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Scantling multi-objective optimisation of a LNG carrier

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A B S T R A C T

Numerous real-world problems related to ship design can be solved by various alternatives. However, the scantling design has conflicting objectives such as minimum production cost, minimum weight and maximum moment of inertia (stiffness). Therefore a multi-purpose solution had to be settled in order to meet all these requirements at once. Ship design is a complex endeavour requiring successful coordination of many different disciplines, both technical and non-technical. Basic design is the least defined stage of the ship design process and seeks to define the optimal amidships section structure. For that purpose, recent improvements have been made to a numerical tool in order to optimise the scantling of ship sections by considering production cost, weight and moment of inertia in the optimisation objective function. A multi-criteria optimisation of a LNG carrier is conducted in this paper to illustrate the analysis process. Pareto frontiers are obtained and results have been validated by the Bureau Veritas rules. The methodology presented in this paper has demonstrated its effectiveness in optimising scantling of ships at a very early design stage thanks to a management of critical problems usually studied at a later stage of the design.

1. Introduction

1.1. Outline

Sustainability of technologies has been the main concern of many recent international debates, seminars and forums. Designing for sustainability requires a consideration of social, economical and

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environmental factors throughout the product life. The Life Cycle Performance (LCP) as a measure of sustainability and competitivity covers a number of key aspects, such as Life Cycle Cost (LCC), environmental friendliness, end-of-life impacts or safety.

In the early stages of design and development of a ship, all technical and ecological requirements have to be considered in terms of their long-term impacts on the entire ship life cycle. An engineering designer should not only transform a need into a description of a product but should also ensure the design compatibility with related physical and functional requirements. Therefore it should take into account various measurable factors of the product life such as its performance, effectiveness, producibility, reliability, maintainability, supportability, quality, recyclability, and cost.

Life cycle optimisation – in a sense of selecting the right design options on a given ship and system levels – is poorly applied. Methods and tools are needed, which connect technical design parameters to life cycle performance, allowing technical experts to quickly assess the impact of design options and parameters on the overall ship performance. An integrated view requires dedicated methods to compare production and operational costs, safety and environmental aspects. It also requires tools for life cycle optimisation in the different design and production phases of a ship.

The closest inter-dependencies between design, life cycle performance and fabrication techniques have been highlighted in a lot of papers [1–3]. These interactions are bidirectional:

- Construction cost and manufacturing conditions are to a large extent defined in early design phases. It is therefore important that the designer is provided with clear methods and also allowed to consider many design alternatives, cost aspects and new fabrication technologies and materials in his work.
- Manufacturing quality, imperfections and accuracy have a significant impact on the structural performance, repair and maintenance and life cycle cost.

Though a holistic approach of the ship design problem appears theoretically well established, researchers and engineers still have to develop and implement a long list of applications, addressing the complex problem of ship design for life cycle. This is a long-term task of decades, requiring profound skills and understanding of the physics, technology and design of ships, and to be performed by properly trained naval architects. This paper deals with the development of scantling optimisation software integrating different life aspects of ships.

1.2. The scantling optimisation

The determination of the scantlings of marine structures always brings up numerous problems to designers. Ships and floating structures are indeed complex structures, generally composed of strongly stiffened plates, deck plates, bottom plates, and sometimes intermediate decks, frames, bulkheads, etc. The optimisation of these complex structures is the purpose of this paper.

To be attractive to shipyards, scantling optimisation has to be performed at the preliminary design stage. It is indeed the most relevant period to assess the construction cost, to compare fabrication sequences and, to find the best frame/stiffener spacing's and most suitable scantlings to minimize ships life cycle cost. However at this stage of the project, few parameters (dimensions) have been definitively fixed, and standard FEM is often unusable, particularly to design offices and modest-sized shipyards. Therefore, an optimisation tool at this design stage can provide precious help. This is precisely the purpose of the LBR-5 optimisation software [4].

LBR-5 is the French acronym of "Stiffened Panels Software" version 5.0. The purpose of the tool is the sizing/scantling optimisation of hydraulic (lock gates), ship and offshore structures. The development of the LBR-5 module is included in the development of a module-oriented optimisation approach [5]. The goal is to create a multi-purpose optimisation model, opened to users and compatible with other structure analysis modules based on codes and specific regulations. Such a model must contain various analysis methods for strength assessment that can easily be enriched and complemented by users. The user must be able to modify constraints and add complementary limitations according to the structure type (hydraulic, ship and offshore structures, etc.), the code or the regulation in force and to his