Energy Efficient Safe SHip OPERAtion

Work package 2: Task 2.5: Field Methods for direct predictions of ship motions

Task 2.5 (UDE, IST, LR)

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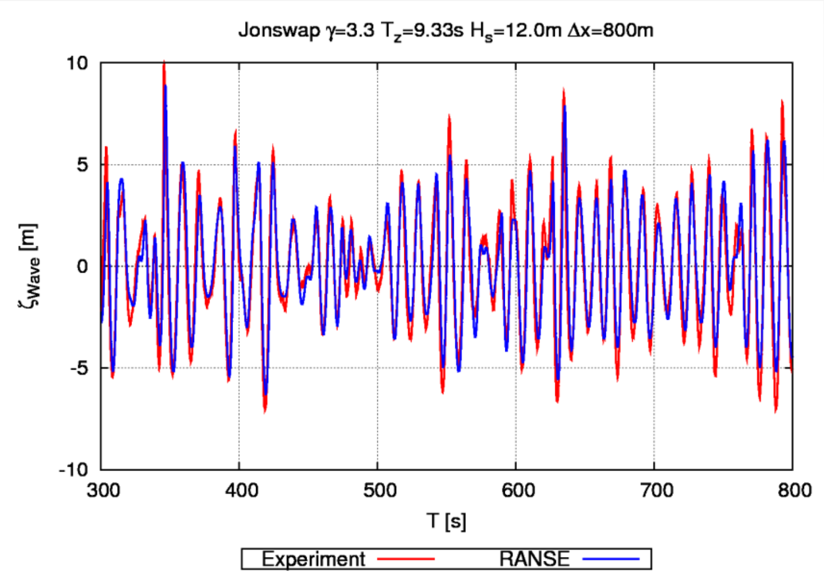
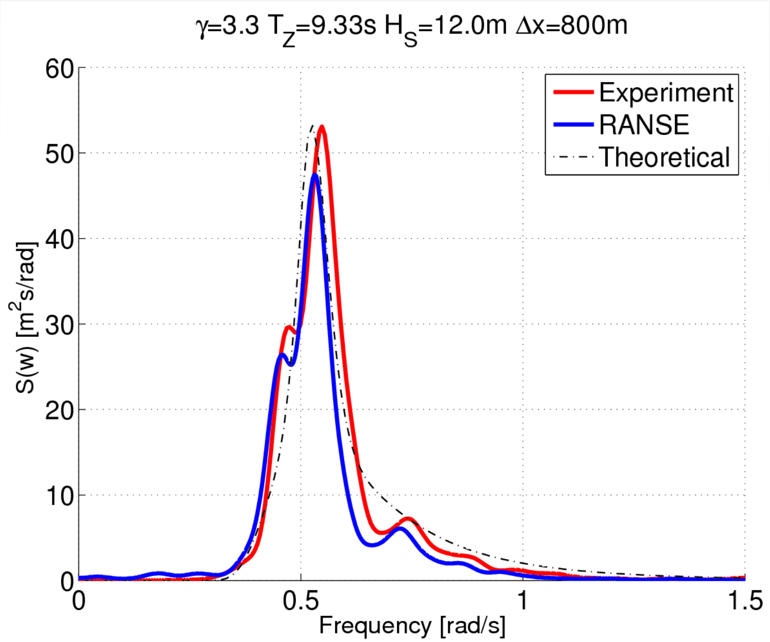
Overview

- Further refinement of Reynolds-averaged Navier-Stokes Equations (RANSE) Solvers for Ship Maneuvering Prediction
- The OpenFOAM CFD toolbox is used
- Several extensions are refined and developed
- Work scope (based on previous developments):
  1. Refinement of irregular waves modeling (Extreme Seas Project)
  2. Refinement and validation of an engine dynamics model (Preman Project)
  3. Implementation of automatic controllers
  4. Coupling with an unsteady propeller model
  5. Refinement of an efficient morphing algorithm
- Deliverables: D2.5 and D2.10 in months 15 and 30

Irregular Waves

- Modeling of irregular waves
- Implicit coupling of the volume fraction transport equation with the RANS Equations
- Refinement of existing implementation (No. of components, Boundary conditions, Discretization)
- Different wave theories





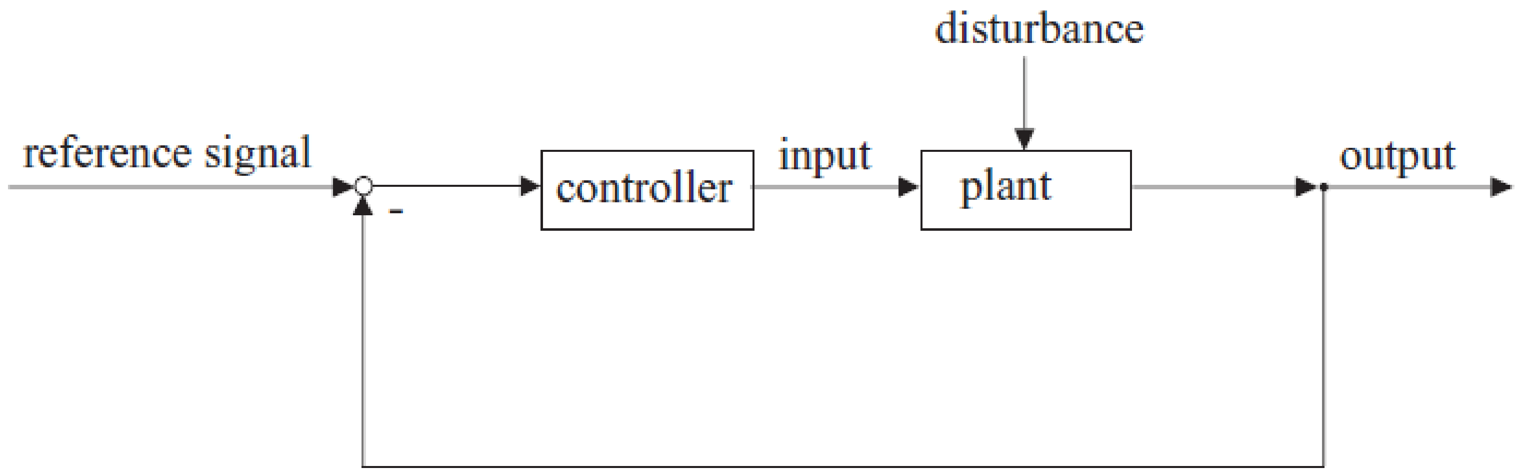
Source. J. Ley, J. Oberhagemann, O. el Moctar, Nutts 2011, project Extreme Seas

Engine Dynamics Model

- Ship motion in adverse conditions may be affected by engine dynamic response
- UDE and DUT have agreed on the concept of the model to be implemented in OpenFOAM
- The model will be presented in WP4

Automatic Controllers

- Usable for course and speed keeping
- Identification of controller constants (eg. for PID controller)



Unsteady Body Force Model

- Propeller model was initiated during the Preman project
- Pre-calculation:
  - Delivers propeller forces in open water cond.
  - Can be performed using arbitrary solver
  - Rotational speed of the propeller is kept constant
  - Inflow velocity is varied to modify advance coefficient with $J \in [0;1]$
- Processing of pre-calculation:
  - Force F_j is calculated for each propeller face j
  - Face positions are converted into a spherical coordinate system
  - Force vectors are converted from cartesian into axial, radial and tangential components
  - Force and position of each face are stored in the database for each J

Body Force Model

- Propeller usage:
  - Propeller disk is defined as a list of cells
  - For each cell k, a local advance coefficient J_k is calculated $J_k = \frac{v_k - v_{induced}}{nD}$
  - Spatial correlation between pre-calculation and cell list is established
  - Cell force F_k is evaluated from the sum of contributing forces in the pre-calculation
  - Interpolation between adjacent J is performed
  - The torque is calculated by applying the procedure to the tangential forces and, using the according lever
- Forces are applied to the rhs of the momentum equation:

$$\frac{\partial (\rho \mathbf{u})}{\partial t} + \nabla \cdot (\rho \mathbf{u}\mathbf{u}) - \rho \mathbf{g} - \nabla \sigma = \mathbf{S}$$

Body Force Model

- Future works:
  - Parallelization
  - Validation
  - Assessment of computational effort
  - Assessment of grid size influence of pre- and post-calculation

Morphing Algorithm

- Body motion S_b has to be realized
- S_b is separated in two parts:
  - Mesh motion part
  - Mesh morphing part
- High computational speed is required for manoeuvering simulations