Basics about ice, Part 1:

Ice properties and ice resistance

Icebreakers and ice-going vessels continuously encounter changing ice conditions during their operation. When developing such vessels, the designer must recognize which ice conditions are relevant and how they affect the vessel design. Typically, four main ice types are considered: level ice, drift ice, brash ice and ice ridges.

Level ice is an intact, continuous ice cover, which is typically encountered in coastal and sheltered waters where the ice cover is frozen to the coastline and islands. It is uncommon in open seas due to wind and waves. Although level ice is less encountered in nature, it is used as the basis when defining the icebreaking capability of an ice-going vessel, because vessel capabilities are then easier to test, calculate and compare.

Drift ice is a broken ice field consisting of ice floes of various sizes. This is the most common ice condition in open sea because wind and waves break the ice. Wind can also drive the drift ice into ice packs or ridges. Coverage is given in tenths i.e. 0/10 open water, 10/10 complete ice. If the ice coverage is less than 5/10, ice generally does not impede vessel passage.

Brash ice and ice channels form on shipping lanes and in harbour basins as a result of regular traffic and constant icebreaking activity. These ice blocks are roughly spherical with a diameter smaller than 2 m, and the thickness of the ice mass grows faster than that of the surrounding level ice. Ice blocks near the surface level may freeze back together, creating a thick consolidated layer. In channels the thickness of the ice mass increases towards channel edges, which can make breaking out from a channel very challenging. This is the typical operational environment for merchant ships in e.g. the Baltic Sea.

Ice ridges are accumulated ice blocks and rubble formed when wind and current push ice floes against each other. The total thickness can be tens of metres and the ice blocks can additionally freeze together to form a consolidated ridge. This is typically the most challenging ice obstacle encountered by ice-going vessels in all freezing seas, and in particular in coastal areas such as the Gulf of Bothnia and the Gulf of Finland in the Baltic Sea, and the Kara Sea in the Russian Arctic.

Ice conditions

In addition to the four different types of ice generally considered in the design process, there are two additional ice features worth noting, namely compressive ice fields and icebergs.

Wind can create compressive stresses in a **drift ice field**. When ice presses against the sides of the vessel, ice resistance increases considerably. If a vessel gets stuck in ice, it may result in ice damage if the hull structures cannot withstand the compression in the ice field. This also means that the channel behind the icebreaker closes and escorting merchant ships becomes more difficult.

Icebergs are large ice blocks calved from glaciers. Formed in high pressure over hundreds, even thousands of years, the ice is very clear and extremely hard. Ships should avoid coming in contact with icebergs, and ice management vessels should steer icebergs away from offshore structures. Small icebergs such as growlers and bergy bits are especially dangerous, as they are difficult to detect and colliding with them at high speed could sink a ship. Icebergs are typically not taken into account in ice-going vessel design, as they are to be avoided. Not even the biggest and strongest icebreakers in the world can withstand collision with an iceberg, contrary to common beliefs.

Ice can also be either first-year or multi-year ice. In the Baltic Sea and most of the Arctic and Antarctic, the ice is first-year ice. This ice is more porous than multi-year ice. The maximum thickness depends on the geographical location, e.g. one metre in the Baltic Sea and up to two metres in the Arctic.

Ice that has survived more than one summer period is called multi-year ice. It has lower salinity and porosity, and is hard and often thick. Glacial ice is an extreme case of multi-year ice, which can be up to a thousand years old. Ships should avoid and circumnavigate multi-year ice whenever possible.

Ice failure process

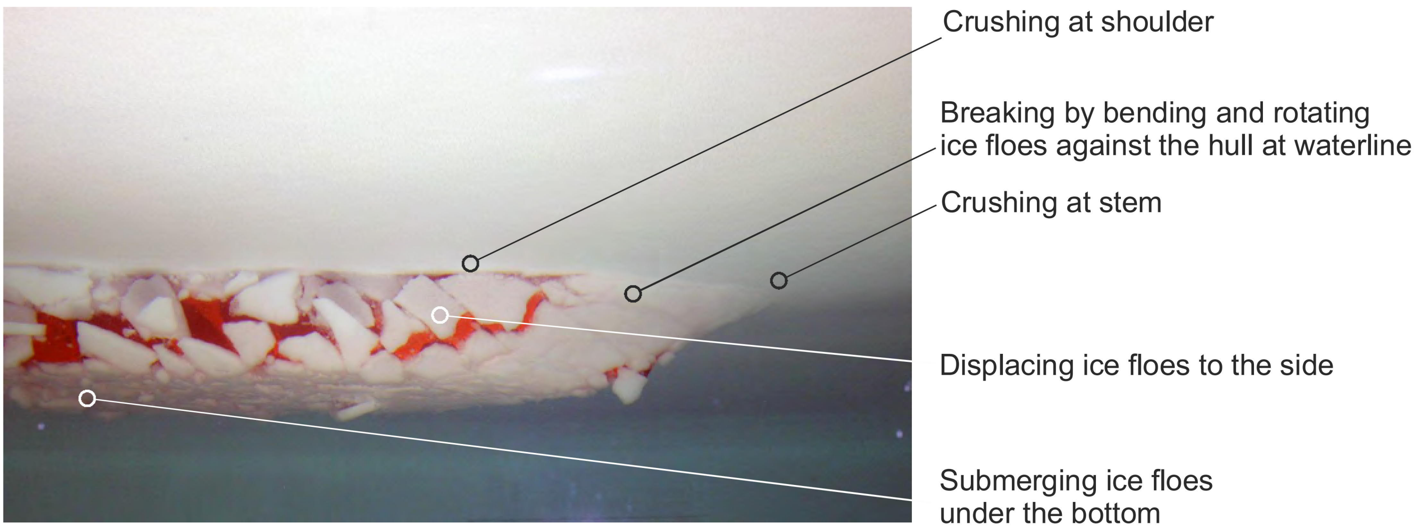
Ice can be broken in two different ways: either by crushing or by bending. Ice loads and resistance become very high in crushing, and the power needed to crush the ice can be up to ten times higher than is needed for bending. The hull must also be much stronger. Therefore bending is the optimal way of breaking the ice, as it is much more efficient. Even very thick ice can be broken with reasonable propulsion power.
A traditional icebreaking bow bends the ice downwards, and sloping sides improve manoeuvring.

The modern method is to use the propeller flushing effect to reduce friction and dislodge ice blocks. It is possible to use bow propellers, as in traditional Baltic icebreakers. The active flushing is done with azimuth thrusters. Double-acting cargo ships can also move in the astern direction. If the vessel is kept in continuous motion, there is no danger of getting stuck in the ice.

Ice resistance

The ice resistance is the added resistance from the icebreaking process, which the vessel needs to overcome in addition to hydrodynamic resistance. The ice resistance as a whole is a result of different stages of the icebreaking process such as crushing, bending and submersion of the ice floes.

Icebreaking and ice-going capability are typically defined for level ice, because vessel capabilities are then easier to calculate, test and compare.
For special purpose vessels, icebreaking capability can also be defined e.g. for thick brash ice or other ice conditions. What is essential is that icebreaking is a complex process and numerical simulation of icebreaking is very difficult. Empirical methods and physical testing are much faster ways to get information and predict performance.



Icebreaking in level ice

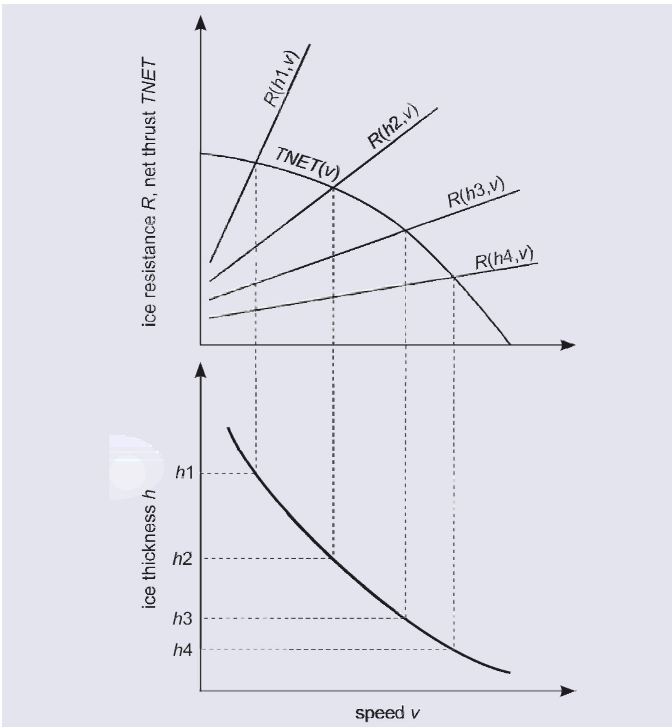
In level ice, the first way in which ice fails is by bending against the bow of the vessel. Crushing may also occur near the stem and shoulders, but one of the design goals is to minimise this. The broken ice floes rotate against the sides of the vessel, after which the ice is displaced to the sides and submerged under the bottom as the vessel moves forward. The second way ice fails is through friction between steel and ice as floes slide along the hull. In which ice-going vessels typically operate, the ice resistance increases linearly as a function of speed in the speed range.

Icebreaking in channels and ridges

If ice is already broken, the ice resistance is primarily a result of displacing the ice mass around and under the vessel, while part of the resistance comes from compressing the ice mass surrounding the hull. Even vessels with no independent icebreaking capability and limited propulsion power may be able to operate independently in ice channels.

Penetrating ice ridges

The traditional method to penetrate ice ridges is “ramming and backing”. The mass and momentum of the vessel is used to drive the hull through the ice feature. However, there is a danger of getting stuck in ice if the vessel cannot back away from the ridge. In order to break free, heeling and trimming systems or air bubbling can be used.



Basics about ice, Part 2: Special features of vessels operating in ice. Read more in next issue of Arctic Passion News.