Effect of substrate roughness and coating chemistry on ship drag resistance, fuel consumption and GHG emissions

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HEMPEL

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Shipping and fuel consumption

Calculation assessment	Result 2007 Mill. Tonnes	Result 2020 Mill. Tonnes
Total Fuel Consumption by ships	369	486
CO_2 emissions from ships	1,120	1,475
Total SOx emission from ships	16.2	22.7
NOx emissions from ships	25.8	34.2
PM_{10} emissions from ships	1.8	2.4

- About 4.5% of global CO_2 emissions
- More than double than aviation
- Emissions from aviation and shipping fastest growing source of GHG
- Likely inclusion in post-Kyoto GHG agreements

Review of MARPOL Annex VI, IMO , SUB-COMMITTEE ON BULK LIQUIDS AND GASES 2007

AF and Estimated Savings

Silicone vs. SPC, for ONE large container vessel…

- 7775 tonnes fuel/year
- $3.9 million US/year
- 24550 tonnes CO_2/year
- 490 tonnes SO_x/year
- 780 tonnes NO_x/year

CO_2 savings in one vessel equivalent to about 5000 family cars/year

AF protection and fuel

- Roughly, a ship burns its entire cost in fuel after about 5 years sailing!
- Global focus on fuel costs are expected to increase in the coming years!
- Also legislative attention to GHG emissions related to Climate Change will gain importance
- "Environmentally-friendly" = safe to non-target species AND highly efficient

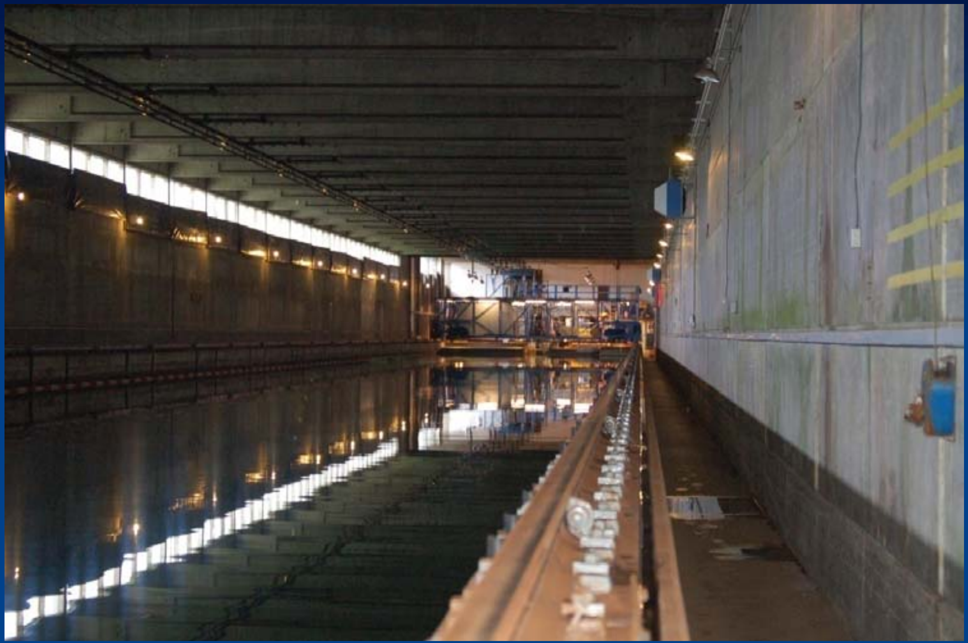
Objectives

- To continue generating knowledge about Hempel's AF coatings
  - To compare towing tank tests to those from Weinell's et al. (2003) study with rotary setups.
- To compare freshly applied silicone topcoats to conventional self-polishing AF
- To study the role of substrate condition (surface preparation/roughness)

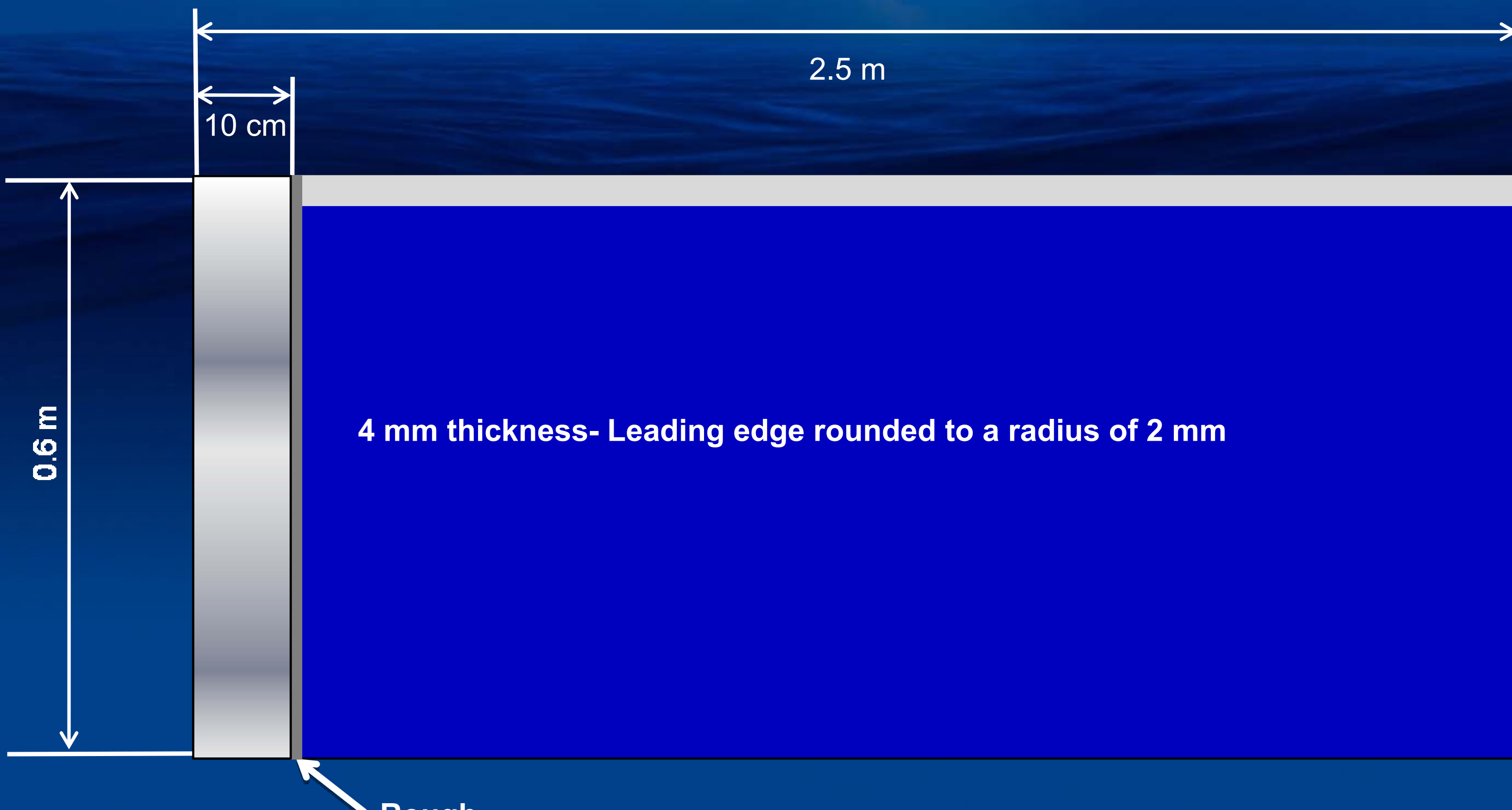
Test panels

Towing tank

- 240 m long, 12 m wide, 5.5 m deep
- Towing speeds up to 7 m/s
- Adapted to tow flat pannels



Test panels



Rough sandpaper to hasten the development of a thick boundary layer

Towing study

- Minimal wake and limited splashing
- Fore and after body drag penalties minimal
- Wave drag, spray drag, body drag and air drag non-significant/estimated
- Constant water temperature 13.7 ºC

Panels	Deviation	Runs
All panels with Re_k <5	0.9%	30
Aluminium references	0.47%	13
Same speed same panel	0.34%	20

Test Panels

- Three aluminium panels were used as smooth references
- Surface roughness was provoked to the uncured epoxy undercoats simulating “realistic” scenarios
- Roughness (R_t) was measured with a BMT gauge (50 mm cut-off) and averaged over the entire surface

Assumptions

- No fouling exposure (Weinell et al., 2003; Holm et al., 2004; Schultz, 2004)
- Freshly applied:
  - No self-smoothening effect of the SPC (Weinell et al., 2003)
  - No surface damage (Holm et al., 2004)

Holm E, Schultz M, Haslbeck E, Talbott W and Field A (2004), 'Evaluation of hydrodynamic drag on experimental fouling-release surfaces, using rotating disks', Biofouling, 20 (4-5), 219-226.
Weinell C E, Olsen K N, Christoffersen M W and Kiil, S (2003), 'Experimental study of drag resistance using a laboratory scale rotary set-up', Biofouling, 19 (supplement), 45-51.

Silicone vs. Conventional AF

Full scale velocity (knots)	Test velocity (m/s)	Increase in C_F from Hempasil to SPC paint (%)		
		New Building	Medium roughness	High roughness
8.2	3.0	2.2	10.2	4.0
9.6	3.5	1.1	11.3	2.8
11.0	4.0	2.3	12.4	4.3
13.7	5.0	1.2	13.6	3.6
16.4	6.0	1.5	13.7	3.9
19.2	7.0	0.1		
		Average		
	ΔC_F	**1.4**	**5.0**	**1.6**

- Smooth case
- Comparison to other drag studies

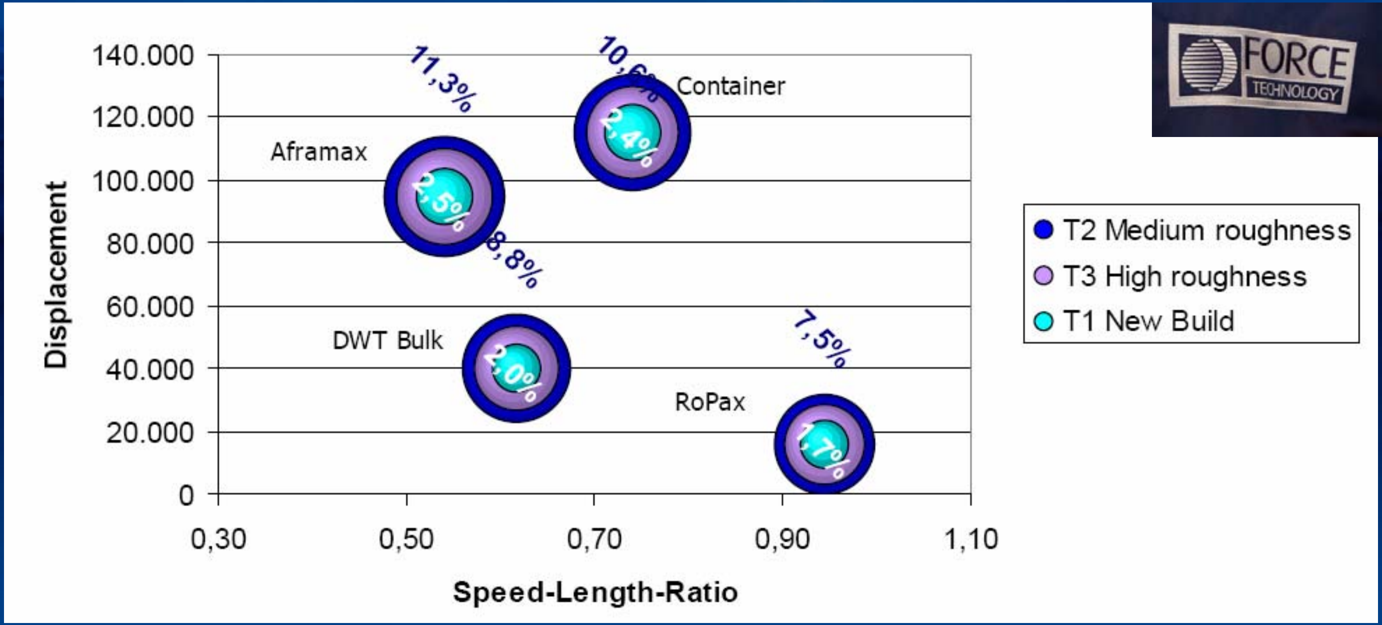
Silicone vs. Conventional AF

Source	ΔC_F%	Remarks
This study	1.4%	Full system on smooth Al/smooth undercoats
Weinell et al. (2003)	6.1%	Rotary study. Topcoat on smooth PVC
Candries et al., (2003)	3.5%	Rotary study. Full system on smooth PVC
Schultz (2004)	3.0-3.8%	Full system on 304SS. No sandpaper strip
Holm et al. (2004)	-2.5%	Friction disk machine. After biofilm removal. Potential surface damage
Candries and Atlar (2005)	5.3%	Topcoat on smooth steel. Turbulent boundary layer measurements

- Small but significant differences for the "smooth" case.
- Note that the self-smoothening of the conventional AF topcoat has not been considered

Candries M, Atlar M, Mesbahi E and Pazouki K (2003), 'The measurement of the drag characteristics of tin-free self-polishing co-polymers and fouling release coatings using a rotor apparatus' Biofouling, 19 (suppl.), 27-36.
Schultz M P (2004), 'Frictional resistance of antifouling coating systems', Journal of Fluids Engineering, 126, 1039-1047.
Candries, M and Atlar, M (2005), 'Experimental investigation of the turbulent boundary layer of surfaces coated with marine antifoulings', Journal of Fluids Engineering, 127 (2), 219-232.

Power efficiency extrapolation



- C_F extrapolated following ITTC standards
- Typical speeds, lengths, and displacements for different ship types from Kristensen (2007)

Kristensen, H. O. H. (2007) Preliminary ship design of container ships, bulk carriers and Ro-Ro ships - including assessment of environmental impact from sea-borne transport compared with land based transport, extract of lecture note from The Technical University of Denmark

Estimated Savings

Choosing Hempasil, for ONE VESSEL…

Source	Tonnes Fuel/year	million $US/year	Tonnes CO_2/year
ROPAX	200-875	0.10-0.44	650-2800
Large Container	1750-7775	0.88-3.90	5500-24550
Aframax tanker	325-1500	0.16-0.75	1050-4700
Bulk carrier	225-1000	0.11-0.50	700-3150

Source	Tonnes SOx/year	Tonnes NOx/year
ROPAX	15-55	20-90
Large Container	110-490	170-780
Aframax tanker	20-95	30-150
Bulk carrier	15-65	20-100

CO_2 savings in one vessel equivalent to 5000 family cars/year

Conclusions

- High-quality towing tank experiments have been carried out at FORCE's facilities
- Fouling release coatings do seem to smooth out high substrate roughness
- Clean fouling release topcoats can save millions of $US/year in fuel per vessel compared to clean SPCs
- Real life results confirm significant savings

Further work

- Further studies should focus on long term drag perfomance of these coatings
- Raft test demonstrate long-term cleanability properties of FR commercial products
- Higher resistance increase reported for FR coatings by e.g. Schultz (2004) and Holm et al. (2004)

Schultz, M.P. (2004), Frictional Resistance of Antifouling Coating Systems. Journal of Fluids Engineering, 126, 1039-1047

Holm, E.R., Schultz, M.P., Haslbeck, E.G., Talbott, W.J., Field, A.J. (2004). Evaluation of Hydrodynamic Drag on Experimental Fouling-release Surfaces, using Rotating Disks. Biofouling 20(4/5), 219-226

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