Energy Efficient Safe SHip OPERAtion

Field methods to determine ship hydrodynamic characteristics

WP 2 – TK 2.4

Partners: TU Berlin, Teknologian Tutkimuskeskus, Instituto Superior Tecnico, University of Strathclyde, Universitaet Duisburg-Essen, Lloyds Register EMEA

Task 2.4 goal:

Improvement of numerical field methods for manoeuvring coefficients, including environmental conditions.

Necessary steps:

• Modelling of wave drift forces (also in shallow water)
• Modelling of current and wind influences
• Implementation of propeller body force model (rudder inflow)
• Carry out virtual captive model tests
• Derivation of coefficients for manoeuvre simulation
Task 2.4: Field Methods
Partner contributions

• TUB (15PM): Virtual tests in calm water for manoeuvring coefficients (focusing torque) + model for mean wave forces

• VTT (8PM): hull-propeller-rudder interaction in restricted waters

• UDE (7PM): offline database for drift forces + approximation of hull forces in shallow waters, rudder forces behind propeller in waves

• SU (4.5PM): manoeuvring coefficients calm water

• IST (3.5PM): hydrodynamic interaction in confined waters, loads on superstructure, hull forces

• LR (0.5PM):
Task 2.4: Field Methods
Waves with different encountering angles

Calculations with RANS code Neptuno:

- Variation of encountering angle $0^\circ$-$180^\circ$ in suitable steps
- Grid with 4.4 million cells
- Calculations on one core
- Calculation time: one week
Task 2.4: Field Methods
Dependence on encountering angle

- Dependence on $\alpha$ ($180^\circ$-$\mu$) modelled with Fourier coefficients

$$F_X(\alpha) = \sum_{k=1}^{m} a_k \cdot \cos(k \cdot \alpha) + b_k \cdot \sin(k \cdot \alpha)$$
Task 2.4: Field Methods
Variation of wave length

Calculations with RANS code Neptuno:

- For each encountering angle: wave length variation in suitable steps
- Grid with 4.4 million cells
- Calculations on one core
- Calculation time: one week
Task 2.4: Field Methods
Dependence on wave length

- Dependence on $\alpha$ (180°-$\mu$) modelled with Fourier coefficients
- Dependence on $\omega$ by polynomial approach of Fourier coefficients

$$F'_Y(\alpha, \omega) = \sum_{k=1}^{m} [a_k(\omega) \cdot \cos(k \cdot \alpha) + b_k(\omega) \cdot \sin(k \cdot \alpha)]$$

![Graph showing dependence on wave length with Fourier coefficients for different wave lengths.]
Task 2.4: Field Methods
Rotating propeller in oblique flow

Calculations with OPENFOAM for database body force model:

- Isolated stock propeller
- Variation of incident angle
- Variation of advance ratio

Body forces in propeller disk are interpolated from the database during forced motion tests yielding the correct rudder inflow and to propeller torque/power

Snapshot of pressure distribution on blades for $\beta=30^\circ$ and $J=0.7$
Task 2.4: Field Methods
Virtual captive model tests with free surface

- Complete set of manoeuvring derivatives obtained from 84 virtual tests
- Propeller torque included in the mathematical model in order to predict power during manoeuvres Not ready yet!

Simulated combined sway-yaw test
Task 2.4: Field Methods
Simulation of pure sway motion

Contours of free surface elevation

Axial component of body force

Velocity field in propeller disk
Task 2.4: Field Methods

Propeller torque in forced pure sway and pure surge motion

Challenges:

• To predict torque time histories during forced motions with a body force model
• To model these complicated functions with proper hydrodynamic coefficients
Task 2.4: Field Methods
Progress: Teknologian Tutkimuskeskus

• Focus on determination of effective wake in oblique flow
• Correction factor method developed by VTT for straight flow is being extended to oblique flow
• The approach may be used to enhance current methods for estimation of the self-propulsion point, maneuverability and especially hull-rudder and propeller interaction
• Calculation conditions to be selected corresponding relevant model tests for validation of the model (KVLCC2)

Related paper work on the topic of effective wakes:

Objectives:

- to re-create model scale manoeuvring experiments using StarCCM+ commercial CFD software, version 9.02, on University High Performance Computing (HPC) facility

- to model 2 / 3 of the case study vessels
  - KVLCC2 geometry (obtained)
  - DTC Container ship (geometry required from UDE)
  - Isle of Lewis geometry obtained
Approach:

- Unsteady RANS, replicating model tests in CFD
- approaches developed in the SIMMAN 2008 will be used

Steps:

- Comparison of resistance and propulsion in calm water with CEHIPAR model tests to validate model and simulation approach
- Simulation of forced motions (pure sway and pure yaw) with Planar Motion Mechanism (PMM) model tests to check simulation agreement
- Simulation of free manoeuvres (turning circle and zig-zag test) with free manoeuvre model tests to check simulation agreement
- Provision of manoeuvring coefficients to Task 2.3 activities to allow for potential flow predictions for manoeuvring in confined waters

Approach:

CFD calculations will be carried out to determine viscous hydrodynamic derivatives and coefficients for propeller and rudder forces instead of using regression formulas as done in the initial analysis.

Test results in different sinkage and trim conditions should be carried out by CFD.

Considering the Kijima model for instance:

- Longitudinal hydrodynamic derivative should be obtained from resistance test since sinkage and trim would result in different wet surface area.
- Nonlinear lateral hydrodynamic derivatives such as $Y_{|v|v}, Y_{|r|r}, Y_{vvr}, Y_{vrr}, N_{|v|v}, N_{|r|r}, N_{vvr}, N_{vrr}$ are also affected by sinkage and trim.
Task 2.4: Field Methods
Progress: University of Strathclyde

Current work:

• KVLCC2 geometry has been made suitable for CFD use
• Modelling KVLCC2 at 1/80 model scale to match CEHIPAR experiments, domain set up to match CEHIPAR water depth, deep water tests
• Simulating resistance in calm water at 6 and 12 knots, with sinkage and trim, at scantling draft

Next steps:

• Simulation of KVLCC2 resistance in calm water at ballast draft
• Simulation of KVLCC2 resistance in calm water with sinkage and trim at both scantling draft and ballast conditions
• Simulations of propulsion predictions in calm water for validation
• Simulations of forced motions and turning circle in calm water
Wave patterns of KVLCC2 advancing in calm water

Wave profile at portside of the vessel, $Fn=0.142$

Wave profile at $y/L=0.1581$, $Fn=0.142$
Convergence behaviour of added resistance in waves using RANS
Wigley Hull: $F_n=0.3$, Added Resistance

Wave length / Ship length [-]

Added Resistance Coef.[-]

Source: Ley, Sigmund, el Moctar OMAE2014-24216
Wigley Hull: $F_n=0.4$, Added Resistance

Wave length / Ship length [–]
Task 2.4: Field Methods
University of Duisburg-Essen contribution

Wave length / Ship length [-]

Added Resistance Coef. [-]

Source: Ley, Sigmund, el Moctar, OMAE2014-24216
Discussion

Thank you for your attention