Tools for early design stage: presentation of LBR-5 Software

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ABSTRACT: LBR-5 is a tool for early design stage. Taking into account numerous kinds of constraints – structural, geometrical, etc. – an optimum scantling can quickly been found. In the framework of IMPROVE European project many new modules have been implemented to increase the quality of the optimised scantling. Mainly 6 major changes have been brought: implementation of a sloshing module, a fatigue module, a multi-structure module, a multi-materials module, a life cycle cost module and finally a vibration module. Tests to validate these modules have been carried out on the three ships studied in the IMPROVE project: a LNG, a Chemical Tanker and a ROPAX.

1 INTRODUCTION

To be attractive for 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 spacings and most suitable scantlings to minimize the production costs. The LBR-5 package performs such early design least cost optimisation.

In the framework of IMPROVE new developments have been carried out in order to improve the quality of the optimised scantling. New phenomenon as fatigue or vibration fatigue can now be taken into account – problems that were rarely studied in the early design stage.

2 PRESENTATION OF LBR-5

LBR5 is built around three basic modules, respectively, OPTI, CONSTRAINT and OBJECTIVE. The OPTI module contains the mathematical optimisation algorithm to solve non-linear constrained optimisation problems. The CONSTRAINT module includes:

- Technological constraints that provide the upper and lower bounds of the design variables;
- Geometrical constraints that are generally based on “good practice” rules to avoid local strength failures;
- Structural constraints that represent limit states in order to avoid yielding, buckling, cracks, etc. and to limit deflection, stress, etc;
- Global constraints that represent constraints affecting the whole structure – as the gravity centre position, global inertia, etc;
- Equality constraints to guarantee homogeneity in the structure.

The OBJECTIVE module assesses the objective function. It could be the construction cost – that includes labour costs and material cost – the global inertia or the weight.

A powerful graphical interface helps users to define their model and all characteristics and constraints. A 3D-view is also available – see Figure 1. Managements of results are easy thanks to this interface.

LBR-5 is also an efficient tool to assess and compare different alternatives. A major capability of the method is to quantitatively assess a change of the production technology on the construction cost. For instance, effect of an improved welding procedure (lower unitary welding cost) can be assessed by comparing the least cost optimum scantling obtained with and without the improvement.

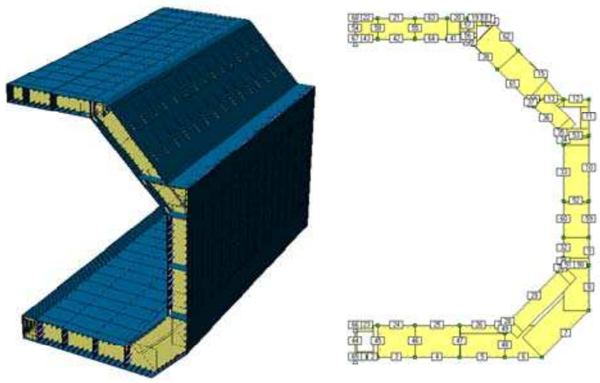

Figure 1. 2D and 3D-view of a LBR-5 model

3 NEW MODULES INTEGRATED IN THE FRAMEWORK OF IMPROVE

Different new modules have been integrated into LBR-5 to perform the optimisation of the three ships. These modules reinforce strongly the efficiently of the software.

The first module is the **sloshing module**. The LBR-5 sloshing module is based on sloshing pressures provided by the *Bureau Veritas* sloshing module. It furnishes quasi-static pressures to be applied on the inner hull structure supporting the membrane cargo containment system, to account, at preliminary design stage. These quasi-static sloshing pressures were obtained through numerical CFD calculations carried out by *Bureau Veritas* and crosschecked with different sloshing model tests campaigns carried out by *Bureau Veritas* in cooperation with *Ecole Centrale de Nantes* and *GTT*.

The second module is the **fatigue module**. It calculates at the early stage design the fatigue damage on critical connections of the ship structures. The procedure adopted is based on the "nominal stress" approach and uses Miner's rule. Generic structural elements have been defined (stiffened panels, web frame or girder and pillars) with pre-defined load modes and fatigue-critical structural details based on results of the damage statistics and pre-existing knowledge. The nominal stress is calculated using beam and plate theory. These analytical formulas are suitable for structural optimization (fast calculation method). The notch stress is obtained based on the hot-spot and notch stress factor. A library of stress concentration factors for a various structural details is predefined.

The third module is the **multi-structure module**. It allows the LBR-5 optimisation tool to optimize several sub-structures simultaneously. The main interest is the possibility to link design variable between these sub-structures.

The fourth module is the **multi-materials module**. To carry out an optimisation structural constraints are imposed at critical areas where stresses are important. Material used influences strongly values of these constraints. It has also an impact on the objective function – weight or production cost. Before this new module only one material could be defined far all the structure. This limitation is now over.

The fifth module is the **Life Cycle Cost module** (LCC). Rather than to optimise the production cost, it is now possible to optimise the life cycle cost. This module contains four sub-modules: the cost of periodic maintenance, the fuel consumption, the operational revenues and the dismantling revenues. Each sub-module can be chosen individually or with others. These new costs can be added to the production cost. A corrosion model that modifies the behaviour of the LCC module can also be selected.

And finally the last module implemented is the **vibration module**. Two methods were developed in order to obtain precisely the first natural frequency. The first, named classic dichotomy is based on Euler-Bernoulli equations and is purely analytical. The main advantage of this method is the accuracy of the results. Nevertheless, this accuracy is limited by the modeling and is influenced by frequency step size. The main inconvenience is the large CPU calculation time in case of complex structures. A second method was developed, named discrete approach. The calculation time becomes very small even for structures with many degrees of freedom and the parasite frequencies disappear. This method was validated with simplified FEA. The both methods allow to obtain only the resonant frequencies corresponding to global vibration modes of the stiffened panel. For the moment, the local vibrations cannot be assessing yet.

Applications of the sloshing, fatigue and multi-structures module have been carried out on the LNG. The multi-materials and Life Cycle Cost module have been used to optimise the Chemical Tanker. Finally the vibration module has been applied on the ROPAX.

4 CONCLUSION

All these new modules have been implemented into LBR-5. Concrete applications were done in optimising each of the three ships studied in the framework of IMPROVE: a LNG ship, a Chemical Tanker and a ROPAX.

Impacts of each module on the optimised scantling have been highlighted.

LBR-5 is now very complete and competitive software to optimise scantling of a ship at very early design stage with management of critical problems studied normally at a later step of the design.

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