APPRAISAL OF RISK ASSESSMENT APPROACH TO STABILITY OF SHIPS

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SUMMARY

The paper presents advantages and disadvantages of the prescriptive and risk-based approach to safety of ships against capsizing. The present situation with regard to the international (IMO) stability requirements including short-term and long-term approach is discussed. It is not clear yet what approach should be adopted in development stability requirements in the long term. Currently, within the “long term “ project, the idea of development of “performance-oriented criteria”, that still will be of prescriptive nature, have been advanced. The definition of the performance-oriented criteria is not clear, however. In the paper an attempt is made to clarify different conceptions, such as prescriptive criteria, performance oriented criteria and risk-based approach. In the opinion of the author, those conceptions should be clarified before proceeding further in development stability requirements. Furthermore, the paper proposes to split the long term project that, according to the deadline set up by IMO should not last longer than three to four years, in two parts: “long-short-term” project (lasting three to four years) and “long-long-term” project extending beyond that date.
Within the first project some performance-oriented criteria could be developed that still will be of prescriptive nature, whether within the second one risk-based approach should be developed. Risk-based approach is the modern approach to safety, is recommended by IMO in MSC/Circ. 1023 and is widely used in many fields of technology. The advantages of adopting this approach but also difficulties that may arise in its application are discussed and some hints on how to approach this difficult problem are given.

1. STABILITY REQUIREMENTS– STATE-OF-ART

The first international intact stability requirements comprising limiting values of stability parameters were adopted by the International Maritime Organisation (IMO) in 1968 by resolutions A.167(VII) (passenger and cargo vessels) and A.168(VII) (for fishing vessels). They were followed by requirements for some other types of ships and by inclusion of weather criterion. Ultimately in 1993 by resolution A.749(18) Intact Stability Code (IS Code) was adopted comprising existing at that time intact stability requirements for all types of ships.

Experience with application of the criteria included in the IS Code to conventional ships constructed recently shows that they are reasonably safe. This may be considered as a paradigm, but in spite of it, the need to revise or supplement the existing criteria is obvious. The criteria were developed between forty or thirty years ago and were tested against the population of ships in service at that time. The criteria were based on statistics and on experience, and the way in which they were developed and the analysis of their application showed that there were a certain percentage of ships that capsized in spite of satisfying the criteria. Therefore, at the IMO forum it was stressed that the criteria did not present the final solution and work on their improvement should be continued. In this context at that time at IMO several proposals to develop so-called “rational” criteria were advanced.

During the discussion, the delegation of Poland to IMO [IMO, 1978] submitted the proposal to perform systematic calculations of probability of capsizing of a population of vessels in rough seas and basing on the results achieved, to perform regression analysis in order to develop new stability criteria. The regression formula could include several stability parameters. This proposal was never followed because at that time, adequate tools for calculation of the probability of capsizing were not available and the amount of work was considered unmanageable.

Recently, some accidents where parametric resonance, loss of stability in wave crest and other effects were the main cause of capsizing, caused that the idea of developing "rational" stability criteria came back to life again. Few examples of such accidents are referred to in [Kobylinski 2004]. In addition, casualty of the postpanamax C11 containership [France et al 2001] where parametric resonance in head seas was discovered contributed to this decision. Francescutto (1992) claims that ships in many cases are unsafe and gives several reasons why it is so. Bearing that in mind, the SLF Sub-Committee decided that the IS Code has to be revised. It was agreed that the revision should consist of two stages:

Stage 1: Short- term approach. Within short-term approach, the Code should be divided in two parts. Part one should include basic requirements that have to be made mandatory by inclusion or by reference to SOLAS Convention. Part two should remain as the recommendation and will include all other requirements and guidelines of the existing Code. Moreover, all the existing stability requirements included in the IS Code have to be reviewed and amended if necessary in the view of experience gained since their adoption.

Stage 2: Long-term approach. Within long term approach entirely new "physics based performance-oriented "criteria have to be developed. Following the initiative of Germany [IMO, 2003], the SLF subcommittee of IMO included in its work programme development of such criteria under heading "performance oriented criteria". The discussion is now under way how to approach this difficult problem. One of the basic questions to be solved is to define more clearly the meaning of "physics based performance criteria" because different experts understand this term differently.

The target date for completion if the revision of the IS Code was fixed to 2007.

2. PRESCRIPTIVE VERSUS RISK-BASED APPROACH

The basic dichotomy in the conception of safety requirements consists of prescriptive approach and risk-based approach.

Traditional regulations were of prescriptive nature and usually were based on deterministic calculations. They are formulated in the way where a ship dimension or other characteristic (e.g. metacentric height) must be greater (or smaller) than certain prescribed quantity. Prescriptive regulations could be developed on the basis of experience (experts opinions) statistics, analytical methods, computer simulation, model tests and full-scale trials. Deterministic or probabilistic calculations may be employed when developing the criteria, although, as a rule, deterministic approach is used in most cases.

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. Usually they were amended after serious casualties happened. The risk involved with the application of prescriptive regulations is not known.

At the opposite of the prescriptive regulations, there is risk-based approach. In the risk-based approach, the regulations specify objectives to be reached, which are safe performance of an object. Risk-based approach could be described as a goal-oriented performance based approach utilizing, as a rule, probabilistic calculations. However, it is possible to imagine risk-based approach utilizing deterministic calculations as well. The same tools could be used as when developing prescriptive regulations.

The prescriptive criteria could be supplemented by the substitution rules allowing application of alternative measures. If the formulation of this provision (rather often used in IMO instruments) is such, that the objectives are specified, it opens the way

to application of the risk-based approach [Chantelave 2005].
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.
All existing stability regulations are of the prescriptive nature. At present, however, the need to apply risk-based approach is recognized. The Marine Safety Committee of IMO recommended this approach as Formal Safety Assessment (FSA) in MSC/Circ. 1023 [IMO 2002]. Risk-based approach is widely used in many fields of technology.
The schematic representation of the above classification is shown in fig.1.

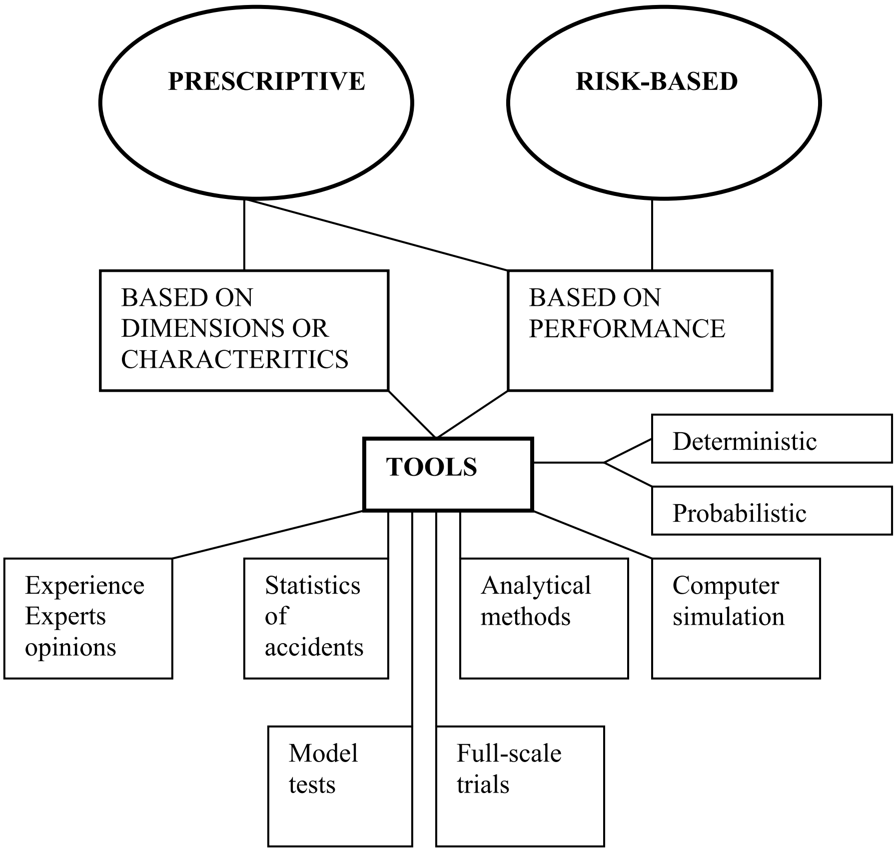

Fig.1. Schematic presentation of various approaches to stability requirements

3. CRITICAL VIEWS ON THE EXISTING REQUIREMENTS

The existing stability criteria are of prescriptive nature and after they had been adopted, they were strongly criticised. These critical views are now enhanced. Statistical criteria were based on data for ships capsized and on those operated safely during the period 1930-1960. The type of those vessels differs from the type of ships operated recently. The data on stability characteristics of ships that capsized in many cases were inaccurate and the circumstances of casualty vague. In general, the population of vessels of each category that capsized was rather small.
Weather criterion was based on rather very simplified physical model of the behaviour of a ship rolling in beam seas including wind heeling moment. Only one situation, where vessel is exposed broadside to the wind and waves was taken into account. The value of wind pressure was adopted in such a way, that the resulting critical KG value would

correspond to average KG values of the population of vessels existing at the time of development of the criterion considered safe in operation.

The existing criteria do not take into account several important capsizing scenarios. Effect of reduced stability on the wave crest, effect of parametric resonance in following and head seas, effect of water trapped on deck and pseudostatic angle of heel, and also some other effects are not taken into consideration.

During the subsequent amendments and in preparation of the IS Code only minor changes were introduced into the original criteria that virtually remained the same.

4. PERFORMANCE ORIENTED CRITERIA

At present, the discussion is going on how to approach the second part of the revision of the IS Code: the long-term task. The long-term task as currently formulated, should be completed by 2007. The long-term task, as agreed by the SLF Sub-Committee should comprise development of the "performance oriented criteria".

Within this task at subsequent sessions of the Sub-Committee and at several meeting of the IS Working Group proposals were tabled to amend the weather criterion by adoption more accurate physical model of the performance of the ship in wind and waves [Bertaglia et al. (2003) Francescutto (2003) Bloome & Krueger (2003)]. Other proposals comprise consideration of loss of stability on wave crest and parametric resonance [Hihrichs & Krueger, 2004] and some other factors. The above are only few exemplary references; the number of papers tabled at meetings of the working group was large.

In essence these proposal have merit with the view of modern ship types, large cruise liners, large container vessels, car carriers etc. In particular, the application of the existing weather criterion that was developed some forty years ago to those ships may be inappropriate.

All the above proposals were table under the heading "performance oriented criteria" or "dynamic criteria". It seems, however, that this might be misleading. First, the present criteria, statistical or weather criterion includes dynamical phenomena: dynamic stability and dynamic wind heeling moment. So calling new criteria as "dynamic" as opposed to existing criteria would be incorrect. Moreover, weather criterion is performance oriented, because it results in assessing performance of a ship situated broadside to wind and waves. It is true, that only one capsizing scenario was considered and the mathematical model used is rather simplified, but all other available models, although more accurate, are also simplified.

All the above-mentioned new proposals fall into the category of prescriptive rules, because their ultimate result will be checking whether the ship parameters satisfy certain prescribed quantities.

They are "performance oriented", but not necessarily "risk-based". To the recognition of the author, the above two expressions are often mixed and different people understand those expressions differently. Therefore, in order to avoid any misunderstanding, there is urgent necessity to define clearly what is understood under different expressions, in particular under often used expression: "performance oriented criteria".

The definition of the performance-oriented approach was proposed by Turan & Tuzcu (2003). The author proposes slightly different definition, preserving, however, the basic idea:

> *"The performance based approach is the approach where the behavior of vessel is analyzed in a set of environmental and operational scenarios taken as realistically as possible on the basis of her performance in terms of safety against capsizing. The performance-oriented criteria should be based on calculations or measurements of performance of the vessel in deterministic or probabilistic terms in the analysed scenarios. The following methods could be used in order to develop criteria:*
>
> - *numerical simulation*
> - *analytical methods*
> - *model experiments*
> - *full scale trials"*

If this definition would be adopted, it would mean that all proposals tabled already to amend or supplement the existing criteria fall into category of performance-oriented criteria. They will not necessary, however, fall into the category risk-based approach.

5. RISK BASED APPROACH TO SAFETY AGAINST CAPSIZING.

Risk–based approach is an approach where the objectives are specified, in this case the safety against capsizing. The measure of safety is risk involved. Safety is assessed in probabilistic terms, because risk is probabilistic quantity. As a rule, calculations should be in probabilistic terms, however, one can imagine calculations in deterministic terms also. Performance oriented approach should be used as a rule.

Recommendations by IMO Marine Safety Committee and Marine Environment Protection Committee [IMO 2002] specified general procedures that should be applied when using the risk-based approach. This specification comprises Formal Safety Assessment methodology (FSA). There is also more specific guidance issued by the American Bureau of Shipping on this matter [ABS 2000]. This matter is not discussed here; the author in several papers considered possibilities to apply FSA methodology to safety against capsizing. Few of them are referred to here [Kobylinski 1993, 2004]. In addition, other publications must be referred to in this context [Vassalos 2002, Spouge 1996]. Some attempts to apply FSA methodology to stability are also known [Erickson et al 1997, Alman et al 1999, McTaggard et al 2000]. All these studies indicate that application of FSA is a complicated process requiring engagement of a team of experts and it is not practical to require SA in the design process of conventional and smaller ships, although it could be required for a fleet of ships. It is clear that development of risk-based stability rules including necessary detailed guidelines for application of FSA requires installation of a comprehensive research programme and much more studies to be performed. This must take much longer than prescribed 3 years.

On the other hand, there are obvious advantages of application this methodology. It provides the designer the possibility to employ non-conventional realizations and it safeguards the safety of a ship against capsizing showing the risk involved and the measures to reduce risk if deemed necessary. This is also a tool to optimisation of the design process geared to "design for safety", and "design for economy" as claimed by Vassalos [1999].

6. RISK-BASED APPROACH – PRACTICAL SOLUTION

Bearing in mind advantages and disadvantages of the risk based approach and the present situation with regard to the revision of the IS Code the following compromise solution could be proposed.

1. The short-term revision of the IS Code should const of splitting the existing Code in two parts: Part A - mandatory requirements and Part B - recommendatory requirements, with addition of Part C – explanatory notes and Annexes. This task has been almost completed and further discussion on this item is not necessary.
2. Within the long-term (lasting 3 years) as agreed at present, the most urgent tasks should consist of the review of weather criterion, and of the problem of parametric resonance and loss of stability on wave crest. Perhaps criteria for some additional ship types (ocean-going tugs, sailing ships etc) should also be developed. The criteria would be of prescriptive nature and performance oriented, based on deterministic or probabilistic calculations.
3. An additional long-long-term task should be installed (lasting 5-7 years) consisting of development of risk-based requirements supplemented by

detailed guidance on application of SA methodology to stability. Risk-based requirements possibly should be brought into practice by including the provision allowing administrations to apply alternative requirements assuring safety against capsizing.

4. In order to open the way for the development of risk-based requirements the provision allowing administrations to apply alternative goal-oriented approach could be included in the IS Code.

According to the opinion of the author, the proposed solution has two advantages: first of all it does not prohibit development of additional urgently needed criteria covering the phenomena not covered in the present IS Code, and secondly, it opens the way for the development of the modern risk-based approach, recommended by the IMO and widely used in other fields of technology.

7. RISK-BASED APPROACH – PROBLEMS TO BE SOLVED

Risk-based requirements have to be formulated in the form of recommended procedure of safety assessment in a similar way as FSA procedure recommended by the MSC Committee of IMO, but with special reference to safety against capsizing. This is not an easy task and it would require solving of several problems. Probably the requirements might be in the form of a set of recommendations related to different steps of the procedure. The author partially has discussed this on other occasions [Kobylinski 2002, 2003, 2003a, 2004] and the discussion is not repeated here. The following recommendations should possibly be developed:

- Recommendation concerning hazards identification (operational profile of the ship in question, possible scenarios of capsizing, methods of assessment of probability of capsizing in different scenarios etc.)
- Recommendation concerning environmental conditions to be assumed for the ship in question
- Tools to be used to calculate probabilities of capsizing (e.g. computer simulation)
- Recommendation concerning methods of assessment of hazard consequences (e.g. problems of evaluation of cost of loss of life)
- Recommendation concerning methods of risk control (design measures, operational measures)
- Recommendation concerning methods of risk acceptance

The above list might be incomplete and should be supplemented during the future discussion.

Certainly, it would be not practical to require the application of such complicated procedure to the majority of conventional ships. Such procedure could be applied to ships of novel type and in all such cases where the application of prescriptive criteria may be impractical or may cause that the ship considered would be deemed unsafe.

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