19th INTERNATIONAL SHIP AND
OFFSHORE STRUCTURES CONGRESS

7–10 SEPTEMBER 2015
CASCAIS, PORTUGAL

VOLUME 3

COMMITTEE I.2
LOADS

COMMITTEE MANDATE

Concern for environmental and operational loads from waves, wind, current, ice, slamming, sloshing, weight distribution and operational factors. Consideration shall be given to deterministic and statistical load predictions based on model experiments, full-scale measurements and theoretical methods. Uncertainties in load estimations shall be highlighted. The committee is encouraged to cooperate with the corresponding ITTC committee.

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1. DISCUSSION

1.1 Official Discussion by Jørgen Juncher Jensen

1.1.1 Introduction

It is a pleasure and honor to serve as official discusser for the ISSC2015 report on Loads, covering the last three years of development within wave (and wind) induced loads on ships and offshore structures. It is clearly an active research area as documented by the more than 400 papers reviewed in the report. This clearly makes the report very valuable as a researcher here can find the most updated list of references within this area. I have already enjoyed finding references useful for my own work. Of course this huge number of references also poses a problem on how to treat them in a balanced way over the allowed number of pages in the report. As I see it the decision among the committee members has been to give a more or less equal space for each reference/close group of references. This allows 5-10 lines for each reference and that only make room for a short introduction to the reference and a short comment to the range of validity of the proposed method included possible comparison with model test results and full scale measurements. This is very good, I believe, for someone who known what he/she is looking for, but for the in-experienced young researcher this might be less helpful. The complete lack of figures and tables also makes the report less readable as an overview of the whole area.

I know it is a very time consuming task to perform benchmark tests and with the limited time the committee members have available to spend on the report it is hard to do. However, in my opinion, such benchmark study can have a significant influence for the future research as it gives e.g. PhD students and other young researcher a quick overview of what can be done, what is missing and what the most promising way forward for their problem may be. A benchmark study could be made in cooperation with e.g. ITTC. A benefit of such studies is also that they can be published as journal papers making them more valuable for a longer period for the research community.

The content of the report follows to a large extend the format of the report for ISSC2012, except that ice loads is left out as a special committee is dealing with it. As mentioned above the description and evaluation of each reference or set of references are rather uniform without excessive focus on a few specific applications. This also implies that a reader interested in, say, probabilistic method get a good overview of what has been done the last three years by reading Section 5.1. However, guidelines on what to use for a specific problem is not given. Here a table could be very useful.

This goes for all sections and thus I do not find it useful here to go through these sections in my discussion as they nearly 100% deals with facts which can be directly retrieved from the papers refereed. Instead I will concentrate on the very relevant conclusions presented in Chapter 8 of the report.

1.1.2 Conclusions

On Zero speed and forward speed cases:

I agree with the conclusions especially that 3D models combining a potential flow solver in the outer domain with an N-S solver close to the structures are very promising as demonstrated in several of the papers refereed. This is especially so when only rigid body motions are considered. For such problems both commercial CFD codes and the OpenFOAM development have reached a maturity making it possible for the maritime industry (ship consultants, Class societies, and engineering companies) to apply these codes on a regular basis.

On Sloshing:

The studies regarding sloshing in tank with various suppressing structures and pipe system are very relevant for the industry, also in the light of LNG as of one the fuels for the future. Accurate predictions are needed taking into account the motion of the vessel and the varying liquid level in the tanks as the consequences of a failure can be large and fatal.

On Green water/wave-in-deck:

The green water problem has at least two issues: estimation of local loads on the deck and deck equipment and the effect the loads might have on the global hull girder stresses. Local load predictions have been studies in quite some details, but I agree with the committee that no general conclusion has been reached so far. As regard the effect of green water on deck on the global wave-induced bending moment it seems that the effect is small as guided from standard strip theory calculations using an equivalent water column on deck, but I believe this is still also a rather open question needing further investigation.

On Loads from abnormal waves:

A fundamental question is here: what is an abnormal wave? Even for the well-known Draupner wave it is not clear whether this wave can be described simply as a rare event using standard second order wave theory or if it requires a fully non-linear wave theory to capture the kinematics. If second order wave theory can give an adequate description then standard probability methods for wave loads can be applied, whereas no real candidate exist if the abnormal wave requires a fully non-linear analysis. The experimental work on abnormal waves is interesting, but does not provide answers to this question. As abnormal waves typically are waves with a very large crest values they are more important for bottom supported structures than for floating structures. This can be considered as an additional argument to weather routing for not dealing with abnormal waves for ships.

On Hydro-elasticity:

As also stressed by the committee a coupling between CFD and FE solvers provides a promising procedure for hydro-elastic problems. Thereby, accurate predictions of impulsive loads and subsequent hydro-elastic responses become within reach even for extreme value estimations in stochastic waves. A good example mentioned in the report is Oberhagemann et al. (2012). A recent contribution not included in the report can be found in Seng et al. (2014). Here, a time-domain hydro-elastic code for evaluating the global hydro-elastic responses on flexible vessels has been developed by combining an OpenFOAM VOF-based free surface flow solver and a flexible-body motion solver in a strongly coupled partitioned FSI scheme. A numerical example shows that it has the potential to accurately predict the global hydroelastic responses of vessels including slamming and springing. Further work in this field should be concentrated on more systematic validation studies in random wave systems where slamming and springing responses are likely to occur.

On Slamming:

For several decades slamming loads on ships have been estimated by a momentum formulation. Recent comparisons as also refereed by the committee have shown that this might give a very conservative estimate of the loads, mostly due to the use of the incident wave kinematics. This is important as the momentum slamming predictions often are used as a predictor of slamming events for further evaluations in subsequent very detailed CFD calculations. Thereby, the CFD calculation might not capture any significant slamming for this wave scenario and the probability of slamming derived from the momentum approach can therefore not be transferred to the CFD results. Hence, improvements as those documented in the report on slamming forces are very useful.

On Measurements:

This is clearly an area where a large development can be foreseen in the near future. Big data is the buzz word. Motion and stress measurements in ships provide ample data for testing various hypotheses on extreme value predictions and also make a foundation for setting operation criteria limiting e.g. roll motions, accelerations and stresses. An important application is also to use these data to make accurate real-time sea state estimation. Much have been achieved so far as documented in the report, but further work is needed in order to cover more complicated sea states with both wind and wave driven components.

On Loads following damage:

The discussion on IACS Common Structural Rules in sec. 3.5 and design loads in sec. 5.3 is very valid and could have deserved a table showing the main points in this development. The inclusion of references dealing with water ingress in damage compartments is nice, but perhaps not expected in a report on loads.

On Weather routing:

The committee rightly point to the question on uncertainty in weather routing systems and operational guidance in decision support systems (DSS). All steps in the procedures: real-time state estimation, voluntary and involuntary speed reduction, models for excessive motions, e.g. parametric rolling, accelerations and stresses need an uncertainty evaluation. An effort should be made towards a uniform accuracy over the whole procedure. Furthermore, proper information (level) to the master must be aimed at in DSS. Otherwise it will be unlikely that such systems will be used in practice on board.

On VIV, VIM and Mooring Systems:

Due to the large wave-induced motions of long cables and pipes non-linear procedures are needed. The report clearly shows that this is a very active research area. The main focus seems to be on hybrid methods coupling local CFD calculation with more simplified global models in the time or frequency domain. Focus is often on fatigue damage and an accurate estimation of the expected fatigue damage is often needed as this is an important design constraint. Also here a table showing the main procedures available would have been very useful.

On Lifting Operations:

I agree on the conclusion in the report regarding further improvements of the non-linear characteristics in this type of operation. In addition some discussion of the accuracy of the probabilistic methods (e.g. AR, ARMA, conditional stochastic processes) available for extrapolation of measured motion responses would have been beneficial. Several papers have been published on this topic, e.g. From et al. (2011), but none are included in the present report.

On FOWT:

This is a huge research area with many publications. I miss several papers published recently, but to cover this area in depth requires a special committee. This is also the case here as V.4 deals with offshore renewable energy. So maybe this area should have been avoided in the present report as done also with ice loads covered by V.6.

On Probabilistic methods:

The committee "are of the opinion that practical methods, applicable for conceptual and preliminary ship design, are still lacking." I do not share fully this statement as a number of extreme value prediction methods, notably the Peak-over-threshold method combined with asymptotic extreme value distributions have shown good results compared with full scale measurements also in case of combined wave and vibratory responses. The use of design waves with specified probability of occurrence has also provided accurate estimates as compared to direct Monte Carlo simulations. A table showing the available procedure and their range of applicability would have been very facilitating for the reader. One area deserving further development is the importance of correlations between peaks in the extreme value predictions, e.g. Gaidai et al. (2010) and in the assessment of bifurcation type of responses like parametric roll, Maki et al. (2011).

On Design methods for ships:

Several rational procedures exist for deriving deterministic design waves based on prescribed probability of occurrence of a prescribed response as described in the papers refereed by the Committee. Usually these design waves are given as a large sum of sinusoidal wave components with associated kinematics. However, for linear systems, the design wave scenarios have a time variation similar to the auto-correlation. This has led to the interesting suggestion to use the Karhunen-Loeve representation of stochastic waves instead of sinusoidal waves as each wave component then much better resembles the shape of the design wave, thereby leading to fewer components to describe the wave, Sclavounos (2012). These so-called critical wave scenarios with known probability of occurrence can then be used in time-consuming CFD calculations in order to improve the accuracy of the response prediction. This is sometimes denoted a model correction factor approach within civil engineering, Ditlevsen & Arnbjerg (1994).

On Fatigue loads for ships:

Generally the largest contribution to the expected wave-induced fatigue damage comes in low to moderate seaways. Thus a linear load and stress analysis is often sufficient. The expected fatigue damage can then be estimated quite accurately by either a rainflow counting procedure or by spectral formulations, also in case vibratory stresses are superimposed on the wave-induced stresses. The main uncertainty in the fatigue damage estimation is, as mentioned by the committee, on the structural side with stress concentrations, sequence effects, corrosion and welding quality.

On Uncertainties:

The statement given by the committee: "We are of the opinion that systematic uncertainty assessment is one of the main issues requiring resolution for the advancement of marine structural design." is very much to the point and hopefully it will be a main research area for maritime research community for the next ISSC reporting period. Only through such investigation prober design loads and design procedures can be formulated and hopefully be able to close the current gab between results based on direct calculations and rule- based design. The paper by Papanikolau et al. (2014) presents some very valuable thoughts on this topic.

1.1.3 Final comment

The three overall solution procedures mentioned for wave-induced loads: (i) a *FSI systems approach,* (ii) *hybrid solutions* (using e.g. model test results, Artificial Neural Networks) for computational efficiency and (iii) *data fusion* combining real-time measurements and computations are the research highways seen at the moments. There are many opportunities for improving these methods and suggestions are presented in many of the papers refereed. Therefore, the present report will be a key publication in the next three years for those dealing with wave loads on ships and offshore structures. My congratulations to the committee members for the work done.

1.2 Floor Discussion

1.2.1 Floor Discussion by Ekaterina Kim

This report covers variety of challenging topics. As a minor suggestion, for future works, it would be beneficial to reformulate the committee mandate and the keywords so they are in line with what is stated in the content. In particular, if the ice loads are entirely omitted from the report, it would be logical to exclude "ice loads" from the list of keywords and also from the committee mandate.

1.2.2 Floor Discussion by Petar Georgiev

I am surprised that one of the statements in the report is "...the uncertainty of the weight and weight distribution and their consequences have not been the subject of scientific analysis.....". What is your opinion about the reason for that - underestimation of the problem or not enough available data from real ship operation?

Personally, I published one investigation concerning the influence of uncertainties in cargo distribution on still water loads for Handymax BC-A type bulk carrier and the results show that the problem can not be neglected (Georgiev, 2011).

1.2.3 Floor Discussion by Per Lindström

You mentioned in your presentation the near future possibility of direct calculation of marine structures. It is well known that there is continuously deviation from a structure's "as designed geometry" (global and local) to the "as is" situation where some local geometries could very well have changed on several occasions during the ship's life time . For example the main stages can be:

- as designed geometry (global and local),
- as build geometry,
- as delivered geometry,
- as loaded geometry,
- as operated geometry (global change due to bunker consumption and ballasting etc.),
- as accidental event geometry (global and local),
- as is geometry (global and local).

May you please advise the geometry to be used at all this advanced calculations to obtain conservative, robust and reliable analyses results?

1.2.4 Floor Discussion by Dustin Pearson

The following comment is in response to the report findings that suggest that the analysis methodology (rule based or direct calculation) to evaluate a ship subject to the design wave should give the same result. Can you please specify what parameters, what rules and what acceptance level would you consider an equivalence between rule based and direct calculation? Does this include a wave spectrum approach or a single design wave? What is your opinion of using a single design wave? How does the equivalence change when using a single design wave or a wave spectrum? If the rule based method and direct calculations should be the same, does that mean the rule may not be conservative? Would this mean there is no added value of using Direct Calculations?

1.2.5 Floor Discussion by Chih-Chung Fang

The committee report did well review the equivalent design wave in the report section 5.2. However, an equivalent design wave is a regular sinusoidal wave that simulates the extreme value of each dominant load parameters as mentioned in the report section 5.3. The equivalent design wave is characterized by wave amplitude, frequency, heading and phase angle. The amplitude of the equivalent design wave usually is to be determined at the wave frequency and wave heading corresponding to the maximum amplitude of the RAO. The viscous effect of hydrodynamic pressure is significant in the resonance for the high speed vessel but cannot be well predicted by the potential theory. Can the committee provide the guideline for selecting the equivalent design wave of high speed vessel based on the hydrodynamic modelling uncertainty?

2. RESPONSE

2.1 Response to Official Discussion by Jørgen Juncher Jensen

2.1.1 Introduction

We thank Professor Juncher Jensen for his kind comments on the value of this committee's report. Copyright issues make including Figures from papers very difficult due to the processes involved in getting the copyright holder's, namely the journal, permission. Our own personal experience with inexperienced young researchers is, by and large, limited to academia. We make available to our students ISSC and ITTC reports relevant to the subjects we teach and the projects they carry out. Over the years our students have become quite adept in homing in on useful papers from relatively short descriptions and keywords and downloading them for further detailed reading, and, by and large, they home in on the right papers.

Professor Juncher Jensen's comment on benchmark studies is very valid. Discussion on this matter took place in the first meetings of the committee. There was a possible ship on which we can work with another committee. However, in the end it was not possible to obtain permission for using all relevant data. Instead members of our committee participated in the ISSC/ITTC benchmark study of a 6750 TEU containership. This study is likely to continue involving relevant ISSC and ITTC committees.

The breadth of this Committee's mandate inevitably results in equal effort and focus to be assigned to the range of loads and applications contained in the mandate, provided there is expertise in the committee membership.

Prof. Juncher Jensen's suggestion for using Tables to summarise the methods and their applications, in some sections of our report, is very useful, and we hope it will be taken on board by future committees.

2.1.2 Conclusions

On Zero speed and forward speed cases:

We agree with Prof. Juncher Jensen that commercial or open source CFD codes have reached maturity; however, their take up is not necessarily uniform in all FSI problems and associated loads, e.g. used extensively in VIV, VIM, sloshing, impact problems related research, but not extensively in seakeeping and prediction of global wave-induced loads. In terms of industry usage we are aware of applications, for example in sloshing, and wave-induced loads by class societies. On the other hand for VIV the industry preference is still semi-empirical methods and for VIM there appears to be reliance on model tests. We agree that the possibilities are there and the use of EDWs will facilitate the usage of more computationally intensive methods, as noted in our report. To this end, use of hybrid approaches will help in improving accuracy and computational efficiency. However, there is a need for systematic validation of the numerical methods. Furthermore, and with particular reference to open source codes where there is extensive user input and coding, there is an urgent need for calculating uncertainties associated with the predictions. We believe these actions will encourage more industry take-up.

On Sloshing:

We agree with Prof. Juncher Jensen on the need for more work on the two-way coupling between hull behaviour and sloshing in waves.

On Green water/wave-in-deck:

We agree with Prof. Juncher Jensen that a lot of effort has focused on the local green water loads and more work is required in clarifying the green water influence on global loads.

On Loads from abnormal waves:

We agree that, although there some empirical definitions on what makes an abnormal wave, there is a need for further work to shed clarity on describing such waves and associated kinematics. However, we believe that experimental work does provide indications on the likely magnitude of loads, within the range of conditions tested, though not conclusive answers to the question. From a ship's point of view avoidance measures may work. However, uncertainties in climate change and associated scenarios make pose questions on the "rare nature" of such events and the suitability of weather routing thereoff.

On Hydro-elasticity:

We thank Prof. Juncher Jensen for the reference. We also agree that two-way coupling between CFD and FE solvers is a promising procedure, and the need for systematic validation studies involving whipping and springing, as this is quite important from fatigue life point of view.

On Slamming:

We agree with Prof. Juncher Jensen that it is important for numerical simulations to capture the complete behaviour of the ship in waves, including slamming, sloshing, green water etc. Some progress in this area has been achieved, as detailed in this committee's report, and the signs for further development are encouraging. Hybrid approaches to achieve computational efficiency are always attractive, as in the case of slamming referred to by Prof. Juncher Jensen. It is important for the users to be aware of the consequences of the numerical approaches and associated assumptions used.

On Measurements:

We share Prof. Juncher Jensen's enthusiasm on big data and associated future developments in collecting full-scale measurements. We agree that there is a need for measurements in more complicated sea states. We did not find any explicit considerations in the literature on the specific issue of using measured responses to estimate the sea state. In our opinion using the response to estimate the heading, significant wave height and period can attain acceptable accuracy levels only in terms of averages, assuming that the ship behaviour in "real/realistic" waves is well modelled for any loading/operational condition. The latter is still an area that requires development, especially in more severe sea conditions.

On Loads following damage:

We believe that modelling water ingress is important from the point of view of accurately calculating loads on a damaged ship. As mentioned in our report, risk based design involves evaluation of such loads. A damaged ship undergoes three distinct flooding phases: the transient phase, the progressive flooding phase and the final, steady phase. Although ship hull may collapse due to excessive bending moment during any of them, second and third phases are considered particularly dangerous because these may last from a several minutes to hours, while the duration of transient phase is measured in minutes or even seconds. For that reason, progressive flooding simulation tools are included in the report, as they are directly related to the loads on damaged ship at intermediate stages during flooding (Rodrigues et al. 2015).

On Lifting Operations:

We thank Prof. Juncher Jensen for pointing out the probabilistic methods and related references. They complement this section of our report.

On FOWT:

We only addressed the general aspects of FOWT as our intention was to provide a degree of completeness in dealing with "floating systems" and the use of generic methods for this specific application, albeit coupled to turbine aerodynamics. The focus of the review is on the global performance of the FOWT in terms of loads and its coupling with motions, as well as coupled simulation tools, which may not be very well covered in Committee V.4 Offshore Renewable Energy.

On Probabilistic methods:

We agree that there exist a number of accurate methods like the ones proposed by Professor Juncher Jensen. However their respective range of validity is still not clear, and still under discussion among the specialists. The idea of a table showing the available procedures and their range of applicability is still a very challenging task. These methods cannot yet be considered as practical, as they require specific statistical skills from the user, and more computations than with a simple regular design wave approach. In addition, the methods mentioned may be applicable for the global responses, such as motions, vertical bending moments, etc, but are not easy for the detailed strength assessment through a FEM method.

On Design methods for ships:

We thank Professor Juncher Jensen for pointing out the so called critical wave scenarios and associated references. These will complement our report. The Karhunen-Loeve representation of a design wave proposed by Sclavounos (2012) is very interesting if the ship (or offshore structure) response can be described by a set of explicit functions of the wave kinematics. If a nonlinear potential code (or a CFD code) is used to compute the response, then we do not see any advantage for using such a description of the design wave.

On Fatigue loads for ships:

We agree with Prof. Juncher Jensen. The state of the art is to consider only the linear response for fatigue damage. The important and formidable nonlinearity in fatigue strength analysis is in the crack initiation and propagation, rather than structural side. Miner's rule is easy to use but has a limitation in the evaluation of fatigue damage because of its linear characteristics. It is still questionable whether the superposition method of fatigue damage can be applied or not. It is, however, possible to consider non-linear effects when the wave environment is very harsh, e.g. in North Atlantic the moderate seaways are 4-5 m. It might then become important to consider nonlinear effects in direct calculations.

On Uncertainties:

We thank Prof. Juncher Jensen for sharing our opinion on systematic uncertainty assessment.

2.1.3 Final comment

We thank Prof. Juncher Jensen for sharing our opinion on future research trends and that effort should focus in the three areas mentioned.

2.2 Response to Floor Discussion

2.2.1 Response to Floor Discussion by Ekaterina Kim

We thank Dr. Kim for her suggestion. Specialist Committees function for one or two congresses.

Therefore, we believe that removing the relevant topics from the mandates of the Technical Committees for that duration is not suitable in terms of continuity of the mandate. The introduction to our Committee's report makes clear the connections to relevant specialist committees. However, ice loads should not have been included in the keywords section.

2.2.2 Response to Floor Discussion by Petar Georgiev

We thank Prof. Georgiev for his comment and the reference provided. The cited statement refers primarly to the period of the last ISSC mandate (2012-2015). There have been investigations, prior to this period, on uncertainty of cargo weight and weight distribution of containerships (Friis-Hansen & Ditlevsen, 2002), as well as of oil tankers (Garre & Rizzutto 2009), amongst others. We believe that there is awareness in the professional community of this issue but not of its magnitude or significance. As we noted in section 7.2 of our report there are only a few data sets openly available from real ship operations. We believe that more data should be collected and analysed in order to examine the importance of this uncertainty and its consequences.

2.2.3 Response to Floor Discussion by Per Lindström

We thank Dr. Lindström for raising a very important issue relating to the hull properties used when predicting wave-induced loads. He has outlined a range of conditions/scenarios, demonstrating the need for the development of proper notation for this matter. We need to set aside the accidental conditions as, due to their complexity, they should be investigated separately, as illustrated in section 3.5 of our report for damage due to collision and grounding. Regarding operational scenarios, this will depend on the aim of the direct calculations. For example, if these are used to provide up to date on board predictions as part of weather routing it will be advisable to use the relevant mass distribution, provided it is available. On the other hand if the direct calculations are to be used to assess the adequacy of the design, it is more than likely that a ballast and a loaded condition will be sufficient. We consider the main problem to relate to the differences between designed, build and as is (e.g. thickness reduction due to operational and environmental factors and changes due to repairs) geometries, and particularly differences relating to structural arrangements and scantlings. For example, the effect of elastic deflection of a ship in loaded condition on hydrostatic particulars and global loads is described by Žiha (2002). We can suggest Monte Carlo type simulations for dealing with this type of uncertainty, as for example the investigations carried out by Teixeira et al. (2013), discussed in section 5.1 of the report, or Gaspar & Guedes Soares (2013) where the variability in material properties and structural dimensions is explicitly accounted for. However, we are not aware of available data, publicly or otherwise, which quantify the level of such geometrical uncertainty. We believe that as a first step this uncertainty should be investigated, before making recommendations on the type of geometry to be used.

2.2.4 Response to Floor Discussion by Dustin Pearson

We thank Mr. Pearson for his comments; however, it appears that he may have misinterpreted the conclusions of the Committee. In several places, we mention the crucial importance of parameter selection for the load analysis methodology on extreme values of wave loads. However, different analysis methodologies could eventually lead to similar answer in terms of the acceptance of ship design, as stated in the concluding remarks of the Committee report. A typical example is the utilization of different partial safety factors in rule-based and direct calculations. Results of load calculations by these two approaches may be considerably different, but if different partial safety factors are used, they eventually could result in the same outcome for the acceptance of certain ship design.

To be considered as equivalent, the rule approach and the direct computation approach should be based on the same assumptions regarding the sea state statistics (scatter diagram), the ship operational profile (heading and speed distribution), the corrosion mode etc. Naturally, the rule formulation being simpler and less accurate, will not give the exact same result as the direct computation: it would be expected that in most cases direct hydrodynamic analysis results in lower extreme wave bending moments than the rule values, i.e. the rules are less accurate but conservative. This is because the direct analysis requires more detailed and elaborate input data whilst relatively simple rule formulae represent an envelope that should normally include implicit margin to account for the uncertainties in the relevant parameters. However, in recent years, there have been a number of investigations showing that this may not be true. For example, the majority of analyses aiming to estimate design vertical wave bending moments (for the North Atlantic environment) by direct hydrodynamic analysis result in higher design values than those given by ship classification rules (Parunov et al. 2004).

When comparing rule loads and direct computations loads, the latter is usually taken as the reference. However, we should pay attention to the methodology used to compute the extreme loads, especially when nonlinear effects are taken into account. One key point is to use a validated seakeeping model. The second key point is the ability to evaluate the lack of accuracy in the methodology when 25 years of navigation are simplified in a few design sea states or a few regular or irregular deign waves. This is still an important research topic.

Excessive wave bending moments obtained by direct analysis, compared to rule values, is a very important fact that needs clearer understanding. Ship designers would perform hydrodynamic analysis either if they are required to do so by Class or if they could obtain, by direct analysis, lower value of design wave bending moment compared to ship rules. The latter possibility would enable material savings by reducing the required section modulus, whilst keeping the ship safety at a satisfactory high level. Unfortunately, both of the aforementioned possibilities are not in use today, at least for conventional merchant ships. The outcome of more complex and, presumably, more accurate analysis would be in most cases an increase of design wave bending moment. In such case, the designer would need to design a stronger and more expensive ship if direct computation of wave loads is performed.

Therefore, there is the added value in terms of ship safety when using direct calculations but not necessarily in terms of ship costs. Our response addresses Mr. Pearson's core question, rather than the details. It also emphasizes the importance of this subject and the necessity for further investigations into the outcomes from different direct analysis methods and rule based approach.

2.2.5 Response to Floor Discussion by Chih-Chung Fang

We thank Dr.Fang for his comments and raising the interesting issue of high-speed hulls. Although we are unable to provide a guideline for selecting the equivalent design wave for high speed vessels, there are a number of pertinent aspects to Dr. Fang's question which we wish to address in our response. First of all it is important to emphasize that the equivalent waves are selected so that responses to the equivalent waves are the same as their corresponding long term extreme values. With reference to viscous effects we believe that understanding the influence, of damping for example on parameters such as vertical bending moment, vertical acceleration and roll is important on the selection of the equivalent waves and their long term extreme values. For example Papanikolaou et al. (2000) investigated the effects of incorporating cross-flow drag correction in a potential flow code, showing that this inclusion greatly improved the prediction of RAO peaks for heave, pitch and vertical bending moment. Selection of an appropriate numerical method is very important in evaluating motions and global loads of high-speed vessels. For example Schellin et al. (2003) applied a frequency and a time domain methods for evaluation motions and loads of high-speed vessels and observed that time-domain technique was found to account for high levels of nonlinearity, including effects of large body motions as well as viscosity.

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