Energy Efficient Safe SHip OPERAtion

Hull Forces in Calm Water

Krylov / UDE method

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SEVENTH FRAMEWORK PROGRAMME

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

  - $X = 0.5\, X' \rho v^2 A_{lateral}$ with $X' = X'_\beta$
  - $Y = 0.5\, Y' \rho v^2 A_{lateral}$ with $Y' = Y'_\beta$
  - $N = 0.5\, N' \rho v^2 A_{lateral} L_{pp}$ with $N' = N'_\beta + N'_\mathrm{r}$

Formula

- Hydrodynamic coefficients can be calculated using excel sheet or simple python script

$$X'_{\beta} = -0.075\, sin\left(\left[\pi - sin^{-1}\left(\frac{X'_0}{0.075}\right)\right]\left[1 - \frac{\beta}{\varphi_x}\right]\right)$$

$$Y'_{\beta} = 0.5c_1 \sin 2\beta \cos \beta + c_2 \sin^2 \beta + c_3 \sin^4 2\beta$$

$$N'_{\beta} = m_1 \sin 2\beta + m_2 \sin \beta + m_3 \sin^3 2\beta + m_4 \sin^5 2\beta$$

$$N'_{\mathrm{r}} = \frac{-C_{M,0} L_{pp}^2 |\mathrm{r}|\mathrm{r} - \frac{C_{M,\mathrm{r}}}{\pi}(v^2 + L_{pp}^2 \mathrm{r}^2)\sin(\pi\Omega)}{v^2}$$

UDE modification I

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

$$\mathrm{X}' = \mathrm{R_T}\cos\beta - \mathrm{Y}\sin\beta$$

  - Calm water resistance at zero drift

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

$$C_F = \frac{0.075}{(\log(Rn)-2)^2}$$
$$C_W \approx 0.2 \cdot C_F \quad for\ Fn < 0.25$$

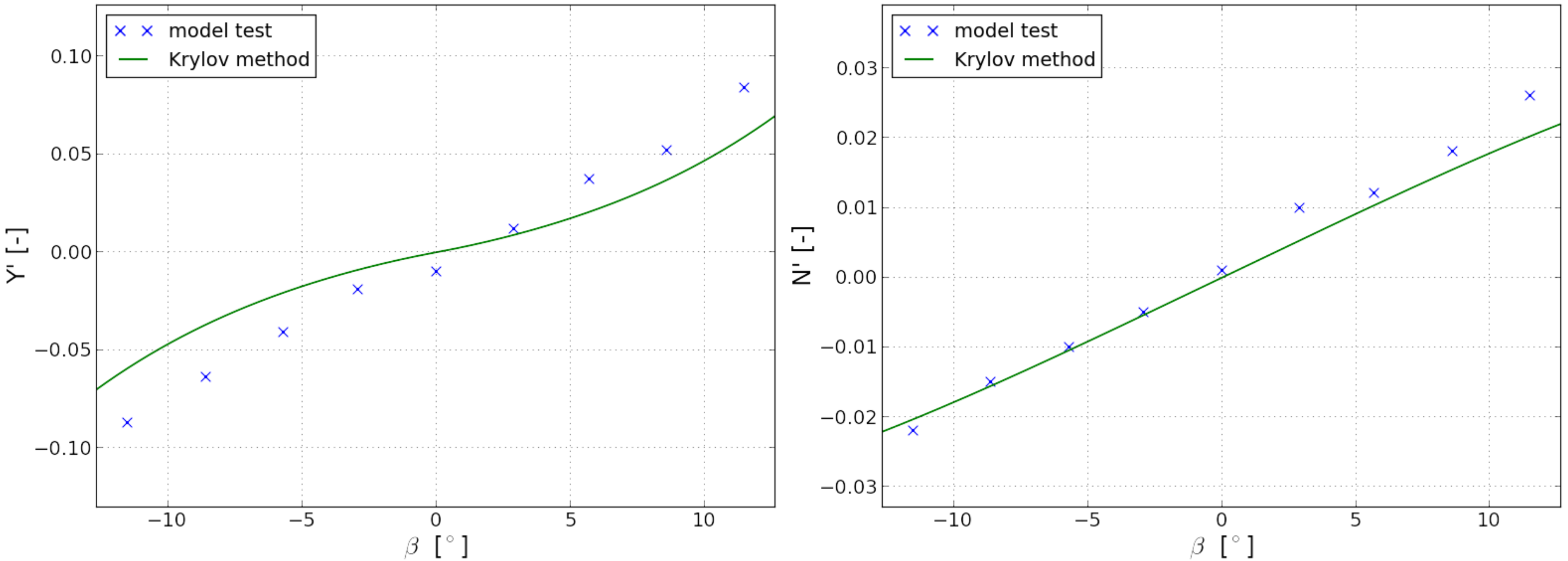
  - If k unknown:

$$k = \begin{cases} 0.1 & for\ C_B \leq 0.7 \\ 0.2 & for\ 0.7 < C_B \leq 0.8 \\ 0.25 & for\ C_B > 0.8 \end{cases}$$

UDE modification II

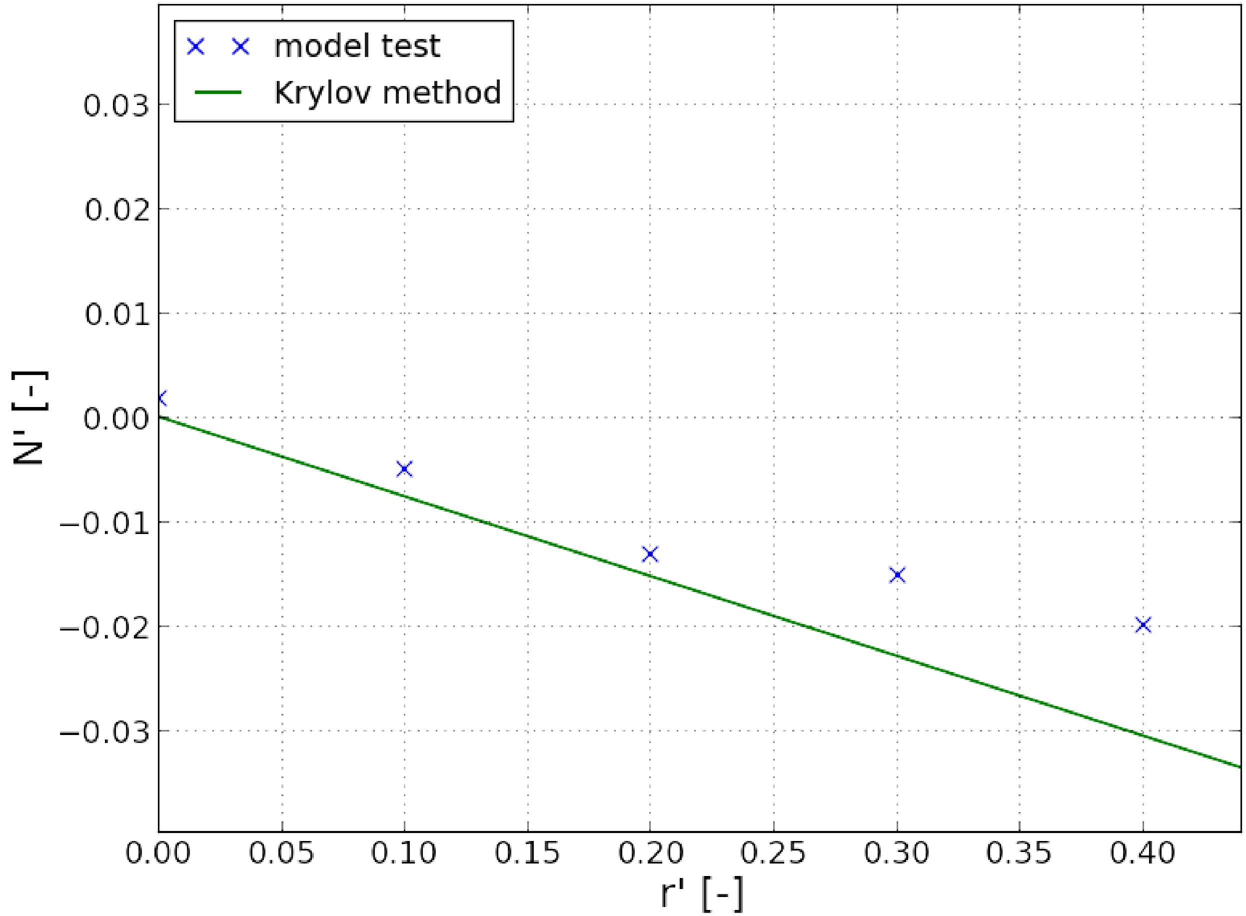
- Working on a formulation for Y'_r

Comparison
Esso Osaka Tanker



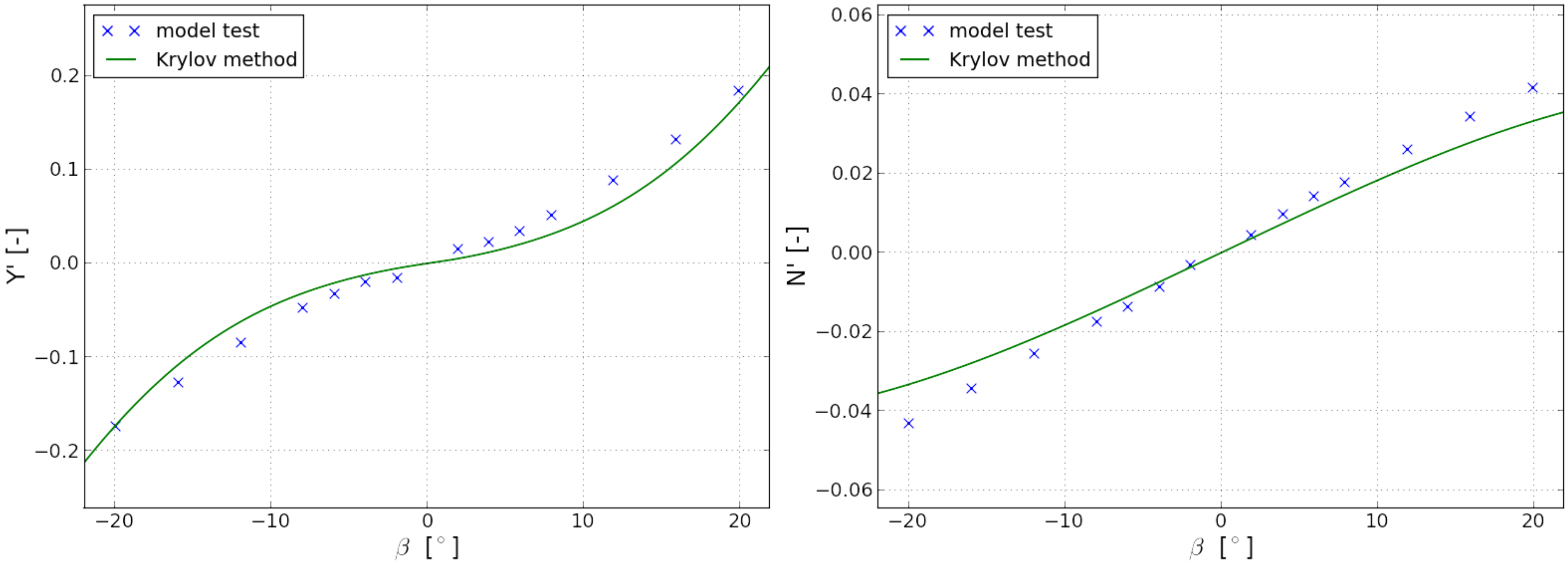
Drift angle

Comparison
Esso Osaka Tanker



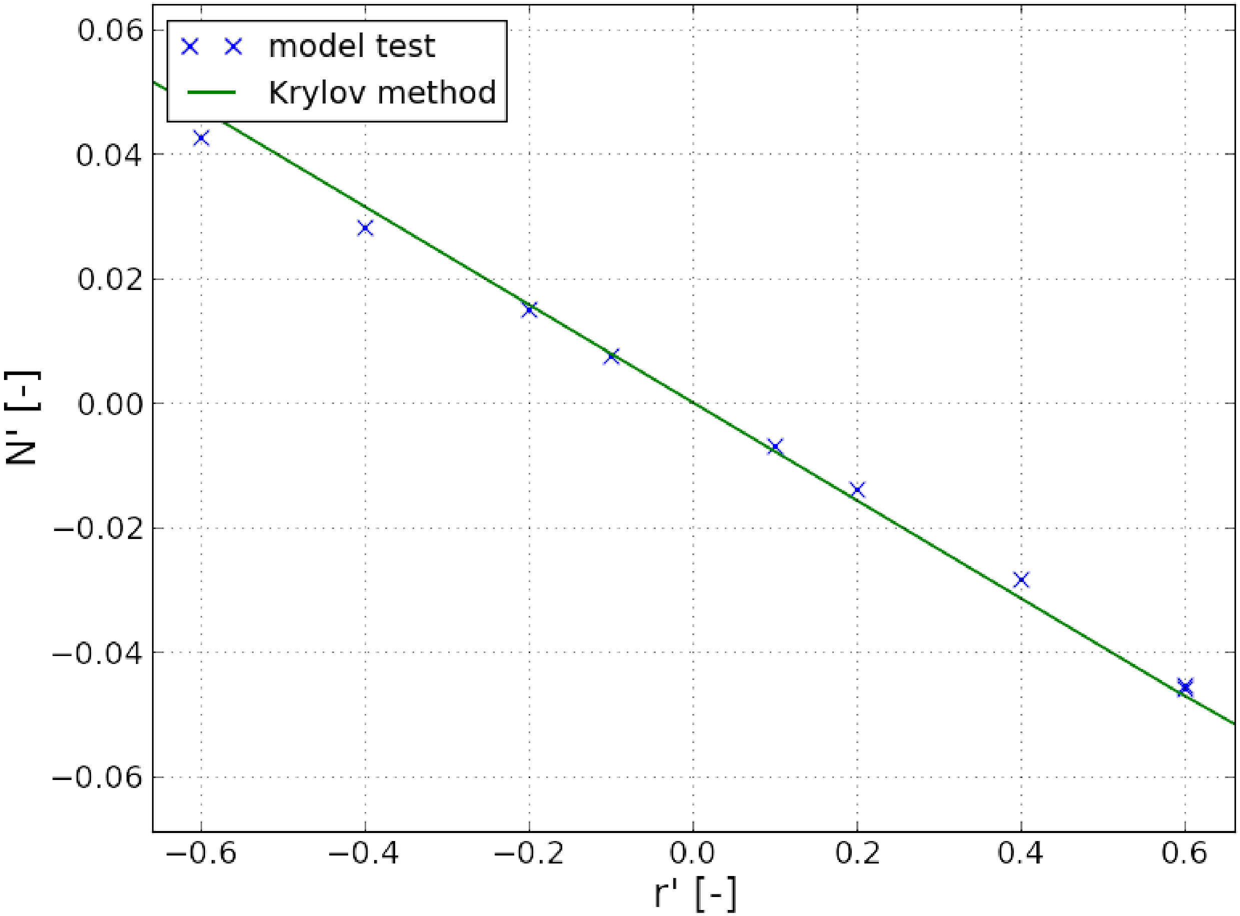
Yaw rate

Comparison
KVLCC2 Tanker



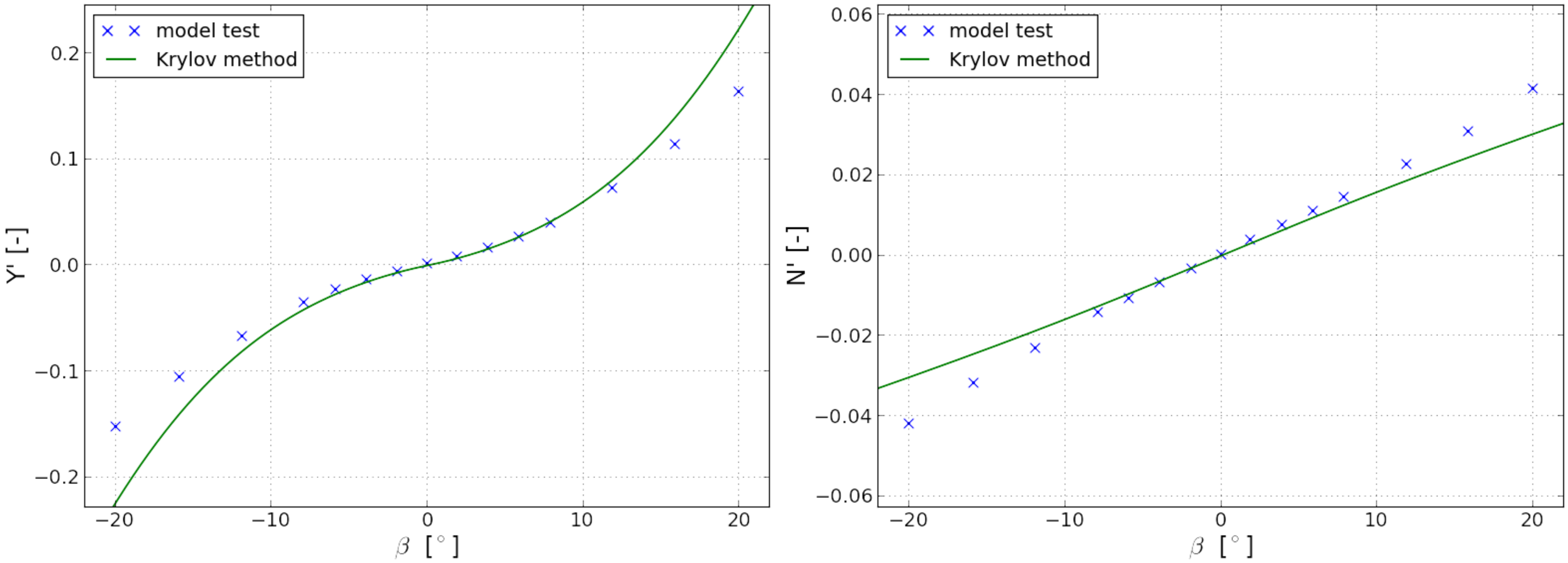
Drift angle

Comparison
KVLCC2 Tanker



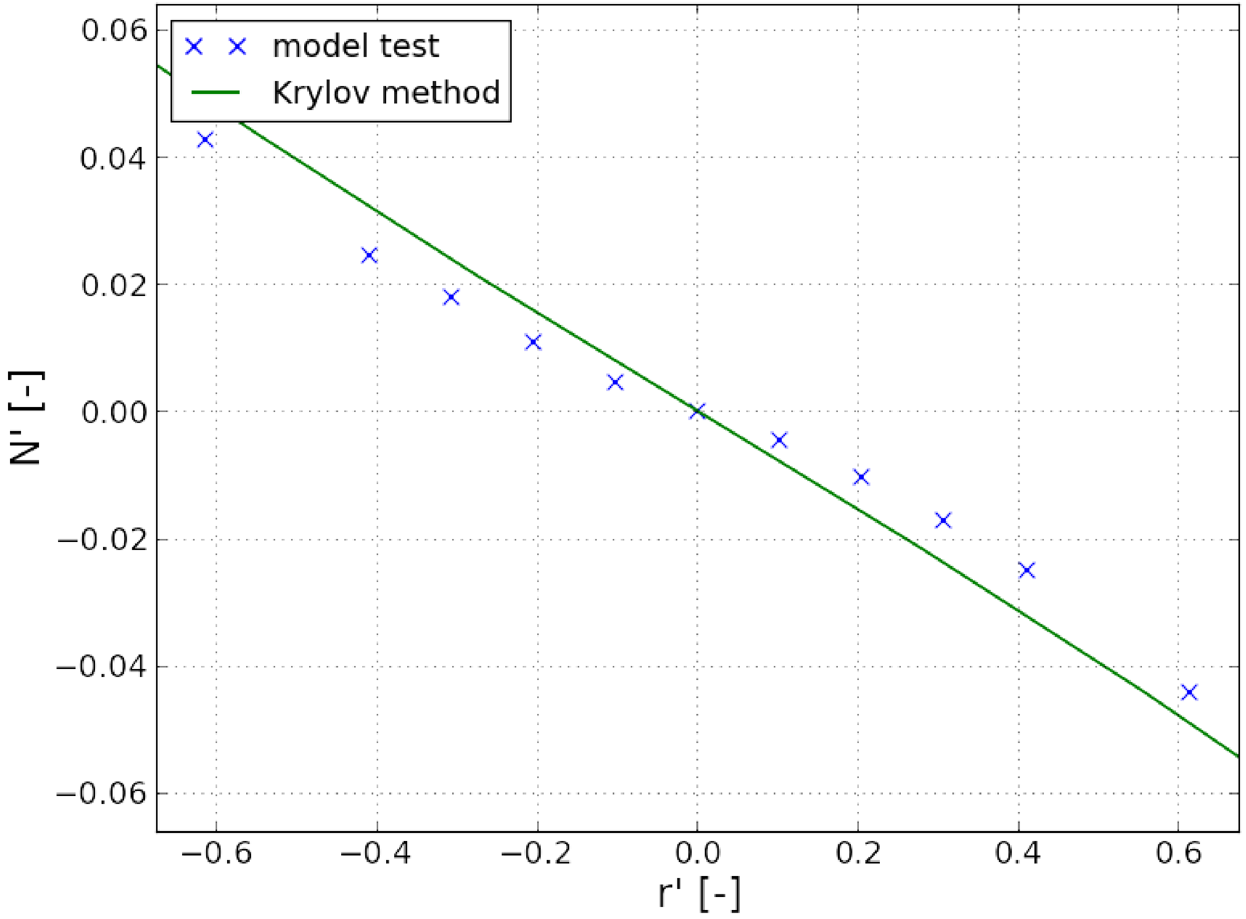
Yaw rate

Comparison
KCS Containership



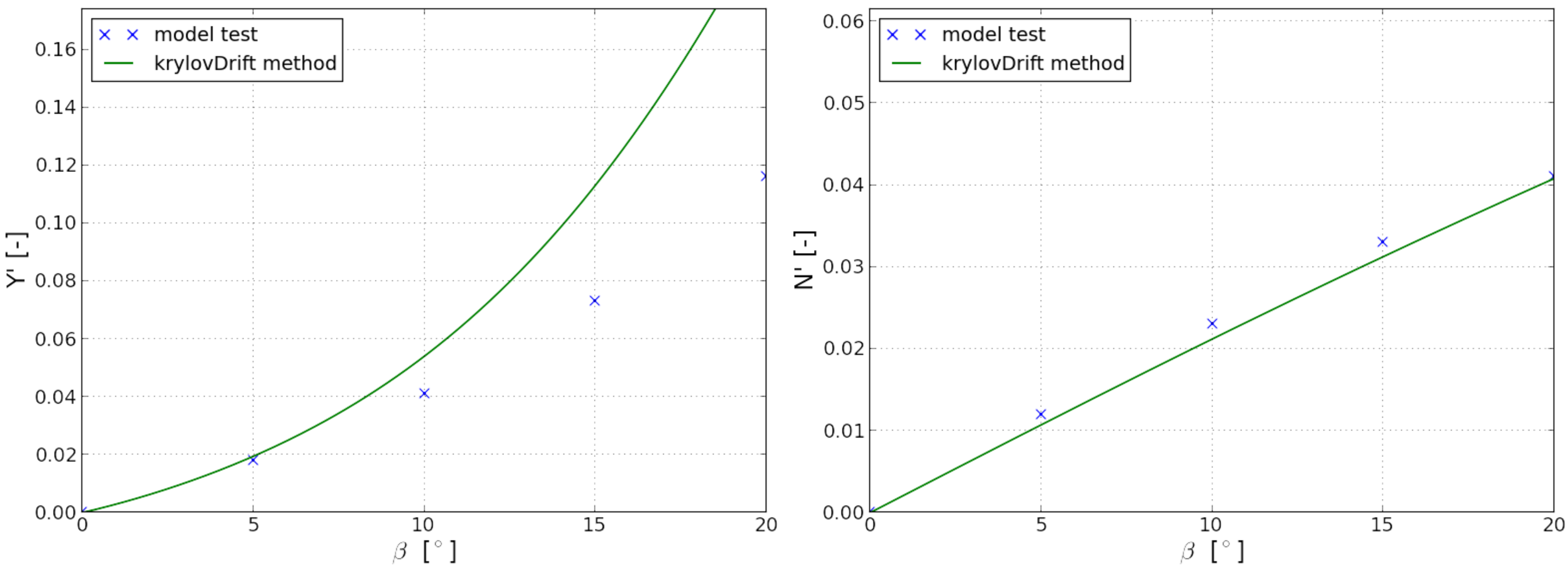
Drift angle

Comparison
KCS Containership



Yaw rate

Comparison
C-Box (multipurpose ship)



Drift angle

Conclusion

- Fair agreement for Y'_{β} and N'_{β} and N'_{r}
- X' based on ITTC and UDE results from previous projects
- Y'_{r} to be formulated by UDE