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# Modern Methods of Hull Cleaning Using Remote Operated Vehicle

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ABSTRACT: During vessel operation, hulls are subjected to corrosion and biofouling by marine organisms, which negatively impacts hydrodynamic performance, increases fuel consumption, and elevates operational costs. Conventional hull cleaning methods typically require dry-docking and involve techniques that may pose environmental risks. The dynamic development of robotics has facilitated the deployment of Remotely Operated Vehicles (ROVs) for in-water hull inspection and cleaning, eliminating the need to take the vessel out of service. ROVs utilize electromagnets to maintain stable adhesion to the ship's surface, high-pressure water jets to remove biofouling and debris, and integrated filtration systems to capture and contain contaminants, thereby minimizing environmental impact. This paper provides a comprehensive review of innovative hull cleaning technologies employing ROVs, highlighting their advantages over traditional methods and assessing their contribution to operational efficiency and environmental sustainability.

## 1 INTRODUCTION

From the moment of launching, a ship is affected by external factors. A vessel, performing sea voyages, is subjected to exploitation, from the technical side as well as mechanically. The marine environment is unfavourable to steel. Saltwater, wave motion and temperature variations have a negative impact on ship's metal hull. A constant and challenging issue in vessel's operation is the corrosion and biofouling of the hull and its components, especially submerged sections exposed to continuous contact with water. Structures immersed in water, such as ship hulls, buoys, drilling platforms and pipes, are susceptible to biofouling by marine organisms. Among them, a significant group are lichens, which can inhabit surfaces in both fresh and saltwater. Lichens, a symbiotic combination of fungi and algae, create permanent deposits, which over time can affect the operating properties of the structure, reducing their hydrodynamics and contributing to the corrosion of materials [2].

The intensity and rate of microorganism accumulation on the hull plating are influenced by many factors of chemical, physical and biological nature. The entire process is influenced by the climatic and geographical conditions of the sea area, the physico-chemical properties of the water and the layers of the ship's hull. Technical factors characteristic of each unit also has a significant impact on hull fouling.

Climatic and geographical factors include water temperature, presence of sea currents, relative water movement and the degree of solar radiation of the water body. The most susceptible to fouling are those structural elements that are most exposed to intense natural light [7].

The physicochemical properties of the water have a significant influence on the development of lichen organisms as well. The content of nutrients, salinity, oxygenation level and the degree of pollution of the aquatic environment are of key importance. Algae, like many species of marine organisms, develop best in warm waters with high salinity, which makes vessels operating in such regions particularly vulnerable to intensive fouling.

Furthermore, the rate of biofouling settlement and growth is influenced by technical factors, which may vary depending on the specifics of a given vessel. The speed of the vessel plays a key role – slower vessels are more susceptible to the attachment and accumulation of organisms on the surface of the hull plating. The location of the port, the length of stay, the frequency of inspections and cleaning of the hull and the use of modern anti-fouling agents are also important. Proper maintenance and protection of surfaces reduce the negative effects of fouling, which can lead to increased hydrodynamic resistance and increased fuel consumption.

Hull damage or fouling can not only affect the vessel's speed and fuel efficiency but can also be hazardous to cargo and have a negative impact on the marine environment. It is estimated that a contaminated hull can increase fuel consumption by as much as 6% to 14% [6, 10]. Although necessary, hull inspections can be an extremely difficult task, but they play an important role in maintaining the operational efficiency of vessels. Traditional methods of cleaning a ship's hull can use chemicals that can be harmful to the marine environment. The rapid development of robotics and advanced sensor systems is opening new possibilities for automating this process.

This review article presents the application of solutions using Remotely Operated Vehicles (ROVs), as a safe, fast and efficient way to conduct hull inspections. Furthermore, the study discusses advanced technologies employed for hull surface cleaning, which contribute to reduced downtime, lower maintenance costs, and minimized environmental impact on the marine ecosystem. The use of remotely operated vehicles is an innovative approach that not only improves cleaning processes but also increases the safety of operations and contributes to sustainable fleet management. This publication is organized as follows. Section 2 entitled "Materials and Methods" presents traditional ship hull cleaning techniques, which are then contrasted with modern methods using ROV units, describing the cleaning process and the tools used. Section 3 entitled "Discussion" considers the modern cleaning techniques presented in the article as an alternative to the traditional stay of the ship in the shipyard dock. The article ends with general conclusions on the use of ROV units during underwater hull inspections.

## 2 MATERIALS AND METHODS

### 2.1 *Traditional cleaning techniques*

Conventional hull cleaning is carried out at the shipyard, where it is necessary to place the ship in a dry dock. The duration of this period is determined by the degree of hull fouling, as well as its technical condition and the scope of shipyard work. On average, it is from 7 to 10 days. However, such a stay requires temporary suspension of operations. The main cleaning technique involves the use of a high-pressure jet operating at 350 bar. In connection with the above, together with the removed organisms, loose fragments of antifouling paint and rust are torn off from the shell. Certain parts of the hull such as screws, rudder blades, thruster grids, due to their design, often require manual cleaning with the use of tools such as scrapers and brushes. If high-pressure water alone is insufficient for complete cleaning, sandblasting of the steel hull surface is performed. This involves spraying quartz sand at high pressure to effectively remove deposits from the plating. Use of above-mentioned technique significantly increases the downtime of the ship and causes significant pollution of the working environment. The limitations of traditional hull cleaning techniques are shown in Figure 1.


Figure 1. Traditional hull cleaning methods – challenges and limitations [own study].

### 2.2 *Underwater cleaning techniques*

The development of technology, robotics and automation causes traditional methods of cleaning ship hulls to become less effective and more expensive. From this perspective, underwater cleaning using ROV technology has become beneficial compared to the manual cleaning performed on the shipyard dock [7, 10]. The impact and cost savings results from many factors, which are presented in the following Figure 2 [3,12].

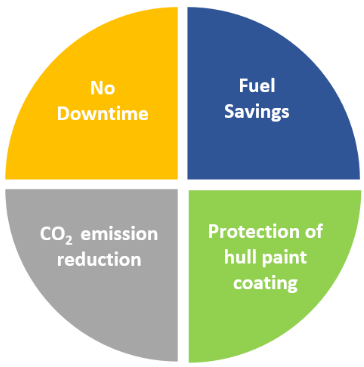



Figure 2. Advantages of hull cleaning with ROV [own study].

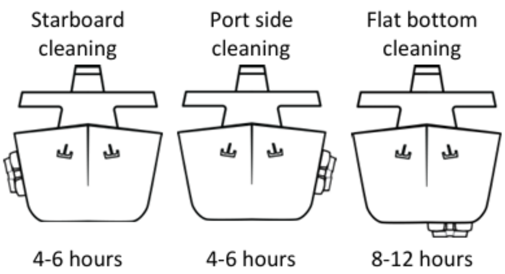
Cleaning the submerged part of the hull using ROV is based on the use of electromagnets, which ensure stable adhesion to the steel surface of the ship's plating. That allows effective cleaning regardless of the environmental conditions. The system ensures effective operation even in ports, where the presence of strong currents, waves and winds could hinder the operation [1,4,11].

Due to environmental protection and its degradation, caused by the release of toxic compounds into sea waters, global organizations and institutions have introduced legal regulations regarding the control of ships and the composition of anti-fouling coatings. Member states of the IMO (International Maritime Organization) during the 80th session of the Marine Environment Protection Committee - MEPC 80) adopted the IMO 2023 Strategy on the Reduction of Greenhouse Gas Emissions from Ships [5]. With growing demand on the market, an increasing number of companies are offering comprehensive underwater cleaning of the the hull, without the need for dry-docking.

The time required for an ROV to clean a ship's hull depends on the vessel type, its dimensions and the extent of fouling. Approximate time values are presented on Table 1.

Table 1. Expected operational times [own study based on [4]].

ROV SERVICE TIMES




The hull cleaning operation involves a barge carrying all the equipment necessary to carry out the cleaning. Hence, to ensure the best possible effect and minimize the operation time, the ship's sides should remain accessible to the working unit. The barge moored alongside the vessel is equipped with all the necessary equipment to coordinate the hull cleaning process [10,11]. The ROV is transported and attached to the ship's hull using a crane mounted on the workboat. The robot is connected to the barge via cable reel approximately 150 m long operated remotely through a control console with joysticks and a computer interface, enabling precise manoeuvring and real-time monitoring. The implemented RTS (Robot Tracking System) allows, continuous tracking, analysis and optimization of the robot's movement in real time. This increases the efficiency of the cleaning process, extending its range and enables the creation of a "hull surface map" which, when loaded into the control and monitoring devices, ensures the performance of various inspection tasks and thorough cleaning of the ship's hull. This also enables the control of the water pressure distribution. The operator stationed on the barge monitors the robot's route and the condition of the hull. The system is capable of functioning even in limited visibility caused by poor water clarity. When encountering greater contamination, the operator can adjust the water pressure as needed, up to 350 bar. The barge is equipped with a filtration system that allows automatic processing of collected waste. In this process, removed biofouling is separated into a designated bag, while the clean, filtered water returns to the ecosystem.

The average dimensions of the cleaning platform are: 2m x 1.8m x 0.6m. While ensuring its solid installation with the ability to work in difficult port conditions, there are certain limitations in the scope of cleaning the underwater part of the hull.

The areas inaccessible for the robot depend on the type of ship and its size. These areas are checked separately, with the involvement of a qualified diver. They mainly include such sections as [4,9]:

- Areas with protrusions: bilge keel, anodes;
- Bow and stern thruster's surroundings, sea chest and other hull openings;
- Significantly curved surfaces: bulbous bow, propeller area and rudder blade.

In Figure 3 the inaccessible areas are marked by yellow.

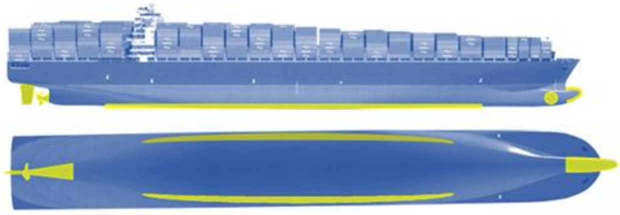


Figure 3. The impassable areas on hull surface [4].

Table 2 outlines the constraints necessary for the correct operating conditions of the ROV. Compliance with the below mentioned constraints allows for appropriate adjustment of the cleaning technology to the operating conditions of the vessel, ensuring operational effectiveness and minimizing the potential risk of damage.

Table 2. Hull cleaning constraints [own study based on [4]].

| HULL CLEANING CONSTRAINTS | |
|---|---|
| Removal of fouling around the waterline | up to 1 meter |
| Ability to clean surfaces with curvature | up to 2.5 meters |
| Minimum clearance under the vessel's keel | 1.5 meters |
| Minimum clearance between vessel and quay | 2 meters |

### 2.3 *Dry dock cleaning techniques with ROVs*

With the development of technology, the use of ROVs has been extended to vessel maintenance during the dry docking. Traditional methods, such as sandblasting, scraping or high-pressure washing, require direct involvement of shipyard personnel and are associated with high operational costs and impact on marine ecosystems [2]. Cleaning robots developed by Vertidrive - a company that creates safe, environmentally friendly and cost-effective solutions in the field of crawler robots, are an innovative approach to the maintenance of hulls during dry docking [12].

According to the manufacturer's website, the three latest ROV machines - VertiDrive M3 (Fig. 4.), VertiDrive M4 (Fig. 5.) and VertiDrive M7 (Fig. 6.), not only speed up work efficiency (up to eight times faster depending on the model), but also reduce cleaning costs from 86% to 92% compared to the conventional, manual hull cleaning. This results in significant savings of both time and resources. As stated by the manufacturer: "All of the previously mentioned

VertiDrive solutions are hull blasting robots that have been designed to clean vessels with maximum productivity and minimal operational costs. Each function as a carrying platform for traditional hand-held blasting equipment, an operator simply needs to connect the robot to the hose line of a hand-held blaster, and they are ready to work. Important to note is that the operator will always be located safely on the ground, far away from any ship hull maintenance related hazards.

These ship hull cleaning robots can be used for ship anti foul removal within a dry dock cleaning scenario. Horizontal, vertical, curves, corners and overhead surfaces are all a breeze for these robots through the use of permanent, powerful magnets." [12]

Additionally, delving into the descriptions of individual machines reveals valuable information useful for selecting the most suitable equipment for hull cleaning operations.

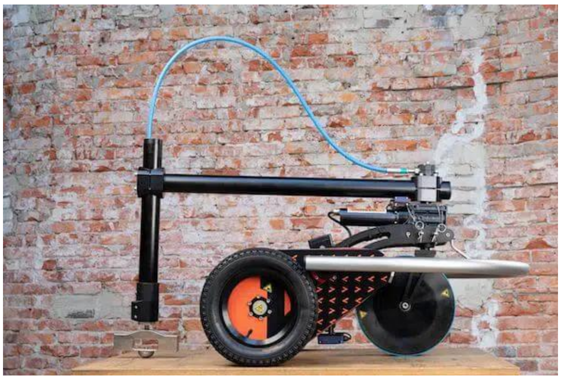


Figure 4. VertiDrive M3 machine [12].

The ease of operation, as well as the comprehensiveness of the services provided, demonstrates that hull cleaning devices are increasingly taking the lead as tools that enhance ship maintenance processes. The ability to quickly adapt the devices makes these systems an efficient solution, whether for cleaning standard hull sections or hard-to-reach areas: "In addition to the perks […] already mentioned, the M3 is an exceptionally simple blasting robot to disassemble. This makes for much easier access to spaces such as manholes and other confined spaces. Interchanging the M3 with the VertiDrive M4 is also possible with the help of the M3 – M4 conversion kit, which allows an operator to make use of the M4's specialized hydro blasting capabilities." [12]

Figure 5. VertiDrive M4 machine [12].

The efficiency of hull cleaning may depend on many factors, such as the impact of the process on the environment, the power of the device or the maintenance stages. Modern machines have a significant impact on increasing work efficiency and reducing negative impacts on the environment, which is emphasized by the technical description of one of the machines: "The M4 is a closed hydro blasting solution. In combination with the VertiDrive Vacuum System the surface worked upon will dry immediately thus, preventing flash rust and reducing environmental waste. This also enables other technicians to simultaneously perform other maintenance work, contributing to significant time savings to bring the asset earlier back into service." [12]


Figure 6. VertiDrive M7 machine [12].

Cleaning large surfaces with curved designs requires great precision, as well as appropriate power, which should also be accompanied by mobility. Modern devices for cleaning ship sides allow for efficient work even in the most difficult conditions.

## 3 DISCUSSION

The solutions presented in the article, which utilize unmanned vehicles for hull cleaning have the potential to become a standard in modern shipping and its sustainable operation.

Although the solutions described in the article may involve high initial cost, they offer numerous compensating advantages:

- Cleaning can be performed during cargo operations in port, along with other port activities such as bunkering, garbage collection or fresh water supply. It is also possible to carry out cleaning operations while the vessel is underway at low speed;
- No additional, costly vessel downtime;
- The ROV is unmanned, making the operation fundamentally safe;
- Hull cleaning is carried out using a high-pressure water jet with fully adjustable and controllable pressure, with a range between 25 and 350 bar;
- The cleaning process has a minimal impact on the coating because the robot does not use scrubbing brushes;
- The removed contaminants are collected in a separate container located on the barge moored alongside and then safely disposed of in accordance with environmental regulations;
- The robot is capable of navigating along the waterline as well as curvature of the hull;

Upon completion of hull cleaning, the vessel emits less GHG (Greenhouse Gas) during operation due to improved hydrodynamics performance.

## 4 CONCLUSION

Operational efficiency, fuel consumption and environmental impact are key aspects of hull cleanliness. While traditional manual methods of removing biofouling and maintaining debris-free hull still remain widely used, they are also expensive, time-consuming and have a negative impact on the marine environment.

In response to this niche in hull maintenance, many companies have developed ROV systems that not only clean but also inspect the submerged part of the hull. The use of ROVs enables hull maintenance in most cases without the need to interrupt the vessel's operation, which significantly reduces both operational and financial losses.

Advanced, electromagnetic adhesion systems, combined with precision control technologies and high-pressure water cleaning, allow minimal to no damage of the hull's protective coating. Additionally, integrated filtration systems allow for limiting the negative impact on the marine ecosystem.

In conclusion the use of ROVs in the automation of ship hull cleaning is a fundamental step towards more efficient use of sea and ocean shipping, as well as greater environmental responsibility.

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