Recent advancements in ice model testing at Aker Arctic

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Abstract

The next generation ice model testing facility of Aker Arctic Inc. (AARC) was inaugurated in March 2006. The new facility is located in Helsinki at the Vuosaari Marine Business Park, next to the new Helsinki harbour. This facility is the third in the history of Aker Arctic starting in 1969 with Wärtsilä Ice Model Basin (WIMB).

Today the new facility has been in operation for three a half years. During this period quite a lot of learning and developing has taken place still even the transfer of the ice making happened quite well.

The new facility has also opened new possibilities.

The paper describes the new facilities and highlights the work done so far. Also among other things the further development possibilities of the AARC FGX model ice is discussed as well as new techniques in test methods.

Making of thick weak ice in the model basin has always been quite a problem. In this respect the enhanced use of AARC FGX ice has given new possibilities in testing. Firstly ice sheets with thickness close to 100 mm were prepared for the new Russian multipurpose icebreaker project to simulate full-scale level ice thickness of 2.85m. Recently model ice with thickness close to 240 mm with flexural strength of 10-20 kPa was manufactured.

The paper will discuss also the processes of making these thick/weak ice sheets.
History

The first ice model testing facility in Finland was established in 1969. That time Esso (Humble Oil) was looking for the possibilities to transport oil from north slope of Alaska to the market through Canadian Arctic Islands, Manhattan project. Esso initiated the building of the Wärtsilä Icebreaking Model Basin, WIMB; test facility in an underground tunnel (bomb shelter) in conjunction with the Manhattan project where Wärtsilä Ice breaking knowledge had a leading role. The experts of Wärtsilä were in charge both the model testing of the vessel and planning its modifications.

This first facility was intended to be a temporary one, but was successfully operated for 13 years till February 1983. In 1980 it was decided to design and build a new testing facility, Wärtsilä Arctic Research Centre, WARC. WARC was inaugurated on February 17, 1983. Simultaneously with the building process, also a project to make a new model ice (FGX), which would have better physical properties than the traditional saline ice, was started. In November 1989 the parent company changed to Masa-Yards and the name of the arctic centre was changed to MARC, Masa-Yards Arctic Research Centre. The property lease under MARC facility expired in 2005 and the construction of the new facility has started in January 2005. In January 2006 the calibration of the new facility started and commercial work started in March 2007.

New facility

The new facility is located in eastern Helsinki, in Vuosaari next to the new Helsinki harbour, where the Valmet Shipyard was operating in the seventies and eighties. The new AARC facility is located next to the new harbour at Vuosaari Marine Business Park. Figure 1 shows the location of the facility.
The area is quite ideal for such purpose. As the new harbour is ready, there will be excellent connections to the centre of city of Helsinki and Helsinki-Vantaa Airport. The old graving dock alongside to the new facility can still be utilized for docking of ships and research installations like strain gauges etc. can be handled at the facility, if needed.

The building of the new facility will follow the similar layout principle as the previous facility. The main principle views are in Figures 2. The main parameters of the test basin are in Table 1.

<table>
<thead>
<tr>
<th>AARC</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Water depth (m)</th>
<th>Water volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>75</td>
<td>8</td>
<td>2.1-2.2</td>
<td>1300</td>
</tr>
</tbody>
</table>

Figure 2. Layout of the new testing facility

**Basin**

The new basin is 8 meters wide throughout the whole length of the basin. The beam has been increased from the previous facility by 1.5 m to better enable maneuvering tests with ships and larger scales with structure tests. The material of the basin is steel.

One of the most important features in an ice model basin is the underwater visibility. In the new basin the side windows (8pcs.) will be wider and in the bottom of the basin there is a continuous window throughout the whole length of the basin.
These improvements enable better visualization of the tests.

The basin area is separated from the preparation/ice melt space and with vertically opened/shut curtain. A view to the basin is shown in Figure 3.

**Refrigeration system**
The new refrigeration system is based on completely new technique. Instead of cooling large amounts of coolant liquid, only 80 kg of freon is cooled and through a heat exchanger liquid CO₂ is cooled and circulated in the refrigeration elements.

In total four (4) cooling compressors with a total cooling power of 600 kW is installed. In the former facility there was only one compressor, which made it very difficult and uneconomic to at higher basin hall temperatures, say -6 °C. Also the new system will be automatic/remote controlled. Machinery arrangement is shown in figures 4.

**Carriages**
In the new facility there are two carriages:

- measurement/test carriage;
  - weight 34 tonnes, speed range 0-3 m/s, pulling force 18.8 kN
- ice treatment/ice making carriage;
  - weight 42 tonnes, speed range 0-1,5 m/s, pulling force 53.9 kN

The carriages are on rails up near the ceiling and the carriages are hanging like any gantry crane. This improved solution also enables better observations from the ice level from the sides of the basin. The features of the carriages are the following:

Both carriages are planned be moved in synchronous mode, one follows the other. Also both the carriages can be taken to the model outfitting area (warm space out from the cold) for installation of models and initial calibration. The measurement carriage is shown in Figures 5.
**Visual observations**

It was already mentioned about the windows around the basin. In addition there is a plan to adopt an online video link to the conference rooms from the cameras recording the tests. Views to the basin through windows are in Figures 6.

![Figure 5. Measurement carriage](Image)

![Figure 6. View through bottom and side windows](Image)

**Calibration of the new basin**

Testing and calibration of the basin and equipment took place in early March 2006.

The first part was to get all the equipment related to ice making process to function according to defined specification; water treatment, refrigeration system and carriages.

The ice making process was in fact adopted directly from the previous laboratory and thus when the conditions are similar, the ice produced follows quite well similar pattern. One of the key parameters is the smoothness of the ice sheet produced. In Figure 7 there are the thickness distribution examples of three different ice sheets of which the target thickness values were 19, 35 and 55 mm. The variation of thickness along the length of the basin is 1-3mm. The lower value is for the thinner ice. This variation is due to several items like functioning of the cooling elements in the ceiling, measuring method (manual) and distance from the over water gates. However, the results are very good and the ice sheet exceed the thickness evenness of the previous laboratory. Of course to keep it good, it needs to be tendered continuously.
The other interesting parameter is the transversal thickness distribution. This is affected by the same parameters as the longitudinal one added by the evenness of the spraying of the water into the air to form the fine grains which laminate the final thickness. The transversal evenness is due to the angles of the spray nozzles. The transversal profiles are in Figure 8. The example shows that there was some discrepancy in the thickness distribution when moving towards the sides of the basin, but very small with no significant effect.
The first model tested was AARC’s standard model of icebreaker Otso. IB Otso is the first new generation Baltic Icebreaker built in the middle of eighties. She has a twin propeller (open, fixed pitch) and rudder aft ship and in the waterline there is a stainless steel belt to keep the friction against ice small. IB Otso in action is in Figure 9.

Figure 9. Icebreaker Otso in the Baltic Sea

The test results in the new basin are in good agreement with the results gained in the full-scale ice trials and previous MARC basin. The calibration test results are shown in Figure 10 and test views in the new basin in Figures 11.

Figure 10. Calibration test results of IB Otso

Figure 11. Calibration test views of IB Otso

In early April after all the calibration, the basin was ready to start tests for projects.

4. Experience during the first three years

During the first year, altogether 80 ice test days was carried out (2005: 61 ice test days). The year started with oil spill tests in the old facility. During the first year 10% of the ice sheets done were consumed for calibration and ice development. During the second year the basin was primarily used for project testing. The selection of the tests (ice sheets produces) by type is in Table 2.
Table 2. Test types by test days at AARC in 2006 - 2009

<table>
<thead>
<tr>
<th>Test Type</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice class Tankers</td>
<td>38</td>
<td>21</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Icebreaking LNG carriers</td>
<td>20</td>
<td>9</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Icebreakers</td>
<td>5</td>
<td>13</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Offshore structures</td>
<td>6</td>
<td>20</td>
<td>27</td>
<td>14</td>
</tr>
<tr>
<td>Drillships</td>
<td></td>
<td></td>
<td>23</td>
<td>10</td>
</tr>
<tr>
<td>Oil spill (old basin)</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cargo vessels</td>
<td>1</td>
<td>13</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Calibration/ice development/R&amp;D</td>
<td>8</td>
<td></td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Offshore service vessels</td>
<td>3</td>
<td>9</td>
<td>12</td>
<td>28</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>80</strong></td>
<td><strong>77</strong></td>
<td><strong>110</strong></td>
<td><strong>101</strong></td>
</tr>
</tbody>
</table>

In Figures 12 there are some views of the tests during first operational year.

![Figure 12. Test views](image1.jpg)  
![Figure 12. Test views](image2.jpg)  
![Figure 12. Test views](image3.jpg)  
![Figure 12. Test views](image4.jpg)

Also during the first year preliminary testing took place to further develop the AARC FGX-model ice. This work continued in 2007.

Traditionally the limits of the FG and FGX model ice are shown in Figure 13 (Nortala-Hoikkanen 1990), where the practical upper limit for ice thickness is 90mm.
In spring 2007 there was a request to simulate 2.85 m thick level ice for the new multipurpose nuclear icebreaker project for JSC AISBERG, St. Petersburg, Russia. Due to the scale factor of the model it resulted to be 90mm in model scale. In these tests it was the first time as the former limit in thickness was approached in the new facility.

The ice manufacturing was a success, without any problems, resulting in thickness 90 mm with flexural strength of 18 kPa, which is really weak but brittle. Views of the tests are in Figure 14.

Encouraged by this success it was decided to try to extend the limits of the FGX ice and ice thicknesses around 150, 200 and 230 mm were produced with flexural strength under 20kPa. The extended graph of flexural strength and ice thickness is in Figure 15.
Figure 15. Extended limits of FGX model ice manufacturing

The manufacturing time of thick ice will be of course longer. In table 3 there are the rough times for making different thicknesses.

Table 3. Ice preparation time vs. thickness

<table>
<thead>
<tr>
<th>Ice thickness mm</th>
<th>Preparation time prior testing (hours)</th>
<th>Number of Ice sheets/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 - 60</td>
<td>5 - 16</td>
<td>4</td>
</tr>
<tr>
<td>60 - 90</td>
<td>14 - 24</td>
<td>2-3</td>
</tr>
<tr>
<td>90 - 120</td>
<td>24 - 50</td>
<td>2</td>
</tr>
<tr>
<td>120 - 200</td>
<td>50 - 70</td>
<td>1-2</td>
</tr>
</tbody>
</table>

Development work

Due to progressive long term trend in oil price and identification of huge hydrocarbon reservoirs in the arctic waters, the interest of industry towards the Arctic has significantly increased during the recent years. Compared to open water conditions, the Arctic offshore conditions are however significantly more challenging and therefore the offshore concepts initially designed to the open water can not be directly applied to the Arctic. Severity of operations in the Arctic have some times been compared to the operations in ultra deep water. Of course the challenges are quite different. In this respect the demand of operation concepts, not just one element but the whole fleet, which are capable to operate safely and efficiently in harsh arctic conditions has also increased.
Aker Arctic is carrying out the R&D program to develop ship-shaped floater concepts, which are specially designed to match with these challenging arctic requirements without losing significantly their open water performance.

The overall duration of the programme is c. two (2) years.

The development work has three main parts:

- Means for self ice management
  - Icebreaking stern
  - Open water bow with increased ice capability, vertical tunnel thruster
  - Open water bow with increased ice capability, horizontal azimuth thrusters
- Underwater mooring system
- Ice management fleet development

**Means for self ice management**

The concept development include one stern shape, that could be used as a bow in ice conditions and one bow shape, which can be used in both open water and ice conditions. The bow has been in addition equipped with propulsion to be adjustably directed towards ice at the waterline level.

Functionality of the designed concepts are being verified by model tests. The fundamental idea of these stern and bow designs are described below.

**Concept 1: Icebreaking stern:**

The vessel operates stern ahead in ice conditions (“i.e. “icebreaking-mode”) and bow ahead in open water conditions (i.e. “open water-mode”). The stern area of the floater (Figure 16) is designed to minimize the ice loads. Reduce in ice loads is achieved by innovative propulsion and stern form solution. The bow of the floater can be fully optimized for open water conditions.

**Figure 16. Icebreaking stern**

**Concept 2: Open water bow with increased ice capability, vertical tunnel thruster:**

The vessel operates bow ahead in open water and in ice. Ice breaking capability of the open water capable bow (Figure 17) is achieved by an innovative arrangement having a vertical tunnel thruster disturbing the ice cover from underneath without loosing significantly the open water characteristics. Moonpool/turret can be located flexibly in the area between the midship and bow allowing proper weather vaning capability in open water and in ice. If required, the stern can be designed for improved orientation control in ice.
Concept 3: Open water bow with increased ice capability, horizontal azimuth thrusters:

In this variant the water flow around the bow for breaking/disturbing ice is arranged by placing azimuth thrusters horizontally to both sides of the bow, Figure 18.

Underwater mooring system
System compromises from underwater carriage device with spring controlled multiple mooring lines, Figure 19. With different spring constants the realistic line forces can be modelled accurately with offset values of interest.

Underwater carriage can be moved towards ice and moored floating structures can be simulated in moving ice conditions. The development and investment has already proved successful and commercial tests have been carried out. Together with Qualisys location system (Figure 20) the set up provides excellent possibilities to study the mooring forces and the movement of the model to get mooring offsets.
The model tests performed so far were done to verify and improve the above mentioned designs. In this paper the early results and views are discussed regarding ice loads and ice behaviour (ice drifting to the moonpool/turret area). In addition, station keeping capability (associated to DP and mooring), effects of thrusters and ice management as well as future steps in development of these concepts are discussed.
Ice management fleet development

In the development work one area has been to deal with managed ice, which will in later stage involve ice management vessels and the system will be studied as a whole, even the floater has some ice management capability of its own. The vessel concepts developed will be based on practical experience in ice management operations.

The final goals of the whole development programme are to study, learn and improve:

- self exited ice management practices
- the understanding of the modeling of mooring operations in ice
- requirements for both ice management fleet and the defended vessel

5. Conclusion

The new facility is working extremely well and all the results so far on the capability in making thicker ice with scaled ice properties are very promising.

This new development has of course just started and there are still a number of issues to be solved. The number of thick sheets done so far is quite limited and more data is needed on the different phases of the process to properly be able to make thick weak ice.

The first test series in the floater development was done in spring 2009 and the tests are being analyzed. Early test results are ready during summer 2009. Further tests are planned to be carried out during autumn 2009. The development of ideas around the ice management vessel alone/together with the floater are being developed and tested in early 2010

References

Nortala-Hoikkanen, A., 1990. FGX model ice at the Masa-Yards Arctic Research Centre, IAHR Ice Symposium, Espoo, Finland