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COMMITTEE V.6
ARCTIC TECHNOLOGY

COMMITTEE MANDATE

Concern for development of technology of particular relevance for the safety of ships and offshore structures in Arctic regions and ice-covered waters. This includes the assessment of methods for calculating loads from sea ice and icebergs, and mitigation of their effects. On this basis, principles and methods for the safety design of ships and fixed and floating structures shall be considered. Recommendations shall also be made regarding priorities for research programmes and efficient implementation of new knowledge and tools.

CONTRIBUTERS

Official Discusser: Brian Veitch

Floor Discussers: Shengming Zhang, *UK*

Reply by Committee:

Chairman: S. Ehlers, *Norway*
F. Cheng, *UK*
W. Kuehnlein, *Germany*
I. Jordaan, *Canada*
P. Kujala, *Finland*
Y. Luo, *China*
K. Riska, *France*
J. Sirkar, *USA*
Y.T. Oh, *Korea*
K. Terai, *Japan*
J. Valkonen, *Norway*

EXTERNAL CONTRIBUTOR

F. Ralph, *Canada*

CONTENTS

1. DISCUSSION

1.1 Official Discussion by Brian Veitch

1.1.1 Introduction

– *Limitations*

Comment: There is no need for a separate section 1.1 Limitations. The paragraph under 1.1 simply describes what is out of scope, which can be added as the last paragraph in chapter 1.

1.1.2 Present design methods

– *General: Summary*

Chapter 2 outlines the regulatory regimes for ships and offshore structures, describes some well-known design rule sets, and introduces some current developments relevant to design.

The report highlights the importance of the FSICR as a basis of ship structural design for FY ice conditions, and the IACS and RMRS rules for MY ice conditions. The basis of the rule-based design loads on (years of) experience with ships that have operated in the corresponding conditions is emphasized.

The report describes the design approach embodied in rules for offshore structures, noting the basis in target safety levels that are subsequently converted into design ice loads. Target safety levels reflect failure consequences, such as loss of life, and damage to the environment. The descriptions serve to illustrate the difference between the rule-based design approaches for offshore and ship structures. Offshore structural design standards are closer to first principles-based design than the rules and conventions that guide ship structural design.

The report recognizes that the limit states used in ship rules typically use elastic limit states with some allowance for plastic limits. A wider use of limit states is used in offshore structures codes: elastic, plastic, ultimate, serviceability, fatigue, and accidental limit states. The approach in the ISO 19903 standard for fixed concrete offshore structures is held up as an example of a rational basis for structural design. The report proposes that this sort of probabilistic approach offers a way forward for ship structural design, incorporating limit states corresponding to elastic-plastic and ultimate plastic limit states (extreme and abnormal annual exceedance levels of 10-2 and 10-4 respectively).

– *Ships*

✓ *Rules*

Comment: In the 1st paragraph, it might be stated explicitly that the ILO is also an organization of the UN, similar to IMO.

Comment: The descriptions of the various rules provide useful background for the report. The writing needs editing for language and clarity. There is probably room to consolidate the descriptions somewhat. There may also be scope to expand the description to include a discussion of the rules as viewed through the lens of first principles-based approach.

✓ *First principles*

Comment: This section is relatively strong. One of the key elements of the design approach described in this section is the exposure of a structure to loads, which is part of the approach that is advocated by the committee's report. The integration of exposure in the CAC classes is described and summarized in Table 1, where it seems that the CAC3, 2 and 1 classes are benchmarked against the CAC4 class, which in turn is based on measurements and experience with a single vessel. The issue of exposure is again raised in Table 3, where the PC classes are compared to the CAC classes. It might be interesting to expand the discussion of this element, as it is not obvious how exposure can be evaluated during a design process.

– *Offshore structures*

Comment: This section is largely descriptive. Some of it is out of scope and should be deleted. For example, the paragraph describing an offshore structure (Arctic TLP) is out of scope. It and the Figure 13 should be removed. Similarly, the three paragraphs that describe DP and ice management should be removed. Alternatively, they should be rewritten as a broad state of art review with appropriately cited references.

- ✓ *Rules*

Comment: This section is relatively strong.

- ✓ *First principles*

Comment: The description in the section is helpful, but it should not rely on references to material that is not generally available. Specifically, it should avoid reliance on references to C-CORE software and corresponding user manuals. (e.g. Software to obtain … (C-CORE 2012)", and "Inputs and models for the software…", and "In C-CORE's SILS, consideration …"). Instead, it should refer to material that is widely available. If the source material is not widely available, the description should be expanded to include the necessary material. Similarly, it should avoid citing personal experience (e.g. "… data collected by PAL …").

– *Validation methods*

Comment: This section needs editing.

1.1.3 Case 1: Ship transportation in Arctic waters – the NSR

– *General: Summary*

Chapter 3 offers a case study to illustrate – and advocate for – the application of a probabilistic approach to the design of ship structures, in this case for ships in sea ice. The case study claims to confirm (1) that MY ice is the design driver with respect to ice loads, even when it is encountered only occasionally, and (2) the suitability of the proposed approach to determine design ice loads for a mission-specific operation, based on the comparison of the results to similar results determined using the AICS Polar Code.

Comment: Using a case study to illustrate the application of a rational design approach is a good idea. The case presented does not succeed in this. It needs another iteration. For example, the number of rams estimated in Table 11 is not credible.

1.1.4 Case 2: Floating offshore structures in Arctic waters

– *General: Summary*

Chapter 4 offers a case study to illustrate the application of a probabilistic approach to the design of offshore structures exposed to icebergs. It builds on material presented in chapter 2. The case is well defined and demonstrates that the method is comprehensive.

Comment: The case study presented for offshore structures includes an illustration of the influence of ice management on design ice loads. It might be interesting to expand the discussion here to other factors that may be relevant to design ice loads in this context, such as operational issues. Does the committee have any suggestions or insight into

how some of the factors that they identify in their introduction (e.g. human factors, operational aspects) might be incorporated into such design approaches?

1.1.5 Future perspectives and challenges

– *General: Summary*

Chapter 5 advocates for application of mission-specific, probabilistic design approaches for ships and offshore structures, recognizing that the approach is already embodied in standard practice for offshore structures. The report provides a brief review of numerical methods and offers a discussion of fatigue damage for ships and slender offshore structures.

– *Numerical simulations*

Comment: No comment.

– *Ice-induced fatigue*

Comment: No comment.

1.1.6 Summary & recommendations

– *General: Summary*

The report concludes with a list of some topics where additional research is needed. This is focused on the near-term, and includes the following:

- Effects of waves on ice floes in terms of the energy of such floes when involved in ship-ice collisions. This is described as a relevant design scenario, particularly for shipping near the marginal ice zone and close to the ice edge. The scenario is analogous to bergy bit impact scenarios.
- Investigation of ice loads on the stern of ships, particularly DAS vessels, and on other areas, such as stern shoulders, to capture relevant load scenarios arising from the relatively recent use of azimuthing main propulsors and the resulting new types of operating maneuvers.
- Investigation of the influence of ice management on the ice loads on protected structures. This is relevant to the design of offshore structures in terms of load magnitudes and exposure.
- Linking ice conditions and ice-induced loads (and design pressures) was identified as an area needing work.
- In connection with numerical methods, the need for a material model for ice was identified.
- The material properties of steel (and welds) under low temperatures were identified as being inadequately known, particularly in terms of fracture behavior.
- Human factors are identified as an area of interest, but no details are offered in connection with research questions.

1.1.7 Acknowledgments

Comment: No comments

1.1.8 References

Comment: The reference list in incomplete. Citation information is incomplete for many references. This should be addressed.

Comment: The reference list draws rather more heavily on conference papers, reports, and www than might be expected of such a report. Conversely, it does not rely as much as might be expected on peer-reviewed journal articles. The committee may wish to consider why this is the case. References to sources that are not generally available, such as user manuals, should be avoided.

Comment: The reference list reflects an apparent bias of the committee authors to self-reference. If the report aims to provide a current status report on the state of the knowledge snapshot, then the authors are encouraged to consider more fully the contributions of the broader academic and engineering communities.

1.1.9 Annex 1 Summary of codes

Comment: The Annex 1 is a useful summary of design codes.

1.1.10 Annex 2 Full-scale ice load measurement campaigns

Comment: The Annex 2 is a useful summary of full scale measurement campaigns.

1.2 Floor and Written Discussions

1.2.1 Shengming Zhang (Lloyd´s Register)

Thanks to the chairman & the committee for the very good report and presentation. You discussed the design methods are moving to first principles from the traditional empirical ways. Ice load is one of the key elements, in ship rules this is done by using hull area factors for Midship Aft region etc. Can the committee comment on how this can be solved from first principals methods? Thanks.

1.2.2 Ekaterina Kim (NTNU)

This is an interesting work. It should be highlighted and acknowledged that the authors of the report not only evaluated and discussed the research in progress (and planned) but also actively contributed to the new knowledge in the field of Arctic Technology. This can be clearly seen from an outstanding list of references that is dominated by scientific publications of the committee members. However, to my opinion, the main shortcoming of this report is the authors' reliance on their own work rather than covering the whole spectrum of recent research and engineering achievements. For example, on page 789 there is dissemination of the results from only one model basin, but the authors offer no information about the experience and/or achievements of others ice basins. In the absence of any information from other basins there is no way of getting a complete overview on the recent developments in the field of ice model testing which is an inherent part of the design process. Little, if any attention is given to the problem of abrasion on structures due to moving ice; interactions between moored structures and drifting broken ice; interactions with first-year sea ice ridges. The latter will often give the design mooring load for structures operating in the Arctic.

1.2.3 Robert A. Sielski

The committee has reviewed the loads on, resistance of, and design of ships that are intended for operation in the arctic. However, with the reduction of ice in the arctic, more ships will be operating in these waters that were not designed for such service including naval vessels. Can the Committee comment on any research that has been conducted on the operation of non-ice reinforced ships in ice?

2. REPLY BY COMMITTEE TO THE OFFICIAL DISCUSSER

The committee appreciates the comments and efforts of the official discusser and the floor and written discussions very much. Following the detailed suggestions, the report has been re-edited where indicated to improve the readability. The points mentioned by the reviewer, where the report may diverge from the scope, are acknowledged. However, since the committee agreed on their inclusion due to their importance, they will remain, also considering that they are rather short. Naturally, the report reflects the contributions of the committee members to the field. Furthermore, the committee agreed only to include papers covering their own believes in an as objective manor as possible. In addition, the overall balance between citations to committee members and non-committee members is considered to be acceptable considering that the committee made significant efforts to publish articles jointly during the committee period prior to including the covered aspects in this report.

The section 1.1 indicating the limitations is considered so important, that it deserves a separate chapter and is thus not merged with the introduction. The rule section is not extended to first-principle-based approaches to ensure a clear separation with the following chapter explicitly addressing first principle approaches. The section on the influence of temperature on steel material properties is now integrated in the rule section.

The first principles chapter for ships includes a comment on how exposure can be evaluated during a design process now.

Reference to the Arctic TLP, Arctic DP and ice management remained in the report since the committee agreed that these address important issues or examples, which are also backed-up with important references. The references in the first principles section for offshore structures are wherever possible easily accessible; eventually they require contact to the reference source mentioned however. Further, since the pages of the report are limited, we could not include further explanations on some of the report contents referenced and trust that the interested reader will consult the references provided.

The case study in chapter 3 was updated to clearly explain a possibility to obtain loading based on physical conditions and interactions.

For the case study in chapter 4 it may indeed be interesting to expand the discussion to other factors that may be relevant to design ice loads, such as operational issues. However, we had to limit these aspects to some comments on operational and human factors found in the summary chapter.

3. REPLY BY COMMITTEE TO THE FLOOR AND WRITTEN DISCUSSION

Reply to Shengming Zhang (Lloyd´s Register): We appreciate this comment concerning exposure. Indeed the probabilistic methods presented based on first principles are suitable to account for different hull area factures, because full-scale experiments exist where vessels have been instrumented at various cross sections along their hull, e.g. bow, bow shoulder, side and aft shoulder frames. However, these measurements are not generally available to the community.

Reply to Ekaterina Kim (NTNU): We agree that we included references to our own articles, which the committee, as nicely pointed out, made significant efforts to publish articles jointly during the committee period prior to including the covered aspects in this report. Furthermore, we agreed to limit the coverage to the ice load assessment suitable for full-scale ship design. Therefore, we omitted general articles considering model scale results apart from the cited research on numerical modelling of model ice, which indicates a first trend towards numerical ice tanks. Abrasion on structures due to moving ice; interactions between moored structures and drifting broken ice; interactions with first-year sea ice ridges are certainly important aspects to be considered in the overall design process and in a future Arctic Technology committee report.

Reply to Robert A. Sielski: We certainly agree that the possible operation of non-ice reinforced ships in ice covered waters or in the marginal ice zone represents an important aspect to be considered, especially considering that even ice-strengthened vessels can damage when operating in ice. Apart from some accident reports involving ice–induced damages the committee is not aware of any general studies on the operation of non-ice reinforced vessels in ice-covered waters.