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Analysis of Relation Between Propulsion Angle and Thrust Generation of SEA-EYE

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Abstract. Analysis of the relation between propulsion angle and thrust generation of SEA-EYE was presented and discussed with three different angles of the boat propeller. The results of this analysis has been decided to solve the problem of the study. Features of SEA-EYE boat and the boat has been analysed in the Ansys Workbench (Fluid Flow CFX). The resulting decision was presented in the form of diagrams, tables and graphs. The results for the three boat propeller angle is almost close to perfect, but the final decision was made after carefully researched and as far as possible.

1. Introduction

SEA-EYE is an Unmanned Surface Vehicle (USV), for sea observation and checking applications. Unmanned Surface Vehicles (USV) or Autonomous Surface Vehicles (ASV) is a vehicle without a driver operating in the water. Harbour protection technologies are assessed through a survey of use Unmanned Surface Vehicles (USV) especially SEA-EYE is used for spying. The SEA-EYE can be controlled in two ways. It can either be remotely controlled physically, or it can work self-sufficiently utilizing GPS. The most exceptional peculiarity of its outline is the way it does away with the requirement for adjustment frameworks that are regularly coordinated into USV to keep them from overturning.

The speciality here is that it can move upside down. There are two sets of propellers, top and bottom, so when it flips over, the top propellers will switch off and the bottom ones will switch on automatically. It's powered by an electric motor, it also produces very little noise, which gives it an added advantage when it needs to approach another boat covertly, according to its developers. Since it doesn't use a fuel engine, it's also claimed to be inexpensive to maintain and operate.

The battery-powered USV can be recharged using the onboard solar panels, helping ensure that it always has enough power to turn back. It can be modified to explore to a specific set of coordinates through GPS, with the administrators mindful of its area at all times as it consistently transmits its coordinates over to the base station.

The advantages: -

- ✓ Anti-capsize system
- ✓ Day and night vision system
- ✓ Ground controller with user friendly GUI



- ✓ Solar powered
- ✓ Autonomous path planning and navigation system
- ✓ Can overcome the problem of using manpower to do the tedious task of spying with alternating same area

2. Unmanned Surface Vehicle (USV)

Unmanned Surface Vehicle (USV) use the electrochemical power sources have classified in four types, such as a seawater battery, inside pressure ship body is standard batteries and working at ordinary pressure, fuel cell, for electrically insulated from seawater is compensated battery working pressure at ambient pressure [1].

There are several techniques to boost the powers and energy conversion system for unmanned surface vehicle is tether method, battery method, environmental energy conversion and docking station establishment [3]. The propeller behind marine hull (astern autonomous underwater vehicles) will cause various effects on the performance because multiple angles. Three separate conditions, including straight movement two steady approaches equivalent to $\alpha = 5^\circ$ and 15° . The general extent for the approach somewhere around 0° and 15° . Comparable hydrodynamic proficiency for propeller at diverse approaches, the created push and subsequently the required propeller torque were altogether higher than those in straight [9].

Propellers there is the utilization of electric power to drive the torque and power control. The parts of the study were the sort or state of the propellers, including peculiarities, element stream and push misfortune impacts. Thruster controller for low level there are two various of typical and great conditions. In typical conditions, when encountering low to direct push misfortunes and in amazing conditions, when encountering substantial and sudden push misfortunes because of ventilation and done and finished with water impacts. In the affectability to push misfortunes, when the loss of propeller stacking may, though changes in propeller push and torque, lead to changes in shaft speed and power [5].

3. Thrust

According to the second and third laws of Newton's, thrust is the mechanical force resulting from the reaction accelerating a mass of gas. System that accelerates mass in one direction causes power equal in magnitude but opposite in direction. Thrust in mechanical engineering is of force orthogonal.

In the direction perpendicular to the surface normal either be used to power and called thrust. Force or thrust, measured in units of the International System of Units (SI) as the Newton (N), and thrust is also used to accelerate 1 kilogram of mass at the rate of 1 meter per second squared.

From Newton's second law of motion: -

$$F = \frac{[(m * V)^2 - (m * V)^1]}{(t_2 - t_1)} \quad (1)$$

The simple force equation: -

$$F = m * a \quad (2)$$

A boat produce thrust when the propeller is turned on by pushing the water backwards and overall force contained in the water moving through the propeller.

$$\mathbf{T} = \mathbf{v} \frac{dm}{dt} \quad (3)$$

where: -

\mathbf{T} = thrust (force)

$\frac{dm}{dt}$ = the rate of change of mass with respect to time (mass flow rate of exhaust)

\mathbf{v} = the speed of the exhaust gases

4. Momentum Flux Correction Factor

The velocity across most inlets and outlets is not uniform. Dimensionless correction factor β , called the momentum flux correction factor.

Fixed Control Volume: -

$$\Sigma \vec{F} = \frac{d}{dt} \int_{CV} \rho \vec{V} dv + \int_{CS} \rho \vec{V} (\vec{V} \cdot \vec{n}) dA$$

$$\sum \vec{F} = \frac{d}{dt} \int_{CV} \rho \vec{V} dv + \sum_{out} \beta \dot{m} \vec{V}_{avg} + \sum_{in} \beta \dot{m} \vec{V}_{avg} \quad (4)$$

β produced either into or out of control surfaces for the inlet or outlet of the cross sectional area A_c is then shown to the mass flow rate \dot{m} and an average \vec{V}_{avg} through the inlet or outlet.

Momentum flux across an inlet or outlet: -

$$\int_{Ac} \rho \vec{V} (\vec{V} \cdot \vec{n}) dAc = \beta \dot{m} \vec{V}_{avg} \quad (5)$$

* Along the inlet or outlet density is uniform while \vec{V} is in the same direction as \vec{V}_{avg}

$$\beta = \frac{\int_{Ac} \rho \vec{V} (\vec{V} \cdot \vec{n}) dAc}{\dot{m} V_{avg}} = \frac{\int_{Ac} \rho \vec{V} (\vec{V} \cdot \vec{n}) dAc}{\rho V_{avg} Ac V_{avg}} \quad (6)$$

where: -

$V_{avg} = \text{constant}$

substituted $\rho V_{avg} Ac = \dot{m}$

At the inlet or outlet area can happen the control surface slices normal: -

$$(\vec{V} \cdot \vec{n}) dAc = V dAc \quad (7)$$

Momentum flux correction factor: -

$$\beta = \frac{1}{Ac} \int_{Ac} \left(\frac{V}{V_{avg}} \right)^2 dAc \quad (8)$$

* β greater than or equal to unit

5. Calculation

The value of Sea-Eye boat such as: -

Dimension of propeller,

$D=2.5 \text{ in} \rightarrow 0.0635 \text{ m}$


Mass of overall boat, $m = 7 \text{ kg}$

Density of water, $\rho = 998 \text{ kg/m}^3$

Gravity, $g = 9.81 \text{ m/s}^2$

Reynold number for water, $Re = 2300$

Area

$A = \frac{\pi D^2}{4}$  for 4 propellers, $A' = A \times 4$

Velocity

$$\text{Velocity inlet, } V_{\text{inlet}} \Rightarrow \text{Re} = \frac{\rho V_{\text{inlet}} D}{\mu}$$

$$\text{Velocity outlet, } V_{\text{outlet}} = \sqrt{\frac{m g}{\rho A'}}$$

Volume flow rate

$$V_{\text{outlet}} = A' V_{\text{outlet}}$$

Mass flow rate

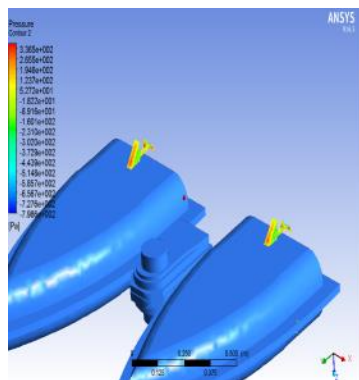
$$\dot{m} = \rho V_{\text{outlet}}$$

6. Results and discussions

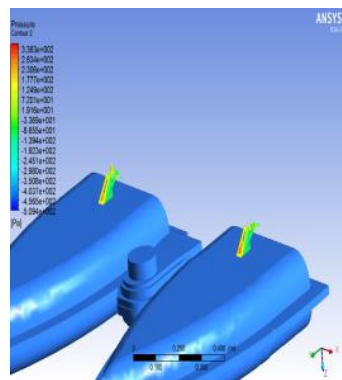
Table 6.1 shows the value of pressure and velocity for every angle of propeller. From the value can find the value of thrust and the results will get a difference results. The results will be able to know which angle the propeller most suitable for a boat moving smoothly. Thus, the pressure and velocity of water distributions analysis are shown in figure 6.1 and 6.2.

Table 6.1. Results of pressure and velocity

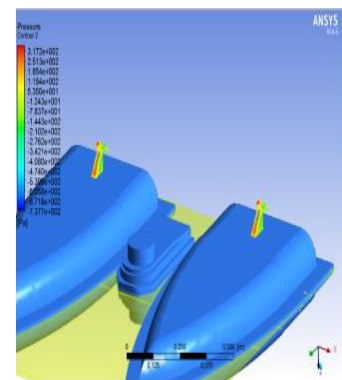
| Angle of SEA-EYE propeller | Pressure (Pa) | Velocity (m/s) | Thrust (N) |
|----------------------------|---------------|----------------|------------|
| 0° | 127900 | 26.04 | 1478.81 |
| 30° | 261800 | 25.98 | 1475.40 |
| 50° | 318900 | 24.46 | 1389.08 |



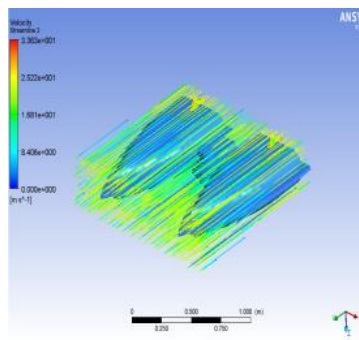
(a) angle of propeller 0°



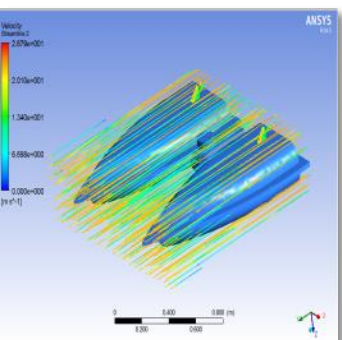
(b) angle of propeller 30°



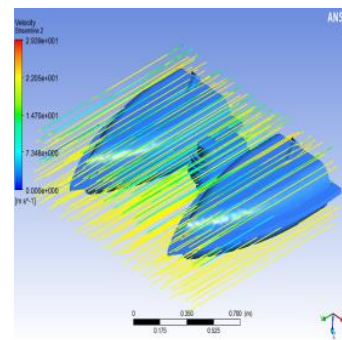
(c) angle of propeller 50°

Figure 6.1. The pressure at propeller for the water (angle of propeller 0°, 30°, 50°)

(a) angle of propeller 0°



(b) angle of propeller 30°



(c) angle of propeller 50°

Figure 6.2. The velocity distribution of the water (angle of propeller 0°, 30°, 50°)

Figure 6.3 describe the value of velocity vs. angle of SEA-EYE propeller. The velocity of each angle is not much difference but there are variations. For angle 0° the velocity is 25.22 m/s, for angle 30° the velocity decrease to 22.62 m/s and for angle 50° the velocity also decreases to 22.05 m/s. Thus, will be able to solve this problem. From the value of velocity can know the pressure at SEA-EYE boat high or low.

Figure 6.4 describe the value of pressure vs. angle of SEA-EYE propeller. The pressure of each angle is not much difference but there are variations. For angle 0° the pressure is 123.7 Pa, for angle 30° the pressure increase to 230.6 Pa and for angle 50° the pressure also increases to 251.3 Pa. Thus, will be able to solve this problem. From the value can know the pressure at SEA-EYE boat is high or low.

Figure 6.5 describe the value of thrust vs. angle of SEA-EYE propeller. The velocity of each angle is not much difference but there are variations. To get the value of thrust from the value of velocity multiply the value of mass flow rate. For angle 0° the thrust is 742.5 N, for angle 30° the thrust decrease to 665.96 N and for angle 50° the thrust also decreases to 649.17 N. From the results will know which angle is the best.

From the analysis, it has been decided to choose the angle of propeller is 0° . This is because the pressure at this angle is low and the thrust is high. Relation between this two value is also have connection with the high value of velocity. For the other two angles 30° and 50° can also be used but are not suitable and not achieve the objectives of this project to get the speed of boat is smoothly.

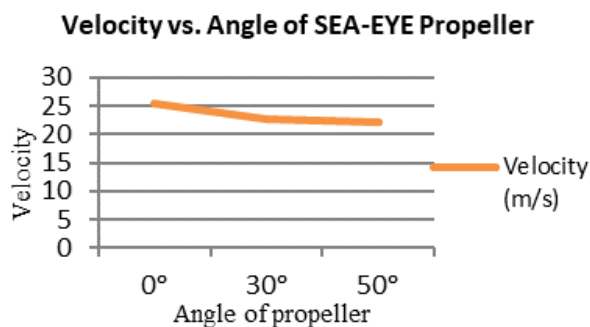


Figure 6.3. Velocity vs. Angle of SEA-EYE Propeller

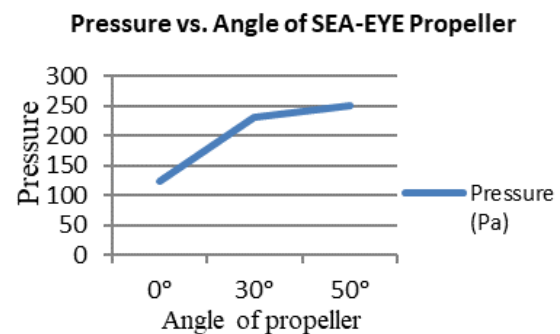


Figure 6.4. Pressure vs. Angle of SEA-EYE Propeller

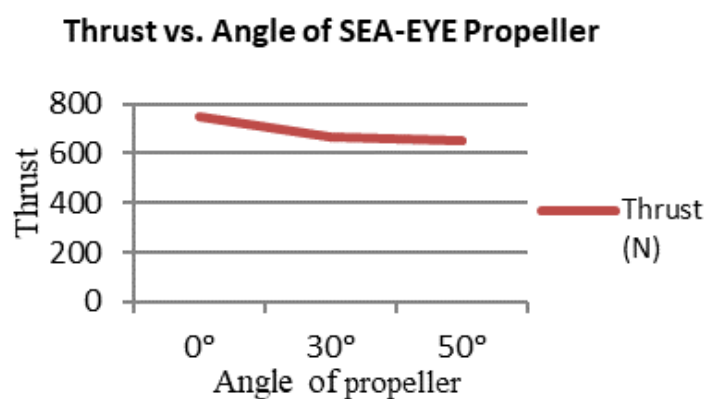


Figure 6.5. Thrust vs. Angle of SEA-EYE Propeller

7. Conclusion and recommendation

This study has analysed the relation between propulsion angle and thrust generation of SEA-EYE. The analysis has assisted by Ansys Workbench (Fluid Flow CFX) simulation and the drawing with Catia. For the objective one has achieved. In Catia software all parts of SEA-EYE were drawn using it. Then, the boat drawing transfer to Ansys software. In Ansys Workbench software have many systems to

analysis any problems. For example, the systems are Fluid Flow CFX, Fluid Flow Fluent, etc. For this project only use system Fluid Flow CFX. The objective number four has achieved with use this software.

This analysis, describe about relation between pressure, velocity and thrust of SEA-EYE boat. The results show details information. The differences of high and low values of parameters are very important to make the right decision. By doing this analysis, we can know more about the boat, pressure, velocity and more. Besides, the causes and why it is so it can be identified.

As a conclusion of this study, the selection of the angle of propeller is 0° is good because before making any decision expires research has been made as far as possible. For other two angle 30° and 50° also good to use but both is not much suitable for this problem.

Acknowledgments

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