Biofouling Remediation Equals Higher Speed, Lower Drag

Advancements in Biofouling Control R&D Offer Increased Capability to Navy Vessels

ENGINEERS AND SCIENTISTS at the Naval Surface Warfare Center, Carderock Division (NSWCCD) have been studying commercial advancements that have the potential to improve hull and propeller coatings thereby reducing the formation of biofouling and lengthening the intervals between cleanings.

Biofouling may actually represent the single largest factor undermining fuel efficiency in surface combatant and Military Sealift Command vessels today.

Biofouling, also known as barnacles and slime, may not be the trendiest, high-tech topic of conversation in the world of operational energy. Most would rather discuss a new weapon system or innovative green technology that allows Sailors and Marines to increase operational tempo or achieve more efficient fuel consumption. What most people don't realize is that biofouling may actually represent the single largest factor undermining fuel efficiency in surface combatant and Military Sealift Command (MSC) vessels today.

The effects of biofouling are straightforward—biofouling accumulation increases the surface roughness of a hull and its associated frictional drag. Increased frictional resistance results in increased fuel consumption and decreased speed and range. To increase operational capability and efficiency, most would rather discuss swapping one design for another—maybe a new hull form, a new propeller design, or a new technology that could result in more fuel-efficient operations, often ignoring the impact of something as uninteresting as biofouling. However, mitigating the effects of biofouling could result in significant increases in fuel efficiency and enhanced operational capability in terms of increased range and top speed.

Biofouling accumulation has been an issue for the Navy since the days of the sail, and the approach for mitigating biofouling—scraping the hull and propeller by hand or with grinding tools—has not been substantially improved in decades.

Improving hull and propeller coatings could reduce the formation of biofouling and lengthen the intervals between cleanings. An NSWCCD team has been studying advancements in commercial coatings and their applicability to Navy vessels. The NSWCCD is also collaborating with Naval Sea Systems Command (NAVSEA) Energy, MSC Operational Logistics (OPLOG) Energy, and other Navy research offices to better understand biofouling's direct effects on fuel efficiency and propulsion. Through better measuring of the

Mature barnacles (*Megabalanus tintinnabulum*) on Navy platform.

costs of biofouling, remediation efforts can be monitored and marked as true improvements. In this way, biofouling research and development (R&D) plays a central role in operational energy advancements.

The Challenges of Biofouling

Biofouling describes the accumulation of microorganisms, plants, and animals on wet surfaces. Types of biofouling are generally divided into two categories:

1. Soft biofouling

   The category of soft biofouling includes biofilm slime, algae and seaweed.

2. Hard biofouling

   Hard biofouling includes barnacles, tubeworms and mollusks.

The Navy uses a Fouling Rating (FR) score of 0 to 100 combined with a percent area affected when describing the biofouling observed during underwater hull inspections. For example, FR-30 denotes heavy slime while a rating of FR-70 denotes medium hard fouling.

The effects of biofouling accumulation and increased drag are well documented. A growing body of literature is expanding the Navy's understanding of the relationship between measured 'penalties' associated with biofouling accumulation. The NSWCCD team estimates that approximately 14 percent of the propulsive fuel bill for the destroyer (DDG) -class fleet is wasted overcoming the effects of biofouling. This amounts to 410,000 barrels and $68 million per year. In 2011, NSWCCD personnel estimated that biofouling cost the Navy $180 million to $260 million per year. Modest improvements in the condition of the hull could yield substantial reductions in fuel consumption and cost. A 2010 article in *Biofouling* magazine concluded that the savings achieved from decreasing fouling from FR-30 to FR-20 in the DDG-51 class of ships would offset the costs of a biofouling control R&D program and all associated materials within a year. (Read the entire article at www.dtic.mil/dtic/tr/fulltext/u2/a575004.pdf.)

One of many technical hurdles associated with quantifying the impact of biofouling control improvement on fleet fuel efficiency remains the large variation in ship type and operational conditions across the Fleet. It is also challenging to account for the type and coverage of fouling on hulls and propellers because measuring biofouling accumulation in and of itself is not a scheduling priority for the Navy. Measuring and quantifying biofouling impact is an important focus of ongoing projects.

The full costs associated with biofouling are not tied to fuel penalties alone. The increased frictional drag on a vessel also increases the shaft power required to attain a particular speed and can reduce vessel top speed. According to the Office of Naval Research, biofouling can reduce a vessel's speed by up to 10 percent.

One point remains clear: improved biofouling control will directly reduce drag and the associated increase in fuel

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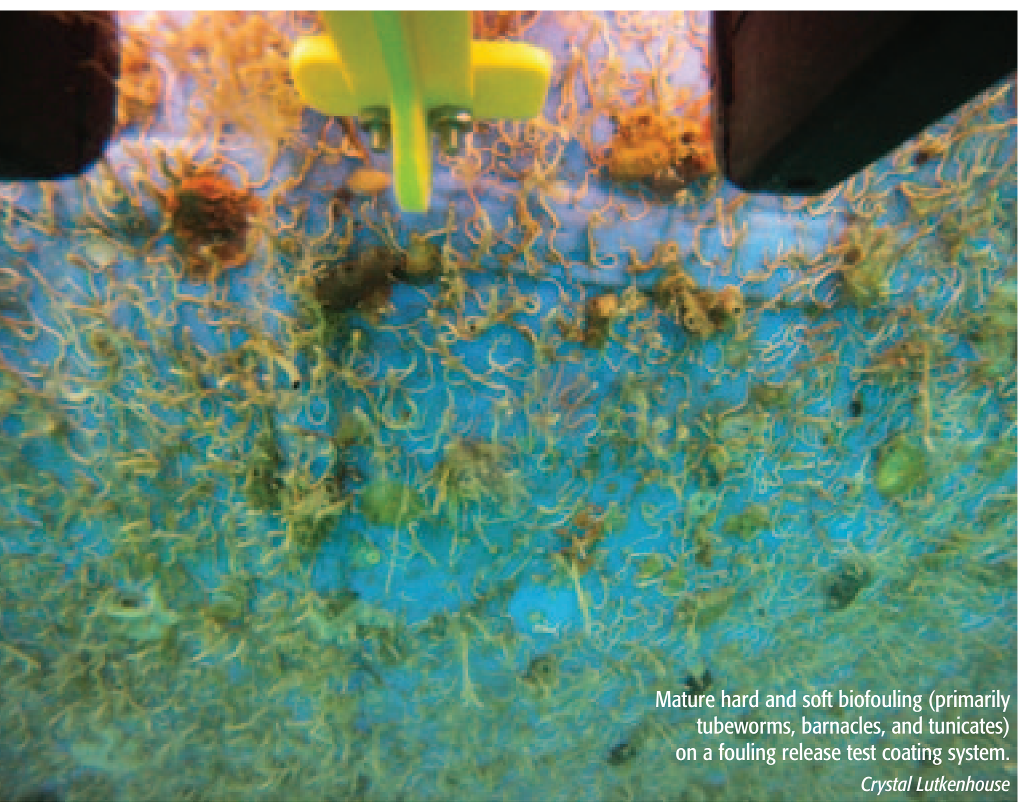
consumed for propulsion. At the same time, mitigating biofouling returns capability to the vessel, an issue far broader than fuel consumption calculations alone.

A Unique Set of Challenges in the Navy

The battle against biofouling is arguably more challenging for military vessels than for most commercial vessels for a number of reasons. The most important factor is probably tied to operational tempo which is comprised of two main components—the frequency with which ships get underway and the speed-time profile of vessels when they are underway (the percent of time spent at each speed). The average Navy ship is underway less frequently than most commercial ships, and steams at a lower and a wider array of speeds. Not only that, the operational profile of military vessels varies widely across ship classes, making them difficult to characterize. To make matters even more challenging, coating companies typically design biofouling control coating systems for the largest market sector (trade ships). Additionally, mission-essential factors can interfere with researchers' ability to demonstrate new solutions. These and an even wider array of interconnected variables present unique challenges to the Navy when working to bring advanced biofouling control solutions to the Fleet.



Mature hard and soft biofouling (primarily tubeworms, barnacles, and tunicates) on a fouling release test coating system.
Crystal Lutkenhouse

While the combination of advanced coatings and maintenance practices seems like a straightforward solution to the problem, the efficacy of these solutions is linked to a set of interdependent variables that must be taken into consideration in the overall analysis. NSWCCD has recently described this group of factors as the "4Ms"—Materials, Maintenance, Monitoring, and Movement. For example, coatings fall under the Materials "M." They should be applied after considering other elements of the vessel's activities:

- When and how often its hull and propeller are cleaned (Maintenance)
- The quality and quantity of data associated with inspections and fuel efficiency measurements (Monitoring)
- Its operating tempo and speed-time profile (Movement).

Demonstrating and quantifying the benefits associated with advanced coatings are optimized only when all 4Ms are taken into consideration. (For more insights, see our sidebar "More About The 4M's.")

Recent demonstration projects involving new fouling release coatings highlighted weaknesses in the way the Navy currently screens, tests, and quantifies the benefits of new coatings. It was determined that without a rigorous biofouling control R&D

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program, the Navy may continue to struggle to identify effective solutions and justify their transition with sound cost benefit analyses.

Working in collaboration with NAVSEA Energy, MSC OPLOG Energy, the Chief of Naval Operations Energy and Environmental Readiness Division (OPNAV N45) and others, the NSWCCD has developed the Navy Biofouling Control R&D Program Plan. This R&D plan seeks to overcome the hurdles that currently get in the way of determining the best combination of solutions to the biofouling problem.

Not a One-Size-Fits-All Solution

The Navy fleet has relied on copper-containing, oxide-based coating technology in combination with in-water cleaning for more than two decades. Because these formulas leach biocides into the surrounding waters, the Navy began to evaluate a new class of biocide-free materials called fouling release coatings in the 1990s. These coatings are based on the concept of reducing the ability of biofilm and barnacles to adhere to the hull (or propeller) through smooth surfaces and hydrodynamic forces. With a fouling release coating, the biofouling sloughs off when the ship moves.

Fouling release coatings represent at best five percent of the current commercial coatings market, but early reports from paint manufacturers and commercial vessels indicate a 10 percent improvement in fuel efficiency for tankers and 22 percent for bulk cargo vessels with their use.

Conceptually, these paint systems have great potential to provide a biofouling control solution for ship hulls and propellers, and they come with lower environmental impact than legacy biocide-based coatings. In 2008, NAVSEA Energy funded a full-scale demonstration of a commercial fouling release coating on ship hulls and propellers. The International Intersleek® 970 coating system was applied to the propeller of USS Gunston Hall (LSD 44) and to the hulls of USS Cole (DDG 67) and USS Port Royal (CG 73). After four years of monitoring it was determined that, as a hull coating system, this product did not perform as expected and the coating was not yet suitable for the hulls of many Navy vessels. This was largely due to the mismatch between the high volume of movement and speed required to slough off the biofouling and the current operating tempo and speeds of Navy vessels. Most ship classes do not regularly operate often or quickly enough to maximize the benefits of International Intersleek® 970.

While the current generation of fouling release coatings may not have

The 4Ms Affecting Biofouling

A COMPLEX COMBINATION of factors known as "the 4 M's" affect the impact biofouling is likely to have on a ship's performance.

1. **Materials**

   There are three main categories of coatings:

   - Antifouling: Contains biocides to inhibit bacterial growth
   - Fouling Release: Prohibits biological material from affixing tightly and may be sloughed off when ship is underway
   - Durable: Withstands frequent cleaning (traditional hard coatings)

2. **Maintenance**

   Tools and techniques used and maintenance frequency all affect coating and biofouling. Maintenance procedures must be compatible with coating material.

3. **Monitoring**

   Hull and propeller fouling condition coupled with underway performance are critical for establishing a baseline, engineering a test plan, and making any conclusions or recommendations regarding coatings.

4. **Movement**

   Operating tempo, speed-time profile, and operating area all affect ship performance and biofouling potential.

Propellers on USS Gunston Hall (LSD 44) after treatment with Intersleek 970 fouling release coating.
David Zuskin

proven to be the panacea that they promised to be for the Navy, they did show promise in specific applications. For example, the fouling release coating performed better on LSD 41-class propellers than it did on hulls. No blade face cleanings were required through at least five years of performance. Early potential also exists on MSC propellers and other vessels with high operating tempos.

In the future, fouling release hull coatings that perform at least as well as if not better than Intersleek 970 may provide improved performance over legacy copper-containing coatings, especially if important formulation changes are made and/or if used on ships with much higher operational tempos. As a propeller coating, Intersleek 970 is being transitioned to the LSD 41-49 class vessels, and the NSWCCD biofouling team is evaluating the suitability of this and other more advanced coating technologies for other ship classes including a subset of MSC vessels.

The Plan: Near- & Long-term

Near-term transition of improved biofouling mitigation strategies is the primary goal of the Navy Biofouling Control R&D Program Plan. This includes identification of mature, commercially available coatings and development of an effective maintenance regimen.

Because the current generation of fouling release coatings appears to be a poor match for the majority of Navy vessel hulls, the NSWCCD biofouling team plans to turn its attentions to emerging antifouling coatings in the near term.

Self-polishing copolymer (SPC) paint systems have been used globally for more than a decade now—and are currently being transitioned to the Royal Australian Navy—but have only recently become available for use in the U.S. These formulations contain biocides which aid in preventing biofouling formation. In fiscal year (FY) 2016, the team will perform an American Society for Testing and Materials test to determine the copper release rate of commercially available SPC formulations. Those products that release more copper than legacy copper ablative coatings used by the Navy will be disqualified. Those releasing the same or less copper will be included in planned panel and ship testing in early FY17. The aim is to identify not only better-performing coatings but also more environmentally friendly systems.

The NSWCCD biofouling team will leverage and build on lessons learned from their recent experience with fouling release coatings while applying the principles of the 4Ms.

In addition to testing emerging hull and propeller coatings, NSWCCD's R&D plan includes the following:

- Developing tools and models to calculate fuel savings associated with hull coating performance.
- Improving screening test methods.
- Characterizing ship operations.
- Tracking coating system service life, performance, and maintenance history.

Among other collaborative efforts, the biofouling team plans to continue to engage with relevant members of the Navy community by attending several conferences such as the Fleet Maintenance and Modernization Symposium, the International Congress on Marine Corrosion and Fouling, and the Hull Performance & Insight Conference (HullPIC).

Summary

The challenges associated with defeating biofouling have existed since even before the birth of the Navy. NSWCCD and its partners and sponsors recognize the current opportunity to build on the momentum from recent projects to modernize the Navy's solution sets to biofouling remediation.

The solution to the biofouling problem in the military fleet is unlikely to be as simple as changing over to the newest hull coating technology, at least not without asking the right questions. NSWCCD's R&D plan attempts to identify the right set of interdependent variables to account for as they determine the suitability of biofouling control solutions for the Navy fleet. Reducing the Fleet's baseline biofouling condition will reduce cost (fuel and maintenance) and enhance capability for Navy warfighters. When the NSWCCD-led efforts are successful, more ships can go to sea for the same fuel budget, and operational efficacy (top speed, range, time between re-fueling) will be enhanced. From the operational energy viewpoint, the Navy Biofouling Control Program will pay deep dividends in the long run.

Shipyard workers in San Diego use high-pressure water to clean the hull of the amphibious assault ship USS Bonhomme Richard (LHD 6).
CMC Specialist Joe Kane

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