

MARITIME

SHOPERA Workshop WP2&4:

Simple Semi-Empirical Models for Time-Average Wave Forces X_d , Y_d and Moment N_d

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[10 min]

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Assumptions

- Proposal:

- for Level 2 methods, approximate quadratic transfer functions in regular waves, and use spectral method to find forces and moment in irregular waves

$$[X_d, Y_d, N_d](v_x, \mu_0, h_s, T_p) = 2 \int_0^\infty \int_0^{2\pi} \frac{[X_d, Y_d, N_d](v_x, \mu, \omega)}{\zeta_a^2} S_{\zeta\zeta}(\omega | h_s, T_p) D(\mu | \mu_0) d\omega d\mu$$

- for Level 1 methods, approximate directly time-average wave forces in irregular seaways (spectral integration is too complex for Level 1 methods)

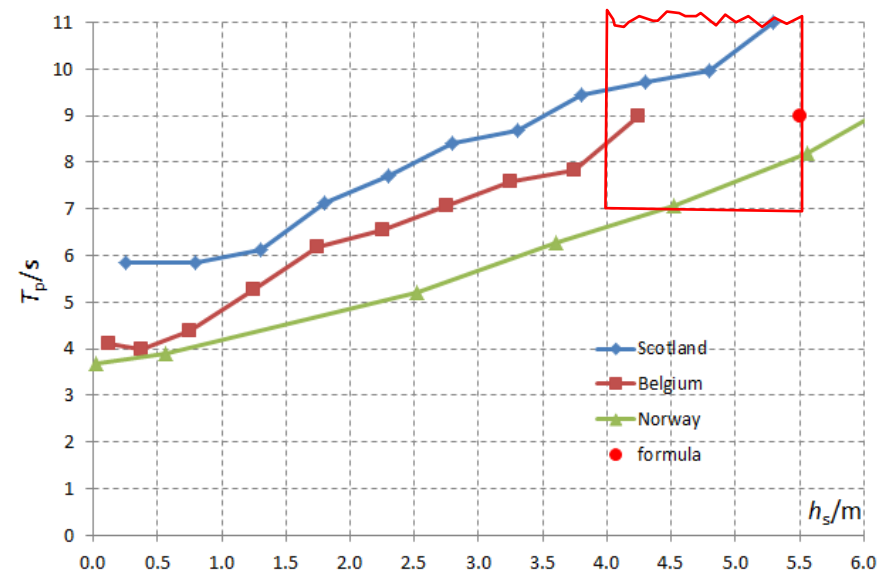
- Task: all three components of time-average forces: longitudinal X_d , lateral Y_d and yaw moment N_d as functions of (SHIP; v_s , μ , T_p , h_s , $S_{\zeta\zeta}$, spreading)

- Still too complex; simplifications:

- small ship speeds v_s only (from 0 to 6 m/s)
- JONSWAP wave energy spectrum with $\gamma=3.3$
- \cos^2 -wave energy spreading with respect to mean wave direction
- Peak wave period $T_p=9.0$ s (corresp. to $h_s=5.5$ m, slightly conservative)

- Remains:

- Mean wave directions μ from 0 to 180°
- SHIP parameters



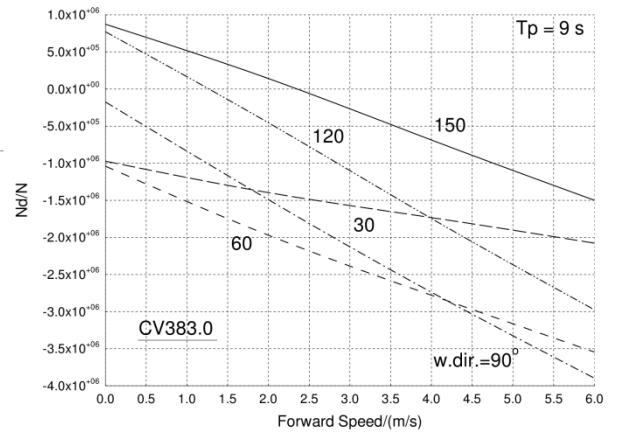
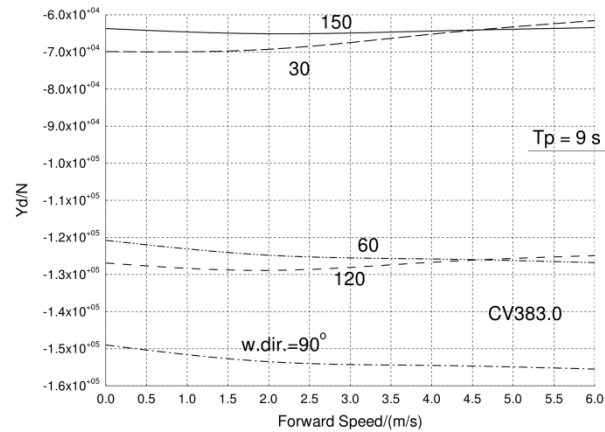
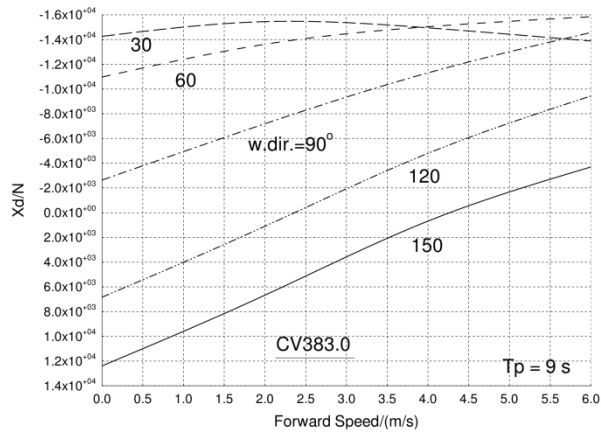
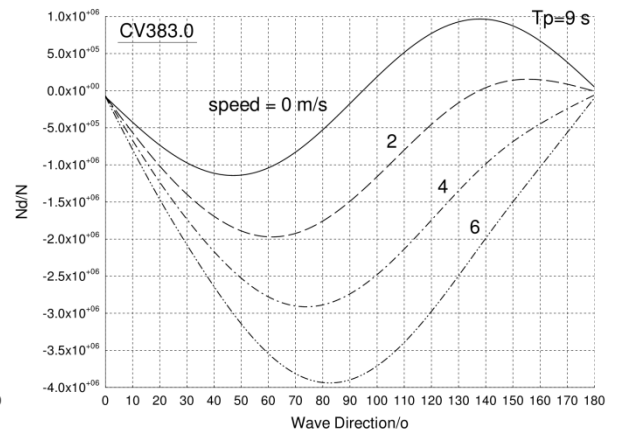
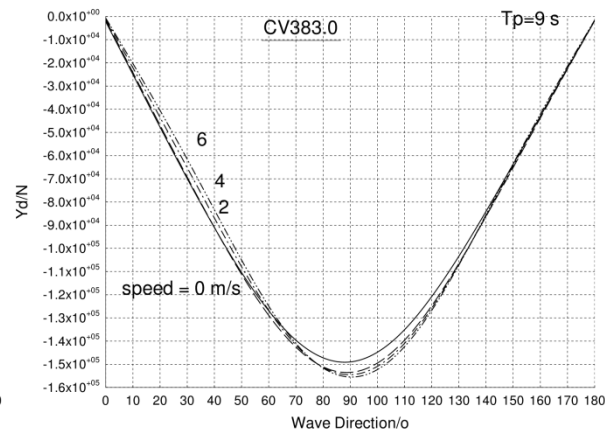
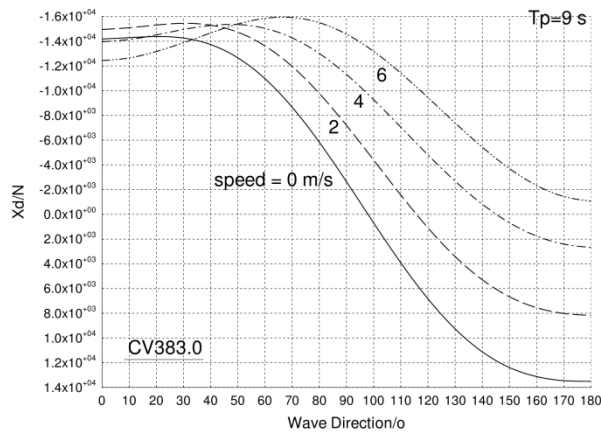
Database of Ships

Type	Lpp [m]	Bwl [m]	Tsc [m]	dwtscl [t]	GMsc [m]	m [t]	CB [-]
BC	168.0	28.2	10.0	32000	6.830	40017.0	0.771
BC	222.0	38.0	14.9	93200	9.730	109515.0	0.796
BC	254.0	43.0	14.5	118799	9.740	138660.9	0.800
BC	283.0	45.0	18.2	180000	8.587	203044.8	0.800
TA	172.0	32.2	11.0	41000	3.698	48947.4	0.734
TA	250.8	44.4	13.5	109000	5.920	129019.1	0.784
TA	319.0	60.0	22.6	317441	6.850	350747.2	0.741
CV	126.8	19.4	7.4	8659	0.600	12305.7	0.614
CV	218.2	32.2	12.0	42074	0.600	57705.9	0.625
CV	251.0	32.2	13.5		0.600	76365.6	0.639
CV	286.6	40.0	14.5		2.200	111732.4	0.614
CV	317.2	43.2	14.5		1.500	140143.3	0.644
CV	355.0	51.2	16.0	165893	4.000	201151.4	0.632
CV	383.0	58.6	16.0		4.000	239080.6	0.608

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Calculations with GL Rankine + Spectral Analysis

Example: CV with $L_{pp}=383.0$ m



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Result

Longitudinal force:

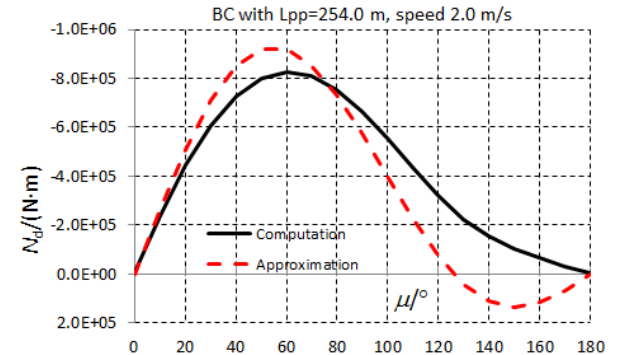
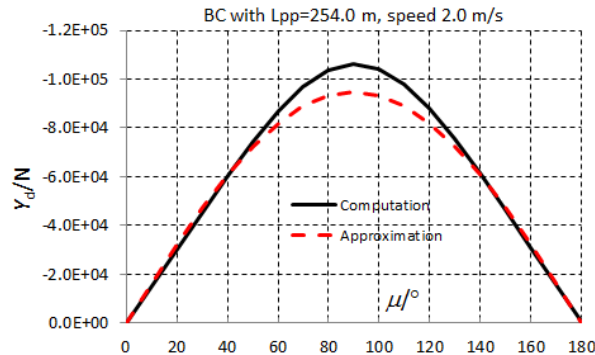
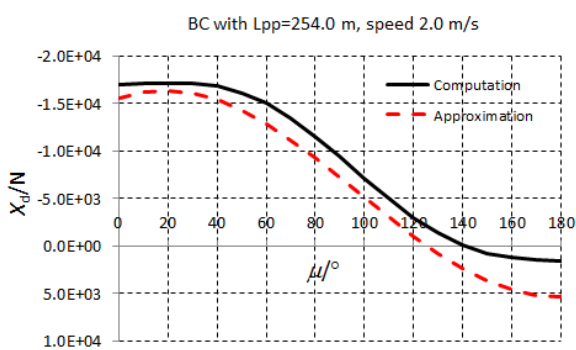
$$X_d = -83L_{pp}C_B^{1.5}h_s^2(1 + \sqrt{Fr})\cos\mu - 280L_{pp}C_B^{1.5}h_s^2\sqrt{Fr}\sin(\mu/2)$$

Lateral force:

$$Y_d = -C_B^{1.5}L_{pp}^{2.13}h_s^2\sin\mu$$

Yaw moment with respect to midship:

$$N_d = -280L_{pp}^2C_Bh_s^2Fr\sin\mu + L_{pp}^2C_Bh_s^2(2000C_B^8Fr^2 - 10)\sin(2\mu)$$



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Summary

- „old“ weather conditions vs. „new“: „new“ lead to less conservative results for course-keeping => careful check and justification are required
- Empirical formulae for time-average wave forces
 - Are reasonably simple
 - Results are acceptable within the applicability range
 - However, should be updated if required applicability range changes
- Work in progress:
 - Assessment with Level 1-wave forces and moment for the 14 ships
 - Results for DTC and KVLCC2 are ready: Level 1-wave forces and moment lead to conservative requirements on installed power and rudder

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