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IMPACT OF AUTONOMOUS ROBOT-ASSISTED PROACTIVE GROOMING ON UNDERWATER HULL CLEANLINESS

EXECUTIVE SUMMARY

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Project Summary

Ships are continuously under attack by marine growth that stems from biodiverse micro and macro marine organisms attaching and spreading along the underwater hull surface. This is problematic due to the serious corrosion effects, unwanted vessel noise, reduction in flow through sea chests, and spreading of invasive species. Prior studies have shown that the accumulation of biofoulers can increase the hydrostatic volume and hydrodynamic friction of the ship thus increasing fuel consumption while robbing the ship of power and speed. Management of marine biofouling via underwater ships husbandry not only reduces the overall time a ship is in dry-dock but also mitigates these costly detractors while retaining the ship in an operational status. While the periodic removal of biological fouling via grooming has been shown to increase efficiencies, the true value in reducing adverse environmental impacts associated with reactive cleaning and out of water hull cleaning has not been well documented. It is theorized that the use of remotely operated vehicles and autonomous submersible devices employed in proactive hull grooming may provide even further benefits in schedule and cost savings over manual grooming methods. The investigation of event periodicities, application to conventional hull surface preparations in typical surface ship hull areas were studied. Correlation of benefits with recommended proactive cleaning schemes, autonomous or remotely operated vehicle (ROV) utilization, and development of functional relationships point to expanded use of robot-assisted proactive grooming as another viable tool to keep marine growth on ship hulls at bay.

Keywords: *unmanned undersea vehicle, UUV, biofouling, ship husbandry, hull grooming, remotely operated vehicle, ROV, hull fouling, fouling pressure, fuel efficiency,* CO_2 *emissions, proactive grooming, autonomous systems*

Background

While it is well understood that the accumulation of biofouling on ship hulls and appendages is detrimental to the cost-effective operation of ships at sea, it is less evident where the introduction of automated systems being utilized for proactive grooming would make the greatest impact in minimizing the occurrence of unacceptable fouling pressures.

The management of hull cleanliness is based on several factors. Variations in ship schedule, ship service speed, port environmental conditions, cleaning technique, and periodicity, all complicate the typical cost-benefit equation. Each element contributes as a weighted function against the cost, schedule, and performance of the ship system. When discussing applications for the U.S. Navy, an additional layer of complexity is introduced as naval vessels rarely follow set schedules, visit the same ports throughout the year, nor follow strict hull cleaning schedules due to ever-evolving mission requirements. Unlike commercial vessels which are optimized around profit, naval vessels are predicated on operational capability. While an increase of half of a knot in ship service speed would undoubtedly be welcomed by ships' captains, the true benefit is potentially lost on a navy's ability to show actual value from this gain as a result of uncontrollable events. Likewise, the capability to accurately track incremental gains from underwater hull cleaning is difficult at best due to fluctuating sea conditions, changes in wetted surface area, and unrelated maintenance schedule driven propulsion plant performance.

The focus of this study was to investigate how the implementation of autonomous robot-assisted systems in the proactive grooming process would impact the overall efforts of combating marine growth. Through the analysis of research findings in the emerging area of proactive grooming of ship hulls, traditional reactive cleaning case studies and other investigations, correlations were able to be made in estimating the necessary resources against predicted benefits. Specific performance considerations sought out included the overall reduction in fouling pressures with respect to ungroomed surfaces, the effect of grooming frequency on traditional surface coatings, the characterization of damage to surface coatings with repetitive grooming operations and dependence on temperature driven growth rate impacts on cleaning periodicals based on vessel schedule and pierside duration.

Findings and Conclusions

The drydocking and associated deep cleaning and preservation processes as part of the ship's overall maintenance scheme is the gold standard which all other hull cleanings are gauged. While reactive in-water hull cleanings on average provide a 20-25% reduction in added resistance, this advantage decreases linearly as a function of time. Recent studies indicate a comparable level of hull fouling reduction can be realized through proactive means, namely periodic grooming. However, both processes which provide significant gains are concentrated on cleanliness of the typical hull area of a vessel, which primarily includes the midbody other areas of mild structural curvature. Running gear, hull appendages, penetrations, and high gradient areas of the submerged structure such as bulbous bows are excluded for these results, whether approached via manual cleaning or robotics assisted cleaning operations.

With regard to performance, while the reactive cleaning process is extremely effective in removal of hull fouling through the nature of the physical abrasion, it too damages the hull coating and potentially exposes underlying metal of the ship hull to a) stand unprotected until the next drydocking period, b) accumulate higher fouling pressures more quickly due to an absence of resistive coatings and c) introduces greater amounts of toxic effluent into the underwater environment due to the removal process. Even with the higher periodicity of contact over reactive type cleaning methods, it has been concluded that proactive grooming using a less abrasive method has the potential to maintain acceptable fouling pressures. This can extend the periodicity of labor intensive out-of-water (drydock) hull cleaning without the resulting surface damage to hull surfaces. Additionally, it can help limit the introduction of toxicity into the environment via the cleaning operation.

The introduction of automated, autonomous or robot assisted cleaning is not a new concept. Research indicates that for the general areas of the ship hull, there is no reason not to adapt this practice in either reactive or proactive cleaning. This study did not specifically address the unique areas such as hull appendages where considerable effort is spent in time and resources due to the unique geometries and accessibility issues.

In dealing with hull fouling accumulation and the ability to provide cost savings analysis of proactive grooming using automated systems, the current work was inconclusive. Tracking of a ship's data to the degree necessary for this investigation was not made available due to the difficulty of parsing inconsistent data and potential security implications. It is proposed for future work that a representative U. S. Navy vessel, such as an Arleigh Burke-Class destroyer, be fully instrumented with specific sensor equipment to record high fidelity and frequency measurements of water temperature, geographic location, sea state (including current estimation), ordered speed, speed made good, windspeed, draft, and other engineering data to correlate with the actual hull cleaning state. In lieu of this, detailed open ocean field testing of surrogate models reactively and proactively cleaned over a substantial period and subjected to sporadic movement and representative flow velocities could be used to inform the outcomes more definitively than qualitative study of sparse historical ship data.

Recommendations for Further Research

The introduction of autonomous hull cleaning robots and their accompanying subscription cleaning services has launched a new offshoot to the traditional reactive hull cleaning model. Largely focused on flat or gradually curving areas of the underwater hull area, fundamental issues such as grappling with navigation algorithms and positioning glitches have given way to challenging speed limitations and cleaning swath constraints. While many of the past physical issues have been minimized, matching periodicity to proactive grooming for vessels with dynamic schedules and fluctuating voyage plans still needs to be refined. Studies in the use of automated undersea robotic systems used for proactive grooming have centered largely on surrogate stationary panels being serviced at various routine schedules rather than on vessels circumnavigating the globe in apparently ad hoc cycles as driven by DoD missions rather than dictated by route planning such as in the case of commercial shipping, where exact schedules drive costs. A better understanding of the true operational impacts and cost benefits associated with these preventative actions needs to be extrapolated onto the sum of the fleet. Additionally, the current use of autonomous robot-assisted cleaning devices is relegated to approximately 80% of the underwater hull surfaces which are mostly flat and easiest to access. Tradeoffs involving the losses endured through avoidance of niche areas such as sea chest openings, running gear, and other appendages as compared to the cost of using dedicated manpower in diver-facilitated reactive cleaning is yet to be fully determined.

References

Acronyms

ROV	remotely operated vehicle
UUV	unmanned undersea vehicle