Sensitivity analysis of the tool for assessing safe manoeuvrability of ships in adverse sea conditions

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Overview

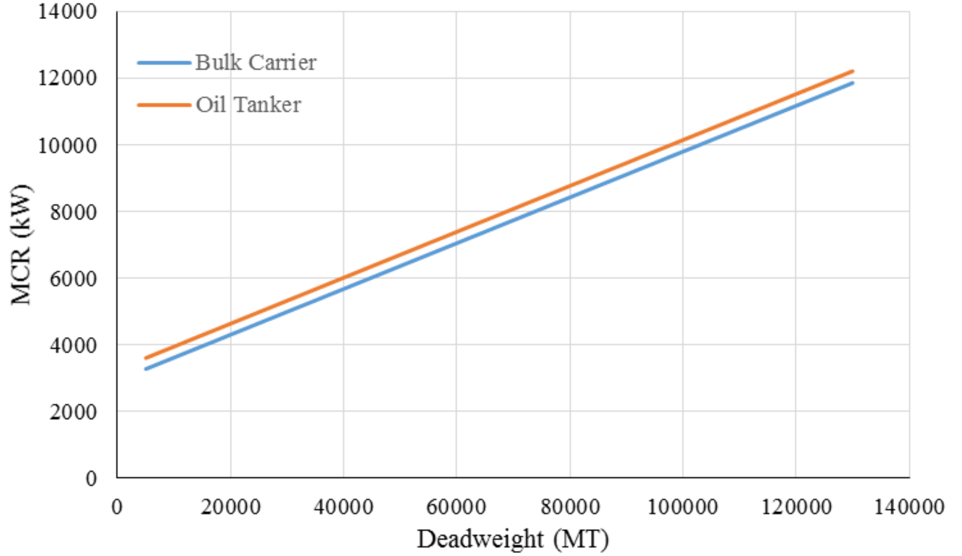
- Background
- Assessment Process
- Analysis
- Conclusion

Background

- UNFCCC target: 2^{o}C below the preindustrial level
  - Emission reduction technologies
  - Alternative fuels
  - CO_2 offsetting
- IMO has introduced EEDI and EEOI as indicators of ship energy efficiency
- MEPC 65: Introduction of "2013 Interim Guidelines for Determining Minimum Propulsion Power to Maintain the Manoeuvrability of Ships in Adverse Conditions"
- MEPC 68: Amendment of 2013 Guidelines
- MEPC 70: Presentation of SHOPERA project outcomes in respect of Minimum Propulsion Power

Background

- Assessment level 1
  - Minimum power line depending on the ship type and deadweight



- Assessment level 2
  - Minimum navigational speed (or course-keeping speed)
  - Installed power to achieve the required speed

General Comprehensive Assessment

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Surge Force: $X_s + X_w + X_d + X_R + T(1-t) = 0$

Sway Force: $Y_s + Y_w + Y_d + Y_R = 0$

Yaw Moment: $N_s + N_w + N_d - Y_R \, l_R = 0$

Oscillatory forces and moments due to waves are neglected

Propulsion critical condition

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- Assumptions:
  - Head seaways (0° – 60°)
  - Drift forces are neglected

Vessel Speed 4 knots

Surge Force: $X_s + X_w^{00} + X_d^{00} + X_R + T(1 - t_H) = 0$

Sway Force: $Y_s + Y_w + Y_d + Y_R = 0$

Yaw Moment: $N_s + N_w + N_d - Y_R l_R = 0$

Manoeuvring critical condition

- Assumptions:
  - Beam seaways (~90^o)
  - Calm water yaw moment lever most important

Surge Force

$$X_s + X_w^{90} + X_d^{90} + X_R + T(1-t_H) = 0$$

Sway Force

Yaw Moment

$$Y_R = -b(Y_w^{90} + Y_d^{90})$$

$$b = l_s/(l_s + l_R)$$

Investigated cases

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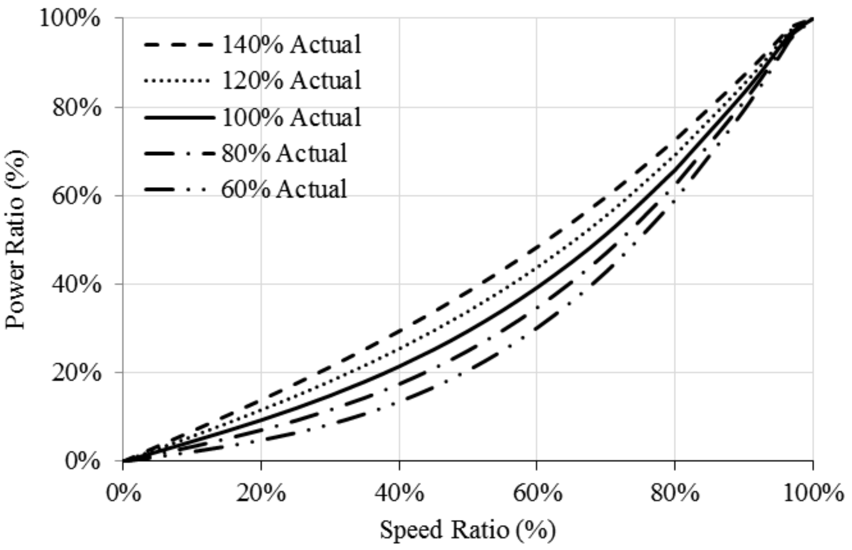
- KVLCC2 – VLCC tanker (Van et al, 1998)
- DTC – 14000 TEU container vessel (Moctar et al., 2012)

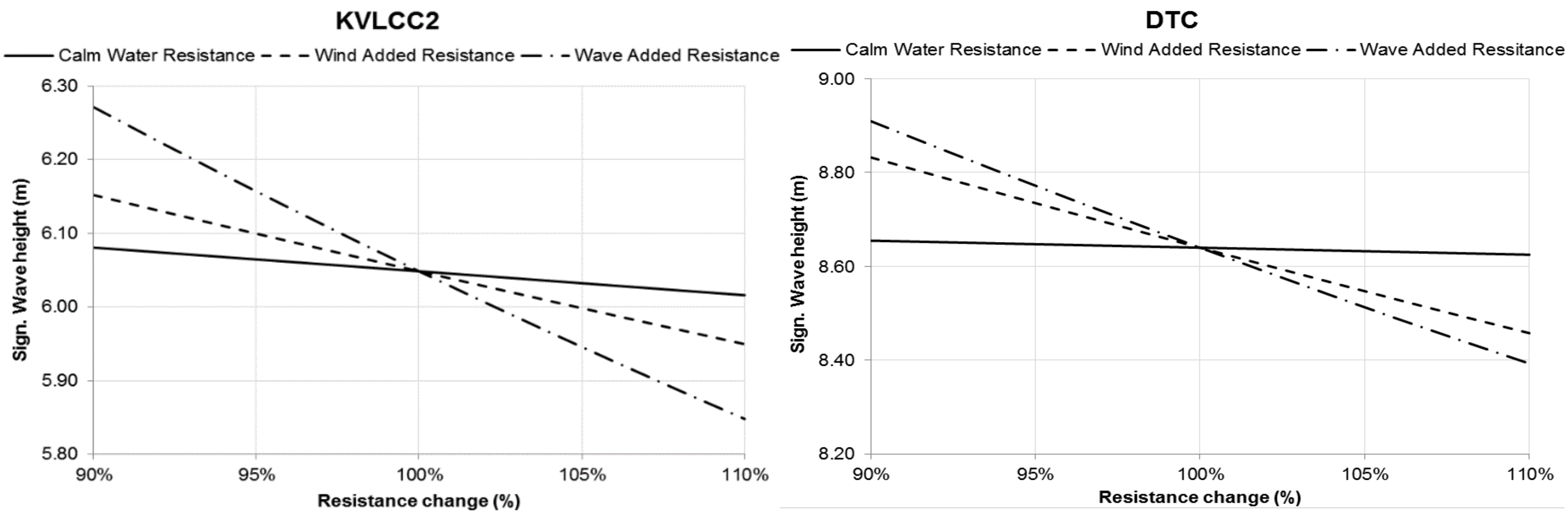
	KVLCC2	DTC
MCR power (kW)	29,340	80,080
Vessel design speed (knots)	15.5	25.0
Propeller design speed (rev/s)	1.34	1.70
Propeller type	Fixed pitch	Fixed pitch

Control Parameters

- Resistance
  - Calm water
  - Wind
  - Wave
- Propeller performance
  - Thrust coefficient
  - Torque coefficient
- Hull – Propeller interaction factors
  - Thrust deduction
  - Wake fraction
- Engine Power/Speed limit

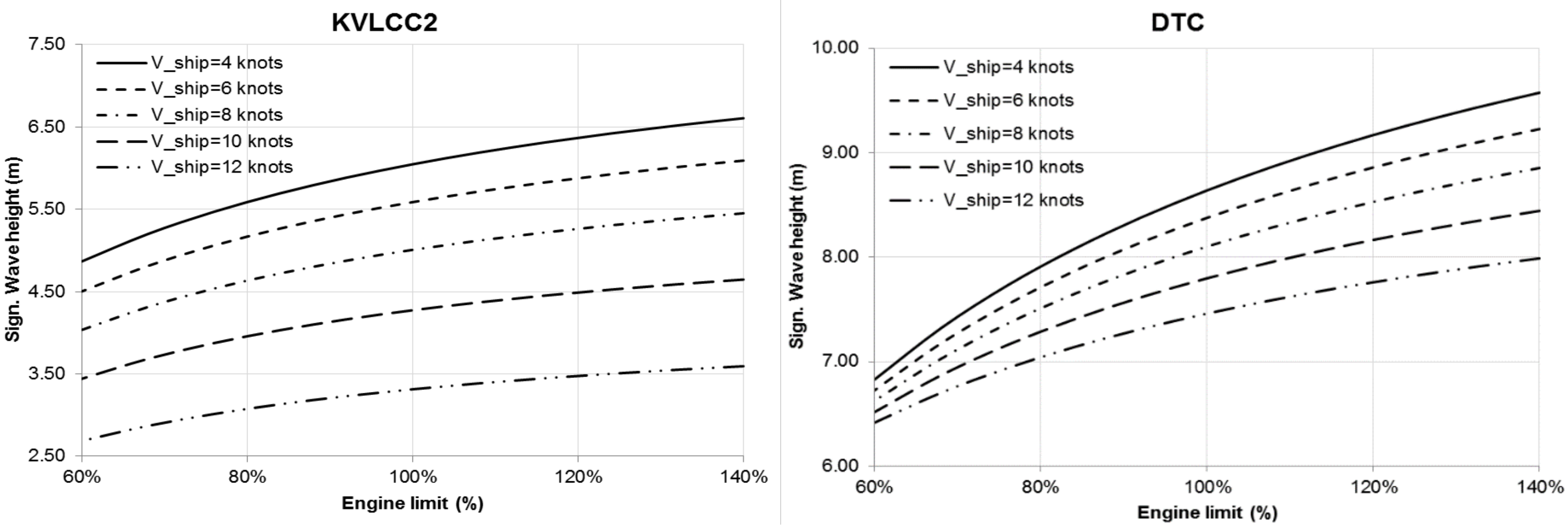


Results - Propulsion



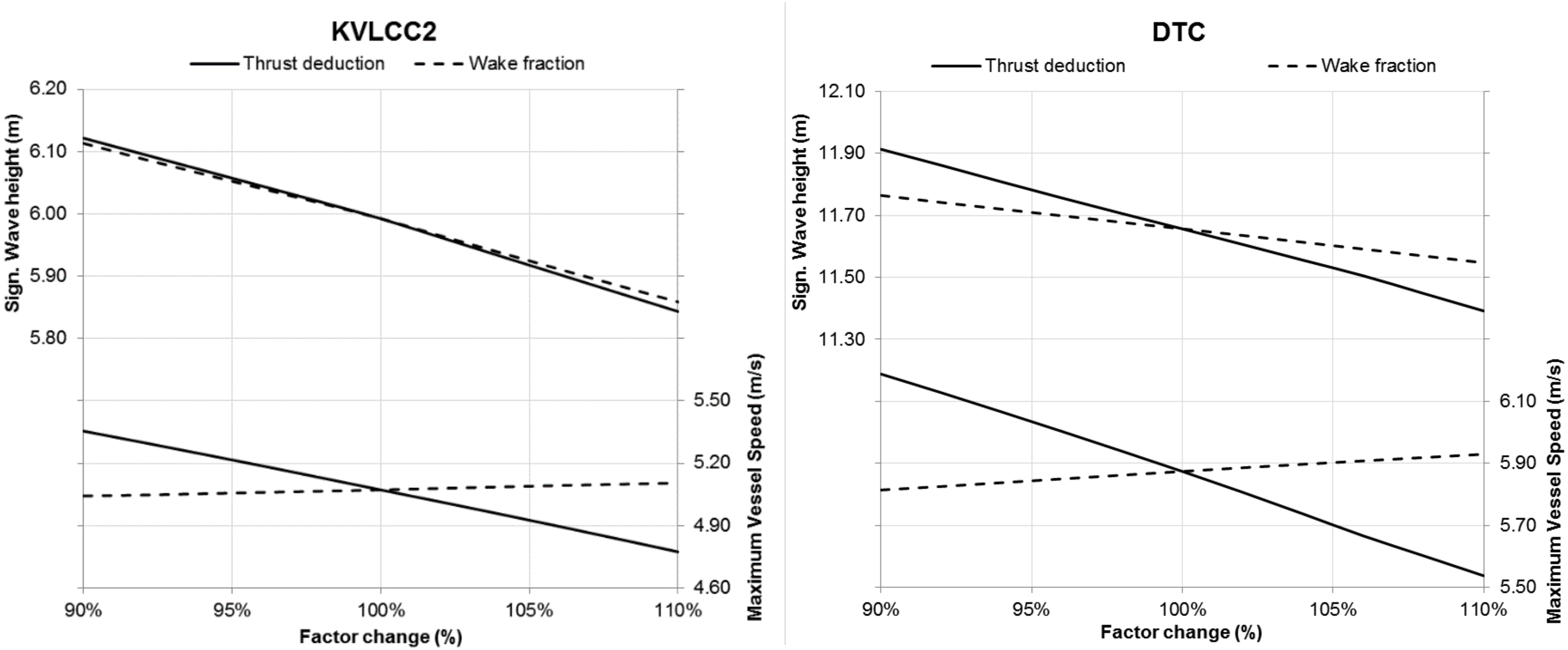
Analysis of maximum head wave height at speed of 4 knots, using calm water, wave added and wind added resistance as control parameters for a) the KVLCC2 vessel and b) the DTC vessel.

Results - Propulsion



Analysis of maximum head wave height at various vessel speeds, using power/speed engine limit as control parameter for a) the KVLCC2 vessel and b) the DTC vessel.

Results - Manoeuvring



Analysis of maximum head wave height and vessel's speed using wake thrust and thrust deduction factors as control parameters for a) the KVLCC2 vessel and b) the DTC vessel.

Results

	Critical Condition		
	Propulsion	Manoeuvring	
	Max. wave height error (%)	Max. speed error (%)	Max. wave height error (%)
Calm water resistance	0.35% / 10%	1.70% / 10%	0.66% / 10%
Added wind resistance	1.93% / 10%	0.08% / 10%	0.03% / 10%
Added wave resistance	3.25% / 10%	4.38% / 10%	1.79% / 10%
Propeller thrust coefficient	5.52% / 10%	3.26% / 10%	4.59% / 10%
Propeller torque coefficient	9.50% / 10%	6.53% / 10%	8.58% / 10%
Thrust deduction factor	4.02% / 10%	5.63% / 10%	2.28% / 10%
Wake fraction factor	0.13% / 10%	0.80% / 10%	1.53% / 10%
Engine power/speed limit	15.15% / 10%	6.54% / 10%	6.31% / 10%

Conclusions

- Analysis of of Level 2 assessment procedure
- Investigation of minimum propulsion power requirement in two different critical conditions (propulsion and manoeuvring) for two different study cases
- Accuracy of the minimum propulsion power depends on the applied methods accuracy
- Limitations of engine power/speed limit is the most important parameter
- Further investigation of propulsion system and engine components contribution to the estimation of critical condition

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