Designing Future Ships and Marine Systems for Future Operating Conditions with a Low Carbon Intensity

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1. Introduction

The future may herald higher energy prices and, following the Paris Agreement, greater regulation of shipping's greenhouse gas emissions. This means that reducing ship's energy consumption and even using alternative fuels to oil may become more important.

This paper gives a general overview of the Whole Ship Model (WSM), which contains a method for quickly calculating the performance and cost of different ship designs, whilst considering energy efficiency measures.

The WSM and consists a number of component parts and their interactions producing a detailed ship level model that can consider off-design performance. The WSM can quickly calculate the performance of a single ship or thousands of ship designs with different design choices. The output is used to improve individual ship designs, compare benefits and side effects of different fuels and technologies and to provide a large database of ship designs with performance and cost information that can be passed to an economic model.

2. Future Energy Efficiency Trends in the Maritime Industry

The ability to look at different efficiency measures and energy options in the early design of ships is becoming increasingly important:

- Regulations concerning emissions in the shipping sector are likely to increase, both in extent and stringency. A "design standard" for ships, the Energy Efficiency Design Index (EEDI), became mandatory for new ships in January 2013 [IMO 2012].
- Ships have an expected service life of around 30 years, although they may change owners during this time. This is an important consideration when introducing new technologies that are only applicable to new build ships [Calleya et al. 2012], or those that require significant rebuild in order to retrofit.
- Fluctuations in fuel price may also be a factor in wishing to reduce energy consumption, as the uncertainty adds to the financial risk when procuring a ship.

It is not unreasonable to imagine that the future may bring higher energy prices and greater regulation of shipping's Greenhouse Gas (GHG) emissions. With the introduction of the EEDI into MARPOL Annex VI, tools are needed to assist Naval Architects and Marine Engineers to select the best solutions to meet evolving requirements for reduced fuel consumption and associated carbon dioxide emissions.

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Some similar early stage design models do exist but they have a different scope than the one of the Whole Ship Model, which is a holistic analysis of ship performance. Notable models are Hans Otto Kristensen's ship environmental assessment models [Kristensen, 2012]. Oceane Balland's work focused on "air emission controls" [Balland et al., 2012] as well as BMT's "Ptool" [Buckingham, 2000].

3. Whole Ship Model

The WSM can be used to design individual ships (by comparing different design variants) or to examine the performance of a number of ships (or shipping fleets), depending on the preference of the designer. Naval architects and marine engineers may wish to design specific ships at a high level of detail, whilst policy makers and commercial decision makers may be more interested in the profitability and regulatory compliance of a fleet of ships or the intentional shipping fleet.

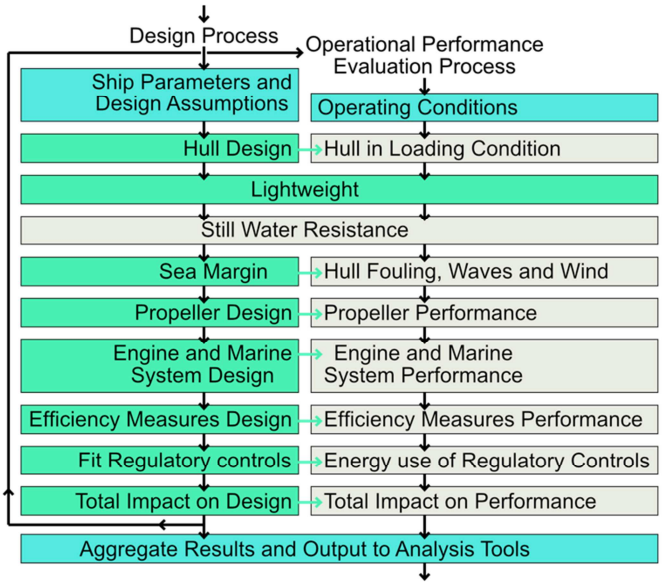

Figure 1: Functions in the (steady-state) Whole Ship Model.

The WSM contains an iterative design process with several complex models; a hull generator, a resistance model, propulsion model, engine and marine system model, technology models, lightweight and layout models and a regulation model (that considers air emission controls and ballast water treatment regulation), see Figure 1. After the design of each ship is fixed by the design process the ship is assessed against an operating profile in an operational performance evaluation process in order to calculate how the new ship design will perform while at sea. The WSM has three cargo ships types (container ships, oil tankers and bulk carriers) and evaluates 29 technologies in the Shipping in Changing Climates (SCC) project (e.g. wave harvester, solar panels, etc.) with 12 different fuel options, which can be run at any number of design and operational speeds.

Apart of improving and analysing ships' efficiency and emissions, WSM also passes on performance and secondary effects of different combinations of technologies, fuels and speeds to the Global Transport Model (GloTraM), an economic shipping forecast model developed by the UCL Energy Institute.

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