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VOLUME 3

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 infested 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.

CONTRIBUTORS

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Floor Discussers: Koji Terai
Wolfgang Fricke
Shengming Zhang
Sören Ehlers
Jørgen Amdahl

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CONTENTS

18th International Ship and Offshore Structures Congress (ISSC 2012) - W. Fricke, R. Bronsart (Eds.)

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1 DISCUSSION

1.1 Official Discussion by Walter Kühnlein

The Official Discussion was presented by Jørgen Amdahl.

1.1.1 Foreword

The ISSC Committee Report V.6: Arctic Technology gives a very good overview over the wide range of ice related issues like definition of ice forces, major ice projects and also about codes and standards. The report references quite a substantial number of papers, but due to the limited size of the report (27 pages without references) all topics could only be touched and a few main research projects have been not mentioned at all, i.e. the two main EU founded research projects LOLEIF and STRICE (www.strice.org). As these two projectswere the first and so far only ones where besides the ice forces acting on an offshore structure (light house tower in the Northern Baltic Sea, close to Lulea) also ice conditions like ice thickness, ice drift speed, ice density, ice strength, ice temperature history, etc. have been measured in conjunction with the ice loads. These results have been extensively used for the generation of the new ISO Code.

As mentioned in the report, the Arctic, i.e. ice covered waters are one of the biggest challenges of the next decades, as it is estimated that not only oil and gas, but also mineral resources are to be found in these areas. On the other side these areas are extremely sensitive to any change of the environmental equilibrium. All this information which has been collected during the last 3 to 5 decades are collected and nicely presented in this report.

But what is missing in this report is the fact that "ice is totally different than any other environment where we operate". This even includes deep sea, air and space. Researcher and engineers are used to design systems/units which are in general able to survive by its own, i.e. systems/units that are designed in order to withstand the environmental forces. As an example offshore platforms in the North Sea are designed that they can withstand 100 year waves (waves with a return period of 100 years) without any support from outside, they are just stronger than the waves. Of course this is not a new statement, that is well known and actually, how engineers design everything, so far.

But when going into ice covered waters, especially into heavy ice this approach does not work anymore. At a sudden, structures in ice need to rely on supporting operations, i.e. ice management and this is a total new and sometimes frightening approach for many engineers. I experienced a few times how reluctant engineers reacted when I presented new concepts and philosophies for field developments in ice where ice management was and need to be a substantial part of the entire concept. But if this new operational based approach is considered this will also give a lot of new possibilities to scope ice related challenges. Therefore I would suggest that design philosophies in ice should be included at least as a foreword to the ISSC Committee Report V.6.

The following discussion of the ISSC Committee Report V.6. is using the same section numbering as the report itself. Only section "13 MISING TOPICS" has been included at the end of the paper and is intended to mention topics which should be included in the final (next) committee report. The topics are briefly mentioned and addressed as it is not the task of the discusser to complete the report.

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1.1.2 Introduction

It should be also mentioned that the Arctic development in the late 1970's and early 1980's was mainly caused by the search for oil and gas and it dropped in the late 1980's because of falling energy prices and also the status of the technology at that time was not sufficient for safe operations in these areas.

1.1.3 Environmental and Climate Change

This section gives a short introduction to climate change (or global warming) and how it would influence the current design practice. It is also mentioned that the ice becomes in general thinner but also more movable, which might even increase the ice load on fixed or moored structures in this area. This is in general the right approach, but could be also described a bit more detailed. I personally do not like charts where the y-axis does not start with 0 (as used in Frig. 2) , as this shows always much steeper trends as they are in reality. But this is my personal opinion!

1.1.4 Arctic Ships

In general I agree with section 3, but I would also include operability of vessels in ice. Because in some cases it can become much more economically if a bigger engine as needed is installed.

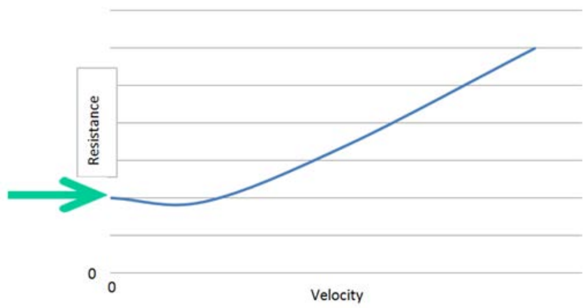

Figure 1: Resistance versus ship velocity (schematic chart)

As a simple example, as the resistance of a vessel in ice does not start with zero for zero speed it can be advantageous (depending on the vessel) if a larger engine is installed, i.e. with 20% more power you might get more than 20% more speed when breaking ice (at low speed). In most of the cases the installed power should be anyhow higher as required by class or rules if the vessel is supposed to operate sufficiently in ice. Operational aspects need to be considered. In ice it is anyhow mandatory that concepts are optimized from an operational point of view and not from an engineering point of view. This also leads back the previous mentioned necessity of having good defined design philosophies where operational aspects governing the design.

Ice classes and rules can and should be only considered as absolute minimum requirements for sufficient operations in ice.

1.1.5 Arctic Offshore Structures

This section is giving quite a good and complete overview of structures in ice. The North Caspian Sea with its challenging requirements due to the limited water depths and extreme ice in winter time could be added to this section. As an example ice management in the shallow waters of the North Caspian is quite different compared

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to deeper areas. Sucking water in the limited areas of the North Caspian is also quite challenging as the sea chest need to be deep enough not to suck ice and get blocked, but not too deep in order to suck water with soil and erode pumps and nozzles. Again, operational aspects could be considered much more in this section.

As mentioned earlier, ice management should more in the focus of this report. Also operational aspects should be considered when it comes to disconnectable solutions. In most of the cases, where a quick release mechanism has been defined in the design premises, the resulting costs have been not defined. Because, different than in open water where you might disconnect a structure when a hurricane approaches and you come back a week later, in ice covered water you might need to wait up to 18 months prior the unit is connected and can start to produce again. This should be a high motivation to spend extra efforts and costs in order to push the limits and make the system safer.

Operation of moored structured in ice should be explained. As an example “weather vaning” and all related problems for moored structures with a turret should be included in the report.

As mentioned in the report SPAR Buoys are quite a good concept for ice covered waters with sufficient water depths. One of the main advantages would be having a summer and a winter draft (cone shaped in winter draft - in order to reduce ice forces and vibrations). Additionally, the limitations of a turret and problems with “weather vaning”are not existing.

1.1.6 Rules and Regulations for Ice-Going Ships

This section is giving a very good overview about ice rules and general approaches to ice loads and ice design on vessels. It is also with more than 7 pages the most detailed one. Operational aspects could be also briefly mentioned.

1.1.7 Guidance for Arctic Structures

This section is compared to the previous section for ice going vessels rather short (1/2 page) and gives just a brief introduction into ISO 19906 and API standards. This section needs to be much more extended.

Operational aspects should be also included. Some decision guidance what kind of structure shall be used in what kind of environment would be also helpful!

1.1.8 Ice Loads

This section is giving a very brief introduction how to determine ice loads and the definition of local and global ice loads. This section also needs to be much more detailed as some paragraphs are not really giving any detailed information, as an example: “Model basin tests have been reported for moored Spar (Evers and Jochmann, 2011; Bruun *et al.* 2009, 2011), ice ridges (Dalane *et al.* 2009), level ice (Wille *et al.* 2011), moored FPSO (Chernetsov *et al.* 2009), and interaction between ice and ship’s bow (Aksenes 2011).”

Especially the problems of fixed platforms with vertical walls causing ice induced vibrations and also the advantage of a cone or a sloped shaped structure, that the ice fails instead of crushing in bending which reduces the force (significantly – only applies for sloped structures) and also eliminates the possibility of ice induced vibrations.

Also some operational aspects should be included, like the reduction of ice loads using ice management.

1.1.9 Structural Response

This section is giving a brief overview of structural responses. But it does not really go into details. As mentioned earlier the STRICE project should be also mentioned here (www.strice.org) as this allowed extensive investigations of ice induced vibrations which have been published in various papers and journals.

In section 8.2 it is mentioned that a cone has been introduced to various monopile constructions.

Please note as the diameter of a cone is rather large compared to the monopile itself, especially if large tidal variations occur, the force on the much wider cone might be in the same magnitude or even higher compared to the original monopile, but as the ice fails now in bending instead of crushing the risk of ice induced vibrations is eliminated.

1.1.10 Numerical Simulation of Ice

This section gives a brief introduction to numerical simulation of ice. An overview should be given why ice is so complicated to model, i.e. because of the bridle and ducktail failure. The section makes references to very actual papers and publications, some more information from these papers should be presented.

Section 9.3 should first explain what ridges are. Readers who know what ridges are, also know about the rest of this small subsection. Ridges are quite an important design feature for structures in ice, as in most of the cases they are defining the maximum design load and also the mooring design, as they can be quite deep (> 30 m).

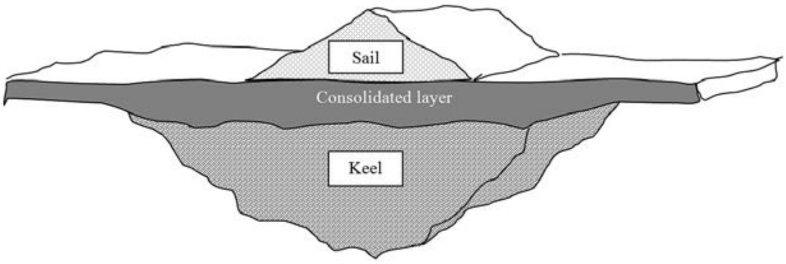

Figure 2: Principle sketch of a typical ice ridge (sail, keel and consolidated layer)

1.1.11 Structural Reliability Analysis

This section is giving a much more detailed overview about structure reliability analysis as the previous sections. This section is rather complete and is going deep enough for such an overview paper. Similar detailed descriptions should be given for sections 6, 7, 8, and 9.

1.1.12 Summary and Recommendations

I fully agree that the committee recommends that ISSC continues this committee, as quite some substantial efforts need to be put into the document in order to make it a good working document. The actual version is not very homogeneous and different sections have been developed and described on rather different levels concerning completeness and information depth.

The extensive list of referenced papers shows that the authors (committee members) are on the right way, but they should transfer more statements/information of the referenced papers into the ISSC Committee V.6 report.

1.1.13 Abbreviations

In general ice related expressions should be also defined:

- Ice
- Ice failure modes
- Crushing
- Buckling
- Bending
- Ridge
- Rafted ice
- Ice floe
- Ice concentration
- First year ice
- Multi-year ice
- Bridle
- Ducktail

1.1.14 Missing Topics

The following main topics should/need be also included in the final (next) ISSC Committee V.6 report. The topics are just briefly mentioned and explained in the following subsections.

Design Philosophies in Ice

As mentioned in the foreword "ice is totally different than any other environment where we operate". Therefore a section about design philosophies in ice including ice management should be included.

Ice Model Tests

A section about ice model tests including advantages and disadvantages should be added to this document. As the parameters of ice can be modelled in ice model tests, these tests are rather different than open water tests, therefore this would be quite an important section of the report.

Ice Management

Ice management, i.e. pre-breaking the ice with ice breakers in order to reduce the ice loads on the fixed/moored/DP operated platform is an essential factor when operations in ice shall become successful.

This section should also include spraying ice in order to create artificial ice reefs protecting structures or increasing the weight of ice barriers.

The use of ice barriers in shallow waters like in the north Caspian Sea should be also included in this report.

Ice Movement Simulation (numerical experimental)

The movement of ice including the overrunning of structures and island should be integrated in the next version of the report. Especially in shallow waters the ice movement around structures including grounding of ice can and will cause quite some problems.

Figure 3: Ice Approaching an Artificial Island (left model test – right full scale)

Dynamic Positioning in Ice

DP in ice introduces quite some new challenges which are totally different compared what is known from DP in open waters. In the following the main challenges for dynamic station keeping in ice are summarized:

- Capability of continuous ice breaking (no ramming is possible).
- No (immediate/direct) interaction between thrust and motion.
- Rotating the vessel on the spot is not possible (large turning circle).
- The vessels needs to be orientated always against the drifting ice with the bow or the aft end, as sidemotions are very limited or even not possible.
- If the ice drift stops, a pre-broken ice flow area needs to be generated, in order to be able to turn quickly into the new ice drifting direction.

DP in ice had two special sessions during OMAE 2012 in Rio de Janeiro.

Evacuation in Ice

Evacuation in ice is one of the most urgent problems to be solved. Evacuation vessels which can operate in open waters, brash ice, thin and thick ice are needed in order to evacuate platforms at any time. Risk based approaches are needed in order to lower the risk if evacuation is limited.

Figure 4: Arktos amphibious vehicles evacuation crafts (left: full scale – right: model tests)

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1.1.15 Oil Spill Recovery in Ice

Oil spill recovery in ice is also a problem that needs to be addressed in such a document. At present oil booms have to be put on the ice in order to allow fuel transfer. I think it is quite obviously that they would not work in case of a spill. Even if no perfect solution can be described it should be mentioned in an such an report.

1.1.16 References

The list of papers is rather comprehensive and give a very good overview of ice related research issues during the last 3 decades. As mentioned before the committee should transfer more information and statements from the cited papers into this report.

Also papers concerning operational aspects and philosophies for ice projects should be included. As ice is so different, it should be worth it to mention, why it is so different!

1.2 Floor and Written Discussions

1.2.1 Koji Terai

I think that collecting and sharing ice loads data is needed in order to promote the research efficiently. So, I have one question:

Do the experimental results and measuring data of ice loads that we can use currently have enough quantity and quality to promote the research?

If we do not have enough, what kind of program is needed?

1.2.2 Wolfgang Fricke

Regarding fatigue, we have seen measurements showing that cyclic loads are of a magnitude that cracks may occur. Are the committee members aware of such damages and if so, what are the structural details affected?

1.2.3 Shengming Zhang

1. Comments: A question whether fatigue of ships by ice loads is a problem or not, Lloyd's Register's Damage Data Base showed that about 57% of ice class ships have cracks/fractures at an average of 13 years. Thus, LR has released ShipRight FDA ICE procedures to address this concern and make sure ships have a sound fatigue performance when navigating in ice regions. A number of LNG ships have been assessed using FDA ICE procedures and are currently under construction.
2. A question on engine power requirement: Baltic Rules require minimum engine power while Polar Ship Rules do not. Can the committee comment on this difference? Thanks.

1.2.4 Sören Ehlers

- Concerning the design philosophy, it would be nice to see a discussion with respect to the applicability of the FSICR, being economic measures, to the arctic sea.
- Design support to the choice of fleet, ice class and entrance time to the arctic sea should be included to give guidance to owners and operators.
- What should be the required safety level for arctic vessels?

1.2.5 Jørgen Amdahl

Ultimate limit state assessment of ice actions

- Design rules should have clear separation of loads and resistance, as is the case for offshore codes

- Loads in IACS PC rules difficult to interpret and compare with ISO19906
- Resistance assessment of plates, stiffeners and girders based on plastic mechanisms is fully adequate as loads are not reversible- corresponds to moderate plastic deformations (this is OK in IACS PC)
- Finite plastic deformations of shell plating may be considered – then based on acceptable strain levels not deformations

Accidental limit state assessment of ship–iceberg collisions

- Large elastic accelerations/displacements reported
- Significant structural damage accepted - but no penetration of cargo tank
- Integrated ice-structure-fluid analysis is required!
- Continuum mechanics modelling of iceberg a challenge
- What local ice-berg shape to use?
- Design guidance needed!

2 REPLY BY THE COMMITTEE

2.1 Reply to Official Discussion

The Committee appreciates the extensive discussions. Dr. Kühnlein has added a lot of interesting aspects from his experiences in the industry and R&D. We think these comments are valuable and would help everyone understand the breadth of the issues.

Dr. Kühnlein wanted to include design philosophies in the committee report. We fully agree. The Committee discussed formulations of loads and responses in ice class rules. Section 5 clearly shows that existing ice class rules differ in their framework, which is also quite different from the practice of modern ship designs. There is a strong need for re-visiting the way ice class rules are based upon. As Dr. Kühnlein pointed out, Arctic is a very challenging environment and ice is totally different than any other environment. This unique situation calls for ice management as an integrated part of operation. Consequentially, we need to think differently and adopt new design philosophies.

The Committee report covers ice management for Arctic offshore structures though our coverage is rather brief. We agree that ice management should be given more attention.

Operations related to disconnectable moorings are not covered in current Rules or Regulations (to our knowledge). As stated by the Official Discusser, disconnectable moorings in open water are mainly designed to allow the offshore facility to escape from hurricane conditions. These conditions allow a certain pre-warning time. In Arctic environment disconnection can be required if an iceberg is heading towards the facility. That will also allow a certain warning time. However, in the current thinking, it may also be required to disconnect a facility from its mooring once the ice loading from level ice appears to reach the maximum capacity of the mooring (if ice loading was underestimated, such could happen without much warning time). This requires disconnection under load, which imposes quite different design requirements on the disconnectable mooring. So this example confirms that operational scenarios are needed to make proper designs. This technical reason for requiring clear operational scenario's comes in addition to cost evaluations of capacity of moorings versus availability of the moored unit.

As for the design guidance of arctic structures, we agree that the industry needs to have more guidance. The current standards are certainly insufficient. The ISO standards are a good step forward. But there is a lot of room for further development.

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The discussions on ice loads are well taken. The Committee has already listed ice loads as a highly recommended area for further research. Additional topics that worth investigation are – Up to what extent is an offshore floating structure allowed to be dependent on ice management?What level of reliability and availability should the ice management be required?

Dr. Kühnlein has a valid comment on the numerical simulation of ice. We agree that this is a fast developing area of R&D, and we included this section to give a general view of the related studies. Our committee was tasked to look at the practical side of design analysis of structures, and we placed our emphasis accordingly.

The Committee thanks Dr. Kühnlein for pointing out a few items that the report overlooked, including North Caspian Sea, EU funded projects of LOLEIF, STRICE.

We are pleased that the Dr. Kühnlein agrees with the Committee's conclusions and recommendations. We thank him for suggesting additional topics for the next committee, especially the topics of ice management, dynamic positioning in ice, evacuation in ice, ice model tests, ice simulation.

Our Committee had tried our best during a challenging time. We wish we could have done better if we have had a stable committee during the last three years. We are glad that the ISSC Standing Committee has started identifying new committee members and we are sure that the new committee will be able to provide more data and information about the state of the art technology, which is evolving very fast and is becoming more and more sophisticated.

2.2 Reply to Floor and Written Discussions

2.2.1 Koji Terai

We think that there is a general lack of measurement data of ice loads. Ice loads measurement taken during the FSICR development is still extensively used now when there is a need for re-visiting the ice loads. As we are well aware of, ship designs have been greatly changed during the last few decades. We should have accumulated enough experiences about the structural performance of modern commercial ships, and these experiences must be fed back into the design codes. A very important step is to systematically collect ice loads and ice damage data so that analysis of these data will become possible.

The Committee also notes that some owners and ABS are collecting ice loads information from instrumented tankers trading regularly to the Arctic region. We expect that many such data will become available in the near future.

2.2.2 Wolfgang Fricke

The Committee was not aware of the fatigue study mentioned by Prof. Fricke. We agree ice-induced fatigue needs to be further studied.

We do agree that ice-induced fatigue deserves more attentions of research. We think that the focus should be ice-induced fatigue of side longitudinal end connections and other structural connections at and around waterline.

2.2.3 Shengming Zhang

The Committee noted the study by LR about the ice-induced fatigue. Statistical data of structural damage is always welcome, and a key aspect of statistical study is interpretation of data. We expect that statistical data will be made available to the research community.

As for the minimum engine power in the Baltic Ice Class Rules, the Committee noted that the industry and research community are well aware of this issue. Classification societies have established supplemental guidance on this issue. For example, ABS (2012) specifies an alternative method for rationalizing the minimum power requirement for FSICR.

The Committee is not fully aware of the rationale behind IACS Polar Class Rules.

2.2.4 Sören Ehlers

Prof. Ehlers raised questions about the design philosophy and safety levels. The Committee agrees that these are very important topics that deserve discussion in depth and by all stake holders.We were pleased to note a few research papers on this topic, and we expected to see more research in this line.

The FSICR is the de facto industry design code that is basis of the majority of ice classed ships built up to date. As mentioned in our committee report, the IACS Polar Class Rules and RMRS IR are also important ice class rules. However, what code is the most appropriate to ships sailing to the Arctic regions will be decided not only on the technical aspects. The decision is often influenced by economy, trading region, period of time during the year, local regulations, accessibility of infrastructure supports, among others.

2.2.5 Kaj Riska

We thank Prof. Kaj Riska for the critical review of our committee report. Prof. Riska pointed out the needs of understanding the basic theory behind the IACS longitudinal strength requirement and associated data, the origin of ice-induced vibrations (and the several different theories presented). We will pass these valid comments to the next term.

Though our Committee had tried our best, our committee report still has room to improve. I am very glad to hear that Dr. Riska has agreed to join the committee, and I am looking forward to a much improved committee report in three years.

2.2.6 Jørgen Amdahl

The Committee agrees in general the comments by Prof. Amdahl. The long list of topics by Prof. Amdahl only demonstrates that our knowledge and practice is far from perfect. We would recommend the coming committee to take Prof. Amdahl's suggestions. They are good directions for continued research and development.