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CORRELATION TESTS WITH MT UIKKU IN THREE MODEL BRASH ICE CHANNELS

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FOREWORD

In this report no 115, the Winter Navigation Research Board presents the results of research project ChanCorr. Correlation tests between model-scale and full-scale resistance measurements were conducted for MT UIKKU. Full-scale test results were reproduced in model-scale using three different model brash ice types.

The test results indicate the correct model brash ice properties are more crucial in model tests conducted with an open water optimized hull shape than in model tests conducted with ice-optimized hull shapes.

The Winter Navigation Research Board warmly thanks Riikka Matala for this report.

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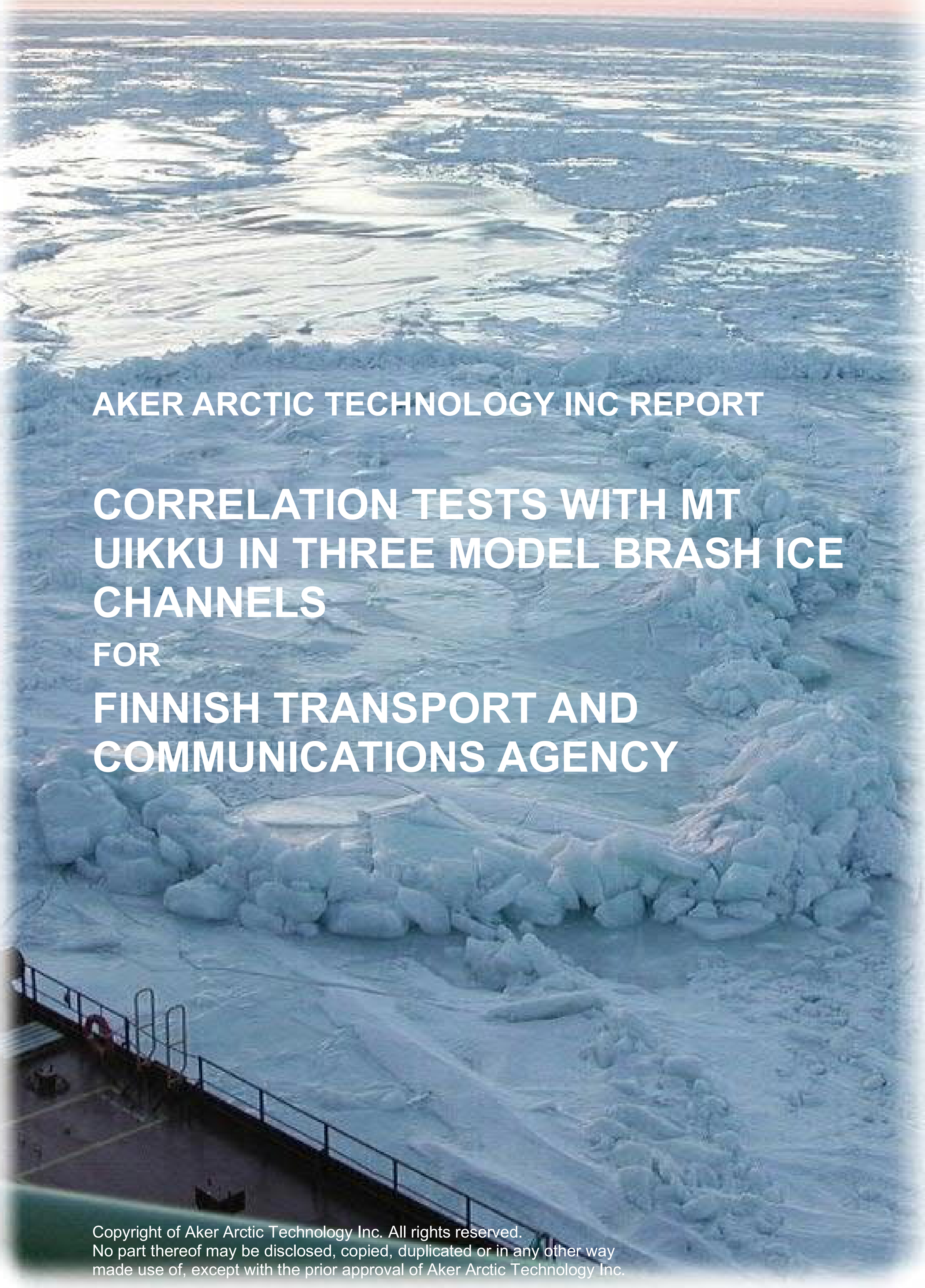

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AKER ARCTIC TECHNOLOGY INC REPORT

CORRELATION TESTS WITH MT UIKKU IN THREE MODEL BRASH ICE CHANNELS

FOR

FINNISH TRANSPORT AND COMMUNICATIONS AGENCY

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Correlation tests with mt Uikku in three model brash ice channels

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Summary:
This study relates to previous research related to vessel channel resistance done in 2016 (W16-6 Model Channel) and 2018 (W18-8 FSC channel resistance), which were also funded by Winter Navigation Research Board.

The power requirement of the Finnish-Swedish ice class rules can be determined by model tests. Despite the relevance of right determination of ice class, the current model test guidelines allow model test procedures to vary around testing facilities, which can result in unstandardized test conditions, and further unharmonized test outcomes.

To add understanding and to develop the test procedures, there was a need for correlation tests of vessels – in full-scale and in model-scale. Before this, a similar correlation pair was acquired in 2018 with an EEDI-type tanker (Aker Arctic report K-379). To understand the hull shape effect on the vessel resistance in brash ice, the correlation tests were conducted using icebreaking tanker, mt Uikku. The full-scale test results from 1999 were reproduced in model-scale using three different; however, justifiable model brash ice types.

The test results indicate the correct model brash ice properties are more crucial in model tests conducted with an open water optimized, EEDI-type hull shape, where the resistance related to ice pile-up is dominant that in model tests conducted with ice-optimized hull shapes.

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1 INTRODUCTION

The aim of this study on correlation vessel channel tests is to continue our research on vessel resistance in brash ice channel. The goal of this research is to study brash ice behavior around a moving ship hull, consequently enabling the development in channel model test procedures towards standardized model test conditions and harmonized channel test outcomes. This research was funded by Winter Navigation Research Board. The previous researches are described in Aker Arctic report A-557 and K-379.

In this study, the full-scale channel tests of mt Uikku (Nortala-Hoikkanen, 1999) are reproduced in model-scale in three different model brash ice types. The model brash ice types and the test procedures correspond to the previous test series (K-379), in which correlation tests were conducted with an EEDI-type tanker. The intention of this test series is to study the hull shape influence on model resistance in different model brash ice types and add understanding on certain brash ice properties influence in channel resistance.

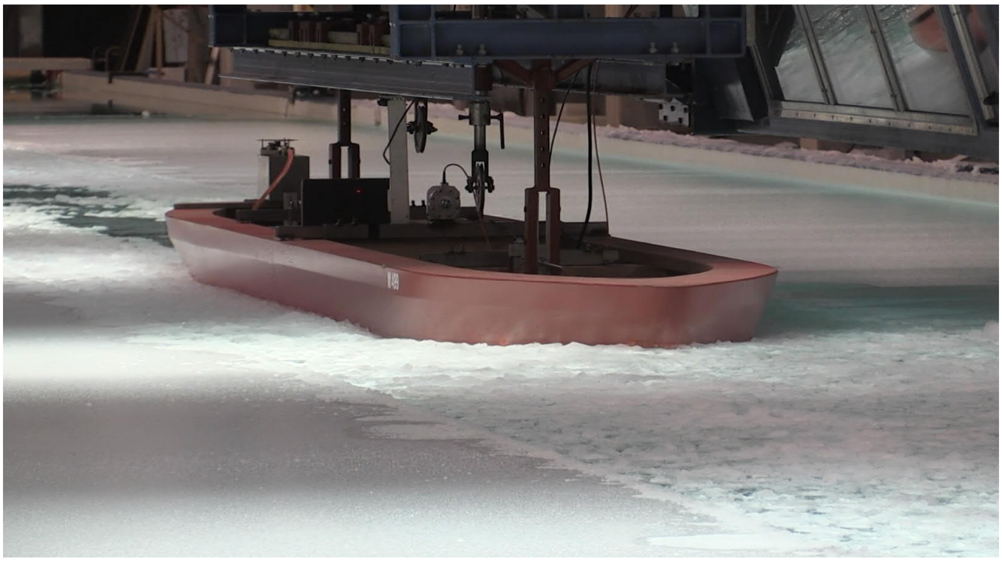

Figure 1-1: Model in brash ice channel

2 DESCRIPTION OF THE VESSEL

The correlation tests were conducted with product tanker m/t Uikku. Uikku was originally designed to independently navigate in the Baltic Sea, consequently the bow shape is optimized in icebreaking, and the vessel sides are inclined. M/t Uikku being one of the first vessels equipped with an Azipod unit, is a well-known vessel and there are several existing vessel measurement results available, both in full-scale and in model-scale. Additionally, the hull-shape of Uikku's sister ship Lunni has been applied in a DEM-analysis of a vessel in an old brash ice channel (WNRB report No. 93).

Uikku and Lunni were originally built as one-shaft vessels but they were converted to Azipod vessels in 1990's. The Azipod unit was pushing type and it could not be turned 360°. The model of m/t Uikku (M-499) and the Azipod unit were produced particularly for this project in scale 1:20. The model was equipped with the propeller which was originally designed for the Azipod installation of Uikku. A picture of the vessel is presented in *Figure 2-2*, pictures of model in *Figure 2-2* - *Figure 2-5*, and the main particulars of the vessel and the model in *Table 2-1*.

Figure 2-1: m/t Uikku on her full-scale channel tests 1999

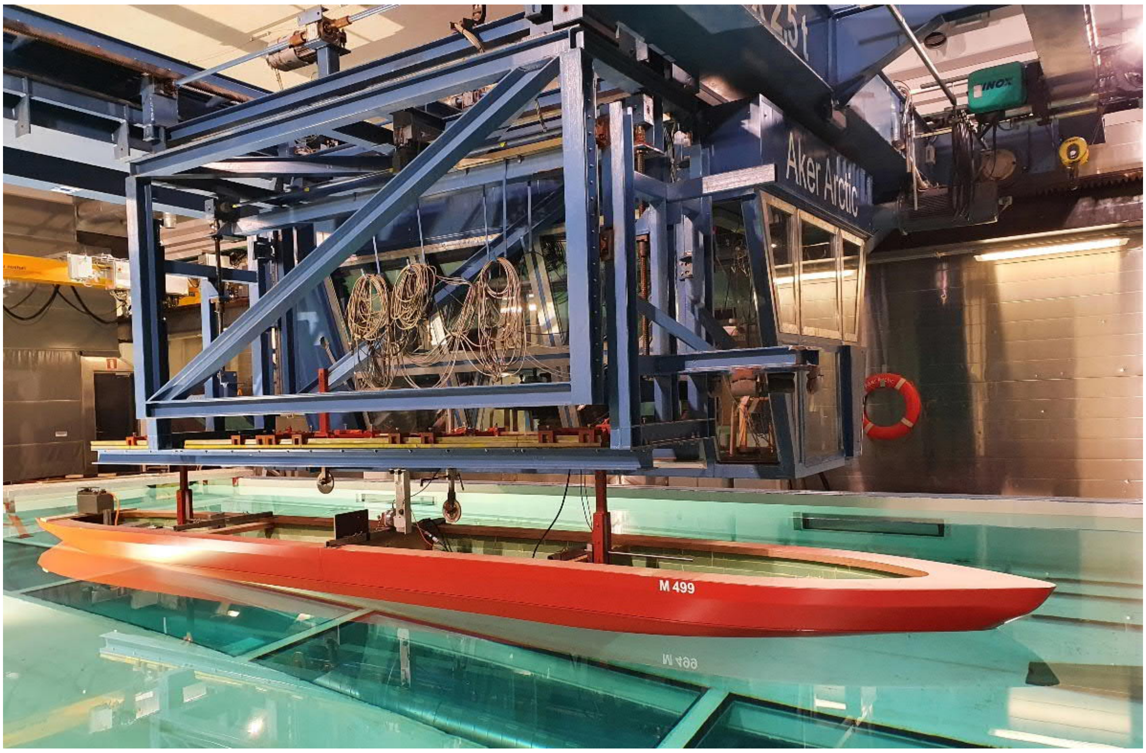

Figure 2-2: Model of m/t Uikku

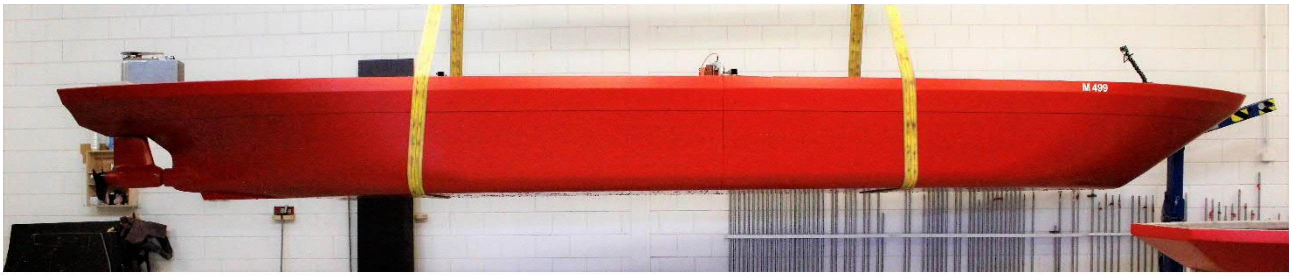

Figure 2-3: Model M-499

Figure 2-4: Model M-499 bow

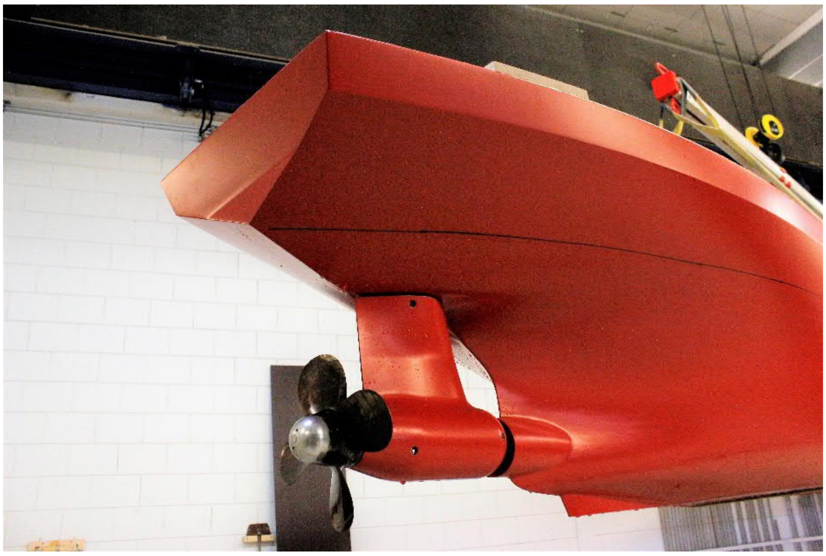

Figure 2-5: Model M-499 stern equipped with a pushing Azipod unit

Table 2-1: The main particulars of m/t Uikku and its model M-499

Dimension	Uikku f.sc.	M-499 m.sc.
L [m]	164.4	8.2
B_{OA} [m]	22.2	1.110
B_{WL} [m]	21.5	1.074
D_{design} [m]	9.5	0.475
D_P [m]	5.65	0.283

3 TESTS

3.1 TESTS IN FULL-SCALE

The full-scale test results, which are reproduced in this test series, are originally presented in MARC report B-145. The tests were conducted in the Bay of Bothnia, near port of Kemi, in an old channel in March 1999.

The channel profile was measured from 6 different locations prior to the vessel channel test. The channel width was 30 – 40 m depending on the definition of channel edge. The profiles were measured in two-meter intervals, and according to the profile measurements, the channel thickness in the middle of the channel varied between 0.65 – 1.2 m, the thickness at 10 m side from the channel center line varied between 1.3 – 2.6 m, and thickness at the channel edge between 1.9 m – 4.1 m. Pictures of the channel piece size are presented in *Figure 3-1 - Figure 3-3*.

According to the Finnish-Swedish ice class rules, the rule-based channels are determined based on their thickness in the mid part. For Finnish-Swedish ice class 1A, the mid part thickness is 1.0 m. By this definition and taking into account the Kemi channel being a typical actively-navigated channel, these full-scale measurement are considered to correspond to 1A model test condition without any numerical corrections. The full-scale results ahead at design draft (9.5 m) in an old channel are presented in *Table 3-1*.

Table 3-1: The full-scale channel test results of Uikku in 1999

v [m/s]	R_{ice} [kN]
5.08	424
4.77	464
4.19	500
3.53	450

Figure 3-1: The Channel brash ice piece sample in the channel center line

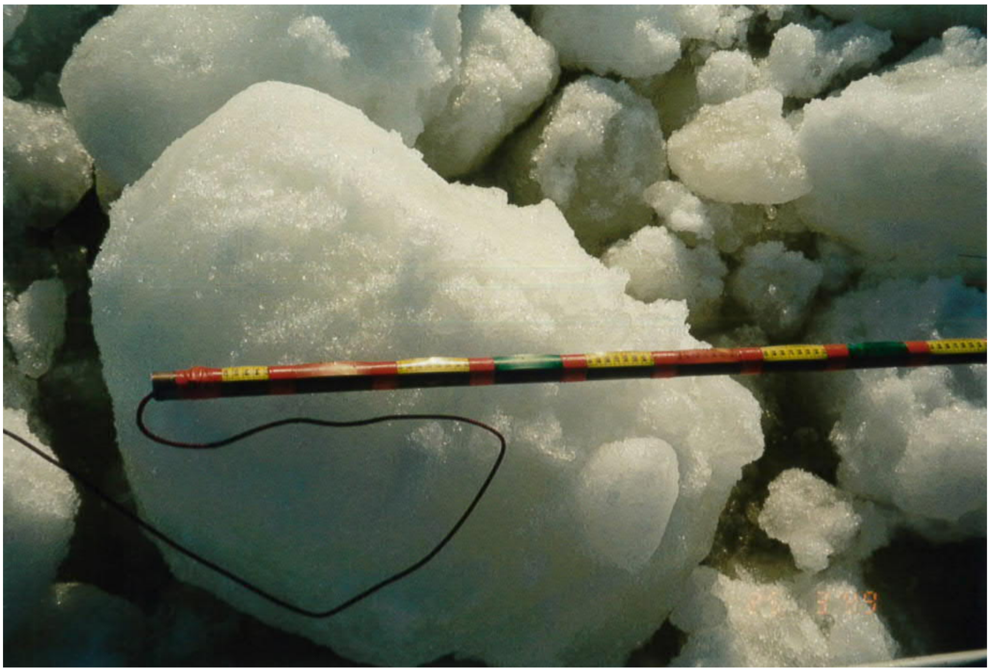

Figure 3-2: The Channel brash ice piece sample at 10 m side from the channel center line

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Figure 3-3: The brash ice channel overview

3.2 TESTS IN MODEL-SCALE

The channel test was conducted in three different; however, justified model ice types. The brash ice types properties were intentionally chosen to represent a different level of ice fragment solidity and separation. This was implemented by setting the different ice piece target strength values to the brash ice types. In practice, two of the brash ice types were produced of broken model ice with target flexural strength of either 25 kPa or 50 kPa, which would correspond to 500 kPa and 1000 kPa in full-scale, given a traditional use of Froude scaling is applied. The third brash ice type did not consist of model ice, but of artificial, fresh-water ice cubes with properties corresponding to natural fresh-water ice.

Table 3-2: Model test program

Test day	Date	Ice type	Test
1	21.10.2020	FGX-ice, σ_c = 500 kPa	Channel 1, 2 power levels
			Channel 2, 2 power levels
			Channel 3, 2 power levels
2	23.10.2020	Ice cubes	Channel 1, 2 power levels
			Channel 2, 2 power levels
			Channel 3, 2 power levels
3	19.11.2020	FGX-ice, σ_c = 1000 kPa	Channel 1, 2 power levels
			Channel 2, 2 power levels
			Channel 3, 2 power levels

4 RESULTS

4.1 MODEL TEST RESULTS

The model test results are presented in *Figure 4-1*. According to FSICR requirements, the model test results are corrected to correspond resistance in equivalent thickness (1.3 m) and friction coefficient of 0.1 between vessel and ice.

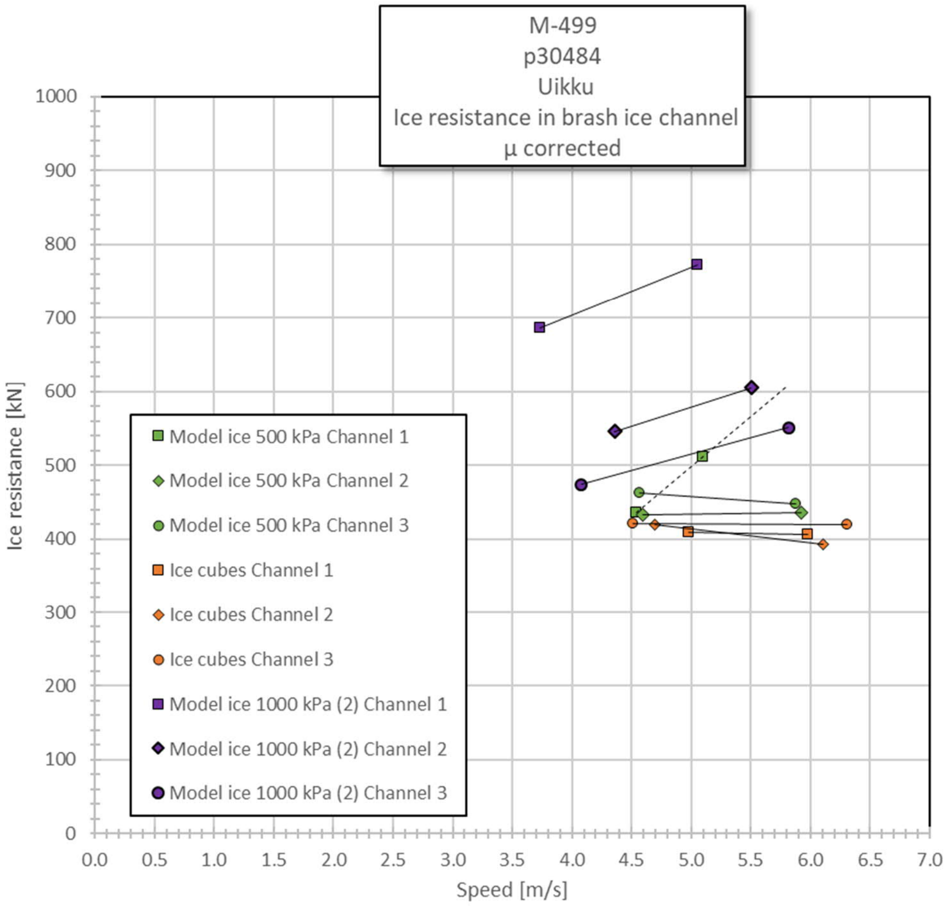

Figure 4-1: Uikku channel resistance versus ship speed

4.2 CORRELATION IN FULL-SCALE AND IN MODEL-SCALE

The model test results together with full-scale test results are presented in *Figure 4-2.*

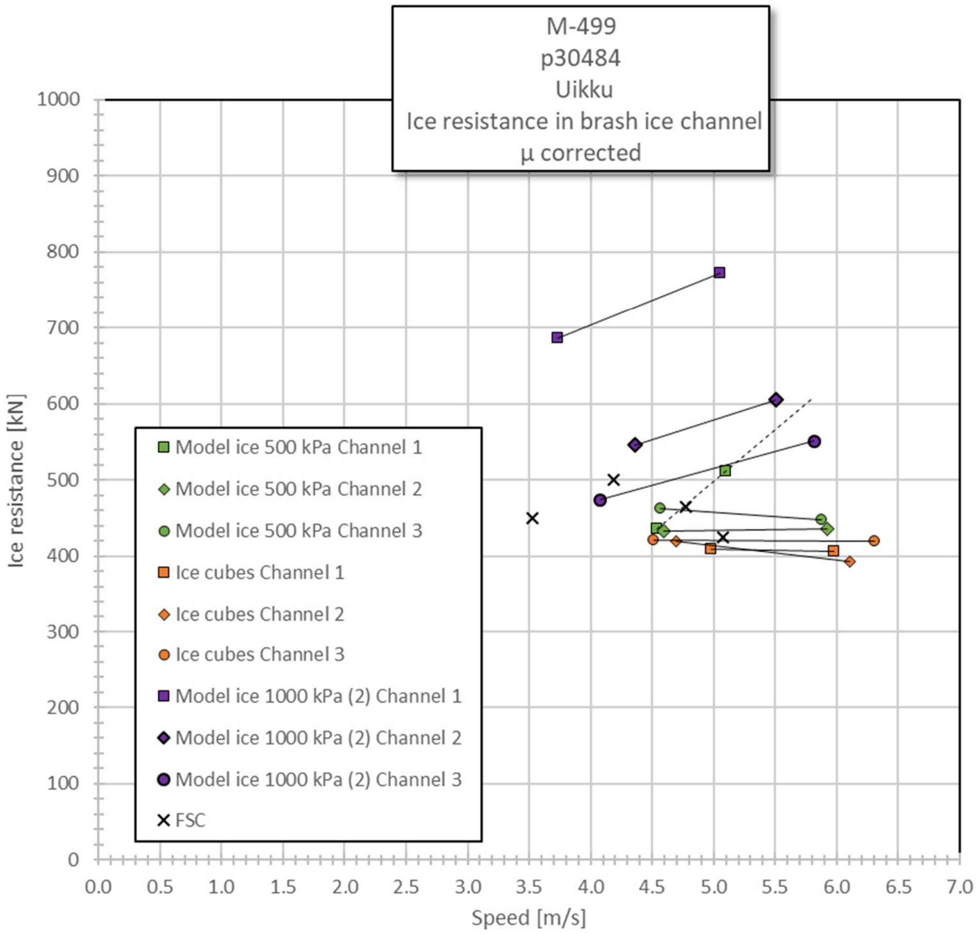

Figure 4-2: Uikku channel resistance versus ship speed in model tests and in full scale test

5 DISCUSSION

The good ice performance on Uikku and the current model scale 1:20 resulted in relatively high speeds in model scale. As the ice tank length is limited, there is only little space for the model speed to settle. Consequently, the constant speed is not always achieved in a test, but the model is still accelerating in the end of test. The constant acceleration or deceleration can be taken into account in analysis as an additional negative or positive resistance component. This resistance due to model acceleration is considered in the analysis according to best practices; however, acceleration causes some uncertainty when interpreting the final results.

The model test results are generally consistent with the available full-scale results except the first test conducted in strong model ice (1000 kPa). The first channel test conducted in 1000 kPa ice indicates higher resistance in relation to all other tests in model scale and in full scale. This result is contradictory with the test outcomes from tests conducted in 500 kPa ice, in which ice fragments are even softer and more transformable, and therefore the resistance was hypothetically even higher. This unexpected outcome in 1000 kPa ice was validated by an additional test day outside this test series. For the present, no clear explanation for this outcome has been found.

6 CONCLUSION

As a continuation to our research on vessel resistance in a brash ice channel, there was a need for correlation tests of different vessels. Before this, a correlation pair in model-scale and in full-scale was acquired in 2018 with an EEDI-type tanker (Aker Arctic report K-379). In this study, the hull shape effect on the vessel resistance in brash ice was investigated by reproducing the full-scale channel tests of mt Uikku (Nortala-Hoikkanen, 1999) in model-scale.

The channel tests of mt Uikku was conducted in model-scale in three different model brash ice types. The model brash ice types and the test procedures corresponded to the previous correlation test series (K-379). The intention of this test series was to observe the hull shape influence on model resistance in different model brash ice types and add understanding on certain brash ice properties influence in channel resistance.

The test results indicate that the full-scale and model-scale correlation is significantly better concerning m/t Uikku, which represents hull shape optimized for ice conditions, compared to the previous project EEDI-type vessel, which represents hull shape optimized in open water condition. One possible explanation for this is that the open-water-optimized hull shapes tend to push the brash ice mass to the sides and even in front of the bow, whereas the ice-optimized hull shapes resistance in brash ice consists mainly from pure submerging. Consequently, the correct model brash ice properties that better model brash ice pile-up are crucial when testing open water optimized hull shapes. For hull shapes optimized in ice conditions the brash ice fragment density is the dominating property. The different model brash ice densities did not remarkably diverge from each other, consequently the model test outcomes also were better harmonized. These different vessel correlation test results will be further discussed in our following research on brash ice channels.