The Specialist Committee on Ice

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1. DISCUSSIONS

1.1 Discussion to the 24th ITTC Specialist Committee on Ice by Mehmet Atlar and Roderick Sampson, University of Newcastle upon Tyne, United Kingdom

We would like to congratulate the Committee's effort on their work in relation to the five Committee tasks. Amongst these tasks, Task 4 involves "Conducting tests to develop an understanding for the performance of open water propeller in ice". With regard to this task, we have noted that no consideration has been given to the effect of cavitation on the performance of open water propeller in ice. In real ice environment when a heavily loaded propeller is operating in the proximity of an ice block (non-contact) or milling the ice block (in contact) it will be easily enforced to develop cavitation that can be extremely severe to cause serious mechanical damage, for instance by erosion and fatigue on the blade, as well as degrading its performance and worsening the shaft vibration problems. Whilst the discussers appreciate that the investigation of the cavitation effect is not a simple matter in a conventional ice tank open to atmosphere and it has therefore been neglected so far, it is possible that some useful knowledge on the nature and magnitude of this effect can be obtained by conducting performance tests in cavitation tunnels if one is really going to understand the performance of an open water propeller in ice as aimed in Task 4.

Within this respect we would like to bring pioneering experimental investigations that were taken place in the Emerson cavitation tunnel of Newcastle University regarding to two different type propellers. One of which was the Canadian R-Class Coast guard propeller while the other one was the podded propeller of the world's first Double Acting Tanker (DAT) briefly discussed below.

Figure 1.1 clearly shows the effect of cavitation on the performance of the R-Class propeller as reported in Minchev et al. (2001) In Fig. 1.1, regardless to the cavitation number, it is clear that the milling results in approximately constant increase in torque and constant reduction in thrust for this propeller. However, when the effect of the cavitation is taken into account the difference for thrust (K_T) and torque ($10K_Q$) values over the maximum and minimum of the cavitation number range (σ) tested is 0.17 and 0.15, indicating 40% and 20% decrease, respectively. This is considerable and propeller design studies based on the performance measurements carried out in towing tanks will not take this into account beside the above mentioned severe erosion and other cavitation related effects. Whereas, assuming that the contact forces are independent of the cavitation number, one can make correction on the propeller performance (K_T

and K_Q) measured in the ice tank by performing the ice-milling tests in the cavitation tunnel.

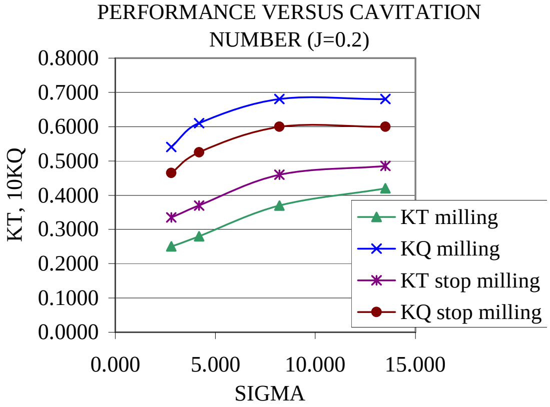

Figure 1.1- Effect of cavitation on R-Class coast guard propeller performance.

Figure 1.2, on the other hand, displays the visual effect of the cavitation that was observed with the DAT podded propeller by Atlar et al. (2003). As shown in Fig. 1.2 (position 2), when the ice block is at the farthest location, a slight sheet cavitation and tip vortex cavitation on the key blade at the top dead centre is apparent. When the leading edge of the key blade is about to contact the ice-block, the sheet cavitation extends from the tip to the contact point, and the space between the frontal side of the ice block and the suction side of the key blade is filled with foam like sheet and bursting tip vortex cavitation as shown in Fig. 1.2 (position 4).

As soon as the key blade starts the milling, the above mentioned foam like sheet cavitation transforms to severe cloud cavitation as shown in Fig. 1.2 (position 6). While the key blade progresses, when the subsequent blade enters into the recess, the space between the suction side of the key blade and pressure side of the following blade also fills with the severe cloud cavitation. The severity of the cloud cavitation was so intense, particularly at the blade exiting side of the recess, resulting in block failure if the propeller stayed relatively long time inside the recess. Large pitting marks caused by the cloud cavitation can be easily observed inside of the milled ice blocks, particularly at the blade exiting side. This cavitation was co-existed with tremendous amount of noise. The cloud cavitation always developed as soon as the blades entered into the recess in the above described manner even if the blade stopped milling as shown in Fig. 1.2 (position 8). As soon as the blades come out of the recess the cloud cavitation disappears.

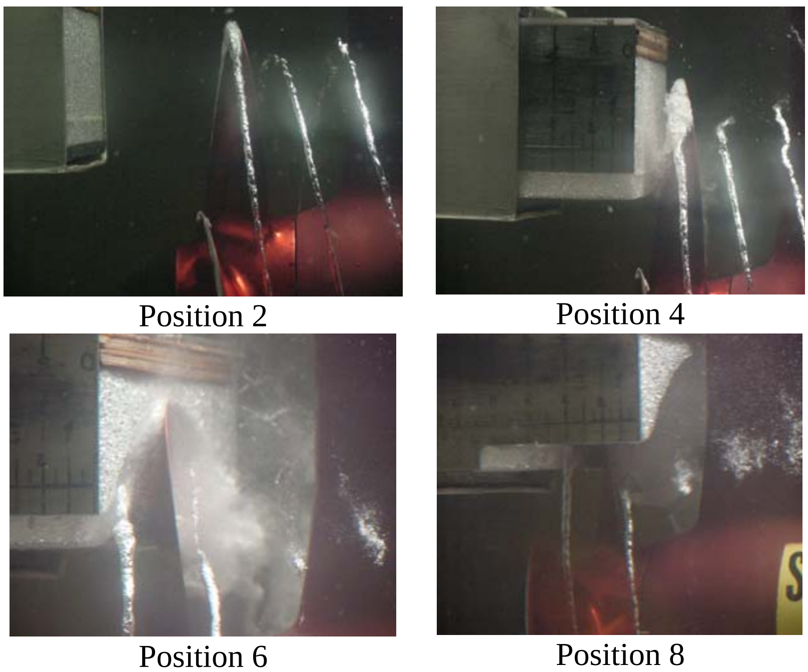

Figure 1.2- Some ice-block location during ice milling test at bollard pull condition.

It is unfortunate that the above mentioned effects related to cavitation have been over looked so far and the discussers would urge this Committee and the ITTC to include this important aspect in their next agenda and recommendations list.

References.

Atlar, M., Prasetyawan, I., Aryawan, A.D. and Wang, D., 2003, "Cavitation in ice-milling with a podded propulsor", Proc. of FEDSM'03, 4th ASME_JSME Joint Fluids Engineering Conference, Honolulu, Hawaii, USA, July 6-11.

Mintchev, D., Bose, N., Veitch, B., Atlar, M. and Paterson, I., 2001, "Some Analyses of Propeller Ice Milling Tests", Proc. of 6th Canadian Marine Hydrodynamics and Structures Conference, Vancouver.

1.2 Discussion to the 24th ITTC Specialist Committee on Ice by Do Ligtelijn, Wärtsilä Propulsion Netherlands BV, The Netherlands

The work of the Ice Committee is much appreciated. Their Report is clear and the results of the analyses of the propeller tests described in the Report will form an important basis for future designs of propellers operating in ice. In the discussion of the Report some discussers felt very reluctant to apply high skew in designs of propellers operating in ice. However, my point of view is that some nuance might be considered regarding such statement. The parameter "skew" should not be regarded on its own, but in combination with blade area, blade shape (such as wide blade tips), the propeller being FP or CP, and the operation area. High skew is also somewhat subjective. Many already consider 25 deg. skew as high, whereas skews of more than 25 deg. are very common. Although one would certainly not apply a high skew blade with low blade area and narrow tips (banana shape) in ice, 25 deg. skew with a high blade area and wide blade tips might result in an acceptable design. Many fast ferries and ROPAX ships operate in the Baltic area with more than 25 deg. skew, but these are mainly CPPs. For FPPs more care should be taken (also without ice class notation) and very high skews are less likely to be applied in those cases, especially when considering backing. The real difficulty is that one should determine the ice loads and hydrodynamic loads properly. Then a finite element calculation for all relevant conditions should be done to determine the necessary scantlings, skew or no skew. The latter leads back to the results of the propeller tests that are being analyzed, on which the next Ice Committee might report.

1.3 Discussion to the 24th ITTC Specialist Committee on Ice by Jerzy Matusiak, Helsinki University of Technology, Finland

My question also concerns the propeller model tests in ice. Did you conduct the tests with varied revolutions? The way you present the results in a form of K_T and K_Q values, suggests that you assume the ice loads to be related to the propeller revolutions squared. Did you check this hypothesis?

1.4 Discussion to the 24th ITTC Specialist Committee on Ice by Alexander Pustoshny, Krylov Shipbuilding Research Institute, Russia

You have presented a job well done job for measurement of the loading on blades. But you have done it for skewed propeller. In this case the measurement of the 6 components of loading on the blade is not sufficient. Experience of Russian ship-owners showed that they very often lose skewed blades in ice due to bending of skewed portion of blade.

I think, that in preparing the testing procedure, the Committee should take into account such circumstances providing measurement or estimation of bending loading to the skewed part or proclaim that the procedure is valid only for symmetrical or near symmetrical blades.

1.5 Discussion to the 24th ITTC Specialist Committee on Ice by Gerhard Strasser, Vienna Model Basin, Austria

I am speaking on behalf of the Quality Systems Group. You stated there are no procedures available. I recall there are at least 5 ITTC Recommended Procedures for ice testing in the Quality Systems Manual.

2. COMMITTEE REPLIES

2.1 Reply of the 24th ITTC Specialist Committee on Ice to Mehmet Atlar and Roderick Sampson

We would like to thank Prof. Atlar and Mr. Sampson for their useful comments. We are very grateful that, beside the direct ice contact loads, cavitation caused by ice blocks being ingested and milled by the propeller was mentioned as another important kind of impact to the propellers operating in icy water. The discussers may be right that there is a significant risk of propeller damage due to ice-induced cavitation, although there is no feedback from the ship owners, which indicates that propellers being operated for longer periods in ice are especially subjected to cavitation damage.

Another important aspect mentioned by the discussers is the possible loss of propeller efficiency due to ice-induced cavitation. This loss accumulates with the loss caused by direct ice milling but is presently not reflected in the ice performance prediction, based on model tests. We can imagine making model and full-scale corrections for ice-induced cavitation affecting the propeller performance. However, this correction might be academic, as long as the ice model basins are still struggling with the correct scaling of the direct ice milling effect. Furthermore, it is not very likely that with regular commercial projects, complex and costly propeller ice cavitation tests will be performed. Finally, it seems to be difficult to simulate in an ice cavitation tests at least some of the unlimited number of possible scenarios of ice ingestion.

It is deemed worthy to note that for most of the ice-going vessels propeller ice interaction is not a continuous process but happens only occasionally.

Even without ice ingestion, the propeller may be subject to cavitation due to the lower advance (speed) and high loading during ice transit.

2.2 Reply from the 24th ITTC Specialist Committee on Ice to Do Ligtelijn

The Committee widely agrees with the comments of Ir. Ligtelijn. The most difficult problem to determine the ice loads on the propeller blades by model tests, is to provide model ‘ice’ material which has correctly scaled physical properties, such as compression and shear strength and elasticity, and which allows the simulation of the bandwidth of natural ice variations. When the present model ices were developed by the various ice model basins, the proper modelling of the ice bending failure and a well-scaled hull resistance were the main tasks. This type of model ice is not necessarily the correct material for propeller-ice load investigations. Propeller model tests in icy water can help a better understanding of the processes when propellers intact with ice blocks. Regarding loads, ice milling tests with model propellers can supplement full-scale investigations, but they can hardly be a substitute for full-scale measurements.

2.3 Reply from the 24th ITTC Specialist Committee on Ice to Jerzy Matusiak

For the lack of a better term, the similar non-dimensional factors to K_T and K_Q for open water tests were used. However, limited investigation showed that T and Q present a linear variation with rps^2 for given test conditions, that is forward velocity and depth of cut, see Fig. 2.1.

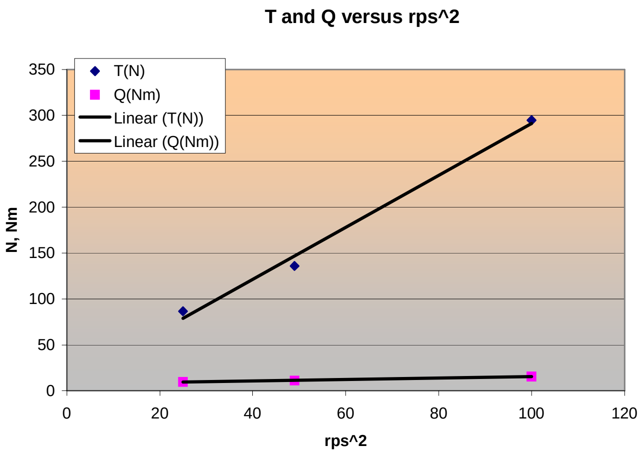

Figure 2.1- T and Q versus rps^2.

2.4 Reply from the 24th ITTC Specialist Committee on Ice to Alexander Pustoshny

Dr. Pustoshny indicates a very good point, that the geometry of the propeller is an important factor for its performance in ice. Therefore, generalization of these results for all propeller geometries is not realistic. The results presented in this work are for a propeller similar to an R-Class propeller hence, they would be more appropriate for propellers similar to this geometry. For higher skewed propellers, one would be cautioned to use these results on their face value. There are other studies done particularly for highly skewed propellers, such as Moores (2002) and Searle et al. (1999). Perhaps, these together with the current work, may constitute a model that can be used in understanding the ice loads on propellers.

References.

Moores, C., 2002, "Shaft and Blade Load Measurements on a Highly Skewed Propeller Model in Ice", Master of Engineering Thesis, Memorial University of Newfoundland, St. John's, Newfoundland.

Searle, S., Veitch, B. and Bose, N., 1999, "Ice-Class Propeller Performance in Extreme Conditions", Transactions Society of Naval Architects and Marine Engineers, Vol. 107, p. 127-152.

2.5 Reply from the 24th ITTC Specialist Committee on Ice to Gerhard Strasser

Prof. Strasser should be thanked for this comment. The Committee appreciates the allusion to the ITTC Recommended Procedures for testing in ice. What we wanted to say is that regarding propeller-in-ice-tests, propeller open water tests in ice, the ITTC Members operating ice model basins are at present only in the status of approaching this rather complicated test matter. The existing Recommended Procedures only partly cover the testing with the propeller or propulsor alone. Specific Recommended Procedure needs to be developed, when the knowledge in this matter is greater.