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DEVELOPING THE PROTOTYPE OF WATER SURFACE ROBOT

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Abstract— Aim of this paper is to develop a Water Surface Robot prototype which can move on surface of water. Most important and interesting part of the robot is that no force is required to keep robot on water surface. The robot will also not sink in the water even in turbulence because waterproofing is also given higher priority. The core fundamental of this prototype is Buoyancy. For moving the robot in water, propeller system is used. Forces are calculated to assure enough thrust required to propel the prototype. The prototype is modeled, manufactured and tested. Software CFD simulation and experimental results are compared for Drag Coefficient and Drag force.

Keywords-Drag force, Drag Coefficient, Buoyancy, Water surface robot, CFD, Water maneuvering.

I. INTRODUCTION

Water surface maneuvering is planned and skillful movement of any vehicle/object in water, which is made for special purposes. Maneuvering in water is becoming an important aspect because of many reasons. Ocean ecosystem is in deep trouble, level of acidity of sea water is increasing. It is increasing rapidly as a consequence that ocean is taking up more than a quarter of the carbon dioxide produced from the burning of fossil fuels.[1] Collecting data from data storage tags equipped wit sensors are used to store measured data and collecting when required so, if the maneuvering vehicle can receive real time data transmitted by Data Storage Tags(e.g. tags on fish), it is a good deal to forward that data to relevant stations where they are necessary[2].

Maneuvering can be made possible by many ways, i.e. manned boats at coastal area for security reasons, for collecting oceanographic data the Hovercrafts also can be used and equipped with required sensors. Hovercrafts may be manned or unmanned according to use and configuration of it. Also, unmanned robots with autonomous maneuvering capability. So, it is clear that if there is a single device that can handle many of the problems and perform required tasks, it will be appreciated. The idea is to design and develop a robot which can perform tasks maneuvering in water.

There are many robots are available today. A silicon swimming robot with dimensions 6 × 9 mm using EWOD technology to propel[4]. A mini hovercraft also can be used as a robot either manned or unmanned. But it will be under utilized as it is capable for maneuvering in water as well as land and also power requirement will be higher[5]. A hexapod underwater robot is also available with six degrees of freedom which uses six paddles to propel[6]. Continuous paddling is required to propel in this robot. All these work is excellent but cannot satisfy purpose of floating without power requirement.

This paper represents the prototype of water surface robot along with its basic principle of buoyancy to remain on surface. For maneuvering in water, propeller mechanism is used to provide thrust to the robot. Weight measurement of robot to calculate buoyancy and according to these calculations, dimensions of the robot is decided. Here, shape of the robot selected is a cone shape to provide robot stability. Second section of this paper represents the use of buoyancy as a core idea to make robot float and necessity aspects to provide stability to cone. In third section calculation, modeling and CFD analysis simulation of the robot is described. Ideal material for the robot should be selected based on its ability of resistance against corrosion in changing environment and rigidity. Considering this, titanium is best material to be used for robot[7,9]. For developing prototype only, mild steel is used to make prototype and iron is used to fill apex of cone to provide necessary weight. DC motor with 1000 rpm is used for rotation of propellers.

II. DESIGN AND MODELING

A. Basic idea

To start from zero, first of all the shape for the robot selected is a cone shape. Two reasons for selecting cone shape, first one is that the robot will be symmetric and no further balancing will be necessary and second one is that the gradually increasing area from apex to base can be well utilized and no empty space will be remaining. Most important and core idea in this robot is the use of buoyancy. In a cone at the apex, if another metal is poured as per equal buoyant force to keep robot on surface of water, it will be stable and balanced without toppling as shown in figure 1. Toppling effect will be cancelled out by two forces; buoyant force and gravitational force and as a result after minor oscillation, cone will be stable.

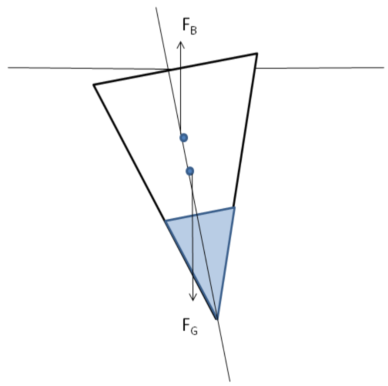

Figure 1: Basic idea for stability

B. Design and simulation

Considering Archimedes principle[3], weight of cone, weight of metal to be poured and extra weight i.e. weight of propellers and assemblies to be attached with cone is assumed first. After assuming all these according to weight of cone and equal amount of water displaced by cone, dimensions were available which are based on assumptions first. By using these dimensions, a cad model assembly is prepared for simulation testing. The dimensions are as follows:

Height of cone: 500mm,
Diameter of cone: 185 mm,
Height of metal inside cone: 210 mm.

These dimensions are helpful in finding Drag force and Drag coefficient from following equation:

$$F_d = ½ ϱv^2 C_d A$$

where, F_d is drag force, ϱ is density of water, v is velocity of water w.r.to robot, C_d is drag coefficient

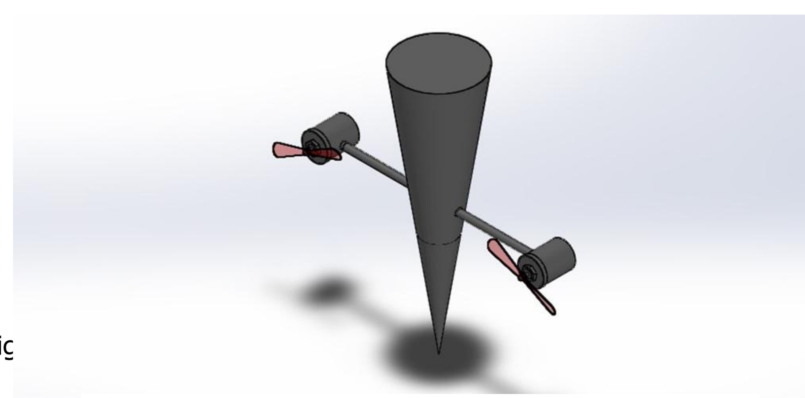

Figure 2: Model of prototype

which varies with shape and of the object[8] and A is reference area i.e. lateral area of cone. Density of normal water is 1000 kg/m^3 and same for the sea water is 1030 kg/m^3[10]. Here for prototype, normal water is used.

For providing thrust, propeller should be attached between center of gravity and center of buoyancy of the robot. Here, propellers are attached at the height of 256 mm from apex. Here, propeller, pipes of steel to pass wires and DC motor casing are modeled by reverse engineering. Final assembly is shown in figure 2.

After modeling, a model is inserted to CFD simulation software. Input for the simulation was first on the base of assumption to find drag force and drag coefficient from equation 1. Velocity of fluid was assumed 1 m/sec first to find above mentioned entities. Results obtained from CFD simulations at 1 m/sec are as follows:

Drag force: 18 N
Drag coefficient: 0.258

However, still actual velocity is to be obtained by experiment as to get exact values. Once experiment is completed after manufacturing prototype, again CFD analysis will be done by using actual velocity of prototype which is discussed in section 3 of this paper.

III. EXPERIMENT AND RESULTS

For manufacturing, mild steel is used for cone. Power given to both DC motor is 12 V by connecting 8 cells of 1.2 V in a series connection. A RF operated circuit is used to control robot remotely. After manufacturing, following weights are measured:

Weight of cone: 1.342 kg
Extra weight: 2.982 kg

i.e. to keep base of cone on surface of water, 2.982 kg of extra weight is necessary. For testing the prototype, steady water tank is used filled with normal water. A picture of prototype while testing is

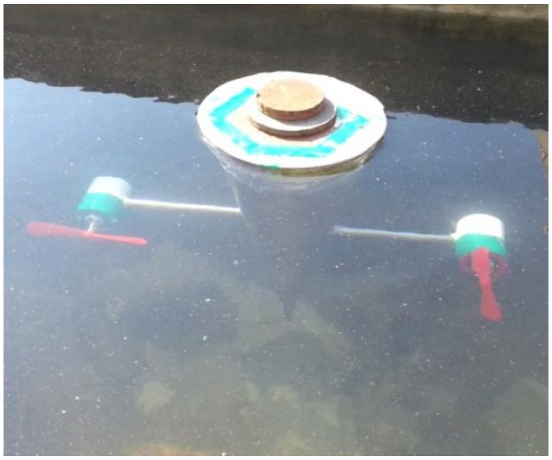

Figure 3: Prototype for testing

shown in figure 3.

After experimenting, F_d can be obtained by using known equation no. 2 of power by using measured velocity

$$P_d = F_d \times V \qquad (2)$$

and then using equation of F_d, C_d can be obtained. Thus performing experiment and measuring velocity, following results are obtained:

Velocity: 0.17 m/sec

Drag force: 0.8031 N
Drag coefficient: 0.3304

These values are not matching with CFD results obtained in section 2. The reason is that velocity in that simulation is kept 1 m/sec while actual velocity for these results is 0.17 m/sec. Again CFD simulation is performed with velocity equals to 0.17 m/sec and following results are obtained:

Drag force: 0.66 N
Drag coefficient: 0.307

Comparison of F_d and C_d by experiment and CFD simulation is listed in table below:

Table 1. Result comparison

Entity	**CFD results**	**Experimental Results**
Velocity 1 m/sec		
Drag coefficient	0.255	N/A
Drag force	18.8 N	N/A
Velocity 0.17 m/sec		
Drag coefficient	0.307	0.3304
Drag force	0.66 N	0.8031 N

IV. CONCLUSION AND FUTURE WORK

Stability of robot is confirmed by keeping center of gravity below the center of buoyancy. Forces necessary to propel in water are calculated both in CFD simulation and experimentally and results are closely nearer as shown in table 1. So it is clear that from power and area of any shape and using few steps, any modification to reduce drag force can be obtained virtually without wasting manufacturing costs. Automation of the robot along with the sensors according to application will be the future work of this paper.

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