Alternative stability criteria for ships

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ABSTRACT

In the year 2010 Intact Stability Code was included by reference to SOLAS Convention and from this date on part A of the Code became compulsory. However, the work on stability criteria has not been completed, and as stated in Code, some problems of safety of ships from the point of view of stability should be considered further. The paper proposes to include in the SOLAS Convention and in the Code provisions allowing Administrations to apply alternative criteria for novel ships, or ships which present high risk to people or environment. Goal oriented approach to the development of alternative criteria including risk assessment methods is proposed.

Keywords: *Ship stability, stability criteria, risk analysis.*

1. INTRODUCTION

Year 2010 could be assessed as a year when IMO work on adopting international stability norms or standards was completed because the Intact Stability Code was included by reference to SOLAS convention and from this date on Part A of the Code comprises compulsory basic stability criteria for all ships to which SOLAS convention applies. Part B of the Code is still, however, recommended only, but this part covers mainly requirements to some special ship types and other requirements and guidelines. This decision taken after almost fifty years of development is an important step towards assuring safety against loss of stability casualties of ships. Adoption of basic stability criteria fifty years ago followed by adoption of the weather criterion seventeen years later resulted in drastic reduction of casualties related to stability. The requirements, however, were based on the characteristics of standard ships, mainly in operation during the second half of twentieth century.

Looking at the text of the Intact Stability Code we see, however, in the preamble an important statement that reads: "*It is recognized that in view of the wide variety of types, sizes of ships and their operating and environmental conditions, problems of safety against accidents related to stability have generally not yet been solved. In particular, the safety of a ship in a seaway involves complex hydrodynamic phenomena which up to now have not been fully investigated and understood. Motion of ships in a seaway should be treated as a dynamical system and relationships between ship and environmental conditions such as wave and wind excitations are recognized as extremely important elements. Based on hydrodynamic aspects and stability analysis of a ship in a seaway, stability criteria development poses complex problems that require further research.*"

This very important statement clearly says that work on stability criteria is not completed and there is a need to arrange further research programs on ship hydrodynamic aspects of stability criteria. In fact this statement reveals also views quite often expressed by some national delegations to IMO Subcommittee, indirectly indicating that future stability criteria should be performance oriented and prescriptive design criteria, of the type such as are current criteria included in the Code.

Almost ten years ago work on so called Second Generation Stability Criteria was initiated by the IMO SLF Subcommittee. Currently work on those criteria was almost completed and the SDC Subcommittee agreed to recommend them and publish in the form of MSC Circular. Moreover, the subject related to further work on stability criteria was removed from the future programme of the subcommittee.

2. CONCEPT OF ALTERNATIVE CRITERIA AND EQUIVALENT METHODS

The above quoted text of the preamble to the Intact Stability Code clearly indicates that the present requirements of the Code are not the final word. Further work in the future might be necessary. The problem is, how to approach this important problem with the view that existing criteria might be not fully adequate to modern ships differing in size and design features from ships operating in the past.

In the introduction to the Code in paragraph 1.3, there is another important sentence included, that reads: *"Administrations may impose additional requirements regarding the design aspects of ships of novel design or ships not otherwise covered by the Code"*. This sentence opens the possibility to the Administration of a particular country to have some flexibility in application of stability norms with regard, however, design features of the ship.

It seems that the above statements, although properly reflecting current status of stability regulations implicate that additional or alternative requirements should be design oriented.

In its 49th session the SLF Subcommittee discussed possibility to introduce in Part A of the Code the clause allowing Administrations to apply equivalent requirements to those already specified in the Code, similarly as it was done in the section 1.4 of Chemical Carriers Code and Gas Carriers Code and in section 1.11 of the High Speed Code 2000. This was proposed by Norway and was supported by some other delegations. Proposal to introduce to the Intact Stability Code a clause allowing Administrations to apply equivalent methods of assessing safety was widely discussed in the paper by Chantelauve (2005). Other authors also supported this proposal, e.g. Vassalos (2002) and Kobylinski (2006). This clause should apply to nonconventional ships or ships to which application of current requirements to existing ship types because of their dimensions, construction and operating conditions would not be practical.

During the discussion at IMO some delegations were of the opinion, that this clause should be formulated similarly as it is included in the SOLAS Convention in the Regulation II-2/17 in relation to fire protection. Text of this regulation shows, that when applying equivalent requirements it would be necessary to apply engineering analysis according to the guidelines included in the IMO/Circ.1002. After discussion the Subcommittee did not take any decision in this matter, however.

All existing stability requirements, including Second Generation Criteria mentioned are design oriented. However analysis of the stability casualties reveals, that design faults only rarely contribute to casualty. It is true, that it is very difficult in the majority of stability failures to discover a single cause of casualty. Usually accident is a consequence of a chain of events where other factors, including human factor play predominant role. The analysis of 364 stability casualties collated from various sources (Kobylinski 2008) allowed to draw some general conclusions revealing that in the great majority of cases (about 80%) human and organisational errors (HOE) are responsible for the accident, that usually results of a sequence of events that involve other factors as well. Most casualties took place in rough sea, although forces of the sea were not often the primary cause of casualty. Many casualties happened in calm sea. Design features of the ship are responsible for a rather small percentage of casualties.

Human factor is not taken into account in any stability criteria, on the other hand all available sources related to loss of stability casualties show that this factor is the most common cause of casualty. Human and organisation errors (HOE) according to some authors are responsible for about 80% of all accidents at sea (Manum 1990). Other source definitely stated that this percentage is between 75% and 80% (US Coast Guard 1995)

Analysis of the P&I Club (Boniface and Bea, 1996) reveals that HOE are the cause of 62% of all marine claims. It may be concluded therefore that operational aspects are the most important in assuring safety at sea.

Other data on the same subject:

According to US Transportation Safety Board:

- 57% of all accidents at sea are caused by wrong organisation of operation and errors of the crew members
- 10% technical errors of pilots
- 33% mechanical problems, weather and other factors

According to Swedish Marine Administartion:

- 71% of accidents are result of errors of crew members and lack of understanding
- 10% lack of knowledge and training
- 19% other factors

Bearing in mind that currently used stability criteria, but also Second Generation Stability Criteria under final development, are basically design oriented, it was suggested that alternative criteria should be holistic, taking into account all elements of the ship stability system.

This system at least should include four basic elements, as shown in the often quoted Venn's diagram reproduced in Figure 1, where all four element are shown: ship, cargo, environment and operation. In the operation element, human factor plays important part.

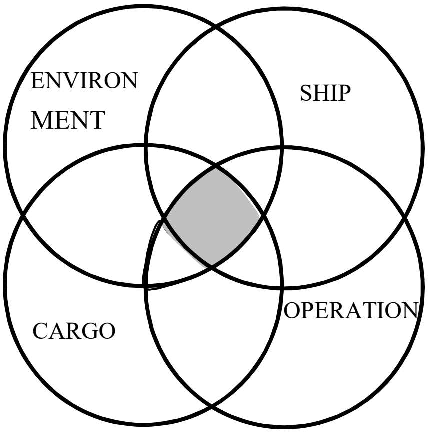

Figure 1. Venn's diagram showing simplified stability system

The essence of the current proposal is to include in the SOLAS Convention, as well as in the Stability Code, a provision allowing national Administrations to use equivalent alternative criteria or methods of assessing safety against stability accident. It should also be recommended, that methods used will be based on holistic approach where all elements of stability system including HOE are taken into consideration. It is obvious that if such provision will be included, there would be necessary to develop suitable detailed guidelines concerning those methods. This clause may be applicable to ships to which present requirements in the view of the Administration are not sufficient to assure safety. Table 1 illustrates this idea:

The schematic presentation of location of the proposed system of stability criteria is shown in Figure 2. In fact Intact Stability Code in few places mentioned alternative or additional requirements. In the introduction (par.1.3) there is included already provision allowing Administrations to impose additional requirements regarding the design aspects of ships of novel design or ships not otherwise covered by the Code. In Part A, second part of paragraph 1.2. says: *"Having regard to the phenomena described in this section, the Administration for a particular ship or group of ship may apply criteria demonstrating that the safety of the ship is sufficient"*. In the text of the Code alternative criteria related to wind effect are mentioned, they also mentioned in several other places in Part B of the Code. However in the first quotation application of alternative criteria is limited to design aspects only, in the second place, to the critical phenomena in waves.

Table 1. Method assuring safety against stability accidents

Ship types	Method of assuring safety
Conventional, not sophisticated	Prescriptive criteria included in the Stability Code
Nonconventional or requiring safety analysis because of their dimensions, construction or functional features	Safety analysis under the provision regarding possibility to apply alternative criteria or methods of assuring safety

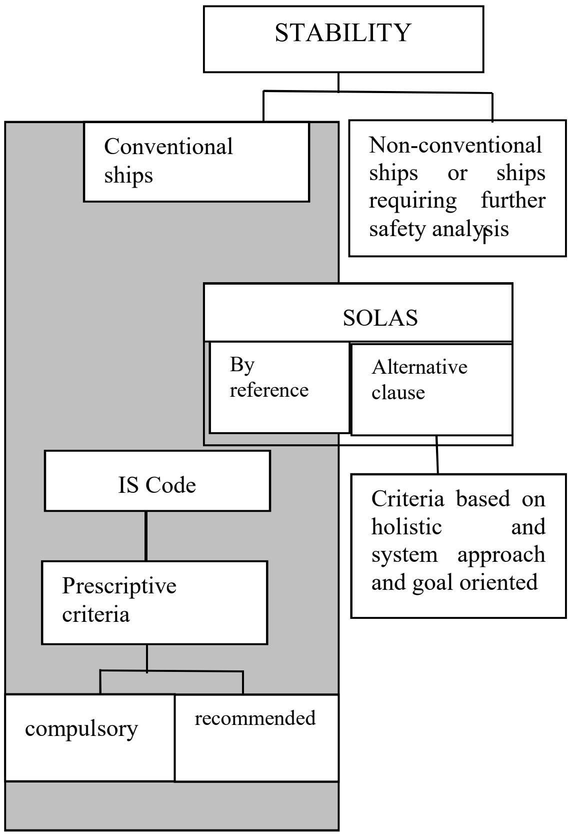

Figure 2. Schematic presentation of location of the proposed alternative clause

In the proposal presented the intention of alternative criteria or methods of assuring safety is to allow Administrations to use entirely different holistic and system approaches. Obviously method or methods used in alternative approach should be approved by IMO, also important part falls to Classification Societies and to Universities and other scientific organizations. Application of the mentioned provision would solve problem of safety for ships of all types, including those of novel design allowing at the same time further continuation of work on the development of new criteria.

3. SUGGESTED METHODOLOGY OF DEVELOPING ALTERNATIVE STABILITY CRITERIA

The most general concept of advanced method of formulation of safety regulations is goal-based approach. Few years ago the concept of goal based regulations was discussed at IMO. Goal based regulations do not specify means of achieving compliance, but sets goals to allow alternative ways of achieving compliance (Hoppe 2006). Goal based standards were for some time considered at IMO and appraised by some authors (Chantelauve 2005, Vassalos 2002) and they were introduced in some areas, but not in the systematic way. Possibility to use goal based approach for damage stability was considered thoroughly by Papanikolaou et al (2012).

Marine Safety Committee recommended a five tier system for goal based requirements as follows:

Tier 1: Goals
Tier 2: Functional requirement
Tier 3: Verification of compliance
Tier 4: Technical procedures and guidelines, classification rules and industry standards
Tier 5: Codes of practice and safety and quality systems for shipbuilding, ship operations, maintenance, training, etc.

When considering goal oriented approach to safety IMO MSC Committee agreed in principle on the following general goal to be met: "*Ships are to be designed and constructed for a specific design life to be safe and environmentally friendly, when properly operated and manufactured and maintained under specified operating and environmental conditions, in intact and specified damage conditions, throughout their life.*"

The goal oriented approach consists of multitude of means assuring safety that includes compulsory requirements as e.g. included in the SOLAS Convention, recommendations related to operational factors, guidelines related to specific subjects and other instruments as shown in the above list.

The goal oriented approach is probably the most suitable methodology that may be used in the development of alternative requirements because in this methodology multitude of approaches could be used and in which all elements of stability safety system could be included. Risk analysis is included as the main element used to develop and formulate those instruments.

Traditional approach, where stability criteria are of prescriptive nature and design oriented probably will not attract much attention in the future, in particular with regard to alternative criteria. The design oriented criteria do not take into account that stability requirements, similarly to all other safety requirements, should be based on system approach where all elements of the stability safety system should be taken into account

Adoption of the proposed clause allowing Administrations to use alternative methods of assurance safety against stability accident opens the problem of developing appropriate recommendations for Administrations. Without doubts suggested methodology would not be a simple one. Some precedents already do exist, e.g. Interim Guidelines for alternative assessment of the weather criterion in MSC.1/Circ.1200. There is a possibility that Second Generation Stability Criteria, or at least some parts of them and associated methodology may be recommended as alternative in a similar way.

The criteria in the above methodology (apart level III criteria) are performance oriented stability criteria, based on physical models of phenomena. The broader definition says that performance based approach where the behaviour of the vessel is analysed in a set of environmental scenarios taken as realistic as possible on the basis of her performance in terms of safety against capsizing.

Another possible approach that could be used in the future work on the development of the future stability requirements is to base them on probability of capsizing in a seaway. Progress in this direction is already substantial and several papers on this subject were presented to IMO (e.g. IMO 2004, 2006, 2008), also paper by Cramer et al. (2004), containing proposals to use the probability of capsizing in the computer simulated wave train as a safety criterion. The probability of capsizing could be also assessed by model test in the towing tank or in open waters. However it seems that capsizing in a seaway is not the only hazard for ships and in assessing safety other phenomena and factors should be taken into account, such as water on deck, broaching, etc. and similar effects important from the point of view of overall safety.

4. SHORT REMARKS ON THE RISK ANALYSIS

Goal oriented approach includes risk analysis. Risk based methodology is a procedure widely used in many areas of industry, also in marine technology, supporting decision making process in particular in situations of uncertainty. In off-shore industry it is used as a rule. It involves estimation of the probability of casualty. The first attempt to use probabilistic approach to damage stability requirements was made in the alternative requirements included in the IMO Resolution A.265 (IMO, 1973).

There are, however not many attempts to apply FSA methodology to stability problems. In the book edited by Papanikolaou (2009) methods, tools and applications of risk-based methodology in ship design are thoroughly discussed. However on the subject of intact stability only brief chapter is included covering probabilistic approach to rolling and parametric resonance. Author in several papers advocated application of risk methodology to intact stability requirements discussing difficulties and advantages of the proposed procedure, e.g. Kobylinski (2005). Briefly FSA method was used to investigate casualty of a small Dutch container ship DONGEDIJK (ter Bekke et al 2006). Also risk approach was used in analysing of cargo shift in rough seas (Ericson et al 1977). Papers by McTaggart and de Kat (2000) and also by Schauer et al. (1995), have to be mentioned in this context.

The basic dichotomy in the conception of safety requirements appears between prescriptive criteria and risk analysis. The main shortcomings of prescriptive criteria is that they 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. Usually they were amended after serious casualties occur. The risk involved and the level of safety with the application of prescriptive regulations is not known.

At the opposite to the prescriptive regulations there is risk-based approach. In the risk based approach the regulations specify objectives to be reached that is safe performance of an object. Risk based approach could be described as a goal oriented approach utilizing usually probabilistic calculations. It gives free hand to designers to develop new solutions, it actually allows taking optimal solutions from the point of view of economy and risk to the public and to the environment. Risk estimated may be accepted or not, taking into account established criteria.

The essential element of the risk analysis is assessment of risk involved in realization of a particular object with the view to support decision. Risk according to the definition is equal to product of probability of failure (P) and its consequences (C):

$$\mathbf{R = P \times C}$$

IMO recommends to use in the risk assessment the logarithmic scale in the form:

$$\mathbf{Log\ R = \log(P) + \log(C)}$$

This formulation is more easy to apply and to construct a risk matrix where for probabilities (frequencies) of failure ranking is adopted from FI = 1 (extremely rare) to FI = 7 (frequent) and for consequences ranking is adopted from SI = 1 (negligible) to SI = 4 (catastrophic) with associated probabilities.

Risk analysis includes the following steps:

1. Identification of hazards
2. Risk assessment
3. Risk control options
4. Cost-benefit assessment
5. Recommendations for decision making

Risk analysis is at present a well-established procedure used as a rule, when planning sophisticated systems. IMO recognized the advantages of using risk-based approach as an alternative to the prescriptive criteria in different areas of ship safety and ultimately the Marine Safety Committee of IMO recommended this approach as Formal Safety Assessment (FSA). IMO adopted several recommendations advising application of risk-based approach in the rule – making process. The main steps in promoting application of risk analysis are as follows:

- 1995 UK proposal on application of FSA (Formal Safety Assessment
- 1997 Interim Guidelines on FSA
- 2002 FSA Guidelines, version 1
- 2007 FSA Guidelines, version 2

Risk analysis, is direct methodology, but complex and time consuming. It requires organization of the team of experts that at several sessions will consider all aspects involved, estimate risk and possible consequences and finally will advise decision makers and all stakeholders accordingly.

Obviously this methodology is not suitable to routine cases but in case of planning construction of a large cruise vessel, for example carrying 6000 passengers it would be fully appropriate.

5. CONCLUSIONS

Adoption of recommended international stability criteria by resolutions A.167(ES,IV) and A.168(ES.IV) in the year 1968 and later on weather criterion by resolution A.562(14) in the year 1985 resulted in a drastic reduction of stability casualties. Replacement of these resolutions by the international code on intact stability, the part A of which was made compulsory in the year 2010, should be considered as an important step towards assurance of safety of ships with respect of stability. However existing stability criteria not are not always applicable to certain types of ships, in particular to ships of novel or unusual design features. For those ships alternative methods of assuring sufficient stability are required. To solve this problem, first of all proper clauses should be included in IMO instruments and secondly, suitable methods for the use of alternative criteria should be recommended. Holistic and goal oriented method including risk analysis would possibly be the best methodology for this purpose.

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