Goal-based stability standards

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ABSTRACT

Goal based standards is a concept that was introduced in IMO work at 89th session of the Maritime Safety Committee. The concept of goal based standard that includes holistic approach and involving risk analysis is an alternative to prescriptive standards widely used in regulatory work.

The author briefly considers how to apply risk analysis to system of safety against capsizing with more detailed consideration of different steps of the procedure and specifically proposing identification system of hazards and methodology of risk assessment.

KEYWORDS

Stability of ships; risk analysis; ship's safety.

INTRODUCTION

At 50th session of the IMO SLF Subcommittee completed the task of revision of the Intact Stability Code. The Code was divided in two parts, the first of which will be made compulsory by the reference in the 1974 SOLAS Convention and 1988 LL Protocol, the other will remain as recommendation (IMO 2006). With this decision the first stage of work towards improved stability criteria was completed (IMO 2007). But this is not the final solution. From time to time stability casualties happen in spite of the fact that ships meet all IMO criteria. The existing criteria may be also not applicable to some types of modern ships incorporating novel design features. There is no previous experience in relation to safety and stability of those ships and to satisfy existing criteria may not assure required level of safety. Due to this, the IMO Maritime Safety Committee has recently included in its work programme the development of performance-oriented criteria for ships of novel ship type.

The author is of the opinion, that with the completion of the work on revision of the basic stability requirements included in the IS Code, it is now time to consider a holistic and risk based approach to stability standards as an alternative to the existing prescriptive criteria. This has to be done in order to enhance safety and not to hinder the development of novel ships types.

CURRENT SITUATION REGARDING STABILITY CRITERIA

The compulsory part of the revised IS Code contains basic stability criteria, virtually unchanged from those in resolution A.167(ES.IV) adopted by the IMO assembly in 1968 and weather criterion adopted by resolution A.562(14) adopted in 1987. In spite of the fact, that some ships satisfying those criteria capsized, the wide experience with application of those criteria, including weather criterion, justifies the general opinion that the great majority of conventional ships that meet the criteria are reasonably safe.

Advent of very large and sophisticated ships some of them revealing novel design features causes, however, that those criteria may be inadequate. Therefore IMO meetings consider possible ways of development of improved criteria. It seems that the opinion of the majority of participants is that the future "improved" stability criteria should be performance-oriented. The understanding of the idea behind the performance-oriented criteria is not, however, clear and the way that such criteria might be developed is now under discussion.

It seems that the merit of the majority of proposals related to the possible methods of developing performance oriented criteria consist of consideration of some phenomena occurring when the ship is sailing amongst the waves, namely parametric resonance in following and head seas, loss of stability in wave crest and broaching to. In fact those are dangerous situations well recognized 25 years ago, when the SLF Subcommittee at its 29th and following sessions recognized those situations as those that need further consideration leading possibly to development of some safety criteria (IMO 1984). The problem was at that time apparently too difficult to solve and the idea was ultimately abandoned. With much better tools (computer codes) available now, the idea of developing criteria taking into consideration those situations came back to life again and the possibility of developing non-structural formulae as a basis for the new criteria was advanced. In the opinion of the author there is a merit in consideration of the dangerous situations mentioned above, but the possibility to develop comparatively simple non-structural formulae that could be used as criteria is doubtful.

PRESCIPTIVE CRITERIA, SYSTEM APPROACH AND RISK ANALYSIS

The existing criteria are design oriented and their essence consists of specification of critical values of some stability parameters, therefore they could be classified as prescriptive criteria. Prescriptive regulations have many advantages. They are formulated in a simple language, which is easily understood by everybody, they are easy in application, they also make checking adherence to the requirements easy. The main shortcoming of prescriptive regulations is that they are bounding designers and they do not allow introduction of novel design solutions. They are based on experience gained with existing objects and they are not suitable for novel types. Mostly, they were amended after serious casualties happened. The risk involved with the application of prescriptive regulations is not known.

At the opposite side of the prescriptive regulations, there is risk-based approach. In the risk-based approach the regulations do not require meeting certain specific measures, they are based on assessment of risk involved that may or may not be accepted. The advantages of risk-based approach are obvious. They give free hand for the designer to develop new solutions, they actually allow taking optimal decisions from the point of view of economy and safety and the risk to the public and to the environment is assessed and accepted.

As mentioned above, existing criteria are design criteria intended to be applied during the design stage of a ship. However, even the preliminary analysis of stability casualties shows, that design features of the ship are neither the most important nor most often cause of casualty. Casualty – it will be in the following called LOSA (loss of stability accident) - (Kobyliński 2006), is usually the result of a sequence of events that involve environmental conditions, ship loading condition, ship handling aspects and human factor in general. Therefore, system approach to stability safety should be adopted.

Ship stability system is rather complicated. However, in most cases it could be considered as consisting of four basic elements: ship, environment, cargo and operation (fig.1, Kastner 2003). The Venn diagram in this figure stresses strong interactions between the four elements. The author proposed the use of the system approach to stability criteria quite long time ago (Kobyliński 1984). It was also partly applied in development of the Intact Stability Code but in general until this day stability requirements remain basically design oriented.

Analysis of LOSA casualties reveals that the causes of casualty may be attributed to:

- functional aspects resulting from reliability characteristics of the technical system, therefore stability characteristics of the ship

- operational aspects resulting from action of the personnel handling the system, therefore crew members but also ship management, cargo handling, marine administration and owners company organisation

- external causes resulting from factors independent from designers builders and operators of the technical system therefore ship environment and climatology (Cleary 1975, Erickson et al 1997)

- cargo related aspect resulting from characteristics of cargo and its way of transporting

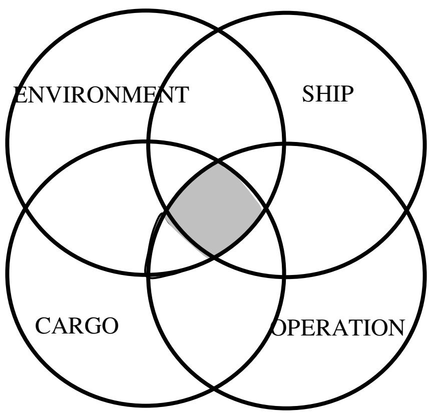

Fig.1. Four-fold Venn diagram for ship stability system

Human factor plays an important part in all four elements of the system. Human and organisational errors, HOE, according to some authors, are responsible for approximately 80% of all marine casualties (Manum 1990), other sources definitely stated that this percentage is 80% (US Coast Guard 1995). In order to achieve sufficient level of safety with respect of stability, all elements creating stability system have to be taken into account. Taking into account the fact, that less than 20% of all casualties are caused by faulty or bad design of the ship, the existing safety requirements that refer mainly to design features of the ship can not insure sufficient level of safety, in particular with regard to ships having novel design features.

CONCEPT AF SAFETY

The oldest concept of safety regulations consists of specifying hull scantlings considered as assuring safety. Krappinger (1967) defined this concept of safety as the assignment of hardware and this concept is often used as a basis of simple safety requirements up to this day.

A more advanced concept of safety does not include assignment of dimensions or proportions of an object, but assignment of its physical properties or performance characteristics. In respect to stability, in a simple case this means, for example, assignment of critical values of metacentric height or of the righting arms at various angles of heel. In a more advanced case, it may mean the assignment of a probability of capsizing in certain assumed situation. In all cases the resulting criteria are prescriptive criteria.

The most recent concept of safety regulations is goal-based standards. Goal based regulations do not specify the means of achieving compliance but set goals that allow alternative ways of achieving compliance (Hoppe 2006). Goal-based standards are being considered at IMO for some time and appraised by some authors (Vassalos 2002, Chantelauve 2005), and they were introduced in some areas, albeit not in the systematic manner. The IMO Marine Safety Committee commenced in 2004 at MSCC 78 its work on goal-based standards in relation to ship construction adopting five-tier system (Table 1).

IMO MSC committee agreed in principle on the following tier I goals to be met in order to build and operate safe and environmentally friendly ships: “Ships are to be designed and constructed for a specific design life to be safe and environmentally friendly, when properly operated and maintained under specified operating and environmental conditions, in intact and specified damage conditions, throughout their life”.

Table 1. Five-tier system for goal-based requirements

Tier I:	Goals
Tier II:	Functional requirements
Tier III:	Verification criteria of compliance
Tier IV	Technical procedures and guidelines, classification rules and industry standards
Tier V	Codes of practice and safety and quality systems for shipbuilding, ship operation, maintenance, training etc

It seems that the future alternative criteria should be based on the above principle. With this in mind, the system of stability requirements proposed may be as shown in fig.2 and in Table 2. Left hand side of the diagram in fig.2 refers to conventional ships, whether the right hand part refers to non-conventional ships. Shaded part is actually completed and the practical problem consists of how to develop requirements for non-conventional ships. The diagram shows, that it could be done using SOLAS clause allowing using alternative means of assuring safety.

Table 2. Methods of safety assurance

Ships	Method of stability safety assessment
Conventional, not sophisticated	Prescriptive criteria as in the IS Code
Novel types, large sophisticated ships	Risk analysis under the provision allowing application of alternative means of assuring safety

Clarification is needed regarding the definition of conventional and non-conventional ships. Traditionally under the term “non-conventional ships”, ships revealing novel design features are understood. However this is a very vague definition and the major difficulty is which features may be classified as “novel”. It seems that the best way to classify ships as non-conventional would be to include in this category all ships to which requirements of the existing IS Code are considered non applicable in the view of designers, ship owners or administrations.

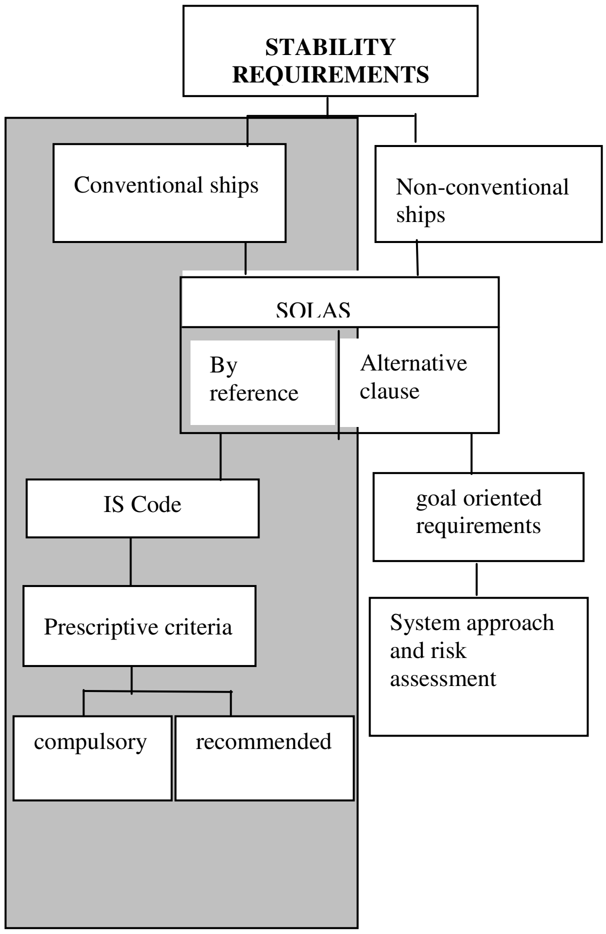

Fig.2. System of stability requirements as proposed

GOAL ORIENTED REQUIREMENTS

With relation to stability goal oriented requirements should be based on risk analysis, because the final stage of risk analysis is assessment of safety measured by risk involved. Risk is a measure of safety and risk estimated has to be accepted; if not accepted risk control measures must be applied including putting some barriers with the result to reduce risk to such level that can be accepted.

Risk-based approach according to IMO recommendation is formalized and includes the following steps:

1. Identification of hazards

2. Risk assessment
3. Risk control options
4. Cost-benefit assessment, and
5. Recommendations for decision making

It is rather obvious that application of risk assessment methodology is a tedious and time-consuming task, but in principle it is feasible. It would be not practical to apply this method to conventional ships that are reasonably safe, but it could be effectively applied to important and large ships of non-conventional design. Risk analysis may, therefore, be recommended as an alternative to existing prescriptive criteria subject to the discretion of the Maritime Administrations involved. The general procedure for application of system and risk approach is shown in fig.3.

HAZARD IDENTIFICATION

The crucial problem in safety assessment analysis is proper identification of various hazards to which a ship may be subjected. According to the definition, hazard is *"a potential to threaten human life, health, property or the environment*" (IMO 2002). In the goal oriented approach and when performing risk analysis all relevant types of hazards must be taken into consideration – environmental, technical, operational and managerial. And the frequency (probability) of occurrence of those hazards should be assessed. Human factor must be taken also into consideration. Belenky et al (2007) proposed to apply "vulnerability criteria" within the system of future criteria. Those criteria are, in fact, hazards. However, the vulnerability criteria are meant as considered in a binary mode, whether hazards are inherently connected with probability.

Hazard identification is carried-out using hazard identification and ranking procedure (HAZID). Hazards could be identified using several different methods.

IMO resolution included general guidance on the methodology of hazard identification. With respect to stability, hazard identification could be achieved using standard methods involving evaluation of available data in the context of functions and systems relevant to the type of ship and mode of its operation. Stability

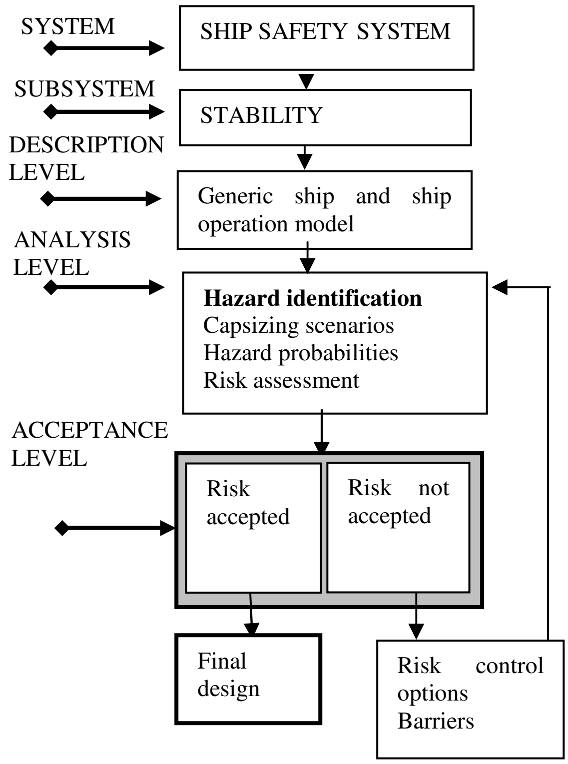

Fig.3. Block diagram of risk analysis

is considered assuming that the ship is intact and accident evaluated is called LOSA (loss of stability accident). LOSA is a new definition covering capsizing, that means taking by the ship position upside down, but also covering a situation where amplitudes of rolling motion or heel exceed a limit that makes operation or handling the ship impossible for various reasons –e.g. loss of power, loss of manoeuvrability, necessity to abandon the ship etc. It does not necessary mean the total loss of the ship. (Kobyliński 2006).

According to general recommendation, the method of hazard identification comprised mixture of creative and analytical techniques. Creative element was necessary in order to ascertain that the process is proactive and is not limited to hazards that happened in the past.

In general HAZID involves several possibilities used separately or in combination:

- statistical data concerning causes of accidents
- historical data including detailed description of accidents
- conclusions resulting from model tests of ships in waves
- conclusions resulting from computer simulation of capsizing
- event and fault trees method
- analysis of accidents scenarios using (e.g. TRIPOD method (ter Bekke et al 2006))
- organized opinions of experts (e.g. according to DELPHI method)

As an example of application of this methodology, the list of hazards in respect of stability is shown in fig. 4. The list was prepared on the basis of evaluation of data for approximately 350 stability casualties, of detailed analysis of several LOSA accidents and of evaluation of results of opinion of experts organized by DELPFI method.

In this example, ranking of hazards is not shown. Furthermore, the sketch could be considered as the first level of the fault tree leading to LOSA. Hazards identified as relevant to safety against LOSA are all strongly interconnected, moreover, human factor understood as performance of an individual (in most cases the master), plays an important part in each case. Hazards identified should be further decomposed preferably using fault trees and/or events trees reproducing various scenarios of LOSA casualty. The set and combination of fault trees and event trees as developed for all hazards identified and all scenarios (defined as risk contribution trees – RCT) is a basis for HAZOP (hazard and operability study) procedure that allows also assessment of frequencies (probabilities) of hazards required for risk assessment. This is rather tedious task bearing in mind the multitude of possible scenarios. This problem, however, is not discussed here.

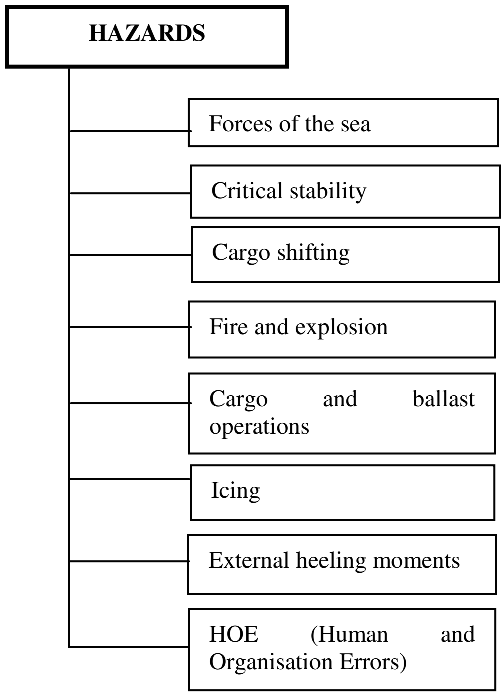

Fig. 4: Basic hazards to stability

Further decomposition of the basic hazards listed in fig.4 leads to hazardous situations and finally, to possible capsizing scenarios. This provides quite a large number of different scenarios for consideration. However, in reality the number of scenarios that need to be considered in a particular case could be substantially reduced, due to their very low probability.

CONCLUSION

In order to proceed with the development of performance based criteria provision allowing for alternative design and arrangements included in the SOLAS convention could be used. Within this provision goal oriented approach may be recommended as an alternative to prescriptive standards. Risk assessment and analysis may be the proper method to achieve the goal, which is the safety of the ship.

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