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# Analysis Resistance on Ice-Hull Interaction of Double Acting Tanker using Couple Eulerian Langrangian in Abaqus Simulation

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## ABSTRACT

This article will discuss the magnitude of resistance force when ships is sailing head or astern in the ice sea. Normally only icebreaker is able to travel on it but in this article will be reviewed special ship a double acting tanker (DAT). This ship was sailing head in open sea ice and astern in the ice sea. This can be done because the presence of azipods in driving system. The approach was carried out using simulation program with base on finite element method. Abaqus has ability to calculate interaction between fluid and solid by Couple Eulerian Langrangian (CEL) facility. While the ship model is made using Rhinoceros software because has Non Uniform Rational Basis Spline (NURBS) facility, so all curves and surface designs have qualify the mathematical rules for computer graphics.

**KEY WORDS:** *Couple Eulerian Langrangian; Double Acting Tanker; Ice Resistance; Abaqus; Rhinoceros*

## 1.0 INTRODUCTION

Resistance of ships at the ice level is a very basic and important field in the early stages in ice class ship design because it is closely related to ship propulsion and determines power of ship engine. Determining the ship resistance in the level ice is more complex than in the open water due to the changing characteristic properties of ice and icebreaking phenomena. Ice resistance is defined as the time average of all longitudinal forces due ship-ice interactions.

The phenomenon of interaction between ice and ship has been studied by researchers through empirical mathematical simulation. The empirical mathematical can be used to determine the power needed by a ship to travel through the ice sheet on certain characteristics according to the desired speed. They can also be used to gain insight into the influence of the hull form on ice resistance. Lewis.et.al (1970) proposed semi-empirical which was developed based on a number of experimental data of ice breakers which included full scale testing on lakes and sea ice and test the model in fresh ice and sea [1]. The method has a semi-empirical relationship between ice resistance and the parameters that characterize ships and ice sheets. The empirical formula consists of ice breaking, friction, ice buoyancy and momentum. Crago et al. (1971) described a set of model test in “wax-type” ice on 11 icebreakers [2]. Enkvist (1972) studied three icebreakers: Moskva-class, Finncarrier, and Jelppari [3]. Milano (1973) made a significant advance in the purely theoretical prediction of ship performance on ice based on conservation energy [4]. Vance (1975) obtained an “optimum regression equation” from five sets of model and full-scale data, of the Mackinaw same data as used by Lewis.et.al (1970) [5, 6]. Lindqvist (1989) developed a formula to calculate ice resistance based on many full scale tests in the Bay of Bothnia [7]. Keinonen et al. (1996) did research on resistance of icebreaking vessels in level ice and developed a formula based on results of a study of escort operations involving five icebreaking vessels [8]. Daley, et.al (1997 & 1998) proposed a level ice resistance formula with some empirical parameters by developing Lindqvist’s formula [9, 10]. Jaswar (2002 & 2005) proposed a method to predict ice resistance of a ship running in unfrozen and frozen ice channels and level ice [11, 12]. Su et al. (2010) stated that is often difficult to make the good relation between model scale test to full scale condition [13]. This is the

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current weakness in the design of an ice class ship. Jeong et al. (2010) proposed new ice resistance prediction formula for standard icebreaker model using component method of ice resistance and also predicted the model test results to full-scale using calculated non-dimensional coefficients [14]. Continuing the previous research, Tan et al. (2013 & 2014) studied the effect of the propeller-hull-ice interaction of a dual-direction ship during running astern obtained from model tests on applied to the numerical procedure [15, 16]. The model tests were conducted by Leiviska¨ (2004) on a model of the M/T Uikku to investigate the propeller–hull–ice interaction [17]. The numerical procedure is in turn used as a performance prediction tool to supplement the model test data to investigate the thrust deduction in ice. Hu.et.al (2015 & 2016) discussed several numerical methods based on Lindqvist, Keinonen, Riska and Jeong to calculate ice resistance and then calculated results are compared against model test results [18, 19]. The prediction of ice resistance of icebreakers has different accuracy and also the empirical methods were under estimates for double acting tanker. Jeong.et.al (2017) presented a semi-empirical model to predict ship resistance in level ice based on Lindqvist's model [20]. Contact between the ship and the ice was assumed a case of symmetrical collision. Efi et.al (2014, 2016, 2017 & 2018) has studied performance double acting ship during running in level ice [21-27]

Design of an ice class ship requires considering the performance, adequate hull and strength of machinery and good functioning of the ship in ice condition and open water condition. The ice bow economically has inescapable disadvantage during sailing in open water due to higher resistance compared with a common bow. Researchers have proposed a Double-Acting Tanker which can sail astern functionally as an icebreaker in ice bound and ahead in open water. The stern part of DAT is specifically designed to be strong enough to break ice and pod propulsion systems. It is generally recognized phenomena of hull-ice-propeller is very complex and difficult to be understand, therefore model and full scale ice tests has been conducted to determine ice resistance of Double Acting Tanker. This paper discusses on effect of bulbous bow on ice resistance of conventional bow ship sailing in ice bounded condition which is analysed using Finite Element Method

This paper will analyze the movement of double acting tanker (DAT) using the Abaqus software. This review would be focus on resistance force that occurs when vessel uses its thrust capability trying to break ice sheet making a channel and travelling on it. Abaqus has a Couple Eulerian Langrangian concept to study fluid structure interaction.

## 2.0 LITERATURE REVIEW

### 2.1 Equation of State

The following equation represents the presence of a fluid in the form of ratio pressure to density ratio.

$$p_H = \rho_0 U_S(U_0)U_0 \qquad 2.1$$

Where, $p_H$ is Hogoniot pressure, $\rho_0$ is material density, $U_S$ is shock velocity, $U_0$ is impact velocity.

In the interaction review ships, water and ice, water is modeled as solid according to linear equation of Mie-Grüneisen. This equation is also known as Us-Up equation.

$$U_S = c_0 + sU_P \qquad 2.2$$

Where, $c_0$ is speed of sound in material, $s$ is material constant, $U_P$ is particle velocity

The Mie-Grüneisen equation requires value of EOS material, and Abaqus is needed $\rho_0$, $c_0$, $\Gamma_0$ dan $s$. In this study because domain is water so the value of $\rho_0$ = 1000, $c_0$=1490, $\Gamma_0$=1.65 dan $s$=1.79 repectively. (Abaqus user manual 6.13).

### 2.2 Shell Ship Model

Besides has a facilities to create 2D and 3D models on itself, Abaqus also provides facilities to import models from various formats. In this study, the ship was imported on 3D in solid condition (.IGES) format, so this need to be converted into shell form with type of element mesh S4R where Abaqus provides facilities for it. So, when Abaqus calculates discrete volume fraction, there will be free space as a ship's hull.

### 2.3 Langrangian Ice model

To calculate the amount of friction, Ice is modelled in 3D solid using C3D8R element mesh with failure criteria namely maximum principal stress (Maxps), accompanied by failure evolution with displacement method. In this study the magnitude of Maxps is 0.5MPa.

### 2.4 Element

In this study elements used are solid with 3 degrees of freedom for each node and reduced integration. Figure 2.1 (a) showing 8 linear brick nodes for example C3D8R is called first order elements refers to group of elements. Figure 1 (b) showing quadratic brick elements for example C3D20R, the elements with quadratic interpolation are category into second order group.

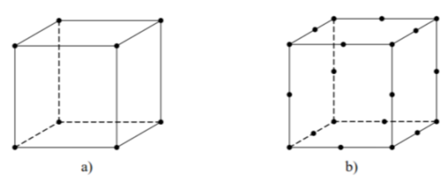


**Figure 1:** (a) C3D8R element is shown, (b) C3D20R (ABAQUS theory manual 6.13 (2013)

### 2.5 Load

Load can be imposed to model in form of deformation at certain time. For example, displacement of a model is in 1mm to other model in frame of 2 seconds.

### 2.6 Coupled Eulerian – Lagrangian

The Coupled Eulerian Lagrangian (CEL) method owned by Abaqus is able to model fluid structure interaction where fluid motion is not a major review but its structure. In The Eulerian part material model can move crossing the mesh while mesh is modeled idle, so that will interact with the Lagrangian (solid part) as finite element model. Flowing material on the mesh uses Eulerian Volume Faction variable (EVF) to represent part of the


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Eulerian element filled by water.

### 3.0 RHINOCEROS MODEL

Abaqus has the capacity to make 2D and 3D models. However, this facility does not support irregular and complex models such as the tanker model that will be created. For this reason, the Rhinoceros software program version 5 was chosen in making ship models, as shown in Figure 2. In Rhinoceros lines and surfaces are constructed based on mathematical model non-uniform relational B-spline (NURBS), so that is precision for handling analytic and models shapes.

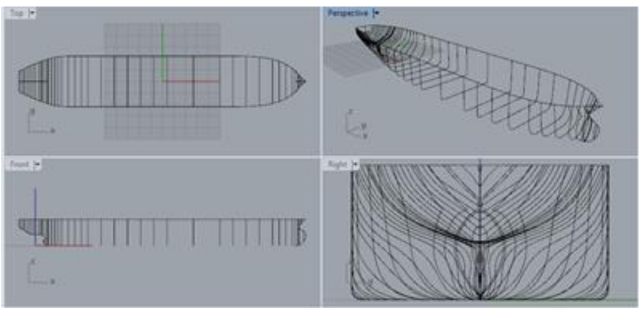


**Figure 2:** Top view, front view, right view and perspective view of curve design ship in Rhinoceros.

Rhinoceros software was chosen in the design of this ship model because it has the flexibility at the arrangement of giving surfaces to curves or polylines. Another advantage is Rhinoceros has a continuity facility which is used to analyze a joining curve before laying a surface. There are three categories results analysis of joining curve, namely G0 as Position, G1 as Tangen and G2 as Curvature. The line connection must be G2, otherwise it will generate an error later. Herein lays the other advantage of Rhinoceros because this program also has facilities that will provide advice so that the connection of a line or curve is worth G2 through the command that is “Match Curve”. The following are some view of ship design result from Rhinoceros such as top view, front view, right view and perspective view before giving surface (Tutorial Rhinoceros, 2018).

After giving the surface, where on this ship design involves more loft surfaces, and network surfaces and then ship design is ready to be exported to Abaqus in the format (.IGES). Make sure that there are no overlapping surfaces and there are no surface parts that have not been perfectly connected. This can be checked by analyzing command "Edge tool". Rhinoceros will inform the edge of the surface that has not been connected, namely the naked edges so that it can be repaired before being exported.

Next on the Figure 3 showing the design of ship after fairing step is carried out and now the ship is in full solid condition accordance with the format required in Abaqus.

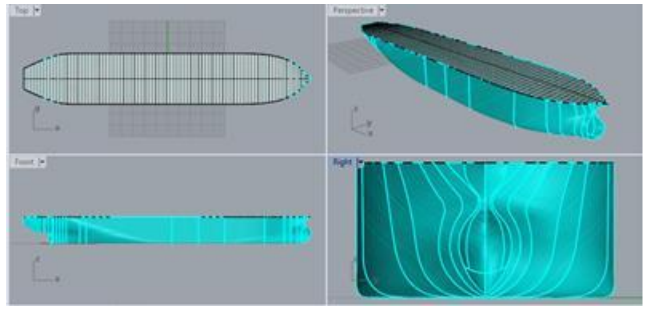


**Figure 3:** Top view, Front view, right view and perspective view after surface condition changing into solid design.

For more details, the following Figure 4 will show the different shape of stern parts and stem parts of ship tankers designed which is not usual so that are called double acting tankers.

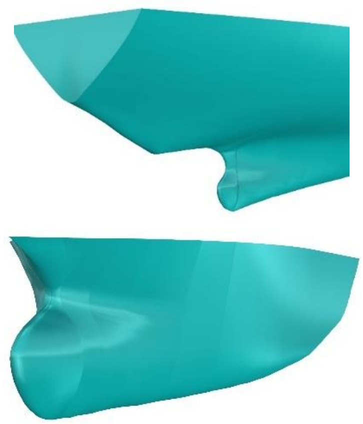
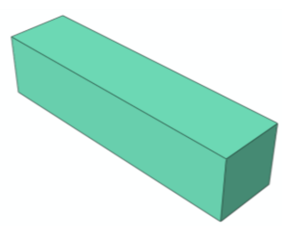


**Figure 4** Stern shape and boulbous at the stem part after becoming a solid on Rhinoceros and ready to export to Abaqus.

### 4.0 ABAQUS SIMULATION

The first thing that needs to be prepared in Abaqus is the creation of a domain in the form of water and water reference as a medium of ship working area later. Domain dimension refers to ITTC regulation 7.2-03 02-03 (ITTC 2011) as a showing in following Figure 5.



(a)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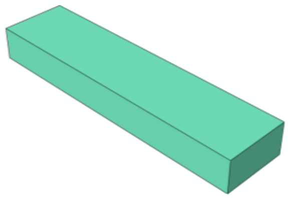
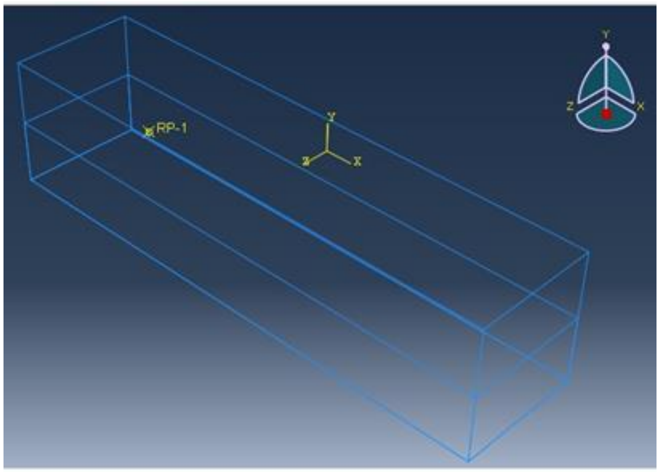


(b)

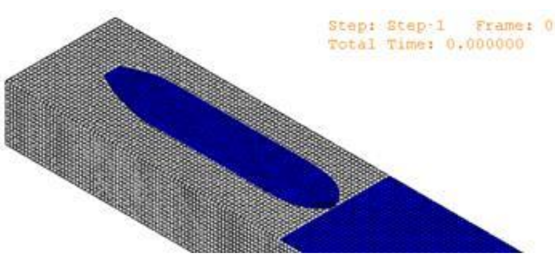



(c)

**Figure 5:** Fluid domain, water (a), water reference (b), asembly water and water reference (c)

After the domain is complete, next step is to import existing 3D design results from the Rhinoceros application. The design with format (.IGES) in Abaqus was converted into a Shell form first.

In position settings, ship is placed away from ice or does not come into direct contact with ice. The goal is that ship has enough energy breaking the ice. The following Figure 6 shows the position of the ship at 0s which is 1m in front of ice.



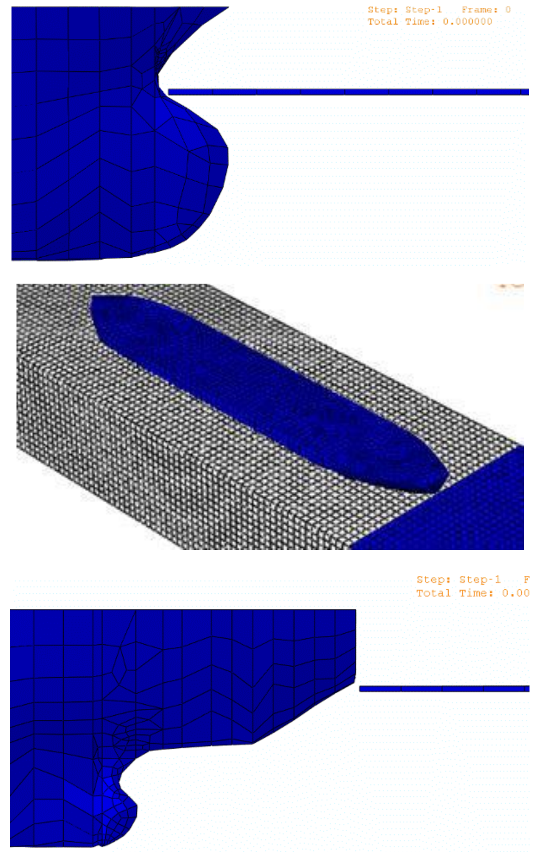




**Figure 6:** Placement of ship at the 1.6m distance from es (head & astern)

The next setting is related to properties of material in simulation. Water is defined by its density and the equation of state (EoS) in the form of Us-Up (ABAQUS theory manual 6.13 (2013). Then ice is also defined by its density and elasticity and the damage criterion of ice, ie Maximum principal stress (Maxps) with evolution failure based on displacement criteria, as to be showing in Figure 7.

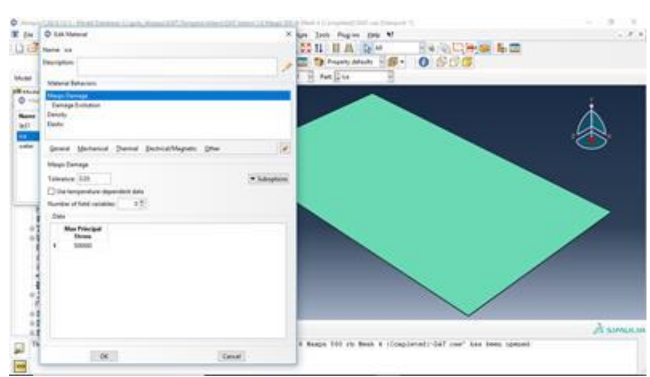


**Figure 7:** Tool for input Maximum principal stress (Maxps) as damage criterion on ice.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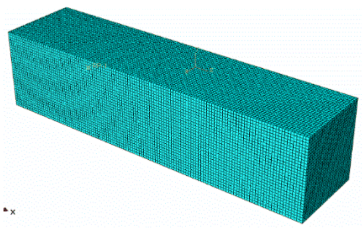
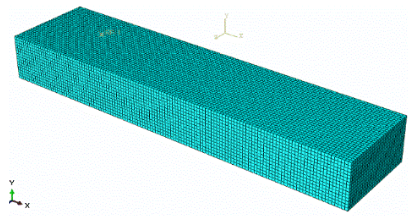
Ship movements are designed to take place in three stages, namely Initial, Step-1 and Step-2. The purpose of grouping is easily control and calculates every event in stages. For example in the Initial stage it will start working for gravity load and arranged active throughout the simulation. While Step-1 is intended to calculate the interaction stage between ships and sea, while Step-2 is interaction between ships and ice. When Step-1 is run, Step-2 is active and vice versa. Properties for each interaction are arranged through Interaction Properties-1 and Interaction Properties-2. While time for implementation of Step-1 is made 4s while for Step-2 is 3s.

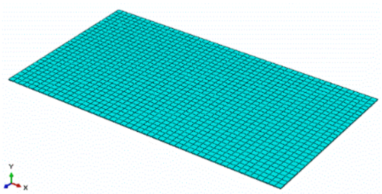
After that, continue with generating mesh. For water and water reference, meshing by 8 node linear Eulerian type reduce integration (EC3D8R), shell type for ship, double node (S4R) and solid type 8 node for ice (C3D8R) as shown in the following Figure 8. Figure 9 shows steps in simulation when an ice ship sailed in ice condition.



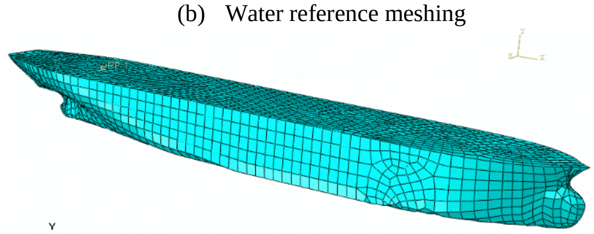
(a) Water meshing



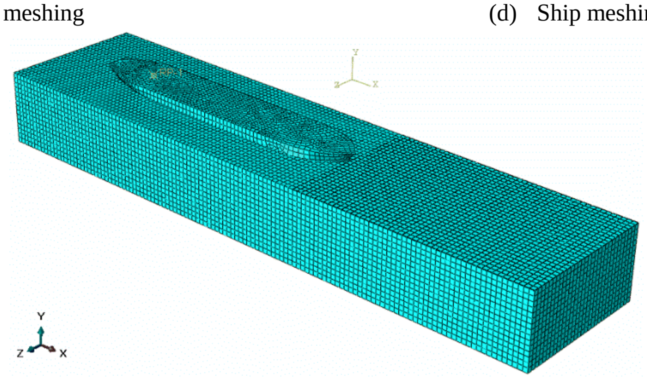
(b) Water reference meshing



(c) Ice meshing

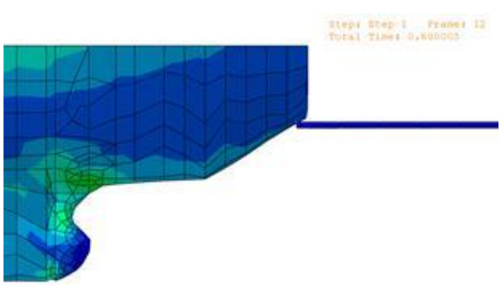


(d) Ship meshing

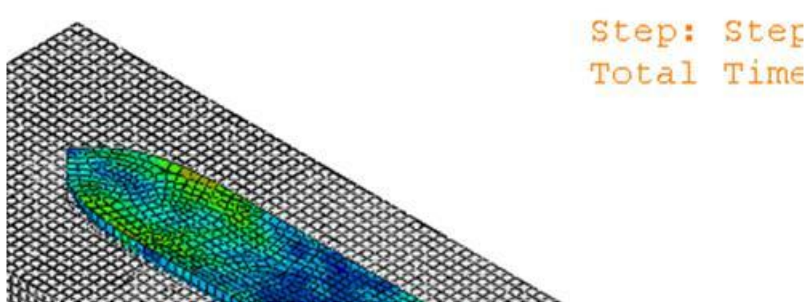


(e) Asembly meshing

**Figure 8** Generating mesh for water, water reference, ice and ship



(a)

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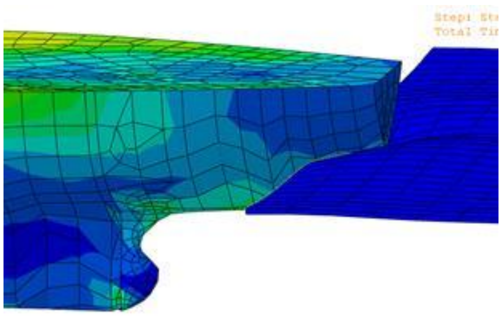


(c)

(b)

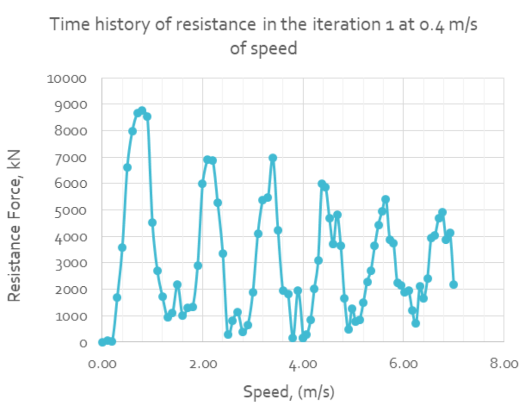
**Figure 9:** Simulation result (a), tauching ice after 0.6s (b), after 2s (c) astern

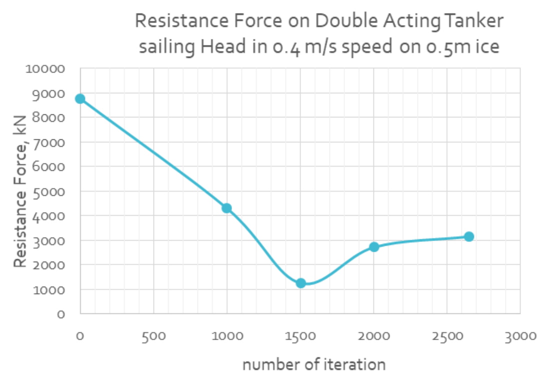
## 5.0 SIMULATION RESULT

### 5.1 Sailing Head

In Figure 10 below a graph shows the relationship between resistance force and ship speed. The figure shows comparison prediction results of Abaqus and series of data at full scale experimental in full load condition. Estimation of Abaqus results has a difference in the range (4-17) % into data experiment (Juurmaa et al. 2001, 2002).

Several outputs can be explored from Abaqus simulation result, one of which is a reaction force. This is the force of resistance occurring on the ship during interaction with ice. Abaqus exhibit the results of reaction force in the form of time history during ship sailing on each of numerical iteration performed. However this result needs to be further extracted, to find which number of iteration in calculation converge and time of ice breaks and value of reaction force involved



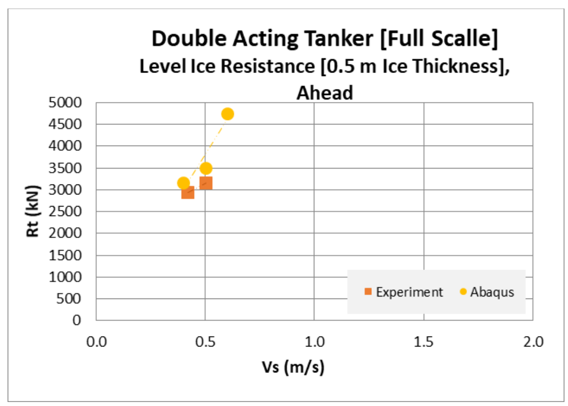




**Figure 10:** Comparing resistance force at head sailing of DAT by Abaqus result, and data experiment into speed of ship

### 5.2 Sailing Astern

In Figure 12 below, showed comparison resistance force of Abaqus simulation results into experiment especially when ship was sailing astern at various speeds. The graph showing there are differences in the results of Abaqus simulation prediction compared to experiment data. This is happened because Abaqus did not take into account the effect of propeller in simulation. In fact there is influence of this because the ship was moving astern supporting by existing azipod in their driving systems.

So, If we look at magnitude resistance force result of Abaqus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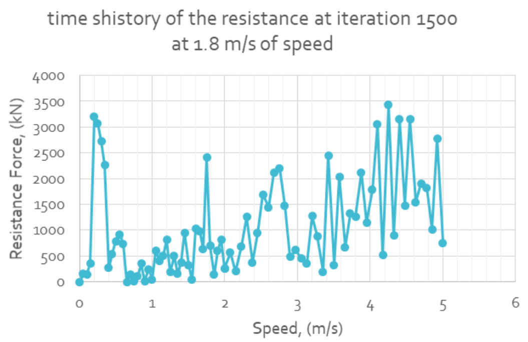
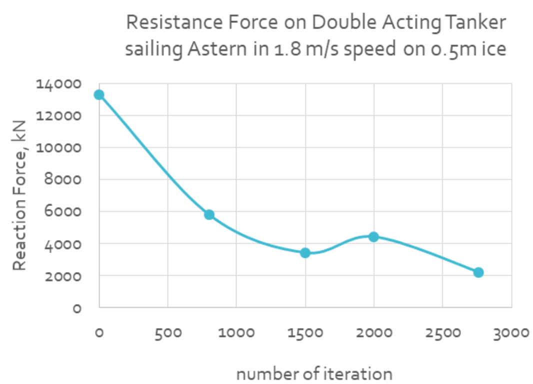
simulation compared to experimental data, there are differences in estimates in ranging (26 – 34)% for the ship speed range between (1.8 – 2.7)m/s (Juurmaa et al 2001,2002).



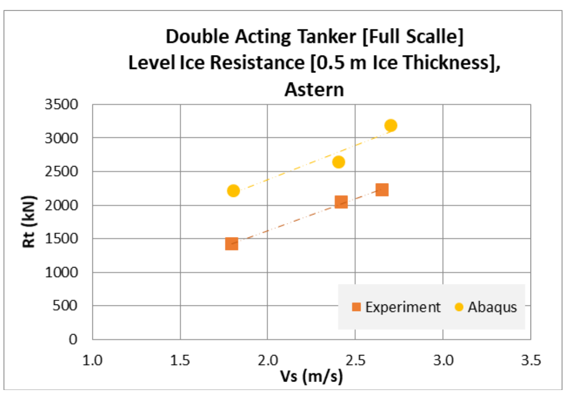




**Figure 11** Comparing resistance force at astern sailing of DAT by Abaqus result, proposed method and data experiment into speed of ship.

## 6.0 CONCLUSION

After was observing the resistance force using CEL (Couple Eulerian Langrangian) facility in Abaqus to approach fluid structure interactions, there were differences compared to other data of full scale experiments which in head conditions was (4-17)% while the biggest difference appeared in astern conditions (26-34)%. Perhaps this is because has not been calculated the effect of propeller on Abaqus numerical calculations. Another thing that can be concluded is Rhinoceros software could be helping to create 3D models complexity or irregular shape. So that output model can be exported to Finite Element Method (FEM) software to be analyzed.

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