

Review on Double Acting Tanker Ship in Ice Mode

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ABSTRACT

In 1994 podded propulsion system has been started to be utilized and that make revolutionary in the integrated ship propulsion and steering system due to diesel-electric and combining pod and rudder in the compact body. This paper would review utilization of podded propulsion system on the Double Acting Tanker (DAT) ship. The DAT ship which can be operated running ahead mode and astern mode in open water and ice conditions.

KEY WORDS: *Ship in Ice, Double Acting Tanker, Podded and Rudder, Propulsion.*

NOMENCLATURE

DAT Double Acting Tanker

1.0 INTRODUCTION

The ship should be having capability to break the ice for travelling in the sea ice. Typically that ship was known as ice breaker, unlikely ordinary ships sailing in the open water the stem part of the ice breaker has an angle formed. It was a sharp and has a function to break the ice. These vessel was really appreciated as tugs in the port activity since could be manoeuvre well in ice. However dimension of the ship is restricted so for the bigger ship

such merchant vessel, cargo, and tanker, they are needed that making a channel and escort them. This procedure has still been used on the present day even though uneconomic due to additional charge for escorted of the ice breaker.

2.0 ICE FRACTURE MECHANISM

Mechanical properties of ice like flexural strength must be investigated so the ship which was going to pass has enough thrust to crush it. Sodhi (2001) had done small-scale indentation test to prove the phenomena of breaking at the ice structure interaction by using non-simultaneous formula for brittle crushing and simultaneous formula for ductile crushing. The experiment concluded during low rate ice but it would be failure ductile on the high rate brittle. On the other case through medium scale indentation test, Sodhi et al. (1998) had been confirmed same summary in regard to transition fracture properties of ice from ductile to brittle when strain rate increased.

Daley et al. (1998) declared failure on ice would be happened continuous gradually and that was called discrete process from naturally to chaotic. It was concluded that after modelled ice as nested hierarchy of discrete. In discrete process, it was formed under plastic deformation. Failure process would be started from micro crack and growth up along of grain boundary to macro crack. That had made desegregation at the edge of ice. This model was tested using medium scale indentation. It can be seen in experimental result, there are occurrence creeps on ice following by micro crack at the low velocity and it is dominated flaking by macro crack on the high velocity.

Sawamura et al. (2008) assumed that the ice has an infinite at edge and semi-infinite at centre line, homogeneous and floating material on simple hydrodynamic fluid with negligible viscosity. Model was made on finite element software Abaqus in 2D and 3D. Penalty contact algorithm has been used to describe frictionless contact in tangential component between fluid and

structure. It can be seen from simulation effect of wedge angle at maximum stress and point of hot spot stress. Result shown shape of the broken ice changed from circle to elliptical when angle of wedge increased. Some complex of breaking pattern had been resulted in indentation mode that must be a considered to find out interaction between ship and broken-unbroken ice float. Overall, it can be resumed that the pressure load on ice is function of density and modulus bulk of water.

3.0 SHIP ADAPTATION

3.1 Azipod Propulsion

Azipod propulsion system consisted of a fixed propeller, which was driven by electric motor. Rotation of motor would be extend using a shaft and put in a pod. To steer the vessel, then above the pod fitted by strud. All of that component would be hanging on the slewing bearing. That system could rotate 360°, so the entirely thrust of the propeller can be used to manoeuvre of the ship. Azipod would eliminate of a rudder, gearbox and complete of shaft or coupling while be using in a conventional powering system. This new system can be giving a low of friction force, a decrease of vibration and cavitation.

Kuiper (1992), Oosurveld et al. (1975) to having a huge result in the thrust of powering since the long periods Wageningen B series propeller had been used due to giving high efficiency and suitable for use because of lower cavitation. Commonly there are two methods to be used in the propeller design. The first is using diagrams where it was obtained from open water propeller experiments for systematic propeller series and second is using mathematical methods. Other researcher, Ekinici (2011) was offering a new design with involved a few parameters, to reduce inevitable error in the step reading of variable at the diagram.

Finish Maritime Administration had been having a better solution to icebreaker operation in ice channel. That idea then was present to the ABB lastly, the joining company generated an Azipod (Azimuthing Electric Propulsion Drive) as a propulsion system which installed first in the pulling mode at 1995 to icebreaker Rotheisen. Pakaste et al. (1998) has confirmed through the model and full-scale test 60% of the power was needed when attacking the ice, besides growth up total efficiency, enhanced maneuverability, redundancy, reduction of equipment, simplicity and proven reliability of the design when using Azipod unit. Recent experiences with the diesel-electric power plant concept combined with the Azipod propulsion system have proven the concept to be an attractive solution for various types of vessels.

Pakaste et al. (1999) in the ABB review 2 have described that podded propulsion system is a type of electric propulsion system which consists of three main components as shown in Figure 1. The Podded propulsion system used on ships is combination of both propulsion and steering systems. The system consists of a propeller which is driven by an electrical motor and the propeller is turned by the rudder which is connected to the system. The motor is placed inside the sealed pod and is connected to the propeller. It should be noted that the sealing of the pod should be perfect otherwise it can damage the whole motor and make the ship handicap from manoeuvring. The motor used for this system is variable frequency electric motor. Using variable frequency, the rotational speed of the propeller can be controlled i.e. the

speed can be increased or decreased. The whole podded propulsion system is situated outside the hull in the aft of the ship. The podded can turn in all the directions i.e. 360 degrees with the help of a rudder, and thus provides a thrust in any direction which is not possible in the conventional system. The propeller in the pod system is moved by the rudder which is placed in the steering flat, also the power module for the system.

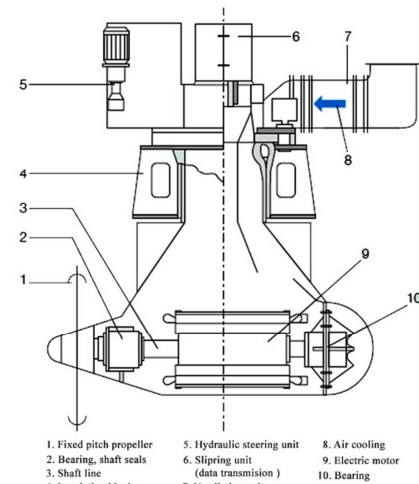


Figure 1: Main components of azipod unit (Pakaste et al. 1999)

Jones (2004) reported propulsion system of ships on ice have been great changing with applied podded propeller until evolving using azimuth thruster. Since 1990 some changing happened in ship propulsion systems, which previously was using diesel engines into electric propulsion system. These systems provides several advantages such as reduced fuel consumption, more friendly in environment because low emissions, increasing in manoeuvre ability due to nothing load from transmission system because electric motor had eliminated reduction gear from old methods. Transformation in propulsion system encourage the emergence of new vessels with double acting ability to sail on traveling route from Kara Sea and Arctic in Russia to ports in Europe which always almost covered by ice.

Taylor et al. (2005) had studied the effect of hub taper angle on the performance of a podded propeller (propeller without pod-strut body) in open water conditions. For open water conditions, the actual propellers used in pull configuration podded propellers perform slightly better than an identical propeller designed for use on push configuration. Pull propellers have higher bollard thrust and torque coefficients than the push ones as well as higher maximum efficiency.

Karafiath and Lyons (1999), Islam et al. (2007), reported result study on the effect of variation in pod geometry on the performance of podded propulsors. Some parameter in this attention is pod diameter, pod length, pod taper length, strut distance and propeller hub angle, as can be seen in Figure 2. According to the parameter, Bal and Güner (2009), deduced that the presence of strut part where it was fused with pod causes increasing the velocities of flow on the pod surface especially close to strut surface.

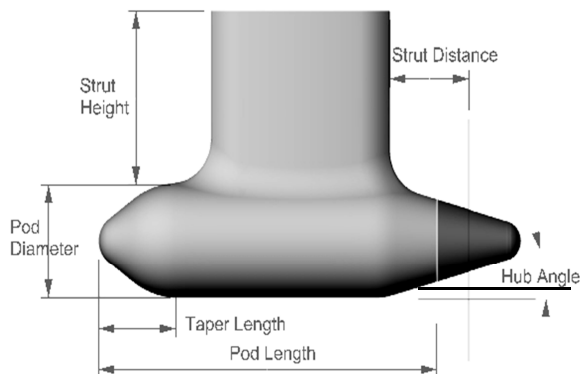


Figure 2: Parameters geometry of pod propulsion (Islam et al. 2007)

Islam et al. (2007) had been investigated some configuration in practical situation for podded propulsion system that could be functioned either as pusher or puller. In a pusher pod propulsion system, the propeller is attached to the aft end of pod, thus the propeller pushes the unit. In a puller pod propulsion system the propeller is attached to the fore of pod, thus the propeller in pulls the unit, as depicted in Figure 3. The centre of the pod was coincided with intersection of the horizontal axis through the propeller shaft centre and the vertical axis through the strut shaft centre.

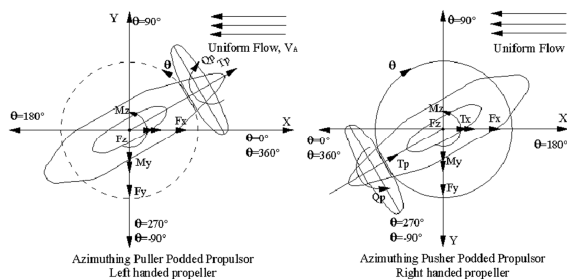


Figure 3: Force, moment, at the pusher and puller Azipod (Islam, 2007)

Carlton (2012) stated in his book that podded propulsor is propulsion or manoeuvring device where placed at the external of the ship hull and directly connected to the propeller. This system had been having rapid growth due to the claim of enhanced propulsive efficiency and ship manoeuvrability especially when turning and stopping, either at sea or at the harbour. In the recently years were many using on the icebreaker, cruise ship, Ro/Pax ferries, tankers, cable layers, naval vessels and research ships because, in the extreme condition, the hydrodynamic loadings of pod could be increasing significantly.

3.1.1 Advantages of Podded Propulsion System

After discussing and reviewing on the subchapter above, below of this could be cite some beneficial of azipod which had been using in the propulsion system:

- 1) Greater manoeuvrability as the propeller can be turned in all directions (360°). This enables better stop distance during crash manoeuvring than that provided by the

conventional system.

- 2) In case of ships having large breadth, two or more podded propulsions which are independent of each other can be used. This provides subtle manoeuvring.
- 3) It saves a lot of space in the engine room as there is no engine, propeller, shafting and other arrangements. The saved space can thus be used for storing more cargo.
- 4) The system can be placed below the ship's height thus providing more efficiency than the conventional system.
- 5) Use of side thruster is eliminated as the pods can be used for providing the side thrust.
- 6) Low noise and vibrations than the conventional system.
- 7) Low fuel and lube oil consumption.
- 8) Environment friendly as emissions are extremely low.

3.1.2 Disadvantages of Podded Propulsion System

Although utilizing azipod was being significant developing but in the other thing still has a weakness and disadvantages such as:

- 1) Podded propulsion system requires massive initial cost.
- 2) A large number of diesel generators are required for producing power.
- 3) There is a limitation to the power produced by the motor. As of now the maximum power available is 21 MW.
- 4) Cannot be installed in large ships with heavy cargo which need a lot of power and large motors.

3.2 Development of Hull Design

Design of ice-going ships requires considering the performance, adequate hull and strength of machinery and good functioning of the ship in ice condition and open water condition. Concept of double acting ship has started developed since 1990 by Kvaerner Masa-Yards Arctic Technology Centre which known as Aker Arctic Technology Inc., a Finnish company. The idea to build ice breaking merchant ship appeared to eliminate ice breaker as assistance when merchant ship sailing in ice conditions as mentioned by Kubiak (2014). Double acting ship was designed to run ahead in open water and astern in ice conditions. Wilkman (2012) had also reported that bow form of the ship which modified without bulbous could give better characteristics in open water than conventional vessels. The structure of double acting ship has been improved by increasing the strength of structure to ensure the hull structure can withstand with ice resistance while break the ice.

3.2.1 Stem Hull Design of Ice-Going Ships

The stem hull design of double acting ship differs from common ships. The common ships have a bulbous bow at the head of ship as shown in Figure 4. The main function of bulbous bow is to reduce the drag force that it was an effect of wave making resistance while ship moving ahead in open water. Therefore, the resistance of ship will reduce that can make increasing speed and improve stability of a ship.



Figure 4: Bulbous bow for common tanker

When the double acting ship moves astern, then bulbous bow would bring in drag force and increasingly more resistance. Therefore, the bulbous bow has been removed and new design on bow form namely Ice Breaking Bow for double acting ship. Jones (2008) identified the parameters of a bow which was desirable for improvement of continuous icebreaking, ramming and extraction ability by decreasing spread angle complement (a blunter bow), decreasing the coefficient of friction and increasing thrust. He proposed a bow form as shown in Figure 5 incorporating to above parameters. This hull form was used on the Manhattan for its voyage in the Arctic.

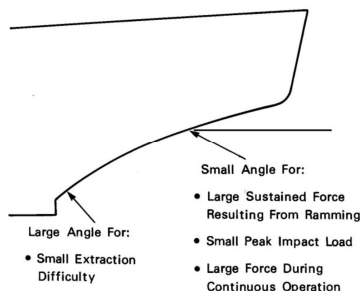
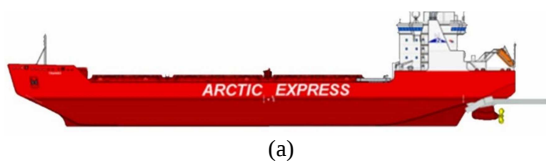
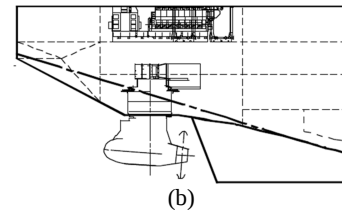


Figure 5: Ice Breaking Bow of double acting ship (Jones 2008)

The stem hull of double acting ship is also important parts to be designed for double acting tanker. Basically, stern hull geometry has been designed with an edge and certain angle to ensure that can break the ice while moving astern and reduced ice resistance. Stern hull also designed with consideration less effect of resistance while moving ahead in open water. Figure 6 shows stern hull design of the ship Norilsky Nickle (AAT 2007). The figure describes design hanger which still existing commonly used to hang a pod. Adding angle at the hanger pod with the intent to reduce ice resistance working and give a better performance when DAT going to breaking ice in the astern mode without it hanger pod would contribute to making additional resistance when ship-ice interaction.



(a)



(b)

Figure 6: Norilsky Nickel tanker running astern and azipod in the stern part, respectively (a), (b) (AAT, 2006)

3.2.2 Development Hull Design of Ice-Going Ships

Since 1990 the major development has undoubtedly been that by using podded propellers in ice with double acting tankers (DAT), which has taken place principally in Finland (Juurmaa et al. 2002) and appropriate for the Baltic Sea. Starting in 1990 with a 1.3 MW buoy tender, MV Seili, podded propellers have been used in conjunction with designs which allow the ship to go astern in heavy ice and forward in open water and light ice. Full power can be applied in either direction by rotating the Azipod. Figure 7 shows the stern of the Seili with an Azipod fitted.

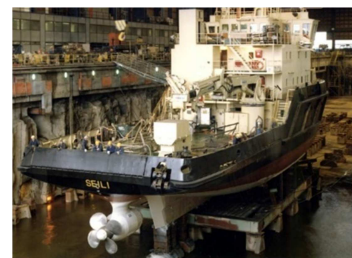


Figure 7: MV Seili, first vessel using Azipod system (Juurmaa, 2002)

Wilkman et al. (2006) was reported that in 1993 the vessel MT Uikku has been delivered by Neste and Kvaerner Masa-Yards (NEMARC) as the owner. It was operated by Artic Shipping services, at Murmansk route in the Northern Sea. This vessel has been converted for better performance in manoeuvring. Figure 8 illustrated the MT Uikku tanker (Wilkman et al. 2006).

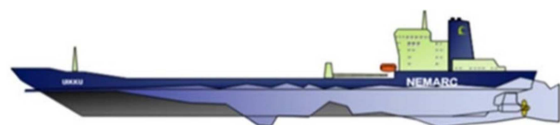


Figure 8: MT Uikku (Wilkman et al. 2006)

In 2002 and 2003, others Double Acting Ships, MT Mastera and Tempera have been launched. The tankers use Azipod in a propulsion system containing a pod capable rotating 360° with maximum power 16 MW. Figure 9 shows the side view of MT Tempera. Below in Table 1 shows main dimensions of tanker Tempera (Wilkman et al. 2007).

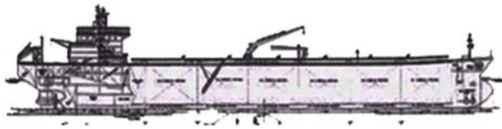


Figure 9: Side view of double acting tanker Tempera/Mastera (Wilkman et al. 2007)

Table 1: Main Dimension of Mastera

Length	230 m
Breadth	44 m
Draught	15.3 m
Power	16 MW
deadweight	106000 dwt

In 2005, Samsung Heavy industries had developed 70000 dwt Arctic Shuttle Tanker namely as MT Vasily Dinkov and MT Kapitan Grotskiy. This vessel used double Azipod in 10 MW for each. Figure 10 shows the general arrangement for the vessel (AAT, 2007). Below in Table 2 shows main dimensions of MT Vasily Dinkov.

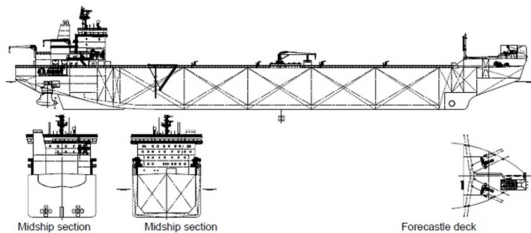


Figure 10: General arrangement of MT Vasily Dinkov (AAT, 2007)

Table 2: Main Dimension of MT Vasily Dinkov

Length overall	258 m
Length b.p	234.7 m
Length w.l	245 m
Breadth, moulded	34 m
Design draught, moulded	14 m
Deadweight	70000 dwt

In 2010, OAO Admiralty Shipyards has been manufactured MT Mikhail Ulyanov and MT Kiril Lavrov. The vessel entirely designed by Aker Arctic Technology to shuttle oil from Prirazlomnoye oil field in Pechora Sea to Floating Storage and Offloading (FSO) unit moored off Murmansk. ABB Marine provides proper solution for propulsion system in the shape of twin Azipods. The azimuthing thrusters enable the ships to penetrate cross ridged ice when running astern with continuous slow speed. Figure 11 shows the picture of MT Mikhail Ulyanov. Below in Table 2.5 shows main dimensions of MT Mikhail Ulyanov, (AAT, 2010).



Figure 11: MT Mikhail Ulyanov (AAT, 2010)

Table 3: Main Dimension of MT Mikhail Ulyanov

Length over all	257 m
Length between perp.	236 m
breadth	31 m
depth	20 m
draught summer load line	14 m
draught ballast open water	8.93 m
deadweight	70000 dwt
trials speed	16 knots

4.0 MODEL MATHEMATIC OF ICE LOAD

Some researchers had been developed and carried out simulation and experiment on ships operating in both ice and open water environment. As reported by Jones (2008) which is followed on this study, in his article was mentioned beginning at 1888 first scientific paper was published by Runeberg talked about icebreakers with particular reference to the Baltic, and lastly then was conducted by Edwards et al. (1972), who done an extensive set of full-scale and model-scale tests on a Great Lakes icebreaker, the USCGC Mackinaw. Other researcher Milano (1973) made a significant advance in the purely theoretical prediction of ship performance in ice. He considered the energy needed for a ship to move through level ice, which varied somewhat with ice thickness, as shown in Figure 12.

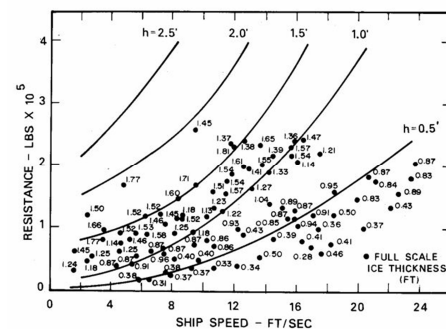


Figure 12: Full-scale tests of ship resistance versus speed for USCGC Mackinaw as a function of ice thickness (Milano, 1973).

Kitagawa et al. (1982) investigated the effect of parallel mid-body length, and beam, on an Arctic tanker model, as shown in Figure 13.

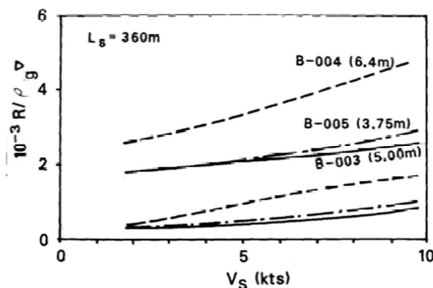


Figure 13: Resistance per unit displacement for three Arctic tanker models of different lengths as shown, scaled-up to a ship of length 360 m (Kitagawa et al. 1982).

Vance (1980) had conducted full-scale tests of the 140 ft (43 m) Great Lakes icebreaker, Katmai Bay. He analysed his results somewhat differently from other workers, plotting Propulsive Coefficient (PC) against velocity, as shown in Figure 14.

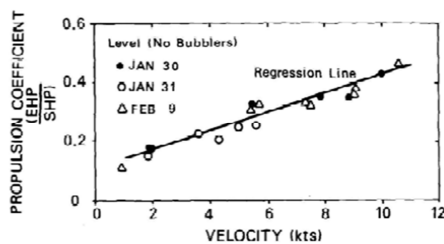


Figure 14: PC versus velocity for Katmai Bay in level ice with no bubblets operating. Clearwater value, not shown, was 0.565 (Vance, 1980).

Lindqvist, G., (1989) had done test on full scale using different ship at the Baltic Sea to verify effect of some parameters such as dimension of ship, hull shape, ice thickness, flexural strength of ice and friction working load when ship interacted on ice. It can be observed from experiment that ice crush due to bending load after vertical force applied during ship moving forward. From underwater observation revealed not merely crushing and bending, submersion ice at the below of hull generated large friction load as a resistance on ship.

Jaswar (2005) reported a result after making modification of stern shape and stern angle while compare with existing hull of DAT Tempera. Analysis was done focus on ice resistance and hull form for operated in open water and ice condition. The result showed modification stern shape and hull form has given lower ice resistance when sailing in unfrozen, frozen channels for full load and ballast situation.

Hänninen et al. (2007) derived ice working load and relation between thrust, torque of propeller when ship structure-ice interaction because there were no Mathematics model reliable to predict ice load on pod propulsion system conjunction with model scale and full scale. Experimental data was collected using strain gauge on container vessel MV Norilskiy Nickel while running with Azipod system. The ship classified into double acting type with power 13 MW operated route from Murmansk to Dudinka and designed to meet requirement of LU7 Russian Register for Arctic ice.

In the medium scale test Moslet (2008) had observed ice-structure interaction with pulling ice floe and hit a fixed cylindrical structure. Other researchers like Wang et al. (2008) using commercial code DYTRAN in finite element analysis to investigate non-linear collision model on LNG ship and crushable ice. Taylor et al. (2010) developed a normalized curve method to find a local pressure in hull as a structure in ice behaviour. He also develops another method by collaborate research with Li et al. (2010) use up-crossing rate method.

5.0 SIMULATION SOLUTION

Chen and Lee (2003) had been investigated through simulation using Chimera concept on RANS. Some propeller configuration was observed when ship moving ahead at open water, back of and crash-astern. This method chose to find flow pattern at propeller whilst distribution load at propeller was determined using MPUF3A software. Azimuth system propulsion which was used series-60 with coefficient hull (C_b) 0.6 became review on this study. Prediction result for thrust and torque of this program apparently was quite accurate and accordance to experimental data. It also concluded that container vessel can be operated astern without stuck on ice harsh environment.

Lee (2006) developed a simulation program through finite element using vortex-lattice method to find out performance of ship traveling on ice. Finish Swedish Ice Class Rule (FSICR) published regulation as hint to be followed by ship which sailing at Baltic seas such as strengthened of hull and running in 5 knots. Those concept was verified through ship model scale referred to merchant vessel Aframax. Simulation model concluded, thickness of propeller blade must be added 12% to protect from cavitation failure and recommendation from experiment mentioned thrusting power of ship must be increased 32% while those were load of ice resistance 1800 kN.

Islam et al. (2007) published article concerning to numerical prediction and experimental result while investigation effect of hub taper angle, pod-strut configuration, azimuth statics condition, pod-strut interaction, gap pressure and pod-strut geometric on performance of pod propulsion system. Experiment had been done on puller and pusher propeller configuration in open water situation. Observation focused on pod diameter, pod length, pod taper length, strut distance and effect of hub propeller angle. Coefficient thrust and torque can be reached higher if propeller was function in puller.

Pivano et al. (2007, 2008) had been created some scheme to estimate thrust and torque especially if propeller being operated in extreme environment. Experimental study base on nonlinear was approach to get closed extreme situation on the ocean. This was done because difficult to make propeller and ship model on dynamic situation and having trouble to measure behaviour of environment. From this concept can be understood where on nonlinear approach thrust and torque have a piecewise relation in linear part.

Islam et al. (2015) used RANS method to find distribution flow when propeller operated in configuration such as puller, pusher or bollard pull. That situation would be happened when in port, a long platform of offshore or area around escorted ship needed to be clean. Characteristic interaction between rotating part (propeller) and fixed part (strut/pod) was investigated

through CFD program. Left Hand Propeller (LHP) with taper angle -15° was function puller whilst Right Hand Propeller (RHP) with taper angle $+15^\circ$ as a pusher. These article concluded performance thrust on puller propeller type higher than pusher but on the other side intensity velocity on pusher propeller type higher than puller. It can be known from turbulence region closed to the pod area.

Lubbad and Løset (2011) had been developed complex system on simulator to describe breaking length of ice and speed of ice floe against conical structure where chosen physx graphics to display result of structure-ice interaction. Real time criterion was completed using elastic foundation for floes and analytic solution for maximum ice stress conducted in numerical modelling, Comsol Multiphysics. Ice was modelled as semi-infinite resting plate subjected by gravitational, buoyancy, damping and contact force. After interaction some crack in ice would initiate and propagate until reach failure criteria beyond flexural strength of ice. The broken pieces of ice were called cusps or wedges.

Tan et al. (2013, 2014) had proposed new semi-empirical model through numerical method using completed coding in Fortran programming language to describe concept superposition in varying load when ship made indentation on ice. Ice breaking is a continuous process. Some breaking pattern would be formed when bow contact with ice followed by chaotic event crushing dominantly and bending that unpredictable event. Then result verified with full scale performance data on icebreaker Tor Viking II while operated in Baltic Sea and implemented pressure-area relation to investigate effect of local contact on ship-ice interaction.

6.0 EXPERIMENTAL MODEL SCALE

Soininen (1998), had combined simulation and experimental to define relation between thrust, torque and another aspect of propeller of ship performance. These method can observe ice spall and extrusion phenomena at propeller blade. Suppression of propeller blade can make crack in contact area when interact in ice these followed by flaking. It was difficult to ensure pressure distribution at blade but not in simulation. Conduct some modified at geometric shape, simulation could predict pressure distribution and bending moment at blade as function of angle of attack. Kinnunen (2015) followed the model of contact load which was developed by Soininen (1998), to investigate the effect of flexibility on the blade when propeller-ice interaction combining with finite element method. It was deduced that 15% relatively difference of axial loading among bent and straight of a blade.

Matsuzawa et al. (2006) were using ice in the setup experiment, his concluded that load in the aft-ship region increases with increasing lateral force of the pods while using twin podded propulsion. Sampson et al. (2009), make a modelling to capture the effect of cavitation during propeller-ice interaction cause inability to scale atmospheric pressure during experiments. That event commonly happened at the harbour where icebreaker was having transit or manoeuvre.

Juurmaa et al. (2002) made a model by scaling referred to Aframax, a tanker vessel with specification: 16 MW of power system, 106000 dwt of weight and using azimuth for propulsion

system. Model was running ahead in open water test and astern on consolidated, unconsolidated, rubble field and ridge ice condition and made some modification on bow shape and stern part. Model test confirmed to fulfil 1A super class vessel on Finnish-Swedish Ice Rules for operated in channel ice and result test was verified using CFD simulation program.

Choi et al. (2012) reported some working load on ice after using impact testing method and verified result using equation issued by DNV and IACS Polar class rule. These article described variant of buttock angle 20° , 25° , 30° , and 40° and investigated effect of ship speed against failure of ice. It can be concluded load on ice increasing linearly as increase of impact velocity. Below 3 m/s ice would start failure in flaking formation, upper that speed ice fractured in brittle mode and maximum load had taking on 40° of buttock angle. At the end, this article proposed new formula to define contact area and ice load on ice structure interaction.

Zhou et al. (2013) summarized working load when ship sailing on ice, some force was used to push ice sheet moving horizontal, to slip block ice down of hull or bow, to lift up ice on sloping or breaking ice. After making model experiment in towing tank, it can be confirmed that ice would be broken in crushing and bending. Large piece could become rubble, some part slid away, rotate then hit hull and another piece going down submerged sliding underneath of hull. Zhou et al. (2013) also did simulation while assuming ice broken slide away but experimental result exhibited ice cusp rotate then against hull at shoulder area and mid hull that can be effect on performance of ship.

Tan et al. (2014) from Norwegian University of Science and Technology had made in numerical and scale model to represent ice breaking tanker MT Uikku, another parameters shown in Table 4. In fact since 1993 Azipod propeller unit in pushing type has begun replaced by conventional rudder propeller which has been used from 1977. From the experiment, it obtained that the ship can be moving with 0.59 m/s if the ice thickness is 18 mm whereas in 29 mm ice thickness maximum speed would reach is reduced to 0.33 m/s.

Table 4: Ship parameter in Full and Scale Model of MT Uikku (Xian Tan, 2014)

Parameter	Notation	Dimension	Full Scale Value	Model Scale Value
Length overall	LOA	m	164.4	5.21
Length between perpendiculars	L_{pp}	m	150	4.75
Breath, moulded	B	m	22.2	0.7
Draught, icebreaking	D	m	9.5	0.3
Propulsion power	P_D	W	11.4×10^6	64.55
Propeller diameter	D_p	m	5.6	0.18

Tan et al. (2014) was confirmed the effect of propeller-ice interaction when ship running astern total hull resistance working is lower than ahead mode. That happened because propeller was

flushing floating of ice fragment, so it could reduce the area covered at the hull by broken ice. Assumption was using in numerical method that 70% bottom shape of hull was cover by submerged broken ice and applied continuous-mode to an icebreaking concept which initially by (Lindqvist, 1989). Total resistance was calculated as the amount of resistance in open water and resistance to ice breaking force which composed by bending failure and crushing failure.

7.0 EXPERIMENTAL FULL SCALE

Juurmaa et al. (2001) had reported full scale experiment result on double acting ship SUMITOMO which had first been built while running ahead in open water and astern in ice condition. Ice breaking capability of ship was shown in Figure 15 in graph form which described velocity of ship related to ice thickness.

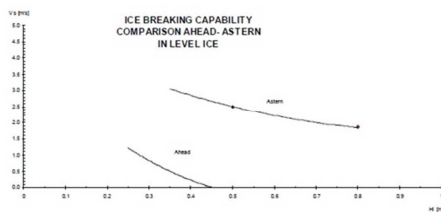


Figure 15: Ice breaking capability of DAT (Juurmaa et al. 2001)

Wilkman and Juurmaa (2002) tried to apply three concepts basis design and compared with functional approach every of typical constant value for geological, typical variable value for weather and ice, and typical changing value for environment. Design concept was applied in ice breaker and independent tanker where operated at Pechora Sea–Murmansk–Rotterdam company with Russian Maritime Register regulation. Result indicated when conventional vessel got assistance by icebreaker there to be needed 11% surcharge compared independent vessel.

Wilkman and Juurmaa (2003) made another experiment test in full scale on double acting tanker Tempera and Mastera where traveling from Porvoo-Primorsk and return Porvoo. Figure 16 shows speed of vessel related to ice thickness. It confirmed tankers can take easy to reach breaking 3 m/s – 4 m/s for traveling on 0.6 m - 0.8 m ice thickness.

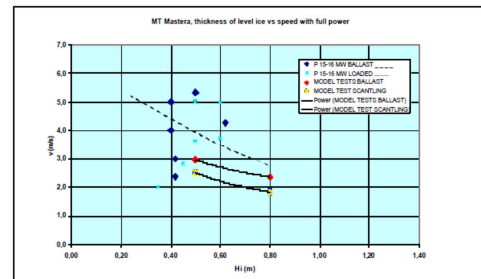


Figure 16: Speed of vessel Mastera related to ice thickness (Wilkman and Juurmaa 2003)

Wilkman et al. (2006) reported result from experiment on full scale of ice breaking tanker MT Uikku while sailing astern using continuous speed. The vessel operated at Bay of Bothnia, Northern Baltic seas in condition 10m thickness ice rubble. It concluded that ice resistance had reduced 14% comparing to the vessel running ahead at the same condition, as depicted in Figure 17.

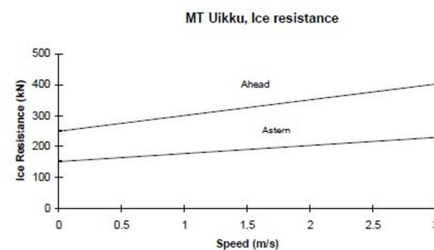


Figure 17: Ice resistance on ice breaking tanker MT Uikku (Wilkman et al. 2006)

The vessels where operated in Arctic have begun to use with consideration it can reduce cost while eliminate existence of ice breaker such done by Tempera, that is tanker which can travel on double acting. Table 5 shows the list of the vessel including name, year of delivered, units of Azipod used and the power of Azipod. Refer to the table, it shows that for single unit Azipod, the maximum power is 16.0 MW that used by Double Acting Ship Tempera and Mastera, otherwise for using double Azipod can produce maximum power 20 MW.

Table 5: List of double acting tanker (DAT) power by podded propulsion system

No	Delivered Year	Vessel Name	Ice Class	Builder	Azipod Rating (MW)	Units	Total Power (MW)
1	1993	Uikku	1A Super	Masa-Yards	11.4	1	11.4
2	1994	Lunni	1A Super	Masa-Yards	11.4	1	11.4
3	2002	Tempera	1A Super	Sumitomo Heavy Inds. Ltd	16.0	1	16.0
4	2003	Mastera	1A Super	Sumitomo Heavy Inds. Ltd	16.0	1	16.0

5	2008	Vasily Dinkov	LU6	Samsung Heavy inds.	10.0	2	20.0
6	2008	Kapitan Grotskiy	LU6	Samsung Heavy inds.	10.0	2	20.0
7	2009	Shturman Albanov	LU6	Samsung Heavy inds.	10.0	2	20.0
8	2010	Mikhail Ulyanov	LU6	Admiralty Shipyard	8.8	2	17.0
9	2010	Kiril Lavrov	LU6	Admiralty Shipyard	8.8	2	17.0

8.0 CONCLUSION

In conclusion, this paper has discussed historical ice going ships, the development of ships in ice such as ice breaker, double acting ship and offshore floating by taken two parameters into account which is hull form design and propulsion system.

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