Coatings Trends & Technologies

Ultra-Low-Friction Marine Coatings

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GRAPHITE INNOVATION & TECHNOLOGIES

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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.

Introduction - Dual regulations reducing ship's carbon impact

- 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.

$$EEXI\ Formula \left[\frac{g\ CO_2}{ton * mile}\right] = \frac{Conversion\ Factor\ \times Specific\ Fuel\ Consumtpion \times \boldsymbol{Engine\ Power}\ (\boldsymbol{75\%MCR})}{Capacity \times \boldsymbol{Ship\ Speed\ at}\ \boldsymbol{75\%MCR}}$$

Introduction – Active Hull cleaning and grooming as a solution for ship performance

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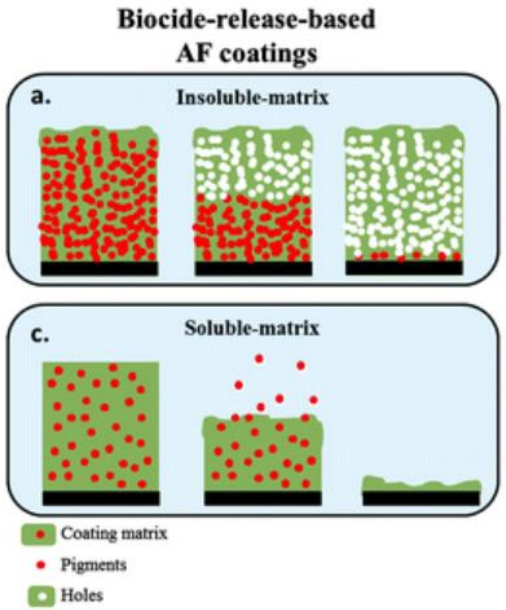
Coatings that are engineer to be cleaned

State of the Art

Biocide Base Coatings

- To prevent <u>biofouling</u> and protect the hull, antifouling coatings are applied.



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

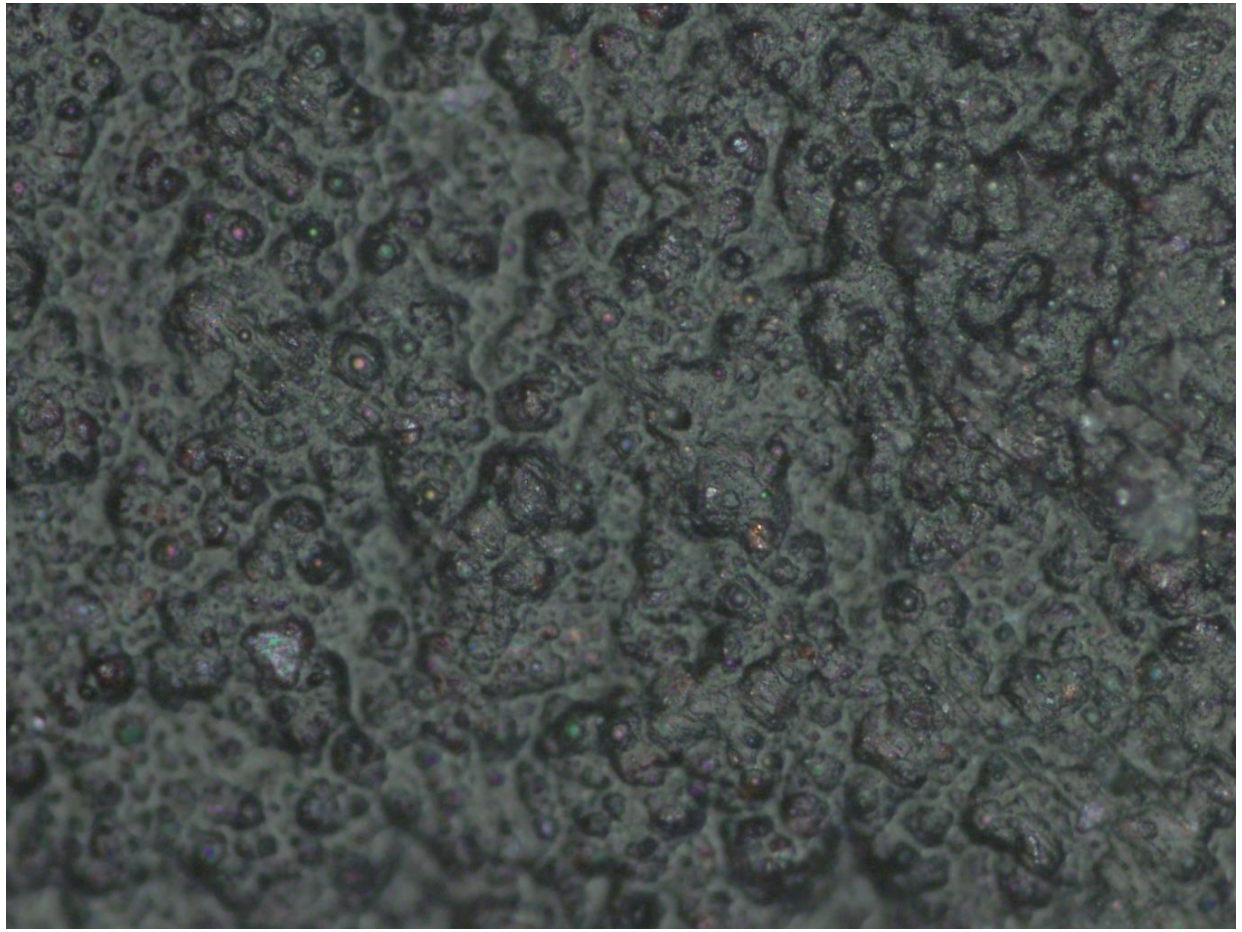
*Selim, Mohamed S., et al. "Recent progress in marine foul-release polymeric nanocomposite coatings." *Progress in Materials Science* 87 (2017): 1-32.

State of the Art

Biocide Base Coatings

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

20x magnification
100 µm Ra



State of the Art

Biocide Base Coatings

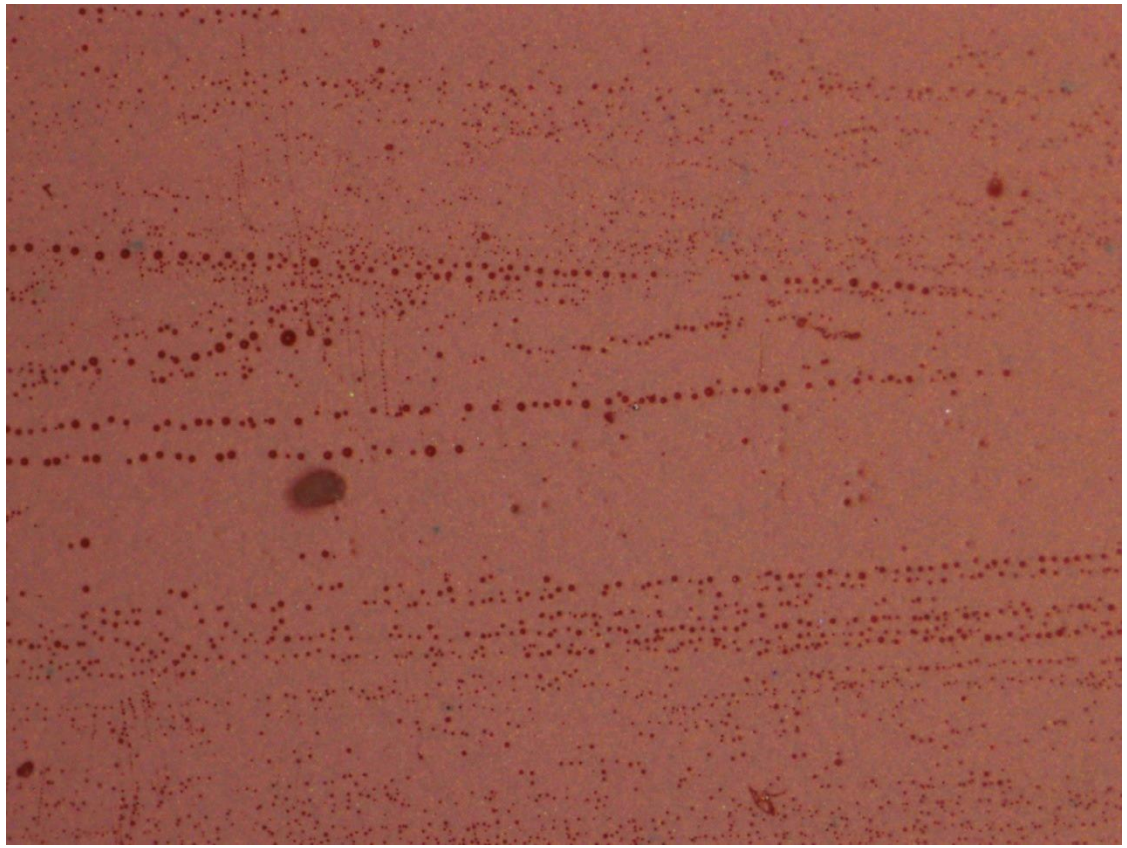
- Once the biocide has leached out, it leaves a porous/rough surface that ***increase the surface area*** for marine growth.

State of the Art

Biocide Free Coatings

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

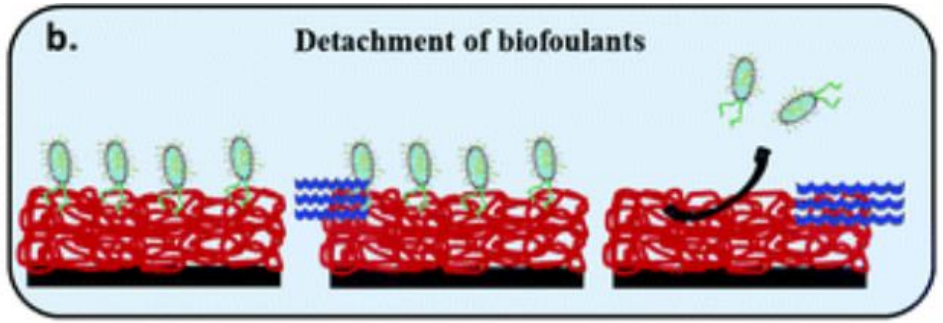
20x magnification
~10 µm Ra



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.



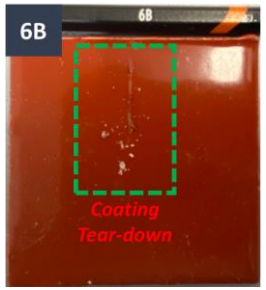
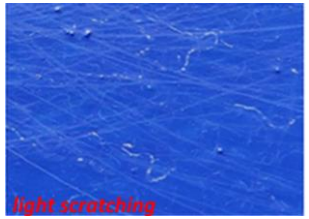
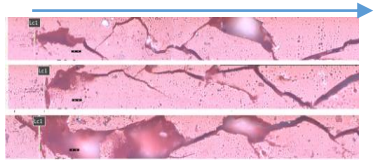
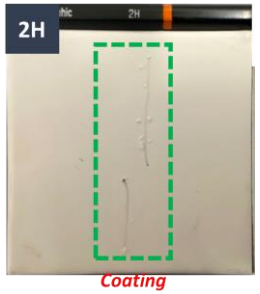
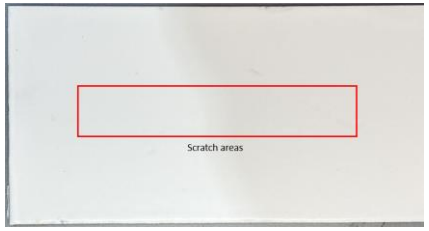
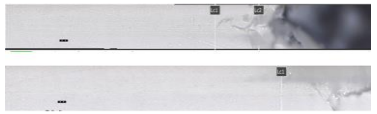
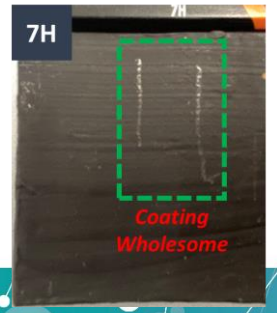
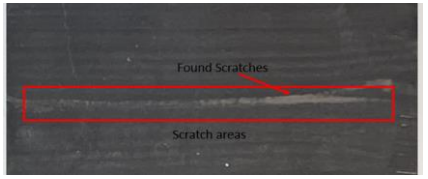
*non-biocide-release based strategies

*Selim, Mohamed S., et al. "Recent progress in marine foul-release polymeric nanocomposite coatings." *Progress in Materials Science* 87 (2017): 1-32.

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

Pencil Hardness	Brush grooming	Scratch test 5kG load	MicroScratch test	Wear-off test	Pull off adhesion
SFR coating 		Visible groove 	Indenter direction 	7.36 g/sq. m mass loss 	2 MPa Adhesive
XGIT FUEL 		Minor groove 	Indenter direction 	5.16 g/sq. m mass loss	5 MPa Adhesive
SPC coating 		Visible groove 	N/A	Engineer to wear	 2.5 MPa Cohesive

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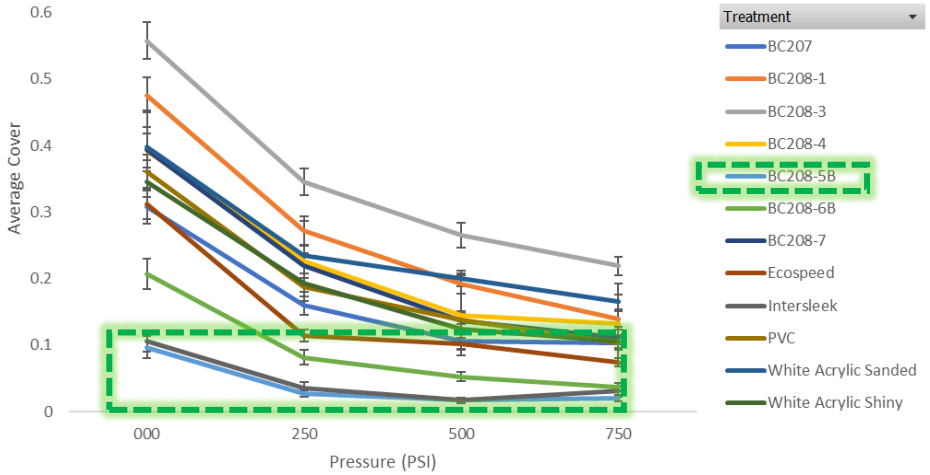
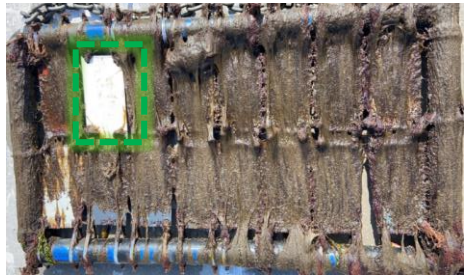
Methodologies – Antifouling tests and grooming/cleaning

Foul-release and grooming performance

Foul-release Pressure washer grooming

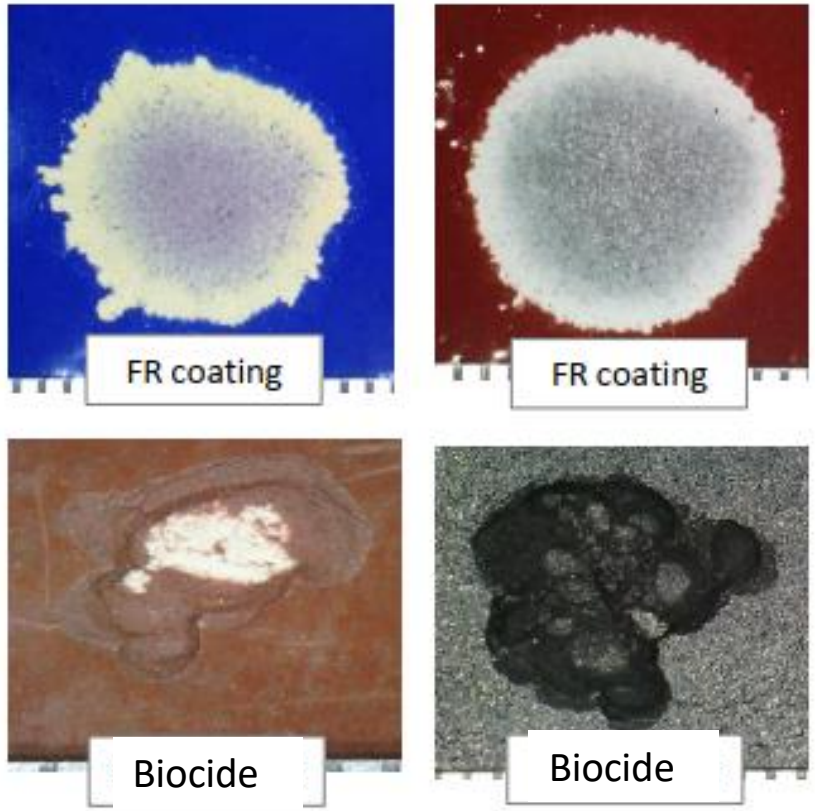




Methodologies - Grooming/cleaning

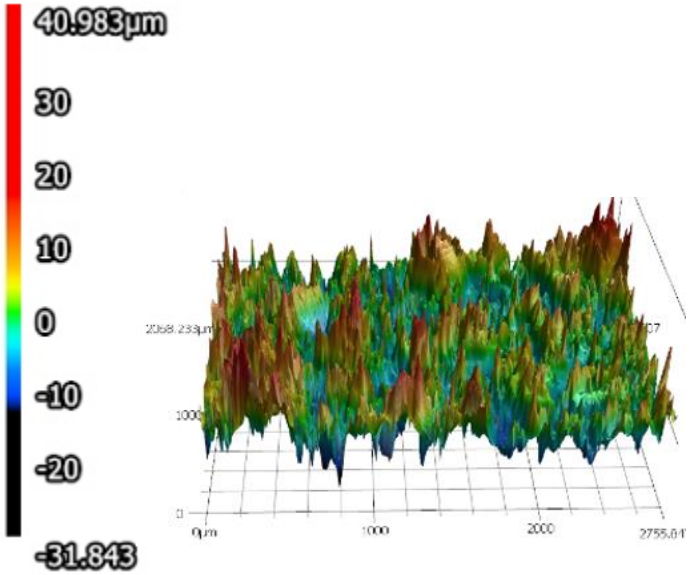
Silicone base coating

Biocide base coating

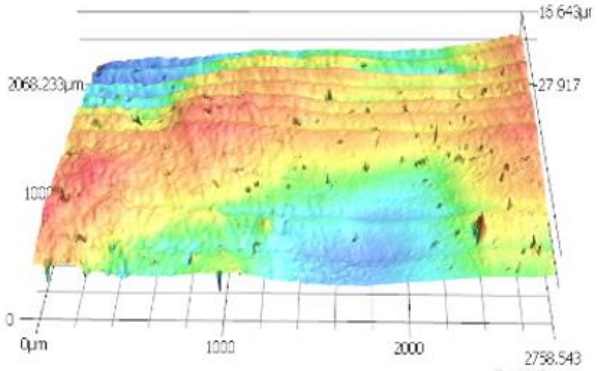


Methodologies - contact angle and surface properties

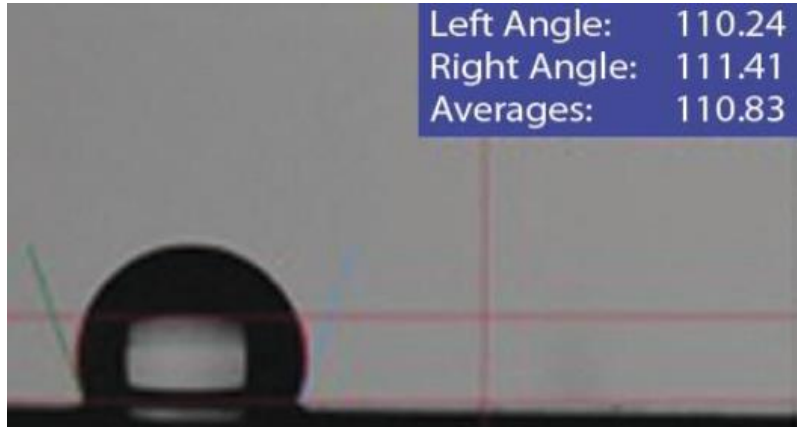
Biocide

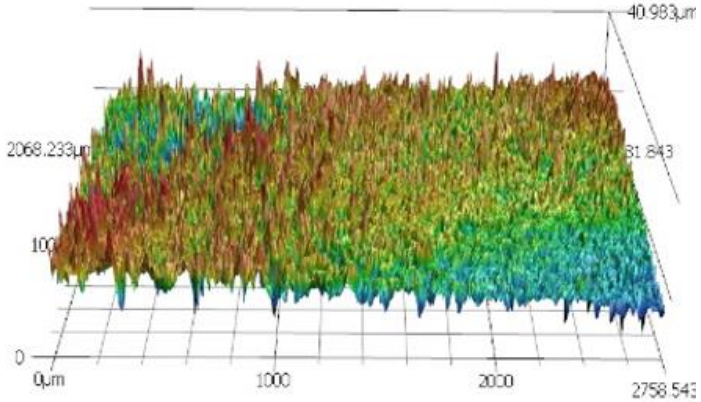


Silicone FR



Hard FR





Methodologies - Frictional resistance

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

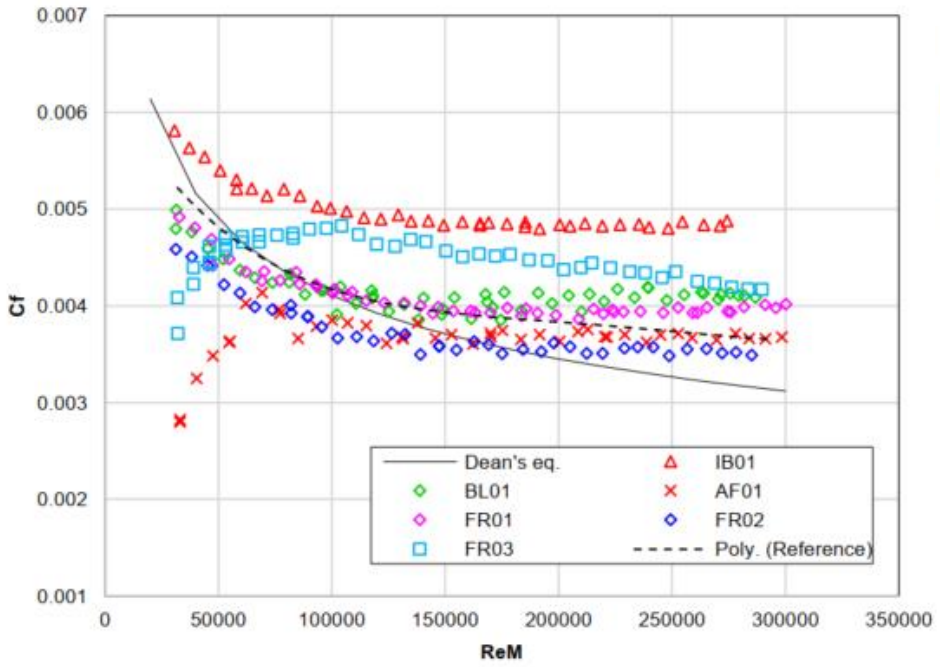


Figure 9: Comparison of skin friction coefficient of all coatings.

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

Results

Advanced Hard Foul Release Coatings

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

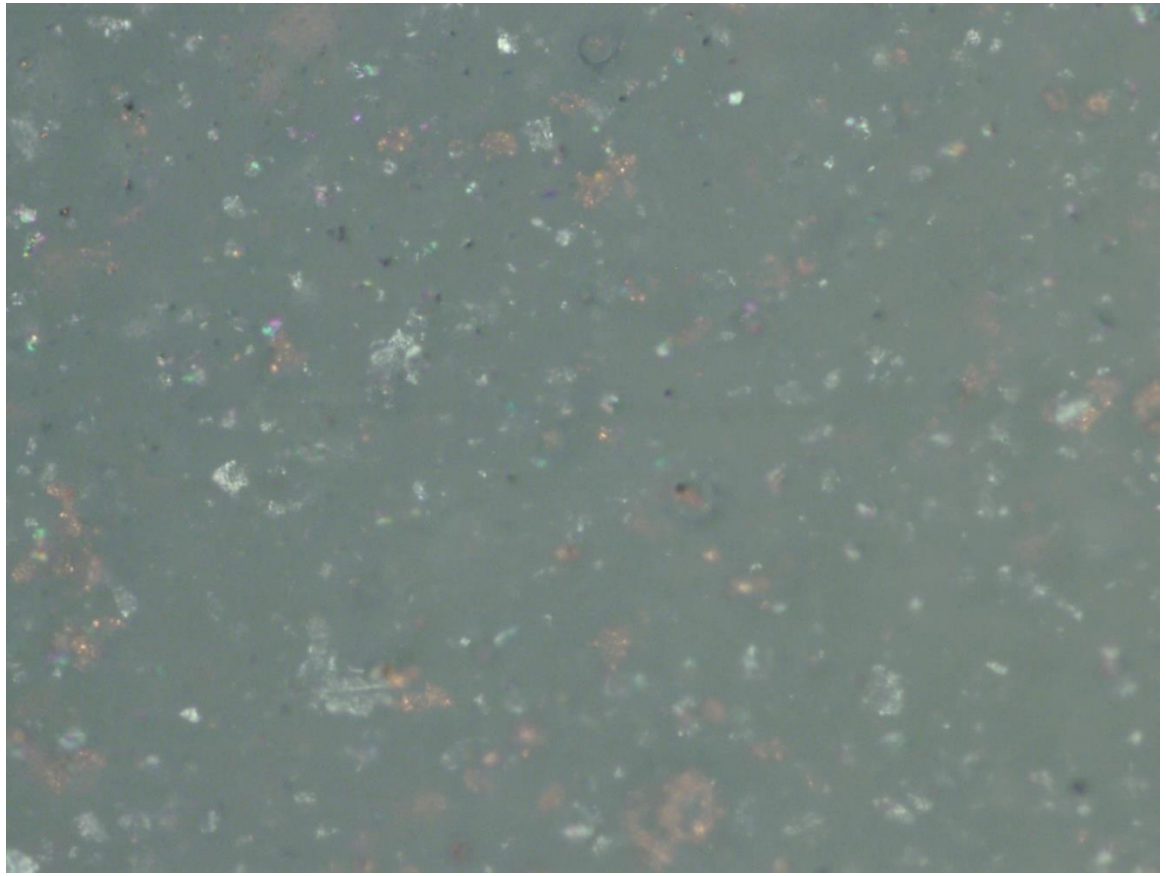
Underwater hull inspection

Results

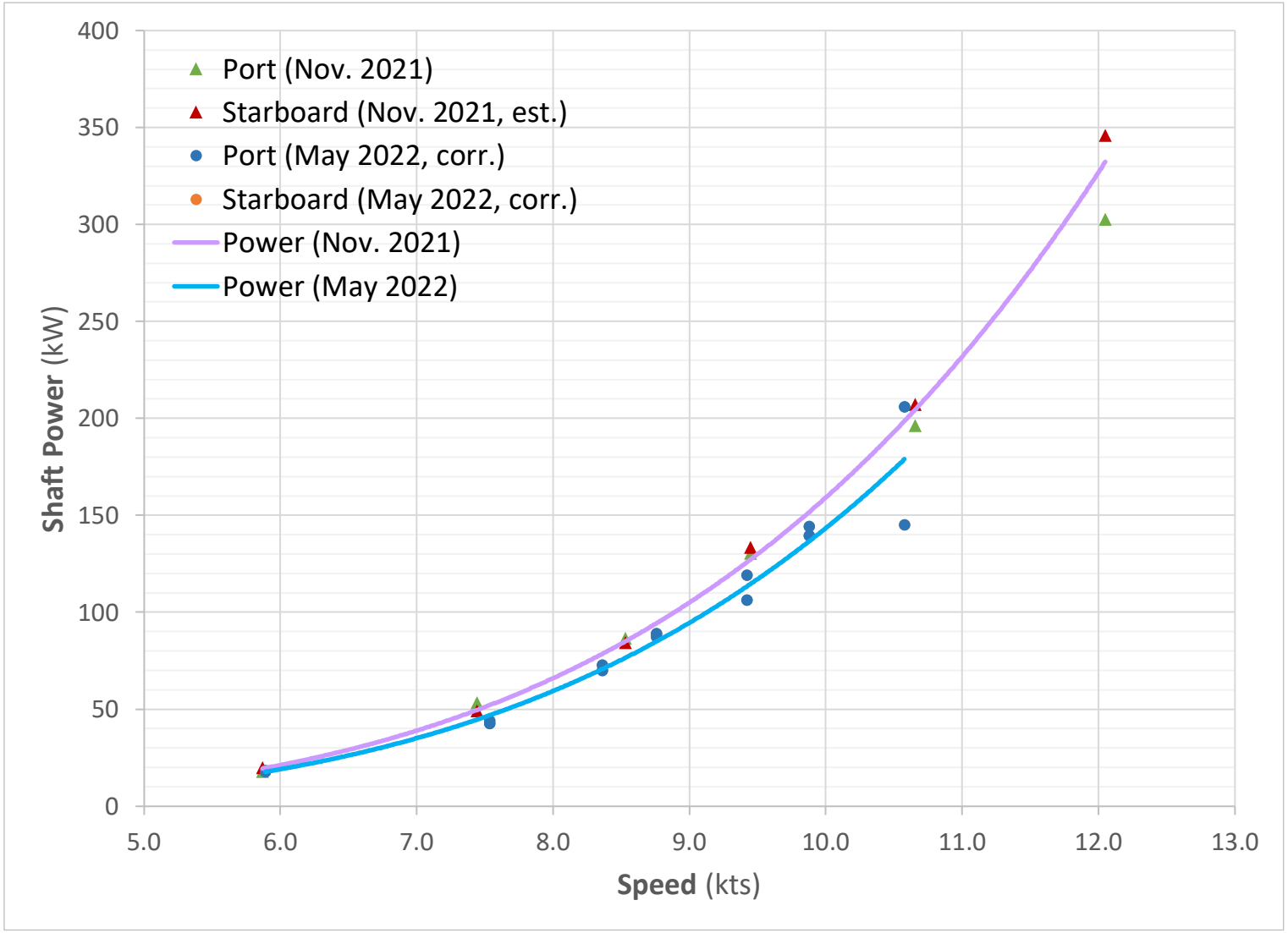
Advanced Hard Foul Release Coatings

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

20x magnification
~1 µm Ra



Shaft Power vs. Speed (Vessel Trials)



Speed (kts)	Shaft Power Nov. 2021 (kW)	May 2022 (kW)	Difference (kW)	Difference (%)
6.0	21.19	19.05	-2.13	10.60
6.5	29.06	26.14	-2.92	10.58
7.0	38.93	35.03	-3.90	10.55
7.5	51.12	46.00	-5.11	10.53
8.0	65.95	59.36	-6.58	10.51
8.5	83.78	75.43	-8.35	10.49
9.0	104.98	94.53	-10.45	10.47
9.5	129.95	117.04	-12.91	10.45
10.0	159.11	143.33	-15.78	10.44
10.5	192.90	173.80	-19.11	10.42
11.0*	231.79	208.86	-22.93	10.41
11.5*	276.24	248.95	-27.29	10.39
12.0*	326.77	294.52	-32.24	10.38
Average	**131.67**	**118.62**	**-13.06**	**-10.43**

*Interpolated for May 2022.

Results

Advanced Hard Foul Release Coatings

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

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.