Hazard identification. Hazard and risk assessment for a ship when surviving

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Abstract

The paper presents some results of investigations regarding the development of a method for ships safety estimation in critical conditions. The objectives of investigations are briefly described including the method introduction. Special attention is paid towards application of the direct and indirect methods. Four modules of the computational model are presented including those connected with the ship/environment definition, hazard identification, hazard and risk assessment. Then, the hazard and risk assessment modules are used to show an application. A simplified cargo type ship is defined to demonstrate how the computational model can enable the risk assessment to be done for the given initiating event and scenario development (it follows from the assumed scenario of flooding the watertight compartments). The risk assessment results can be used by both the risk reduction and risk management procedures. The preliminary practical remarks regarding the ships safety estimation in critical conditions using the presented method and computational model are given.

1 Introduction

The paper presents the preliminary results of development of a method for the ships safety estimation in critical conditions which can be applied at the preliminary stage of design. The background of the method are the naval architecture, ship hydromechanics and system approach to safety. The IMO regulations concerning the survivability of ships and the Formal Safety Assessment (FSA) algorithm have been applied for the risk estimation.

Implementing the method the theoretical and computational models for calculation both the hydromechanic characteristics of a damaged ship and risk functions have been worked out. Using the direct and indirect methods the ships safety may be estimated in critical conditions when surviving. And these methods concern both the static and dynamical phenomena acting when a ship in damaged conditions. The theoretical and computational models incorporate the modern numerical formula and techniques. The logical structure of the design system and computational model are introduced.

The critical conditions may follow from flooding due to the internal impacts like the cargo and/or ballast shift and external impacts caused by the waves and wind. But it always concerns the ingress of external water into the watertight compartments of a ship

Four modules of the computational model regarding the ship/environment definitions, hazard identification and hazard and risk assessment are briefly introduced in the paper. Using the computational model the safety assessment may be done for the initial event and scenario development assumed. The risk assessment is the base for the safety estimation.

According to the entire concept of the method a few either seakeeping, stability, damage stability or survivability related characteristics may be evaluated for the risk assessment.

At this moment both the seakeeping and stability characteristics data are treated as the initial inputs for the risk assessment regarding both the damage stability and survivability. But it really follows from the hazard scenario development.

The method presented in the paper has been limited to the problems regarding stability, damage stability and survivability in critical conditions. The safety estimation concerns the assessment of probability of survival when flooding any group of compartments.

The design procedure consists of two sub-methods. The first is called a parametric related method connected with evaluation of the damage stability and survivability characteristics according to the above specified set. The second is associated with the risk assessment according to the existing both semi-probabilistic and probabilistic concepts of survival.

There are two particular features of the design method which indicate it as a modern tool. The first is the set of design objective functions, parameters variables and safety measures defined for the above mentioned domains. The second concerns a possibility to use the computational model for the iterative parametric investigations of ships safety in critical conditions including modifications of parameters. Practically, the influence of parameters of the hull form, arrangement of internal spaces, loading condition including both the cargo distribution and permeability can be taken into account within the iteration process of design..

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The paper presents the method and computational model for ships safety estimation in critical conditions and there a few remarks concerning creating the modern design tools are given below..

Today ship designs concern modern one-off vessels and there is a potential risk concerning the design process. Usually a ship design process is connected with satisfying a set of often conflicting requirements and the best design should be achieved using a kind of multiobjective optimization approach or by carrying out a lot of parametric-variation type. It is often connected with using a suitable computer software particularly when there is a short time scale associated with preparation of design proposals.

At the preliminary stage of a ship design process the software tools applied should respect the demands of later design stages and both the quantity and quality of data demanded by such tools make them very special. It follows from the fact that the design information available then may be incomplete and of poor standard. Therefore it is important to develope the design methods and computational models to bridge this substancial gap in the range of computer-based tools available to the designers.

The current challenges in ships design require further development of design systems to meet new requirements. Big advances in hydro-numeric techniques, computer hardware, tool software, computer graphics, networking and databases have brought new possibilities in creating modern design tools. The newest technologies coming into design practice are as follows: expert systems, neural networks and parallel computing. The current design codes are often supported by new theoretical approximations and unfamiliar numerical techniques. Run on supercomputer architectures they give a great amount of textural, numerical and graphical details. Growing interest of acquiring, transitioning and managing new technology in ship design is creating new possibilities but the responsibility of designers is getting bigger as well.

The method and computational model presented in the paper deal with the design for efficiency and design for safety. Despite of the ordinary design requirements associated with the efficiency and economical aspects there is a set of the so-called safety related requirements.

2 Current problems regarding the ships safety estimation for design

There are many safety related projects all over the world. After the "Estonia" passenger ferry disaster the project entitled " Safety of Passenger/RoRo Vessels " was established by the Nordic countries. It concerned the stability and safety requirements for new passenger/ro-ro vessels with special regards to the damaged and flooded conditions. That work was aimed towards establishing an entirely new risk based stability standard including developing the survivability criteria. The problems studied were as follows[1]: damage stability modelling methods, watertght integrity, collision damage extent and dynamic effects in waves. The particular tasks of the project concerned as follows [1]: damage stability modelling methods, damage extent, large scale flooding, dynamic effects in waves, cargo securing and cargo shift, development of survival criteria for ro-ro vessels in damaged condition, framework for new damage stability standard, example design and safety assessment. The results of the project contained three important new elements [1]: minor damage concept, probability of survival, major damages.

There is the SAFER-EURORO programme directed by the Ship Stability Research Centre at the Strathclyde University in the United Kingdom. This is a multi-disciplinary research programme for developing an integrated approach to designing safe passenger/ro-ro ferries and to implement this approach to actual design examples. The programme is structured as a cluster of individual projects, each addressing a special area in ship design and operation [2]. The "Project 2" of the programme called the " Design for Survivability (DESURV) " consists of seven tasks to solve [2]: damage survivability, hydrodynamics of flood water, water ingress by model tests, progressive and transient flooding, sloshing and dynamic stability, risk assessment of large-scale flooding and design for ship and cargo survival.
A few problems have been solved, already [3][4].

There is a big progress in ships survivability investigations. But it will take many years to create the new regulations regarding the safety of ships in damaged condition. For this purpose there is a necessity to keep good international collaboration coordinated by IMO.

In Poland there has been a set of reserch projects concerning the ships safety problems. A few of them have been done at the Ship Design and Research Centre in Gdansk. There is a research project No. 9 T12C 026 16 founded by the Scientific Research Council KBN which concerns a new method for the ships safety estimation in critical conditions. This project is under way at the Faculty of Ocean Engineering and Ship Technology and it will terminate by the end of 2000.
The tasks associated with the above mentioned project are as follows:
- damage stability modelling methods;
- large scale flooding;
- dynamic effects due to internal (ballast and /or cargo shift) and external (waves, wind) impacts;
- development of survival criteria for the ships in damaged condition;
- example design and safety assessment.

The following paper presents a few aspects connected with the project.

3 A method for ships safety estimation in critical conditions

The safety of ships is one of the most important aspects of modern Marine Technology. And this opinion is strongly supported by the list of tragic examples regarding the safety of navigation at sea [5][6][7][8][9][10]. The latest considered by the author are as follows:

1. loss of the ro-ro passenger and vehicle ferry "Herald of Free Enterprise" on 6th March 1987;
2. loss of the ro-ro passenger and vehicle ferry " Jan Heweliusz " on 14th January 1993
and
3. loss of the ro-ro passenger ferry " Estonia " on 27th September 1994.

Of course, it should be noticed that the preliminary reasons of each mentioned accident could be different (ie. free surface effect, loss of manoeuvrability, slamming) but finally each ship lost its stability/damage stability and did not survive. The accident of the "Jan Heweliusz" Polish ferry which sank on the Baltic very close to the Arcona Peninsula on 14th January 1993, was very tragic. And it was studied by the author. Twenty two Polish seagoing ships were lost between 1946 and 1993. And about one hundred twenty eight people died during those tragedies. The most dramatic between them were the accidents of the following ships [11]: m/s "Mazurek" on the Baltic Sea in 1963, m/s "Nysa" on the North Sea in 1965, m/s "Kudowa Zdrój" on the Mediterranean Sea in 1983, m/s "Busko Zdrój" on the North Sea in 1985 and m/f "Jan Heweliusz" on the Baltic Sea in 1993.

It follows from the studies that the majority of the above mentioned accidents occur in abnormal conditions. The reasons of such and similar accidents at sea have always been very complex and difficult to explain particularly when all the mariners and passengers lost their lifes. The reasons of majority of accidents in abnormal conditions depend on many factors.
From the general point of view the following factors may secure a ship at sea [12][13][14]: human factor, control systems / technical means and legislative actions. And these are the factors of first level . There are existing interrelations between them and they play the major role for the ship safety.

There is a group of factors which have an immediate influence on each ship safety at sea and the most important between them are the factors associated with the parameters of the following [14][15]:

1. ship including hull, propeller and rudder particulars;
2. cargo including arrangement of internal spaces, cargo and ballast distribution and loading condition;
3. environment including wind, waves and current;
4. operational connected mainly with the integrated ship management system if available;
5. human including both the psychological and physical predispositions, character, morale, integrity, knowledge, experience and training degree.

And these are the factors of second level .

It is obvious that the safety domains like stability, survivability or manoeuvrability depend on a complex set of parametrs which belong to the different factors from either the first or second levels. And, there are the interrelations between the safety domains as well. All of them, often depend on the same factors of the second level for example. The interrelations between the safety domains and the interrelations between certain hydromechanic characteristics/parameters are the reason why a common complex set of such the parameters they depend on is necessary to create. And these parameters should be the factors of third level.

Taking into account the interrelations between the factors at different levels and the interrelations between the factors at each level we may come to the conclusion that applying the system approach for the ship safety estimation is both very complicated and difficult tool to use it.

The major source of information on hazards and risks involved in shipping are both the statistics and investigations into serious casualties [11][16][17][18]. Studing these data it becomes clear that the safety of life at sea and the pollution of the environment are a function of the actual ship's design, operation and maintenance conditions. Therefore, an integrated rational framework is necessary to work out which should apply the approach based on risk acceptance criteria.

A method for the safety estimation in critical conditions has been worked out and it is associated with solving a few problems reagarding both the naval architecture, ship hydromechanics and ships safety and it is novel to some extent. As it can easily be observed the method consists of two sub-methods:

1. parametic method - when stability and damage stability characteristics are calculated;
2. semi-probabilistic- or probabilistic- based method - for the survivability and risk assessment related problems.

A proposal of Intregrated Ship Safety Estimation Method (ISSEM) has been prepared towards solving a few safety related problems at the preliminary stage of design and it uses the oryginal theoretical and computational models. The theoretical model describes both the global and technical approaches used by the method. The computational model uses these approaches in the form of a dynamical data base.

The global approach adopts some knowledge from the Formal Safety Assessment method which is combined with the integrated system approach [19][20][21][22].

The basic assumptions when applying the global approach were as follows [14]:

1. ship operation is associated with a risk from the safety point of view;
2. safety measures should be quantified as without this you can not manage the safety;
3. ISSEM method should be applicable.

The global approach has enabled to prepare the ISSEM method framework as follows [14][23][24]:

1. method philosophy development including reviewing literature, estimating safety of existing vessels, reviewing regulations, etc.;
2. ship and environment definition;
3. hazard and scenario identification;
4. hazard and risk assessment;
5. hazard resolving and risk reduction;
6. decisions made on ship safety (selection of optimal design, operational and mitigation measures).

Finally the ISSEM method should enable to prepare a Safety Code proposal.

The technical approach has been connected with developing the following [14][23][24]:

1. logical structure of ISSEM design system;
2. logical structure of ISSEM computational model;
3. both analytical and numerical methods for ISSEM;
4. application methods for ISSEM.

4 Ship and environment definition

Between the most important elements of the ship (hull form) definition are as follows [14]:

1. hull form representation;
2. arrangement of internal spaces;
3. watertight compartments form representation.

The above mentioned elements enable to obtain the parametric related characteristics which are fully specified in Chapter 6.

The environment description consists of the wave and wind definitions. Despite of different application methods used by the ISSEM method, the regular wave theory and pseudo spectrum approach (similar to the St.Denis & Pierson method) are used for the wave definition [14][25]. The wind is defined by the apparent wind speed used for the wind resistance calculation [26]. And it depends on the ship speed, real wind speed and ship course angle according to wind.

5 Hazard and scenario identification

The major hazards on board ship include [16]: ship casualties, human casualties, failures, pollution and lawful acts. In this work we have mainly been interested in the ship casualties from the hydromechanic point of view and the hazard identification is closely connected with the system approach applied by the ISSEM method. The following methods can be used to identify the hazards [14][16]: casualty statistics, failure rates, failure mode and effect analysis, hazard and operability studies (HAZOP). Up to now the casualty statistics have been applied by the ISSEM method. The statistics were taken from the publications: [11][16][17][18]. All the statistics have been put into the DHDB Dynamical Hydromechanic Data Base presented below. Considering the potential hazards and initiating events it is possible to identify the significant accidental scenarios. Such an analysis needs a lot of both the model tests and full scale trials data as well as numerical simulations.

This is in order to identify the consequences of initiating events.The event tree analysis, fault tree analysis, cause consequence analysis and escape, evacuation and rescue analysis may enable to assess how the initiating event arises and how the consequences look like.

An example of a simple ISSEM event tree for a cargo-passenger ferry accident is presented in Figure 1 [14].

Figure.1. A simple ISSEM event tree.

The exciting forces which may follow from the following sources:
- external: wind, wave and current defined as the environment;
- internal: cargo and/or ballast shift

may have the biggest influence on the event tree structure.

The problem of identifying the event trees become even more complicated when there are the other exciting forces existing as the rudder hydrodynamic force. The human factor influence should be taken inyto account as well.

6. Hazard and risk assessment

The hazard and risk assessment needs the hydromechanic design procedures to be combined with the risk assessment methods. According to the hazard and scenario identification the relevant hazard and risk assessment procedures should be applied for the safety estimation. The entire risk assessment procedure may concern the seakeeping, stability, damage stability and survivability domains for the ISSEM event tree presented in Figure 1. In this paper the risk assessment concerns the survivability in critical conditions for different scenarios of flooding.

The logical structure of both the design system and computational model is presented in Figure 2.

Figure.2. Logical structure of design system (computational model) presented as a module for the risk assessment for stability and damage stability.

It is show in Figure 2 that before both the stability, damage stability and survivability assessment is initiated the following modules of the ISSEM Dynamical Hydromechanic Data Base for the given ship should be prepared:

1. hull form representation;
2. arrangement of internal spaces;
3. watertight compartments form representation;
4. estimation of hydrostatic characteristics for undamaged ship including:
   - Bonjean scale;
   - hydrostatics;
   - cross curves of stability;
5. estimation of hydrostatic characteristics of watertight compartments and tanks including volumes;
6. estimation of loading condition including:
   - light ship weight;
   - distribution of cargo, ballast and stores;
   - permeabilities;
   - centre of gravity;

Generally, the risk assessment can be done independently for each design domain. But the ISSEM computational model enables to follow the ISSEM event tree accepted and then the risk assessment can be done for each domain step by step. But this is outside the interest of this paper. When, the cargo and ballast shift can happen for the given wind and waves characteristics it may be followed by a hull skin damage for example. After that, both the damage stability and survivability assessment should show if the ship is able to survive in critical conditions. It must be clearly indicated that the main objectives of the ISSEM method are both the risk assessment and safety estimation of a ship in critical conditions including the damaged condition.

7 Risk assessment for stability and damage stability

The stability assessment can be done using either the cross curves or constant displacement method. Of course, the stability is evaluated according to the current loading condition. The loading calculations are based on the arrangement of internal spaces and cargo, stores and ballast distribution, using the iterative approach. When the full information on the loading condition is achieved and the centre of gravity is known, the stability righting arms can be obtained.

The damage stability assessment concerns calculation of the residual stability characteristics for a ship in damaged condition. This is a typical naval architecture problem involving both the linear, two-dimensional and three-dimensional integration. The cross curves method for the damaged ship may be used to obtain the residual stability characteristics. But more advanced method for the damage stability calculation seems to be the Krylov-Dargnies constant displacement method [35][36]. This method is based on the properties of equivolume waterplanes where two equivolume waterlines inclined at $\Delta\varphi$ angle to each another are *tangential to a cylinder*.

Of course, the radius of cylinder varies with φ angle of heel but if $\Delta\varphi$ angle is relatively small, less than 5 degrees for example, the r radius of the cylinder may be assumed to be constant. This method is fully presented in [13][35][36]. Finding the constant displacement waterlines inclined at different angles becomes less time-consuming exercise than by the usual iterative method based on the longitudinal integrations of sectional areas (cross curves method). Both the stability and damage stability charactristics are checked against the IMO stability and damage stability criteria [28].

Having both the stability and damage stability assessed it is possible to start the risk assessment procedures. Generally, the probabilities of capsizing for both the intact and damage stabilities have been based on the idea published in [37]:

$$P_{CI} = 1 - P_{SI}$$
$$P_{CD} = 1 - P_{SD}$$

where: P_{CI} , P_{SI} - probabilities of capsizing and stability for intact stability conditions;
P_{CD} , P_{SD} - probabilities of capsizing and stability for damage stability conditions.

The main objective of the paper is to show how the survivability can be assessed therefore the algorithm for the stability and damage stability risk assessment may be briefly explained during the conference.

8 Risk assessment for survivability

The probabilistic concept has been adopted for the ISSEM survivability assessment and the algorithm was presented in the following papers [13][29]. The risk assessment for survivability is connected with calculation the survivability index A as follows [35]:

$$A = \sum_i p_i s_i \qquad (11)$$

where: p_i - probability of flooding any group of compartments;
s_i - probability of surviving of flooding any group of compartments.

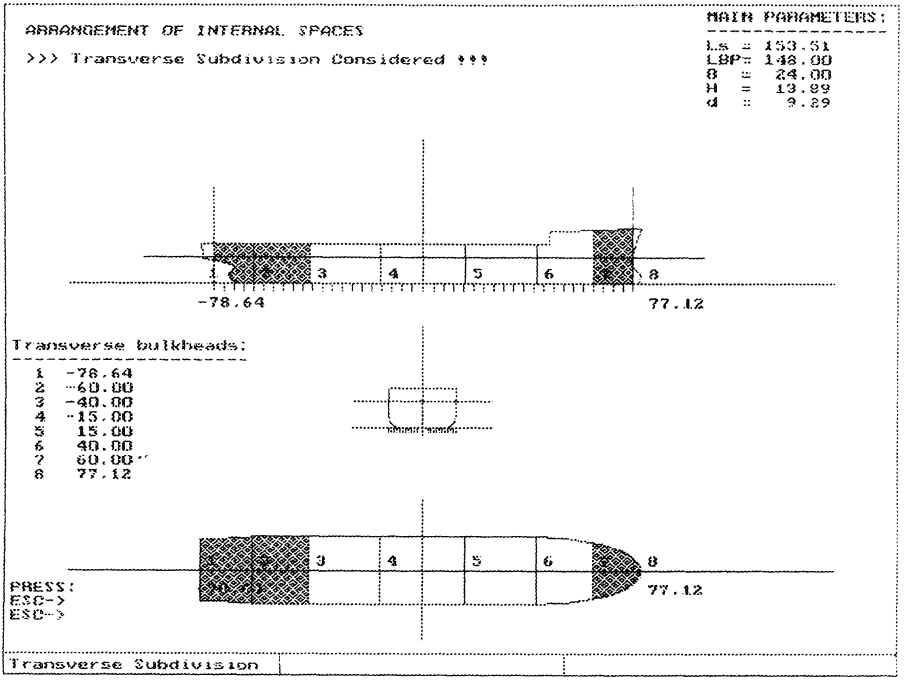
The precise information regarding both the indexA and local safety indices calculation will be shown during the conference. In the same time the way how the internal and external impacts affects the survivability will be presented as well.

The algorithm of the risk assessment for survivability for a cargo ship is presented by the following algorithm regarding the A value optimization for the different arrangements of internal spaces for the same hull form. A cargo vessel hull form have been choosen and three design versions were taken into account.

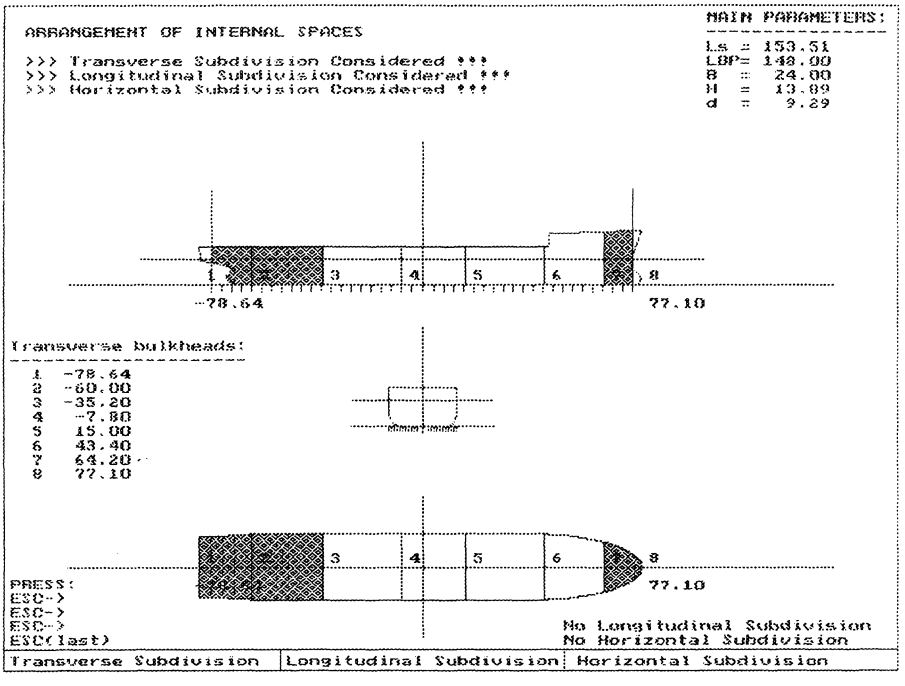
The hazards have been defined as flooding any group of compartments starting from single watertight compartment groups up to the case when the p_i value became null for flooding the groups of compartments consisting of three and more single watertight compartments.

The results of design optimization are presented in Table 1.

DESIGN VERSION A: preliminary arrangement of internal spaces
(7 transverse watertight compartments)



DESIGN VERSION B: partially-fixed arrangement of internal spaces
(7 transverse watertight compartments)



DESIGN VERSION C: partially-fixed arrangement of internal spaces according to a shipyard design
(8 transverse watertight compartments)

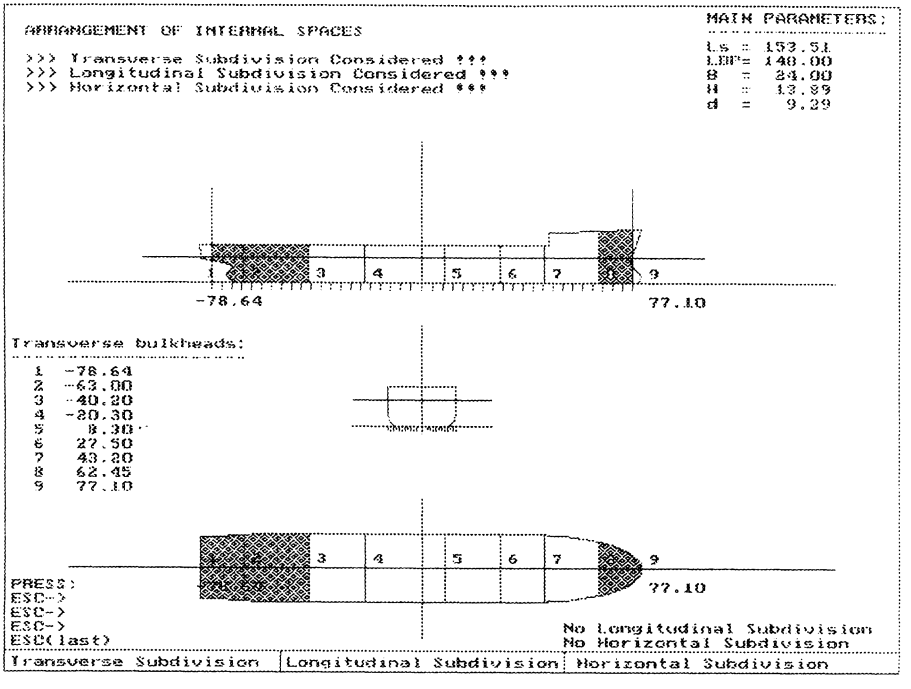


Table 1

Risk assessment for survivability for a cargo ship Design criteria: optimization of index A value											
Versi--on	No. of iterat-ion	Position of transverse bulkheads [m]									Risk value: A[-]
		1	2	3	4	5	6	7	8	9	
A	**I**	**-78.64**	**-60.00**	**-40.00**	**-15.00**	**15.00**	**40.00**	**60.00**	**77.10**		**0.656**
	II	**-78.64**	**-60.00**	**-40.00**	**-15.00**	**15.00**	**38.40**	**60.00**	**77.10**		**0.718**
	III	**-78.64**	**-60.00**	**-40.00**	**-16.69**	**15.00**	**38.40**	**60.00**	**77.10**		**0.816**
		Further calculations gave the following A values: 0.8171, 0.8174 and 0.8177 (still moving bulkhead no. 4)									
B	**I**	**-78.64**	**-60.00**	**-35.20**	**-7.8**	**15.00**	**43.40**	**64.20**	**77.10**		**0.605**
	II	**-78.64**	**-60.00**	**-35.20**	**-7.8**	**15.00**	**41.29**	**64.20**	**77.10**		**0.726**
	III	**-78.64**	**-60.00**	**-35.20**	**-9.63**	**15.00**	**41.29**	**64.20**	**77.10**		**0.795**
		Further calculations gave the following A values: 0.7974 and 0.7976 (still moving bulkhead no. 4)									
C	**I**	**-78.64**	**-63.00**	**-40.20**	**-20.30**	**8.30**	**27.50**	**43.20**	**62.45**	**77.10**	**0.669**
	II	**-78.64**	**-63.00**	**-40.20**	**-20.99**	**8.30**	**27.50**	**43.20**	**62.45**	**77.10**	**0.821**
		Further calculations gave the following A values: 0.8225, 0.8278 and 0.8233 (still moving bulkhead no. 4)									

9 Hazard resolving and risk reduction. Decisions made on ship safety (selection of optimal design, operational and mitigation measures). Safety objectives

The results of risk assessment (scientific calculations) should be compared with the assigned risk targets. In the case of survivability assessment it should be the required index R of subdivision. Generally, there are a few methods to show the acceptable risks in comparison with the intolerable one and they are as follows [16]:

1. ALARP (As Low As Reasonably Possible) concept;
2. F-N curve;
3. Risk acceptance matrix.

The third one has been accepted for the ISSEM method. The following division of risk levels was introduced according to the frequency and consequence categories: broadly acceptable, acceptable with controls, undesirable and unacceptable.

The risk reduction decisions should be made by designers, operators and safety managers. And they can be very different depending on the stage of design process. The Table 1 presents an example from the ISSEM model where the risk reduction decisions depend on the intolerable risk values.

The knowledge base on both the intolerable risk values and risk reduction decisions can be complicated mainly due to the number of project stages, loading conditions, environment loads, ship speed and course. Therefore the decisions making process should be controlled by both the designer, operator or safety manager and knowledge-based system.

Having established the risk acceptance criteria we may identify the safety and environmental protection objectives which should be known for a given operation to avoid hazardous situations and accidents. The safety objectives could be as follows: avoidance of injuries, death, ship's loss or spillage of oil. And they may be introduced in the form of a ISSEM safety code.

The above method/code is still under the development and there are changeable numbers in the second last row according to the risk assessment provided. The proper safety code in the form presented in Table 2 or in the form of prescriptive rules should be prepared according to the data available from the DHDB data base. It should be taken into account that there is lack of risk assessment methods including the risk acceptance criteria for a few safety domains represented within the ISSEM method.

10 Some remarks on design system and computational model

The structure of the ISSEM design system combines both the global and technical approaches and it is presented in Figure 2. All the particulars of the ISSEM design system has been described in the author's D.Sc. thesis being published in 1999. And the most important features of the ISSEM system are as follows:

1. system is open;
2. system structure is hybrid-modular;
3. system has a common library of analytical and numerical methods;
4. system has a common library of application methods (direct geometry-based methods are preferable);
5. system should enable the analysis to be done at a few project stages.

The links between the global and technical approaches are also incorporated by the computational model which keeps the structure of the design system. From the practical point of view the computational model is based on the ISSEM DYNAMICAL HYDROMECHANIC DATA BASE (DHDB) concept and it is oryginal. The basic information concerning the DHDB was published a few years ago when a computer program for the preliminary ship design of operational stability was presented [33]. The structure of DHDB data base is modular and it relates to the logical structure of the ISSEM computational model.

The DHDB data base enables to provide the safety estimation when the ship hydromechanic characteristics can be obtained using either the numerical calculations (direct methods), model tests results, results from the full scale trials, empirical and hydronumerical calculations (semi direct methods) or empirical calculations (indirect methods). Both the ship and environment are defined as hydromechanic objects described by a set of parameters. The safety domains ("Hydromechanic Analysis") are called the design methods using both the functions and procedures associated with solving particular hydromechanic problems. The "Risk Assessment" module includes the methods which combine both the "hydromechanic" and "risk assessment" functions and procedures. Currently this module applies a limited number of methods. The DHDB data base has a lot of advantages and a few disadvantages. In fact this needs another publication to be done on the DHDB data base concept details.

The main ISSEM requirements may be as follows: general requirements, IMO regulations, requirements of classification societies and requirements of conventions. The current set of requirements used by the ISSEM DHDB consists of the IMO regulations.

The ISSEM DHDB should include both the risk acceptance criteria, safety objectives, main requirements and design criteria and constraints. These are the very important components of the computational model and they shall be discussed by another paper.

11 Conclusions

The idea of the Integrated Ship Safety Estimation Method has been worked out. Currently, the method is a risk-based method and it may be used on a case by case basis and for the rule development purposes. A few safety levels are introduced in the ISSEM method. The method is based on the Formal Safety Assessment approach.

The hazard identification can be done according to both the statistics data and analysis of accidents at sea. The hazard and risk assessment may be performed according to the IMO regulations using the ISSEM method.

The ISSEM method and computational model have been used for investigating the new solutions regarding the ships safety from the damage stability and survivability point of view. A few arrangements of internal spaces for a simplified ro-ro type ship have been designed using the method. Both the damage stability and survivability/risk assessment were done for each case. The preliminary results are very promising from the practical point of view and the following results should be presented during the MARINE TECHNOLOGY ODRA 99 Conference.

Generally, both the probabilistic and deterministic safety measure techniques can be used by the ISSEM method. And it can be classified as a joined " parametric - risk assessment method" for the ships safety estimation in critical conditions (when surviving) for preliminary design.

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