Ultra-Low-Friction Marine Coatings

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Table of Contents

- Introduction
- State of the Art
- Discussions
- Results
- Conclusions
- Q&A
Introduction

- All surfaces submerged in seawater are subject to marine organisms, including hundreds of thousands of types of bacteria, algae, and mollusks;
- To prevent Biofouling, a functional marine coating is used on the bottom of the ships.
- Hull deterioration occurs through coating degradation, wear and damage, bio-corrosion, and an increase in hull roughness.
- Biofouling costs the shipping industry billions of dollars per year in transportation expenses;
- No solution is perfect for all the vessels – eventually the coatings loose their performance causing the hull to be fouled.
The International Maritime Organization (IMO) has set ambitious decarbonization targets for the shipping industry, and the key dates for compliance are edging closer.

By 2030, the IMO aims to reduce vessels’ carbon emissions per transport work by at least 40% and is targeting a 70% reduction for 2050.

This should be done in parallel with an overall reduction of greenhouse gas (GHG) emissions by 50% across the sector.
Introduction – How coatings can help ship owners achieve better EEXI rating?

The EEXI formula for ships contains a fixed Engine Power value at 75% of the Maximum Continuous Rating (MCR). Therefore, any fuel efficiency benefit is realized as an increase in speed at constant power in the EEXI calculation as shown in the table below.

\[
\text{EEXI Formula} \quad \left[ \frac{g \ CO_2}{\text{ton} \times \text{mile}} \right] = \frac{\text{Conversion Factor} \times \text{Specific Fuel Consumption} \times \text{Engine Power (75\% MCR)}}{\text{Capacity} \times \text{Ship Speed at 75\% MCR}}
\]
Introduction – Active Hull cleaning and grooming as a solution for ship performance

Coatings that are engineered to be cleaned
State of the Art

Biocide Base Coatings

- To prevent biofouling and protect the hull, antifouling coatings are applied.

*Schematic of marine AF coating approaches: (a and c) Biocide-release based strategies;

State of the Art

- This antifouling coatings are “rough” by their nature.

Biocide Base Coatings

20x magnification
100 µm Ra
State of the Art

**Biocide Base Coatings**

- Once the biocide has leached out, it leaves a porous/rough surface that *increase the surface area* for marine growth.
State of the Art

- To prevent biofouling and protect the hull, foul release coatings are applied.

**Biocide Free Coatings**

20x magnification
~10 µm Ra
State of the Art

Biocide Free Coatings

• Once the surface is damaged, all the silicon oil has leached out biofouling is able to perforate the silicone pain being permanent adhered to the ship hull.

How do we engineer hull coatings for the future?

• Mechanical Properties
• Antifouling/Foul release performance
• Surface friction – simulations to scale up to real ships
• Grooming/Hull cleaning performance
## Methodologies – Mechanical Properties

<table>
<thead>
<tr>
<th>Pencil Hardness</th>
<th>Brush grooming</th>
<th>Scratch test 5kG load</th>
<th>MicroScratch test</th>
<th>Wear-off test</th>
<th>Pull off adhesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFR coating</td>
<td>Visible groove</td>
<td>Indenter direction</td>
<td>7.36 g/sq. m mass loss</td>
<td>2 MPa</td>
<td>Adhesive</td>
</tr>
<tr>
<td>XGTF FUEL</td>
<td>Minor groove</td>
<td>Indenter direction</td>
<td>5.16 g/sq. m mass loss</td>
<td>5 MPa</td>
<td>Adhesive</td>
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<tr>
<td>SPC coating</td>
<td>Visible groove</td>
<td></td>
<td>N/A</td>
<td>Engineer to wear</td>
<td>2.5 MPa</td>
</tr>
</tbody>
</table>
Methodologies – Antifouling tests and grooming/cleaning

### Foul-release and grooming performance

**Hybrid and Blade brushes attached to grooming tool**

![Image of Hybrid and Blade brushes attached to grooming tool](image)

**Foul-release Pressure washer grooming**

![Graph showing performance of different treatments](image)
Methodologies - Grooming/cleaning

- Silicone base coating
- Biocide base coating
Methodologies - contact angle and surface properties

Biocide

Silicone FR

Left Angle: 115.08
Right Angle: 114.19
Averages: 114.64

Hard FR

Left Angle: 110.24
Right Angle: 111.41
Averages: 110.83
Measurements of frictional resistance of fouling-control coatings using Fully Turbulent Flow Channel (FTFC)

For the attention of: Roberto Ravenna*, Soonseok Song, Yigit Kemal Demirel

Department of Mechanical Engineering of Dalhousie University, Halifax, Canada

The results obtained from the pressure drop measurements display the behaviour of all the coatings in a fully developed turbulent flow. Many of them appear to have reduced drag characteristics at lower speeds, while they display increased frictional drag with increasing speeds. As stated earlier, most coatings, especially FR02, show great performances at high speeds. The coatings tested present $c_f$ values that are very similar to those produced by the smooth reference panels.

----- Black Line: perfectly flat glass
- Biocide base coatings
- Silicone Foul Release coatings
- Hard Foul Release coatings

Figure 9: Comparison of skin friction coefficient of all coatings.
Results

- To prevent biofouling and protect the hull, hard foul release coatings are applied.

Advanced Hard Foul Release Coatings

Underwater hull inspection
To prevent biofouling and protect the hull, hard foul release coatings are applied.

20x magnification
~1 μm Ra
Shaft Power vs. Speed (Vessel Trials)

<table>
<thead>
<tr>
<th>Speed (kts)</th>
<th>Nov. 2021 (kW)</th>
<th>May 2022 (kW)</th>
<th>Difference (kW)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>21.19</td>
<td>19.05</td>
<td>-2.13</td>
<td>10.60</td>
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<tr>
<td>6.5</td>
<td>29.06</td>
<td>26.14</td>
<td>-2.92</td>
<td>10.58</td>
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<tr>
<td>7.0</td>
<td>38.93</td>
<td>35.03</td>
<td>-3.90</td>
<td>10.55</td>
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<tr>
<td>7.5</td>
<td>51.12</td>
<td>46.00</td>
<td>-5.11</td>
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<td>8.0</td>
<td>65.95</td>
<td>59.36</td>
<td>-6.58</td>
<td>10.51</td>
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<tr>
<td>8.5</td>
<td>83.78</td>
<td>75.43</td>
<td>-8.35</td>
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<td>9.0</td>
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<td>94.53</td>
<td>-10.45</td>
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<td>9.5</td>
<td>129.95</td>
<td>117.04</td>
<td>-12.91</td>
<td>10.45</td>
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<tr>
<td>10.0</td>
<td>159.11</td>
<td>143.33</td>
<td>-15.78</td>
<td>10.44</td>
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<td>10.5</td>
<td>192.90</td>
<td>173.80</td>
<td>-19.11</td>
<td>10.42</td>
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<tr>
<td>11.0*</td>
<td>231.79</td>
<td>208.86</td>
<td>-22.93</td>
<td>10.41</td>
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<tr>
<td>11.5*</td>
<td>276.24</td>
<td>248.95</td>
<td>-27.29</td>
<td>10.39</td>
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<tr>
<td>12.0*</td>
<td>326.77</td>
<td>294.52</td>
<td>-32.24</td>
<td>10.38</td>
</tr>
<tr>
<td>Average</td>
<td>131.67</td>
<td>118.62</td>
<td>-13.06</td>
<td>-10.43</td>
</tr>
</tbody>
</table>

*Interpolated for May 2022.
Results

The EEXI formula for ships contains a fixed Engine Power value at 75% of the Maximum Continuous Rating (MCR). Therefore, any fuel efficiency benefit is realized as an increase in speed at constant power in the EEXI calculation as shown in the table below.

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\]

<table>
<thead>
<tr>
<th>Coating System Comparison</th>
<th>Reduction rate of Power</th>
<th>Speed with ESM ((V_{ref} \text{ at 75% MCR}))</th>
<th>Increase Speed [knot]</th>
<th>Improvement rate of EEXI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard FR vs. Soft FR</td>
<td>-1.6%</td>
<td>14.07</td>
<td>+0.07</td>
<td>+0.5%</td>
</tr>
<tr>
<td>Hard FR vs. Copper Biocide AF</td>
<td>-5.8%</td>
<td>14.27</td>
<td>+0.27</td>
<td>+1.9%</td>
</tr>
<tr>
<td>Hard FR vs. Icebreaking</td>
<td>-11.7%</td>
<td>14.55</td>
<td>+0.55</td>
<td>+3.9%</td>
</tr>
</tbody>
</table>
Conclusions

• Marine and Protective industry is going through a decarbonization. New coatings solutions are needed;
• Ships need to cut emissions. Active hull cleaning and grooming is becoming a habit;
• Traditional soft or biocide base coatings are not engineer to be groomed.
• Hard, “slippery” marine paints that can sustain hull cleanings and offer fuel savings for ship owners using low surface friction.