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# CHALLENGES IN DESIGNING MOTORS FOR REMOTELY OPERATED UNDERWATER VEHICLES: A FOCUS ON HYDRODYNAMICS

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*Abstract*

***Exploration of oceans and other marine bodies has become a crucial contribution to major scientific and technological advancements. Over time, modern equipment has been developed to aid in the exploration of marine bodies and the expansion of marine technology. Among the technologies developed are the remotely operated vehicles, which operate underwater without a human onboard. These vehicles are built based on the various principles of hydrodynamics, which allow them to maneuver marine environments easily. However, due to their unique operating environment, there are numerous challenges in designing and developing these underwater remotely operated vehicles. This paper addresses the various hydrodynamics of underwater robots and analyses the different challenges in designing motors for these vehicles. Various hydraulic forces acting on the robot underwater must be considered in their design, such as drag and water resistance, stability and buoyancy, depth and pressure, and maneuverability. The challenges discussed include designing hydrostatic pressure tolerance control systems, underwater actuated conditions, corrosion and material durability, and coupling issues. Solving the problems highlighted could lead to a remarkable ROV industry and maritime technology breakthrough.***

***Keywords:** Hydrodynamics, Marine, Underwater remotely operated vehicles (ROVs), Underwater robots*

## I. INTRODUCTION

The deep seas were initially explored through underwater diving, which was limited and risky for human life. However, the development of underwater technology has brought about modern equipment that has revolutionized underwater exploration. The invention of remotely operated vehicles (ROVs) that can operate in marine environments was a major technology breakthrough in the successful and safe exploration of the deep seas. Remotely operated underwater vehicles are advanced robots designed and equipped to undertake underwater operations such as deep sea infrastructure maintenance and exploration. ROVs are unoccupied submersible robotic systems. These vehicles are built based on the various principles of hydrodynamics, which allow them to maneuver marine environments easily. However, numerous challenges are faced when designing and developing these underwater ROVs. This paper addresses the various hydrodynamics of underwater robots and analyses the various design challenges faced in their development.

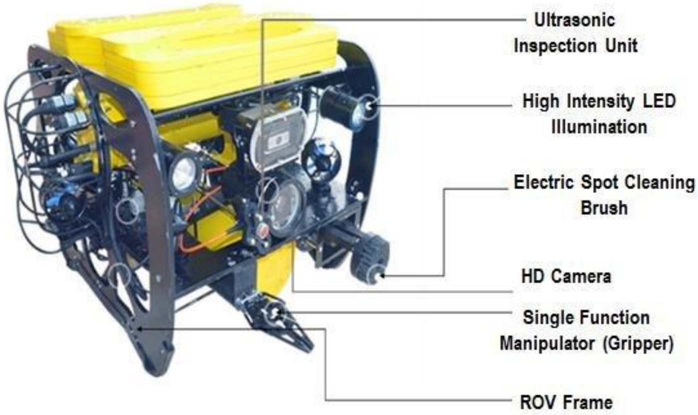


Fig. 1. Key Features of a ROV. Adapted from A. A. Jacob, M. Galipalli, V. Upadhyay, P. Rajagopal, and K. Balasubramaniam NDE 2018 Conference & Exhibition Paper [2]

## II. HYDRODYNAMICS OF UNDERWATER ROBOTS

The manoeuvrability of underwater robots is a crucial factor in their efficiency. For a robot to be effective, it must be able to move underwater under minimal stress. The various hydraulic forces acting on the robot underwater must be considered in their design for the robot to operate smoothly. Underwater robots face different forces, such as drag and water resistance, making their movement difficult underwater. In other instances, these robots are exposed to complex fluid flow fields such as waves and flowing water. However, these forces are curbed in the hydrodynamic designs that are applied in the production of these robots.

There are various methods that scientists have applied to the hydrodynamic development of underwater robots. These include the test-based method and the computation of fluid dynamics. The test-based method is a hydrodynamic experimental method that is applied to the development of ROV models. The models are tested under various hydraulic tests to determine their underwater capabilities. This method has been applied in actual marine and model environments before the approval of mass production or commercial production of ROVs. Although the models always undergo theoretical analysis during their design, failures may occur due to human error or unaccounted marine occurrences, such as heavy tides, which may cause the failure of these robots. Test-based methods are conducted to ensure that the projected efficiency of the ROV in production matches the actual performance underwater.

## III. CHALLENGES IN DESIGNING MOTORS FOR UNDERWATER ROVS

### 3.1 Control System

Over time, controlling underwater vehicles has been a challenge for developers due to the non-linear nature of hydrology. Unlike air, water has more complicated fluid dynamics, which makes it difficult to have precise standard ROV models. Due to this, engineers encounter difficulties when developing automatic control of underwater vehicles, which is attributed to the nature of the marine system — this leads to disappointing results when basic control models are used in ROVs. [4]. Controlling ROVs underwater is also affected by underwater uncertainties such as accuracy and parameter uncertainties. Numerous nonlinearities and modeling, such as inertial nonlinearities, hydrodynamic nonlinearities, and problems brought about by the degree of freedom, generally affect the control of underwater vehicles. This necessitates the development of more complex control systems that could work well in marine environments instead of incorporating controls used in typical environments. For instance, developing the Proportional integral derivative control system has shown tremendous improvement in controlling ROVs.

**3.2 Operation Modes**

ROVs are developed for different operations in the marine environment. There are ROVs developed for biological studies, others for military research, and others for the development of underwater infrastructure. These different operations make the development of ROVs complicated. ROVs are expected to be dynamic and incorporate different modes of operation to make them useable under different operation procedures. These underwater vehicles have several operation modes. There are times when the ROVs are expected to operate on the water surface without being submerged. This includes when performing meteorological surveys in the sea or military surveys. In such times, ROVs are operated while floating on water, which requires them to be adopted for floating. In other instances, such as repairing underwater pipelines and designing offshore oil rigs, the ROVs are expected to operate underwater while fully submerged. [6]. To accommodate these different operation modes, the designs of ROVs should be fitted with devices and modifications that enable them to operate seamlessly and fulfill their expected duties.

**3.3 Under Actuated Conditions**

Due to the unpredictable nature of the marine environment, ROVs may face actuated conditions while in operation. Actuated conditions are experienced when an ROV possesses fewer control capabilities compared to its degree of freedom. [7]. Failure of actuation in surprise conditions has caused numerous failures in the operation of ROVs, creating many drawbacks in developing maritime technology and learning. ROV underactuation could occur in different scenarios. For instance, the most common underactuation is thruster malfunction. ROVs are fitted with various thrusters, which help them maintain the desired depths and paths during operation. These thrusters may, however, be overpowered by tides and other hydraulic forces that occur in water, leading to unexpected malfunction. The unpredictability of marine conditions has called for the developers of ROVs to create thrusters that have enough power and are nearly immune to underactuated conditions.

**3.4 Corrosion and Material Durability**

Sea water is known to be highly corrosive, more so for certain elements such as metals. To ensure the durability of ROVs, manufacturers need to consider the corrosiveness of water and work on preventive measures. Many ROVs are made of metals due to their hardness and ductility. However, metals are highly prone to corrosion when exposed to seawater, hence the requirement for their protection against corrosion. Various methods are used to help reduce the impacts of corrosion on ROV materials. Metals can be coated using less corrosive or non-corrodible materials, which provides a barrier against direct contact with seawater. This can be achieved through metal plating with non-corrosive metals or non-metallic coating. [10]. Recent developments have embraced the adoption of cathodic protection. The process of suppressing the corrosion current and forcing it to flow to the metal that needs protection is known as cathodic protection. It is accomplished by affixing a more active (anodic) substance to the structure that has to be protected or by using a power source.

### 3.5 Coupling Issues

Controlling ROVs is done off the water, which requires the vehicle to be properly coupled with its controller. This calls for the development of quality underwater control systems that will not disconnect from the ROV during operation. The stability of ROVs in water is greatly affected by the coupling between the ROV and the controller. However, various factors, such as costly, sophisticated sensors, propulsion systems, esoteric structural materials, and embedded electronics, are required for successful control. Most ROVs require cable to transfer power and communication from the controller, while others are coupled through modern wireless controls. However, coupling is limited by various factors, such as parametric uncertainty and the highly dynamic nature of the underwater environment. [13]. These factors have limited the ability to control ROVs and the capacity for advancement in marine technology and scientific explorations.

## IV. CONCLUSION

ROVs have proven to be of great importance in maritime exploration and learning. However, their development has faced various challenges that affect their navigation. Some developments and innovations are required to improve the different challenges faced in the operations of ROVs. Advancements in materials, computational fluid dynamics, and motor technology have significantly improved ROV motor design. However, challenges such as energy efficiency, heat dissipation, and adaptability to varying water conditions remain prominent. Future research should focus on integrating AI-driven control systems, advanced propulsion technologies, and bio-inspired designs to overcome these limitations.
In conclusion, designing motors for ROVs is a multidisciplinary effort that must consider hydrodynamics as a central factor. Solving the problems addressed could lead to a remarkable ROV industry and maritime technology breakthrough.

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