Three years to IMPROVE design

The three year European Commission-supported 'IMPROVE' ship design research project is heading towards delivery.

The final report on the three year IMPROVE research project is due for formal launch at an event in September*, with a view offering European shipbuilders a new rationale for making decisions pertaining to the design, production and operation of three new ship generations.

Coordinated by ANAST, University of Liege, IMPROVE has involved 17 partners, including shipyards such as STX Europe (St Nazaire) and Uljanik of Croatia, plus owners Exmar, Grimaldi and Tankerska Plovidba Zadar, class society Bureau Veritas, three other universities, two ship design companies, two engineering companies and two software companies, as well as WEGEMT (European Association of Universities in Marine Technology and Related Sciences).

IMPROVE has aimed to use advanced synthesis and analysis techniques at the earliest stage of the design process, considering structure, production, operational performance, and safety criteria on a current basis. The nature of shipbuilding in Europe is to build small series of very specialised ships. Thus, the IMPROVE project has addressed ships which, with their complex structures and design criteria, are at the top of the list for customisation.

Three new concept vessels are set to emerge from the final IMPROVE report, due in September.

The specific objectives of the project have been to:

a) develop improved generic ship designs based upon multiple criteria mathematical models,
b) improve and apply rational models for estimation of the design characteristics (capacity, production costs, maintenance costs, availability, safety, reliability and robustness of ship structure) in the early design phase,
c) use and reformulate basic models of multiple criteria ship design, and include them into an integrated decision support system for ship production and operation.

The operators buying specialised ships generally plan to operate them for the majority of their lives. This means that the maintenance characteristics of the design are very important. For this reason, IMPROVE has focused on designing for a reduction in operation costs (particularly relating to painting and corrosion). Designing ship structures in such a way as to reduce the problems, for instance, of structural fatigue can help in this cause. Additionally, designing for minimal operational costs can help in increase the structural reliability and reduction of failures thus increasing safety.

The targets have been to increase shipyard competitiveness by 10% to 20% and reduce manufacturing costs by 8%-15%, production lead-times by

*The invitation is open for those wishing to attend the final workshop of the IMPROVE FP6 research project: "Design of Improved and Competitive Ships using an Integrated Decision Support System for Ship Production and Operation", which will be held on 17th, 18th and 19th of September 2009 at the Centre for Advanced Academic Studies (CAAS), Don Frane Bulica 4, Dubrovnik, Croatia (http://www.caas.unizg.hr). Further details of the IMPROVE Project can be found at: http://www.improve-project.eu/final.html.

The invited speakers will be Prof. Kai Levander, who will present "Ship Design for Performance", and Prof. Dr. Owen F. Hughes, who will present "Next Generation Ship Structural Design"

Kai Levander, Professor, Dr. H.C.

Kai Levander (pictured), who graduated as a naval architect from Helsinki University in 1967, went on to a career that has taken work at Aker Yards, Kvaerner Masa-Yards and Wärtsila Marine. His responsibilities have included research and development, concept development, feasibility studies and newbuilding projects in the cruise and ferries business areas. Since 1995 Kai Levander has been Associated Professor in Ship Design at the Norwegian University of Science and Technology in Trondheim. In After nearly 40 years in the shipbuilding business Kai Levander retired in September 2008 and is now an independent consultant.

In his paper "Ship design Performance", Prof Levander says: "Naval architects need a methodology for ship design that guides them through the design process. This methodology needs to be open for new solutions and innovations. The capacity and performance of alternative solutions are evaluated against a few major design criteria to optimize the ship for the intended mission. Key performance indicators are used to select the most suitable design. Today energy efficiency and reduction of emissions have become very important among these performance indicators."

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10%-15%, and to find benefit of 5%-10% on maintenance costs related to structure (painting, corrosion, plate replacement induced by fatigue).

Front and centre of the IMPROVE project, however, has been the three specific ship types selected for the study.

The first of these is an 220 000m^3: capacity LNG Carrier, designed by STX Europa (France).- see *The Naval Architect*, May 2009, pp17-19.

The second ship type is a large ro-pax ship, with capacity for 3000 lane metres of freight and 300 cars, plus 1600 passengers, with design by Uljanik Shipyard (Croatia).

To achieve defined objectives an existing line of vessels, as designed by Uljanik shipyard and Grimaldi Group have been re-assessed (structural limit states, production cost, maintenance assessment) to help to tune the new tools/ procedures within Uljanik and Grimaldi design/maintenance environments..

In this case, the arrangement of cargo space without pillars will require sophisticated structure solutions. Reducing height of deck structure is said to be a very demanding task, but can result in many benefits regarding general ship design, e.g.:

- Lower VCG (better stability).
- Reduced light ship weight (increased deadweight)
- Smaller Gross Tonnage

The challenge has been to improve Rule structural design at the concept stage and to find optimal design solution using tools developed within IMPROVE and continue the design process at the preliminary stage (where more detailed FEM calculations are performed) with the better starting point/design). Cutting production costs has been the relevent design objective. Regarding general ship design, other targets have been:

- Selection of resistance friendly hull form
- Smaller propulsion engine for same speed
- Reduced fuel oil consumption
- Selection of hull form in order to reduce length of engine room (increased length of cargo space)

This application also used TRIDENT, a fully integrated CAD/CAM solution based on PTC® CADDS®5i product database developed in Uljanik Shipbuilding Computer Systems (USCS). It has all the advantages of the CADDS®5i environment (full interactive, 3D, modern user interface, subsystems integrated in the same data bases), and it integrates all project and construction activities.

The third ship is a 40,000dwt chemical tanker, designed by Szczecin Shipyard (SSN, Poland).

Here, the IMPROVE project has engaged in treating numerous characteristics of the tanker's structure either as constraints or as objectives, depending on the assumed available information, resembling therefore a possible scenario in the early stage of design development.

The early design stage is characterised by missing information on e.g. precise loading, or structural details, while the boundaries of some requirements, such as weight, vertical centre of gravity, nominal stress levels or length of weld meters are not precisely defined. In general it has been considered useful to venture into analysing the correlation between them, thus investigating their sensitivity for the considered structural arrangement. This can then assist the designer in making optimal decisions.

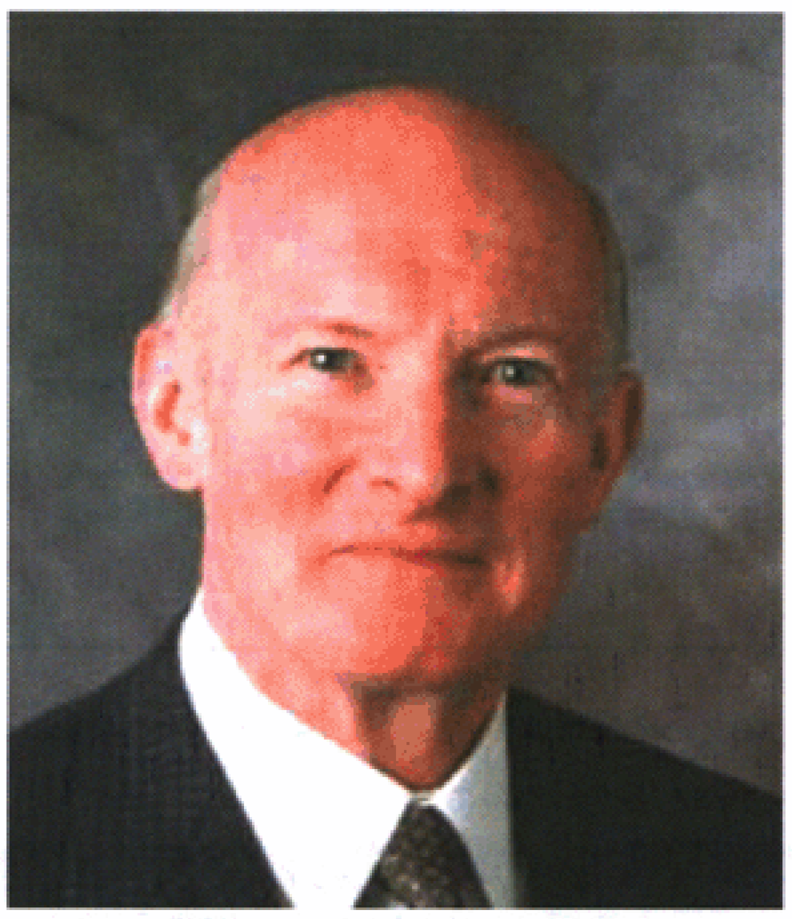
To perform this task, IMPROVE has considered exploiting a novel approach based on vectorisation and 'omni-optimisation'. Vectorisation assumes converting constraints into additional objectives and their optimisation alongside original objectives. Precisely, vectorisation has shown capability to significantly improve the search for the optimum design alternatives (Klanac and Jelovica 2007a, 2008), but it has also allowed for an easy handling of design criteria, thus

Owen F Hughes, Professor, Dr.

Dr. Owen F. Hughes (pictured) is Professor of Ship Structures, Department of Aerospace and Ocean Engineering, at Virginia Tech. He is recognised as a pioneer in the field of first-principles structural design, having been one of the first to achieve a synthesis of finite element analysis, ultimate strength analysis and mathematical optimisation. In doing so he has made several fundamental developments in all three of these areas. His book Ship Structural Design, published in 1983, presented an entirely new method of ship structural design. He also implemented the method in a computer program called MAESTRO (Method for Analysis, Evaluation and STRuctural Optimization).

Dr. Hughes has been NavSea Research Professor at the US Naval Academy, chairman of the SNAME Panel on Design Procedures and Philosophy and chairman of the ISSC Committee on Computer-Aided Design.

Of his paper "Next Generation Ship Structural Design", Dr Hughes says: "Ship structural design continues to pose challenges for the design team to effectively address inherent complexities, evolving performance requirements from owners and regulators, and need for efficient integration with the overall ship design process. Next generation ship structural design tools and methods must further unify structural design process sub-elements into a more efficient and higher fidelity process that supports the realization of engineering integrity with optimized performance for the owner/operator. Advances in design tool architecture, geometry and topology modelling, loads analysis, and structural evaluation must be better unified in order to achieve progress toward these objectives."



benefiting the objective of this study. An algorithm that can solve a vectorised structural optimisation problem is called an omni-optimiser; while the process of its application is called omni-optimisation.

The IMPROVE project used the 40,000dwt chemical tanker as its example to obtain reasonably good design alternatives with respect to hull steel weight and weight of duplex steel. From that point on, the request was to increase the safety of the structure, so that the corresponding adequacy was maximised. If scantlings of deck strakes are maximised, there will be less probability of crack initiation. This objective caused an increase of hull and duplex weight, and fairly distributed Pareto front between them was achieved.

However, in looking behind the designs themselves, it is important to focus on the methodology driving the IMPROVE study. The IMPROVE Project's remit has taken in innovative approaches to shipbuilding, which include:

1. Maintenance/repair and production oriented life-cycle cost/earning model for ship structural optimisation during conceptual design stage.

Here, the aim has been to investigate the effect of the change in structural weight due to optimisation experiments on life-cycle cost and earning elements using the life-cycle cost/earning model, which was developed for structure optimisation. The relation between structural variables and relevant cost/earning elements has been explored in detail. The developed model is restricted to the relevant life-cycle cost and earning elements, namely production cost, periodic maintenance cost, fuel oil cost, operational earning and dismantling earning. The maintenance/repair data was collected from three ship operators and was solely used for the purpose of regression analysis.

2. Multi-objective optimisation of ship structures: using guided search versus. conventional concurrent optimisation

Here, structural optimisation has been considered in the context that it regularly involves conflicting objectives, where beside the eligible weight reduction, increase in e.g. safety or reliability is imperative. For large structures, such as ships, to obtain a well-developed Pareto frontier can be difficult and demanding in terms of time. Non-linear constraints, involving typical failure criteria, result in complex design space that is difficult to investigate. Evolutionary algorithms can cope with such problems. However, they are not a fast optimisation method.

In this case, IMPROVE has aimed to improve their performance by guiding the search to a particular part of Pareto frontier. For this purpose it has used a genetic algorithm called VOP. Beside weight minimisation, an increase in safety has been investigated through stress reduction in deck structure. The proposed approach suggests that in the first stage one of the objectives is optimised alone, preferably the more complicated one. After obtaining satisfactory results, the other objective are added to optimisation in the second stage. The results of the introduced approach are compared with the conventional concurrent optimisation of all objectives utilising a widespread genetic algorithm NSGA-II. Results show that the guided search brings benefits particularly with respect to structural weight, which was a more demanding objective to optimise. *NA*