«BOXNEP» ADVANCED MODULAR UNDERWATER ROBOT

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Abstract

The article discusses the relevance of the underwater vehicles' ability to solve a wide range of problems. The idea put in the basis of this research is designing a modular underwater robot. It allows to mount various equipment and test it in underwater environment. The paper deals with the concept of the robot and its characteristics.

Key words: underwater robotics remotely operated underwater vehicle, robot, mechatronics, modular construction.

Introduction

Nowadays, people are actively exploring the World Ocean. This activity is related to resource development and exploration of the biosphere. However, the World Ocean still remains the least explored area of the Earth; among others, the exploration of the Ocean's bed is of greatest interest to humanity. Yet, the main risk is that underwater environment represents a real danger for divers [1].

Underwater robotics is one of the newest branches of science and technology. Development of automatic underwater vehicles can save people from the risk that they may suffer while working under water, and also help to study and explore the underwater world.

Initially, underwater vehicles have been used by the military, but today we can say that they are used for a wide range of scientific and applied purposes related to the development and monitoring of the World Ocean, support for solving environmental issues, problems of climate forecasting, control of biological resource base, development of underwater mineral resources, seismic measurements, used as a means of control and alert in case of an emergency. Consequently, underwater robots are tools that are used for a wide range of applications [2].

With the help of underwater vehicles, humanity can study the system of rivers and reservoirs under the ice cap of the Antarctic. In addition, these vehicles can facilitate the underwater equipment maintenance (oil and gas sea-lines).

The central aim of the project is to ensure human safety during exploration of the Ocean's mineral resources. For this purpose, a remotely operated underwater vehicle will be designed that will allow exploring the bottom of the Ocean for an unlimited period of time. This robot will be able to perform underwater photography to search for objects, such as dangerous marine animals, rare mineral resources, amazing abyssal (ненаучно как-то звучит) species, etc. Also, the robot can be used for testing new underwater devices (e.g. manipulators, water analysis sensors, etc.) in the real operating conditions. The modular construction allows to install and replace the equipment on the robot.

Underwater robot's concept

The main purpose of creating the first robot prototype is its proper positioning under water. However, on the prototype, the robot construction should include the possibility of integration of additional equipment. This function is needed to test this equipment in real-life conditions. In addition, Closed Circuit Television System (CCTV system) must be placed on the robot to control the environment in which the vehicle is.

The frame of the robot is made of profiled aluminum tubes with a rectangular cross-section of 50 x 40 mm (Figure 1). This form has a number of advantages, the most important among which is the low resistance of water when the robot moves. The frame has the sufficient safety margin to dive to depths of up to 15–20 m. The body frame is made of hollow aluminum tubes welded together at the end surfaces (the wall thickness of the tube is 1.5 mm). This technology provides positive buoyancy. Moreover, it is possible to install additional equipment up to 20 kg inside the frame after pressurizing it.

The robot’s motion system will consist of six electric thrusters. It will be immersed by the force of four special motors and moved by two other ones. This way, the underwater vehicle will have a modular structure, which will allow using specific modules, e.g. sensors, detectors, manipulators, video cameras, etc., for different tasks.

Firstly, mass, capacity, buoyancy, forces, etc. should be calculated using hydrodynamic rules and principles. Then, the robot system with required parameters is tested in MATLAB Simulink for reliability and stability. Later, this math model is used to model a PID regulator for the control system, and manufacture the robot.

The main body of the program code for the robot’s system is shown in Figure 2. This code includes two parts: the first is PID controller work description and the second one is connected to the robot, which is a control object for an automatic computer system.

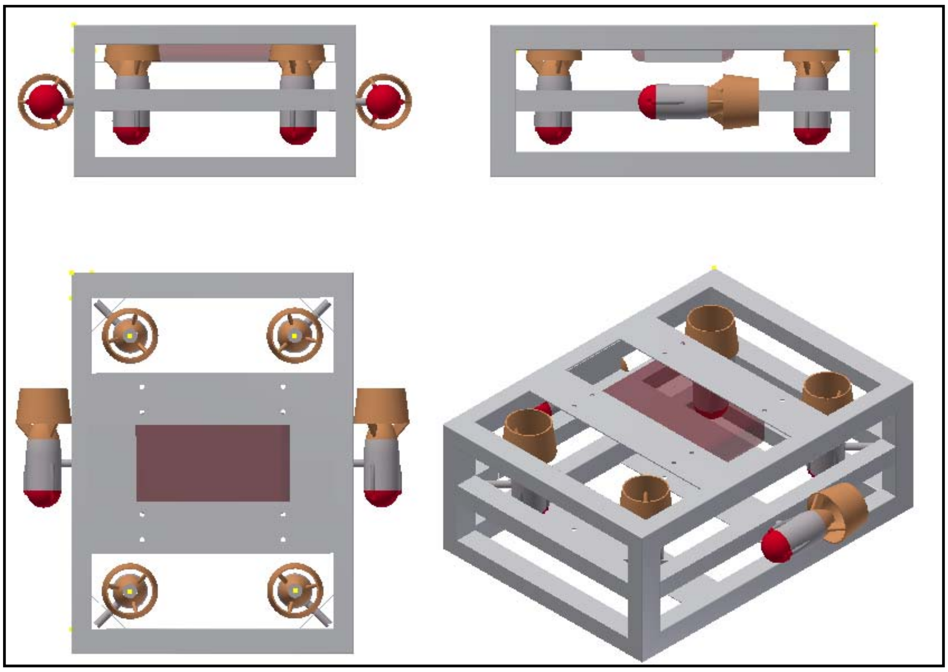

Figure 1. Construction of the «BOXNEP» underwater robot

Technical specifications of the underwater robot

- Frame Dimensions (LxWxH): 750 × 550 × 300 mm;
- Robot Weight: 10 kg;
- Carrying capacity: up to 20 kg;
- Maximum depth: 20 m;
- Control method: remote-controlled;
- Number of thrusters: 6;
- Frame material: aluminum;
- Installation of additional equipment: yes;
- Horizontal thrust: 20 kg;
- Vertical thrust: 10 kg.

```
function y=PID_02(oldErr,Err,oldInt)

Kp = 2;
Ki = 0.3;
Kd = 1.5;
Saturation_value = 0.7;

P = Kp*Err;
Int = oldInt + Err;
I = Ki*Int/100;
dErr = Err - oldErr;
D = Kd*dErr*100/1.5;

if (I > Saturation_value)
    I = Saturation_value;
end

if (I < -Saturation_value)
    I = -Saturation_value;
end

U = P+I+D;

y(1)= Err;
y(2)= U;
y(3)= Int;
```

Figure 2. Program code of the robot's control system

Let us explain the program code. Each program body contains some main function (**y=PID_02** is the name of the code's main function) with arguments: **OldErr** (old error), **Err** (real error), **OldInt** (value of the PID controller's integral part). $\mathbf{K_p}$, $\mathbf{K_i}$, $\mathbf{K_d}$ is in accordance with the proportional, integral and deferential coefficients of the controller. **Saturation_value** is the integral part of saturation for system's work stability. **P, I, D** is in accordance with the proportional, integral and deferential parts of the PID controller. **Int** is the sum of old error and real error values, **dErr** is the difference between real error and old error values. The code contains two conditions with logic operator **if**: these ones are needed to turn on and off the integral part of the controller when necessary during the system's operation. **U** is the sum of the proportional, integral and difference parts of the controller. The value of this function (**y(2)=U**) is the output of the PID controller, which corrects the system's work. Variables **y(1)** and **y(3)** are used to save the values of the real error and the PID controller's integral part.

Conclusion

The project shall produce a remotely operated underwater vehicle that will be able to substitute human divers. Creating this vehicle may also lead to a breakthrough in science, in particular it can accelerate the exploration of the World Ocean. The developed control system for this robot makes it possible to integrate different equipment for testing purposes.

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