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Research Article

Analysis of The Impact of Different Angles of Thrusters in Underwater Vehicles on Thrust Force in CAD Environment

Talha Gülgün[1]*, Göksel Alankaya[2], Muhammet Emin Duran[3], Mertcan Erdoğdu[4], İsmail Yalçınkaya[5], Akif Durdu[6], Hakan Terzioğlu[7]

[1] Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Makine Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0003-4896-8611)
[2] Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Makine Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0001-7158-112X)
[3] Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Makine Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0001-9686-8602)
[4] Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Makine Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0003-4613-8729)
[5] Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Makine Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0002-6567-399X)
[6] Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0002-5611-2322)
[7] Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Konya, Türkiye (ORCID: 0000-0001-5928-8457)

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Abstract

The need for unmanned underwater vehicles is increasing in the world and in our country. The use of unmanned underwater vehicles in ocean exploration, search and rescue, military and industrial applications is expanding day by day. In particular, unmanned underwater vehicles are an attractive option for underwater search, research and survey operations, as they are low cost compared to manned vehicles. In this article, a detailed vehicle design has been created and analyzed using the computer-aided design tool SOLIDWORKS. With these analyses, the effects of the angle of the engines positioned in unmanned underwater vehicles on speed, time, thrust force and precise positioning parameters will be explained by 2 simulation studies. The first of the simulations is the explanation of the data obtained as a result of the 45 degree angles of the thrusters to the body, and in the second simulation, the data obtained as a result of the positioning of the thrusters at 90 degree angles to the body. It has been observed that the angle of the thrusters positioned in line with the models made directly affects the maneuverability and thrust force. It has been observed that a vehicle positioned at an angle of 90 ° should be preferred in applications requiring gain from speed and time, and a vehicle positioned at an angle of 45 ° should be preferred in applications requiring precise positioning. In conclusion, in this study, it is defined how the thrusters positioning should be in order for the underwater vehicle designed to meet the requirements of a user to be the most efficient and suitable vehicle for the desired environment of mobility.

Keywords: Analysis, Angle of Thrusters, Mobility, Thrust Force, Unmanned Underwater Vehicle

Su Altı Araçlarında İtici Motorların Farklı Açılarda Konumlandırılmasının CAD Ortamında İtki Kuvvetine Etkisinin Analiz Uygulamaları

Öz

Dünyada ve ülkemizde insansız su altı araçlarına duyulan gereksinim giderek artmaktadır. İnsansız su altı araçlarının okyanus keşfi, arama – kurtarma, askeri ve endüstriyel uygulamalarda kullanım alanı her geçen gün genişlemektedir. Özellikle, insansız su altı araçları, insanlı araçlara kıyasla düşük maliyetli oldukları için su altı arama, araştırma ve anket işlemleri için cazip bir seçenek haline

*Corresponding Author: Konya Teknik Üniversitesi, Mühendislik ve Doğa Bilimleri Fakültesi, Makine Mühendisliği Bölümü, Konya, Türkiye, ORCID: 0000-0003-4896-8611, talhagulgunn@gmail.com

gelmektedir. Bu makalede, bilgisayar destekli tasarım aracı olan SOLIDWORKS programı kullanılarak ayrıntılı bir araç tasarımı oluşturulmuş ve analizlere tabi tutulmuştur. Bu analizler eşliğinde insansız su altı araçlarında konumlandırılan motorların açısının hız, zaman, itki kuvveti ve hassas konumlanma parametrelerine etkileri 2 simülasyon çalışması ile açıklanacaktır. Simülasyonlardan birincisi motorların gövdeye 45 derecelik açılar ile yerleşimi sonucu elde edilen verilerin açıklanması, ikinci simülasyonda ise motorların gövdeye 90 derecelik açılar ile konumlandırılması sonucu oluşan verilerin paylaşılmasıdır. Yapılan modellemeler doğrultusunda konumlandırılan motorların açısı manevra kabiliyetine ve itki kuvvetine doğrudan etki ettiği gözlemlenmiştir. Motorları 90° açı ile konumlandırılmış araç hız ve zamandan kazanım gerektiren uygulamalarda, 45° açı ile konumlandırılmış araç ise hassas konumlandırma gereken uygulamalarda tercih edilmesi gerektiği görülmüştür. Bu çalışmada, bir kullanıcının gereksinimlerini karşılamak için tasarlanan su altı aracının, hareket kabiliyetinin en verimli ve istenilen ortama uygun bir araç olması için motor konumlandırmalarının ne şekilde olması gerektiği tanımlanmıştır.

Anahtar Kelimeler: Analiz, Hareket Kabiliyeti, İnsansız Su Altı Aracı, İtki Kuvveti, Motor Açısı.

1. Introduction

Nowadays, unmanned underwater vehicles are used in a wide range of areas such as underwater search and rescue operations, ship underwater maintenance and repair operations, taking images from hazardous environments where divers cannot enter, military use, wrecks inspection and underwater cleaning (Li, Zhao, & Ge, 2018; Yi & Al-Qrimli, 2017).

The first remote-controlled underwater vehicle, closer to the form that is common today, is the Poodle vehicle designed by Dimitri Rebikoff in 1953 (Bovio, Cecchi, & Baralli, 2006). The US Navy's CURV Cable Controlled Underwater Recovery Vehicle removed an atomic bomb from under the sea after a plane crash off the Spanish town of Palomares in 1966, rescuing the crew of a submarine that sank off the coast of Ireland in 1973 when they had only a few minutes of oxygen left. They are the most important examples of how underwater vehicles can be operationally beneficial (Moore, Bohm, Jensen, & Johnston, 2010; Vukić & Mišković, 2016). Due to the as a matter of course of scientific research, more advanced technologies are needed. For this reason, the underwater systems used in the scientific field use the most complex and competent equipment (Eustice, Pizarro, & Singh, 2008). Unmanned underwater vehicles are basically evaluated in two main groups as Cable Controlled and Wireless-Autonomous (Omerdic & Roberts, 2004). The cable-controlled one is called" ROV (Remote Operating Vehicle)", while the autonomous one is called" AUV (ATONOMUS Underwater Vehicle)" (Amory & Maehle, 2018; Wu, 2018).

ROV systems have the best equipment and sensors among underwater systems for water base and underwater research purposes. Thanks to these sensors, extreme deep underwater biology and ecology, as well as habitat and organisms can be observed in detail. The flexibility of ROV systems enables different equipment and sensors to work harmoniously in many different scientific researches (Cui, Ge, How, & Choo, 2010). Furthermore, the high photographing capability and video recording systems in the cameras installed on the ROV systems enable the discovery of previously unexplored areas in the diving areas (Christ & Wernli Sr, 2013). In other words, ROVs provide scientists with more detailed information that man could not reach and provide before. ROV, in its most general definition, is an underwater robot that is controlled remotely by an operator and performs a number of functions that may be dangerous under water for different purposes.

Therefore, a ROV system consists of the operator controlling the vehicle as well as the equipment provided by the operator to control the vehicle, the cable connecting the vehicle to the surface, and the crane mechanisms that allow the vehicle to be land in water and taken back into the ground. ROVs " can be relatively small and simple vehicle means of taking images and making some measurements through underwater cameras for tracking purposes only. Many sensors that will be placed on them are cameras, sonar etc. By the help of these, there can also be large systems capable of operating largely autonomously and performing highly complex functions using manipulators (Christ & Wernli Sr, 2013). Today's technology, which makes the design and use of AUVs"s possible, enables unmanned underwater vehicles to act completely independently by hosting their own navigation systems and power units without cable connections that pose many problems and operational challenges (Alam, Ray, & Anavatti, 2014).

The aim of this thesis was to study two methods for determining appropriate thruster positions and angles in order to ensure the high maneuverability of remote controlled unmanned underwater vehicles (ROV) and autonomous unmanned underwater vehicles (AUV) in line with the specified targets. The first of these is the design model of the thrusters positioned at 45 degree angles. The reason for working on this model is that it provides the maneuverability that will enable the operator controlling the vehicle to perform the task more easily in applications requiring precise positioning. The other application studied is the design model, which deals with positioning the thrusters at 90 degree angles for situations requiring gain speed and time.

2. Material and Method

Underwater vehicles are robotic systems that can float underwater and are controlled from land by an operator (Stutters, Liu, Tiltman, & Brown, 2008). The main components of unmanned underwater vehicles are the chassis, thrusters, motor driver, battery(or power supply) and Control Board (Christ & Wernli Sr, 2013; Morgansen, Triplett, & Klein, 2007). If necessary, it can be equipped with different sensors and designed so that its operational capacity can be increased. These sensors are sonars (Forward View sonar, side scan sonar), magnetometers, cameras with different viewing capacities (low light camera, infrared camera, etc.), CTD (conductivity, temperature and depth), robot arm and cutting arm, water sample collector and equipment measuring water cleanliness can be given as examples (Choi, Hanai, Choi, & Yuh, 2003). Reasons why underwater vehicles are generally preferred; There is no-life-threatening during the mission (Singh, Roman, Pizarro, Eustice, & Can, 2007). Thanks to imaging techniques, monitoring of dangerous situations providable and can be taken precautions in advance. By means of purpose-oriented sensors, the desired data can be obtained from the environment in which it is located. Thanks to its autonomous capabilities, it is able to perform tasks alone (Choi et al., 2003). With the purpose-oriented equipment to be installed on them, it can make instant interventions.

2.1. Thrusters

Underwater thrusters are called all underwater robots that need electric propulsion to move underwater, consisting of propellers and nozzles. In underwater vehicles, thrusters can be preferred in different configurations with different thrusters numbers and positioning variety (Omerdic & Roberts, 2004). According to the efficiency of the thrusters used, different thrust forces can be obtained by using them in the vehicle designed. The resulting thrust determines the performance of the vehicle by directly affecting parameters such as maneuverability, speed and time (Gonzalez, 2004).

2.2. Thrust

Thrust is a mechanical force generated by the engines to move the vehicle through in water. Thrust is used to overcome the drag of an vehicle, and to overcome the weight of a vehicle. Thrust is a force, so it is a vector with direction and magnitude. Thrust force T and drag force D forces are vectors associated with their direction and magnitude. The thrust minus the drag of the vehicle is called the excess thrust and has an effect on vehicle.

2.3. Computational Fluid Dynamics (CFD) Applications

Modeling and simulation is the practice that is at the heart of current technological innovations and has become a fundamental tool in many engineering fields. When designing underwater vehicles it is useful for time and cost to be subjected to some tests and analyses in a computer aided design (CAD) environment because the test stages are costly and time consuming.

With the increasing development of computers, Computational-Fluid Dynamics (CFD) applications have gained importance in the maritime industry (Amory & Maehle, 2018). Besides, for initial design and prototype testing, smaller-scale testing is often desirable and economical to run during the developmental stage (Chin & Lau, 2012). Two different methods can be used when carry out flow analysis.

The first of these is the ROV moving forward at a constant speed while the fluid domain remains static with no current flow. Another situation is that, instead of the ROV moving, the flow moves at a constant speed in the opposite direction to the ROV, which is statically stationary. Since the drag force depends only on the relative motion between the ROV and the fluid, the result obtained from the two situations is the same (Chin & Lau, 2012). Simulations were carried out taking in consideration of the stated circumstances.

2.4. Modeling of Thrusters

The main challenge in flow analysis is to determine the fluid domain size. In an unconnected fluid domain, an infinitely large fluid domain is needed to study the damping force acting on the ROV. This is impractical in both CFD and experimental process (Cely, Saltaren, Portilla, Yakrangi, & Rodriguez-Barroso, 2019). Because the environment being analyzed is a computational area, it was observed that the fluid field dimensions directly affect the resulting thrust Force values as a result of the flow analysis experiments.

Therefore, the simulated vehicle is placed in the center of the flow volume of 10 m x 5 m x 2m which is the testing area. The analysis was carried out in Solidworks Flow simulation. Flow analysis is based on the first case where the water is stationary and the vehicle is moving. In order to transfer this situation to the simulation environment, it is necessary to model the thrusters that enable the vehicle to move.

For the 3-blade propeller region of the thrusters, there will be a newly formed cylindrical disc covering the propeller in flow simulation. For the boundary zone, the rotor part of the thruster is chosen as the real wall and the stator (Aras et al., 2019). The analysis will result in the force target relative to the y-axis at 3075 rpm, at 3600 rpm, at 3783 rpm which are the angular speeds at which the thrusters is suplied at different operating voltages. The resulting force is shown by graphs. This force provides the movement of the vehicle by overcoming the resistance of the water against the movement of the vehicle.

3. Results and Discussion

3.1. Positioning of Engines at A 90 Degree Angle

2 thrusters were used for forward movement in the vehicle design. In Solidworks program, flow analysis was performed in the flow domain in the size of 10 meters x 5 meters x 2 meters. The following results were obtained when the thrusers were suplied current at different voltages.

At the forward motion of the vehicle;

- When 2 thrusters are powered by 12 V, it operates at a maximum of 3075 Rpm. As a result, the vehicle has a maximum speed of 3,7902 m/s and a total thrust of 5,4364 Kgf.
- When 2 thrusteres are powered by 16 V, it operates at a maximum of 3600 Rpm. As a result, the maximum speed of the vehicle is 4,5040 m/s and the total thrust is 7,4835 Kgf.
- When 2 thrusters are powered by 20 V, it operates at a maximum of 3783 Rpm. As a result, the maximum speed of the vehicle is 4,8161 m/s and the total thrust is 6,7559 Kgf.

Figure 1 shows the graph of the thrust force that generated when the thrusters are suplied with 16V and in Figure 2 the visualization of the flow lines formed at the time of simulation. When the graph is examined, the total thrust is initially high and it has been observed that after 60 iteration it becomes stable by taking on a stable structure.

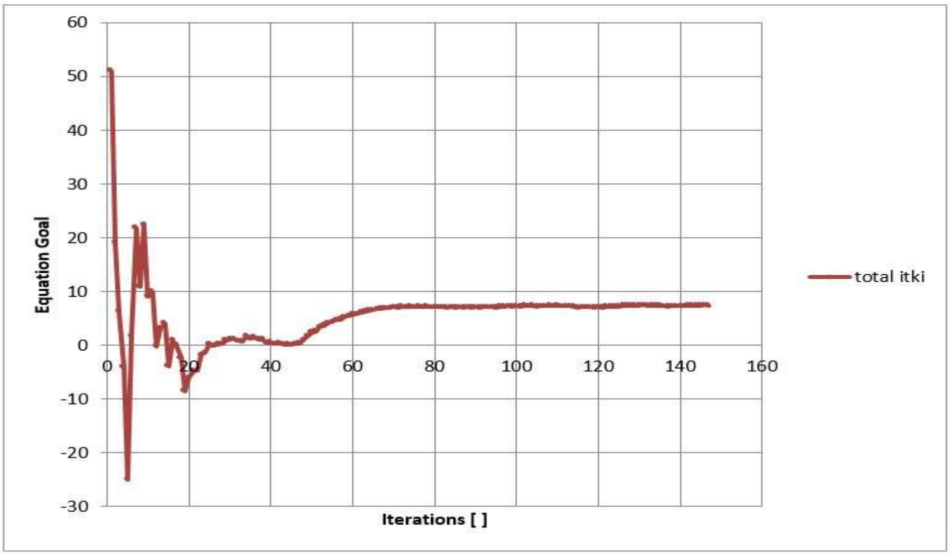

Figure 1. Graph of thrust force when thrusters are fed by 16V

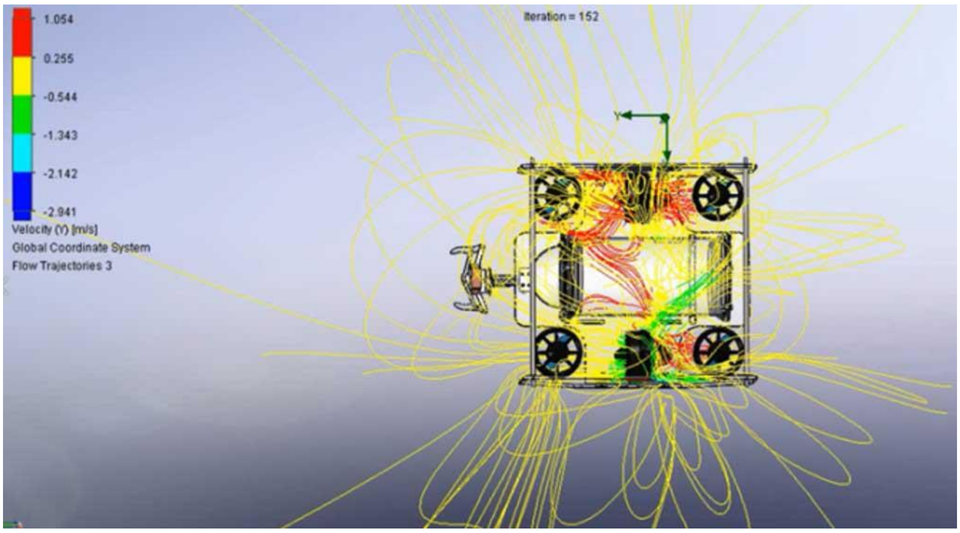

Figure 2. Visualization of flow lines formed during simulation

3.2. Positioning of Engines at A 45 Degree Angle

4 thrusters were used for forward movement in the vehicle design. In Solidworks program, flow analysis was performed in the flow domain in the size of 10 meters x 5 meters x 2 meters. The following results were obtained when the thrusters were suplied current 16V voltages.

- When 4 thrusters are powered by 16V, it operates at a maximum of 4200 Rpm. As a result, the maximum speed of the vehicle is 10,8719 m/s and the total thrust is 4,6233 Kgf.

Figure 3 shows the graph of the thrust force that generated when the thrusters are suplied with 16V and in Figure 4 the visualization of the flow lines formed at the time of simulation.

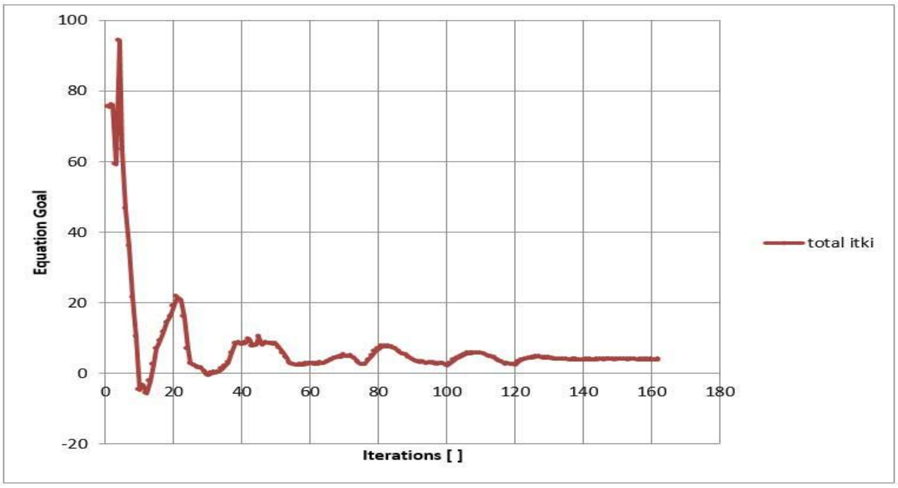

Figure 3. Graph of thrust force when thrusters are fed by 16V

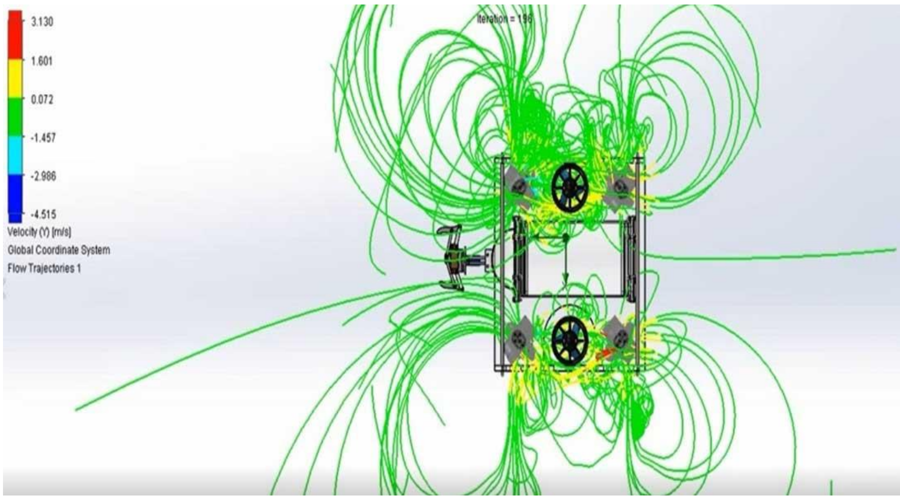

Figure 4. Visualization of flow lines formed during simulation

According to Newton's second law(basic principle of dynamics); while the mass of the vehicle remains constant, the reduction of the thrust force will mean the reduction of the acceleration (Yi & Al-Qrimli, 2017). As can be seen in the results of the analysis, it was observed that the thrusters, positioned at two different angles and operated at equal voltage values, it generate different thrust values. The acceleration of the vehicle, whose thrusters are positioned at a 90° angle relative to the body, is greater than that of the vehicle positioned at a 45° angle to the body. In this case it has been seen that this positioning will be appropriate for applications that require gain speed and time. It has been observed that positioning the thrusters at an angle of 45° to the body of the vehicle is appropriate in applications requiring precise positioning, since the thrusters array positioned at an angle of 90° to the body of the vehicle may cause problems due to high acceleration in applications requiring precise positioning.

The results from this study can be used in the scientific, technological and defense industries. After this article, it is aimed to make the right choices at the idea stage of the project, to develop these data and to serve the wishes of the designers by providing the engineers who want to conduct research on underwater vehicle design to learn about the propulsion force, acceleration and speed of the vehicle they will design. It is thought that the unmanned underwater vehicles to be designed will contribute to the defense industry as well as the purpose of underwater observation and exploration in our country, which is surrounded by sea on three sides by autonomous and/or remote control.

4. Conclusions and Recommendations

In this article, the speed, thrust and acceleration of underwater thrusters operating at equal voltage values on the same design model are calculated by positioning them at different angles. According to the results of the analysis, vehicle mobility, improving the maneuvers that the vehicle will perform in accordance with the desired function and these values were tested and compared in computer environment (CFD).

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