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TOWING IN ICE DURING ESCORT

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FOREWORD

In this report no 116, the Winter Navigation Research Board presents the results of research project TIDE Towing in Ice During Escort. Towing practices and towing forces for existing and new bow types were evaluated to determine challenges to towing of merchant vessels by icebreakers, which could be addressed by new requirements or guidelines.

The Winter Navigation Research Board warmly thanks Heikki Juvani, Rob Hindley and Sabina Idrissova for this report.

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Aker Arctic

AKER ARCTIC TECHNOLOGY INC REPORT

TIDE TOWING IN ICE DURING ESCORT

FOR

FINNISH-SWEDISH WINTER NAVIGATION RESEARCH BOARD

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This project evaluates towing practices and towing forces for existing and new bow types, specifically EEDI bow types, to determine if there are challenges to towing in ice which can be addressed by updates to existing requirements, rules or best practice documents. The evaluation was undertaken using feedback from operators of EEDI compliant merchant ships, feedback from captains of icebreakers that have undertaken towing in ice of EEDI compliant vessels, a review of mooring arrangements of EEDI compliant vessels and an analysis of the towing forces using force-vector analysis. In addition, the Aker Arctic Ice Simulator, usually used for training crews operating icebreakers, was used to simulate towing forces. Based on the analysis and operational feedback a number of recommendations are made, notably: To revisit the operational feedback from interviews at a later date, once more EEDI compliant vessels are in operation; To attend onboard icebreakers involved in towing at a later date, once more EEDI compliant vessels are in operation; To review, with icebreaker operators, the standard equipment provision for towing (especially whisker wire length) to confirm commonality; To consider an update to the bollard / chock location guidelines in combination with input from the icebreaker operators whereby icebreaker geometries and standard whisker wire lengths are provided to enable appropriate mooring arrangements to be implemented by the designer, whatever the bow type.

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1 SUMMARY

This project has aimed to evaluate towing practices and towing forces for existing and new bow types, specifically EEDI bow types, to determine if there are challenges to towing in ice which can be addressed by updates to existing requirements, rules or best practice documents. The evaluation was undertaken using feedback from operators of EEDI compliant merchant ships, feedback from captains of icebreakers that have undertaken towing in ice of EEDI compliant vessels, a review of mooring arrangements of EEDI compliant vessels and an analysis of the towing forces using force-vector analysis. In addition, the Aker Arctic Ice Simulator, usually used for training crews operating icebreakers, was used to simulate towing forces. Due to COVID19 restrictions a number of planned activities associated with direct observation of towing in ice (both onboard the icebreaker and merchant vessels) were subsequently cancelled. The project has therefore drawn the majority of its practical conclusions from interviews.

With respect to towing the main differentiating point for EEDI compliant ships is the sharp bow form, the main operational consequence of which (with regards to towing) is the positioning of the chocks and bollards on the merchant vessel mooring deck: Sharper EEDI bows may lead to situations where the bollard and chock positioning results in a smaller angle between the whisker wire and the centerline (spread angle), leading to less control of the merchant vessel (course stability).

Although utilising the Aker Arctic Ice Simulator did not advance to a stage where the system can be used as a platform for testing different mooring arrangements, insight from using the simulator, combined with a review of full scale towing measurement data and more straightforward analytical analysis confirmed the overall operational view that bollard location has a direct influence on the course stability of the ship under tow and consequently that bollard / chock location is an important factor in the tow. However, considering regulating the bollard / chock location in isolation poses problems, because the line towing angle (which is the driver for course stability under tow) is also dependent on the whisker wire length (from the icebreaker) and the distance between the bow of the merchant vessel and the icebreaker's aft deck (which is driven by the operational need to have the towing block over the icebreaker's aft deck to enable ease of connection / disconnection). Consequently, the recommendations from the project are:

- To revisit the operational feedback from interviews at a later date, once more EEDI compliant vessels are in operation
- To attend onboard icebreakers involved in towing at a later date, once more EEDI compliant vessels are in operation
- To review, with icebreaker operators, the standard equipment provision for towing (especially whisker wire length) to confirm commonality
- To consider an update to the bollard / chock location guidelines in combination with input from the icebreaker operators whereby icebreaker geometries and standard whisker wire lengths are provided to enable appropriate mooring arrangements to be implemented by the designer, whatever the bow type

2 BACKGROUND AND PROJECT STRUCTURE

2.1 PROJECT DESCRIPTION

The project aim was to evaluate towing practices and towing forces for existing and new bow types (EEDI type) employed on merchant ships in the Northern Baltic. The original project plan aimed to achieve this by in-situ evaluation of merchant ship mooring arrangements which lead to easy and difficult tows, identification of trends for successful arrangements, use of the ice operations simulator (numerical model) to model new and existing bows in the towing notch and evaluate how the forces are distributed. The outcome of which was expected to identify if there is a need to adjust the towing / mooring arrangement included in the Guidelines to the Application of the Finnish Swedish Ice Class Rules – FSICRs Guidelines (TRAFICOM & Swedish Transport Agency, 2019).

Due to reduce sea-ice in the Baltic during 2019-2020 season and the effects of COVID19 with respect to restrictions on travel and visiting ships, availability and accessibility of icebreakers and merchant ships was significantly restricted and attendance for operational monitoring onboard icebreakers and merchant vessels was cancelled.

However, interviews with merchant ship and icebreaker operators, as well as a review of mooring arrangements and towing practices has enabled conclusions to be drawn which are considered useful and in-line with the original project objectives described below.

2.2 PROJECT OBJECTIVE

Trafficability of winter navigation in the Northern Baltic depends to an extent on the ability of icebreakers to perform close towing of merchant ships, often where the bow of the merchant vessel is in direct contact with the icebreaker's towing notch. New ships, especially those designed to higher open water efficiency in order to meet the EEDI requirements, are equipped with different bow shapes, which may be generally considered as “blunt” or “vertical”. These may not effectively fit into the towing notches which were designed for older ship types. Bollard configuration on merchant vessels is not standard for towing: while icebreaker arrangements are well known there is only general guidance in the FSICRs Guidelines on bollard locations for towing, which relate to older bow types. Towing of such new bows may result in poor contacts in the notch, or loss of tow directional stability, which may lead to inefficient and sometimes dangerous towing situations.

2.3 SUMMARY OF WORK PACKAGES

The project was divided into seven work packages, as described below:

- WP1 – Fleet review
- WP2 – data gathering plan
- WP3 – onboard evaluation of towing arrangement performance
- WP4 – onboard survey of merchant vessel arrangements
- WP5 – modelling of merchant bows and bollard arrangements
- WP6 – testing of AAT ice simulator for bow force determination
- WP7 – final reporting

The purpose and description of the work packages is included in Table 2-1 including the outcomes achieved during the project which are further described in the following report. Note, due to continued limitations and restrictions on attending vessels due to COVID19 the onboard aspects of the work packages were not carried out.

Table 2-1 Summary of Work Packages

Work Package	Name	Description of tasks / Purpose	Outcomes
WP1	Fleet Review	Review of vessels operating in the Baltic during the wintertime which have been built to comply with EEDI requirements. To establish a list of known ships to evaluate and operators to approach to ascertain operational feedback	Short list of vessels and operators identified. This small list means limited operational experience is currently available.
WP2	Data Gathering Plan	Undertake initial interviews with icebreaker operators to establish pertinent questions and issues to follow up when attending onboard and witnessing operations.	Proforma of questions developed and subsequently used ashore in discussions with operators. Feedback on EEDI ships behaviour under tow ascertained.
WP3	Onboard Evaluation of towing arrangement performance	Develop suitable questionnaire for use and observe towing arrangement performance onboard icebreakers operating in the Baltic	Questionnaire developed and interviews undertaken onshore with icebreaker operators. Onboard observations not undertaken due to access restrictions. Principal outcome is that the towing efficiency is influenced by the chock location which is dependent on the bow form (mooring deck shape).
WP4	Onboard survey of merchant vessel arrangements	Develop suitable questionnaire for use and observe towing arrangement performance onboard merchant ships operating in the Baltic	Questionnaire developed and interviews undertaken onshore with merchant ship operators. Onboard observations not undertaken due to access restrictions. Principal outcome is that the towing efficiency is influenced by the chock location which is dependent on the bow form (mooring deck shape).

WP5	Modelling of merchant bows and bollard arrangements	Review mooring / bollard arrangements and model forces using force-vector analysis.	Analysis of the forces and inferred course stability under tow for a number of bollard and tow configurations. Principal outcome is that it is shown that the whisker wire spread angle influences tow efficiency.
WP6	Testing of AAT ice simulator for bow force determination	Simulate operations of towing in ice to determine if towing forces can be extracted from a ship dynamics-based simulation model to be able to evaluate the impact of bow form geometry and bollard location on towing forces.	Simulation of towing operation and forces / time history compared with full scale measurements. Principal outcome is that such a simulator is unable to be used as a tool to efficiently model multiple tow configurations accurately for the purpose of investigating the influence of bow shape and towing wire arrangement on the tow performance.
WP7	Final Reporting	Reporting of activities and recommendations to be carried forward.	This report.

3 FLEET REVIEW

3.1.1 IDENTIFICATION OF EEDI COMPLIANT SHIPS

In order to identify suitable merchant ships to evaluate in full scale and model analytically a review of the fleet traffic in the Baltic over the last winters was undertaken to identify new EEDI compliant ships. After the ships were identified, the associated shipowners with new EEDI compliant ships were contacted. A filtering of these ships was undertaken based on feedback and comments from icebreaker Captains interviewed as part of the project in addition to Aker Arctic's understanding of the ship configurations.

As a part of the EEDI Assistance project (Aker Arctic Technology, 2020) for the Winter Navigation Research Board a list of EEDI vessels has been compiled, based on observations of ships operating in the northern Baltic ports during past winters. The IHS database was used as a basis, with the first filter by ships assigned a Finnish-Swedish ice class. The vessel's EEDI phase 0 or phase 1 EEDI vessel was assigned based on the ship type, order date and deadweight. Note it is assumed (reasonably) that none of the ships assigned a Finnish Swedish ice class operating in the Northern Baltic has an independent icebreaking capability above 1.0m level ice, which would exclude it from the EEDI compliance requirements. Table 3-1 provides a summary of Baltic trading ships that were built to comply with EEDI Phase I (no ships built to comply with Phase II were in the database).

Table 3-1 provided a starting point for discussing ships which are difficult to tow with icebreaker Captains.

The list of merchant vessels complying with EEDI has assisted in informing of the basic characteristics of EEDI compliant vessels. The list and description of the vessels was taken forward for discussion with the Icebreaker Captains, in order to provide a basis for discussion. It should be noted that the list of vessels is relatively small, which limits the sample of ships for evaluation both operationally and in terms of towing arrangements for this project.

Table 3-1 EEDI Compliant Merchant Ships Operating in the Baltic

Ship No.	Ship type	DWT	Dimensions
1	Tanker	7998 t	LOA 119,9 m B19,4 m
2	Tanker	7998 t	LOA 119,9 m B 19,4 m
3	Tanker	17993 t	LOA 149,9 m B 22,8 m
4	Tanker	17994 t	LOA 150 m B 23 m
5	General cargo ship	25532 t	LOA 160 m B 26,08 m
6	General cargo ship	23650 t	LOA 160 m B 26,08 m
7	General cargo ship	5019 t	LOA 103 m B 13,6 m
8	General cargo ship	5019 t	LOA 103 m B 13,6 m
9	General cargo ship	14330 t	LOA 149,95 m B 15,9 m
10	Oil/Chemical tanker	17500 t	LOA 155,44 m B 23,95 m
11	Oil/Chemical tanker	17500 t	LOA 155,47 m B 23,96 m
12	Cement carrier	6145 t	LOA 100 m B15,8 m

3.1.2 CHARACTERISTICS OF EEDI COMPLIANT VESSELS

Figure 3-1 provides a comparison of bow types. These are shown to illustrate the main differences between typical merchant vessels pre-EEDI and EEDI compliant vessels. The main characteristics of EEDI compliant bows identified from a review of the ships in Table 3-1 are:

- Vertical or near vertical stem angle
- Very steep / vertical frame angles at the forward bow
- Narrow waterline shape, leading to a narrow mooring deck above

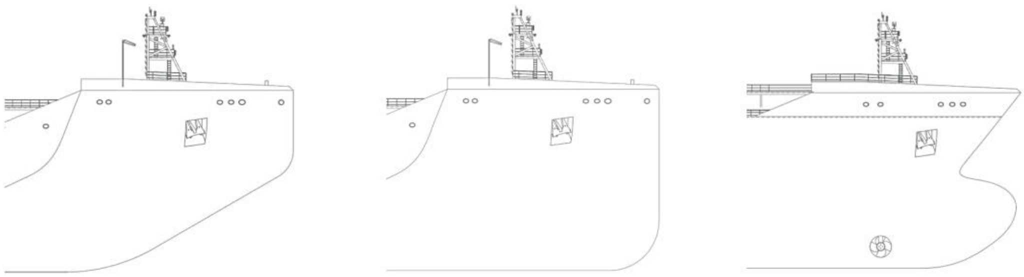


Figure 3-1 Different Bow Types, from left to right, ice bow, EEDI bow, bulbous bow

The performance of EEDI compliant ships within the Baltic Winter Navigation System has been dealt with in other reports, notably EEDI and the need for icebreaker assistance Part 1 and Part 2 (Aker Arctic Technology, 2019), (Aker Arctic Technology, 2020). In general the conclusions have been:

- that to be a clear correlation between the power-deadweight ratio of the merchant vessel and the need for icebreaker assistance and towing
- there seems to be a trend that for the EEDI-compliant vessels the assistance and towing times and distances are longer, and speeds are lower compared to non-compliant vessels
- ne new ice-classed EEDI vessels are less powerful than the older pre-EEDI ice-classed vessels

In addition from Aker Arctic's experience of ice model testing the typical vertical type bows adopted for EEDI vessels generally perform well in a brash ice channel where the vertical bow helps to assist in clearing ice from around the ship, although the vertical bows are very ineffective in ice ridges and level ice where the vertical stem causes significant loss of energy through ice crushing. (Hindley, 2019).

In general, the operational performance of EEDI bows is not considered further in this report, instead emphasis is made on the consequences that such bow forms have to the towing efficiency, in particular the impact of the mooring deck geometry and how this in turn impacts the course stability under tow. Thus, the main link to highlight is that EEDI sharp bows with narrow waterline entrance angles usually lead to narrow mooring decks and consequently different orientation of the mooring equipment and line securing and feeding devices (bollards, chocks / fairleads).

4 TOWING OPERATIONAL PRACTICES

4.1 EXISTING GUIDELINES FOR TOWING IN ICE

A number of guidelines exist that address the topic of towing in ice. The Instructions for Winter Navigation Operators (Väylävirasto, 2020) include a section on towing which mainly deals with a practical description of the towing arrangement generally and considerations for operators preparing for towing in ice. The Guidelines to the Finnish Swedish Ice Class Rules (TRAFICOM & Swedish Transport Agency, 2019) include similar details with regards to towing, and also provide a recommendation for the location of the bollards and chocks to enable efficient towing. This guidance states that “Two fairleads must be fitted symmetrically off the centreline with one bollard each. The distance of the bollards from the centreline is approximately 3m. The bollards must be aligned with the fairleads, allowing the towlines to be fastened straight onto them.” Thus the recommendation currently specifies a bollard location which is not dependent on bow form (or mooring deck geometry). Relevant excerpts from both of these documents are included in the Appendix.

Guidelines for arranging tows in ice covered waters are also included in “Towing in Ice-Covered Waters” (Dunderdale, 1997) however the majority of this text is associated with large offshore marine towing and evaluation of the risks of single long-distance tows. Two Russian texts on towing in ice have also been reviewed and are discussed further in Section 4.3 (Kulikov & Sazonov, 2003) (Starshinov;Ionov;& Makeyev, 1990). These texts focus on the numerical modelling of the towing dynamics of ships being towed in ice.

4.2 OPERATIONAL FEEDBACK

Two separate interviews were conducted with Icebreaker Captains in co-operation Arctia Shipping. In addition one interview with a merchant vessel Captain was undertaken. Additional discussions, over phone and by email, also took place with other merchant vessel operators on an ad-hoc basis while undertaking this study.

Interviews were conducted separately, through MS Teams due to Covid-19 restrictions in place. Details of the interviewees were as follows:

06.10.2020 Veli Luukkala, Master of Icebreaker Kontio

26.11.2020 Simo Haaslahti, former Chief officer and relief master of Polaris and currently stationed onboard IB Otso.

17.06.2021 Captains of Ship’s identified in Section 4.2.2

The Purpose of these interviews was to gather experience and knowledge from the people facing the potential issues that come from towing merchant vessels in ice in general and towing of the existing (limited) EEDI compliant vessels in particular. Based on the outcome of the interviews a more detailed questionnaire for use onboard was derived. In addition, the outcomes provided validation on some assumptions regarding the expected need to update the regulations and the emphasis of these updates.

4.2.1 FOCUS TOPICS FOR INTERVIEWS

The following section lists the focus topics determined in order to guide discussions on towing during the interviews:

Issue: What type of issues are there typically concerning vessel assistance?

- Timesaving issues
- Functional issues
- Accidents caused or potential hazards
- When do the issues become apparent?
- Damages caused by assistance operations

Issue: EEDI vessels vs. Standard vessel assistance

- Is there a difference in frequency of assistance?
- Are there any differences in procedure?

Issue: Notch towing vs Line towing

- How to choose between the type of assistance?
- Is one preferred over the other, is this dependent on bow shape?

Issue: What effect do the environmental conditions have on the tow?
Issue: Any particularly problematic or interesting vessels we should look into?

In addition, a general discussion on topics related to icebreaker assistance and operations in the Gulf of Bothnia was encouraged in order to give context:

- Arrangement of equipment
- Differences of different IB vessels
- Effects on vessel operation during assistance
- Any and all other related discussion that came up during the meeting

4.2.2 FEEDBACK ON EXISTING VESSELS

Feedback on the towing characteristics of existing EEDI compliant vessels was taken from the interviews. The following sections detail the comments provided by the operators. Ships are identified by running numbers as in Table 3-1.

4.2.2.1 SHIP 5 & SHIP 3

Initial feedback from the icebreaker captains is that the towing arrangement is difficult for this ship with respect to the bollard location and means to connect the tow. Aker Arctic approached the owner and discussed the mooring arrangement. The ship was identified as a candidate for a ship visit to examine the arrangements and potentially witness towing operations, however COVID restrictions prevented ship visits. In follow up Aker Arctic discussed with the operators it was confirmed that the main issue for these ships is that the mooring arrangements restrict the tow, in particular towing of the ship is limited to through the centreline (Panama) chock because other mooring points are not built to withstand the towing forces of a vessel this size.

As such the conclusions are that the mooring arrangement itself (whatever the bow form configuration) leads to practical problems with arranging the tow.

4.2.2.2 SHIP 12

Two forward chocks were added during the building phase. The Icebreaker Captain questioned why these were not part of the original design?

Conclusion for the study: Aker Arctic approached owners to understand if the additional chocks were added to aid towing in ice, however no response from the owner was forthcoming.

4.2.2.3 SHIP 8

In general, the Icebreaker Captain's comment that this ship hasn't caused any issues in towing operations. Only the amount of power available is an issue.

An interview was conducted with the Captain of Ship 8. It was noted that in practice that the ship rarely has any issues with assistance operations. Some ship specific issues are its limited power, causing the ship to go full speed during assistance majority of the time and depending on the ballast difference between the ship and the towing vessel, the notch sometimes sits quite high on the bow causing dents above the strengthened area of the bow. A review was also undertaken of the forward mooring deck arrangement of the ship. The towing arrangement on board is functional and easy to operate, but due to the ship's small size the guidelines for arrangement of towing are not fully realized.

4.2.3 GENERAL FEEDBACK ON TOWING

The following identifies the key points regarding general feedback on towing from the operators interviewed, see Appendix for consolidated notes from the interviews:

Towing operations in bay of Bothnia are very proactive and typically it is known well beforehand which vessels require assistance.

Close contact towing is more often used in the Bay of Bothnia. Long distance towing is oftentimes unnecessary due to merchant vessel's ability to follow in the channel by itself.

Weather conditions and vessel speeds are the biggest influencers on towing operation success.

The presence of the pilot onboard typically makes the process easier. Inexperienced crew might not know what steps are expected of them and a pilot can help with this.

Conclusion for the study: Aker Arctic questions if the merchant vessels operating in the area should have a manual on board to describe the steps to make the towing process as safe and smooth as possible? This idea is confirmed by the interviewees.

From icebreaker operator feedback it appears that the biggest concern with EEDI bows is not the geometry for towing in the notch, but that EEDI compliant ships have lower power.

Notwithstanding the above point, based on initial comments and a review of the waterline shape at the level of the notch between more “normal” bows and EEDI bows, it can be seen that once the ship is in the notch the EEDI bow, because it is quite sharp, should not have an issue with carrying loose.

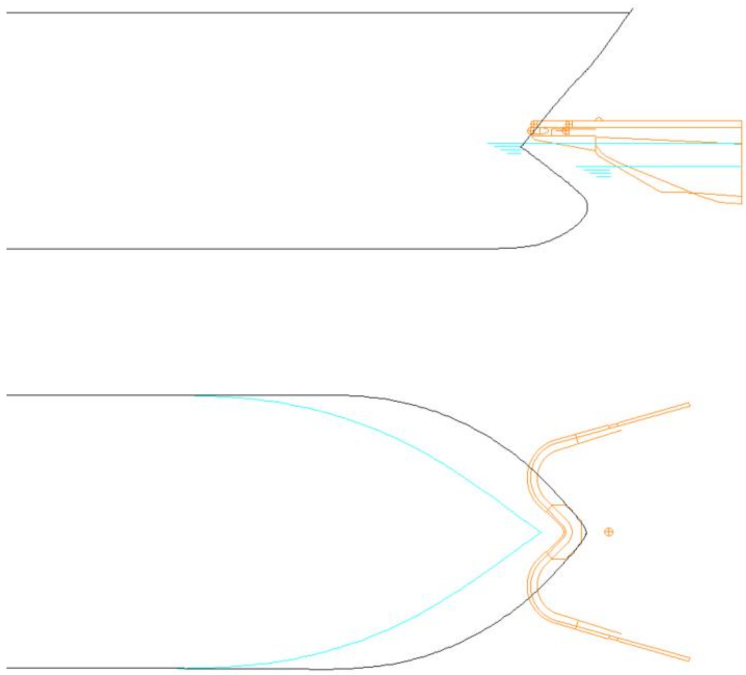


Figure 4-1 Sketch of bulbous bow in towing notch

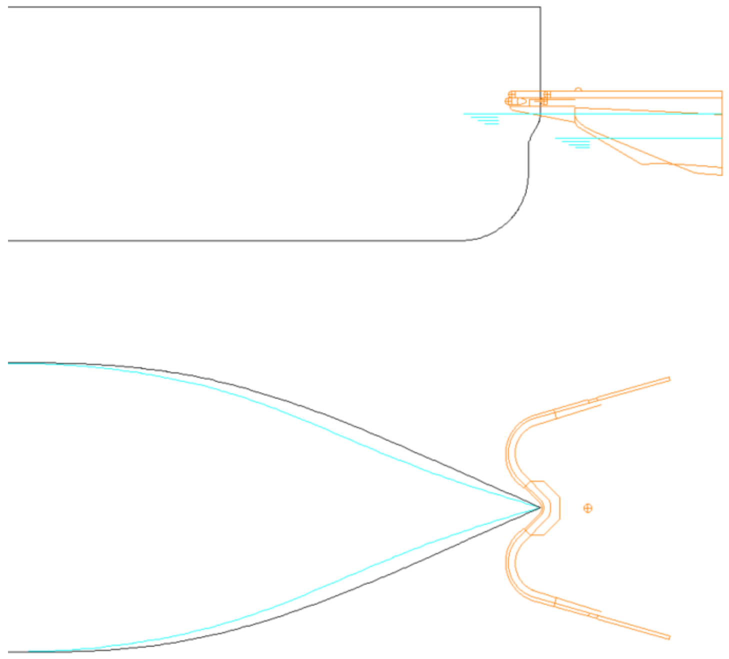


Figure 4-2 Sketch of EEDI bow in towing notch

Initial considerations on the forces on the notch (based on a high-level evaluation of the collision scenario between the bow and the notch) appeared to indicate that EEDI bow shapes may induce more severe forces on the towing notch due to the vertical stem. This was studied and reported as part of the Interim findings (Aker Arctic Technology, 2020) and it was concluded that the vertical stem angle will produce higher forces on the towing notch. However, because this conclusion relates mostly to the need to evaluate any new towing notch design for the icebreakers for the ability to withstand these higher forces, rather than impacts to the merchant vessels this is not reported in further detail in this final report.

The key issue from the operator feedback appears to be location of bollards for towing, which is to some extent driven by the EEDI bow shape, as the fineness of the bow at the waterline somewhat dictates the breadth of the mooring deck: A narrower mooring deck (as shown as the black line in Figure 4-2) necessitates a different location of the mooring bollards which are used to connect the whisker wire to. Location of the mooring points inevitably will lead to a different distribution of towing forces.

4.2.4 TOWING EEDI VESSELS

The following identifies the key points regarding towing EEDI vessels from the operators interviewed, see Appendix for consolidated notes from the interviews:

The biggest issues seem to arise from EEDI vessels not having as much power output available as their counterparts.

Bow shapes of EEDI vessels have no significant difference in towing operations. There is a bigger concern of larger vessels and vessels with a bulbous bow.

.

Chock location on the merchant vessel is key to towing operations as they cannot be located too far from the centerline. This is due to the effective length of the whisker wire (roughly 30m). The centerline chock (Panama chock) is all but useless for towing purposes and should be avoided unless it is the last resort. It was also the opinion of one of the Captains that roller type chocks should be avoided as they break easily during towing operations.

4.2.5 ONBOARD OBSERVATIONS

Based on the interviews with Captains, and also a study of EEDI ships the following scope of questions (in Table 4-1) for the on-board survey are developed.

The questionnaire was intended to be used by Aker Arctic in WP3 and WP4 to guide the questions and observations of towing activities when onboard.

Table 4-1 Questionnaire for on-board survey

Personnel to interview	Topic	Question
Icebreaker Captain	Perceptions about difficulty of towing “EEDI bows”	Are EEDI vessels more difficult to tow
		How different are EEDI vessels to tow than i) conventional merchant vessels ii) bulbous bows
		Rate the importance of installed power compared with towing arrangements in performing a successful tow
		Do you see any issues with EEDI bows coming in the future
	Concrete experiences	Describe situations where escorting EEDI compliant ships (such as those listed in the Appendix) have been difficult, why…
		What are the dimension limitations for close contact towing
		Equipment limitations? (whisker wire, winch etc.)
Icebreaker Deckhands	What is the process of being assisted by an IB	Preparations before starting assistance
		Procedure for coupling the vessels and starting the assistance

		Procedure during and ending the assistance
		Tools necessary for the process
	Rope handling	Are lines difficult to throw / pass to the any particular types of escorted ship
		Are there occasions where the whisker wire (or any other wires) are the wrong length for the most preferred attachment
Merchant Vessel Captain	What is the process of being assisted by an IB	Preparations before starting assistance
		Procedure for coupling the vessels and starting the assistance
		Procedure during and ending the assistance
	Other questions	Any difficulties you would like to mention considering the assistance operations
		Are there any differences in assistance operations when comparing different icebreakers
Merchant Vessel deckhands	Handling towing operations	What arrangement decisions help with assistance preparations
		How is the communication handled between the IB and merchant vessel
		What tools are used in the preparations
		Are lines difficult to catch from the mooring deck
		Is the towing line difficult to secure to existing bollard arrangements
		Any difficulties you would like to mention considering the assistance operations

4.3 TOWING ARRANGEMENT ANALYSIS

4.3.1 GENERAL

The section presents an analysis of towing forces related to the towing arrangement. Two approaches are presented. The first evaluates the towing forces analytically and looks to investigate the influence of the towing line geometry on the tow efficiency (course stability). This is generally analysed as a static problem where the course stability influence is considered with respect to the rotational stiffness of the towing system. The second attempts to evaluate the towing forces numerically by using the Aker Arctic Ice Simulator. The simulator is generally used for operational training purposes (including towing in ice) and models the dynamic behaviour of the icebreaker and the escorted merchant vessel. The simulator has the facility to output forces during the tow simulation which are evaluated for use as a tool to be able to investigate the towing situations as a system.

4.3.2 EVALUATION OF TOWING FORCES

4.3.2.1 METHODOLOGY

To analytically evaluate different towing arrangements, force distribution in a towing bridle line was analysed using a DNV recommended practice (DNV, 2009). The methodology provided in the recommended practice considers length of towline, angle of rotation of towed vessel and angle between vessel CL and the bridle line. The calculation procedure is presented below:

When the towed structure is rotated an angle α, the forces in each of the towing bridle lines will be different (this is essentially the “whisker line” for Baltic close towing). Assuming each line forms an angle β with vessel CL, and the towing force is T_0, the distribution of forces in each bridle line for small rotation angles, is given by:

$$\frac{T_1}{T_0} = \frac{\sin(\beta + \alpha + \gamma)}{\sin 2\beta}$$

$$\frac{T_2}{T_0} = \frac{\sin(\beta - \alpha - \gamma)}{\sin 2\beta}$$

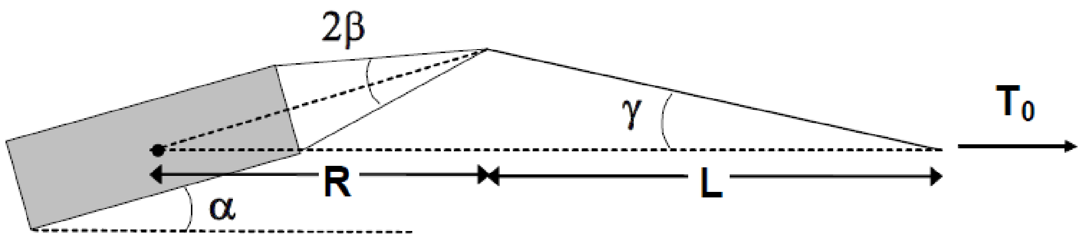


Figure 4-3. Layout of towline and towing lines (DNV, 2009)

where,

T_0 – towing force [N]

T_1 – force in port bridle [N] (for rotation of towed object towards port)

T_2 – force in starboard bridle [N] (for rotation of towed object towards port)

L – length of towline, measured from bridle [m]

R – distance from centre of gravity of towed structure to end of bridle lines [m]

β – angle between each of the bridle lines and the vessel centreline [rad]

α – angle of rotation of towed structure [rad]

$\gamma - \frac{R}{L}\alpha$ [rad]

The force in starboard line becomes zero when

$$\alpha = \frac{L\beta}{L + R}$$

For rotation angles greater than this value, one bridle line goes slack and only the other bridle line will take load. The moment of the towing force around the rotation centre of the towed structure is given as:

$$M_G = T_0 R \left(1 + \frac{R}{L}\right) \alpha \quad [Nm]$$

The rotational stiffness due to the towing force is given by:

$$C_{66} = T_0 R \left(1 + \frac{R}{L}\right) \quad [Nm/rad]$$

These main formulations were used to investigate the influence of chocks and bollard positions on the bridle forces. Calculations were done for different rotation angles of the vessel α and towline lengths L.

4.3.2.2 Length of the whisker wire

As can be seen from the formulations presented in the above section, forces and angles are depended on the length of the towing bridle, in this case commonly termed a “whisker wire”. A Whisker wire is used as a connection point from the actual towing line driven from the icebreaker towing winch to the merchant vessel. A Whisker wire is thinner and easier to handle when compared to much stronger and bulkier towing wire and this makes it possible for the crew of both vessels to transfer the towing lines between each other.

A typical whisker wire used on board an icebreaker is around 30 m in length. A whisker wire includes spliced eyes on both ends of the wire that are around 2m in length. For a safe and effective hitch, the bollards should be located more than 2 meter distance away from the chock. This location would allow for the whole splice to be located inside the vessel bulwark and would thus reduce any odd wear on the whisker wire caused by friction on the chock.

4.3.2.3 Configuration of the towing block

The methodology makes a simplification that the towing block acts as a triangular plate as opposed to a sliding block which is more common for icebreaker tows. This simplification is considered valid for small angle variations, but it is acknowledged that a sliding block will adjust the distribution of the forces between the two ends of the whisker wire as the eccentricity of the block location from the centreline increases. Further development and consideration of this detail is necessary before finalising recommendations for towing as presented in Section 5.

4.3.2.4 Analysis of whisker wire spread angle

Two mooring arrangements were investigated. The first towing arrangement corresponds to Figure 4-4, where the angle between bridle line and CL of the vessel β is 13 degrees. The second arrangement corresponds to Figure 4-5, where the angle β is 33 degrees. In these calculations it assumed that vessel rotates to the portside. The results of calculation of force distribution in a towing bridle for the two towing arrangements are shown in Figure 4-6.

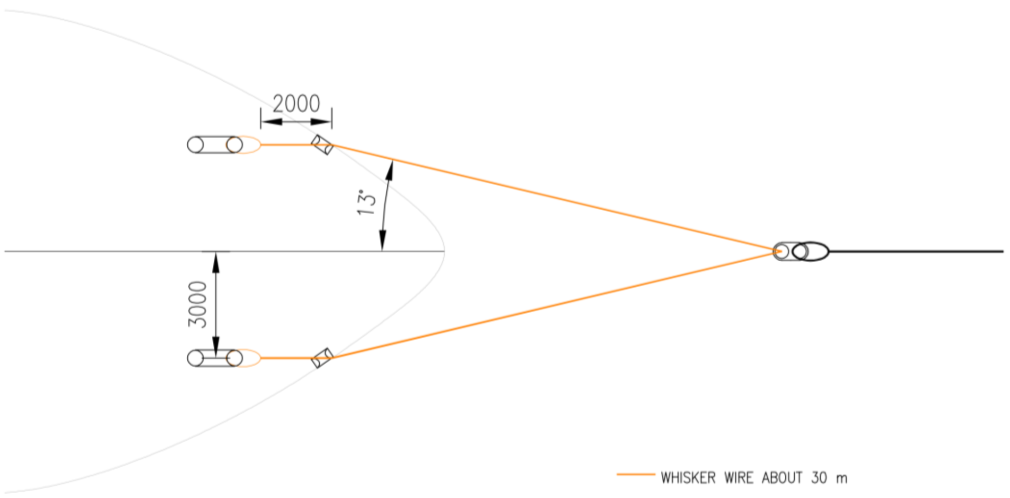


Figure 4-4 Mooring arrangement with 13 degree whisker wire spread angle

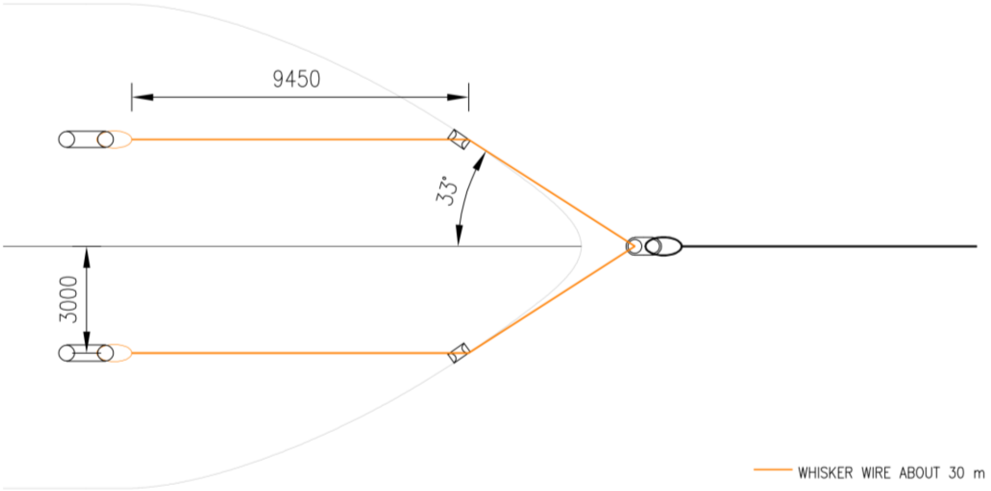
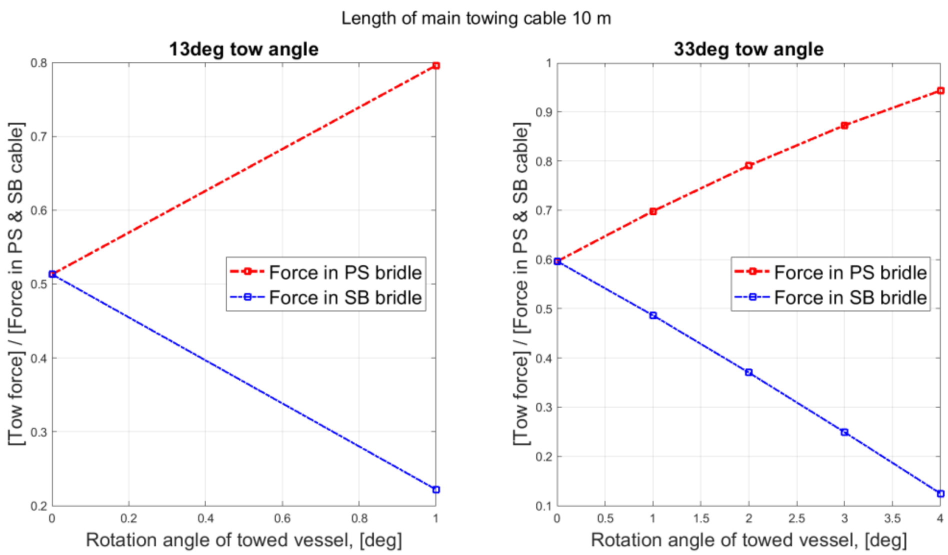
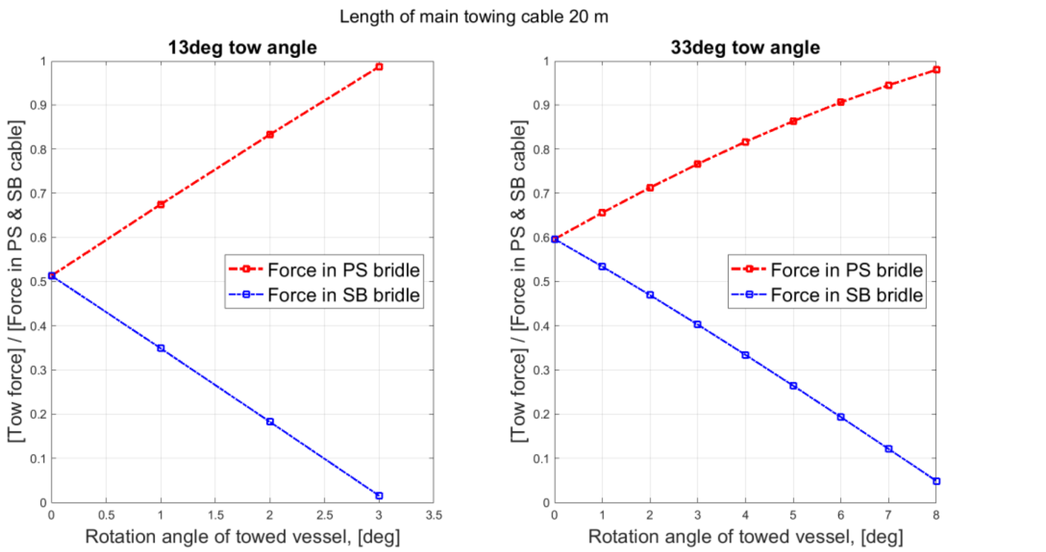
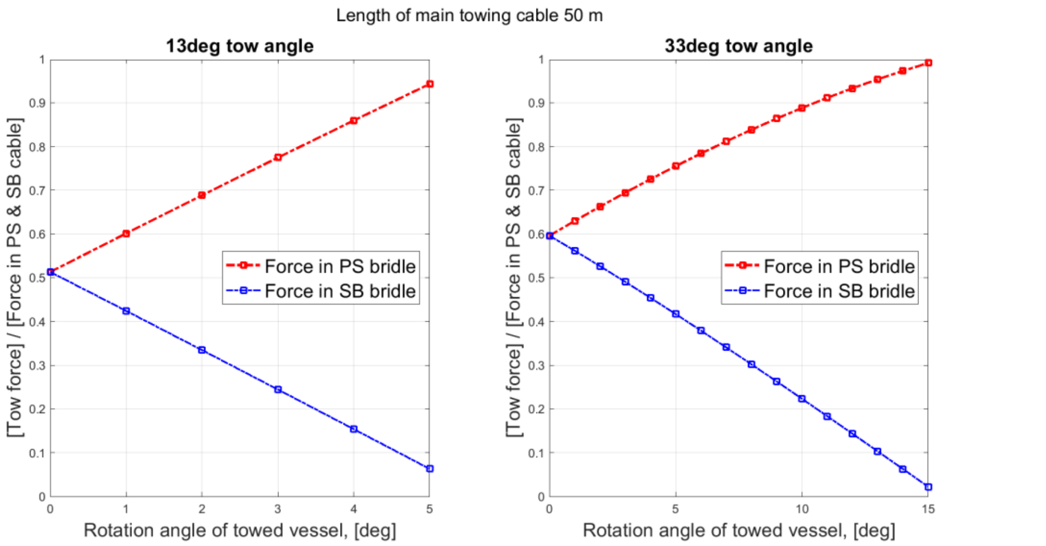
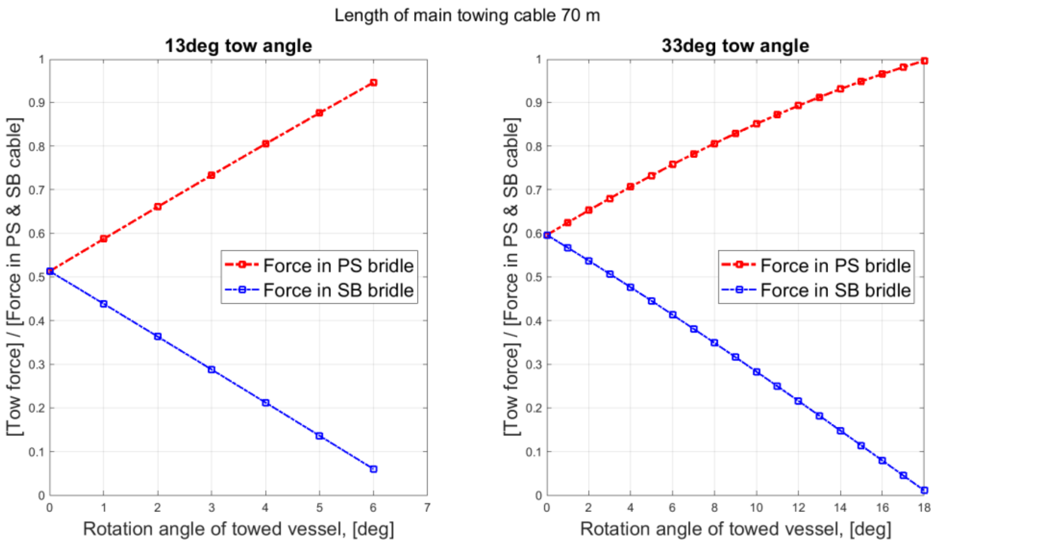


Figure 4-5 Mooring arrangement with 33 degree whisker wire spread angle




Length of main towing cable 20 m
13deg tow angle
33deg tow angle
[Tow force] / [Force in PS & SB cable]
Force in PS bridle
Force in SB bridle
Rotation angle of towed vessel, [deg]


Length of main towing cable 50 m
13deg tow angle
33deg tow angle
[Tow force] / [Force in PS & SB cable]
Force in PS bridle
Force in SB bridle
Rotation angle of towed vessel, [deg]


Length of main towing cable 70 m
13deg tow angle
33deg tow angle
[Tow force] / [Force in PS & SB cable]
Force in PS bridle
Force in SB bridle
Rotation angle of towed vessel, [deg]

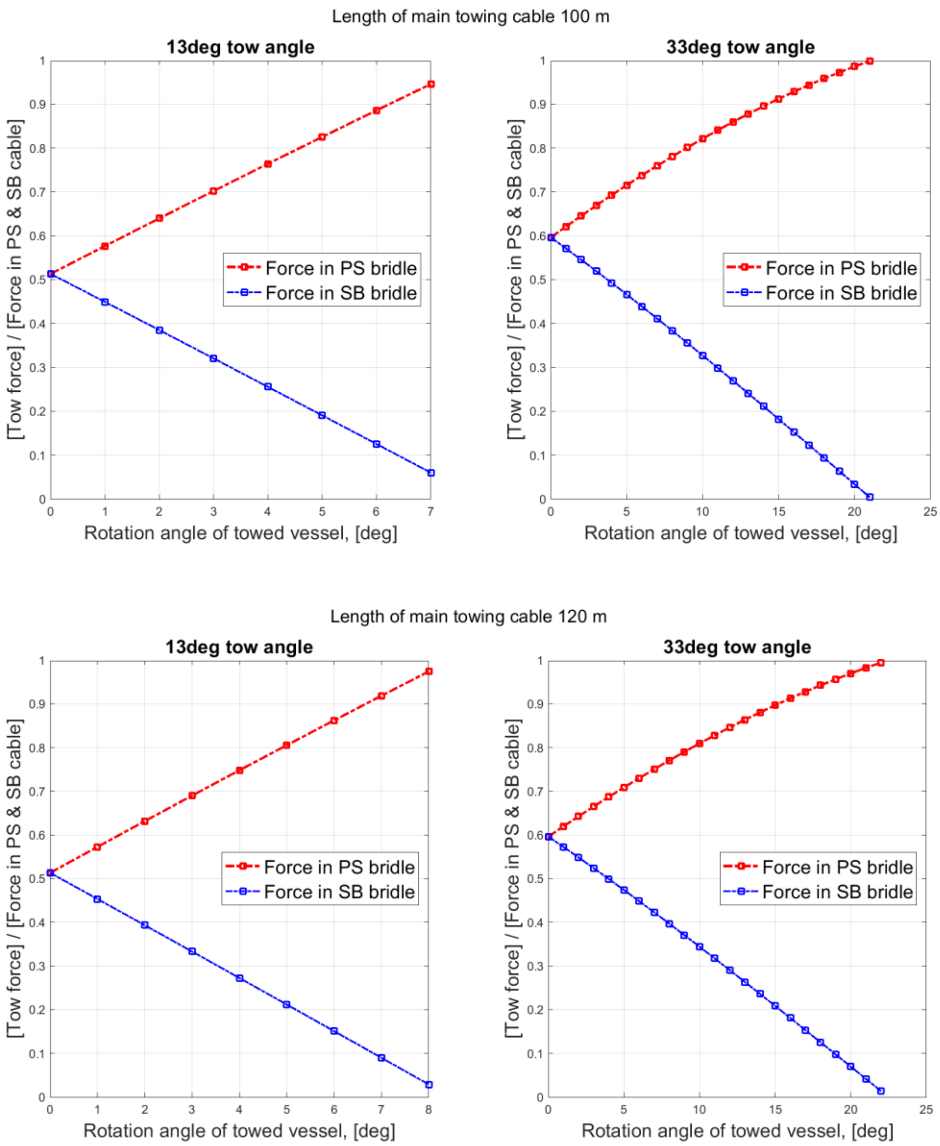


Figure 4-6. Results of force distribution in a towing bridle

The results show that portside bridle takes more force when ship rotates. When the rotation angle goes above maximum specified on each plot in Figure 4-6, the starboard bridle does not carry any force anymore, and the portside bridle takes all load. This maximum rotation angle increases with main towing cable length L.

For the same towing cable length, the 33 degree tow angle β shows a better distribution in the forces between two bridles than the narrower towing arrangement which has 13 degree tow angle β. Hence, when increasing the distance between two bridle lines, which effects β, towing force distributes better in the bridles at the same rotation angle. This means that expanding the distance between chocks and moving bollard forward have a positive effect on the force distribution between towing bridles.

4.3.2.5 PLACEMENT OF THE FAIRLEADS

From calculations done in 4.3.2.1 a determination can be made that a wider angle on the whisker wire will help with controlling the towed vessel and reduces the forces on the towing line in most situations. Having a bollard and chock placement, according to the FSICRs Guidelines (about 3m from the CL) we can see from Figure 4-7 and Figure 4-8 how we can adjust the angle on the whisker wire just with the bollard placement. Examples given are extreme values considering a typical whisker wire length and placement but the effect on the angle will be the same regardless.

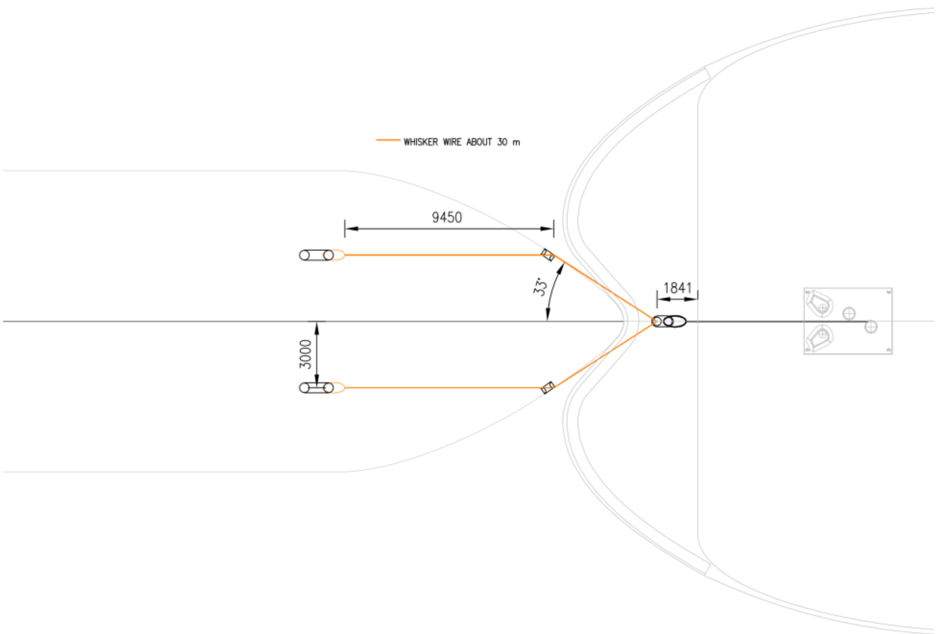


Figure 4-7 Mooring arrangement with bollards 3000mm 33 degree spread angle

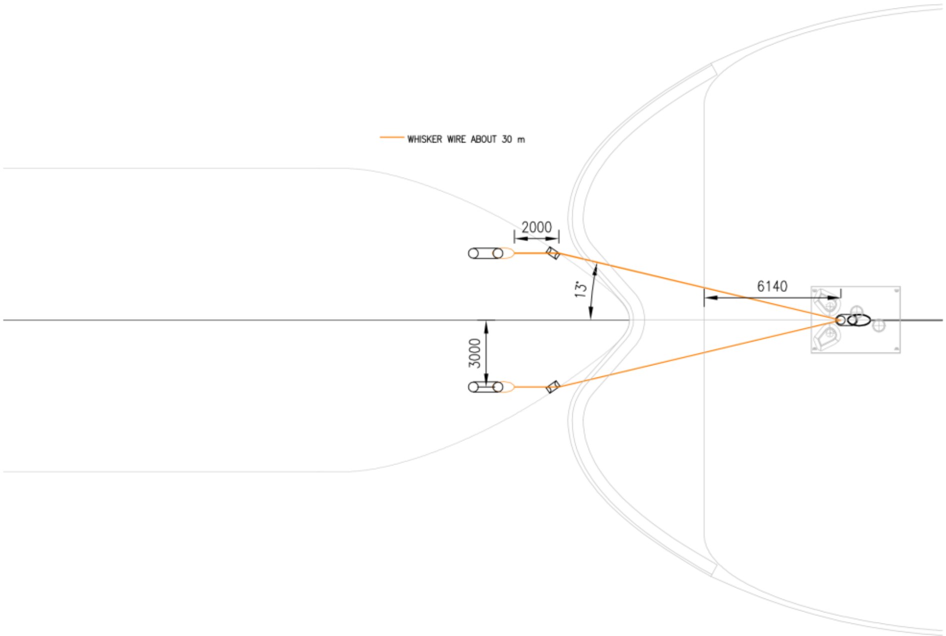


Figure 4-8 Mooring arrangement with bollards 3000mm 13 degree spread angle

Bringing the towing block closer to the towed vessel bow and at the same time increasing the angle on the wire seems to be beneficial to increasing the spread angle, however operational effects this will have on the assistance operations should also be noted.

When determining the distance of the towing block from the bow of the towed vessel, the transfer of the wire when starting and finishing the assistance is an important aspect to consider. Figure 4-9 and Figure 4-10 show the situation shown in Figure 4-7 and Figure 4-8 with different icebreaker stern. In the overall towing system design the situation where the towing block falls either into the sea, or on equipment on board the icebreaker, causing possible damage is to be avoided.

The length of towing notch on icebreakers operating on the bay of bothnia area is not standard. The distance on the center line from #0 to the bottom of the towing notch can vary from 0mm (Botnica) to 3500 mm (Polaris). As such the optimal distance for the towing block varies as well. The aim is for the towing block to fall on to the deck of the icebreaker, avoiding the notch and equipment. For this reason the bollard location onboard the merchant vessel should be considered, as far as applicable, to the distance where a length of whisker wire places the towing block far enough away from the bow that when the wire is released the block will land forwards of #0. The exact location will depend on the height difference of the forecastle deck and the icebreaker deck, the bow shape, the chock and bollard location.

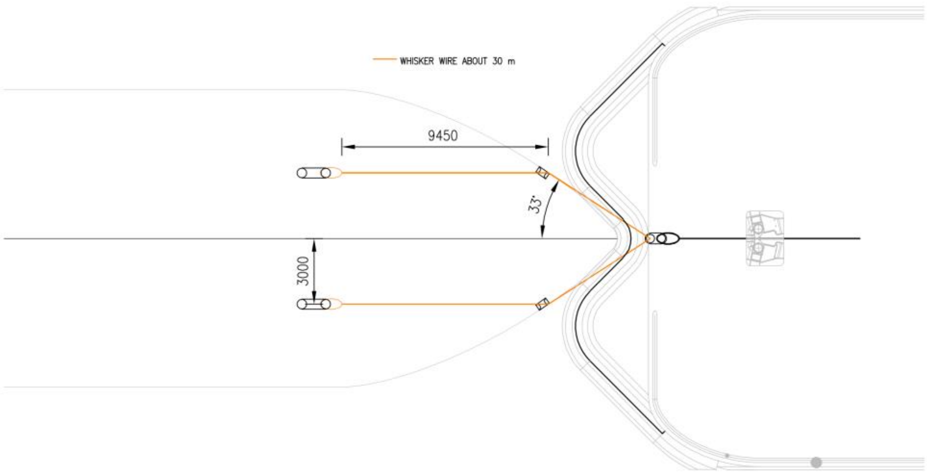


Figure 4-9 Mooring arrangement with bollards 3000mm 33 degree spread angle alternative icebreaker stern

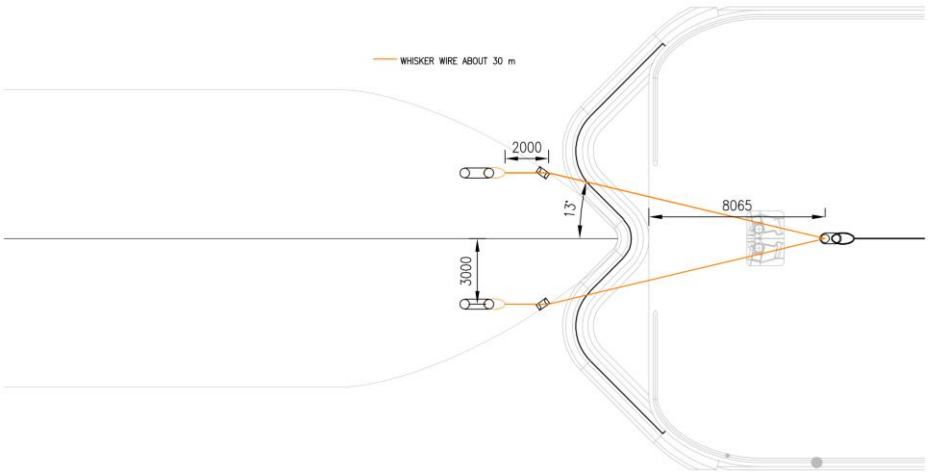
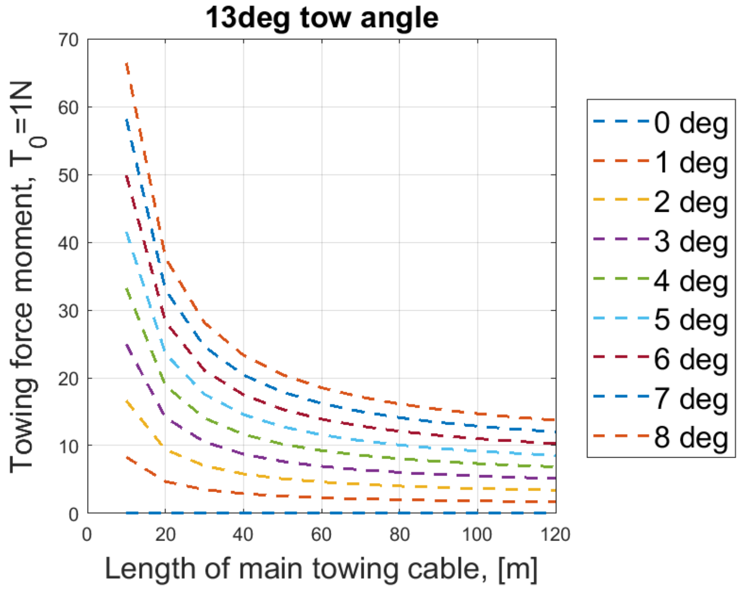


Figure 4-10 Mooring arrangement with bollards 3000mm 13 degree spread angle alternative icebreaker stern

4.3.2.6 TOW COURSE STABILITY

The moment of the towing force around the rotation centre of the towed vessel is shown in Figure 4-11, and rotational stiffness in Figure 4-12. For comparison it was assumed that towing force T_0 is 1N.

Towing force moment grows with rotation angle of the towed vessel, and it is higher for narrow towing arrangement (13deg tow angle). The percentage increase of towing force moment or rotational stiffness between 13deg tow angle in relation to 33deg tow angle is shown in Table 4-2.



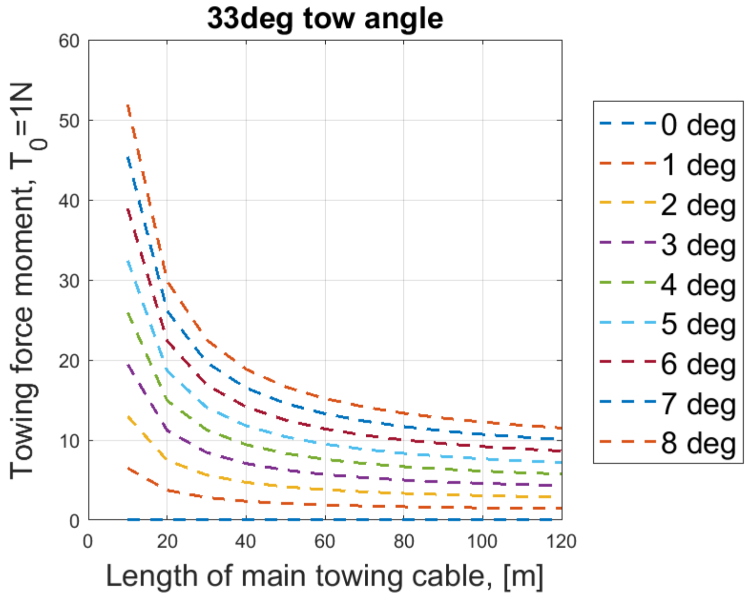


Figure 4-11. Towing force moment

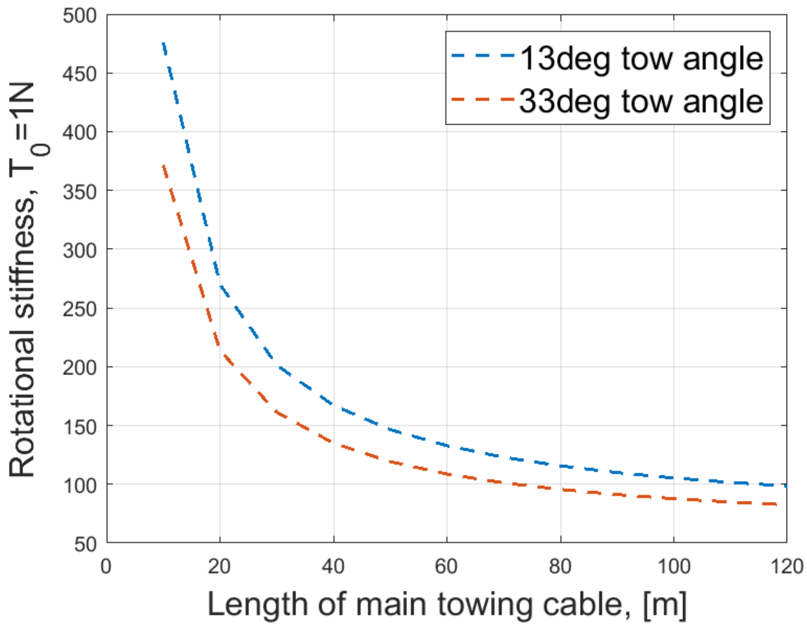


Figure 4-12. Rotational stiffness due to the towing force

Table 4-2 Percentage increase of towing force moment or rotational stiffness between two towing arrangements

Length of towline, [m]	Percentage increase of towing force moment between two towing arrangements, [%]
10	22
20	21
50	19
70	18
100	17
120	16

As a summary Table 4-2 shows that for a varying length of tow line there is an increase in towing force moment between a 13 degree and 33 degree angle. As the rotational stiffness improves the directional stability of tow, it can be seen that larger towing angles give rise to larger towing moments and thus better directional stability under tow. i.e. any means by which the towing angle is increased (either by locating the bollards further outboard, or by reducing the distance between the bow of the merchant vessel and the towing block) generally will improve the tow stability, however the practical operational aspects of the location of the towing block also need to be considered as a constraint.

4.4 TESTING OF AAT ICE SIMULATOR FOR TOWING EVALUATION

4.4.1 BACKGROUND AND GENERAL METHODOLOGY

The purpose of this part of the study was to evaluate if the Aker Arctic ice simulator can be used to evaluate towing forces and if so to trial the use of the simulator with a number of bow forms.

Towing of ships in ice is one of the important operations performed by icebreakers. In difficult ice conditions, including ice compression and ridging, the merchant ships are not able to follow the icebreaker with their propulsion power. Therefore, the icebreaker must tow the merchant vessel. The towing operations require skilled crews, and it is risky as high forces act in the towing line and there is a risk of collision. However, relatively little is known about the forces acting during the notch towing operations both from the measurement and simulation points of view.

One of the available sources describing mathematical formulations for the simulation of the icebreaker assistance in a close towing is presented in (Kulikov & Sazonov, 2003), and another source that summarizes the results of measured forces on the towing notch in different conditions is described in (Starshinov;Ionov;& Makeyev, 1990). Both sources are related, where the experimental results of the measurements and observations were further used in the development of the mathematical model of close towing in ice (Kulikov & Sazonov, 2003). The method is based on solving the differential equations of motion and approximation of ice resistance, and it includes two separate models: one for linear and another for nonlinear motions. Both models account for many parameters, such as hull form; propulsion; geometry of the notch and properties of the fender; location of towing cables; variations of the cable length during the towing; water, level ice (with or without compression) and ridges resistance etc. The models were applied by (Kulikov & Sazonov, 2003) for numerical simulation of towing in ice where the results and some important findings were also described.

The first case scenario was presented with the consideration of only ice ridges (no level ice or compression included). Several conclusions based on the results of the simulation were made:

- A significant change in the resistance of a system icebreaker-towed vessel increases the likelihood of a cable rupture, which can be observed when loops and jerks appear in the cable: the cable loses and then rapidly tights back.
- In general, when the initial tension of the cable increases, towing forces and loads on the notch increase as well.
- The significant tension in the cable appears when towing a nonpropelled object, and in this case, the load on the notch is minimum. With an increasing thrust of the towed vessel, the situation changes in the opposite direction. When the thrust is maximum, the cable tension is minimum and the load on the notch increases.

- Regarding the speed effect, it was found that an increase in speed leads to a decrease in towing forces, which is related to the changes of trim angles of both ships. With a higher speed, the variations of trim angles are smaller, which result in the decreasing of load on the towing equipment.

- One of the important conclusions was made on the influence of the ridge keel on the results. It was found that the cable tension does not depend on the keel dimensions, which is related to the fact that the significant influence on the cable tension has variations in trim angles, which weakly depends on the ridge resistance. However, the situation is opposite with the loads on the notch. With an increase of the ridge resistance, the loads on the notch increase as well.

The second scenario considered only level ice. Several conclusions based on the results of the simulation were made:

- It was found, that due to changes in level ice resistance, all dynamic and kinematic characteristics of the motion result in fluctuations. In this case, the speed of two vessels is in antiphase, which causes force fluctuations in the towing equipment.

- With increasing the speed of the icebreaker, cable tension increases and indentation of the bow of the towed vessel in the notch reduces. It leads to the increase of an additional resistance for the icebreaker. If ice resistance is constant, speed oscillations will disappear, and if the external ice conditions do not change, the speed fluctuations will only depend on level ice resistance.

- The maximum towing forces appear when the difference between the speed of the icebreaker and the towed vessel is at maximum. The peak loads on the notch correspond to the moments when both ships have the same speed.

- In the situations when the full thrust of the towed vessel is used and the motion is steady, the tension of the cable may disappear, it may happen when the vessel is pushing the icebreaker.

- The influence of level ice resistance is significantly seen with the towing forces more than to the loads on the notch.

These main findings were concluded based on the observations and numerical simulations. However, the amount of such simulations is limited, and the applied mathematical model has a number of parameters that affect the final result, thus, only one icebreaker and merchant ship were tested by (Kulikov & Sazonov, 2003).

In general the available numerical models that focus on towing in ice can be used to investigate overall dynamics of the towing situation, however they are not considered useful or reliable for comparative testing and evaluating small changes to the towing arrangement such as the location of the bollard and chocks.

4.4.2 FULL-SCALE MEASUREMENTS

To create a towing scenario for the AAT ice simulator and evaluate the simulated results, full-scale measurements and observations from towing operations are used in this study. The measurements were done onboard Finnish icebreaker Kontio in March 2016 and are described in detail in (Aker Arctic Technology, 2016). In total, 21 towing operations were recorded, where towing line forces, navigational data and propulsion data of the icebreaker were measured, and the towing operations were videotaped. This data is an important verification point for results produced by simulations. However, the current version of the AAT ice simulator has only two models of a towed ship available to run the simulations. And from the measurements, only one towing operation/ship was close to one of the simulator models. Thus, this specific towing operation/ship is selected further for the comparison, and it is a general cargo ship “Eemshorn” with 1A ice class. The main parameters of the vessel and measured results are summarized in Table 4-3.

Table 4-3. The main parameters of “Eemshorn” and summary of measured results

Parameter	Summary of ice trials on 13.03.2016
Assisted icebreaker (IB)	Kontio
Assisted vessel IMO (vsl)	9393278
Bow type vsl	Bulb, ice knife
Towing cables, number	2
Location of towing cables	Distance between chocks is around 4.5m, chocks are located on 51-53 degrees from CL
Diameter of the main cable	60 mm
Diameter of the secondary cable	40 mm
Breaking load of the cable 1 (main)	225 ton
Breaking load of the cable 2 (secondary)	112 ton
Ice conditions	Level ice, ridges, average 50 cm, channel thickness was not recorded
DWT vsl	6000 t
LxBxT vsl (current T)	110.74x14x5.5
Propulsion vsl	2243 kW
Loaded or ballast	loaded
Speed tow, max	12.1 kn
Speed tow, average	8.3 kn
Speed tow, standard deviation	1.9 kn
Speed max delta (difference between two vessels max speed)	0.561 kn

Speed av delta	0.002 kn
COG av delta	0 deg
COG std delta	2.7 deg
Torque IB max	113.7 %
Torque IB av	82.3 %
Torque IB std	10.5 %
Power IB max	16.7 MW
Power IB av	14.5 MW
Power IB std	1.9 MW
Ruddle angle, std	17 deg
Towing force, av	38.6 ton
Towing force, max	171.7 ton
Towing force, std	25.2 ton

The arrangement of towing operations with “Eemshorn” is shown in Figure 4-13. As can be seen from Figure 4-13 there are two cables that are used in towing:

- main towing cable which goes through a large roller fairlead and keeps the towing line at a suitable angle for the winch and prevents the towing line from being in a contact with the winch room walls;
- at the end of the main towing line is a strop in which a large single block/pulley is attached. A secondary towing (whisker wire) line runs through this block and the secondary towing line is attached to the bollards of the towed vessel through two chocks.

At the very stern of the icebreaker, a towing notch is located. The bow of the towed vessel is fitted inside the notch. A small gap is left between the towed vessels to allow the stern of the icebreaker to turn/move. It is typical for ships that have bulbous bows, which cannot fit inside the towing notch. In addition, if the assisted vessel is heavy, a small distance is required to improve manoeuvrability: the stern of the icebreaker must be free as the steering is done with rudders located at the stern. On the other hand, the gap between the vessels allows the merchant vessels to hit/push another side of the towing notch. It will start to turn the icebreaker making steering difficult.

Figure 4-13. The arrangement of towing operations of "Eemshorn"

4.4.2.1 EXAMPLE RESULTS OF FULL-SCALE MEASUREMENTS

The results of the towing are presented in Figure 4-14-Figure 4-18. There are several observations were made during the towing of "Eemshorn". First, the towed vessel pushed the stern of the icebreaker and caused the icebreaker to turn (Figure 4-14). During the towing, the towed vessel broke loose from the towing notch, and the ship moved to the side of the icebreaker (Figure 4-15). It resulted in high forces in the towing cable and in difficult steering of the icebreaker, which can be seen from the extreme rudder angles shown in Figure 4-18. As a result, about 2 meters of towing cable slid from the towing winch. Then, the towed vessel moved to the side of the icebreaker, and slack appeared in the towing cable, which additionally caused the cable to slide from the winch. As the towed vessel was in a contact with the channel edge, the vessel slowed down, and the cable suddenly tightened causing a high force peak (172 ton), as shown in Figure 4-16-Figure 4-18.

Figure 4-14. The towed vessel pushes the stern of the icebreaker

Figure 4-15. The towed vessel breaks loose from the towing notch

Figure 4-16. Moment of appearance of a high force peak (172 ton)

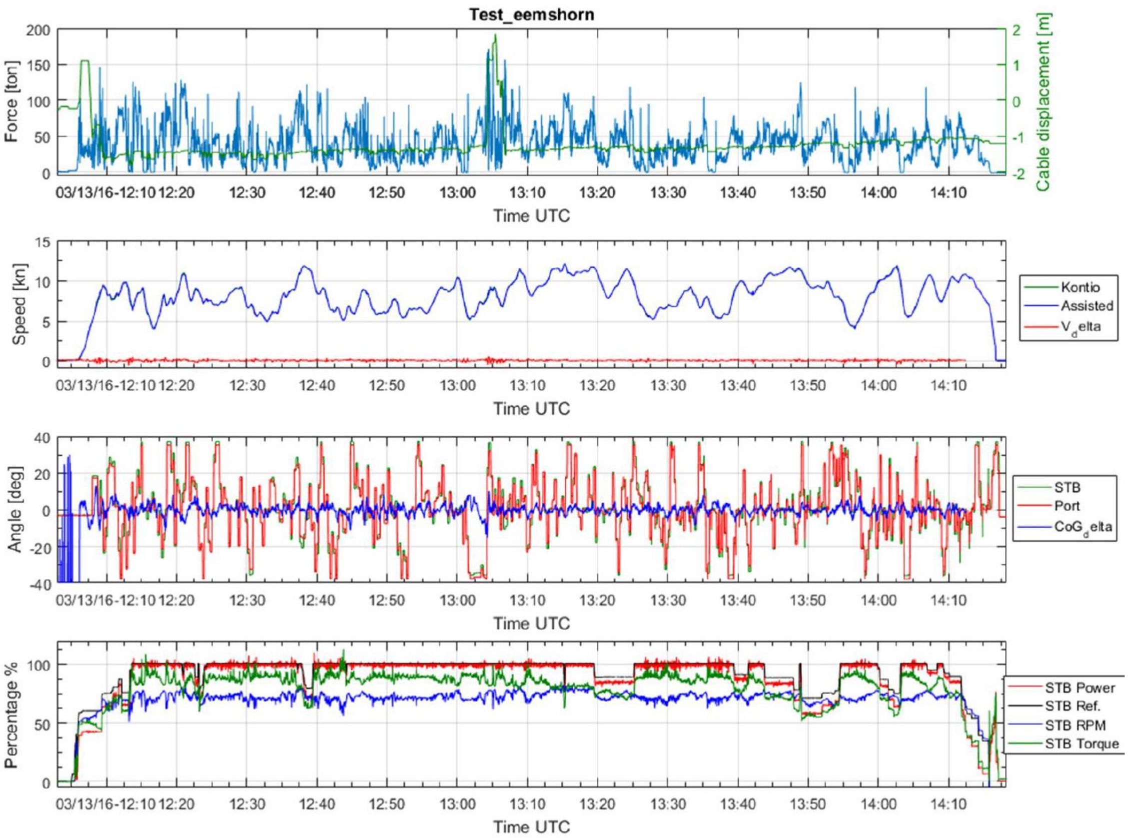


Figure 4-17. Time history of the towing operation

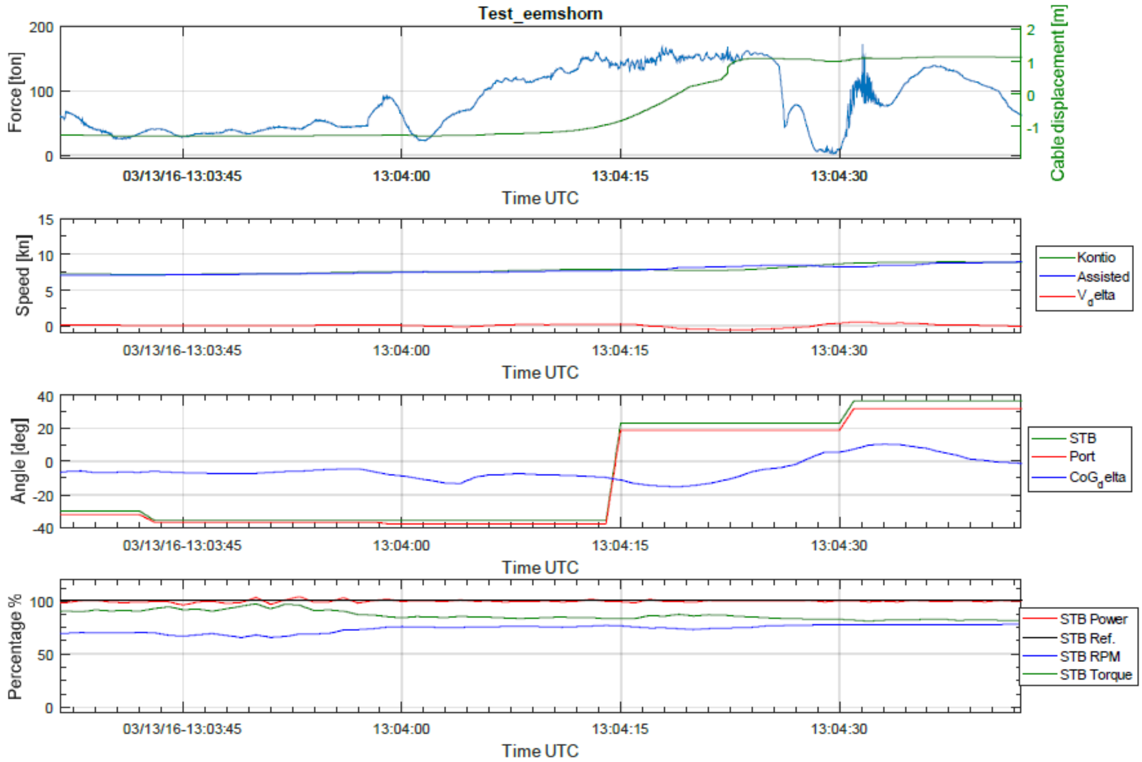


Figure 4-18. Time frame when the towed vessel broke loose from the towing notch, high force peak occurs at ~13:04:35

Higher forces occurred when there were bigger differences in the relative motions between the vessels. Thus, the skills of the helmsman of the towed vessel are a crucial factor for towing. If the towed vessel is not able to follow the icebreaker in a straight path, the risk of breaking loose from the towing fork and high forces will increase.

All reported observations and measurements presented in Figure 4-17 and Figure 4-18 were used for further comparison with results from AAT ice simulator.

4.4.3 ICE SIMULATOR

The current version of the AAT ice simulator has two options for cable arrangement:

1. A towing with one cable is attached to the CL of a towed vessel.

2. A towing with two separate cables attached to two chocks of a towed vessel, where the location of the chocks can be changed in the input file. In this case, one cable is controlled by the icebreaker winch, and the other by a towed vessel.

To be close to the towing operations presented in Chapter 4.4.2, and to study the influence of the chock's location, a tow with two separate cables was done in the ice simulator. However, this arrangement is not used in towing, thus, several tests were done to study if towing module gives reliable results.

The example of the towing arrangement is shown in Figure 4-19. The winch is controlled by the length or tension of the cables, both options were tested.

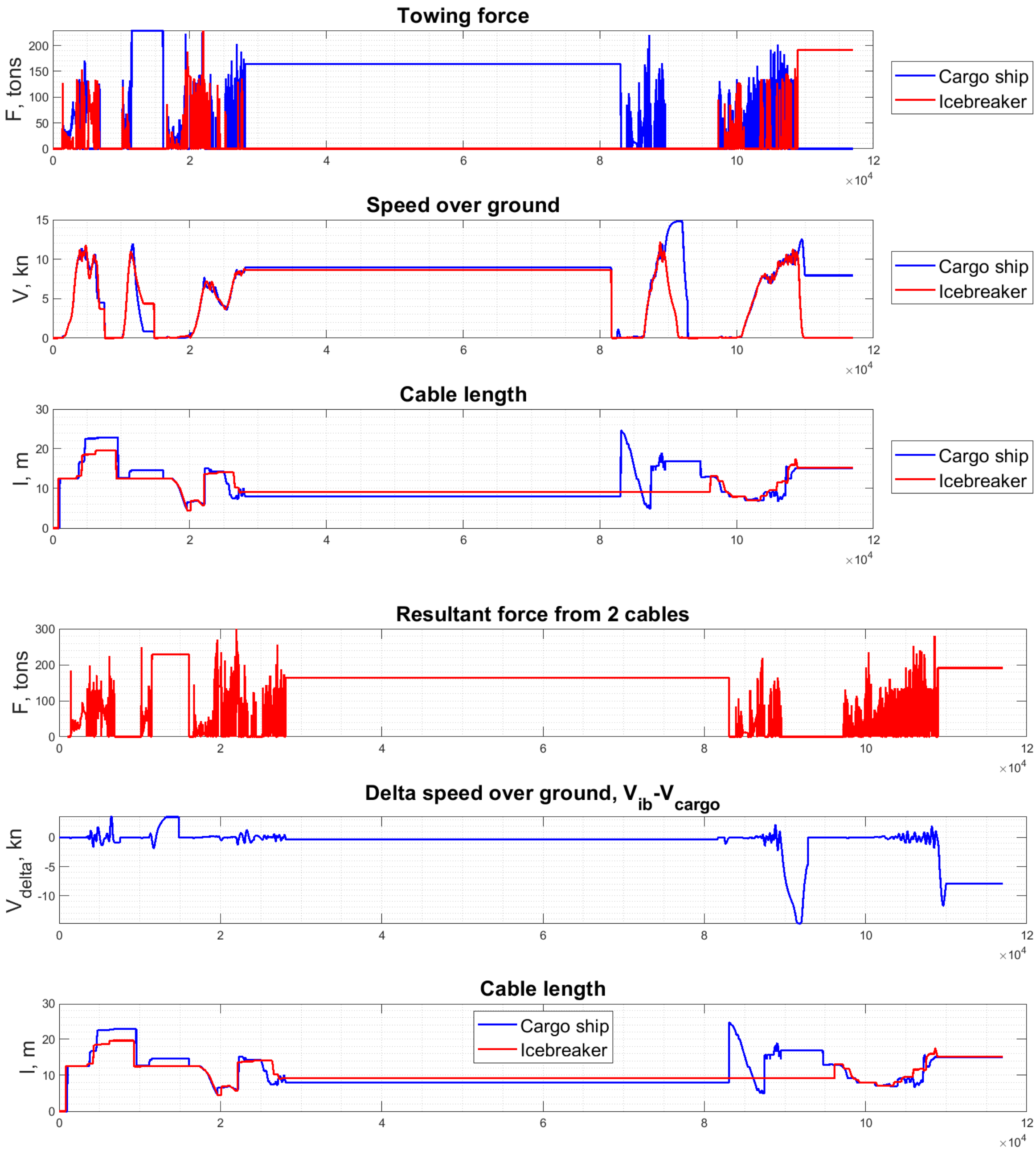
It is important to highlight, that towing module in the AAT ice simulator has never been numerically evaluated before. During the towing simulation manual steering control of the winch were required, which overall affected the results.

Figure 4-19. Towing arrangement in the AAT ice simulator

Figure 4-20. Towing in ice in the AAT ice simulator

The first test results are shown for the case scenario where the distance between chocks was 4.5m, and the length of the cables was controlled manually (Figure 4-21). A quite significant influence of both speed and cable length on the force was seen. Variations of cable length (when it is tight or with a slack) and speed result in fluctuations of forces as well, which can be seen from the resultant force. If speed is steady, the force is constant, and there are no loops or jerks that occur.

However, the results are not reliable, since the changes in cable length are in a wide range, which does not happen in practice. Similar trends can be observed in speed variation of both vessels in full-scale, the speed of the towed vessel is close to the icebreaker speed, and no significant jumps in speed must be experienced.



<u>Figure 4-21. Towing force from ice simulator: winch with length control, distance between chocks 4.5m</u>

The second test results are shown for the case scenario where the distance between chocks was 4.5m, and the tension of the cables was controlled manually (Figure 4-22). This test was done to see how to use winch control in length and tension modes. The average magnitude of forces was below 200-ton, speed fluctuations and variations in cable length resulted in similar behaviour of towing forces as in Figure 4-21.

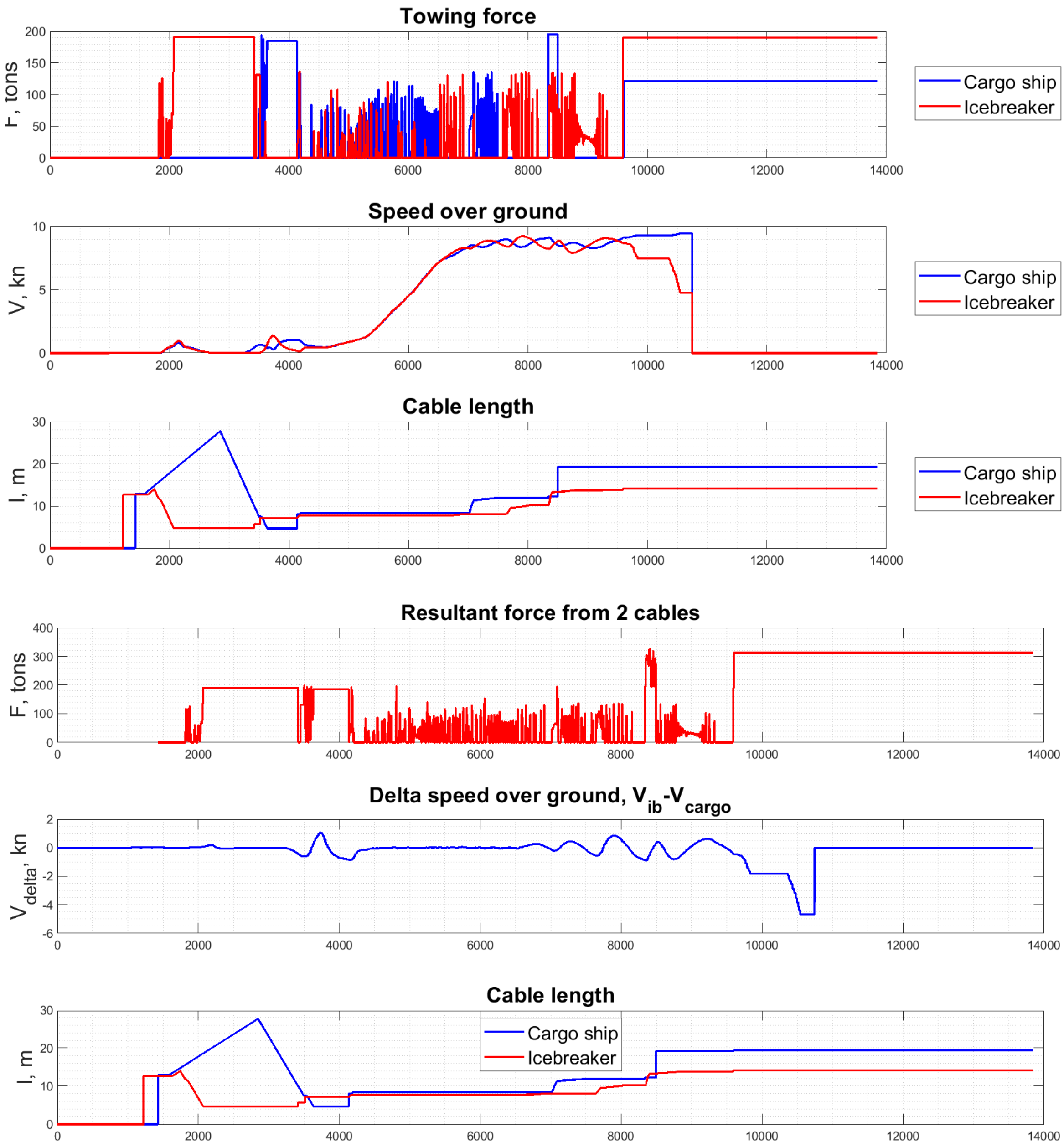


Figure 4-22. Towing force from ice simulator: winch with tension control, distance between chocks 4.5m

The third test results are shown for the case scenario where the distance between chocks was increased up to 8m, and the length of the cables was controlled manually (Figure 4-23).

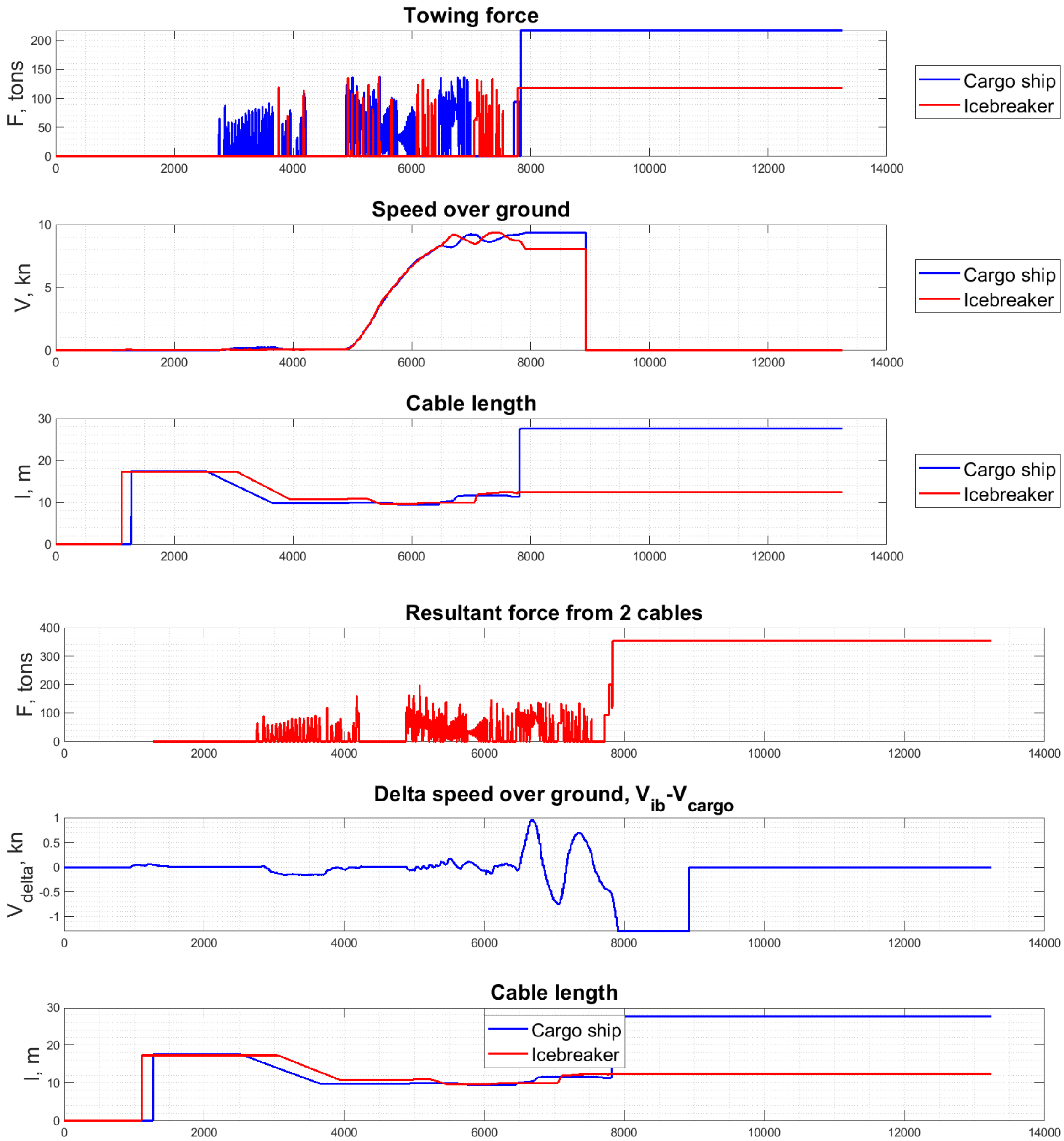


Figure 4-23. Towing force from ice simulator: winch with length control, distance between chocks 8m

The fourth test results are shown for the case scenario where the distance between chocks was 8m, and the tension of the cables was controlled manually (Figure 4-24). The cable length went up to 40m, which is a dangerous practice during the towing. It can be seen that the force increased in the cable controlled by the icebreaker.

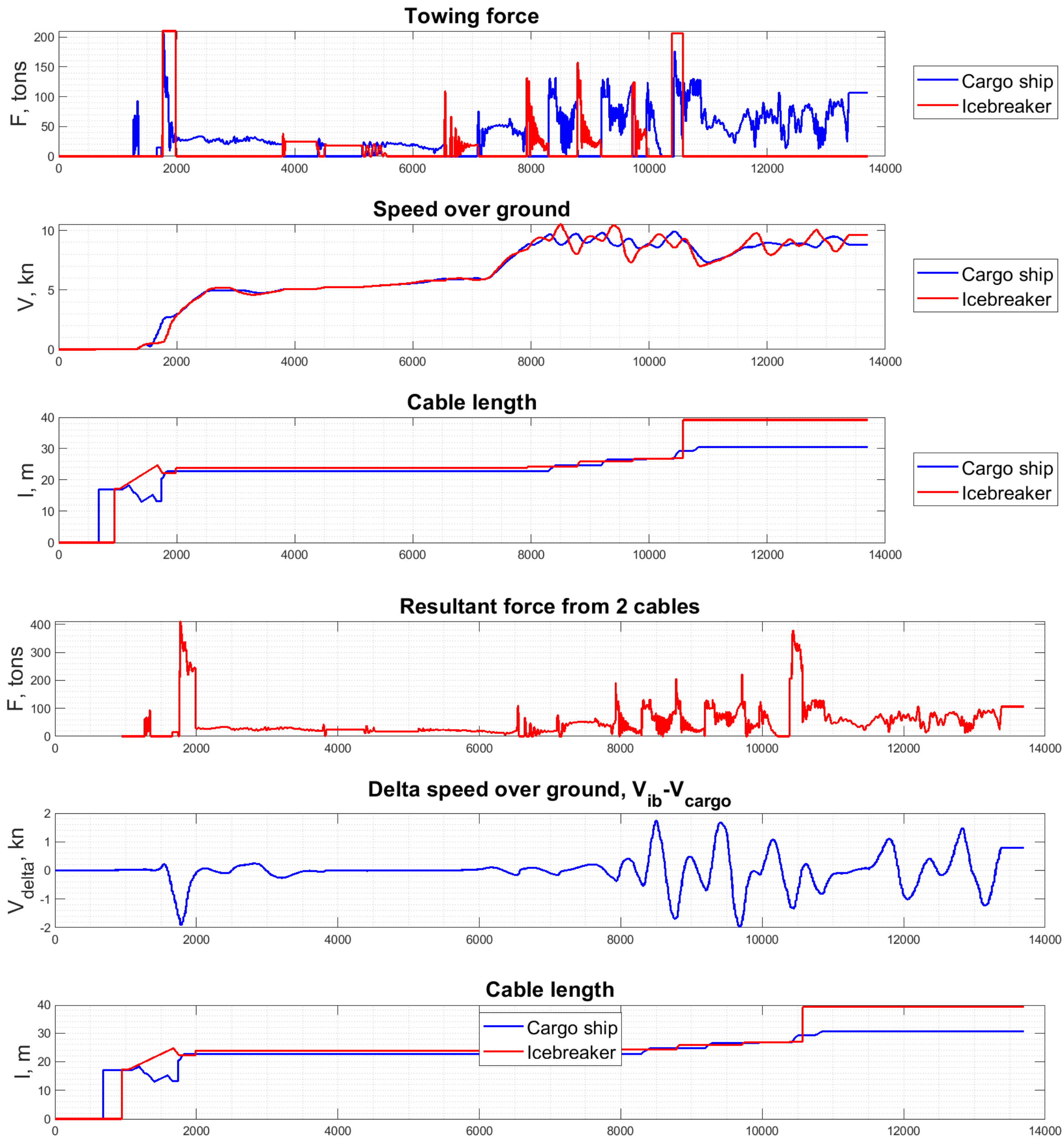


Figure 4-24. Towing force from ice simulator: winch with tension control, distance between chocks 8m

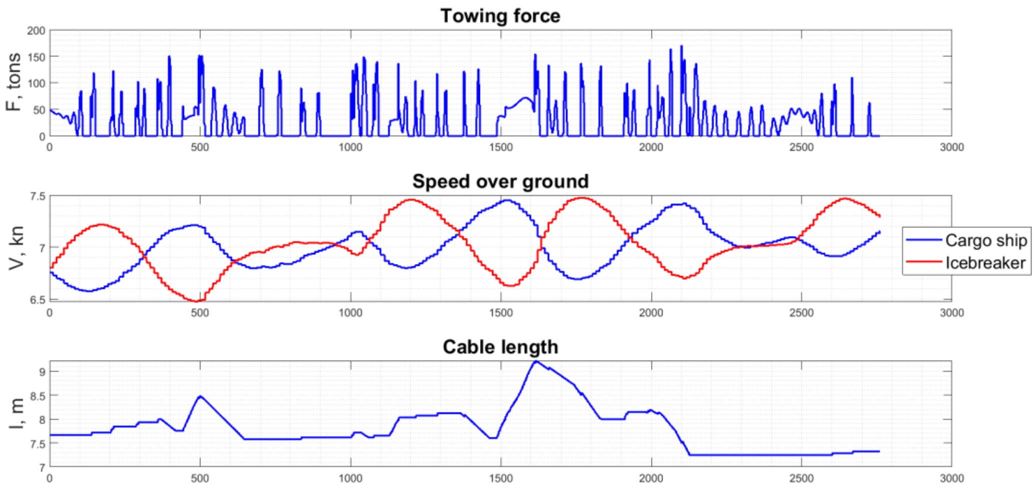
The ice simulator also has one towing arrangement with one cable. To test what results the ice simulator will give from one cable attached to the towed vessel, an additional simulation was run. The results are presented in Figure 4-25, from which several observations can be made:

In Figure 4-25a the speed of two vessels is in antiphase, and here fluctuations in forces appear. The cable displacement changes as well, which also coincides with peak forces. Similar results from numerical simulation were observed by Kulikov & Sazonov (Kulikov & Sazonov, 2003). In Figure 4-25b, the speed of both vessels is near zero, and cable length reduces significantly, which can be related to the manual control of the winch. Some forces which are present in the cable can be due to cable weight or manoeuvring activities. In Figure 4-25c in the first half of the simulation similar results are observed. In the second part of the simulation, when the speed starts to increase, cable length and force reduce and stabilize.

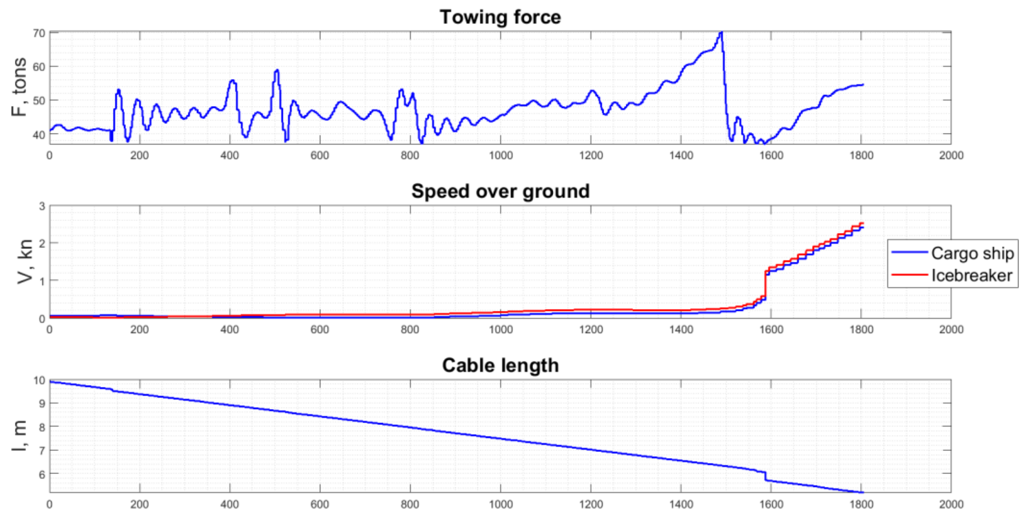
From Figure Figure 4-25d when the speed of both vessels is close to each other, and cable length tights slightly, forces try to balance. When cargo ship moves faster, slack in the cable appears, forces fluctuate. Then the forces begin to stabilize with constant cable length and speed of both vessels. In Figure 4-25e, the vessels move with the same speed, cable tights without jerks, and forces fluctuate less as well. When the cable tights below 4.7 m, the forces increase.

Comparing with the previous results, this simulation with only one cable correlates more with the observations and full-scale measurements. However, manual control was required during the simulation by the simulator, and the arrangement with one cable cannot answer how the location of towing chocks will affect the towing operations.

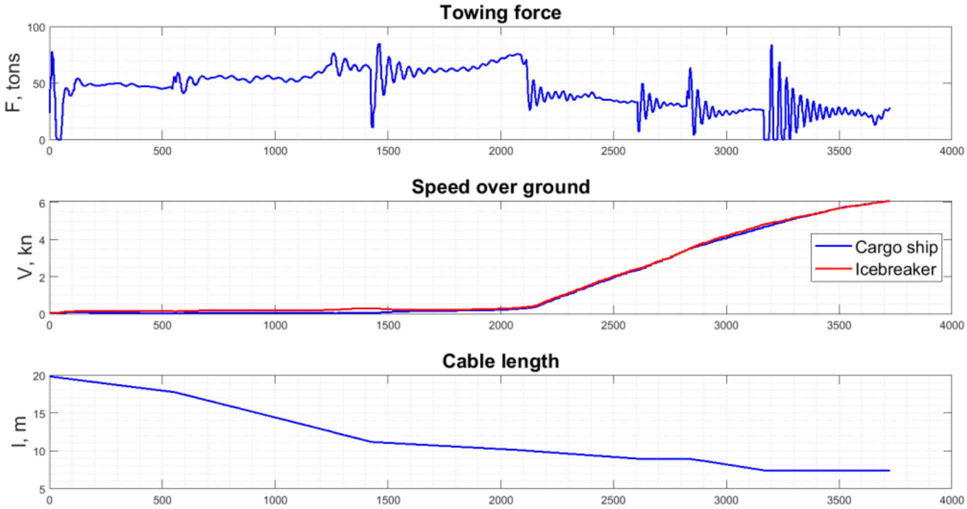
<u>Figure 4-25. Towing force from ice simulator with one cable used in towing</u>



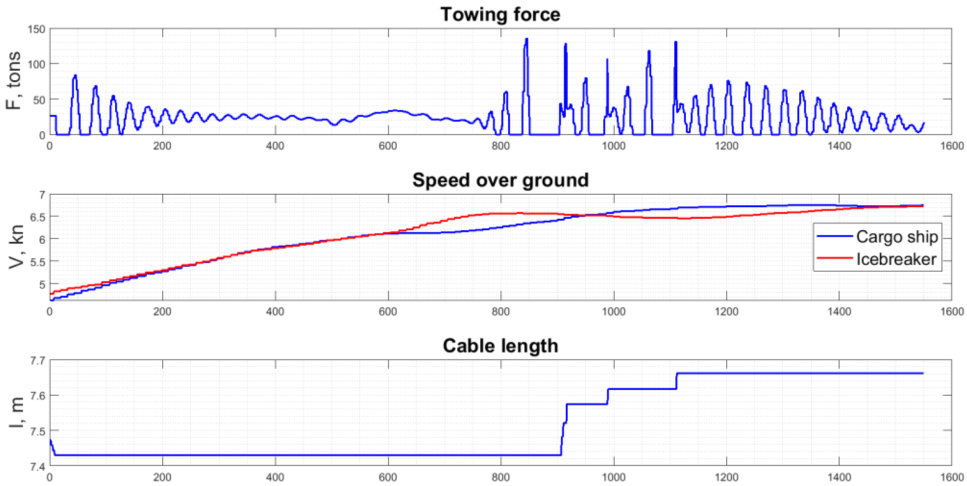
a



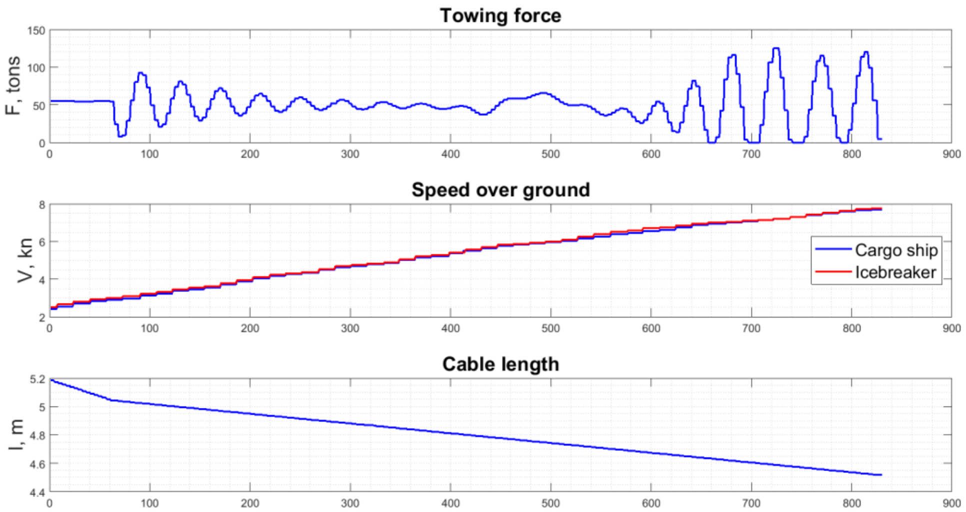
b


Towing force
F, tons
Speed over ground
V, kn
Cargo ship
Icebreaker
Cable length
l, m

c


Towing force
F, tons
Speed over ground
V, kn
Cargo ship
Icebreaker
Cable length
l, m

d


Towing force
F, tons
Speed over ground
V, kn
Cargo ship
Icebreaker
Cable length
l, m

e

From test results presented in Figure 4-21-Figure 4-24 it was concluded that AAT ice simulator cannot be used for the analysis of influence of different bow shapes of towed vessels on the towing forces due to the following reasons:

1. The AAT ice simulator has been used for training purposes; it was not designed to run multiple simulations with controlled parameters. Every simulation requires manual control, which for example, includes constant steering and winch handling. It leads to the complexity in analysing how the bow shape and location of chocks influence the results. The simulator is sensitive to the manipulations carried out by the individual person that is running the simulation.

2. For towing, there must be arranged either two cables (method 1), so-called main and secondary, as shown in Figure 2-6; either one cable (method 2) in the case if towing with two cables is not possible. As it was discussed above, the ice simulator does not have similar towing arrangements with the first method. The simulator allows us to model one cable, however, after all, we cannot judge the influence of chocks location. On the other hand, the second method is used in limited cases, and it is usually related to how the bow is fitted in the notch.

3. The towing module in the simulator has not been updated, and it does not allow modelling of current towing practices. The towing arrangement in the simulator with two cables is not close to a real case scenario. Each cable in the simulator is controlled by a separate winch: one from the icebreaker and the other from the towed vessel. However, both cables must be controlled from one master ship, which is an icebreaker.

4. There are only two models available in the simulator, thus, it is not possible to study the influence of different bow shapes on towing forces. It also limits the amount of possible towing arrangements that can be studied, which depend on when one or two cables should be used.

5. The results from the ice simulator when using two cables attached to the chocks of the towed vessel are not reliable. Significant speed differences and cable displacements occurred in the results. These can be mainly due to two reasons: towing arrangement with two cables in the simulator differs from real practice, and the simulation required manual steering and control.

5 CONCLUSIONS AND RECOMMENDATIONS

This report has presented the results of a number of studies associated with towing in ice when the ship is under escort. The following conclusions are drawn:

- The fleet of existing ice classed vessels operating in the Northern Baltic that are EEDI compliant is still small, therefore experience of towing these vessels in ice is still relatively small

- Of the existing EEDI compliant vessels a number have been identified by the operators as having issues that complicate the tow, or make the tow more problematic, but because these are individual cases from a small sample set it is difficult to draw general conclusions and identify trends

- Generally feedback from operators of the icebreakers and merchant vessels indicates that the main issue with towing EEDI compliant vessels is a lack of engine power, further consideration of which is outside the scope of this study

- With respect to arrangements, feedback from operators indicates that the main implication of the EEDI requirements is that the finer bow shape results in a narrower and finer mooring deck, which in turn can be problematic in terms of location of bollards and chocks for efficient towing (and indeed in securing a towline at all)

- From an arrangement perspective the existing guidelines are relatively general and do not account for the towing line arrangement as a system (merchant ship bollard location, whisker wire length and towing block location) which in turn is effected by the bow shape (or mooring deck shape)

- Simple force-vector analysis has supported the general operational conclusion that wider towing angles between the chocks and the towing block result in more directionally stable tows

- The Aker Arctic ice simulator, whilst producing results which are of comparable magnitude to those measured in full scale was considered inappropriate to be taken forward as a tool for analysing chock locations and the ship response / towing force: The simulator is too dependent on manual input which cannot be easily replicated or correlated with full scale ship handling inputs.

The study presents the following recommendations:

- Because the size of the EEDI compliant merchant vessel fleet is still small the sample size for identify trends and learning from current operations is relatively limited and conclusions may be skewed by individual cases. It is recommended that the size of the EEDI compliant merchant fleet be monitored and practical issues with towing such ships revisited after a few more seasons of operation.

- Although much data was gathered through interviews, because it is considered that potential improvements in towing efficiency need to consider the towing operation as a system it is still considered a vital part of this work that any guideline changes be tested / validated with operational experience and monitoring. Consequently it is recommended that the onboard attendance planned as part of this project should be implemented, using the questionnaires prepared in the future, again when the size of the EEDI compliant merchant vessel fleet is larger.

It is recommended that the design of towing arrangements on merchant vessels for EEDI bow shapes (and any abnormal bow shapes) needs to be considered in the context of the tow arrangement as a system: large spread angles of the whisker wire would lead to improvements in tow stability but the arrangement as such is limited by the whisker wire length and the need for the operational towing block to land on the icebreaker aft deck. Updates to the towing guidelines in the Finnish-Swedish ice class rules could have the following format, generally presenting the designer with the necessary constraints and information to implement an efficient towing arrangement rather than the existing guideline which recommends an explicit spacing distance of the bollards:

- After consultation with icebreaker operators a standard set of whisker wire lengths could be included;

- The guidelines could also include the stern configuration of all icebreakers (some stern configurations are already included) or alternatively a generic icebreaker stern with a “window” of an allowable area in which the towing block must be assumed to be located;

- The guidelines could indicate (after consultation with icebreaker operators) the requirement that the towing block needs to be located in a specific sector or “window” of the aft deck to enable efficient connect and disconnect;

- Within these bounds the designer locating the bollards and chocks would have design space to maximize the whisker wire spread angle (minimum and maximum angles could be considered to be included)

It is considered that the actual content proposed above needs further refinement and validation and discussion with icebreaker operators before being included in updated guidelines to the Finnish-Swedish ice class rules. In particular, the implications of the sliding towing block configuration should be further investigated.

6 REFERENCES

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7 APPENDIX 1 – EXISTING BALTIC TOWING GUIDELINES

7.1 INSTRUCTIONS FOR WINTER NAVIGATION OPERATORS

Guidelines already exist with regards to instructions for towing. The following is extracted from “Instructions for Winter Navigation Operators” (Väylävirasto, 2020) for reference.

QUOTE

4.6 Instructions for towage

9. In difficult ice conditions, towing may be the only means of ensuring safe and effective assistance.
10. The vessel must be prepared to make fast or cast off the towing wire at any time. The icebreaker decides when a vessel is taken into tow.
11. The vessel towed by an icebreaker may only use its propulsion machinery in accordance with the instructions given by the icebreaker. The vessel’s main machinery must be ready for rapid manoeuvres
12. During towage, the vessel in tow must use manual steering. By steering manually, the vessel should try to stay in line with the icebreaker. Towage The method normally used is notch towing. This means that the merchant vessel’s bow is brought into the towing notch of the icebreaker. The icebreaker will also hand over two wires which are to be fastened to the merchant vessel’s bitts which have been designed to withstand the stresses of towing.

Notch towing

Notch towing is applied when the icebreaker and the towed vessel are connected as below

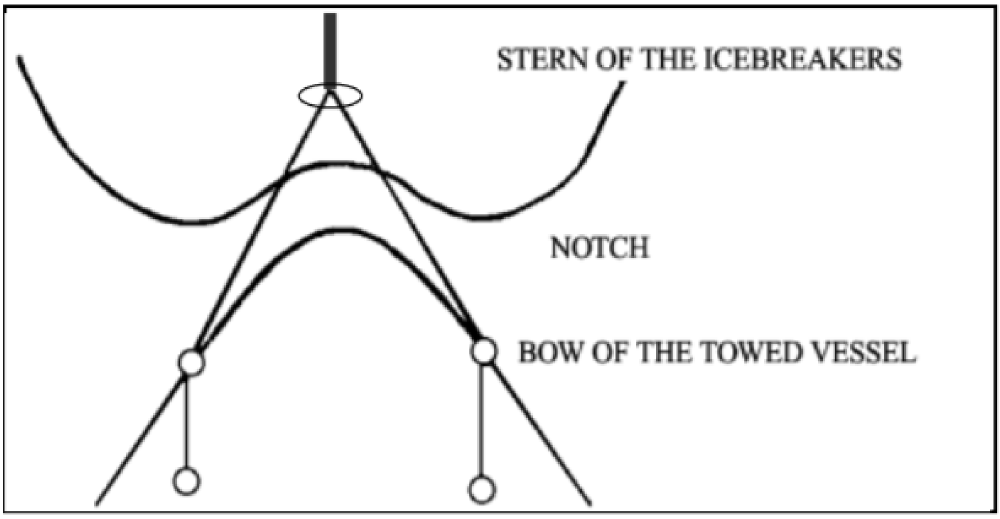

Figure 7-1 Notch towing schematic

The hull of the towed vessel is always acting as an active rudder of the icebreaker

If the towed vessel has sufficient engine power and follows the instructions of the icebreaker, it acts as an active rudder steering in the right direction. Proper use of the rudder ensures safe towage, helps avoid accidents and increases towage speed.

When proceeding straight ahead the vessel should keep its masts in line with the masts of the icebreaker.

[illustration omitted for brevity]

If the vessel cannot keep the engine output as high as required or it is affected by rudder problems, the icebreaker should be notified immediately, so that it can reduce its speed.

Altering course

If the icebreaker asks the vessel to help with altering the course, the helm has to be turned enough in the opposite direction of the one normally used, as the vessel's hull is acting as the rudder of the whole combination.

[illustration omitted for brevity]

Special measures for safe towing

Vessels with a bulbous bow should be trimmed so that the distance between the top of the bulb and the hull of the icebreaker is at least two (2) meters. If the ship's anchors are located on the outside of the hull and could thus come into contact with the towing notch, they must be pulled back or lifted onto the deck well in advance before the assistance.

[illustration omitted for brevity]

Factors complicating towage

The shape of the vessel's bow greatly influences the towage. The principle is that in cases where an unsuitable bow complicates the towage or makes it virtually impossible, the vessel is only assisted when this can be carried out without towage. The master of the icebreaker makes the final decision on towage.

END QUOTE

7.2 GUIDELINES FOR THE APPLICATION OF THE FINNISH-SWEDISH ICE CLASS RULES

Guidelines already exist with regards to instructions for towing. The following is extracted from "Guidelines for the Application of the Finnish-Swedish Ice Class Rules" ((TRAFICOM & Swedish Transport Agency, 2019)) for reference.

QUOTE

8.5 Arrangements for Towing

The towing method normally used in the Baltic by icebreakers is notch towing. Notch towing is often the most efficient way of assisting ships of moderate size (with a displacement not exceeding 30,000 tons) in ice. If the bulb or ice knife makes a ship unsuitable for notch towing, in heavy ice conditions this kind of ship may have to wait for the ice compression to diminish before the ship can be escorted without notch towing. During towage, the towed vessel acts like a large rudder for the icebreaker and this causes difficulties, particularly if the merchant vessel is loaded or the bow does not fit well with the notch.

The towing arrangement usually involves a thick wire, which is split into two slightly thinner wires, shown in Figure 5. Two fairleads must be fitted symmetrically off the centreline with one bollard each. The distance of the bollards from the centreline is approximately 3m. The bollards must be aligned with the fairleads, allowing the towlines to be fastened straight onto them. A typical towing arrangement is shown in Figure 5. The additional installation of a centreline fairlead is recommended, since this is still useful for many open water operations and some operations in ice.

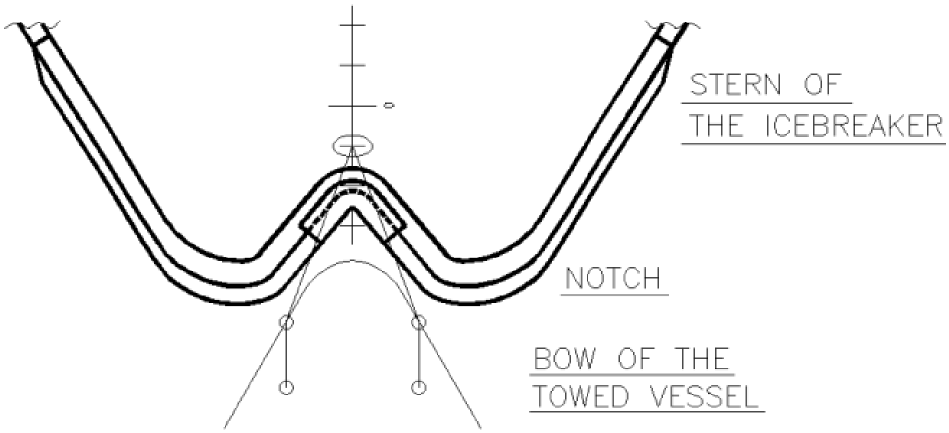

Figure 5. The typical towing arrangement.

A bollard or other means for securing a towline, structurally designed to withstand the breaking force of the towline of the ship, must also be fitted. Operational experience indicates that the bollards can never be too strong and should be properly integrated into the steel structure. As a guideline for bollard design, it should be required that they withstand at least the maximum icebreaker winch force, which is usually 100 – 150 t. The maximum possible force on the bollards is given by the breaking load of the most commonly used cable, a 62mm cable. This has a breaking load of about 200 t.

The ship bow should be suitable for notch towing. Such suitability involves the proper shape of the bow waterline at the height of the icebreaker notch. This height is around 2.5m. If the bow shape is too blunt, it will not fit well into the icebreaker notch. For guidance, the notch shape of IB Otso and Kontio, together with the notch of MSV Botnica, are presented below in Figure 6.

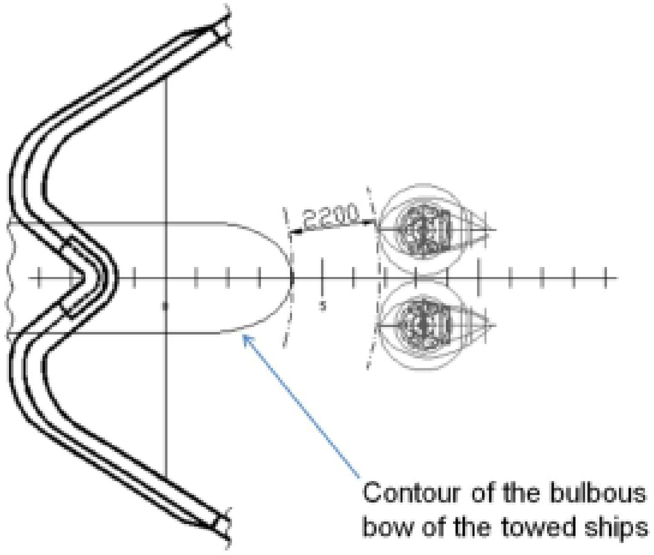

Figure 6a. A sketch of the notch of IB Otso and Kontio, also showing the bulbous bow of the towed ship.

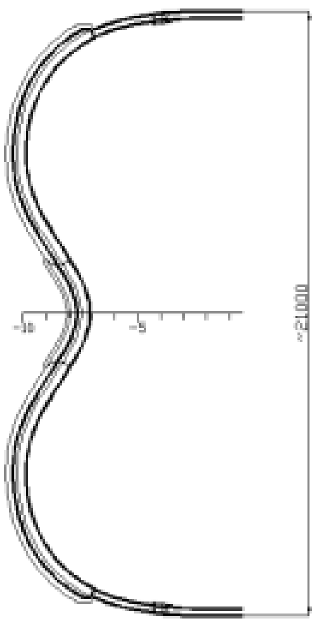

Figure 6b. The notch of MSV Botnica.

UNQUOTE

8 APPENDIX 2 – CONSOLIDATED NOTES FROM OPERATOR INTERVIEWS

8.1.1 WORK DONE

The onboard survey of merchant vessels could not take place due to access restrictions and availability of ships. The survey was limited to “desktop” reviews with the mooring arrangement plans with the merchant vessel operators ashore.

Interviews were conducted at various points during spring 2021. Captains were interviewed on various topics related and not so related to this study. Their overall experiences and opinions were discussed and noted below.

8.1.2 ASSISTANCE OPERATIONS IN GENERAL

Veli Luukkala:

Weather conditions and vessel speeds are typically what cause most of the issues during assistance.

Close contact towing is more typical and long-distance towing is rarely needed as the assisted vessel can typically follow in the channel created by the icebreaker.

Simo Haaslahti:

Assistance operations on bay of bothnia is really pro-active. Usually the vessels in need of assistance are known well beforehand and schedule can be built around that information.

Trim difference between the vessels sometimes becomes an issue. Icebreakers can typically correct by about 0.5 m but that is not always enough.

Merchant vessels need to fulfil the trim requirements for good and functional operations.

Vidar Tollander:

Advance notice for the need of assistance is given. Afterwards VTS provides points (in ice) that the vessel follows for as long as it can and if the vessel ca not proceed further on its own they will wait for icebreaker escort.

If a conwoy of vessels fails, typically the “weakest” vessel is towed while the rest follow.

8.1.3 ASSISTANCE OPERATIONS SPECIFIC TO THEIR VESSEL

Veli Luukkala:

Towing notch on Kontio is too short and will be extended during the next drydock visit, same as was done for Otso.

Simo Haaslahti:

DWT of about 4-6t vessels can still be towed on the notch. draught of the vessels also have a significant effect on the notch towing operations.

Vidar Tollander:

Notch sometimes sits very high causing dents in weaker areas of the bow

8.1.4 CREW OPERATIONS

Veli Luukkala:

Most timesaving issues are typically caused by inexperienced crew (onboard merchant vessel) and not necessarily any design choice. Pilot on board typically helps a lot.

Vidar Tollander:

Communication with icebreakers works and no specific issues with crew.

8.1.5 ON EEDI BOWS

Veli Luukkala:

No significant differences in towing operations. Bigger effects caused be general dimensions of the vessels and bulbous bows.

Simo Haaslahti:

EEDI bows typically have lower engine power and poorer manoeuvrability. Sharp bows also might cause issues on angle of steering during notch towing if the merchant vessel is not located exactly on CL.

Vidar Tollander:

EEDI bows are easier in the sense that there are no bulbous bows to worry about but ship specific differences have a bigger impact. For example, Aava is easier to manoeuvre compared to Mirva due to its hull shape.

8.1.6 EQUIPMENT RELATED TO TOWING

Veli Luukkala:

Centerline chock (Panama chock) and roller fairleads are all but useless for towing purposes. For chock placement, Luukkala indicated that the distance of the chocks used for towing sometimes causes issues when the whisker wire is not long enough.

Simo Haaslahti:
Winch has caused some issues in the past by not functioning properly but this is a rare occurrence.

Otso/Kontio does not have auto tensioning winch which would make assistance operations easier.

Vidar Tollander:

Mirva VG has had no issues transferring wires between the vessels. Messenger line is taken onboard, whisker wire is pulled in and eyes is attached to bollards. Deck is cleared of personnel and IB will tighten the wire correctly.

8.1.7 OPINIONS ON ICEBREAKERS

Simo Haaslahti:
Polaris towing notch really good functionally. It is wide and deep enough to accommodate most merchant vessels in need of contact towing.

Vidar Tollander:
Good experiences in the past couple of years with IB operators.
No major differences between icebreakers except on some IB vessels the towing rope stays tighter. Cannot identify which ones.