Simulation-based design for sustainable development of Arctic maritime industry

Japan-Norway Arctic Science and Innovation Week 2016
Tokyo, Japan, June 2-3, 2016.

Professor Roger Skjetne
Professor Sveinung Løset
Norwegian University of Science and Technology

Illustration: Bjarne Stenberg. Copyright: NTNU.
Motivation for sustainability

The Arctic is indeed valuable, but it is also vulnerable.

Damage of a chemical tanker’s plating caused by multi-year ice (Hanninen, 2005)

This may explain the extreme public scrutiny towards any field development in the Arctic. This also demonstrates the need for reliable and trustworthy tools and procedures to verify the designs of Arctic structures and operations.

Courtesy: Raed Lubbad
Drivers for Arctic industries

• Main drivers:
  – Oil and gas
  – Mining
  – Shipping

• Contributing industries:
  – Fisheries
  – Aquaculture
  – Tourism
  – Scientific research
  – Military

The Arctic is likely to attract substantial investment over the coming decade, potentially reaching $100bn or more. There is a wide range of potential scenarios for the Arctic’s economic future, depending principally on local investment conditions and global commodity prices. Oil and gas, mining and the shipping industries will be the biggest drivers and beneficiaries of Arctic economic development. Industries supporting these activities, such as fisheries, aquaculture, tourism and scientific research, could also contribute to the longer-term economic sustainability of Arctic communities. Based on current trends, expected investment in the Arctic could reach $100bn or more over the next decade. However, given the high risk/potentially high reward nature of Arctic investment, this figure could be significantly higher or lower.

Courtesy: FBI factbook
Activities in the Arctic

- Main drivers:
  - Oil and gas
  - Mining
  - Shipping

- Contributing industries:
  - Fisheries
  - Aquaculture
  - Tourism
  - Scientific research

The Arctic is a fragile environment and all operations require strict planning and risk minimization.
Motivation for sustainability

The fishing vessel Saputi is now on route to Nuuk, Greenland, after striking ice and taking on water Sunday night. All 15 crew members are safe. (Nataaqnaq Fisheries)
ArcISo – an NTNU spin-off

Simulator for Arctic Marine Structures (SAMS) is based on:
• Arctic marine experience gathered over 3 decades
• Data acquired from more than 20 projects and 20 man-years

✓ **Vision**
  Pioneering sustainable development of Arctic marine activities.

✓ **Business Idea**
  Safer and more profitable Arctic marine activities through assessment of structure designs and operational procedures, and delivery of decision support tools using superior sea-ice simulation technology.

✓ **Mission**
  Securing the integrity of your Arctic operations.
ArcISo – an NTNU spin-off

Simulator for Arctic Marine Structures (SAMS) is based on:
• Arctic marine experience gathered over 3 decades
• Data acquired from more than 20 projects and 20 man-years

✓ Vision
Pioneering sustainable development of Arctic marine activities.

✓ Business Idea
Safer and more profitable Arctic marine activities through assessment of structure designs and operational procedures, and delivery of decision support tools using superior sea-ice simulation technology.

✓ Mission
Securing the integrity of your Arctic operations.
## Team

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dr. Raed Lubbad</strong></td>
<td>Ass. Professor Arctic Marine Technology; Ice-structure interaction, Multi-body dynamics.</td>
<td></td>
</tr>
<tr>
<td>Palestine</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dr. Sveinung Løset Sunnmøre, Norway</strong></td>
<td>Professor Arctic Marine Tech.; Dir. of SAMCoT, Ice-struct. interaction. Awarded best dr. thesis at NTH, 1993.</td>
<td></td>
</tr>
<tr>
<td><strong>Dr. Roger Skjetne Stord, Norway</strong></td>
<td>Professor Control Systems; Electrician Aker Elektro, Product manager Marine Cybernetics. Awarded best dr. thesis at NTNU, 2005.</td>
<td></td>
</tr>
<tr>
<td><strong>Dr. Andrei Tsarau Belarus</strong></td>
<td>Postdoc; Hydrodynamics in icy waters; Propeller wash, ice in waves.</td>
<td></td>
</tr>
<tr>
<td><strong>Dr. Øivind Kjerstad Sunnmøre, Norway</strong></td>
<td>Postdoc; Marine Control Systems; Onboard systems, Simulation technology, Ice surveillance.</td>
<td></td>
</tr>
<tr>
<td><strong>Mr. Marnix v.d. Berg Netherlands</strong></td>
<td>PhD candidate; Multi-body dynamics, ridge-structure interaction.</td>
<td></td>
</tr>
</tbody>
</table>

(6/7 located in Trondheim)
Period: 2011-2019
Research Partners: 8
Industry Partners: 13
Governmental Partners: 2
Turnover to date: 193 MNOK
Number of PhDs: 24
Number of PostDocs: 5
CRI/SFI - RCN
NTNU Host Institution
Arctic drivers

- **Main drivers:**
  - Oil and gas
  - Mining
  - Shipping

- **Contributing industries:**
  - Fisheries
  - Aquaculture
  - Tourism
  - Scientific research

The Arctic is likely to attract substantial investment over the coming decade, potentially reaching $100bn or more. There is a wide range of potential scenarios for the Arctic’s economic future, depending principally on local investment conditions and global commodity prices. Oil and gas, mining and the shipping industries will be the biggest drivers and beneficiaries of Arctic economic development. Industries supporting these activities, such as fisheries, aquaculture, tourism and scientific research, could also contribute to the longer-term economic sustainability of Arctic communities. Based on current trends, expected investment in the Arctic could reach $100bn or more over the next decade. However, given the high risk/potentially high reward nature of Arctic investment, this figure could be significantly higher or lower.

2020 Arctic business scenarios:

1. **Oil in demand – Arctic take-off.**
2. **Green transformation – Arctic tranquillity**
3. **Re-freeze – Arctic East-West division.**
There is a need to establish sets of common, enforced standards in all industries targeting Arctic business in order to enable designers to develop safe and cost effective solutions that meet acceptance of the society for operating in this pristine environment.

Currently, it is difficult to prove the reliability of structures, and the feasibility and safety of marine operations in the Arctic, to authorities and the public.
Full scale experiments

- Great validity
- Highly limited parameter control
- Limited scenario control and test matrix
- Tedious in planning and execution
- Extremely expensive

Courtesy: OATRC15
State-of-the-art

Kinematic based simulation
(Hamilton et al., 2011a &b)
Model scale experiments

- Widely used
- Good parameter control
- Limited scenario control and test matrix
- Tedious in planning and execution
- Relatively expensive

Courtesy: DYPIC
ISO 19906 Arctic Offshore Structures standard

<table>
<thead>
<tr>
<th>Ice scenario</th>
<th>Fixed structures</th>
<th>Floating structures</th>
<th>Artificial islands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>vertical</td>
<td>conical or sloping</td>
<td>multi-legged</td>
</tr>
<tr>
<td></td>
<td>wide</td>
<td>narrow</td>
<td>ship-shaped</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>spar / buoy vertical</td>
</tr>
<tr>
<td>FY level</td>
<td>A.8.2.4.3</td>
<td>A.8.2.4.4</td>
<td>A.8.2.4.3</td>
</tr>
<tr>
<td></td>
<td>A.8.2.4.10</td>
<td>A.8.2.4.4</td>
<td>A.8.2.4.3</td>
</tr>
<tr>
<td></td>
<td>A.8.2.4.10</td>
<td>A.8.2.4.4</td>
<td>A.8.2.4.3</td>
</tr>
<tr>
<td>FY ridges</td>
<td></td>
<td>A.8.2.4.4</td>
<td>A.8.2.4.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A.8.2.4.10</td>
<td>A.8.2.4.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A.8.2.4.10</td>
<td>A.8.2.4.4</td>
</tr>
</tbody>
</table>
The determination of ice actions depends on the selection of the interaction scenario.

To setup a scenario, the designer will have to make a choice of:

- Ice feature
- Limiting mechanism
- Failure mode
Question

How to characterize a managed-ice field (or a naturally broken-ice field)?
How to characterize a managed-ice field (or a naturally broken-ice field)?

Answer:

- A single-feature representation of a managed-ice field is often insufficient. ArcISo’s complete description includes:
  - Floe size distribution
  - Ice concentration
  - Lateral pressure
  - Ridge frequency
  - etc.
What is the limiting mechanism when dealing with a managed-ice field?
What is the limiting mechanism when dealing with a managed-ice field?

Answer:

- In fact, the 3 limiting mechanisms coexist during the interaction between managed-ice and offshore structures.

- It is a very challenging exercise to identify the limiting mechanism that will cause the highest load on the structure. This is because the processes are nonlinear and the outcome depends strongly on the initial and boundary conditions, driving forces, structure response, etc.

This gives us no choice but to go for time-domain analysis.
Full-scale observations of interaction processes

Major physical interaction processes:
- Novel theory developed based on 1st principles
- Numerical implementation
- Continuously > 6 man-years input
- Full-scale data for observing phenomena and validating models
Simulator characteristics

Time-domain simulations

- Full parameter control
- Full scenario control
- Replicability
- Flexibility
- Cheap
Simulation-based design

Example
Design and assessment of an Arctic stationkeeping system for a research vessel
Examples of what to assess?

CAPABILITY
- Structural dimensioning
- Stationkeeping sys.
- Operation design
- Crew competence

LOAD STATISTICS
- Ice load statistics
- Impact loads from unhandled ice features

ICE DYNAMICS
- Ice fracture patterns
- Ice transport
- Wave propagation

COMPARISON
- Strategy of operation
  - Single or multi-vessel
- Conical vs. ship shaped

- an NTNU spin-off Company
Solution of Arc

A detailed and cost-efficient analysis and design review of concepts based on numerical simulations.
Products and value chain

ArcIsGo Technology Platform

SAMS Design

Oil Company or Arctic business developer

Ship Owner

Available ship matches specifications?

Yes

No

Fit-for-purpose

SAMS Design/Ops

SAMS Operation

SAMS Onboard

Shipyard

Conceptual design

Detailed engineering design

Classification

Classification

Classification

SAMS Design

Design Variation

Design Review

Model Tests

Vessel in operation

Operational analysis & optimisation

Operational training
## Value proposition

<table>
<thead>
<tr>
<th>Customer</th>
<th>Product/service</th>
<th>Value proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification societies</td>
<td>SAMS Design</td>
<td>The <em>SAMS Design</em> will be the state-of-the-art app for accurate calculations of loads and load effects from ice on a structure, which is essential for any class society for verification and classifications of Arctic structures.</td>
</tr>
<tr>
<td>Ship designers and consultancy companies</td>
<td>SAMS Design Expert review products</td>
<td>In addition to using <em>SAMS Design</em> to calculate ice loads, ship designers and consultancy companies can approach ArcISo for Expert review products without the need to have in-house ice mechanics competence. This will save considerable time and money during the design process.</td>
</tr>
<tr>
<td>Oil and gas companies and other Arctic business developers</td>
<td>SAMS Design Expert review products</td>
<td>In addition to using <em>SAMS Design</em> to calculate ice loads, the customer here can approach ArcISo to optimize concept design and document detailed engineering design, as well as planning complex operations. ArcISo aids customers in assessing feasibility and suitability of existing ships under consideration. In addition to considerable savings, this will be very useful to attain public trust and authorities permit to operate.</td>
</tr>
<tr>
<td>Contractors and ship-owners</td>
<td>Expert review products</td>
<td>Using <em>SAMS Operation</em>, ArcISo can identify operational hazards, aid in development of operational procedures, provide training and hazard awareness to crew, document the safety margins and fit-for-purpose of their ships/structures, and support optimized design of new ships/structures. This is very important to increase the overall safety and reliability.</td>
</tr>
</tbody>
</table>
IceMaker module
Examples of simulations from SAMS

Moored structure in drift ice

Ice in waves

Oil spreading in ice

Structure fracturing ice

Video