CURRENT PROBLEMS IN SHIP INTACT STABILITY AND ACTIVITY FROM JASNAOE SCAPE COMMITTEE
- FINAL REPORT OF SCAPE COMMITTEE (PART 1) -

Naoya UMEDA
Department of Naval Architecture and Ocean Engineering, Osaka University, JAPAN

ABSTRACT

This paper reviews current problems in intact stability criteria, including the development of new generation intact stability criteria at the IMO (International Maritime Organization), the activities of the ITTC(International Towing Tank Conference) 's Specialist Committee on Stability in Waves (SiW) and relevant international researches as the backgrounds of the SCAPE Committee (Strategic Research Committee on Estimation Methods of Capsizing Risk for the IMO New Generation Stability Criteria) in the JASNAOE (Japan Society of Naval Architects and Ocean Engineers). Then the achievements of the SCAPE Committee are overviewed. Based on them, the SCAPE Committee is ready to submit a proposal on the new generation intact stability criteria to the IMO via the RINA (The Royal Institution of Naval Architects) as a NGO representing the learned societies.

KEY WORDS: Performance-Based Criteria, SCAPE, Intact Stability Code, Dead Ship Condition, Parametric Rolling, Broaching.

INTRODUCTION

Intact stability, an ability not to capsize without damage of enclosed buoyant space, is one of the most fundamental requirements for ship design and operation. Stability criteria of intact stability are enforced by each administration: in Japan the ship stability standard came into force in 1957 and since then no accident due to the lack of intact stability has been reported for passenger ships built with this standard. Based on this remarkable achievement, the weather criterion, as a part of the standard, was adopted by the IMO in 1985 as a recommendation to the member states. Until now, the intact stability criteria are not mandatory at least at the level of the IMO.

Recently opinions looking for mandatory intact stability criteria to be internationally applied, which would be comparable of mandatory damage stability criteria in the SOLAS (Safety of Life at Sea) Convention, form the majority at the IMO. This is partly because latest large cruise ships and RoPax ferries have high beam-draught ratios so that the IMO weather criterion could be excessively stringent and partly because mega containerships occasionally suffer parametric rolling resulting in container damage. Thus it is expected to develop rational and mandatory criteria in place of the current recommendatory ones for ensuring internationally consistent safety level against capsizing or cargo damage. Responding to this situation, the SLF (Sub-Committee on Stability, Load Lines and on Fishing Vessel Safety) had five sessions to discuss this matter and then in October 2007 the MSC (Maritime Safety Committee) approved the 2008 IS (Intact Stability) Code, a part of which is to be used as a mandatory one from 1 July 2010. The contents of this code, however, are almost the same as the current recommendatory requirements, which are mainly based on empirical backgrounds. On the other hand, the 2008 IS Code states that rational criteria for dynamic stability phenomena in waves should be developed in the near future. Therefore, the IMO started to develop performance-based intact stability criteria and its target date is 2010. This is because the majority of the IMO understands prescriptive criteria are insufficient to prevent capsizing due to such dynamic stability phenomena and performance-based approach allowing the use of latest research in ship dynamics shall be introduced. As a result, stability research is now highlighted to respond to this strong demand from the regulatory bodies.

Responding to such demand from the IMO, the JASNAOE established a strategic research committee, which is named as "Strategic Research Committee on Estimation Methods of Capsizing Risk for the IMO New Generation Stability Criteria" (SCAPE) in June 2005. Eighteen stability experts from research institutes, universities and industry take part in the SCAPE committee, and intensively execute researches for this purpose for two years. Its outcomes had been reported at five organized sessions during the spring and autumn meetings of the JASNAOE under the title of "Intact Stability Assessment towards the IMO New Generation Criteria" for members of the JASNAOE mainly in Japanese. On this opportunity, this paper attempts to overview activities of the SCAPE committee as well as current problems of the IMO and to present recommendation to be published for the IMO via the Royal Institution of Naval Architects (RINA) as a NGO representing the learned societies in the world.

RELEVANT ACTIVITIES AT THE IMO ETC

Stability Criteria of the IMO had been separately recommended such as the GZ curve criteria (resolution A. 167(ES.IV)) and the weather criterion (resolution. A. 562(14)) and were assembled into a single document as the "Code on Intact Stability for All Types of Ships Covered by IMO Instruments (IS Code)", the resolution A. 749(18), in 1993. The sub-chapters 3.1 and 3.2 of the Code correspond to the GZ curve criteria and the weather criterion, respectively. In 1998, further refinements were made as the resolution MSC.75, which enables the Code to be consistent with the Torremolinos Convention on Fishing Vessel Safety and so on. On the other hand, since the UR L2 of the IACS requests to comply with the sub-chapters 3.1 and 3.2 of the Code, these are *mandatory* for obtaining the IACS class certificates.

As explained earlier, the IMO started to consider the comprehensive revision of the IS Code at the SLF45 in 2002. Its working group was established under the chairmanship of Prof. A. Francescutto. This is because Germany (2002) and Italy (2002) stated that the weather criteria could be an excessive design constraint for Ro-Pax ferries and large passenger ships, respectively. And the United States (2002) reported that a post-Panamax containership complying with the IS Code suffered cargo damage due to parametric rolling in head waves. Then Germany, Denmark and Australia proposed to replace the weather criterion with performance-based criteria allowing the use of model experiments and numerical simulation. Italy proposed to modify the empirical coefficients in the weather criterion. Japan expressed its view that weather criterion has a role to ensure current safety levels of conventional ships so that it should be kept but no support to this view existed at the moment.

Considering the above situation, at the informal correspondence group meeting in March 2003, Japan (2003A) presented the calculated results for capsizing probabilities of 75 conventional ships marginally complying with the IS Code, and stated that safety level of conventional ships should be kept. Japan explained that this is because medium-sized passenger ships occasionally suffer dead ship conditions, which result in beam wind and wave condition without forward velocities, due to freak-wave-induced damage to their wheel houses and current weather criterion well ensures stability under such circumstances. Then Japan concluded that preventing capsizing under such dead ship condition has been well realised by the IMO with its weather criterion and is one of fundamental roles for the IMO in the future. This statement obtained the unanimous support from the participants. Then the IMO agreed that a stability criterion for dead ship condition is indispensable so that the revision of the weather criterion emerged as a high priority issue at the IMO.

At the SLF 46 held in September 2003, Japan (2003B) presented the systematically executed sample calculations with proposals from various delegations. Based on this result, Japan, together with Italy, proposed to allow the use of model experiments for wind-heeling lever and roll back angle in the weather criterion. As a result, the SLF sub-committee agreed with this proposal and requested Japan and Italy to draft the revised weather criterion with model test guidelines.

At the SLF47 in 2004, Italy and Japan (2004) jointly submitted the draft revision of weather criterion: the draft model test guidelines on wind heeling lever and roll back angle were developed by National Maritime Research Institute and Osaka University, respectively. Italy also developed the draft on roll back angle with the experience of Trieste University. Then the SLF decided to continue to further consider the model test guidelines.

At the SLF48 in 2005, by harmonising Japanese and Italian drafts, the interim model test guidelines were finalised. As a result, the draft revision of the weather criterion allowing the use of model tests was agreed at the SLF. With the urgent need of this alternative route, this revision was adopted as a separate instrument, i.e, MSC.1/Circ. 1200, in May 2006.

In parallel to the revision of the weather criterion, a draft of restructuring the IS Code was developed and was tabled by the intersessional correspondence group coordinated by Mr. C. Mains at the SLF49 in 2006. It consists of three parts: Part A includes the GZ curve criterion and the weather criterion as mandatory requirements, Part B collects recommendatory criteria such as criteria for fishing vessels and containerships and Part C is the explanatory note of the Code. Responding to this draft, France, Norway and Greece expressed their concern that the criterion for the maximum stability angle is too stringent for ships having large beam-draft ratio such as RoPax ferries and large passenger ships. Thus, the restructured draft was not finalized at that session.

To overcome this difficulty, at the SLF50 in May 2007, Italy, Japan and China proposed to use the Offshore Supply Vessel Code, multihull criteria in the High Speed Craft Code and the pontoon criteria, respectively, as alternatives to the maximum stability angle criterion. All these proposals intend to relax the requirement for the maximum stability angle but with more stringent requirements for the area of righting arm curve up to smaller roll angle. Since these are empirical criteria, it is very difficult to rationally revise them. Thus, the alternative use of the Offshore Supply Vessel Code was selected among the three because the USA reported its successful experience in their domestic standards. Then the draft revision of the IS Code was finalised at the SLF together with the draft revision of the SOLAS convention and LL convention for making the part A of the Code mandatory. Then it was approved, as the 2008 IS Code, by the MSC in October 2007.

Other than the above short-term revision of the IS Code, the consideration of the performance-based criteria as the long-term revision of the Code became serious since 2005 (Germany, 2005). First, three dangerous modes to be dealt are selected: 1) stability variation problems such as parametric rolling, 2) stability under dead ship condition and 3) manoeuvring-related problems such as broaching-to. These are clearly noted in the Part A of the 2008 IS Code.

For each mode, a single splinter group was established: Ms. H. Cramer was nominated as the coordinator of the group for 1) and Dr. N. Umeda was nominated as the coordinators of groups 2) and 3). Responding to this situation, Japan (2006A, 2006B, 2006C) reviewed the numerical simulation methodologies on these three modes and proposed a way to use them as alternatives to the existing prescriptive criteria. First, numerical prediction on parametric rolling well agrees with the model experiments in regular waves but not so well in irregular waves. Second, a piece-wise linear approach seems to be promising for quantifying capsizing probability under dead ship condition. Third, a bifurcation theory can efficiently predict thresholds of surf-riding, which is a prerequisite of broaching, in regular following waves. Germany (2006) systematically conducted numerical simulation in irregular waves for many ships and then proposed a new empirical criterion for the stability variation problem. Italy (2005) proposed a calculation method of capsizing probability based on a linearization procedure that takes into account the presence of a critical rolling angle and, in a simplified way, nonlinearities of restoring moment.

Based on the above proposals and the relevant discussion, at the SLF50 in 2007, Japan, the Netherlands and the USA (2007) jointly submitted a document describing the framework for developing the new generation intact stability criteria. Here the new generation criteria are expected to be applied to unconventional ships, not to be new empirical criteria and to be supplemented with ship-specific operational guidance. A ship is firstly judged by vulnerability criteria, which are easily used but are based on physics, and, only if she fails to comply with it, she is categorised as unconventional and then direct stability assessment utilising numerical simulation or the equivalent means should be applied. Germany (2007) updated the proposal of a new empirical criterion for all ships and proposed not to use ship-specific operational guidance. As a result of discussion, significant majority of the working group supported the proposal from Japan, the Netherlands and the USA. Therefore, the IMO will develop new generation intact stability criteria based on the framework agreed at the SLF50 with the new target date of the year 2010.

Outside the IMO, the European Commission runs its FP6 project named SAFEDOR, coordinated by Dr. P. Sames. Here, for realising risk-based approach, ship safety including intact stability, damage stability and fire protection is systematically investigated by several research organisations and universities in Europe. Its ultimate goal is set to export its results to regulations. For intact stability, Jensen (2007) applies the First Order Reliability Method (FORM) to the out-crossing problem of parametric rolling and Themelis and Spyrou (2007) attempts to evaluate probabilities of dangerous wave condition by combining deterministic analyses on nonlinear ship motion with probabilistic analyses on Gaussian waves.

As a world-wide independent association of research organisations on ship hydrodynamics, the ITTC established a specialist committee on stability in waves since 1996. It was chaired firstly by Prof. D. Vassalos, then by Dr. J.O. de Kat and is currently chaired by Dr. N. Umeda. This committee developed and is updating the recommended procedure of model tests on intact stability and executed benchmark testing of numerical codes on intact stability, covering parametric rolling and broaching, by utilising the capsizing model experiments in Japan. (The Specialist Committee on Prediction of Extreme Ship Motions and Capsizing, 2002; The Specialist Committee on Stability in Waves, 2005) These standardisation efforts will be crucial for implementation of the new generation intact stability criteria.

ESTABLISHMENT OF SCAPE ACTIVITIES

In 2005, three learned societies in Japan were merged into a new society named the Japan Society of Naval Architects and Ocean Engineers (JASNAOE). Under the chairmanship of Prof. S. Naito, the JASNAOE decided to have research committees for specified topics and specified terms. The SCAPE committee is one of the research committees that the JASNAOE established in 2005. The purpose of this committee is to contribute to the consideration of new generation intact stability criteria from researchers' viewpoint. It could help the activities of the Stability Project of Japan Ship Technology Research Association, which discusses under the chairmanship of Dr. N. Umeda the response of the Japanese delegation to the SLF sub-committee. The SCAPE committee plans to contribute not only to the documents from the Japanese delegation but also to the documents from the RINA, which representing the learned societies on naval architecture in the world, via the JASNAOE. In addition, the SCAPE committee is expected to support the activities of the SiW committee of the ITTC. The committee was established with members from universities, research institutes and industries as listed in Table 1 and is requested to complete its task by 31 March 2008. The budget of this committee was supplied by the Japan Society of Promotion of Science, based on the application of group members, as well as the JASNAOE.

Table 1 Membership list of the SCAPE committee

G. Bulian	Osaka University	till Feb. 2007
T. Fujiwara	Osaka Prefecture University	from Dec. 2007
H. Hashimoto	Osaka University	Secretary
M. Hori	Osaka University	till Mar. 2006
Y. Ikeda	Osaka Prefecture University	
T. Iseki	Tokyo Maritime University	
S. Ishida	National Maritime Research Institute	
T. Katayama	Osaka Prefecture University	
N. Kogiso	Osaka Prefecture University	from Nov. 2007
A. Maki	Osaka University	from Nov. 2007
A. Matsuda	National Research Institute of Fisheries Engineering	
T. Momoki	National Research Institute of Fisheries Engineering	from May 2006
A. Munif	Osaka Prefecture University	till Feb. 2006
Y. Ogawa	National Maritime Research Institute	
D. Paroka	Osaka University	till Mar. 2007
H. Taguchi	National Maritime Research Institute	
N. Toki	Mitsubishi Heavy Industries	
N. Umeda	Osaka University	Chairman

OUTCOMES FROM THE ACTIVITIES OF SCAPE COMMITTEE

The SCAPE committee published 43 conference papers at the spring and autumn meetings of the JASNAOE and many papers in the refereed journals and international conferences. Based on these, the outcomes from the SCAPE committee are overviewed. More details can be found in companion reports of this report for individual topics.

For parametric rolling, free-running model experiments of a post-Panamax containership in head and bow waves in the seakeeping and manoeuvring basins of National Research Institute of Fisheries Engineering and National Maritime Research Institute and observed parametric rolling with the roll angle exceeding 20 degrees. It was found that maximum roll angles are almost the same among regular waves, long-crested irregular waves and short-crested irregular waves. Regarding the restoring variation due to waves as the cause of parametric rolling, the prediction of its harmonic component was attempted not only by the Froude-Krylov component on its own but also the radiation and diffraction components as well. For the mean of the restoring variation, a formula using a momentum law was developed. These results were compared with the captive model experiments and then better agreements than the existing approach were reported. Taking these aspects into account, numerical simulation of parametric rolling in head waves was executed and compared with the fore-mentioned experiments. While good agreements for the case in moderate regular waves between the calculation and the experiments were reported, some discrepancies can be found for the cases in severe regular waves and irregular waves. For investigating this reason, direct measurement of restoring variation acting on scaled models in irregular waves were executed. It was found, however, that rather acceptable agreement exists also in irregular waves. On the other hand, if we repeat many realisations in model experiments and numerical simulations in irregular waves under the same wave parameters, the scatter of the roll angles could be large. This is because parametric rolling in irregular waves can be regarded as “practically non-ergodic”. Parametric rolling appears only if the level of restoring variation exceeds a certain threshold. Thus it is neither Gaussian nor practically-ergodic. Therefore, it is extremely difficult in principle to obtain good agreement among individual realisations so that it is presumed the ensemble average should be used for this comparison. Time-Varying coefficient Vector Auto-Regresive (TVVAR) method, bispectrum analysis and trispectrum analysis were applied to parametric rolling of the post-Panamax containership in head waves for clarifying the nonlinear nature of parametric rolling. Furthermore, model experiment and numerical simulation study were carried out also for a latest PCTC, which is similar to one suffered parametric rolling in the Northern Atlantic, and its parametric rolling in regular and irregular head waves were identified (Hashimoto et al., 2008).

For stability under dead ship condition, a method for calculating capsizing probability in irregular beam wind and waves with Belenky’s piece-wise linear approach (Belenky, 1993) were intensively investigated. Here the restoring arm curve is approximated with piece-wise linear curves and then capsizing probability can be analytically calculated. Comparing this method with the Monte Carlo simulation, some discrepancies exist in extremely severe sea state. This is probably because the Poisson assumption is not appropriate for the case out-crossing probability is very high. In moderate sea state, such as the average wind velocity of 26 m/s that the weather criterion assumes, acceptable agreement within the confidence interval was found. Therefore, the committee concluded the piece-wise linear approach could be well applied and to extend the method further. First, since dead ship conditions does not directly mean beam sea condition, a method for calculating drifting velocity and attitude was developed and then capsizing probability under such condition was calculated. Second, effects of trapped water on deck, which is indispensable for fishing vessels, and effect of critical angle for down-flooding or cargo shift were taken into account in the calculation of capsizing probability. Considering these aspects, annual capsizing risk for ships having large windage areas, i.e. a PCTC, a RoPax ferry, a large passenger ship and a containership were calculated. As a result, it was remarked that shift of down-flooding point for the PCTC and avoiding severe weather for the RoPax ferry are effective measures. For purse seiners, their safety level ensured by the IMO weather criterion on its own is not always sufficient but that by the water-on-deck criterion of the Torremolinos Convention seems to be appropriate. So far, it was assumed in the calculation of long-term capsizing probability that wind is fully correlated with waves. The effect of this assumption was examined by calculating capsizing probability with a joint probability density function of the average wind velocity, the significant wave height and the mean wave period (Ogawa et al., 2008).

Moreover, it was found that significant parametric rolling occurs during model experiments of a large passenger ship without the bilge keels drifting in beam waves. The reason of this is presumed by numerical simulation and model experiments to be restoring variation due to resonant relative heave motions (Ikeda et al., 2008).

For broaching, it is important to predict the threshold of surf-riding, which is a prerequisite to broaching. In case of regular following waves, its prediction methods with an uncoupled surge model were already established. In case of regular stern quartering waves, it is essential to take coupling with manoeuvring motions into account. Therefore, a global bifurcation analysis was applied to a surge-sway-yaw-roll mathematical model with a PD auto pilot. As a result, the critical ship speed for surf-riding in stern quartering waves was obtained as a function of the auto pilot course. By investigating whether the surf-riding results in broaching or capsizing was investigated by systematic numerical simulation in regular waves, areas of rudders and stabilizing fins as well as control gains were optimised. For broaching in irregular waves, a stochastic theory for estimating broaching probability with the deterministic broaching conditions in regular waves was developed and is well validated with the Monte Carlo simulation (Umeda et al., 2008).

For preventing the above phenomena, devices were proposed and were successfully validated with model experiments. An anti-rolling tank was proved as a cost-effective risk control option for preventing container damage due to parametric rolling of a containership (Hashimoto et al., 2008). In addition, its design method with a CFD technique was developed. Wings attached to a ship above calm water surface were proposed for preventing broaching (Umeda et al., 2008).

Further, model experiments based on the interim model testing guidelines for the weather criterion were performed and the reported results enabled us to examine the usefulness of the interim guidelines including its effect on stability assessment (Ogawa et al., 2008). A model testing technique for evaluating amount of trapped water on deck in beam waves (Ogawa et al., 2008) and a model test method for measuring hydrodynamic forces acting on a ship heeled up to the deck submergence with a forward velocity (Umeda et al., 2008) were improved and results with them were reported.

As mentioned above, the outcomes from the SCAPE committee already contributed not only to research progress in ship dynamics but also to the proposals from the Japanese delegation for the IMO to some extent. Since common sense based on a linear theory faces difficulty to understand these nonlinear phenomena, an explanatory note is under development.

RECOMMENDATION FOR THE IMO NEW GENERATION CRITERIA

Based on the research outcomes from the two year-activities of the SCAPE committee, the committee would like to invite the IMO to take the following suggestions into account for developing its new generation intact stability criteria.

First, the following principles should be adopted: 1) the new performance-based criteria will be applied to unconventional ships while the conventional ships should be dealt with the existing prescriptive criteria, 2) no further empirical criterion should be developed, 3) design criteria should be supplemented with operational criteria. Although it is important to rationalise intact stability criteria, we should bear in mind the fact that most of conventional ships under the current criteria are safely operated and that the current intact stability criteria are quite reliable at least from statistical viewpoint. It is noteworthy that such sufficient safety level also does realised with appropriate operation and it is unrealistic to separate design criteria from operation ones. In the case of unconventional ships, empirical criterion is not applicable because no empirical data exists for unconventional ships. If a new criterion stays empirical, it could rather prevent a design of unconventional ships.

The vulnerability criteria, which distinguish unconventional ship from conventional ones, should be as simple as possible because they should be applied to all ships in principle. It is not so good idea to spend much effort on ships having sufficient stability, such as tankers and bulk carriers, which do not have real danger against capsizing. Pursuing this principle, a candidate of the criterion for dead ship condition could be a weather criterion with some reasonable prediction of roll damping and effective wave slope coefficient. For broaching, it could be sufficient to identify surf-riding thresholds in pure following waves as the current IMO operational guidance. For parametric rolling or pure loss of stability on wave crest, a simplified prediction formula for metacentric height on wave crest is desirable.

It might be practical to use numerical simulations for the performance-based criteria for ships which fail to pass the vulnerability criteria, because model experiment requires prohibitively large amount of cost and time as well as many testing facilities and their staff. For the dead ship condition and broaching, the methodologies developed by the SCAPE committee are available. It is desirable to obtain measured data of capsizing probability under a dead ship condition from model experiments in artificial irregular wind and waves with sufficient statistical confidence and to validate the proposed theory with them. For parametric rolling, it seems to be necessary to calculate ensemble average of many numerical realisations. The first order reliability method (FORM) may provide a way to make this procedure more efficient. (Kogiso & Murotsu, 2008) In addition, the effect of time-varying resistance increase in irregular waves may be important and its effect is now under investigation.

CONCLUDING REMARKS

Responding to the demands of research for new generation intact stability criteria at the IMO, the JASNAOE established the SCAPE committee in 2005 and the SCAPE committee has completed their term. Based on the outcomes of the research on probabilistic stability assessment methodology for parametric rolling, stability under dead ship condition and broaching, the committee provides recommendations to be submitted to the IMO via the RINA.

ACKNOWLEDGEMENTS

This work was supported by a Grant-in Aid for Scientific Research of the Japan Society for Promotion of Science (No. 18360415). The work described here was partly carried out as a research activity of Stability Project of Japan Ship Technology Research Association, funded by the Nippon Foundation. The committee SCAPE itself is run under the umbrella of the Japan Society of Naval Architects and Ocean Engineers. The author expresses his sincere gratitude to the above organisations.

REFERENCES

Belenky, 1993, “A Capsizing Probability Computation Method”, Journal of Ship Research, Vol. 37, pp. 20-207.

Germany, 2002, “Remarks Concerning the Weather Criterion”, SLF 45/6/3, IMO.

Germany, 2005, “Report of the Intersessional Correspondence Group (part 1)”, SLF48/4/1, IMO.

Germany, 2006, “Proposal of a Probabilistic Intact Stability Criterion”, SLF 49/5/2, IMO.

Germany, 2007, “Proposal on Additional Intact Stability Regulations”, SLF 50/INF.2, IMO.

Hashimoto, H. et al., 2008, “Prediction Methods for Parametric Rolling with Forward Velocity and Their Validation – Final Report of SCAPE Committee (Part

2)-", Proceedings of the 6th Osaka Colloquium on Seakeeping and Stability of Ships, (in press).

Ikeda, Y. et al., 2008, "Prediction Methods for Parametric Rolling under Drifting Condition and Their Validation – Final Report of SCAPE Committee (Part 3) –", Proceedings of the 6th Osaka Colloquium on Seakeeping and Stability of Ships, (in press).

Italy, 2002, "Weather Criterion for Large Passenger Ships", SLF 45/6/5, IMO.

Italy and Japan, 2004, "Proposal on Revision of the Weather Criterion", SLF 47/6/16, IMO.

Italy, 2005, "A Modular Methodology for the Estimation of the Ship Roll Safety under the Action of Stochastic Wind and Waves", SLF 48/4/6, IMO.

Japan, 2003A, "Examination of the Weather Criterion", SLF46/6/15, IMO.

Japan, 2003B, "Sample Calculations for the Draft Weather and Wind Criteria", SLF 46/6/16, IMO.

Japan, 2006A, "Proposal of Methodology of Direct Assessment for Stability under Dead Ship Condition", SLF 49/5/5, IMO.

Japan, 2006B, "A Methodology of Direct Assessment for Capsizing due to Broaching", SLF 49/5/6, IMO.

Japan, 2006C, "Remarks of Numerical Modelling for Parametric Rolling", SLF 49/5/7, SLF49/5/7/Corr.1, IMO.

Japan, the Netherlands and the United States, 2007, "Framework for the Development of New Generation Criteria for Intact Stability", SLF 50/4/4, IMO.

Jensen, J.J., 2007, "Efficient Estimation of Extreme Non-Linear Roll Motions Using the First-Order Reliability Method (FORM), Journal of Marine Science and Technology, Vol. 12, pp.191-202.

Kogiso, N. and Murotsu, Y., 2008, "Application of First Order Reliability Method to Ship Stability – Final Report of SCAPE Committee (Part 5) –", Proceedings of the 6th Osaka Colloquium on Seakeeping and Stability of Ships, (in press).

Ogawa, Y. et al., 2008, "Prediction Methods for Capsizing under Dead Ship Condition and Obtained Safety Level – Final Report of SCAPE Committee (Part 4) –", Proceedings of the 6th Osaka Colloquium on Seakeeping and Stability of Ships, (in press).

Themelis, N. K. and Spyrou, K.J., 2007, "Probabilistic Assessment of Ship Stability", SNAME Marine Technology Conference, Fort Lauderdale, pp.18.1-18.19.

The Specialist Committee on Prediction of Extreme Ship Motions and Capsizing (chaired by D. Vassalos), 2002, "Final Report and Recommendations to the 23rd ITTC", Proceedings of the23rd ITTC, Vol. 2, pp. 611-649.

The Specialist Committee on Stability in Waves (chaired by J.O. de Kat), 2005, "Final Report and Recommendations to the 24th ITTC", Proceedings of the24th ITTC, Vol. 2, pp. 369-408.

Umeda, N. et al., 2008, "Prediction Methods for Broaching and Their Validation – Final Report of SCAPE Committee (Part 6) –", Proceedings of the 6th Osaka Colloquium on Seakeeping and Stability of Ships, (in press).

United States, 2002, "Head-Sea Parametric Rolling and Its Influence on Container Lashing Systems", SLF 45/6/7, IMO.