Aker Arctic
The Ice Technology Partner

Arctic Passion News

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- Xue Long 2 sea trials successfully completed
- New LNG bunkering vessel concept
- Boris Sokolov tested in arctic ice
- Ice Load Monitoring System installed

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Front cover

China's first domestically built icebreaking research vessel, *Xue Long 2*, successfully completed her sea trials in June this year, where all design requirements were verified. She was delivered in July at the Jiangnan Shipyard in China and will in October depart for her maiden voyage to Antarctica, where the full-scale ice trials will take place. Read more on page 4.

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17 – 20 September	NEVA 2019, St. Petersburg, Russia
01 – 04 October	RAO/CIS Offshore, St. Petersburg, Russia
16 – 17 October	AECO's Arctic Cruise Conference, Oslo, Norway
29 – 31 October	Arctic Shipping Forum North America, Montreal, Canada
03 – 06 December	Marintec China, Shanghai, China

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Arctic Passion News 2 / 2019

Dear Reader,

You are holding the fresh issue of our bi-annual magazine where we aim to keep you updated on our customer projects as well as the latest technical developments in the field of icebreaking vessels.

For decades, Aker Arctic has focused

on the design and construction of icebreaking vessels. Many complex systems, that are not common to typical open water vessels, are needed to ensure these vessels can operate efficiently and independently.

For example, icebreaking vessels need sophisticated propulsion systems for increased manoeuvrability, special paint and heeling systems to reduce the friction between the hull and the ice and advanced heating and insulation systems to withstand the cold environment.

Additionally, there are essential services such as ice model testing and full-scale ice testing (sea trials in ice) to verify the performance of the vessel. These trials include scientific measurements of ice properties, assessing the vessel's technical performance and understanding the practical operation of the ship in ice.

An exceptional number of ice trials

were held during the past winter season in both the Baltic Sea and the Russian Arctic, many of them performed by us. You can read about them in this issue. We have several articles to tell you about the technology used in ice trials and how measurements are completed.

Full-scale ice trials are one of the final stages of the design of an icebreaker. At Aker Arctic, we provide services for all aspects of the design and construction phases of an icebreaking vessel. We believe in an integrated design approach where communication between key stakeholders is continuous and open.

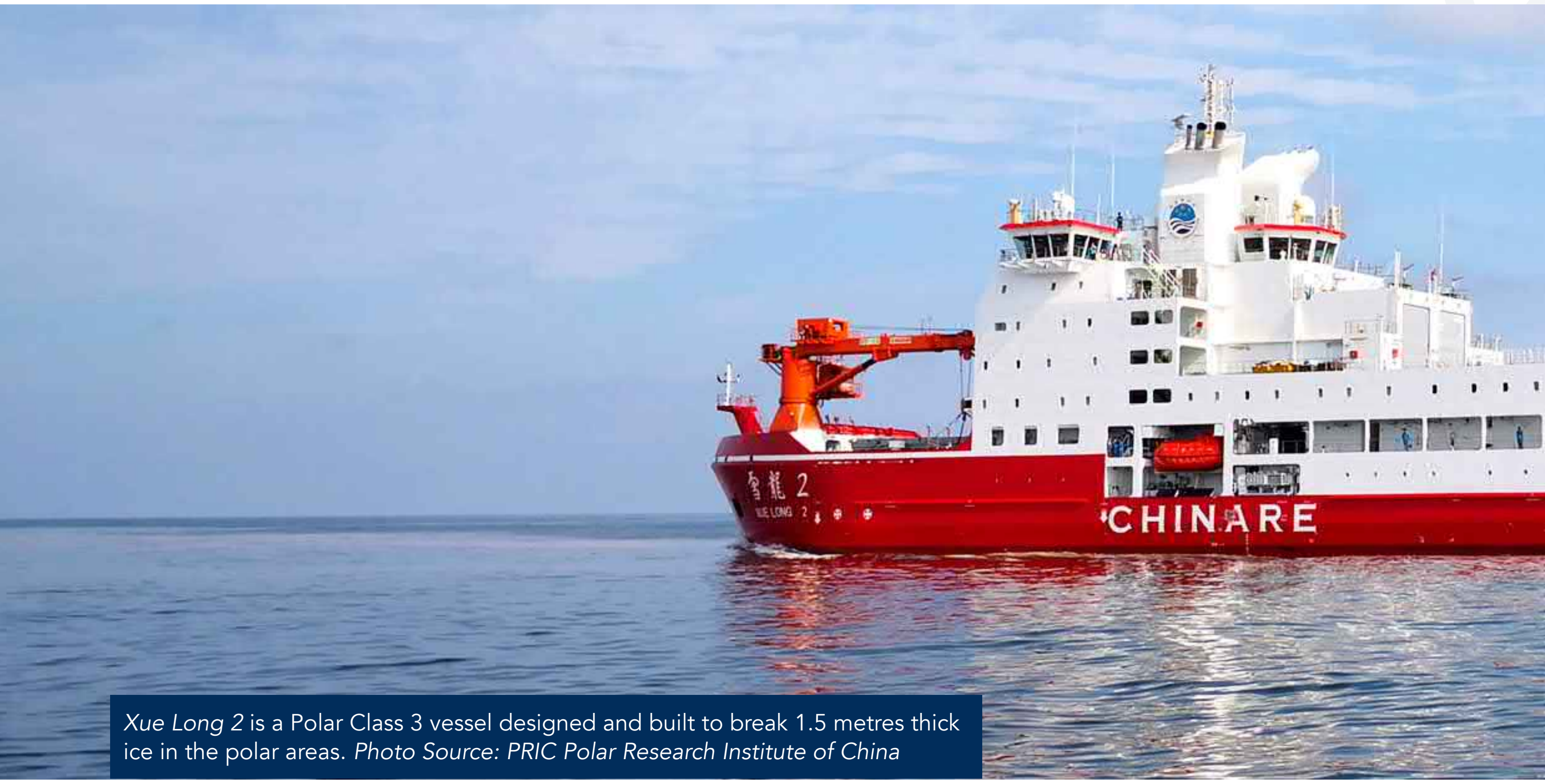
Design work is an evolving process,

where information and decisions from previous phases are crucial. Communication and continuity are important parts of a successful, high-quality design, where errors are minimized. This helps mitigate the risk of delays and cost overruns for the builder and ship owners. We strive for continuous, long-term partnerships in the overall ship acquisition and building process. The ice trials you will read about in this issue are the outcome of our collaborations, where all parties, including the designers, the builders and, finally, the satisfied owners, benefit.

Sincerely,

Reko-Antti Suojanen
Managing Director

Xue Long 2 enters into service



Xue Long 2 is a Polar Class 3 vessel designed and built to break 1.5 metres thick ice in the polar areas. *Photo Source: PRIC Polar Research Institute of China*

China's first domestically built icebreaking research vessel, *Xue Long 2*, successfully completed her sea trials in June this year, where all design requirements were verified. In October, she will depart for her maiden voyage to Antarctica, where the full-scale ice trials will take place.

The long-term ship design and construction project for the Polar Research Institute of China culminated in the two-week sea trials in May/June 2019. Chief Designer Lars Lönnberg and Project Manager Kari Laukia from Aker Arctic participated in the voyage to ensure that the design objectives were met and gathered data on the ship's performance.

All requirements met

"Overall, the trip was a success, with the vessel fulfilling all specification requirements, and in some cases surpassing them," Laukia says. "This affirms our efforts in designing a technologically advanced polar research vessel through long term cooperation with our clients. The ship will be perfect for the use it is designed and built for, namely serving the permanent research stations in Antarctica and conducting sophisticated scientific research at sea and in the ice."

Xue Long 2, Chinese for "Snow dragon 2", departed from Jiangnan Shipyard in Shanghai, where it was built over the past two years, on 30th May 2019. All required sea trial tests were performed in the East China Sea during two weeks, including the witnessing of tests required by both China Classification Society and Lloyd's Register, as the ship was built under survey of both classification societies in a dual class arrangement.

Testing the vessel

From the designer's perspective, the most important testing situations was the overall behaviour of the vessel, verification of seakeeping, fulfilling speed targets, ensuring the economical speed, inboard noise and vibration tests, and manoeuvrability in extreme situations.

"Sea conditions during the trials were mostly good and all vessel behaviour and seakeeping tests could be carried out to owner and class satisfaction," Laukia highlights. "The wind peaked up during a few days and wave height reached 3 metres, and the ship performance was further tested."

The economic speed of 12 knots was also verified. This speed will be used while sailing to Antarctica, as it only requires the use of one diesel engine and therefore saves fuel substantially. To reach a speed of 15 knots, two engines are used and in actual icebreaking situations all four engines can be used for maximum power.

> In October, she will depart for her maiden voyage to Antarctica, where the full-scale ice trials will take place.

From left: Zhimin Xiao, PRIC, Chief Officer; Lönnberg Lars, Aker Arctic, Chief Designer; Laukia Kari, Aker Arctic, Project Manager; Xu Ning, PRIC, Head of Vessel & Craft Management Division of PRIC, Zhao Yanping, PRIC, Captain; Huang Rong, PRIC, Chief Engineer; Wu Gang, Maric, Chief Designer

Focus on low noise and vibration

During the design stage extensive vibration analysis was used to refine the design with special arrangements made in order to achieve low vibration and noise levels. The full-scale tests confirmed that the vessel complies with China Classification Society's and Lloyd's Register's comfort class 2.

"Inboard noise and vibration tests were executed at the economical speed of 12 knots, the service speed of 15 knots and while using dynamic positioning," Laukia explains.

Low underwater noise is also important, as the vessel will move in the sensitive polar areas. Underwater radiated noise levels were consequently also measured during the trials.

Additional special features

The full technical details of *Xue Long 2* have been presented in a previous issue of Arctic Passion News (see issue 15). However, the vessel has a few special features worth highlighting.

Large seminar room

Xue Long 2 is equipped with a grand conference room suitable for up to 80 persons. The sloping floor allows good visuals from every seat to the stage area, which includes a speaker podium and a big screen for presentations, videos or movies.

Wide outside deck corridors

Internal logistics on the ship is efficient and transportation of equipment between the cargo hold and aft deck is easy using the wide outside deck corridors on the side of the vessel.

Multifunctional aft deck

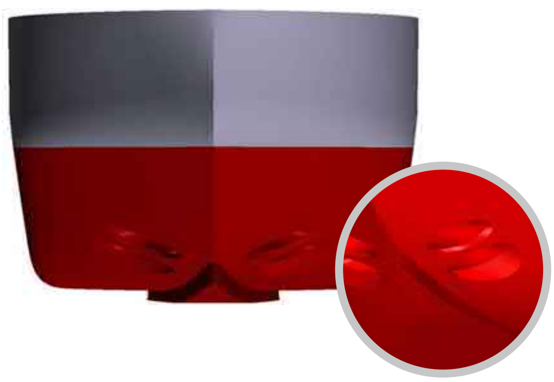
The compact aft deck is equipped with large cranes, A-frames and a core sampler. It has designated spaces for seismic containers, which are loaded onboard when needed. The modular design of the deck allows the vessel to be equipped differently for each trip according to mission needs.

Scientific control room

All research vessels have scientific control rooms, but the one onboard *Xue Long 2* is especially spacious with big windows towards the moonpool workshop and the aft deck, enabling visual contact between researchers and the deck crew.

Box keel protects equipment

A specially designed box keel in the bow of the vessel protects scientific equipment from ice pieces and is designed so that underwater disturbance can be avoided while performing scientific tasks. The box keel has been tailored to retain icebreaking properties without increasing open water resistance.



Successful delivery

"The *Xue Long 2* Polar Scientific Icebreaker was successfully delivered at the Jiangnan Shipyard in China on July 11, 2019," comments Mr. Xu Ning, Head of Vessel & Craft Management Division of Polar Research Institute of China (PRIC).

"Since winning the basic design in July 2012, Aker Arctic has played an irreplaceable role in the ice performance prediction, icebreaking type and structural design of the *Xue Long 2* project. This resulted in the basic design achieving the double approval of China Classification Society (CCS) and Lloyd's Register of Shipping (LR). The class approval provided a solid foundation for the subsequent detailed design and production design. Aker Arctic carried out close cooperation with the Chinese participants, especially the domestic design institute China Marine and Ocean Engineering Design and Research Institute (MARIC). We appreciate Finnish Aker Arctic for its contribution and support to the successful construction of China's *Xue Long 2*."

Ice trials in October

Xue Long 2 will depart on her maiden voyage and first mission in October 2019. She is scheduled to sail first to Hobart, Australia, from where she will continue to Antarctica delivering equipment and supplies to the Chinese research stations located on the continent, as well as executing scientific research en route. The full-scale ice trials will be performed during this first trip to Antarctica.

"The bollard pull was verified in Shanghai after the sea trials in mid-June and met the specification requirement," Laukia adds. "This is an essential prerequisite for the ship's icebreaking performance in order to fulfil the icebreaking target of 1.5 metres level ice she is designed and built for." ■

A long history of cooperation

The Finnish embassy in Beijing opened in 1952, with bilateral trade relations developing quickly under the lead of ambassadors Helge von Knorring and Carl-Johan Sundström.

In 1953, the first commercial ship agreement was signed, based on which Finland delivered six 3,200 DWT steam cargo ships of Crichton-Vulcan design. The six vessels, named *Ho Ping 18, Ho Ping 19, Ho Ping 21, Ho Ping 22, Ho Ping 23 and Ho Ping 24*, sailed from Finland to Shanghai and were delivered between 1955 and 1957.

SS Rigel, built in Turku in 1937, was the lead vessel in the series, of which six units were built for China between 1955 and 1957. Photo Source: FÅA- Silja Line, Maritime Museum of Finland, Finnish Heritage Agency

Text by Mikko Niini, CEO of Aker Arctic 2004–2014

LNG bunkering vessel for use in ice

Winters in the Baltic Sea can be challenging, especially in the Bay of Bothnia where the ice cover can grow up to one metre thick and wind forces ice into heavy ridges.

With the growing number of gas-fuelled vessels sailing in the Baltic Sea, the availability of liquefied natural gas (LNG) has been a bottleneck. Aker Arctic has now developed a concept for a bunkering vessel capable of operating in all prevailing ice conditions in the Baltic Sea.

Winters in the Baltic Sea can be challenging, especially in the Bay of Bothnia where the ice cover can grow up to one metre thick and wind forces ice into heavy ridges. Close to harbour areas, brash ice builds up over time creating uneven layers of rubble ice that can grow to be several metres thick.

New concept

"To improve the offering of LNG fuel to vessels sailing year-round in these conditions, we have developed a bunkering vessel concept with improved icebreaking capability compared to the ones currently in service or on order," says Naval Architect Joakim Konsin.

The versatile bunkering vessel is designed to bring LNG both to a terminal and directly to vessels, by rafting alongside another vessel at sea for delivery of fuel. The bunkering vessel will be able to move around in ice-infested areas to serve LNG-fuelled ships needing to bunker fuel.

The 115-metre long and 16-metre wide vessel concept is strengthened to the Finnish-Swedish ice class IA Super. It can manage harsh winters and all possible ice conditions in the Baltic Sea.

Equipped with two azimuthing propulsion units, the vessel can operate stern-first in heavy ice conditions utilizing the Double Acting Ship (DAS™) principle, to provide LNG bunkering services without need of icebreaking assistance. The LNG capacity of 5,000 m^3 is stored in independent Type C tanks.

Safety at all times

The hull form features a strengthened bulbous bow for efficient operations in open water and moderate ice conditions. The stern is designed to provide remarkable icebreaking capability while sailing stern-first in the worst ice conditions.

"Adopting this configuration, the ship is able to operate cost-efficiently and safely at any time," Konsin adds.

The ship's propulsion configuration provides a high degree of redundancy, reliability and superior manoeuvrability – which all are essential in ice navigation as well as provides efficient operation for bunkering. The twin azipods in the stern also ensure that the ship's ability to penetrate ridged ice fields will be excellent.

"The ship's open water design speed is 12.5 knots. Using its full propulsion power of 7 MW, the vessel can break 1 metre thick level ice in astern mode," Konsin says.

Additionally, all primary safety-related equipment and systems are protected by means of anti-icing arrangements and many deck elements are fitted with de-icing measures.

LNG bunkering operation in open water conditions.
Photo by courtesy of Nauticor.

More availability of LNG

"A possible market for this type of vessel is delivering LNG from larger terminals in the area to smaller satellite terminals or storage facilities, which are currently served by trucks," Konsin contemplates. "Harbours in both Sweden and Finland could benefit of an ice-going bunkering vessel delivering LNG."

Newly opened terminals

Since last winter, several new LNG facilities have begun operations in the Baltic region. In addition to the terminal in Tornio in the north of Finland, a terminal in Vysotsk in south-western Russia has opened. Other LNG terminals include FSRU *Marshal Vasilevskiy* in Kaliningrad, Russia and Klaipeda in Lithuania.

The next developments in the LNG fuel industry are a bunkering vessel in Tallinn, Estonia, an LNG-terminal in Hamina, Finland (2020) and a large LNG terminal in Ust-Luga, Russia (2023).

"It is clear, that with the tightening of IMO emission regulations, LNG is increasingly chosen as fuel in new vessel acquisitions. An ice strengthened bunkering vessel is a viable option for securing fuel distribution in the toughest parts of Bay of Bothnia and also in the Gulf of Finland," Konsin says. ■

The new vessel concept is fitted with twin azimuth thrusters.

Technical details	
Lenght over all	114.0 m
Length between pp	111.5 m
Breadth moulded	16.0 m
Height	14.7 m
Design draft (LNG)	6.5 m
Draft (ballast)	6.0 m
Cargo volume	5200 m^3
Deadweight	2800 tons

Boris Sokolov in successful arctic ice trials

The arctic condensate tanker *Boris Sokolov* has been delivering cargo from Sabetta to markets since January 2019. The vessel was built by GSI shipyard based on the Aker Arctic design. Ice trials are part of the comprehensive design package and these were carried out in heavy ice conditions in the Russian Arctic.

The arctic condensate tanker Boris Sokolov has been delivering cargo from Sabetta to markets since January 2019

The Aker Arctic team responsible for the testing consisted of Teemu Heinonen, Veikko Immonen, Heikki Juvani, Sami Saarinen and Alexey Shtrek. They travelled to Sabetta and boarded *Boris Sokolov* at the end of April 2019.

Tests in the Kara Sea

After loading a full cargo of gas condensate from the Arctic harbour, the RMRS Arc7 vessel departed towards the north-east to the Bay of Mikhaylov, where the first tests were conducted.

"The level ice thicknesses were measured to be 145 cm and 160 cm thick with a 30 cm of snow layer on average," says Teemu Heinonen. "The first level ice tests were performed, in which the vessel was tested ahead in the thinner ice and stern-first in both thicknesses."

From there *Boris Sokolov* headed south-west to an area close to the Kamenny Islands where the forward moving test was performed in 125 cm thick level ice as well as an astern turning test in about 150 cm thick level ice.

Design targets confirmed

"Based on the level ice tests, we concluded that the vessel fulfils its icebreaking requirements of moving ahead in 150 cm thick ice with a speed of 2 knots, and in 180 cm thick ice moving stern-first with the same speed, according to design targets," Heinonen adds. "The turning diameter of three kilometres in 150 cm thick ice was also clearly fulfilled."

> The vessel operates stern-first in heavy ice.

Boris Sokolov has been designed according to the Double-Acting Ship (DAS™) principle that allows tankers and cargo ships to operate independently without icebreaker assistance in challenging ice conditions. In moderate ice conditions and in open water, the vessel sails ahead normally, while in heavy ice conditions the vessel turns to operate stern-first.

Clearly over ridges

The next destination was a pressure ridge field off the coast from Dikson. The ridge keel depth measured to be at least 10 metres and the sail height between 2 and 3 metres. Bad weather and poor visibility limited the ridge measurements.

"The condensate tanker managed to penetrate easily through the ridge without any problems, from which we could conclude that it will clearly fulfil the design requirement of 15 metres thick ridges," Heinonen underlines.

High ice class

The tanker's ice class, RMRS Arc7, means the vessel is intended for year-round independent navigation in western parts of the Arctic Ocean and for a six-month period in summer/autumn in eastern parts of the Arctic Ocean. The vessel can also take advantage of the frequent traffic of large LNG carriers and navigate in convoy with them.

In 2017, Heinonen participated in the ice trials of the first Arc7 LNG carrier, *Christophe de Margerie*, the concept of which was also developed by Aker Arctic (read more in issue 14). The last ships in the series of fifteen exceptional tankers, capable of sailing independently through ice up to 2.1 metres thick, will be delivered this year by the South Korean shipbuilder Daewoo Shipbuilding & Marine Engineering (DSME).

From left: Alexey Shtrek, Sami Saarinen, Yamal LNG representative Alexey Chernov, Heikki Juvani, Veikko Immonen, polar bear guards Mikhail Korelskiy and Dmitry Konichev, Teemu Heinonen.

En route to Rotterdam

In addition to the Aker Arctic team, there were representatives of the owner Dynacom, the builder Guangzhou Shipyard International, the charterer Yamal LNG, the propulsion system provider ABB, and members of the Arctic and Antarctic Research Institute (AARI) who provided ice reconnaissance and indicated suitable test areas. Everyone disembarked in Murmansk on the 14th of May to return home after the successful trip.

Boris Sokolov continued on her normal route towards Rotterdam along the coast of Norway with her full cargo load. This was her fifth voyage since she began her regular work delivering gas condensate, a liquid by-product from natural gas fields, from Sabetta to Europe and Asia.

"The ice trials went very well and the vessel behaves according to design targets and manages well in the conditions she was designed for," Heinonen highlights. "The vessel was delivered on time and keeps her cargo delivery schedules, exactly as planned."

"This was our second successful co-operation project with Guangzhou Shipyard International. They also built the two heavy arctic module carriers *Audax* and *Pugnax* delivered in 2016, which have been essential in the construction of the arctic LNG plant in Sabetta."

Testing the turning diameter of three kilometres in 150 cm thick ice. All design targets were fulfilled in the test.

Aker Arctic was responsible for ice property measurements as well as measurements onboard the vessel including propulsion and navigational data measurements. In addition, Aker Arctic conducted the ice trial analyses.

DIVEC data gathering system used in ice-trials

Example of display with consolidated data using DIVEC (values are not from real vessels).

Full-scale ice trials involve gathering more data than the ice conditions. Information concerning the ship's location, speed, propulsion power, engine use and propeller rotation is vital to provide context to the ship's performance. Until now, the information has been gathered from various systems on-board, consolidated manually and then analysed. With the new DIVEC (Distributed Intelligent Vessel Components) data gathering system, the manual work will become history.

For the ice-trails of *Boris Sokolov*, the new Arctic condensate tanker, Aker Arctic's research team developed a data gathering system, which was connected to the various systems on-board the vessel and automatically gathered data from them. The data was displayed on a monitor for a clear, real-time overview, while simultaneously saving the details for later analysis of the trials.

Useful for improving performance

Research engineers Veikko Immonen and Olli Kokko are excited about the new system. "The data gathering system is not only useful for ice trials, but could be installed on any vessel wanting to improve its operational efficiency, safety or performance in ice," they say. "It can easily connect various systems, which normally wouldn't interoperate."

This could include for example analysing speed, fuel usage, engine efficiency and effectiveness of various manoeuvres. Inefficiencies could be identified, and suggestions made for improvement in operations.

"The framework allows transmitting data in all directions, which means that the information could also be available online," Kokko adds. ■

Double-ended ferry tested in ice

Saaremaa and Hiiumaa are two large islands off the Estonian coast with daily connections between them by sea. The double-ended ferry *Soela* began operation in 2017 and was tested in ice last year.

Soela is one of the three double-ended Ro-Ro and passenger ferries built by Baltic Workboats for the Estonian Maritime Administration between 2015–2017. She operates daily between Saaremaa and Hiiumaa islands throughout the year, using an ice channel in the winter. The ice trials were performed in her normal operational area.

Trial Results

The objective of the full-scale ice trials was to verify that the vessel fulfils its design requirement, 2 knots in 45 cm thick level ice with a flexural strength of 500 kPa. Before the ferries were built, their ice-going capability had been evaluated with model tests at Aker Arctic's ice laboratory in 2013.

The average ice thickness in the area was measured to be 30 cm based on 38 measurements. The flexural strength was on average 578 kPa based on ice sample temperature profile and salinity. *Soela* performed well in this ice thickness and also in a 50 cm thick ice channel. Through calculations and comparisons to model test results, the full-scale ice trials verified that the Estonian double-ended ferries *Kihnu Virve, Ormso* and *Soela* fulfil their design requirements.

Technical details	
Length	45 m
Breadth	12,48 m
Capacity	200 persons, 32 cars or two trucks

Full-scale tests for Swedish ferry

Yxlan is a commuter ferry in the Swedish archipelago.

On the shores of Stockholm, the capital of Sweden, lies a network of islands where people live year-round. Instead of taking the bus to work or school, the inhabitants jump on a ferry which transports them to the mainland, regardless of season or weather.

There are several ferries commuting in the Stockholm archipelago year-round as part of the public transport system. Last year, a new ferry named *Yxlan* was built by Baltic Workboats in Estonia and joined the Waxholmsbolaget fleet in Sweden.

Testing in ice

Aker Arctic performed the ice model tests for *Yxlan* two years ago to support the design work. The full-scale ice trials were performed this spring, confirming the design target of 2 knots speed in 25 cm thick level ice.

The main focus of the ice trials was to conduct tests in level ice.

"The ice outside Stockholm was not thick enough for the test, therefore the location chosen for the test was in the Ångerman River, about 500 km north," says Topi Leiviskä, Head of Research and Testing.

Measurement methods

Ice thickness was measured by drilling holes into the ice along the ship track and measuring the thickness with an L-shaped rod. Altogether 47 measurements were done which had an average ice thickness of 38 cm.

Flexural strength was defined using the three-point bending method. For this method, 500 mm long ice beams were cut out from the ice with a chain saw. The beams were then shaped to have a final thickness of 50 to 70 mm. A purpose-built device was then used to load the ice beams and the breaking force was measured. A total of nine measurements were made with an average flexural strength of 406 kPa.

"The easier method of measuring flexural strength is using the water's salinity and temperature," Development Engineer Jukka-Pekka Sallinen explains. "However, river water has no salinity, therefore the more complex method needed to be used."

The ice measurements were then converted to reflect sea ice conditions and used to analyse the results from the full-scale tests.

"The results showed that the vessel clearly surpassed the design targets, reaching double the speed in 25 cm level ice," adds Leiviskä.

The client and the owner also performed operational tests during the same trials.

Technical details	
Length	27 m
Breadth	8 m
Capacity	150 persons

Ice thickness was measured by drilling holes into the ice along the ship track and measuring the thickness with an L-shaped rod.

Full scale ice measurements

Flexural strength

The flexural strength of ice can be measured using three different methods: a cantilever beam test, a simply-supported beam test or with brine volume measurements.

The cantilever beam test is done by cutting a beam into the sea ice while keeping one end of the beam connected to the ice sheet, similar to the method used in model tests. The free end of the beam is loaded until it breaks. Cantilever beam tests are very laborious to do and, therefore, are very seldom used in full-scale measurements.

In simply-supported beam tests, the ice beams are cut from a larger block of sea ice. A beam is simply supported from both ends in an A-frame and vertically loaded in the middle until it breaks (picture 1).

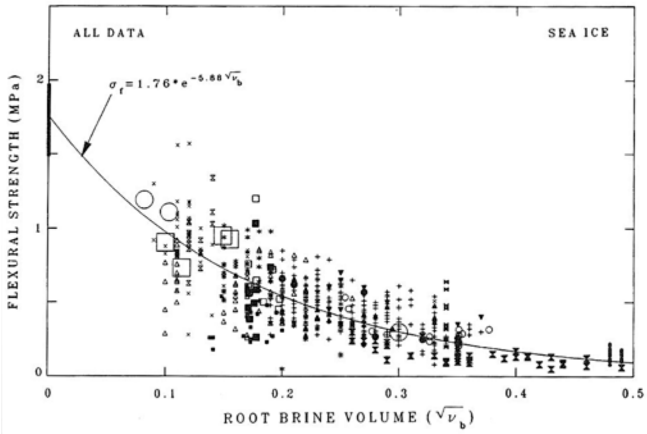
Picture 1. A-frame with ice beam.

The breaking force is measured with a force transducer and the flexural strength can be calculated from the measured force according to Euler-Bernoulli beam theory.

Flexural strength can also be defined by measuring the salinity and the temperature of the sea ice. Ice samples are collected with a core drill specifically made for this purpose. The drilled core is divided into samples to obtain both a salinity and a temperature profile.

The ice salinity can be measured by melting an ice sample and measuring its salinity with a salinometer. The temperature of the ice core is measured with a digital thermometer immediately after drilling.

The flexural strength of the sea ice can then be estimated by using the brine volume calculated from the ice temperature and the salinity according to picture 2.



Picture 2. Flexural strength versus the square root of the brine volume for first-year sea ice (Timco and O'Brien, 1994)

Thickness

Level ice thickness can be measured with an L-shaped stick from drilled holes. In brash ice and ice ridges, the thickness can be measured using a mechanical drill when the drill length is known.

Picture 3. A hydraulic press is used for compression strength measurement.

Ice compressive strength, uniaxial unconfined

The compressive strength of sea ice is determined from ice cores drilled from the level ice. The cores are cut to a specific length with perpendicular ends and inserted into a hydraulic press. The hydraulic press includes a strong frame and a cylinder which crushes the ice core. The compressive strength is defined from the pressure required to crush the ice core.

Ice density measurements

Ice density can be measured by defining the weight needed to submerge a freely floating ice sample. The weight is measured with a small digital scale. The ice density can be calculated when the water density is known. ■

Text by Toni Skogström, Research Engineer at Aker Arctic

Ice risk assessment of Qajaq W

The Qajaq W in ice, photo taken from the Canadian Icebreaker, CCGS Henry Larsen

Last year, Aker Arctic was tasked with evaluating the strength of the hull and propulsion of a ferry intended for traffic between Newfoundland and Quebec in Canada, in order to evaluate the risks of operating in ice.

M/V Apollo has run regular ferry services across the Strait of Belle Isle, between Saint Barbe in Newfoundland and Blanc-Sablon on the south east coast of Quebec, for the last 18 years. She was built in Germany in 1970 and originally operated in the Baltic Sea. The ship was purchased in 2000 to operate the 36 km long route year-round for Labrador Marine Services Inc.

The strait can be ice covered between February and May, especially when south westerly winds push ice from the Gulf of St Lawrence northwards, creating particularly challenging pressured ice conditions. With the *Apollo* aging, the operator was in the process of acquiring a replacement vessel from Germany, the *M/V Grete*, and wanted to have a thorough understanding of the ice operational risks associated with deploying the new vessel on the route, to ensure continued safety for future years. The *Grete* was subsequently renamed *Qajaq W*, meaning kayak in Inuktitut.

Strength evaluation

Aker Arctic's scope of work was to evaluate the strength of the hull and propulsion systems, compare them with the expected ice conditions the ship would face, and with the regulatory requirements for operation in Canadian waters.

"We began by looking at the strength of the hull of the existing ship (*Apollo*) and the new ship (*Qajaq W*)," says Rob Hindley, Head of Machinery and Structural Design at Aker Arctic.

A direct analysis of the structure against the rules was done, with a comparison of rule design pressures for the various structural areas of the ship. The capacity of the structure to withstand ice load was also assessed. These were then used as a comparison to see whether the strength was higher or lower than the *Apollo* and the regulatory rule minimums that would be required.

Propeller ice loads

"For the propeller, we modelled the blade using the Finite Element Method and loaded the propeller with different ice loads to compare the limiting ice load with the rule requirement," Hindley explains.

The two ships have different propulsion configurations, with the *Apollo* being a conventional twin shaft and twin propeller arrangement, whereas *Qajaq W* has one azimuth thruster forward and one aft. As a result, the risks associated with ice loading could not be compared directly.

"We solved this by creating different loading scenarios for various operational manoeuvres, particularly regarding the propulsion. We also had a look at the hull form shape, looking at how ice goes into the propeller from various angles to get a better understanding of the operational risks," says Hindley.

Past ice conditions

The assessment team also looked at the ice conditions the *Apollo* had been operating in, gathering all ice chart data from the strait for the past ten years. The Canadian Arctic Ice Regime Shipping System (AIRSS) assessment tool, which is a Canadian regulatory requirement, was used to evaluate the level of risk to the ship in various ice conditions.

"More importantly, it links the ship's ice class to ice conditions," Hindley underlines.

POLARIS, the IMO system of evaluating operational risk in ice, was also used in the assessment, the POLARIS risk index outcome being compared with the Ice Numeral determined from AIRSS. Actual data from the ship's log, what ice conditions the ship had been operating in both independently and with icebreaker assistance, and days where the decision had been made by the operator not to sail due to tough ice conditions were used to develop an operational risk profile for the *Apollo*, effectively setting a baseline to compare *Qajaq W* against.

Conclusions

"Looking at the strength of both ships in terms of the actual ability of the structure and the propulsion to withstand the ice load we concluded that the new ship is comparable, and in some areas, significantly stronger than the old ship," Hindley concludes.

It was clear from the review of the previous ship's log entries that the *Apollo's* operators had been prudent in deciding when to proceed out in ice and when not.

"Together this information was used to make the case that the *Qajaq W*, if operated with the same prudence as *Apollo*, should be able to continue the safe ice operational track record that the *Apollo* set originally."

"Being equipped with a different propulsion configuration, we also identified that there were specific areas needing to be addressed through training and operational guidance and we included that advice to the operator, to ensure we had given the complete risk picture," Hindley adds.

First winter

The *Qajaq W* now has her first winter season behind her.

"The *Qajaq W* is much more capable in ice than the *Apollo*," comments Captain Wade Roberts of the *Qajaq W* (and also previously of the *Apollo*). "This past season presented some extremely tough operating conditions with heavy ice and the vessel operated successfully without damage to the hull or thrusters."

Technical details – Qajaq W	
Length	97.8 m
Breadth	17.9 m
Draught	4.2 m
Capacity	700 passengers, 160 cars

Technical details – Apollo	
Length	108.7 m
Breadth	17.2 m
Draught	4.6 m
Capacity	240 passengers, 220 cars

Ice Load Monitoring System for detachable icebreaking bow

The self-propelled detachable icebreaking bow, developed for the Finnish Transport Infrastructure Agency (FTIA), will be equipped with Aker Arctic's innovative ice load monitoring system, measuring strength and functionality of both the bow and its integrated propulsion system. The FTIA has procured Alfons Håkans owned tugboat Calypso to push the bow.

A few years ago, the FTIA and ILS Oy developed a self-propelled detachable icebreaking bow concept to improve icebreaking capacity on Lake Saimaa, Finland's largest freshwater lake, and the Saimaa Canal. The vessel was contracted and is now under construction at Turku Repair Yard. The developing and building work are done as part of WINMOS II, an EU CEF co-funded project.

Aker Arctic designed and delivered two complete 600 kW shaft lines for the bow unit, with the purpose of improving the bow's icebreaking capability and manoeuvrability.

The self-propelled detachable icebreaking bow was developed to improve icebreaking capacity on Lake Saimaa, Finland's largest freshwater lake, and the Saimaa Canal.

Ice load measurements

The installation of Aker Arctic's Ice Load Monitoring System (ILMS) on the bow is now complete, with commissioning to commence soon. The ILMS will be used to measure the loads at the connection between the bow and the tugboat *Calypso*, and on the two shaft lines of the detachable bow. In addition, the ice loads on *Calypso's* own two shaft lines will be monitored, which means that all four propulsion lines will be measured and the ice loading compared.

"The self-propelled detachable bow is a new concept, and therefore the Finnish Transport Infrastructure Agency wants to understand the ice loads and evaluate the performance and durability of this innovative product," explains Kari Laukia, Head of Equipment Business at Aker Arctic.

Improved safety

The Ice Load Monitoring System has been developed especially to improve safety in ice, but can also be used for measuring open water loads in harsh seas, as loads can become significant also in open water.

The sensors installed on the hull and the shaft lines send information to a central computer for real-time processing. The information is then displayed on a monitor on the ship's bridge to help the Captain in deciding how to proceed and at what speed.

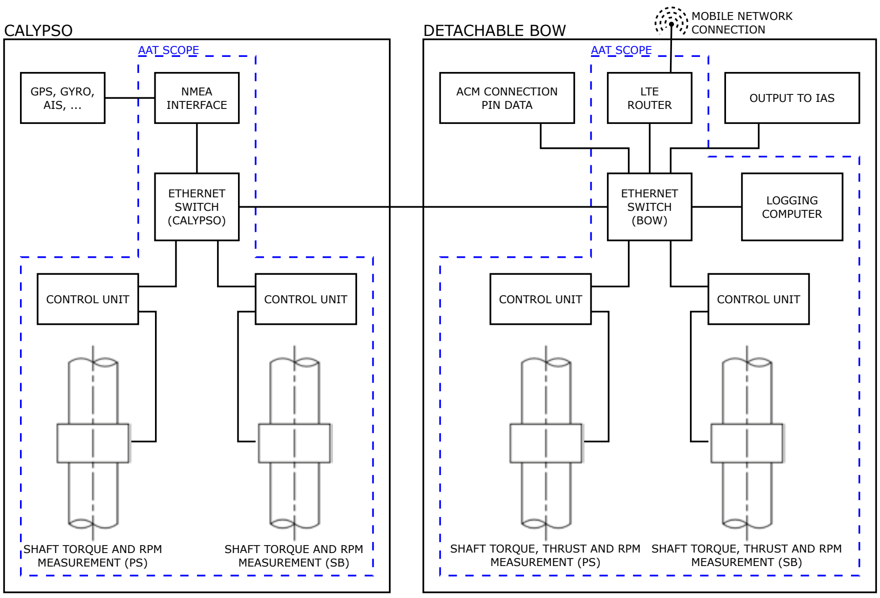
"The information displayed at the monitor can be tailored according to customer wishes about what to follow and how. The information is clear and the tool is easy to use," Laukia adds.

All information is available online and can additionally be monitored from the customer's premises if so desired. It is also saved to a hard-drive for later analyses.

Recommended use

"Typical vessels to benefit from this tool would be larger ice strengthened merchant ships, high speed special vessels and navy ships," Laukia highlights. "Even existing icebreakers wanting to continually monitor ice loads could have it installed for the same cost as they order a one-time special load survey."

The self-propelled detachable bow will be delivered before winter this year with testing scheduled during the coming winter months.



The sensors installed on the hull and the shaft lines send information to a central computer for real-time processing. The simplified measurement system diagram shows the information gathered from shaft lines.

The Ice Load Monitoring System (ILMS) has been developed especially to improve safety in ice.

The ILMS will be used to measure the loads at the connection between the bow and the tugboat Calypso, and on the two shaft lines of the detachable bow.

Pictures: Kuvakasvot Oy/TRY/FTIA

EEDI ships need more assistance in ice

The purpose of the Energy Efficiency Design Index (EEDI), introduced by the International Maritime Organization (IMO), is to promote energy efficient ships and thereby reduce CO_2 emissions per ton-mile of transported cargo. According to the latest research, ships with low power-to-deadweight ratio fulfilling EEDI requirements need more assistance in ice, compared to ships with higher installed power, built before the requirements entered force.

An ongoing concern regarding the new legislation is that new vessels built according to EEDI requirements would not manage well in ice conditions. Development Engineer Teemu Heinonen from Aker Arctic recently finished a research project, funded by the Finnish-Swedish Winter Navigation Research Board, in which he compared new vessels designed to meet EEDI criteria and older vessels not required to fulfil the latest energy efficiency requirements with regard to the need of icebreaker assistance to Finnish and Swedish harbours during the three past winters (2016-2018).

"When investigating all Finnish and Swedish ports in the northern Baltic Sea, the conclusion was that 20–30 % of EEDI compliant vessels required icebreaker assistance during the time with traffic restrictions, whereas only 5–10 % of non-EEDI compliant vessels needed help in ice," Heinonen says.

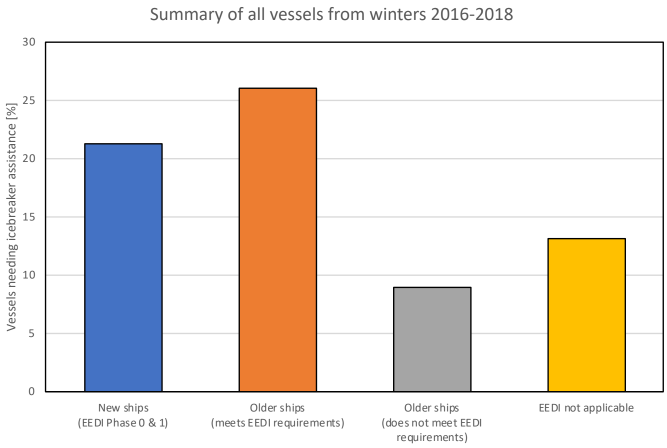
Map of the researched area.

Comparing data

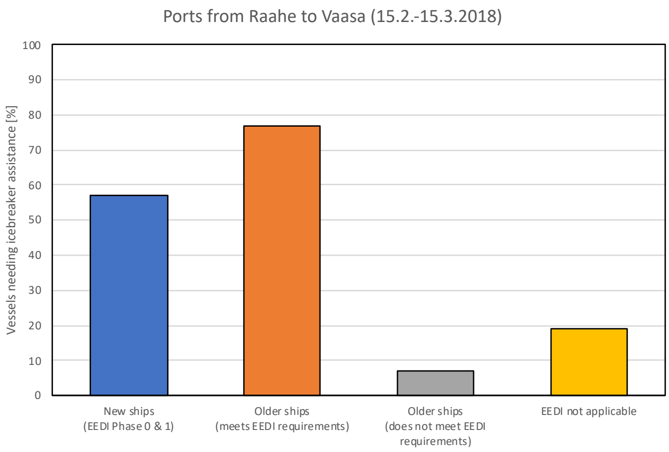
Heinonen compiled and reviewed data regarding the number of vessel harbour calls, the vessel type and the need of icebreaker assistance. When assistance was needed the distance and length of assistance provided, as well as the distance and time under tow, was evaluated.

Vessels were divided into four categories: new ships designed and built to meet EEDI requirements applicable to them; older ships that predate EEDI but nonetheless meet the requirements through good energy efficiency; older ships that do not meet EEDI requirements for similar ships built today; and ships of any age not covered by EEDI.

"I then grouped all harbours into smaller geographical areas for a clearer overview," he says



Summary of all vessels needing assistance during the winters researched.

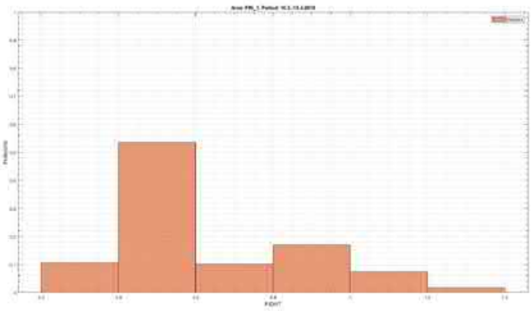


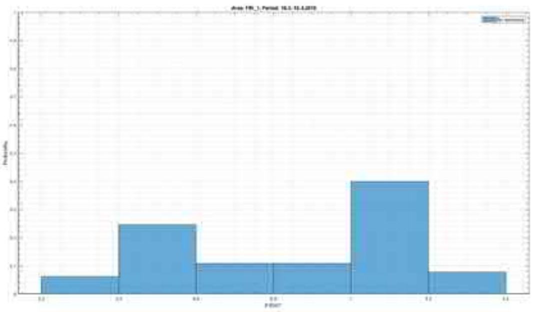
Example of vessels needing assistance between Raahe and Vaasa mid-February to mid-March 2018.

Assistance requirements for EEDI ships

From the three-year data, Heinonen concluded that nearly all vessels requiring towing assistance were EEDI-compliant vessels. "Ships that didn't fulfil EEDI criteria hardly ever needed to be towed," he says. Heinonen underlines that there is a clear correlation between assistance requirements and the power-to-deadweight ratio.

"The data shows that when the power-to-deadweight ratio is below 0.6 kW/ton, the vessel will most likely need assistance or towing in ice by an icebreaker. For power-to-deadweight ratios above this, the likelihood of the vessel requiring assistance decreases significantly."





There is a clear correlation between assistance requirements and the power-to-deadweight ratio.

More icebreakers needed

The number of ice-strengthened vessels built according to EEDI regulations is still relatively small. During the three winters researched, only 23 different new EEDI vessels entered the Finnish and Swedish harbours. However, there are a large number of old vessels which fulfil the EEDI requirements adding numbers to the research.

According to Heinonen, the results tell us that EEDI compliant vessels need more assistance and towing for longer time and longer distances than non-compliant vessels. But, with the sample being relatively small, he would rather focus on the power-to-deadweight ratio as it gives more reliable figures.

"The ratio comparison clearly shows that, if the power-to-deadweight ratio diminishes in the future, i.e. a growing fleet of EEDI vessels with lower installed power, more availability of icebreakers will be required to support these vessels." ■

EEDI bow with improved ice performance

Last year, a series of model tests was performed to evaluate how well the new EEDI compliant vessels manage in ice conditions.

At the start of the project Naval Architect Mikko Elo joined the tanker *Suula*, a conventional product tanker with a bulbous bow designed for ice conditions, to gather facts about the real ice conditions the ship meets during normal operation in Bay of Bothnia. Following this exercise, a testing programme was established, for which a two-part model with interchangeable bows was used.

"The EEDI bow we developed for the test had all the typical characteristics of a vertical EEDI bow, but we included a small wedge at the waterline, which we thought could improve its ice-going characteristics," Elo explains.

The testing programme included level ice conditions, tests in two different ice channels, pack ice and finally tests with a small ice ridge. The aim was to reflect the expected ice conditions the ship meets during normal operation.

Positive results

In general, the tests went well and both bow forms performed relatively effectively in most ice conditions. Surprisingly, the sharp EEDI bow performed better in pack ice and the brash ice channel, as it split the floes and pushed them aside, instead of breaking and submerging them as with the bulbous bow form.

However, the biggest difference was the channel breaking out test.

"The traditional bulbous bow slowly chewed its way through the channel edge, whereas the EEDI bow could not manage it at all," Elo says. "After making contact with the channel edge, the vessel model bounced back into the channel, which in real life might pose a safety risk when passing another vessel."

"We also noticed that the EEDI bow was sensitive to changes in icebreaking mode in level ice. Sometimes the bow worked very well in level ice, breaking the ice by bending, whereas at other times the ice was broken by cutting and crushing resulting in a reduced speed."

Lower steel weight with nonlinear analysis

Structural engineer, Ville Valtonen, has investigated how to improve safety in high ice class vessels while simultaneously reducing the amount of steel needed using nonlinear analysis methods. The benefits are lower costs, easier production methods and environmental benefits.

The International Association of Classification Societies (IACS) Polar Class rules divide the hull structure analysis into two parts: shell plate and frames (secondary structures) and stringers and web frames (primary structures). The secondary structures are designed with rule equations, which are based on the plastic capacity of the structure. The primary structures are typically designed based on linear elastic analysis, as it is a straight-forward and well-established practice.

Imbalance in structures

Experience has shown, however, that using linear-elastic analysis methods to design primary structures in ice-going vessels often leads to an imbalance between the primary and secondary structures, particularly in high ice class vessels. The imbalance is seen as excessively heavy primary structures compared to the shell and frame structures. Furthermore, new vessel designs produced using linear techniques differ significantly from successful designs with proven track records in Arctic operations.

Nonlinear analysis methods provide an alternative for designing primary structures. To investigate the potential benefits of nonlinear methods, Ville Valtonen, Structural engineer at Aker Arctic, compared designs produced using linear and nonlinear tools for both low and high ice classes.

Less steel

The results of the study show that for low ice class vessels (PC6) the weight difference between structures dimensioned based on linear and nonlinear analysis is insignificant. However, for a high ice class vessel, typically PC3 and above, the nonlinear calculations provide significant reduction in the scantlings of primary structures, thus significantly lowering the steel weight for the vessel. For medium ice classes, the usefulness of nonlinear calculation depends on how weight-critical the vessel is.

Furthermore, nonlinear analysis improves the safety of the structures since it provides the designer a better understanding of the failure modes of the structures and the design margins in overload situations.

"By using nonlinear methods, the structures are more balanced, and steel weight is significantly reduced, therefore saving money and the environment," Valtonen highlights. "My calculations also show that the structures reflect older high ice class vessels, which have a proven track-record of safety in ice, thus confirming the results."

Valtonen presented his research at the 25th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC 2019) in the Netherlands. ■

Measurement methods developed for model brash ice

Aker Arctic is leading a research project with the aim to ensure that brash ice model tests in all model testing facilities correspond to real life in the best manner. The ultimate goal is to give ship designers reliable guidelines for building safe vessels that correctly fulfil the ice class requirements.

Last year, a series of full-scale channel tests were performed in the Bay of Bothnia (see issue 16). Then, a series of model tests were performed in the model test basin in Helsinki for comparison. The model-scale tests in the brash ice channels were prepared to fulfil the Finnish-Swedish Ice Class Rules (FSICR).

Test results vary

The Finnish-Swedish Ice Class Rules define the minimum engine power required for safe operations in certain conditions. The rules present an equation for required engine power, but a vessel with less engine power can be approved if the engine power is sufficient according to ice model tests.

Recently, variations in model-scale channel test results have been observed, especially when the new EEDI- type tankers have been tested. These inconsistent results occur even though the channels in which the ships have been tested fulfil the test performance requirements of the FSICR.

"In the FSICR, a model brash ice channel is defined only by its thickness and its width," Riikka Matala, Research Engineer at Aker Arctic, explains. "Ice coverage is a requirement, but does not need to be verified."

Different model test results indicated that the channel resistance depends on parameters, which are not defined by the guidelines.

Five parameters identified

Test equipment to measure different brash ice parameters was built and used with three different brash ice types. The difference between the materials was the target crushing strength of the ice pieces. Two of the materials were fine-grained, salt-doped model ice (FGX-ice) with crushing strengths 29 kPa and 57 kPa, which were manually cut into small pieces. The third brash ice channel consisted of fresh water ice cubes (crushing strength about 3 MPa).

To be able to compare the brash ice types, some basic parameters were measured from the parental ice: flexural strength, compressive strength, ice density, and friction between ice and model.

Matala presented her research at the POAC-conference in Delft in June 2019. Photo: Toni Skogström

The research team then identified five parameters, which could potentially explain the different results and developed measurement methods for the following: porosity, piece size distribution, angle of repose, angle of internal friction (or shear strength) and compressibility.

Porosity

Porosity of the brash ice was measured according to ITTC recommendations by submerging a known amount of brash ice and measuring the ice mass buoyancy. An instrumented box was completely submerged through the brash ice channel and held steady until the buoyancy force was constant.

The force was measured with a force transducer and the ice channel porosity was calculated according to Archimedes' principle.

Piece size distribution

In soil mechanics, grain size is useful as a distinguishing property of materials. However, the same grain-sized materials can have different mechanical properties.

Piece shape also affects the mechanical properties. For example, material consisting of round particles has lower shear strength than a material consisting of particles with sharp edges. Therefore, the distribution of the size of pieces is as important as the actual grain size.

Piece size distribution was defined by pouring a known volume of brash ice on a plate, on which an indicative grid was drawn. The plate was photographed and the picture analysed using Matlab so that the program defined the area of each individual ice piece and produced a distribution chart from the observations.

Angle of repose

The angle of repose is defined as the steepest slope of the unconfined material measured from the horizontal plane, on which material can be heaped without collapsing.

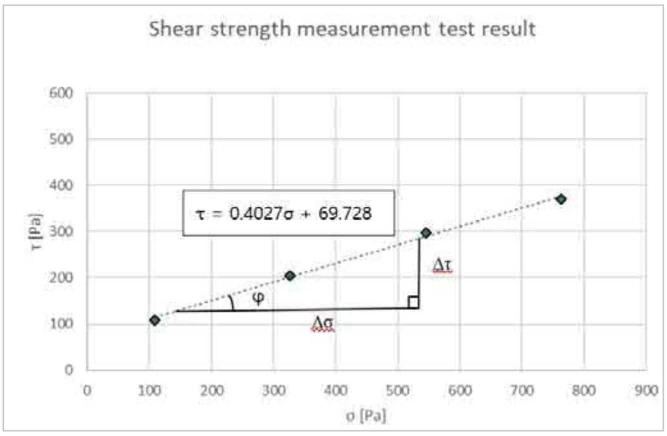
Angle of repose below water was defined with a container made of plexiglass. The container was set just below the surface level and filled with brash ice. The angle of repose was defined visually under water, using an underwater camera and then measured from the picture.

The angle of repose above the water was defined by piling ice brash gently on a horizontal plane. A picture was then taken and the angle measured from the picture in the same way as under water.

Brash Ice Angle of Internal Friction and Shear Strength

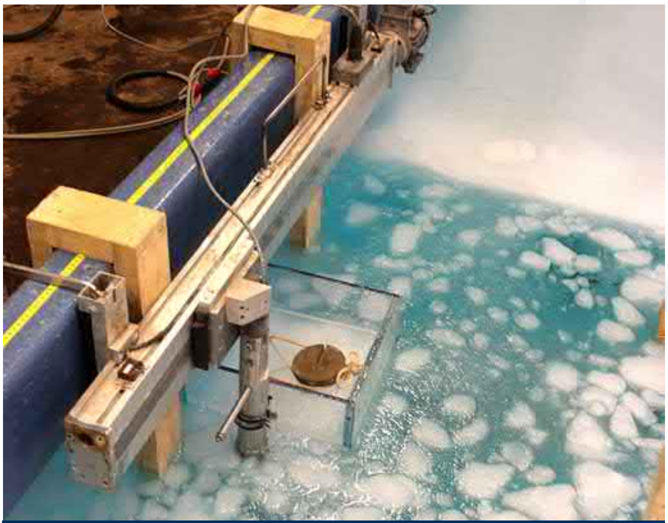
The shear strength measurement was arranged by building a plexiglass box, which consisted of two separate halves. The box was filled with brash ice and a weight was positioned on top of the upper box to cause a normal load. The upper part was slightly relocated and the required force was measured using a force transducer.

The results were plotted in a chart and a line was fitted to the data points. The slope of the line represents the internal friction angle, φ. An example of test results is presented below.

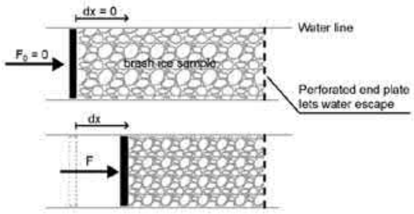


Compressibility

The compressibility is defined as the change in volume as a function of external pressure. The compressibility of brash ice was defined using a measuring device made of low-friction plexiglass. The end plate of the box was made of a perforated plate allowing water to escape. The front plate was attached to a piston, which moved forward when a weight was added in the wire system.



A double-box device was developed for studying shear strength and internal friction angle of brash ice.



Compressibility measurement in theory and practice.

Going forward

The objectives of developing new devices and practices for measuring brash ice properties are to enable comparison between different brash ice types. The comparison, in turn, is relevant when studying the brash ice channel behaviour in vessel's ice model tests.

The devices functioned well in general so that the comparison between the materials could be done, and the results were reasonable. However, the most relevant question for channel testing is to understand the physics behind the behaviour of the brash ice mass in the ice channel. Based on that, reliable models can be developed to estimate the resistance of ships in channel ice. Furthermore, reliable testing methods in model scale can be developed when the physics of brash ice behaviour is well studied.

"Our next step is to compare the full-scale tests with the model tests and see which model test corresponds better with the full-scale test," Matala says. "We also want to investigate which of the measured parameters could explain why a certain model test would correspond better. Our aim is to repeat the full-scale tests, hopefully next winter, in order to get more results to compare with so that the impact of the hull form could be studied." ■

ANNOUNCEMENTS

Mauri Lindholm, who joined Aker Arctic in 2005 when the company was spun off from the shipyard, retired from daily work in the end of April this year. However, he will continue sharing his extensive knowledge as a part-time advisor and mentor.

Mauri studied naval architecture at Helsinki University of Technology and graduated in 1979. Before joining Aker Arctic, he worked for 25 years at Turku Shipyard in project design, sales support, design coordination and development studies. Over the years, he has been involved with various types of projects, from dredgers to passenger vessels and cargo ships.

In the 1990s, Mauri's main focus turned to LNG carriers. He participated in the entire shipbuilding process of a series of large LNG carriers from early development to detail design, delivery and after sales support duties. At Aker Arctic, his main lines of work have included gas carriers, gas fuelled vessels and oil tankers.

During his leisure time, Mauri enjoys gardening, sailing and cooking with his family.

NEWS IN BRIEF

Port icebreaker Ob soon ready

The port icebreaker *Ob*, based on the Aker ARC 124 design, will be delivered this fall from Vyborg Shipyard. Once delivered, the vessel will be deployed to Sabetta to assist the LNG carriers that transport natural gas from the Arctic terminal.

Photo Source: Vyborg Shipyard

Keel laid for Chilean Antarctic vessel

The official keel-laying ceremony for Chilean Navy icebreaking vessel, referred to as Project Antártica I, took place on the 18th of July, 2019. The Polar Class 5 vessel, under construction at ASMAR Shipyard in Chile, is the first of its kind built in South America. Aker Arctic supported Vard Marine in the design of the hull form and performed ice model tests in Finland. The ship launch is planned for 2022 and delivery to the Chilean Navy is expected in 2023.

Photo Source: Asmar

Atomenergomash JSC and Aker Arctic to begin cooperation

On June 13, 2019, Alexander Rantsev (First Deputy General Director for Atomic Energy and New Businesses of Atomenergomash JSC) and Reko-Antti Suojanen (Managing Director of Aker Arctic) signed a memorandum of understanding for co-operation in various Arctic projects in St. Petersburg. The proposed projects range from floating nuclear and LNG-fuelled power plants to specialised vessel designs, such as semi-submersible heavy-lift vessels and ice-going container ships capable of year-round navigation in the Northern Sea Route.

Arctic Passion Seminar 2019

For the 14th year, speakers from shipping and shipbuilding companies, the oil and gas industry, classification authorities and other partners gathered in Helsinki to discuss the latest trends in the Arctic industry.

Ilona Lundström, Director General for the Ministry of Economic Affairs and Employment in Finland, opened the day with a speech about the achievements during the Finnish chairmanship of the Arctic Council.

Icebreaking vessels are increasing

Reko-Antti Suojanen, Aker Arctic's Managing Director, gave an update on the latest news from Aker Arctic as well as the Arctic market in general. Despite the increasing need for icebreaking services in the coming years, more than half of the current worldwide icebreaking fleet is over thirty years old.

The day was filled with interesting presentations about the Canadian Arctic and investments, growth plans on the Northern Sea Route, climate change and how it is affecting sea ice, technical requirements when using LNG as fuel in icebreakers, as well as practical experiences from sailing on the Northern Sea Route among others.

Manoeuvring test in model ice

The highlight of the day was the ice model test demonstration, which showcased a remote-controlled vessel model of the Finnish icebreaker *Polaris*. The test demonstrated some of the newest technology in model testing. Manoeuvring tests with several propulsion units are easier to conduct as there are no obstructing cables; the only limitations are the basin walls.

We thank all our guests for joining us in Helsinki!

The presentations are available on our website www.akerarctic.fi.

Model testing expert Ann-Cristin Forsén

Ann-Cristin Forsén, Anki to her colleagues, celebrated her 60th birthday recently at a traditional Aker Arctic staff gathering of afternoon coffee and cake.

Anki began her work at the Wärtsilä Ice Model Basin (WIMB) in December 1982 as a young student. At the time, she studied shipbuilding at the Swedish Institute of Technology in Helsinki; today part of Arcada University of Applied Sciences.

"I was passionate about boats and decided to turn a hobby into my profession," Anki recalls. "At that time, most students were men. I was only the second woman graduate, but after me the numbers slowly began to increase."

Trailblazing projects

Anki has been part of a long list of shipbuilding projects, mostly involved in model testing as a project engineer and more recently as a research engineer. One project is especially close to her heart:

"The tiny Austrian river icebreaker *Röthelstein* was one of the early projects where Göran Wilkman and I did both the model tests and full-scale testing. The vessel was built by Kvaerner Masa-Yards in Helsinki in 1994 and was the first new icebreaker fitted with Azipod propulsion units. *Röthelstein* is still used on the Danube River to keep power-stations open and push barges year-round," Anki says.

Another important and interesting project Anki took part in was the recent icebreaker *Polaris*. "Being the first LNG-fuelled icebreaker, *Polaris* has been very visible in the media."

Spearheading development

Anki has always enjoyed her work at Aker Arctic and the preceding companies. "I have especially liked that we have always been at the forefront of doing things, ahead of others."

In her free time, she likes reading and theatre visits as well as nature walks with her dog.

Anki turned 60 this year. A tradition at Aker Arctic is to gather the staff for an afternoon to celebrate the big occasion with coffee and cake. Happy birthday!