Loads on Ship Hulls - Workshop on North American Experience

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ICE LOADS ON SHIP HULLS
Workshop on North American Experience

R. Frederking

Technical Report CHC-TR-01

January, 2002

CHC CANADIAN HYDRAULICS CENTRE
CENTRE D'HYDRAULIQUE CANADIEN

ICE LOADS ON SHIP HULLS
Workshop on North American Experience

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Technical Report
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ABSTRACT

A group of 20 people met for two days in a workshop format to review the state-of-art on ice loads on ship hulls. Measurement methodologies as well as the results of about 15 field trials in which Canada and/or the United States played a major role were reviewed, and the completeness and availability of the data assessed. Needs for ice loads R&D were reviewed and gaps in data and analysis identified. Future directions for R&D and priorities were identified. In addition to this record of the Workshop, presentations and comments by participants are included in 20 files in pdf format on an included CD.

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1. INTRODUCTION

Since 1980 there have been a number of projects in which ships have been instrumented to measure hull ice loading. In some cases instrumentation was applied to a small area of the bow to measure local and possibly global loads. In other cases the hull girder was instrumented to measure global loads. Lately vessel motions have been measured with a view to relating them to ice loading. The measurements made during vessel field trials during the 1980s played a key role in the revision of the Arctic Shipping Pollution Prevention Regulations (ASPPR) in the early 1990s. More recently the International Maritime Organization (IMO) Guidelines for Ships in Ice-Covered Waters has spawned a set of Polar Ship Unified Requirements (UR) prepared for the International Association of Classification Societies (IACS). Data collected from ship trials since the 1980s were used in formulating the UR. Transport Canada has supported much of the R&D that was conducted in Canada and elsewhere.

It was deemed useful to review the current state of knowledge and determine what future directions might be pursued for R&D on ice loading on hulls. This is in the context of Canadian requirements and preparatory to possible participation in international collaborative R&D in the area. The means for doing this review was a two-day workshop organized by the National Research Council on behalf of Transport Canada. The objectives were to (i) review and inventory the work done on measurements of ice loads on ship hulls from various trials conducted over the past two decades, (ii) identifying data or analysis gaps and (iii) indicate R&D which might be necessary to meet current and future requirements of Transport Canada and the marine sector of Canada.

2. SUMMARY OF PROCEEDINGS

2.1 ATTENDEES

A list of workshop attendees, affiliations and contact information is provided at Annex A.

2.2 AGENDA

2.2.1 The overall agenda for the workshop is shown at Annex B. The order of presentations shown for Day 1 was rearranged to allow for travel alterations, but all scheduled presentations were made. Copies of the materials presented are included on the CD-ROM attached to this report and are indexed in Annex C. Questions and answers directly associated with each presentation have not been minuted directly, but were in general recapitulated in the discussions during Day 2 which are outlined below.

2.2.2 The Day 2 Agenda was not adhered to rigidly, as the discussions were free-flowing. Significant issues are consolidated under the headings below, which encompass, but are not limited to the main points from the Agenda.

2.3 NEEDS ANALYSIS

2.3.1 It was generally agreed that prior to any other discussion it was necessary to review the probable future needs for ice loads R&D. Possible needs include code development for safety and environmental protection, support of sustainable development, and promotion of Canadian innovation and expertise.

2.3.2 Areas in which new challenges exist or are anticipated in the near future include:

- Operation of lower ice class ships and ships with no ice strengthening, notably in:
  - the East Coast (Labrador and Grand Banks)
  - the St. Lawrence Gulf and River
  - the Great Lakes and Seaway
  - Hudson's Bay
- Renewed operation of more ice-capable ships in the Beaufort Sea

2.3.3 It may be useful to formulate the safety and performance requirements for these types of operations in a common framework, to identify those elements that are common and those that are more service specific.

2.3.4 It was noted that current Transport Canada (TC) policy does not include the extension of 'Arctic-type' regulatory systems to ice-covered waters South of 60^o; however other mechanisms such as Guidelines and Standards could be developed. Environmental impact reviews, which must form a part of any new development initiatives require that shipping components be considered. TC requires the tools to allow this work to be undertaken in a meaningful way.

2.3.5 A number of guidelines for operations in ice-covered waters South of 60^o do exist, but are obsolete. This includes the Joint Industry-Coast Guard Guidelines (JIGS) for tanker operations and guidelines related to passenger vessels and ferries. See reference to these two documents in Appendix C.

2.4 DATA GAPS

2.4.1 Many participants noted that most local load data is confined to the bow area and work is needed to put loads on other hull areas on a more rational basis. Traditional hull area factors are implicitly based on certain operating scenarios that may not be appropriate to many future operations. Similarly, they may not be appropriate to all sizes and configurations of ship. Data should be collected for midbody and stern areas and for other parts of the hull assumed to be at risk.

2.4.2 Some specific issues where better data/models are needed include pressure loads on the side shell (especially for the lower ice class ships noted in 2.3.2), and the extension of current impact load models to cover vertical bows and non-infinite ice features (area and thickness).

2.4.3 Dedicated trials data are essential to the collection of high-quality data that can clarify the physics of ship/ice interactions but two other types of data collection may warrant more attention. These are the collection of statistical data over long periods of actual operation, and the collection of better quality damage data. In both areas, different philosophies of data collection are required and some regulatory/administrative changes may be required to facilitate collection efforts. These might include (for example) mandating the use of voyage data recorders for certain types of operation, and changing the reporting requirements for certain types of damage.

2.4.4 The types of instrumentation needed to fill data gaps were discussed. A frequent problem area is ice data. For dedicated trials, the ice needs as much attention as the structural side. For longer term trials, where on-ice work is less practical, techniques such as remote sensing and over-the-side video need to be used. Both dedicated and longer-term measurements can be facilitated by building-in suitable sensors at the construction or refit stages of ice capable vessels. These should be given some level of redundancy, and an allowance should always be made for the degradation that is likely to occur in service both to the sensors and to the data collection systems. The latter need to be automated and designed for minimal intervention for maintenance and for data download. Such efforts obviously require long-term collaborative relationships with the shipowners.

2.4.5 The uses and limitations of data collected from icebreakers received attention. Icebreakers are lower displacement and higher rigidity ships than almost all commercial vessels. Loads deduced from their responses will not always be relevant to other ships, and can certainly not be extrapolated with great confidence to much higher displacements. The greater manoeuvrability of icebreakers (and the size difference) may also limit the reliability of hull area factor comparisons.

2.4.6 A very important area in which more data are required relates to human factors. Actual risk in cases where dangerous ice is present is strongly related to voyage planning, quality and timeliness of ice information, and the ability of navigators to identify this ice and to avoid it or reduce impact severity by temporary speed reductions or course changes. Both long-term data collection and other tools such as ice navigation simulation can be used to quantify the parameters involved.

2.4.7 The question of safe speeds in ice and 'ice passports' was discussed; this relates to many of the subjects outlined above. The concept of the ice passport as an aid to operational safety was generally endorsed but more work is needed to put it on a scientific basis. The Ice Regimes Database compiled at the Canadian Hydraulics Centre

(CHC), in support of developing a scientific basis for the Arctic Ice Regime System (AIRS), is a source of data that can aid this endeavour.

2.5 ANALYSIS GAPS

2.5.1 On both days of the workshop it was noted that much of the data collected in previous dedicated trials has not been analyzed fully and/or in ways that allow easy comparisons between data sets. Examples include the early Louis trials, for which the accelerometer data was not fully processed, the Polar Sea/Star data, where only some incidents are partially captured, the M.V. Arctic 1984 trials, where the local strain gauges were never analyzed in detail, and the Louis 1995 trials, where no analysis at all has been undertaken. Another potential source of useful data is the US work on Great Lakes winter navigation, undertaken in the late 1970s by the University of Michigan. The Arctic Institute of North America and the CHC have considerable amounts of data in more or less accessible formats.

2.5.2 In a number of these cases the original records are stored on obsolete media and should be transferred onto modern systems before the experience and equipment required is completely lost. This problem is most acute in the pre-1983/4 period, where most records were originally in analogue form.

2.5.3 It was noted that Program for Energy Research and Development (PERD) funds have been assigned to continue the analysis of the 2001 Bergy Bit impact trials with the “Terry Fox”. Results from this program will be kept confidential for two years due to the commercial involvement, but will be made available for regulatory safety needs in the interim period.

2.5.4 The approach for the design of the shuttle tankers for the Grand Banks was based on the use of ASPPR, IACS Rules and guidance from CSA S471 with regard to likely occurrence of glacial ice impacts. Analysing Arctic ice load data and putting it in a probabilistic format has allowed its application to various exposures for CACs, and shuttle tankers and FPSOs in the sub-Arctic ice of the Grand Banks. This probabilistic framework could be used to analyse additional load data. Steel ductility and membrane action provided a safety reserve. Membrane action merits further attention in safety/reliability.

2.5.5 There were extensive discussions on the nature, suitability and application of “pressure-area” relations. The results of analysing data on this basis can lead to apparent contradictions.

2.6 OTHER R&D PROGRAMS AND OPPORTUNITIES

2.6.1 The Workshop was given an overview of the evolving situation regarding the European Union (EU) 6th Framework program for R&D. A focus of this framework is the development of R&D networks that extend beyond EU countries. Unlike the previous frameworks, this one is expected to facilitate greater collaboration with non-EU countries such as Canada. It has not yet been determined how the Canadian side of such cooperation will be managed, but it is anticipated that lead agencies will be designated in each main technical area.

2.6.2 Some approaches have already been made to TC by Finland suggesting future cooperation. It was noted that two important considerations that should be borne in mind are reciprocity (in areas of real common interest) and the need to maintain Canadian leadership where the needs and expertise are primarily Canadian.

2.6.3 The relationships between Canadian and Baltic requirements were discussed. Some participants were of the opinion that the Baltic Rules may provide a framework for future ice loads work. Others felt that the Baltic experience is invaluable, but that the principles underlying the current system represent a different scientific approach and are not easily amenable to improvement. There are also considerable political problems inhibiting progress, due to the sensitivity of both government and industry to change. On the other hand, the existence of obsolete versions of the Baltic Rules within the Canadian regulatory system needs to be addressed.

2.6.4 Other R&D programs within Canada were reviewed to the extent that the knowledge of those present allowed. The Program of Energy Research and Development (PERD) programs on Marine Transportation and Offshore Safety, and on Transportation Efficiency were mentioned. R. Frederking can be contacted about these PERD programs. DFO/CCG has a number of R&D programs which are outlined in a report available from DFO HQ (W. Ellwood). It was noted that DFO (Institut Maurice Lamontagne) is lead agency for a major project on ice navigation in the St. Lawrence which seems to be somewhat decoupled from other ice R&D. IMD could offer no information on its future research directions in this specific field other than the continuation of the bergy bit work. The Ice Navigation Simulator has entered the verification phase at the Marine Institute in St. John's, with continuing development of the Ice Navigators course supported by TC. The Simulator may be a useful vehicle for operations research as well as a training tool.

2.6.5 Some other projects and programs that could provide vehicles for cooperative R&D were discussed. These include the coming need for new shuttle tankers for the White Rose project, the activities off Sakhalin and in the Caspian Sea, and initiatives in the Baltic such as the development of the new St. Petersburg oil terminal.

2.7 FUTURE DIRECTIONS AND PRIORITIES

A large number of suggestions were made by Workshop participants, related to and in addition to the themes and geographical priorities outlined above. The list below focuses initially on those items that were identified by several participants.

2.7.1 The need to 'rescue' data sets from the Polar Class vessel trials, etc. was generally supported. Work should be undertaken to quantify the costs associated with this and to identify potential partners, such as USCG and industry.

2.7.2 Work related to improving hull area factors was recommended by many participants, particularly as this relates to lower ice class, large commercial vessels. This may involve better definition of loading scenarios, such as side shell pressure.

2.7.3 Future bow loads work should focus on increasing the accuracy of load models for upright (or lower ice class) bow forms, and also for level icebreaking loads.

2.7.4 Long-term statistics on ice loads should be collected both to support the previous 2 items and to help in the development of risk models for operational safety. This would also provide a risk basis for AIRS.

2.7.5 Simple, easy to maintain instrumentation for unattended monitoring of ship hull response and ice conditions was identified as a means of facilitating the previous item.

2.7.6 In a dedicated trial as much attention should be addressed to gathering high quality ice information before, during and after each ice loading event as to hull structure responses.

2.7.7 The use of simulation should be considered to supplement statistics and risk analysis.

2.8 NEXT STEPS

Based on the workshop, the following immediate actions are suggested:

2.8.1 Compile a complete inventory of trials data and analysis identified during the workshop and prepare a list of actions and costs that would ensure the integrity and conversion, as necessary, of such data.

2.8.2 Communicate findings of this workshop to the PERD Programs at Objective Level (POL) that support research in related areas; 1.2.3 "Marine Transportation and Offshore Safety" and 2.2.4 "Optimization of the Energy Efficiency of Transportation Systems" so that the findings can be used in the development of POL R&D plans.

2.8.3 Participate in the proposed international meeting to discuss the scope and extent of collaborative research in the general area of ships in ice and more specifically on ice loads on ship hulls.

3. ACKNOWLEDGEMENTS

The assistance of Andrew Kendrick in summarizing the record of the Workshop is acknowledged. Cover photo is from the Bergy Bit Impact Study, compliments of Bob Gagnon IMD/NRC.

Annex A

Workshop Attendees

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*	regrets, but submitted written contribution
**	participated by teleconference
***	part-time attendance

Annex B

Final Program

Ice Loads Workshop – North American Experience
Ottawa, Marriott Hotel, Wellington Room (3rd floor)
100 Kent Street (at corner with Queen)
November 8-9, 2001

Day 1 Introduction and Objectives (start 0900)

Review of Data Available

1) Measurement systems
   a. Local loads
      i. Strain gauges on frames (Ron)
      ii. Special sensors (Bob G)
   b. Global loads
      i. Strain gauges on hull girder (Andrew)
      ii. Inertial (Michelle)
2) Trials Results
   (brief description of location, time, ice conditions, measurement methods, data, analysis, conclusions, data archived)
   a. Louis (1977,1980) (Ian G)
   b. Canmar Kigoriak (1981) (Merv)
   c. Polar Sea/Star (1981-86) (Claude)
   d. M.V. Arctic (1984) (Andrew)
   e. M.V. Arctic (1986+) (John)
   f. Oden (1991) (Ron)
   g. Louis (1994) (Ron)
   h. Palmer (John)
   i. Healy (2000) (Alfred)
   j. Louis (2000) (Michelle)
   k. Terry Fox (2001) (Bob G)

Day 2 Where do we go from here (start 0900)

1) Data Gaps
2) Analysis Gaps
3) Relation to EU (6th framework) and other R&D programs
4) Requirements for Codes
   a. ASPPR (Equivalent Standards)
   b. Unified Requirements (IACS)
5) Other Requirements
6) Future R&D directions

Adjournment (1500)

Annex C

Index of Files on CD

(If CD is not with report, contact Robert.Frederking@nrc.ca).

Measurement systems

Local loads:

Strain gauges on frames	Ritch_Local_Loads_Using_Strain_Gauges.pdf
Special sensors	Gagnon_Impact_Panel.pdf

Global loads:

Strain gauges on hull girder	Kendrick_Hull_Girder.pdf
Inertial	Johnston_MOTAN.pdf

Trials Results:

Louis (1977,1980)	Glen_Louis_Probe.pdf
Canmar Kigoriak (1981)	Edgecomb_CANMAR_Ship_Ice_Rearch.pdf
Polar Sea/Star (1981-86)	Daley_Polar_Sea.pdf
M.V. Arctic (1984)	Kendrick_1984ARCTIC.pdf
M.V. Arctic (1986+)	----------
Oden (1991, 96)	Ritch_Oden_1991_Trials.pdf
	Ritch_Oden_1996_Trials.pdf
Louis (1994, 95)	Ritch_LSSL_1994_Trials.pdf
	Ritch_LSSL_1995Trials.pdf
Palmer	----------
Healy (2000)	Tunik_Comments.pdf
Louis (2000)	Johnston_Louis.pdf
Terry Fox (2001)	Gagnon_Bergy_Bit.pdf
	Ritch_Terry_Fox_Strain_Gauge_Panel.pdf

Analysis

Oden and Louis data	Browne_Analysis.pdf
Shuttle Tanker Design	Allan_Design_Specification.pdf
Comments on Data Use	Jordaan_Notes_Loads_Ship_Hulls.pdf
Pressure-Area-Force	Daley_Pressure_Area_Question.pdf

Support documents

JIGS Joint Industry-Coast Guard Guidelines for the control of Oil Tankers and Bulk Chemical Carriers in Ice Control Zones of Eastern Canada, Amendment No. 8, June 1995

JIGS_Tankers.pdf

Interim Standard for the Construction, Equipment and Operation of Passenger Ships in the Sea Ice Areas of Eastern Canada, Transport Canada TP 8941 E, 1987

on Transport Canada web site:
http://www.tc.gc.ca/Marine Safety/Directorate/tp/TP8941/TP8941E.htm

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R. Frederking</td></tr>
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<tr><td colspan="6">CORPORATE AUTHOR/PERFORMING ORGANIZATION/
AUTEUR D'ENTREPRISE/AGENCE D'EXÉCUTION

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A workshop reviewed the state-of-art of ice loads on ship hulls. Measurement methodologies as well as the results of 15 field trials were reviewed, and the completeness and availability of the data assessed. Needs for ice loads R&D were reviewed and gaps in data and analysis identified. Future directions for R&D and priorities were identified.</td></tr>
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15. Supplementary Notes - Remarques additionelles	16. Project Officer - Agent de projet: V. Santos-Pedro

17. Abstract - Résumé

A group of 20 people met for two days in a workshop format to review the state-of-art on ice loads on ship hulls. Measurement methodologies as well as the results of about 15 field trials in which Canada and/or the United States played a major role were reviewed, and the completeness and availability of the data assessed. Needs for ice loads R&D were reviewed and gaps in data and analysis identified. Future directions for R&D and priorities were identified. In addition to this record of the Workshop, presentations and comments by participants are included in 20 files in pdf format on an included CD.

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