Master's Thesis Proposal: Impact of Roll Motion Reduction on Fuel Consumption of Container Ships

Research Question: How much fuel can be saved by reducing ship roll motion under different operating and environmental conditions?

Background

Roll motion negatively affects the hydrodynamic performance of ships by increasing resistance, altering propeller inflow conditions, and reducing propulsion efficiency. Various technologies such as active stabilization systems, anti-roll tanks, and advanced control solutions can reduce roll motion, potentially leading to fuel savings and lower emissions. However, the quantitative relationship between roll reduction and fuel consumption for different container ship sizes and sea conditions is not yet fully understood.

Objectives

The objective of this thesis is to quantify the fuel-saving potential resulting from roll motion reduction and develop a prediction tool using Computational Fluid Dynamics (CFD) that estimates these savings for different vessel types and operating conditions. User-friendliness, computational efficiency and automatic data post-processing are important features for a successful application of the tool.

Methodology

1. Literature Review

Conduct a comprehensive review of:

a) Ship roll motion, roll-damping devices and seakeeping theory
b) Impact of vessel motions on resistance and propulsion efficiency
c) Fuel consumption in calm water and waves
d) Previous studies investigating roll reduction and energy efficiency

2. Development of CFD Models

Develop CFD models for several representative container ship classes, for example: Panamax container vessel, Post-Panamax container vessel, Ultra Large Container Vessel (ULCV), etc.). The models will serve as the basis for evaluating hydrodynamic effects under different operating conditions. Therefore, convergence studies regarding time and grid dependency as well as validation with existing data is required for waves, motions, resistance.

3. Investigation of Fuel-Saving Effects in Calm Water

Analyze how roll reduction influences:

a) Total ship resistance
b) Wake field characteristics
c) Propeller inflow uniformity
d) Propeller efficiency
e) Required engine power

Estimate potential fuel savings resulting from improved hydrodynamic performance for different roll angles.

4. Investigation of Fuel-Saving Effects in Waves

Evaluate the influence of roll reduction on:

a) Added wave resistance
b) Ship motions in irregular seas

c) Propulsion efficiency in seaways
d) Fuel consumption under realistic weather conditions

Investigate different sea states and headings representative for major shipping routes and analyze fuel saving vs. roll angles.

5. Optional/Delete: Development of a Fuel-Saving Prediction Tool
Develop a user-friendly engineering tool that allows the user to input:

a) Container ship size and principal dimensions
b) Operating speed
c) Geographic region or route
d) Sea state statistics
e) Expected roll reduction percentage

The tool will estimate:

a) Resistance reduction
b) Power reduction
c) Fuel savings
d) CO_2 emission reductions

6. Results and Conclusions
Summarize

a) Relationship between roll reduction and fuel consumption
b) Differences between container ship types
c) Influence of environmental conditions
d) Practical benefits of roll stabilization technologies
e) Recommendations for ship owners and operators

Expected Deliverables

a) Literature review on roll motion and fuel consumption.
b) CFD models for representative container ship types.
c) Quantification of fuel savings in waves.
d) Sensitivity analysis for different ship sizes and operating conditions.
e) Prediction tool for estimating fuel savings from roll reduction.
f) Final thesis with discussion and recommendations for industry implementation.

Expected Contribution
The research will provide a quantitative framework for assessing the economic and environmental benefits of roll reduction technologies. The developed tool can support ship designers, operators, and technology providers in evaluating the return on investment (ROI) of stabilization systems and advanced motion-control solutions.

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