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Hydrodynamic Energy Devices to Improve the Efficiency of Propulsion System in AUVs

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Abstract

Usually, most of the AUV has the propeller and it is placed in a suitable position for maneuvering in the required direction. For single propeller AUVs, propeller is placed at the aft, and direction is controlled using wings that are placed aft. Energy is a major part of an underwater operation to decide the duration of underwater operation. To increase the duration of the battery, either the energy consumption can be reduced or the efficiency of the propulsion system needs to be improved. Here the possible opportunities to improve the propulsion system using hydrodynamic energy devices are discussed. Though many options are available, based on space availability & speed, a suitable combination of devices can be added. It is recommended to carry out CFD analysis to make sure that proposed devices can bring improvement in the propulsion system before it is implemented.

Keywords: propulsion system, energy saving device, rudder, computational fluid dynamics

1. Introduction

Marine transport is the world's largest, cheapest and less pollution transport system when compared to road, railway, and air. International maritime organization (IMO) has taken initiative to reduce the pollution and three standards were introduced as (i) Energy Efficiency Design Index (EEDI), (ii) Energy Efficiency Operational Index (EEOI), and (iii) Ship Energy Efficiency Management Plan (SEEMP). Under the EEDI, optimization is recommended in ship particular, hull, and improves the propulsion system with new technology. It was encouraged to use renewable energy sources like wind and solar. Altogether, pollution can be reduced and fuel oil consumption can come down which is saving for the ship operator. The propulsion system consists of the main engine, shaft, gearbox, propeller, and rudder where the engine is efficiency can be improved by the manufacturer. To improve the propulsion system, as a designer, the scope is limited to that propeller and rudder. In total energy, only 70% is used for the thrust generation, and the remaining 30% goes as a loss of heat, friction, wave, and vortex.

The conventional method, traditional way of propeller, and rudder is used to generate thrust and manoeuvrability. Achieving the maximum performance of the propulsion system is the ultimate aim for the ship designer. During the initial design stage itself, a suitable underwater propulsion device needs to be tested before it is ready for implementation. Energy saving devices (ESD) an additional part which are added to the existing conventional propulsion system in the ship. To improve the propulsion system, different technology, and energy-saving devices were used to reduce fuel oil consumption [4,5,6,9]. Based on earlier experience, every ship is unique because of its unique hull shape, main particulars, and operational parameters. Even operation parameters like speed, draft, and trim can bring changes in the performance of the vessel which can lead to increase in fuel consumption [11,12]. Considering the uniqueness of the vessel, suitable technology, and energy-saving devices are checked and implemented which can improve the propulsion system.

Best AUV is decided based on the maximum travel with less battery energy consumption and completes the targeted goal in lesser time by reaching in a short route. Hydrodynamic energy devices can reduce the wastage of energy. For the underwater propulsion that too for AUV, energy consumption is monitored and needs a proper design to increase the operating time of AUV. In this paper, the authors would like to present the selected device which can improve the propulsion efficiency from a hydrodynamic point of view.

2. Propulsion system

Propulsion forces are used for the movement of the underwater vehicle in the water. Performance of the vehicle is based on the propulsion system where every engineer/naval architect spend critical time to decide the architect. For underwater vehicles, the propulsion system can be varied from one to five depends on the shape and purpose of the vehicle. For most of the commercial vehicle underwater vehicle, single propulsion is used. There was a vehicle for underwater hull inspection which was used five propulsion systems. Here the propulsion means the setup which includes motor and propeller in some cases direction controller is added. This controller helps the moor to change the direction of rotation. Let us take the propulsions system which is fitted at the centre to move the vehicle top and bottom. When the rotation is clockwise direction, it can move the vehicle downwards and when it rotates in anticlockwise direction, it can move upwards. Upward movement helps the vehicle bring out of the water and the clockwise direction helps the vehicle to immerse vehicle.

3. Hydrodynamic Energy Devices

A hydrodynamic energy device is a device that can divert a fluid flow path as an energy orientation towards an energy absorber or dissipater to utilize in the improvement of the underwater propulsion system from the hydrodynamic point of view. Aerofoil theory can be compared to change the direction and directly changing the flow of energy. Energy devices must be planned to divert the flow towards the upstream of water and the ultimate aim is to bring better flow. The shape of the device is preferred to have an aerofoil shape. Usually, this energy device is placed before and after the propeller. There are some options to have at the propeller. Though the improvement is small in long run, it can bring a lot of energy savings. The author recommends having more than one device in every propulsion system and reducing the energy loss. For the marine application, a pre-swirl energy saving device was discussed with performance and life cycle assessment [1,2].

4. Propeller Efficiency and Energy Loss

Propeller efficiency is the power produced to drive the vehicle divide by the power applied through the motor or engine. Propeller parameters are fixed to achieve maximum efficiency for the desired rotational speed, propeller pitch, and diameter of the propeller [10]. Propeller efficiency can be analyzed using CFD in open water and near the hull. This analysis brings the performance of the propeller and if the necessary experimental study can be carried out for the propeller. Propeller efficiency needs to be compared with a different combination of devices and few cases are discussed by Salma [3]. Energy loss is the resistance generated by the body and additional objects which are used for the operation of the vehicle. It is recommended to have the optimization of shape in the entire body. It is observed that more than 30 percent of energy is being wasted in transportation. To reduce the energy loss, proper route planning for the vehicle, well algorithm to control the propulsion system. In marine industry, energy saving progress is unavoidable to satisfy the regulatory bodies and some of the energy saving possibilities are discussed [7,8]. The AUV also needs to have a different configuration of the device to have a better propulsion system.

5. Location and Energy Devices

In general, the energy saving device can be used in the entire hull and again it depends on the device. For the AUV, it is targeted to use only in propulsion system area. Many devices have been implemented in marine ships for different ships and few devices have been recommended to have for AUV. These devices have been categorized into three as per the location of fitting with reference to the centre of the propeller. After the propeller devices are referred to as (i) Upward stream of propeller (ii) At propeller and (iii) downward stream of the propeller which is before the propeller. Now each category can be seen with images which are self explanatory. Though it is used in a ship and this can be used for AUVs.

5.1 Downward Stream of Propeller

Under this section, figure 1 to 4 shows the different hydrodynamic energy devices and these need to be modified with minor changes. Figure 1 to 4 are showing the possible device which can be executed to increase the battery life for the AUV operation.

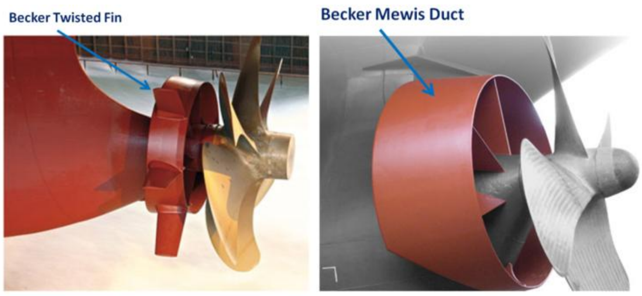
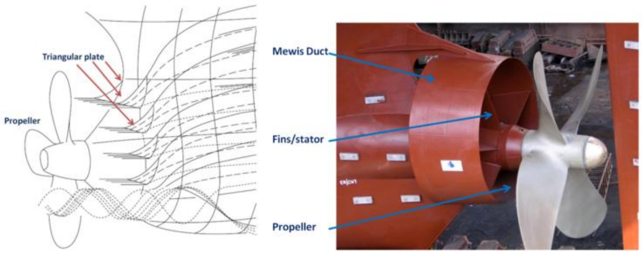


Fig.1. Becker Twisted Fin and Becker Mewis Duct



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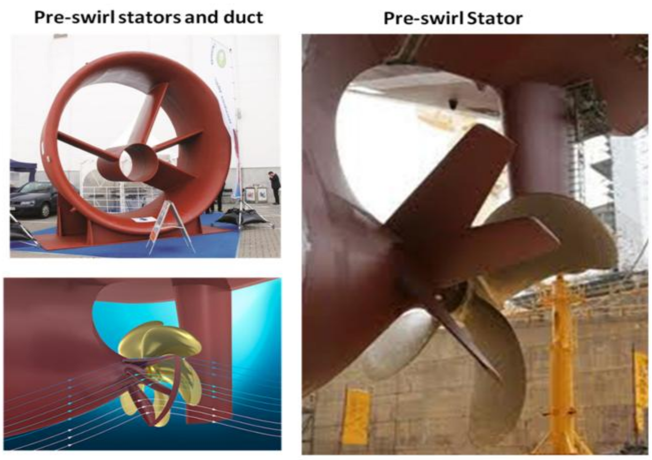

Fig.3. Pre-swirl stators and duct and Pre-swirl stators

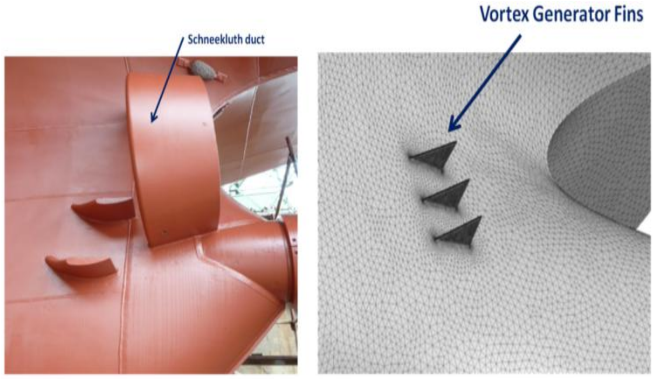

Fig.4. Schneekluth duct and Vortex Generators Fins

5.2 At Propeller

In this section, changes are proposed at the propeller and each image is well drafted sketches. The author prefers to have ducting for every AUV because it can help for manoeuvrability. Same time, it does not add more resistance. Figure 5 to 7 are showing the possible device which can be executed at the propeller location to increase the battery life for the AUV operation.

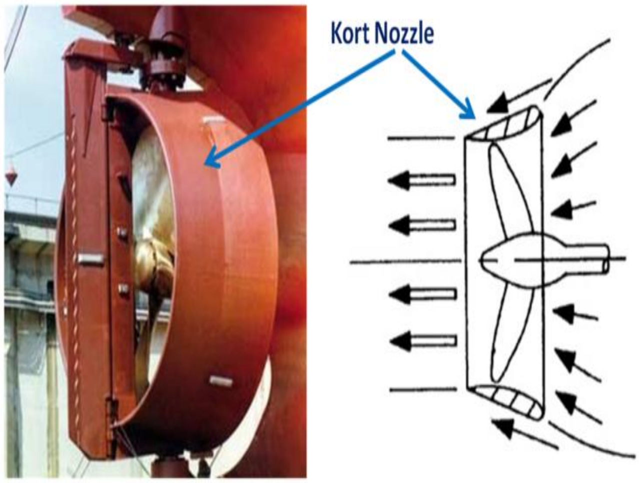

Fig.5. Kort Nozzle

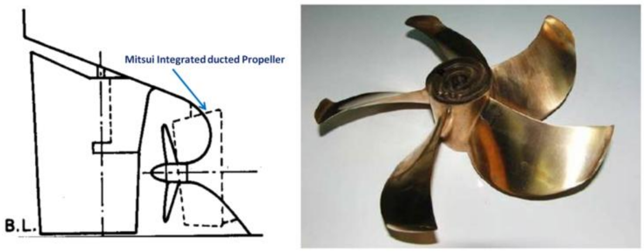

Fig.6. Mitsui Integrated Ducted Propeller and Tip Modified Propeller

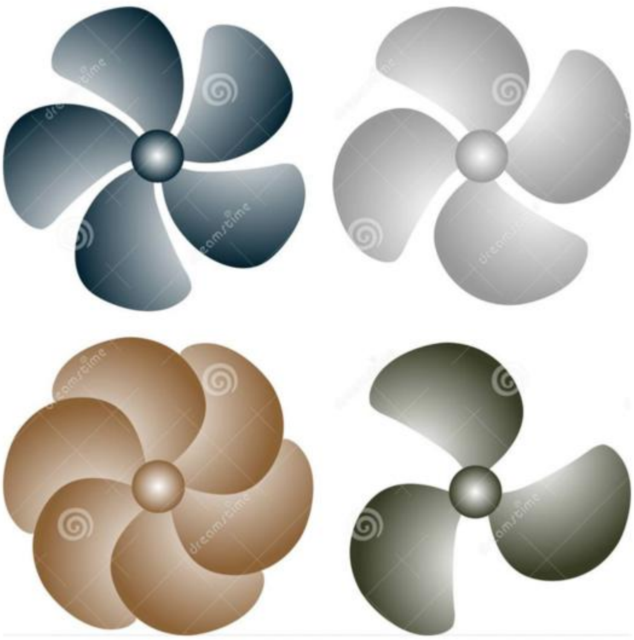

Fig.7. Number of Blades in Propeller

5.3 Upward Stream of Propeller

When water leaves from the propeller, it can add resistance, or divergence of flow that can happen which can increase the resistance. Small changes can bring improvement in performance. In underwater operation, one unit of saving is equal to 5 units of energy. Figures 8 and 9 are showing the possible device toward the flow after the propeller and everything needs to be analysed before the execution.

Fig.8. Grim Vane Wheel and Post-swirl Device

Fig.9. Propeller Cap Fin and Propeller Boss Cap Fins

6. Implementation Approach

Though there are many hydrodynamic devices are discussed, it is a good practice to make sure that the selected device can bring improvement to the propulsion system either by reducing the energy consumption or increase the propulsion system efficiency. A suitable device comes from the experience of the designer and expertise in understanding the flow. Considering the size of the propeller, this device can be implemented and the test can be carried to see the performance. As it was discussed that performance depends on the speed, shape, and size of the entire AUV, it is good to study the different combinations of devices. Before implementing in the AUV, the Author is preferred to study the performance using CFD and CFD can solve practical application for the marine industry [8] and CFD is treated as an alternative tool to carry out experimental analysis [9]. This helps to explore the different devices for the same propulsion and the optimum device is selected for this vehicle.

Conclusions

Considering the future demand, this paper explained the importance of an efficient propulsion system for the Autonomous Underwater Vehicle. Saving of energy by the hydrodynamic property is well expressed and this has been implemented in the ship propulsion system. Based on the hydrodynamic property and shape, each setup has been named an energy saving device. For the AUV, three locations have been identified as a primary location from the propeller location based on the existing implementation at the ship. These energy saving devices are discussed with images. Though many devices are discussed, the engineer needs to select a suitable combination of devices based on the shape and speed of AUV. The author has a strong recommendation to have CFD for the selected energy saving device before implementation which increases the confidence of energy saving and assured the customer to have to get an efficient propulsion system.

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