A PERFORMANCE-ORIENTED RISK-BASED METHOD FOR ASSESSMENT OF SAFETY OF SHIPS. MODELLING UNCERTAINTIES IN HAZARD AND RISK ANALYSIS

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Abstract: The paper presents some information on the alternative performance-oriented risk-based method for assessment of safety of ships in damaged conditions. The method can be used for the risk-based design where one between the main design objectives is safety. The assessment of safety is based on the risk assessment. For the risk assessment the Formal Safety Assessment methodology has been applied.

1. Introduction

The paper presents some results of research regarding development of an alternative method for assessment of safety of damaged ships at the preliminary stage of design. The present regulations related to safety of damaged ships are included in SOLAS Chapter II-1 parts A, B and B-1. Those regulations are prescriptive in their character and are based on the quasi-probabilistic approach. Application of requirements included in those regulations to certain types of ships e.g. large passenger vessels, Ro-Ro vessels or car-carriers may lead to insufficient level of ship safety or provide unnecessary design restrictions. Instead of prescriptive requirements IMO has decided to use within the rule making process the safety assessment which consists of requirements based on satisfying the objectives. One of them is a sufficient level of safety. For this purpose IMO has recommended an application of Formal Safety Assessment methodology published as MSC Circ. 1023.

The current method of assessment of safety of ships in damaged conditions is based on the harmonized SOLAS Chapter II-1 parts A, B and B-1. The proposed alternative method is a kind of performance-oriented risk-based analysis incorporated in the design process with reduction of risk embedded as a design objective. It should be underlined that this method can easily be adopted for assessment of safety of undamaged ships as it very much depends on the problem (system) definition.

In the paper the alternative performance-oriented risk-based method of assessing safety of ships is briefly discussed because of limited space available. The detailed discussion is currently published by the Gdansk University of Technology.

2. Current method of assessment of safety of ships in damaged conditions based on the SOLAS Chapter II-1 parts A, B and B-1

Using the current methodology the estimation of the probability of survival of flooding any group of compartments is connected with calculation of the attained subdivision index A. The basic condition is as follows: $A > R$, where:
A - attained subdivision index. Calculated according to the formula: $A=\sum p_i s_i$;
p_i - probability of flooding the group of compartments under consideration;
s_i - probability of survival after flooding the group under consideration;
R - required subdivision index.
The logical structure of the system for assessing the condition (1) according to the current SOLAS methodology is presented in Figure 1.

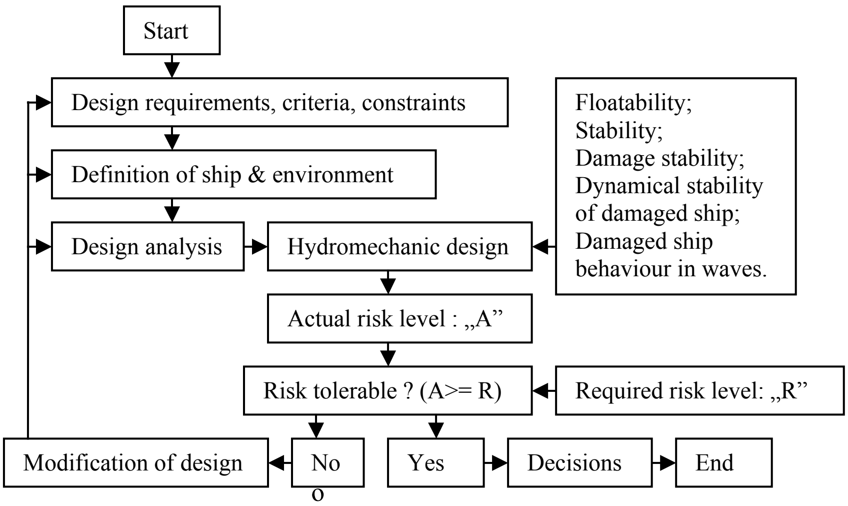

Fig. 1. Basic logical structure of system for assessing the condition (1) according to the current SOLAS requirements

Both the indices A and R are calculated according to the well known formulae accepted by IMO. For the following example we may use the formula included in the Resolution MSC 19/58 regarding the subdivision and damage stability of cargo ships over 100 m. Lets consider the survivability of the 1100 TEU container ship at the early stage of design.

The main data for the calculations are as follows, Gdynia Shipyard (1999-2005): length between perpendiculars L_{BP} = 145.000 m, subdivision length L_s = 158.655 m, subdivision (full) draught dL = 10.200 m, partial draught dP = 7.560 m, light ship: Mass = 6800 t, LCM = 58.10 m from A.P., VCM = 11.10 m above B.P. A graphical examples following from the survivability analysis of this ship are presented in Figure 2.

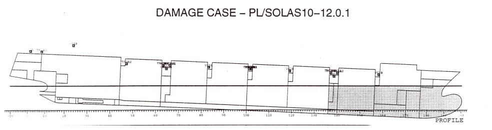

Fig. 2. The general arrangement of internal spaces and an example of final stage of flooding the data group of compartments, Stocznia Gdynia (1999-2005)

The calculations of the attained subdivision index A are connected with the large scale numerical calculations and they are time consuming. The final results of the probabilistic damage stability analysis for the given example are as follows:

$$A = \sum \Delta A_i = 0.52605 \quad (1)$$

$$R = 0.52510 \quad (2)$$

$$A > R \text{ as } 0.52605 > 0.52510 \quad (3)$$

From a designer point of view a question can arise if the ship is safe indeed. The briefly presented prescriptive method has been the base for creating the new techniques for solving some design problems. The nature of these techniques was prescriptive as well. It concerns the procedures for optimization of the index A and optimization of the local safety indices. Good examples concerning these are presented in the previous publications, Gerigk (2005).

3. A performance-oriented risk-based design

The risk-based design is a formalized design methodology that integrates systematically risk analysis in the design process with the prevention/reduction of risk embedded as a design objective, along standard design objectives, SSRC (2005). This methodology implies the adoption of a holistic approach that links the risk prevention/reduction measures to ship performance and cost by using relevant tools to address ship design and operation. This is a radical shift from the current treatment of safety (risk) as a design constraint imposed by rules and regulations. The risk-based design offers freedom to the designer to choose and identify optimal solutions to meet safety targets. For the risk-based design to be realised safety must be treated as a life cycle issue, which in turn implies focus on risk-based operation and need for a risk-based regulatory framework. The risk-based design in the maritime industry will follow the well-established path of quantitative risk assessment used in other industries. The term “risk based design” is also in common use in other industries. The following steps are needed to identify the optimal design solution: set objectives, identify hazards and scenarios of accident, determine the risk, identify measures and means of preventing and reducing risk; select designs that meet objectives and select safety features and measures that are cost-effective, approve design solutions or change the design aspects. This approach is briefly introduced in the logical structure of the risk-based design system presented in Figure 3.

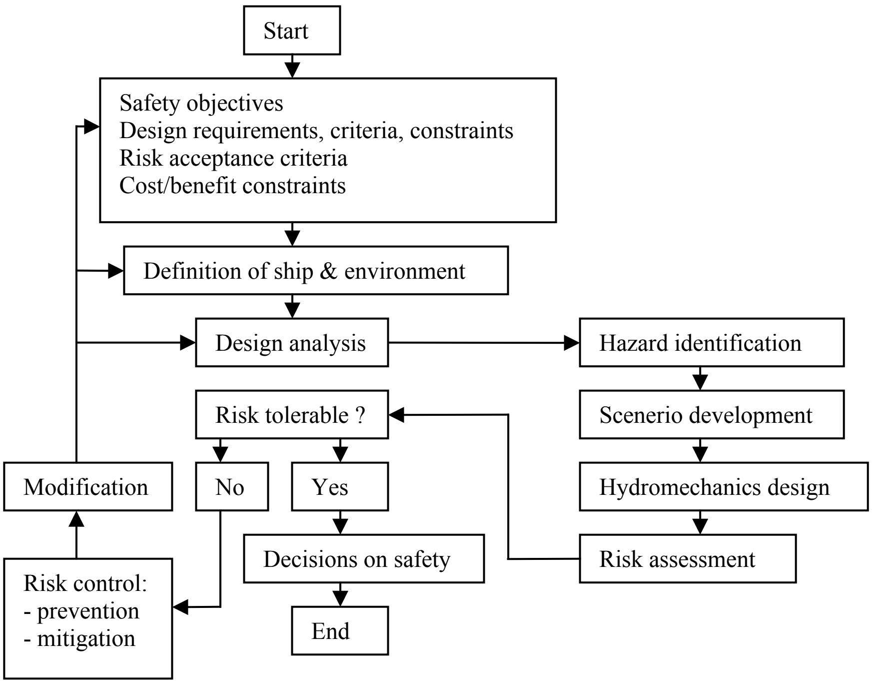

Fig. 3. Logical structure of the risk-based design system (method)

Because of limited space available the performance-oriented and risk-based approaches applied within the alternative method will be presented during the KONBIN Conference.

4. A performance-oriented risk-based method for safety assessment of ships

The modern approach to ship safety is connected with combining the elements of system approach to safety and Formal Safety Assessment (FSA) methodology, IMO (2002). The major elements of the FSA methodology are as follows: hazard identification, risk analysis, risk control options, cost-benefit assessment, recommendations for decision making.

Combining the above mentioned with the modern ship design spiral the basis for the performance- and risk-based formal method for safety assessment of ships is considered. Integrating the systematically used risk analysis in the design process with the prevention/reduction of risk embedded as a design objective (along standard design objectives) the risk-based design method is proposed as presented in Figure 3. The entire structure of the method have been published by Gerigk, Gerigk (2005).
Regarding the risk assessment methods, there is a research going on further incorporating the risk assessment techniques into the design procedure regarding the safety assessment of damaged ships. The following methods are used for the risk assessment, ABS (2000): hazard identification methods, frequency assessment methods, consequence assessment methods and risk evaluation methods. The current set of the hazard/risk analysis methods includes: preliminary hazard analysis (PHA), preliminary risk analysis (PRA), what-if/checklist analysis, failure modes and effects analysis (FMEA), hazard and operability analysis (HAZOP), fault tree analysis (FTA), event tree analysis (ETA), relative ranking, coarse risk analysis (CRA), pareto analysis, change analysis, common cause failure analysis (CCFA) and human error analysis (HEA).

The following risk reduction principles and strategies have been adopted for the method, Grabowski (2000):

1. reducing the probability of an accident;
2. reducing the probability of consequences of accident.

A method for the ships safety estimation when surviving is introduced and it is associated with solving a few problems regarding the naval architecture, ship hydromechanics and ships safety and it is novel to some extent. When preparing the method for the preliminary design purposes the global and technical approaches are used, Barker (2000). The global approach mainly regards the problems associated with the development of methodology, ship and environment definition, hazard identification and hazard assessment, scenario development, risk assessment, risk mitigation measures, hazard resolving and risk reduction and decisions made on ships safety. The technical approach concerns the logical structure of design system and computational model, design requirements, criteria and constraints, library of required analytical and numerical methods and library of application methods. There are two approaches to risk management: bottom-up approach and top-down approach. The top-down risk management methodology has been applied for the method which is suitable for design for safety at the preliminary design stage. This approach should work in the environment of performance-based standards and help designing the ships against the hazards they will encounter during their operational life.

5. Challenges

Currently, there are a few problems under consideration regarding the safety of ships in damaged conditions which are associated with the existing prescriptive method included in the SOLAS Chapter II-1 parts A, B and B-1. The first problem concerns how to obtain the same required level of safety for different types of ships. The second regards updating the statistical data for the p_i factor estimation. The next problem which can probably not be solved using the prescriptive approach is the problem of calculation of the s_i factor according to the pure probabilistic concept. The new formula for s_i factor should include the components following from the fact that there are a few stages during the flooding process, IMO (2002), IMO (2004), Dudziak (2001), Santos (2001), Santos (2002), STAB (2003): creation of damage (stage 1), transient heel and intermediate flooding (stage 2), progressive flooding (stage 3), final stage (stage 4). During the above mentioned stages the internal and external impacts may appear according to the following: wind heeling moment, action of waves, ballast/cargo shift, crowding of people, launching life saving appliances, etc.

6. Conclusions

The alternative performance-oriented risk-based method for assessment of safety of damaged ships is briefly presented in the paper. No details given because of limited space available. The current work regarding the method is associated with integrating the performance-oriented and risk-based analyses into the system briefly presented in Figure 3. The method is novel to some extent and is currently published by the Gdansk University of Technology.

The method uses the performance-oriented risk-based approach. The elements of Safety Case and Formal Safety Assessment methodologies are incorporated within the method. The hazard identification, scenario development, ship hydromechanics analysis, risk estimation and risk control options are combined together. In this respect, the method is a risk-based design method as it integrates the systematic risk analysis in the design process with the reduction of risk embedded as a design objective.

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