

## **Range of Ice Management Using Azimuth Thrusters**

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The following lists and describes the key operational and ice management tasks, which can be performed with the use of the wake of the azimuth thrusters:

- Breaking and clearing ice jams
- Breaking ice ridges
- Breaking and clearing moving pack ice
- Clearing a track behind the vessel
- Clearing ice from around the hull of the icebreaker
- Clearing ice from between the icebreaker and a secondary object
- Widening a track behind the vessel

Each of these ice management tasks is addressed below:

### ***Breaking and clearing ice jams***

This operation takes place backwards. It requires the vessel to back slowly into an ice jam and use high power astern. Both propeller units are oriented in the same direction. They are swayed from one side to the other side, sufficiently to suck ice from the ice jam, clear a way for moving backwards, as well as breaking ice along each side of the vessel one side at a time. The vessel progresses in this mode of operation at a speed twice that of ahead ramming mode of operation, and clears a path possibly as wide as twice the width of the vessel. The current power of the Research vessel is expected to give a performance about half of that of Botnica, or approximately 0.1 knots in an ice jam of a total average thickness of 6 m.

The icebreaker may be slowed down considerably in a longer distance of penetration of such an ice jam, as the low power will tend to introduce the risk of getting stuck, into an extensive ice jam.

### ***Breaking ice ridges***

Ice ridges are broken by use of both thrusters oriented close to 90 degrees out. One thruster will break the ice ridge and remove ice in it, whilst the other thruster is used to slowly move the icebreaker ahead, alongside the ridge in the direction of its sail line. The power of current research vessel is expected to be able to remove close to 50000 tonnes of ridge mass, from thick ridge fields, in an hour. This assumes that it is possible to turn one of the thruster units 180 degrees relative to the other, and reverse the propeller rotation. It would be beneficial to have the pushing propulsion unit dismantle the ridge, as the propeller is much closer to the ridge, than if the propeller operates in a pulling, tractor mode.

### ***Breaking and clearing moving pack ice***

It is possible to orient the stern of the vessel into oncoming ice, and orient the thrusters at an angle which keeps the vessel practically stationary, The oncoming ice is broken partially by its stern, and partially by the propulsion wake, and is removed

towards the sides. In this process, the amount of ice that can be broken, and the width of the channel created, are a function of the ice thickness, the power applied, and the rate of ice movement.

The current Research vessel design can perform this task, when propellers are operated both in tractor mode. When the thrusters are operated in the tractor mode, the angle that is possible simultaneously for the thrusters, for a moderate length of time, a few minutes, about 45 degrees. A short time would be possible to apply high power at up to 60 degrees thruster angle. However, the suction of the tractor propellers takes place from the same source of water, which will soon induce vibration and loss of thrust.

The effective breaking and clearing of moving ice maintaining an approximately constant position for the vessel, requires at least a 70 degree or higher angle. If the thruster propellers are reversed in rotation, and operated in a pushing mode, there is no propulsion unit interference based restriction to use of propulsor angles out. However, in this mode the wake of propellers would be oriented somewhat down into the water and the icebreaking and clearing efficiency would be highly limited.

### ***Clearing a track behind the vessel***

This operation is best achieved with thruster angles of 5 – 30 degrees. The ice concentration in the track behind the icebreaker is expected to be reduced from a typical value of 8 to 9+ tenths, to less than 3 tenths. The propulsor angles in the range of 15 – 30 degrees are small enough, that channel widening, through breaking of ice with the wake, will not take place.

### ***Clearing ice from around the hull of the icebreaker***

When the icebreaker is stopped, perhaps stuck, it is possible to turn the thrusters in various angles to clear ice from around the hull. The wake will push ice, and clears an area which varies in size. The amount of ice all around the vessel determines this size of space that can be created.

An early estimate for the Research vessel is that in a 6-m ridge, the propulsion can create a space around the vessel, with significantly less ice than in the ridge, up to a distance of at least 6-m each side. It is not possible to remove all the ice when there is a continuous ridge or ice jam mass around the vessel. It is not possible to clear the ice from around the full length of the hull in a highly compacted ice condition either. In advantageous conditions, where there is no piled up ice around the vessel, it is expected to be possible to clear the ice from around the vessel within a few minutes to half-length of the vessel, in all directions. The ice breakage through wake, of level ice, is expected to occur up to about 55 cm in thickness, and requires a few minutes of exposure time. It should be noticed that this performance is only possible in those operational conditions where the propulsion units can be operated in the tractor mode, and the wake is pointed up at an angle of typically 3 degrees, to bring the wake towards the surface, to enable the ice breakage. This type of operation is limited in those situations where the thrusters have to act one against the other, in order to keep the vessel in position for the ice management exposure time to be sufficient. When an operational propulsion configuration has to be kept, which requires use of one unit in tractor and the other in pushing mode, the efficiency of ice management by the wake on one side of the vessel is higher. It is higher on the side where the tractor mode

propeller is used. This is due to the orientation of the wake, which is up for the tractor unit and down for the pushing unit.

### ***Clearing ice from between the icebreaker and another obstacle***

This operation is one requiring a high operational skill, as well as significant caution, especially when performed next to vessels with no or low ice class. The operation takes place using one azimuth thruster at an angle pointing the wake out, into the space between the icebreaker and the beset vessel. The other thruster is used to give longitudinal movement to the icebreaker at the desired rate, and to balance the sideways force from the thruster performing the ice clearing.

The operation is something no previous icebreaker generation has been able to perform, as the thrust and propulsion wake has only been available in the longitudinal direction. In this situation application of net thrust in one direction has resulted initiating move of the vessel to the opposite direction. The alternative, crossing the thrust, one propeller forward the other aft, still only gives mostly longitudinal only thrust and no or little ice clearance alongside the vessel.

A high caution is also required for protection of the secondary structure, at which ice clearance is required. The propeller wake tends to throw ice at a high speed against the hull of any structure in the wake, especially if a higher propulsion unit angle and higher power is used than necessary to perform the operation. Over clearing the ice will lead to individual even large ice blocks being propelled at high speed in practically ice clear water

### ***Widening a track behind the vessel***

This operation is performed using both thrusters angled out, so that the wake of propulsion will break the edges of the solid ice sheet, and thus widen the channel. The operational efficiency is a balance between the power used and the angles of the propulsion units, determining the speed of the vessel as well as the efficiency of the wake outside of the width of the vessel. No practical ice breakage has taken place to widen a channel with propulsor angles less than about 45 degrees out. This is mainly due to the fact that the speed of the vessel is so high at lower angles that there is insufficient exposure time for the wake to take effect and break the ice.

The Research vessel is expected to be unable to perform the channel widening operation, at any power and any speed, in any significant ice thickness. The reason is that it is not possible to continue operating the propulsion units at an angle of even 45 degrees out for any length of time. The vibration of the propulsion units, and apparently also associated loss of their efficiency, when the tractor propellers suck water from the same space, makes the channel widening operation impractical.

If the stern of the Research vessel is redesigned, so that it is possible to reverse the rotation of the thrusters, and operate them efficiently in a pushing mode, and still send the wake to the surface (requiring specific stern angles at propulsion units), then this operation is expected to become of practical importance. The relatively low power makes it a low efficiency operation, widening a channel in level ice or in an old brash ice channel. However, this operation, especially in an old brash ice channel, can have a major impact on improved efficiency of shipping. The channels get lighter and stay lighter for ship transits, when such channel widening is performed. Furthermore, in

floe ice this ice clearing is highly efficient, and enables performance of research well beyond what was thinkable prior to use of azimuth thrusters. The limiting thickness in which the channel widening is possible will be analyzed for the Research vessel. An early estimate is that 60-cm thick ice can be widened at a speed of 1 knot, at the current Research vessel power. The added width of the channel is expected to be in the range of 25 % wider than the vessel. Furthermore, loose rubble at the edges of a brash ice channel will be moved further out from the center of the channel, which further makes the channel easier to transit, especially with wide vessels.

A specific application of the outward turned azimuth thrusters is, however, the fact that a virtually guaranteed clearance of ice behind the vessel can be achieved. It is easy tow items behind the vessel, without ice interference. It is also easy to create open water space alongside the vessel for an indefinite length of time in virtually any ice conditions, outside of 10 tenths ice. This is done by orienting the wake slightly out.