WORKING TOWARDS THE DESIGN OF SAFER SHIPS AND PRAGMATIC SUPPORT FOR SAFE OPERATION

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ABSTRACT

Recent examples of (dynamic) intact stability problems and research show that the current rules and regulations – which are based on empirical criteria related to the calm water lever arm curve – do not and can not represent todays vessels sufficiently well. Thus in ship design and approval there is a strong need for new and more reliable means of assessment. At IMO-SLF the Intact Stability Code is currently under revision and there is a strong demand to include the IMO MSC/Circ. 707 also, in order to provide more appropriate guidance for ship operation.

In this paper some examples will be given how numerical motion simulations and appropriate evaluation methodologies which were and are developed within the German BMBF-funded projects Roll-S and SinSee can support

- the design and approval of safer ships
- the revision of rules and regulations and
- the compilation of general and ship specific guidance manuals.

1 INTRODUCTION

All three ship design, ship approval and ship operation determine the safety of a vessel in rough conditions. Now while designing as much seaworthiness as economically feasible into a ship from the start provides the best basis for safe operation, it alone is not enough. Experience from ship operation shows, that the safety of a vessel and its crew relies strongly on the ability of the crew to judge the vessels performance and its limits. Consequently it is necessary to improve both:

- the understanding of ship dynamics and its importance for the ship's safety in the ship design process as well as
- the support given to the crew for decision making to avoid dangerous conditions.

Furthermore internationally binding rules and regulations have to define the required minimum safety standard and should allow for a comprehensive evaluation of a ship's performance with respect to safety.

Traditionally the ship design and approval process is based on the application of empirical formulae and the past experience of the naval architects. This approach proved to be a very fast and efficient way of ship design and approval in the past, especially as other approaches were unavailable for most problems. In today's highly competitive environment ship designs change very rapidly. Especially in areas where the design process is supported by advanced design and analysis tools which are available for application worldwide today, e.g. CFDor FE-analysis used either by the yards themselves or being accessed through subsuppliers. Consequently a lot of the traditional commonly used empirical formulae, some of which are also the basis of current rules and regulations, fail to deliver reliable answers. This is one of the reasons for current examples of dynamic intact stability problems, e.g. large containerships being susceptible to parametric rolling and/or pure loss of stability, ferries and cruise ships suffering from very short roll periods and/or high accelerations and the like.

Focussing on resonance problems and especially the phenomena of parametric excitation as application example, this paper aims at showing

1. how the safety of ships regarding intact stability and seaworthiness can be significantly improved when the ship's dynamic behaviour is studied using direct calculation methods early within the ship's design process

2. practical examples, how based on the results of first principle based studies, useful and pragmatic aids for ship operation can be developed, which then can provide a sound base for decision making, i.e. to identify and avoid dangerous conditions at sea

3. how these methods for direct calculations and experience from these studies can support the IMO's Intact-Stability-Code revision process

2 OBSERVATIONS AND PROBLEMS IN SHIP DESIGN, SHIP APPROVAL AND OPERATION

2.1 Intact stability and seaworthiness in ship design and approval

Many examples have shown, that safety needs to be established as design goal and thus must be integrated into the ship design and design optimization process in order to enable competitive, cost-effective solutions. The main goal of the ship design process is to create a design solution with the largest possible performance potential regarding the demands from the owner while at the same time controlling the technical and economical risks involved from a yard point of view. In order to be successfull a designer thus needs to be able to identify potential problems and optimization potential and needs to be able to analyse the belonging underlying physics.

With respect to intact stability and seaworthiness an increasing demand for reliability and safety in rough and severe conditions can be observed. "Safety sells" - especially for passenger ships and whenever valuable or time crucial products are transported. Consequently there is an increasing need for appropriate means of safety evaluations.

As far as rules and regulations are concerned the assessment of the stability of ships –intact or damaged– is confined to the fulfilment of empirical criteria related to the static lever arm curve for still water condition only. The IMO intact stability criteria (Resolution A 749, IS-Code [10]) are prescriptive rules which were developed based on the experience with ships quite some years ago. But due to market demands ship designs change very rapidly and thus the old criteria, being based solely on the static lever arm curve for still water condition, do not and can not represent the (dynamical) physical characteristics of modern vessels sufficiently well.

Furthermore the current intact stability rules do not support the decision making process in ship design, as they deliver a fulfilled or not fulfilled only but neither a level of compliance which would be necessary to compare different solutions nor means to identify optimization potential. Also there are no established means to control the reliability and quality of the assessment which leads to problems in both ship design and approval (e.g. regarding the applicability of the formulae etc.).

Using the IMO Weather Criterion as example to illustrate these deficiencies leads to the following observations:

The current IMO Weather Criterion is based on a combination of steady wind, wave and wind gust action. Thus there are static components (heel due to steady wind) as well as dynamic components (wave and wind gust exciting a roll motion) while the assessment itself is based on the calm water lever arm curve. The ship parameters having the largest influence on the results are the windage area, the initial stability of the vessel, its natural period of roll and the vessel's roll damping.

From a designer's and an approval point of view wind and waves are both important but influenced by completely different parameters. The danger imposed on a ship due to wind depends on the windage area and wind heeling lever of the ship above the waterline and the righting potential of the ship at small heel angles, with the minimum GM case being worst. Whilst the danger imposed on a ship in beam sea resonance for example is dominated by the ship's natural period of roll and its roll damping, here the minimum GM case is not necessarily the worst case. Consequently measures taken to improve a design's stability with respect to wind action are completely different from measures taken to reduce the impact of beam sea resonance. Unfortunately applying the Weather Criterion where wind and waves are combined does not include an answer to the question whether it is a wind or a wave related problem. And in general the GM value is the only parameter which is altered to fulfill the Weather Criterion - this means no matter whether it is a wind or a roll resonance problem, the design is made stiffer.

Currently the Weather Criterion delivers a "fulfilled" or "not fulfilled" only, but no level of compliance. The stability assessment itself is based on a comparison of resulting areas below the calm water lever arm curve, but there are no requirements regarding the size of these areas. And as KG_{max} values from the damage stability assessments influence the initial stability for which the Weather Criterion is to be evaluated the resulting areas strongly vary for different ships.

Last but not least many examples (e.g. [12],[13], [14]) show, that the current formulation of the IMO Weather Criterion is inappropriate for quite a few types of ships. But while it is reasonably easy to give examples where the empirical formulations within the Weather Criterion are unsuitable, there is no obvious direct alternative which would allow an easy evaluation of the deficiencies and an improvement of the complete Weather Criterion. Francescutto intensively investigated the shortcomings of the current formulation (e.g. [7] and [8]), and it seems that it might be possible to improve the current formulation on this basis. But Francescutto's efforts also illustrate how difficult it is to use direct calculations and/or test methods alternatively. One main problem in this respect is, that within the Weather Criterion the required ship's performance is not explicitely described. The ship's performance is assessed via a set of empirical formulations which are applied and were developed as a set. It is not a sort of system were any component might be exchanged by a more appropriate one, as they become available. So just "polishing" up the coefficients is difficult and will not bring the needed break through in the long run.

A revision process of the current IS-Code was started at the 45^{th} IMO-SLF meeting. It was decided that next to some short term amendments the code should be completely revised with two major aims:

1. all new criteria shall be formulated as performance based criteria

2. alternative direct assessments via model tests and/or numerical simulations shall be possible

And all three ship design, ship approval and most importantly the ship's safety with respect to intact stability as such would clearly benefit from the realization of these intended changes.

2.2 Problems in ship operation

When leaving port it is the responsibility of the master to ensure that the loading condition is such, that the ship fulfills all applicable stability rules at any time of the voyage. The usual "interface" between ship design and approval on the one hand and operation on the other are either KG_{max} or $GM_{required}$ curves. And this "interface" has proven to be very efficient and practical.

It is well known that the weight–characteristics of the cargo are not always available with suffient reliability. Whilst this fact has a large impact on a ship's safety, it is not the topic of this paper.

Here the performance and safety of ships in severe weather conditions is to be discussed. A very efficient way to reduce the risk imposed on the ship, her crew and cargo is to avoid sailing in such conditions. Many modern weather routing systems are available and frequently used today to avoid severe conditions as far as possible. But of course a complete avoidance of dangerous conditions is not possible as navigational restraints exist, weather forecasts might be wrong plus the pressure to make the harbour in time is very high in most trades.

As already explained ship designs and thus their dynamic characterics rapidly change, e.g. barge type aftbodies are commonly built to optimize calm water resistance and cargo capacity, the bow flare is often increased to allow for additional cargo capacity, the vertical centres of gravity tend to travel upward, the characteristics of the righting lever curves change for many ship types, such that they have a large initial GM with low or no form stability at higher heeling angles, large ships tend to become even larger, etc.

The crews on board can hardly judge the consequences of these developments and it becomes increasingly difficult for them to correctly identify dangerous combinations of encounter angle and speed in rough or severe seas. One example is the susceptibility to parametric excitation of quite a few modern designs (being not only container ships, but also RoRo, RoPax, Ferry and Cruise vessels). Heading slowly into the sea in rough conditions is (or better was) considered as safe by the majority of the maritime community. Only after some of the large Container ships recently suffered from parametric excitation, loosing and/or damaging a lot of cargo [6] and/or being in the danger of capsizing this phenomena is now being addressed. But appropriate guidance on how to avoid these situation is in general not available.

Other (dynamic) problems which are frequently reported are excessive horizontal accelerations due to short roll periods and insufficient roll damping, course keeping problems in rough seas, etc.

There is a large demand for more reliable and up to date guidance than current rather general guidelines like e.g. the IMO MSC/Circ. 707 [9] can provide.

3 NUMERICAL SIMULATIONS FOR QUALITATIVE AND QUANTITATIVE ASSESSMENTS

3.1 General remarks regarding the use of numerical simulation methods in ship design and approval

In general numerical simulation methods are well established in many areas of ship design and approval today and numerical motion simulation methods are and have been frequently used to investigate ship accidents, e.g. [15] and [6]. Also numerical motion simulation methods are used in studies to provide insight into physical phenomena and for rule development, e.g. [1] and [11].

In some areas of ship design (e.g. FE-analysis, fire and evacuation) numerical simulation methods are accepted for approval purposes – usually by demonstrating equivalence with rule-based alternatives. For the assessment of a ship's intact stability the use of numerical motion simulation methods or other direct alternatives is not yet established. This is very unfortunate, especially as many examples from ship design, accident investigation, rule development, etc. show the potential direct assessments inherit.

Direct methods, like numerical motion simulation methods, can provide very valuable support during all phases of ship design. At FSG numerical motion simulations are used to evaluate the sea keeping performance of different designs in the very early design stages already – the earlier potential problems or optimization potential are identified, the more efficient (cost-benefit) solutions can be found. Based on the results from numerical simulations different phenomena are studied and based on this knowledge and understanding of the background designs are optimized.

In addition to adequate numerical tools, suitable methodologies are necessary which allow for a systematic approach to evaluate a design's performance. When intact stability and seakeeping characteristic are to be evaluated typically numerous numerical simulations have to be run to sufficiently cover the operating range and important environmental conditions.

For design optimization a qualitative ranking ("better" – "equal" – "worse") is in general sufficient to support design decisions. While of course quantitative numbers would be favourable, as only quantitative numbers allow for a real cost-benefit analysis.

For approval purposes qualitative assessments can be useful, when they provide sufficient reliability to prove equivalence to rule-based alternatives. But of course quantitative numbers are favourable in general and necessary when it comes to the evaluation of unconventional designs.

3.2 Towards quantitative assessments for ship design and approval

Within the German research project ROLL-S numerical motion simulation tools were further improved and additionally basic methodologies for qualitative comparisons were developed. [4] gives an overview and examples.

Figure 1 shows a typical example of a polar plot presenting the results from numerious simulations for different speeds (radial) and encounter angles (circumferential) in short crested seas with a significant wave length of about ship length. The colouring illustrates up to which wave height the vessel can be considered as safe according to a certain criterion (here the Blume criterion, [3]).

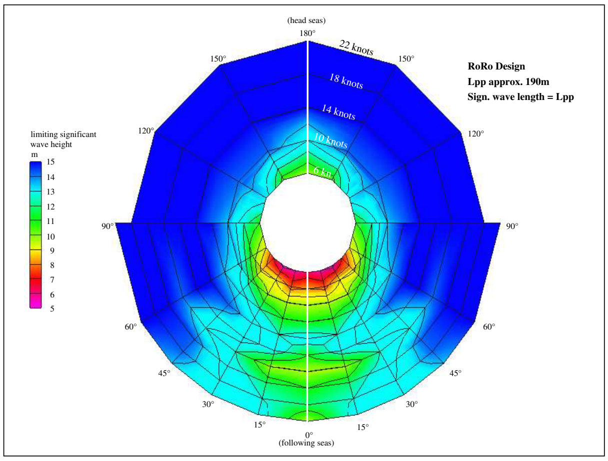

Figure 1: Example for a polar plot showing limiting significant wave heights for a RoRo-Design

These diagrams are used to identify dangerous operating conditions. In this example a region were the vessel is endangered by parametric excitation can be seen for slow speed in following seas. Furthermore these diagrams can be used to compare (visually) different load cases and/or different designs.

Individual simulations in the dangerous regions then allow to investigate the physical background causing the problem and solutions for better performance are developed on this basis. Fig. 2 and 3 show typical presentations of simulation results which are used for this purpose. Fig. 2 shows a snap-shot from an animation of the simulation results. Fig. 3 shows a plot of the angle of roll and the wave amplitude at midships for a case of parametric excitation over time.

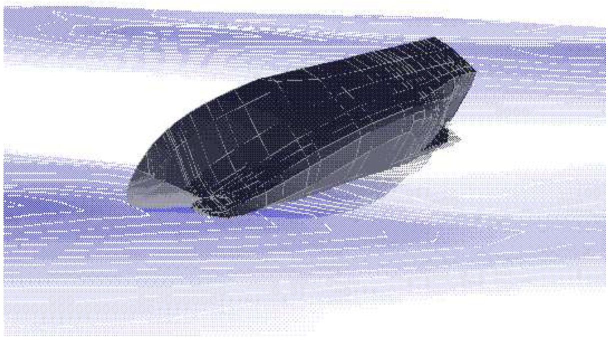

Figure 2: Snap-shot from an animation just prior to a capsize due to parametric excitation

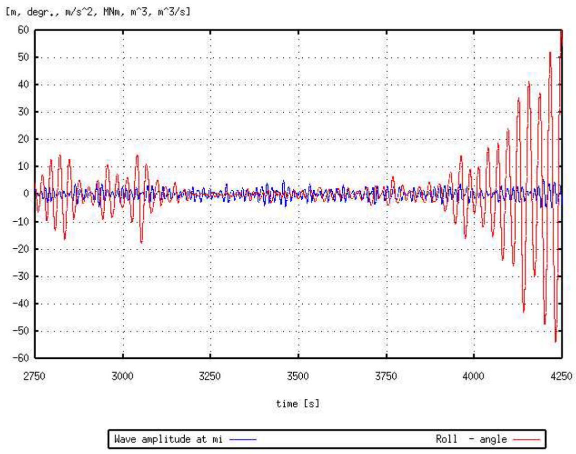

Figure 3: Example for a plot of roll angle and wave height over time in case of parametric excitation

But numerical motion simulations of ships in rough weather can not only be used for the qualitative comparison and optimization of ship designs, they can also lay the basis for the determination of an equivalent safety level. And the development and use of such methodologies is one of the main goals of the BMBF funded research project SinSee.

To do so, again many simulations are carried out covering different combinations of significant wave length and height, respectively. As governing criterion, the Blume-Criterion, a maximum significant roll angle or acceleration are used. Based on these results probabilities for each seastate scenario can be obtained by linking the calculations to certain areas of operation, e.g. the North Atlantic. If further speed and course probabilities are known or assumed, the direct calculation of capsizing probabilities is possible and gives a rational basis to compare ship designs, [2]. This is illustrated in Fig. 4, where two different designs of a 140m, 26kn RoPax ferry are analyzed.

The comparison shows the body plan of a conventional design on top, where the deplacement is concentrated more or less in the middle part. The calculations have been performed with the belonging $GM_{required}$ according to the IMO Weather criterion limit, resulting in 2.1m GM. The polar diagrams show the limiting significant wave heights according to the Blume-Criterion for the significant wave lengths of 88m, 113m, 141m, 176m, 205m, and 241m. The results show that the shorter wave lengths where critical resonances in following seas occur are the most dangerous. In these short waves the righting lever alterations between wave crest and wave trough condition are very pronounced, with the stability loss in wave crest condition being largest in waves somewhat shorter than shiplength as the immersed volume concentrates in the midship area. For the shorter wave lengths, the 1:1 and 1:2 resonances regions can clearly be identified. With increasing significant wave length the critical situations shift to head sea scenarios. In general it is found, that the design suffers from its large alterations of righting levers between wave through and wave crest situations, which thus lead to a high probability of dangerous situations.

Below, a design of a comparable ferry is shown which focused on good seakeeping behaviour on one hand as well as on fuel efficiency (safe ships can also be economical) on the other. The governing design philosophy was to minimize the through-crest alterations of the righting lever arms. Thus the hullform and deplacement distribution were designed and optimized under this respect while at the same time taking care, that the lines lead to a low calm water resistance and that a full width stern ramp can be fitted. Several hullform variations were investigated using numerical methods for both wave making in calm water and motion simulations to investigate the behavior of the design in rough conditions.

The polar plots for this design, which is also operated at the IMO Weather Criterion limit clearly shows a great improvement – the limiting wave heights are significantly larger. In our reference area North Atlantic the capsizing probability of the improved design is **151** times

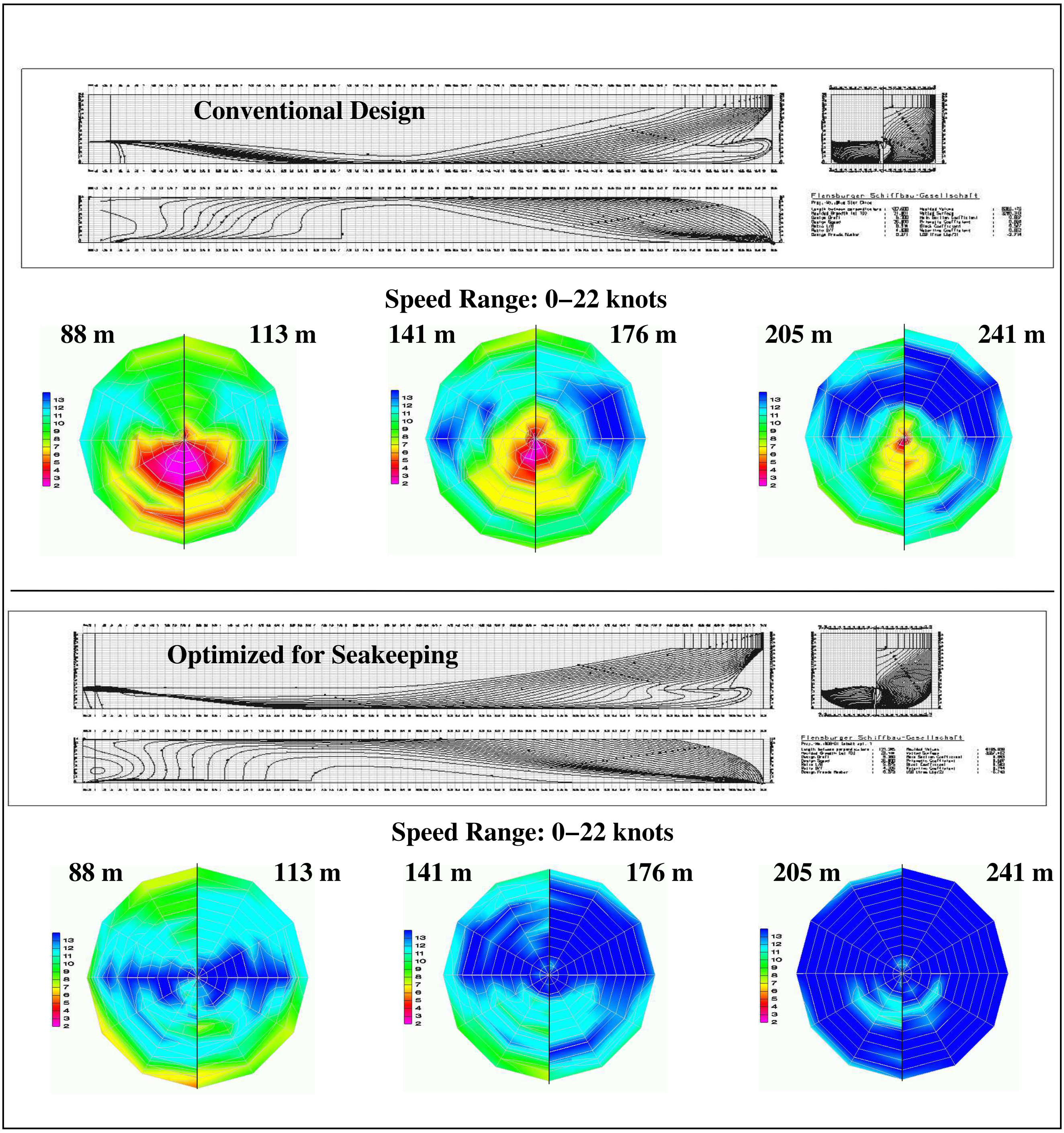

Figure 4: Comparison of two different RoPax Designs with respect to the danger of capsizing

lower, although both designs are operated at the same stability criterion. This difference might of course take other values in other operational areas, but it needs to be noted that the main contributions come from waves significantly shorter than ship length. The reason is, that these shorter waves lead to both high leverarm alterations and occurence of critical resonances within the operational speed range. Also these waves occur in typical operational areas for such kind of vessel (e.g. the Baltic or the Meditarenean Sea). So there is no doubt that the improved design is much safer and that ships with improved safety levels can also be efficient designs.

In [5] different calculation approaches are presented, ranging from methodologies where only regions of the calculation domain are covered which are assumed to be unsafe to "brute (computational) force" approaches. The results presented here (Fig. 4) correspond to a brute force approach. In order to assure that all potentially dangerous scenarios are included which can be assessed via the used numerical tool the entire calculation domain is covered.

The results in means of capsizing probabilities of this approach do, of course, depend on the basic assumptions (e.g. probability distributions and Blume Criterion) as well as the used numerical simulation tool – thus they are not absolute. But they provide a good basis for the comparison of very different and also unconventional ships.

In the long run absolute numbers are the target, as only absolute numbers allow to compare and balance risks of different design (and approval) areas, e.g. damage and intact stability.

4 DEVELOPMENT OF PRAGMATIC SUPPORT FOR SAFE OPERATION

As already mentioned above there is an increasing demand for operational guidance to support crews in their decision making when travelling in rough conditions.

4.1 General guidelines

Several national and international guidelines and handbooks exist, which aim at explaining the different phenomena that might endanger a ship in rough or severe weather conditions. These need to be updated on a frequent basis, as ship designs develop and consequently their characteristics with respect to ship dynamics change. The IMO MSC/Circ. 707 [9] is probably the most famous and currently also the most critizised guideline which aims at supporting crews to avoid dangerous conditions.

One phenomena which is generally not sufficiently treated is the parametric excitation. For a long time this was considered as a rather academical problem by the majority of the maritime community, and this is especially true for the danger of parametric excitation in head seas. Today (mainly due to respective accidents) parametric excitation is considered a relevant problem to be examined, but appropriate guidance for operation is in general still lacking.

Another observation when studying guidelines, articles and experiences from operation is, that today the "state of the art" of choosing a speed and a heading in severe conditions is to slowly head into the sea independent of the type of vessel in question. While drifting at zero speed in severe beam seas is considered as rather dangerous by many members of the maritime community. This seems surprising, as results from studies as well as experiences from earlier days of ship operation show, that for many ships the drifting at zero speed in severe beam seas condition is a very safe option.

In order to respond to the demands from ship operators and ship crews for support and guidance regarding the ship dynamics of modern ships a booklet called "Richtlinien für die Überwachung der Schiffsstabilität" was developed in a joint effort in Germany. Here phenomena like the parametric excitation, pure loss of stability, problems due to resonances in general, etc., and combined impacts are described explaining both the physical background as well as possibilities to identify and avoid potentially dangerous conditions.

The development of this booklet and first comments from ship operators on the draft version emphasize the need for such a general guidance for both: as a basis to understand the phenomena a ship might encounter in rough or severe conditions and for decision support on board. But of course, especially with respect to the latter – the decision support – there are phenomena which allow a generalization with sufficient accuracy while others will remain more difficult to judge for the crews on board. One example is the identification of dangerous speeds with respect to parametric excitation in following seas: Especially for vessels which experience a significant loss of stability in wave crest condition the roll period tends to elongate to the period of encounter over a large range of periods. Plus the changes in ship speed can be substancial in steep following seas and thus substancially change the period of encounter. For these situations it becomes very difficult to formulate general advice on how to identify the "dangerous zone of speeds".

4.2 Ship specific guidance

Based on numerical motion simulations these described gaps which are left by general guidelines can be closed. Many motion simulation programs which are able to predict parametric excitation and other phenomena leading to dangerously large angles of roll are internationally available. And based on the results comprehensive ship specific guidelines can be compiled. This also includes the chance to be proactive, as all problems which are identified via the numerical investigations can be included in the guidelines. No matter whether they are of general interest or "just" important for the design at hand.

But of course such guidelines can only be compiled on an appropriate basis – linear theory and/or studies in regular waves are not sufficient for the prediction of phenomena like stability losses, parametric excitation, etc.

And not only the ultimate safety of the ship is of interest. For many types of ships cargo safety is as important from an operational and safety point of view. As cargo shift does not only endanger the ship, but leads additionally to high economical losses for the operator. Plus cargo securing itself is time consuming and costly – thus operators have an interest to use sufficient but also efficient cargo securing.

Fig. 5 shows polar plots which are extracted from a ship performance manual of a RoRo-ship. Here the limiting criterion was not a capsize, or a large angle of roll, but the exceedance of a certain (reasonable low) value of horizontal accelerations in more than two percent of the time. Such diagrams are given for a number of significant wave length and roll periods of the ship. Here only the plots for three wave length (increasing from the top to the bottom diagram) and two roll periods are shown for comparison.

It can clearly be seen how the areas where resonance occurs shift with increasing wave length. In this case these are areas were 1:1 resonance occurs. Furthermore it can be seen, that the stiffer load case on the right hand side is more likely to encounter significant horizontal accelerations, due to the shorter period of roll. While the simulations showed, that the roll angles as such are slightly smaller for the stiffer load case.

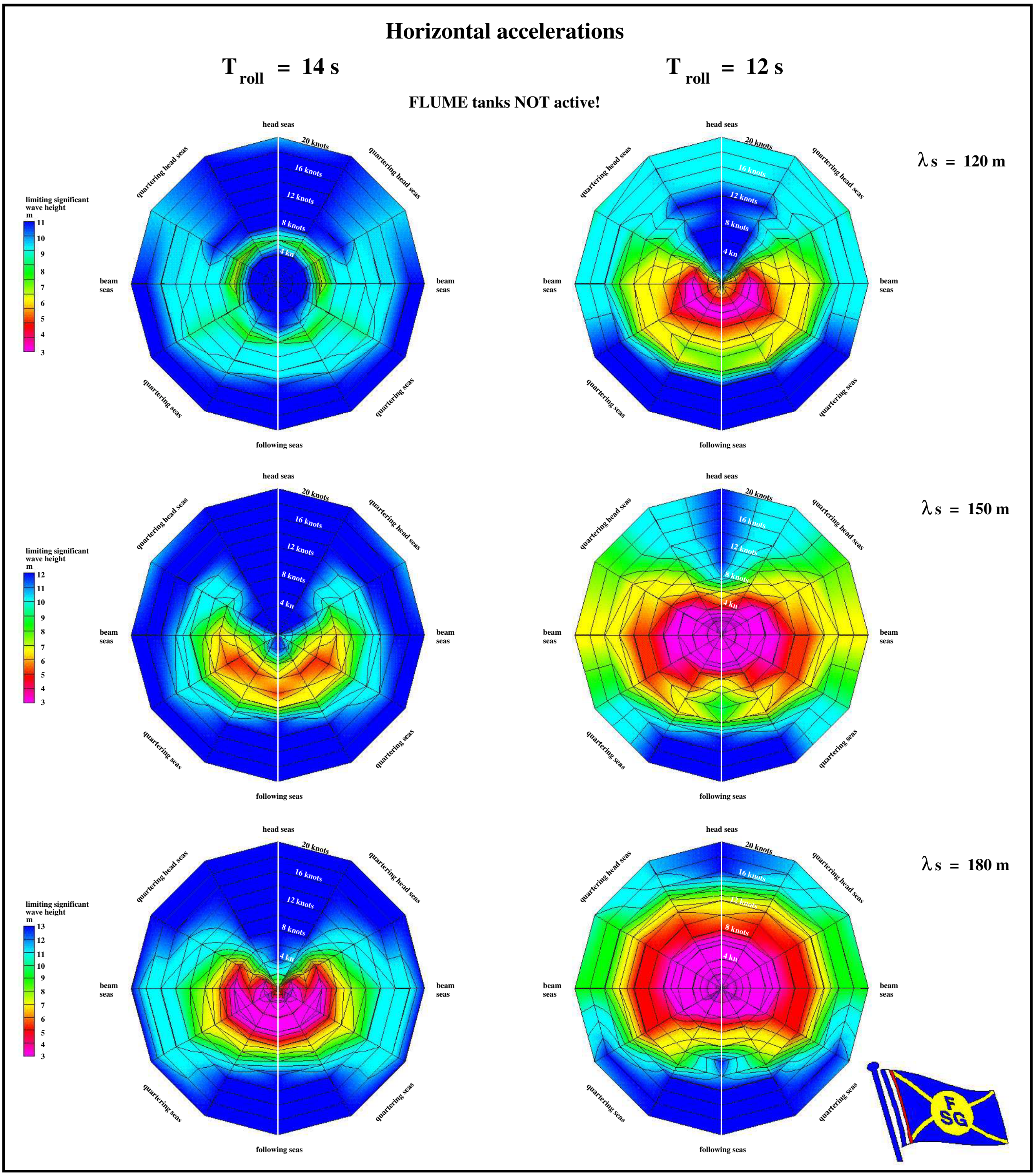

Figure 5: Polar plots with respect to horizontal accelerations for two different load cases extracted from a ship performance manual

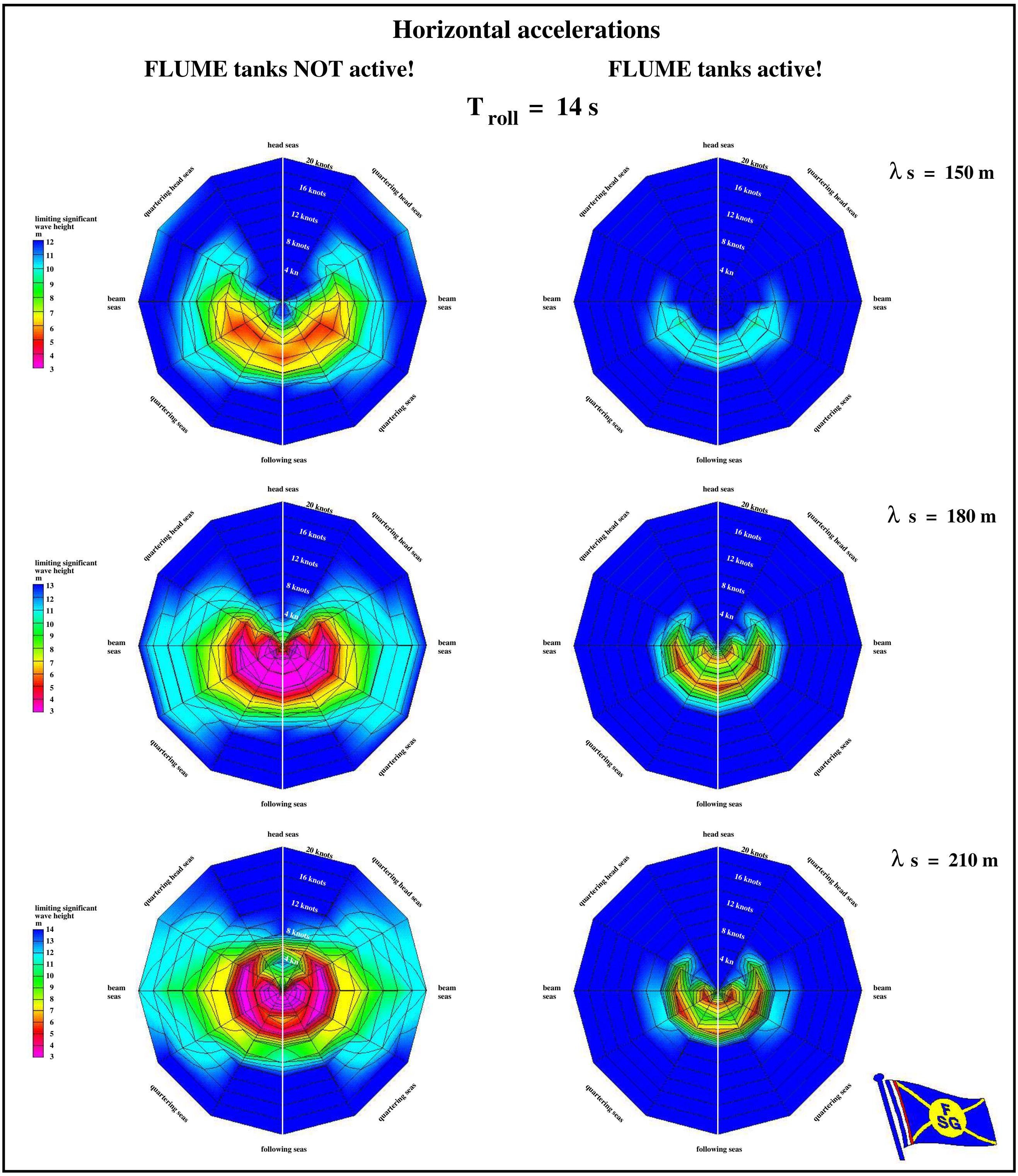

Figure 6: Polar plots with respect to horizontal accelerations illustrating the effectiveness of the FLUME-Tank arrangement extracted from a ship performance manual

Many of the modern ships (and especially Passenger and RoRo-Ships) have active or passive means of roll damping installed. Fig. 6 shows again polar plots which where extracted from a ship performance manual of a RoRo-ship. On the left hand side are polar plots for the unstabilized condition (as shown in Fig. 5 already), while on the right hand side results are shown for the same loading condition with activated Flume-tanks. The efficiency of the tanks is well illustrated by these diagrams.

Both the compilation of these diagrams as well as the format of presentation are under further development, based on the experiences from both sides – the naval architecs running the simulations and the crews using the diagrams on board.

One difficulty is clearly the sufficiently accurate observation of seaway parameter (with respect to wave height and wave period in particular). The same problem is often causing difficulties in the interpretation of full-scale measurements of ship motions or loads on the ship's structure. Within the German research project SinSee the WaMoS (Wave Monitoring System) will be futher developed and tested to enable reliable identifications of the relevant seaway parameter in the future.

5 REVISION OF INTACT STABILITY RELATED REGULATIONS

5.1 IMO's IS-Code

The IMO's IS-Code [10] is currently being revised. In order to bring the intended change towards a performance based formulation the following steps have to be performed in the revision process:

- Identification of safety related situations/mechanisms endangering the intact ship
- Collection of existing related knowledge and further research with respect to the physical phenomena endagering a ship and the assessment of ships performance in dangerous situations
- Development of a framework of performance based intact stability criteria
- Definition of criteria with appropriate standards

Besides analyzing designs, numerical simulations can be used to evaluate existing stability criteria and assist the development of revised regulations. In this respect, one of the aims of the German BMBF-funded research project SinSee is to work out proposals for possible criteria taking into account the dynamic behaviour of the ship in rough seas. Several ships have already been analyzed and capsizing probabilities were determined following a.m. approach. All ships are simulated in conditions according to the existing intact stability limits and the following phenomena which may lead to a capsize are investigated:

- Insufficient stability on the wave crest, leading to a pure loss failure.
- Excessive heeling moments in heavy weather due to large roll exciting moments
- Parametric roll, and resonances in general, especially in combination with pure loss and/or excessive heeling moments

For most of the ships included in the study so far, the IMO Weather Criterion is the limiting criterion. And one result of this study is, that this criterion does not represent a unique safety level. Consequently, the ships analyzed have a large bandwith of capsizing probabilities, and for the development of new criteria it would be required that all ships have more or less an equivalent capsizing probability. Though the tolerable minimum capsizing probability might also depend on the type of ship (e.g. depending on the number of persons on board - passenger vessel vs. freighter or the like). Nevertheless, even on the basis of the data determined so far some trends can be observed as the following figures show:

Fig. 7 shows some interesting results for ships that tend to suffer from pure loss failures due to low stability on the wave crest. Here the idea was that there might be a connection between the alteration of the maximum righting lever between wave trough and wave crest condition and the capsizing probabilities. And the general trend shows clearly that the capsizing probability increases with higher maximum lever alterations, which suggests that the stability values for GZ_{max} to be attained in calm water should somehow depend on their alterations in waves.

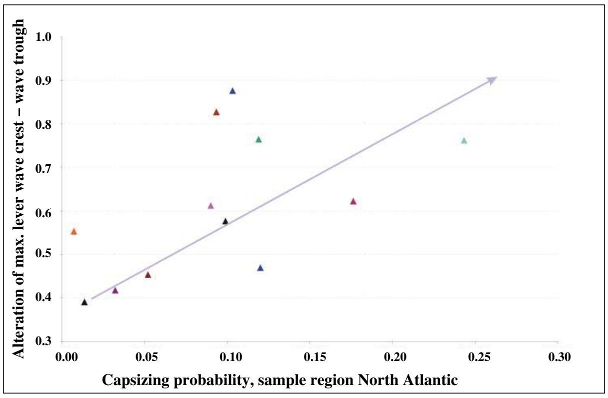

Figure 7: Capsizing probabilities versus alterations of the maximum righting lever between wave crest and wave trough condition for vessels suffering from pure loss of stability

Fig. 8 shows results for ships which are characterized by failures due to excessive heeling moments. This phenomenon seems to correlate with the roll energy in the system which could be expressed via the alteration of the area below the leverarm curve between wave crest and wave through conditions. As before, the trend is that the capsizing probability increases with larger area alterations, suggesting that the calm water area value to be attained should be a function of its alterations in waves.

The results show that it might be possible to generate criteria from such systematic simulations, but much more data is required.

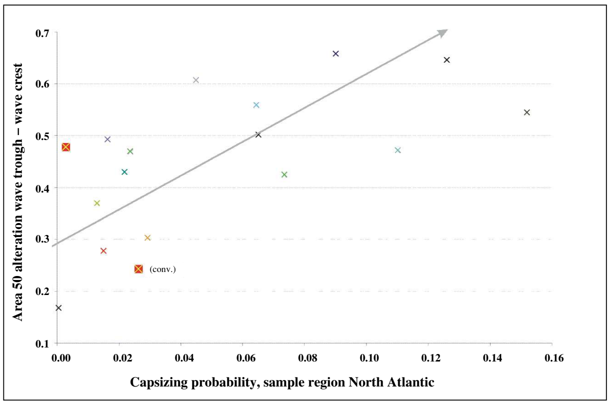

Figure 8: Capsizing probabilities versus alterations of the area 50 between wave crest and wave trough condition for vessels suffering from excessive heeling moments

5.2 IMO MSC/Circ. 707

While not yet included in the revision process at IMO-SLF the IMO MSC/Circ. 707 [9] urgently needs to be updated and extended. Numerical motion simulation tools can be used to support the revision process and also a lot of experience regarding many dangerous phenomena in rough and severe seaways is internationally available – from ship operation, model testing, numerical simulations, etc.

In Germany a joint effort of many members of the maritime community was undertaken to respond to the demand for more reliable guidance for the ship's crew in rough and severe conditions and the first draft version of a booklet called "Richtlinien für die Überwachung der Schiffsstabilität" was compiled, as already stated.

6 CONCLUSIONS

All three ship design, ship approval and ship operation determine the safety of a ship in rough conditions. Recent examples of (dynamic) intact stability problems show that the current rules and regulations are not able to represent todays vessels sufficiently well, and thus there is a strong demand from all three, design, approval and operation for more reliable and transparent regulations and guidance.

In this paper some examples are given on how numerical motion simulations and appropriate evaluation methodologies can support the design of safer ships and provide a basis for the compilation of ship specific guidance. Further examples show how these developments can also be used as a basis for rule development and the compilation of general "guidance to the master" applicable to all ships. Further developments are targeted in the ongoing research project SinSee in order to allow for quantitative safety assessments of a ships intact stability in the future.

At IMO-SLF the revision process of the IS-Code is ongoing and all three ship design, approval and operation will clearly benefit from the intended change towards transparent, perfomance based criteria – as will the ship's safety with respect to intact stability as such. And also the IMO MSC/circ. 707 needs to be included in the revision process, in order to provide more appropriate guidance for ship operation.

7 ACKNOWLEDGEMENTS

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References

[1] V. L. Belenky. Probalistic approach for intact stability standards. *SNAME transactions, Vol. 108, 2000*, pages 123–146, 2000.

[2] Tobias Blome and Stefan Krüger. Stability in quartering Waves – a critical Review of today's Stability Code. In A. Papanikolaou, editor, *Proceedings IMDC 2003*, Athens, 2003.

[3] P. Blume. Development of new stability criteria for modern dry cargo vessels. In n.n, editor, *PRADS – Practical Design of Ships and Marine Units*, Trondheim, 1987. Elsevier.

[4] H. Cramer and S. Krüger. Numerical capsizing simulations and consequences for ship design. *STG summer meeting*, 2001.

[5] H. Cramer and J. Tellkamp. Towards safety as a performance criteria in ship design. In The Royal Institution of Naval Architects, editor, *Passenger Ship Safety, International Conference*, London, 2003.

[6] W. N. France, M. Levadou, T. W. Treakle, J. R. Paulling, K. Michel, and C. Moore. An investigation of head-sea parametric rolling and its influence on container lashing systems. *Marine Technology, Vol. 40*, (1):1–19, 2003.

[7] A. Francescutto and A. Serra. A critical analysis of weather criterion for intact stability of large passenger vessels. In A. Francescutto, editor, *5th international workshop Stability and operational safety of ships*, Trieste, 2001.

[8] A. Francescutto and A. Serra. Experimental tests on ships with large values of B/T, OG/T and roll period. In S. Grochowalski, editor, *6th International Ship Stability Workshop*, New York, 2002.

[9] International Maritime Organization IMO. Guidance to the master for avoiding dangerous situations in following and quatering seas. MSC/Circ. 707, IMO, 1995.

[10] International Maritime Organization IMO. Code on Intact Stability for all types of ships covered by IMO instruments. Resolution A.749(18) as amended by resolution MSC.75(69), IMO, 2002.

[11] K. McTaggart and J. O. deKat. Capsize risk of intact frigates in irregular seas. *SNAME transactions, Vol. 108, 2000*, pages 147–177, 2000.

[12] Germany SLF45. Proposals with regard to the scope of revising the IS Code and the related MSC/circ. 707. Document SLF 45/6/2, IMO – SLF Sub–Committee, 2002.

[13] Germany SLF45. Remarks concerning the Weather Criterion. Document SLF 45/6/3, IMO – SLF Sub–Committee, 2002.

[14] Italy SLF45. Weather criterion for large passenger ships. Document SLF 45/6/5, IMO – SLF Sub–Committee, 2002.

[15] H. Söding. Ermittlung der Kentergefahr aus Bewegungssimulationen. *Schiffstechnik Bd. 34*, pages 28–39, 1987.