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NEW ICE BASIN OF THE KRYLOV STATE RESEARCH CENTRE

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ABSTRACT

In 2014 the Krylov State Research Centre completed construction of its new ice basin. The main purpose of the new ice basin was to significantly enhance the experimental capabilities taking full advantage of previous experience in model investigations. This paper highlights the key achievements of Krylov Centre in developing the new model basin. This project has led to elaboration of new ice making techniques and model test methods raising the efficiency of various tests.

BACKGROUND

The methodology of model tests in ice basins has been elaborated for more than half a century. The Krylov State Research Centre is a leading Russian Federation company operating in this field, which is equipped with relevant experimental facilities for these purposes. The model ice research technologies are developed along the following lines:

- development of new model test methods and procedures for ships and marine structures;
- development of methods for modeling full-scale ice conditions in model tanks;
- development of model ice making techniques to simulate physical properties of full-scale ice;
- development of test facilities and equipment for experimental research including the design of ice model basins.

The first ice model tank of the Krylov Centre was commissioned in 1985. At that time it was an up-to-date facility meeting all demanding requirements for such laboratories.

That model tank was equipped to support the design of prospective icebreakers and ice class vessels (Sazonov, 2013). However, by the turn of the XX century the focus of interest shifted to the engineering issues associated with ice effects on marine structures. Major upgrades were carried out to address the emerging challenges, with additional equipment being installed in the existing ice tank to allow towing of model marine structures through ice at very slow speeds for simulating ice drift speeds in model scale. In addition, the Krylov ice model tank acquired a license from Kvaerner Masa Yards, Finland, for making fine-grained model ice. Implementation of this technology made it possible to raise the testing efficiency for a wide range of various experiments. Throughout its lifetime the ice model tank was a platform for innovations. The research staff of the facility developed and introduced more than twenty inventions for improvement of experimental research including a multi-purpose screw drive enabling model tests of ice-resistant platforms at slow ice drift, test rig simulating the seabed properties at the platform installation site and many other developments.

After more than 25 years in operation the Krylov's ice model tank could no longer fully satisfy research aspirations of ice scientists and engineers. Besides, almost all ice model basins in operation around the world were much younger than the Krylov facility. In view of these considerations and the need to perform a range of various investigations in the immediate future to support industrial development of the Russian Arctic it was suggested to build a new modern ice basin. Appropriate estimations and justifications were done (Appolonov, Sazonov et al.) to support the new ice basin project and the work was started.

DESIGN PARTICULARS OF THE NEW KRYLOV ICE BASIN

The Krylov Centre scientists and engineers have thoroughly elaborated the concept of the new ice basin (Sazonov, Appolonov et al.). Table 1 summarizes the main design particulars of the basin defined in accordance with this concept and compares it with the main data of the older ice tank. The newly built ice basin of the Krylov Centre has a capability to make two fundamentally different types of model ice for more accurate simulation of operating environments for various ships and marine structures, which no other existing ice basins around the world can do.

Table 1. New and Old Ice Basins of the Krylov State Research Centre

Characteristics	Old	New
Basin length including bay, m	50	102
Ice sheet length, m	35	80
Basin width, m	6	10
Basin depth, m (in brackets – depth of 20% length section at the basin end)	2 (3)	2 (4.6)
Ice thickness range, mm	10 – 100	10 – 130
Speed of towing carriage, m/s	0.005 – 1.0	0.0005 – 1.5
Average time to make one ice sheet, days	2	1-2

One of these types is a so-called columnar ice, which is produced using the method suggested by the Arctic and Antarctic Research Institute (Kashtelyan & Poznyak et al., 1968). This method was instrumental in the development of the first ice tank in the last century. However, many scientists around the world continued to further investigate this issue, and Finnish specialists have invented a fine-grained ice modeling technology. This technology enables ice basins to double or triple their ice test productivity. The new ice basin of the Krylov State Research Centre is now able to apply this technology along with the more traditional Russian model ice technology to carry out a broad spectrum of various research studies (Figure 1). Based on the experience gained from the use of the fine-grained ice technology in the older ice tank some improvements have been made to increase the range of modeled parameters. E.g., according to the Finnish recommendations it was originally specified that the minimum model ice thickness and flexural strength should be limited to 20mm and 20kPa, respectively, obviously falling short of the requirements in testing new offshore Arctic technologies. The Krylov State Research Centre has managed to push the minimum limits and double the range with a major enhancement of experimental capabilities.

Figure 1. Fine-grained ice sheet, view of the Krylov new ice basin

A significant length of the new basin called for optimization of water supply to the auxiliary (service) carriage to avoid any ice in water supply hose or spray system during model ice making process. For solving this problem the ice laboratory engineers suggested a channel that should run outside and parallel to the basin bowl and be connected to the main water volume of the basin by a system of pipelines (Figure 2). The water depth in this channel should be about 0.5 m to prevent ice pieces getting into the pipe extending from the service carriage. A bubbling system was arranged on the channel bottom to aerate water and prevent ice formation on water surface. Thus, the model ice making process is going uninterrupted when the temperature in the room is sufficiently low.

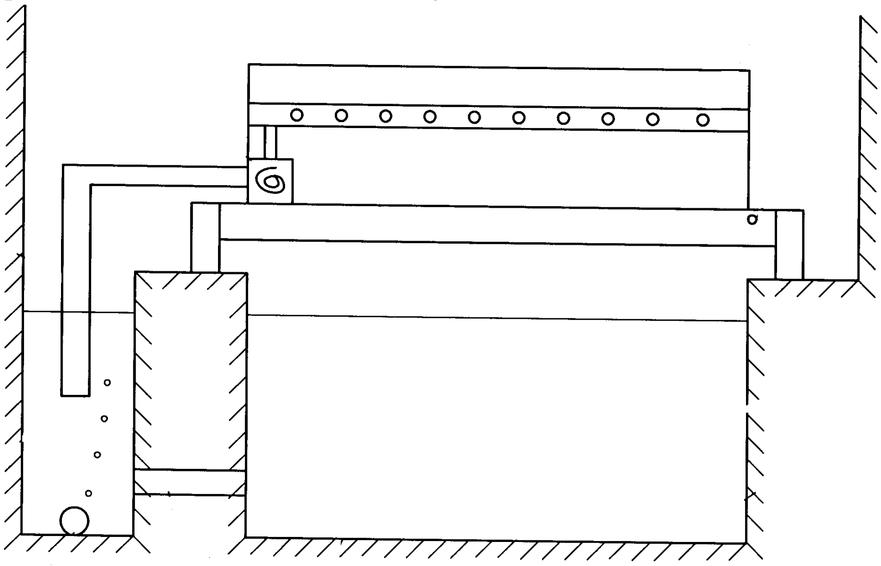

Figure 2. Water supply of service carriage in ice-making mode

Special design efforts have been taken to provide the best possible visualization of ice/structure interaction processes in this new ice test facility. For this purpose the basin bottom is provided with large view ports to allow observation, video and photography from the bottom. In addition, two observation tunnels are provided on both sides of the basin. One of the tunnels enables observers to view a running test model from top, while the other one makes it possible to have a side view of models below water level.

A wide range of model tests can be staged in the new ice basin to investigate various ships and marine structures. For this purpose new ice-making and test techniques have been developed in an effort to raise the productivity of experiments.

One of the routine types of experimental studies conducted in ice tanks is ice resistance tests of icebreakers and ice-class vessels providing initial data for further refinement of hull lines (Figure 3). A major advantage of the newly built Krylov's ice basin is a marked improvement in productivity of such tests being 2 to 4 times higher as compared to many other existing ice tanks. It is achieved owing to long lengths of ice sheets which can now be frozen in the basin, as well as more efficient utilization of the ice sheet width when experiments are conducted in parallel channels using special reinforcements, so-called "ice scratches". Moreover, our researchers have worked out a technology, which is now under verification, for making an ice sheet with two different thicknesses. Combinations of various techniques will enable the ice basin to perform integrated test packages for our customers as required for design of ships and marine structures with significant savings in time and cost.

Ship model tests often go hand-in-hand with the studies addressing the design of propulsion systems for icebreakers and ice-class ships under consideration. Special-purpose test rigs have been developed for the new ice basin to explore the interaction of various propulsors with ice including advanced propulsion systems like combinations of a conventional screw propeller with a podded propeller.

Figure 3. An icebreaker model test in the new ice basin of Krylov State Research Centre

In the recent years we have witnessed a fast progress in ice technologies giving rise to a new field of research studies in ice tanks focusing on so-called ice management techniques, i.e. special icebreaking operations intended to relieve ice loads on marine structures. The Krylov Centre researchers have developed a system for physical modeling of ice management operations.

Ice management systems usually involve a number of processes and procedures, which are as follows (with reference to ISO19906):

- Detection, tracking and forecasting;
- Threat evaluation;
- Physical ice management;
- Ice alert procedure;
- Disconnection and departure.

During ice management operations the sequence of events evolves in time near the installation site. A similar chain of events is considered in the design of marine structure and ice management system.

For this purpose special equipment was developed to be installed on the ship model under study for recording physical values, fixing model position coordinates as well as execution of real-time control functions. This equipment includes propulsion pods, model remote control panel integrated into the data monitoring and visualization system, model controls and radio-link unit for ship model position fixing (Figure 4). Underwater processes are viewed with assistance of a special remotely controlled submersible adapted for operation in cold and salty water.

Figure 4. Optimization of ice management modeling techniques using icebreaker model in the ice basin

In the experimental investigations the physical values are recorded at optimum sampling rate and monitored using time history plots or other display formats with required accuracy, and then these data are scaled up to full size. Among the parameters logged during such experiments are linear coordinates of the basin; heel, trim, and yaw angles; forces and moments at pods (load in pod, forces on shaft and shaft torque); engine torque and number of revolutions.

This complex enables researchers to carry out self-propulsion tests in the ice basin to explore tactics in breaking various ice features, eroding of ice ridge keels using thruster jets as well as to study ship maneuverability, etc.

It should be noted that the Krylov ice basin incorporates a range of other novel features intended for refining of ice navigation tactics including interactions with icebreakers, offloading terminals, etc. Another merit of the newly built ice facility is the capabilities of its service carriage usually intended for seeding and removing ice. The service carriage of the basin can be additionally outfitted with measuring instrumentation and used as a platform for a wide range of non-standard experiments.

For the investigations of ship maneuverability in ice the main towing carriage is also equipped with a Planar Motion Mechanism (PMM) running normal to the basin axis according to the prescribed law. In addition, PMM can be used to impart a prescribed angular speed to ship model. Thus, it enables measurement of ice forces and moments acting on a model under curvilinear motion. In testing of floating and fixed marine structures PMM is also used in testing of floating and fixed marine structures to model changes in ice drift directions for examining the ice load effects and ice/structure interaction.

Other common types of experiments in ice basins are the tests conducted to determine global ice loads on marine structures, sometimes including bottom effects; study and optimization of ice protection systems and elements. A new design of the towing carriage incorporating a number of lifting panels and rotating gears makes it possible to save time and power during performance of such experiments. The model orientation with respect to the ice drift heading can be changed in a matter of minutes. As for the seabed simulation, a number of alternative techniques are available. The modeled bottom can be fixed or mobile, which also significantly augments the experimental capabilities of the facility.

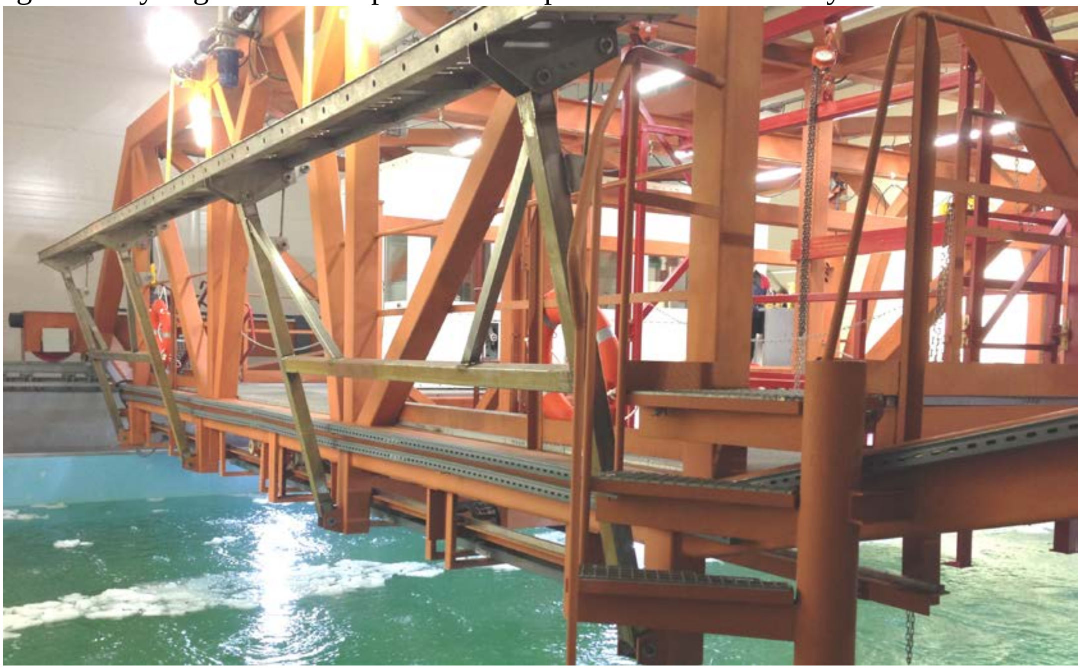

Figure 5. Planar Motion Mechanism on the towing carriage of ice basin.

Major attention in the ice basin design was paid to correct modeling of ice/moored structure interaction processes. For accommodation and simulation of mooring systems a 4 m deep section was provided extending over 20% of the basin length. This deep-water test section is surrounded with view ports for detailed visualization of processes affecting the mooring system elements.

The newly built ice basin is capable of modeling and reproducing the following ice conditions:

- continuous level fast and drifting ice;
- brash ice, broken ice, ice floes;

- ice ridges, ice hillocks, rubble ice;
- simulation of ice compression processes;
- fresh and old channels in ice.

Based on the wealth of previous ice research experience Krylov scientists have developed up-to-date technologies for modeling ice ridges with a specified thickness of consolidated layer positioned at any desired angle with respect to model heading or ice drift direction. Ice ridges present the most serious challenges to ships and cause high global loads during interaction with marine structures, therefore accurate modeling of such ice features in experiments is an important requirement. It is possible to model both ice ridges and rubble ice fields in the basin.

Modeling of physical processes happening in ice channels that are periodically navigated by icebreakers and ships is central for providing efficient operation of full-scale marine transportation systems. As time goes by a fresh navigation channel grows into an old channel filled up with brash ice (ice fragments measuring under 2 m across). Similar brash ice can be found in harbors, around marine structures at the locations with slow ice drift speeds, etc. Full scale observations and model experiments show that the growth rate of such ice in a channel is higher than the rate of level ice growth. [Sazonov & Shahov, 2006]. For this reason, at some point in time the navigation in such channels becomes difficult or impossible. Model experiments help to properly plan transport operations. It should be noted that the basin also makes it possible to investigate how changes in ice drift direction affect the mooring forces retaining a vessel by the side of the offloading terminal; to simulate pressure ice, etc.

CONCLUSION

The main task of the first ice model tanks was to investigate ship ice resistance. The scope of research studies has been increased to keep pace with time. In view of the present-day challenges it is now required to perform research studies in support of design and construction of advanced and sophisticated technologies for reliable operation in Arctic, coping with newly emerging issues. The new ice basin of the Krylov State Research Centre is a state-of-the-art ice research and engineering laboratory. The scientists and engineers of the Krylov Centre have been developing and gradually implementing new model test technologies and methods to address a range of major issues in the field of marine ice engineering. The paper presents part of the Krylov developments in model test technologies and procedures as well as major improvements in the equipment of new ice basin designed to cover a broad spectrum of model experiments.

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