Apostolos Papanikolaou
Editor

A Holistic Approach to Ship Design

Volume 1: Optimisation of Ship Design and Operation for Life Cycle

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Preface

The face of ship design is changing. The vastly increasing complexity of high-value ships and maritime structures as well as the growing number of rules and regulations calls for novel concepts of product design and testing in short lead times. To address this challenge, a team of 40 European maritime industry and research partners[1] has formed the HOLISHIP (HOLIstic optimisation of SHIP design and operation for life cycle) project in response to the MG 4.3-2015 Call of the European Union's Horizon 2020 Transport Research Programme and received funding to develop the next generation of a ship design system for the European maritime industry.

HOLISHIP sets out to address urgent problems of today's ship design and operation, focusing on future requirements by developing a holistic approach to ship design capable of meeting tomorrow's challenges. Most maritime products are typically associated with large investments and are seldom built in large series. Where other modes of transport benefit from the economy of series production, this is not the case for maritime products which are typically designed to refined customer requirements increasingly determined by the need for high efficiency, flexibility and low environmental impact at a competitive price. Product design is thus subject to global trade-offs among traditional constraints (customer needs, technical requirements and cost) and new requirements (life cycle, environmental impact and rules). One of the most important design objectives is to minimise total cost over the economic life cycle of the product, taking into account maintenance, refitting, renewal, manning, recycling, environmental footprint, etc. The trade-off among all these requirements must be assessed and evaluated in the first steps of the design process on the basis of customer/owner specifications.

[1] HSVA (coordinator), ALS Marine, AVEVA, BALANCE, Bureau Veritas, Cetena, CMT, CNR-INSEAN, Damen, Danaos, DCNS-Naval Group, Deutsche Luft- und Raumfahrt DLR, DNV GL, Elomatic, Epsilon, Fraunhofer Gesellschaft-AGP, Fincantieri, Friendship Systems, Hochschule Bremen, IRT SystemX, ISL, Lloyds Register, MARIN, Marintek, Meyer Werft, Navantia, National Technical University of Athens-Ship Design Laboratory, Rolls Royce, Sirehna, SMILE FEM, Star Bulk, TNO, TRITEC, Uljanik Shipyard, University of Genoa, University of Liege, University of Strathclyde, van der Velde, IRT SystemX.

The HOLISHIP approach brings together all relevant main disciplines of maritime product design under the umbrella of advanced parametric modelling tools and integrated software platforms enabling the parametric, multi-objective and multi-disciplinary optimisation of maritime products. The approach includes market analysis and demand, economic and efficiency considerations, hull form design, structural design, and selection of prime movers and outfitting. Together they form the mission requirements and enable the formulation of a rational foresight analysis for the viability of the product model over its life cycle ("from cradle to cradle"). It considers all fundamental steps of the traditional "ship design spiral", which, however, are better implemented today by a systemic, parallel processing approach and not a serial, step-by-step procedure.

The present book deals with the HOLISHIP approach and the associated design synthesis model, which follows modern computer-aided engineering (CAE) procedures, integrates techno-economic databases, calculation and optimisation modules and software tools along with a complete virtual model in form of a Virtual Vessel Framework (VVF), which will allow the virtual testing before the building phase of a new vessel. Modern GUI and information exchange systems will allow the exploration of the huge design space to a much larger extent than today and will lead to new insights and promising new design alternatives. The coverage of the ship systems is not limited to conceptual design but extends also to relevant major on-board systems/components. Their assessment in terms of life-cycle performance is expected to build up further knowledge of suitable outfitting details, this being a highly relevant aspect especially for the outfitting-intensive products of European shipyards.

The present book derives from the knowledge gained in the first phase of the project HOLISHIP (http://www.holiship.eu), a large-scale project under the Horizon 2020 programme of the European Commission (Contract Number 689074), which started in September 2016 and will be completed in August 2020. It will be supplemented by a second volume dealing with applications of developed methods and tools to a series of case studies, which will be conducted in the second phase of the HOLISHIP project.

The book is introduced by an overview of HOLISHIP project in Chap. 1 by the project manager, *Dr. Jochen Marzi* (HSVA). The holistic ship design optimisation, related concepts and a tanker ship application case study, presented by *Prof. Apostolos Papanikolaou* (NTUA & HSVA), are following in Chap. 2. A state of the art on ship design for life cycle is presented by *em. Prof. Horst Nowacki* (Technical University of Berlin) in Chap. 3. An outline of the effect of market conditions, mission requirements and operational profiles is presented in Chap. 4 by *Mr. Anti Yrjänäinen* (Elomatic). In Chap. 5, a systemic approach to ship design is elaborated by *Mr. Alan Guagan* (Sirehna) and his co-authors *Rafine Benoit and Le Nena* (both from DCNS-Naval Group). Hydrodynamic methods and software tools for ship design and operation are elaborated in Chap. 6 by *Dr. Jochen Marzi* (HSVA) and *Dr. Ricardo Broglia* (INSEAN). Parametric optimisation of concept and preliminary design are elaborated in Chap. 7 by *Profs. George Zaraphontis* (NTUA), *Andreas Kraus and Gregor Schellenberger* (University of Applied Sciences

Bremen). In Chap. 8, the CAESES-HOLISHIP platform for process integration and design optimisation is presented by *Dr. Stefan Harries and Mr. Claus Abt* (both from Friendship Systems). Chapter 9, co-authored by *Prof. Philippe Rigo, Abbas Bayatfar* (both Univ. of Liege) and *Jean-David Caprace* (Federal Univ. of Rio de Janeiro), deals with the structural design optimisation tool and methods. Chapter 10, authored by *Prof. Stein-Ove Erikstad* (Norwegian Univ. of Science and Technology, Trondheim), is dealing with design for modularity. In Chap. 11, issues of the application of reliability, availability and maintenance (RAM) principles and tools to ship design are elaborated by a team from Bureau Veritas led by *Dr. Philippe Corrignan*, co-authors *Vincent le Diagon, Ningxiang Li and Loïc Klein*. In Chap. 12, methods and tools for the life-cycle performance assessment are elaborated by a team consisting of *Prof. Paola Gualeni and Matteo Maggioncalda* (both from University of Genoa), *Chiara Notaro and Carlo Cau* (both from CETENA), *Prof. Markos Bonazuntas, Spyros Stamatis and Vasiliki Palla* (all from Epsilon International). Chapter 13 by *Messrs Sverre Torben and Martijn De Jongh* (both from Rolls Royce) deals with the modelling and optimisation of main machinery and power systems. Chapter 14 by *Dr. George Dimopoulos and Mrs. Chara Georgopoulou* (both from DNV GL) deals with advanced modelling and simulation tools for ship's machinery. Finally, Chap. 15, by *Messrs. Maarten Flikkema, Martin van Hees, Timo Verwoest and Arno Bons* (all from MARIN), outlines the HOLISPEC/RCE platform for virtual vessel simulations. The book is complemented by a glossary/list of acronyms and a comprehensive list of references. Editor of the book's material was *Prof. Apostolos Papanikolaou* (HSVA), assisted by Mrs. *Aimilia Alissafaki* (NTUA).

The present book does not aim to be a textbook for postgraduate studies, as contributions to the subject topic are still evolving and some time will be necessary until full maturity. However, as the topic of the holistic ship design optimisation is almost absent from today's universities' curricula, the book aims to contribute to the necessary enhancement of academic curricula and to address this important subject to the maritime industry. Therefore, the aim of the book is to provide the readers with an understanding of the fundamentals and details of the integration of holistic approaches into the ship design process. The book facilitates the transfer of knowledge from the research conducted within the HOLISHIP project to the wider maritime community and nurtures inculcation upon scientific approaches dealing with holistic ship design and optimisation in a life-cycle perspective.

Thus, the main target readership of this book is engineers and professionals in the maritime industry, researchers and postgraduate students of naval architecture, marine engineering and maritime transport university programmes. The book closes a gap in the international literature, as no other books are known in the subject field covering comprehensively today the complex subject of holistic ship design and multi-objective ship design optimisation for life cycle.

The complexity and the evolving character of the subject required the contribution from many experts active in the field. Besides experts from the HOLISHIP consortium, some renowned experts from outside the HOLISHIP project could be gained and contribute to the book's material. As editor of this book, I am indebted

to all authors of the various chapters reflecting their long-time research and expertise in the field. Also, the contributions of the whole HOLISHIP partnership to the presented work and the funding by the European Commission (DG Research) are acknowledged.

Athens, Greece
June 2018

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About the Editor

Prof. Dr.-Ing. Habil. Apostolos Papanikolaou studied Naval Architecture and Marine Engineering at the Technical University of Berlin, Germany. He was Professor and Director of the Ship Design Laboratory of the National Technical University of Athens (NTUA, Greece) for more than 30 years. He is today Senior Scientific Advisor of the Hamburg Ship Model Basin (HSVA, Germany), Emeritus Professor of NTUA and Visiting Professor at the University of Strathclyde, UK. He headed more than 75 funded research projects and is author/co-author of over 600 scientific publications dealing with the design and optimisation of conventional and unconventional vessels, the hydrodynamic analysis and assessment of the calm water performance and the performance of ships in seaways, the logistics-based ship design, the stability and safety of ships and related regulatory developments of the International Maritime Organisation. He received various international prize awards for his research work and scientific contributions to ship hydrodynamics, innovative ship design and safety assessment, among them in the last 10 years the *Lloyds List 2009 Greek Shipping technical innovation award* (jointly with Germanischer Lloyd), the prestigious *Dr. K. Davidson medal/award* of SNAME for outstanding achievement in ship research in 2010 and the *European Champions 1st prize for Senior Researchers in Waterborne Transport* in 2014. He is Fellow of the Royal Institution of Naval Architects

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Chapter 9
Structural Design Optimization—Tools and Methodologies

Philippe Rigo, Jean-David Caprace, Zbigniew Sekulski, Abbas Bayatfar and Sara Echeverry

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Abstract This chapter focuses on methodologies to perform ship structure optimization, decreasing steel weight and keeping the production cost at an acceptable level. Ship performance is always an important concern when a design is started, and should always be considered for new designs. This is in line with the evolution of ship

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classes and size. For this reason, several aspects are important to be taken into account within the optimization procedure, and therefore, multi-objective optimization is the common route. This chapter outlines actual trends in optimization methodologies, comments on the quality assessment of the obtained Pareto solutions and describes modern tools used in/by the maritime industry (with focus on the LBR-5, BESST and HOLISHIP projects). The importance of consideration of risk assessment in the structural design optimization procedure (e.g. of a ship collision with an offshore structure) is also elaborated with a highlight on the response surface method and its use in combination with optimization algorithms for ship and offshore structures in early design stages.

Keywords Holistic ship structural design · Multi-objective optimization
Pareto optimal dominance · Optimization algorithms · Integration sets
Quality assessment