Energy Efficient Safe SHip OPERAtion

Hull Forces in Calm Water
Krylov / UDE method

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Krylov method

- Based on series of model tests conducted by the Krylov Shipbuilding Research Institute (KSRI)
- Parameters:
  - Main dimensions
  - Speed
  - $C_B$
  - $LCG$
  - Trimm
  - Stern shape
Force definition

• Maneuvers
  – Steady drift (drift angle)
  – Steady turn (yaw rate)

• It is assumed that the yaw rate does not contribute to longitudinal and side forces

\[ X = 0.5 \ X' \rho v^2 A_{lateral} \quad \text{with} \quad X' = X'_{\beta} \]
\[ Y = 0.5 \ Y' \rho v^2 A_{lateral} \quad \text{with} \quad Y' = Y'_{\beta} \]
\[ N = 0.5 \ N' \rho v^2 A_{lateral} L_{pp} \quad \text{with} \quad N' = N'_{\beta} + N'_{r} \]
Hydrodynamic coefficients can be calculated using excel sheet or simple python script.

\[ X'_{\beta} = -0.075 \sin \left( \left[ \pi - \sin^{-1} \left( \frac{X'_0}{0.075} \right) \right] - \frac{\beta}{\varphi_x} \right) \]
\[ Y'_{\beta} = 0.5 c_1 \sin 2\beta \cos \beta + c_2 \sin^2 \beta + c_3 \sin^4 2\beta \]
\[ N'_{\beta} = m_1 \sin 2\beta + m_2 \sin \beta + m_3 \sin^3 2\beta + m_4 \sin^5 2\beta \]

\[ N'_r = -C_{M,0} L_{pp}^2 |r| r - \frac{C_{M,r}}{\pi} \left( v^2 + L_{pp}^2 r^2 \right) \sin(\pi \Omega) \]

\[ v^2 \]
UDE modification I

- Longitudinal force calculated according to ITTC’78 and side force contribution

\[ X' = R_T \cos \beta - Y \sin \beta \]

- Calm water resistance at zero drift

\[ R_T = 0.5 \rho v^2 S C_T \]
\[ C_T = (1 + k) C_F + C_W \]

\[ C_F = \frac{0.075}{(\log(Rn) - 2)^2} \]

\[ C_W \approx 0.2 \cdot C_F \quad \text{for } F_n < 0.25 \]

- If \( k \) unknown:

\[ k = \begin{cases} 
0.1 & \text{for } C_B \leq 0.7 \\
0.2 & \text{for } 0.7 < C_B \leq 0.8 \\
0.25 & \text{for } C_B > 0.8 
\end{cases} \]
• Working on a formulation for $Y'_r$
Comparison
Esso Osaka Tanker

Drift angle
Comparison
Esso Osaka Tanker

![Graph showing the comparison between model test and Krylov method for yaw rate.](image)

**Comparison**
**Esso Osaka Tanker**

![Graph showing the comparison between model test and Krylov method for yaw rate.](image)
Comparison
KVLCC2 Tanker

Drift angle

- Model test
- Krylov method

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Comparison
KVLCC2 Tanker

\[ N' \] vs. \( r' \)

- Model test
- Krylov method

Yaw rate
Comparison
KCS Containership

Drift angle

- Y [

- N [

model test
Krylov method
Comparison
KCS Containership

![Graph showing a comparison between model test data and Krylov method results for Hull Forces in Calm Water - KSRI-Method]
Comparison
C-Box (multipurpose ship)

Drift angle

- Drift angle graphs showing model test and krylovDrift method comparison.

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Conclusion

- Fair agreement for $Y'_{\beta}$ and $N_{\beta}'$ and $N_r'$
- $X'$ based on ITTC and UDE results from previous projects
- $Y'_{r}$ to be formulated by UDE