Basics about ice, Part 2:

Special features of vessels operating in ice

Ships operating in ice can be referred to as either “ice-going” or “icebreaking” depending on their mission and general characteristics. Ice-going ships are structurally strengthened for navigation in ice-covered waters, but often have to rely on icebreaker escorts in challenging ice conditions. Icebreaking vessels are designed to operate independently and, when necessary, break their own path through the ice field.

Both ice-going and icebreaking ships have certain design features that set them apart from vessels operating in open water: increased structural strength, higher propulsion power and a hull form fit for purpose.

The icebreaking hull form

The development of an ice-going or icebreaking hull form begins by outlining the operational conditions of the vessel concept. This includes: the location (where it will operate), the time (when it will go there) and the mission (what it does once it gets there). This will be used to establish the icebreaking capability of the built-for-purpose vessel, for example the maximum level ice thickness that can be broken in a continuous motion. As most vessels operate in ice for only part of the year, open water performance and seakeeping characteristics typically cannot be neglected; sometimes the hull form may be a compromise between open water and ice operation. However, some icebreakers feature a no-compromise extreme icebreaking bow that allows them to break very thick ice with relatively low propulsion power.

An icebreaking hull form is designed to minimize the additional resistance resulting from hull-ice interaction. A modern icebreaking bow, characterized by smooth rounded waterlines and small flare angles, breaks the ice in the most energy-efficient way: by bending it downwards. Stem and shoulder areas are designed to minimize crushing of the ice. After breaking, the ice floes are accelerated smoothly as they are displaced around or submerged under the moving vessel. Special attention needs to be paid to hull appendages when designing an icebreaking vessel: for example, a badly designed forefoot can significantly increase the ice resistance.

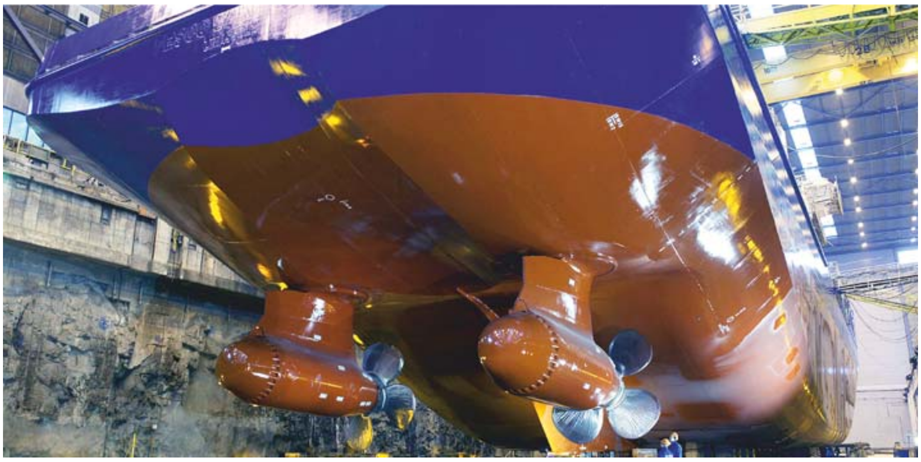
Icebreaking vessels typically feature sloping sides which serve two functions: they increase the manoeuvrability of the vessel in the ice, which is particularly important for escort icebreakers operating in close proximity to other ships, and they reduce the ice loads on the hull structures in compressive ice.

Most modern icebreakers are capable of operating in both ahead and astern directions in the same ice conditions, meaning that the stern hull form is designed following largely the same principles as the bow. In addition, the stern must be designed to work efficiently with the selected propulsion system. Double Acting Ships (DAS™) combine an ice-going bow with an icebreaking stern, resulting in a vessel that is capable of operating independently in ice in the astern direction while remaining economical in open water and light ice conditions where it sails bow-first.

Propulsion system design

While ice-going ships typically feature conventional mechanical shaft lines and rudders like their open water counterparts, icebreaking vessels have more variety in propulsion systems: up to four shaft lines or azimuthing propulsion units, or a hybrid propulsion with combinations of both. Many icebreakers have propellers also in the bow of the vessel. This is a result of following the same principles as with the hull form: the design is tailored according to project-specific operational parameters and limitations. Regardless of the project, the goal is to achieve the desired icebreaking capability with the smallest installed power, resulting in a vessel that is less expensive and more economical to operate. While icebreakers have high propulsion power compared to other ships, it should be kept reasonable.

Typical icebreaking bow form



Icebreaking aftship hull form –”double acting ship”

Sloping sides increase manoeuvrability in ice

Centreline skeg improves course stability

While a diesel-electric powertrain is generally favoured due to the good low-speed torque characteristics of electric motors and fixed pitch propellers due to their simplicity and robustness, a number of icebreakers have been equipped with controllable pitch propellers mechanically coupled to the main engines. In case of the latter, oversized flywheels are sometimes used to protect the main engines from sudden torque peaks resulting from propeller-ice interaction. The flywheel also prevents the propeller from stopping while the vessel is moving, a situation where most propeller damage occurs. Open propellers are usually preferred in icebreaking applications as nozzles may suffer from clogging in heavy ice conditions.

Regardless of the selected solution, the design principles regarding strength are the same: the propulsion system components must be strong enough to withstand the propellers coming in direct contact with the ice. Icebreakers typically use built-up propellers with detachable blades. The design follows the so-called strength pyramid where a propeller blade should fail before damage to other components occurs. Most icebreakers carry spare blades and have provisions for changing them at sea, but repairing other propulsion components would usually require drydocking.

Ice strengthening

Both icebreaking and ice-going vessels require additional structural strengthening to be able to operate safely in ice-covered waters. If the ice loads on the hull are excessive, the results can range from small dents in the shell plating to buckled frames and, in the worst case, loss of watertight integrity and sinking of the vessel.

Both ice-going and icebreaking vessels typically have a transverse framing system which distributes the ice loads more effectively than longitudinal framing. High strength steel is typically used at least in the ice belt area to reduce weight; using mild steel could result in a shell plating thickness of up to 50 mm. The basis for ice strengthening is a so-called ice pressure plan where the hull of the vessel is divided into separate regions and a design ice pressure is assigned to each part:

"In addition to classification society rules, we use our in-house calculation methods and experience in determining the extent of each region and the design ice pressure. The hull strengthening is based on the selected ice class and the overall operational icebreaking capability of the vessel," Project Engineer, Tuomas Romu explains. "In particular, highly manoeuvrable icebreakers may require additional hull strengthening in parts of the hull."

Icebreaking Supply Vessels "Arcticaborg" and "Antarcticaborg".

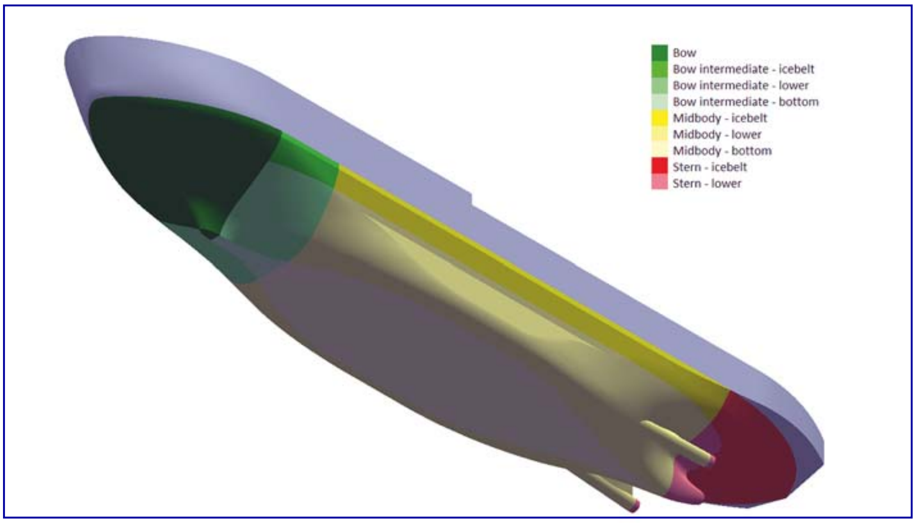
Nuclear Icebreakers "Taymyr" and "Vaygach".

Series of five Arctic Container Vessels.

"Mangystau 1-5". Series of five Shallow Draught Icebreaking Tugs.

Arctic Shuttle Tankers "Mikhail Ulyanov" and "Kirill Lavrov".

Arctic Module Carriers "Audax" and "Pugnax".



The selection of ice class, which determines the general level of ice strengthening for ice-going and icebreaking vessels, is not straightforward. If it is too low, there is a risk of ice damage due to inadequate strength and local administrations may impose traffic restrictions during the worst part of the winter. If it is too high, excessive steel weight will increase the construction cost and operational expenses, and reduce the amount of fuel and cargo that can be carried onboard.