor, measured by the feedback circuit through the sensors *S1* and *S2*, or by direct measurement of the values of the tension forces.

3. Test stand development

The model of physical modeling allows us to study various modes of coordinated operation of the engines of the anchor-cable propulsion device, for example, the movement of the load with a given ratio of tension forces, the implementation of a cycle of one "step" with the movement of the load along the program trajectory. The interface of the program, controlling the stand, allows us to carry out control of electric motors, to set rotation angles of each electric motor separately, to measure and display sizes of the torques for each electric motor, and it allows us to monitor current values of tension of cables, calculated according to mathematical model. The developed stand allows you to simulate the movement of load with one degree of freedom and evaluate the effectiveness of the selected control actions.

The solution of the problem of synthesis of control signals for electric motors can be based on the conditions of simultaneous search for extreme values of several criteria - based on the solution of multi-criteria optimal control problem, for example, by the criterion of minimizing the effort in a particular cable, by the criterion of its minimum or maximum elongation, by the criterion of the load on a particular engine.

4. Results

During the process, a mathematical model of control of the translational motion of a solid body under the influence of two drives is developed, the criterion of optimal control, providing the required ratio of forces developed by the drives, is proposed, and the features of control of DC motors and stepper motors are considered.

References

[1]   Serov V A, Kovshov I V and Ustinov S A 2017 *Izvestiya YUFU. Tekhnicheskie nauki*. **9** (**194**) pp 181-91

[2]   Jin-Ho Kim, Tae-Kyeong Yeu, Suk-Min Yoon, Hyung-Woo Kim, Jong-Su Choi, Cheon-Hong Min and Sup Hong 2013 Electric-Electronic System of Pilot Mining Robot, MineRo-II *Proc. of the Tenth ISOPE Ocean Mining and Gas Hydrates Symp. Szczecin* pp 269-73

[3]   Verichev S, Laurens de Jonge, Wiebe B and Rodney N 2014 Deep mining: from exploration to exploitation *Proc. Int. Conf. VNII Okeangeologia* pp 126-38

[4]   Briskin E S , Chernyshev V V, Maloletov A V and Sharonov N G 2013 Comparative analysis of wheeled, tracked and walking machines *Robototekhnika i tekhnicheskaya kibernetika* **1** (**1**) pp 6-14

[5]   Chernyshev V V and Arykancev V V 2015 MAK-1-underwater walking robot *Robototekhnika i tekhnicheskaya kibernetika* **2** pp 45-50

[6]   Briskin E S, Penshin I S, Smirnaya L D and Sharonov N G 2017 Determination of forces in the engines of the anchor-cable type *Izvestiya VolgGTU*. Aktual'nye problemy upravleniya, vychislitel'noj tekhniki i informatiki v tekhnicheskih sistemah **14** (**209**) p. 87-90

[7]   Briskin E S, Serov V A, Sharonov N G and Penshin I S 2017 About features of control of movement of mobile robots with movers of anchor and cable type *Ekstremalnaya robototekhnika* pp 337-43

[8]   Sharonov N G, Penshin I S and Platonov V N 2017 Underwater platform motion control with anchor-rope propulsion devices *Proc. Int. Conf. MIKMUS* pp 353-5

[9]   Kenio T. 1987 *Stepper motors and their microprocessor control sytems* (Moscow: Energoatmizdat) p 200.