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Development of Software to Analyze Performance of an Ice Ship

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ABSTRACT

The increasing of shipping activities through the Northern Sea Route (NSR) and growth of oil and gas activities in Arctic and Sub-Artic regions require suitable design of ice-going ships and planning operations in ice. In 2002, Sumitomo Heavy Industries has built advanced ice-ship called "Double Acting Tanker". This paper discussed development of methodology to determine the Double Acting Tanker operated in ice condition such as: unfrozen and frozen channels and level ice conditions. The methodology consists of ice failure test, mathematical model of ice resistance and software development was carried our using VB language. The ice failure characteristics were determined from experiment conducted in Universiti Taknologi Malaysia.

KEY WORDS: *Methodology; Ice Ship; Double Acting Tanker; Simulation.*

NOMENCLATURE

AAT	Aker Artic Technology
DAT	Double Acting Tanker
DWT	Deadweight
MW	Mega Watt
NSR	Northern Sea Route

1.0 INTRODUCTION

The use of advanced technologies to search new resources of oil and gas has experienced a rapid progress. Support from advanced technology enables the offshore drilling company to explore in the areas where rarely look-in such as at area of deep sea or area of extreme environment conditions such as ice or frozen seas. At those conditions, the drilling company will face limitation from equipment and need high investment. Besides that, development of innovative ships by the shipyard contributed to design a ship with better performance when sailing and manoeuvring at the frozen sea condition

The increasing of shipping activities through the Northern Sea Route (NSR) and growth of oil and gas activities in Arctic and Sub-Artic regions require suitable design of ice-going ships and planning operations in ice. The characteristic of ice should be noted which depends on locations of ice sea, form of level ice, ridges and icebergs. Figure 1 shows the geographic regions that are typical of frozen seas where the ice profiles a growing concern (Gürtner, 2009).

Figure 1: Location of ice actions (Gürtner, 2009)

The area at the north of Europe like as Baltic sea, Gulf of Finland, Gulf of Bothnia, North sea and the region around of

Artic such as Norwegian sea, Barent sea, and Kara sea were nearly covered by ice throughout the year in any seasons. Even on the summer from June to September, the thickness of ice is still in 80 to 250 cm with temperature -7°C to 10°C as reported by Riska (2011). However in the extreme environment, history recorded in 1890 there was a ship Murtaja, a Swedish ice–breaker ship travelled on it, according to Jones (2008). The icebreaker ship had unusual bow unlikely other open water ships. It was eventually recognized as the icebreaker because this ship has ability breaking the ice to make a channel.

Offshore Varandey at the Pechora Sea has been drilling operated in early 2000. Wilkman and Niini (2011) were reported since that the Artic shipping activities was also increasingly not only for tanker but also merchant ship passing. Those some fleets would be able to sail on ice in the position behind of the icebreaker ship. Juva and Riska (2002) in reports declared that condition would bring in an additional cost in the operational especially if the ship is having a width beam, it will be escorted by two of icebreakers.

Icebreaker ship was built initially following the shape of the ship which has success operated previously. Afterward, it would be duplicated in the next fabrication even of bow form, hull shape till powering and dimension of ship. Consequently, there is not much progressing at the icebreaker unlikely development on the open water ship. This condition happened in the long term until a new period begun in the improvement design and building of icebreaker with operating ice towing tank Wartsila on Finland on 1969 as illustrated in Aker Artic Technology (AAT, 2010). Nevertheless, Wilkman (2015) noted it was still consuming more fund to make a model and conduct trials. Nowadays, there are 11 ice towing tanks spread in world including in Japan, Rusia, Canada, America, Finland, Germany, and Korea.

With existence of ice towing tank engineering design and development to icebreaker can start to be done experimental in model scale and it was seen over articles diverse which are published by researchers. Some of them such as Yamaguchi et al. (1997) had observed performance of icebreaker and related to some affected factor like powering, dimension of ship and ice thickness like deduced by Juva and Riska (2002). There are also any researchers like Niini (2001), Park et al. (2008), Su et al. (2010) investigated ability of ice–breaker to manoeuver and Martio (2007), Wang, and Jones (2008), and Riska (2011) were studying strength of structure of icebreaker

Although, that had been supported by ice towing tank, some obstacles are still encountered by researchers. For instance, Liukkonen (1989), Lindqvist (1989), Jebaraj et al. (1992), Daley et al. (1997), Riska and Jalonen (1994), Daley et al. (1998), Valanto (2001), Martio (2007), Riska and Kämäräinen (2011), Su (2011), Lubbad and Losset (2011), Kujala and Arughadhoss (2012), Choi et al. (2012), Tan (2014) whom made a mathematical model to determine the minimum force to be required by ice–breaker to breaking ice in order to pass thru sea ice. Problems to be found including thickness of ice at ice towing tank is fluctuation and not uniform, that is difficult to get the same load at repeated test and having a trouble in located positioning of instrumentation.

Besides the properties of ice, the power is generated by ship propulsion system must be enough to break the ice and the whole structure of the ship has enough strength to stand with the resistance of load due to the friction of fragment ice on the hull of a ship. Many researchers had attempted to investigate factors which influence the ice breaking resistance when ship traveling in the sea ice. Kujala and Arughadhoss (2012) express that the ice bound shipping is more dangerous than water under extreme conditions because of the thickness of average ice is about 70 cm in the winter. His works was done by using statistical analysis to investigate the ice crushing pressure on a ship's hull in random condition. While Su, Riska and Moan (2011) used numerical model and measured field performance at the level ice of a double acting intervention ship in full–scale and model–scale

Fundamental development has occurred since 1993 since Azipod introduced an Azimuthing Electric Propulsion Drive unit used as the propulsion system. Tan, Riska, and Moan (2014) had been investigated this system was firstly fitted at the icebreaking tanker M/T Uiku. This ship made 1977 and operated by conventional propulsion then modified at the stern part to accommodate Azipod units. However efficiency at astern still lower than ahead because propeller rotate inversely in pushing type and could not be able to rotate 360 degree. Pakaste et al. (1998) also reports some improving had been success applied on icebreaker Rothelstein 1994, Seili 1995 and cruise liner M/S Elation 1997 " in the high power 2 x 14 MW was using pulling propeller.

2.0 ISSUES ON DOUBLE ACTING TANKER

Nowadays the ice–going ships have been developed called as Double Acting Tanker (DAT) which can be travel more efficient in astern than ahead at ice conditions as shown in Figure 2 (Juurmaa et al. 2002). A lot of researches have been developed to find the optimum hull design of double acting tanker while operating in sea ice as astern mode. Recent development is by optimization diesel-electric power plan concept combine with an azipod on the propulsion system of DAT. Sasaki et al. (2004) reported experimental result at the full-scale Double Acting Tanker "Mastera" and "Tempera" with 106000 DWT of weight and 16 MW of powering. The experiment had been done at Sagami Bay, Japan for Mastera and at route between Porvoo to Primorsk, Rusia for Tempera. Improvement on performance was obvious when ship could be sailing at the astern mode in the frozen seas where it does not need escort anymore by icebreaker ship.

Figure 2: Double Acting Tanker in ice condition (Juurmaa et al, 2002)

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Based on previous findings, the special design was required for ships to be operated in open water and ice conditions. The phenomenon of interaction between ice and ship has been carried out by researchers through empirical mathematical simulation such as Chen and Lee (2003), Lee (2006), Islam, Veitch and Liu (2007) and Tan et al. (2013, 2014). In the phenomenon, there are two forces acting at the same time that compressed by the hull and sucked by the propeller. Jaswar (2005) has developed an empirical mathematical model to predict resistance of Double Acting Tanker (DAT) without taking into account the impact of suction force caused by the propeller as the ship walked toward the rear. This paper discusses mathematical model to predict the strength of the suction force caused by the propeller of DAT during sailing astern.

3.0 SOFTWARE FOR INVESTIGATION OF AN ICE SHIP

3.1 Introduction

As previously described in the introductory section, there are several important issues to analyze the performance of ice ship. The first issue is to propose a new method to determine the performance of ships which operating on the sea ice. The second issue is to define the resistance of working load when ship-interaction with ice. Thirdly, development of simulation tool to predict a real condition is another issue as well verification the results simulation by experimental full scale data.

3.2 New Concept of Ice Ship

The present study proposes new icebreaking theory to determine ice resistance of ice ship sailing ahead and astern modes at unfrozen and frozen channels and the level ice condition such as shown in Figure.3. A proposed method was introduced as solution in the Double Acting Tanker (DAT).

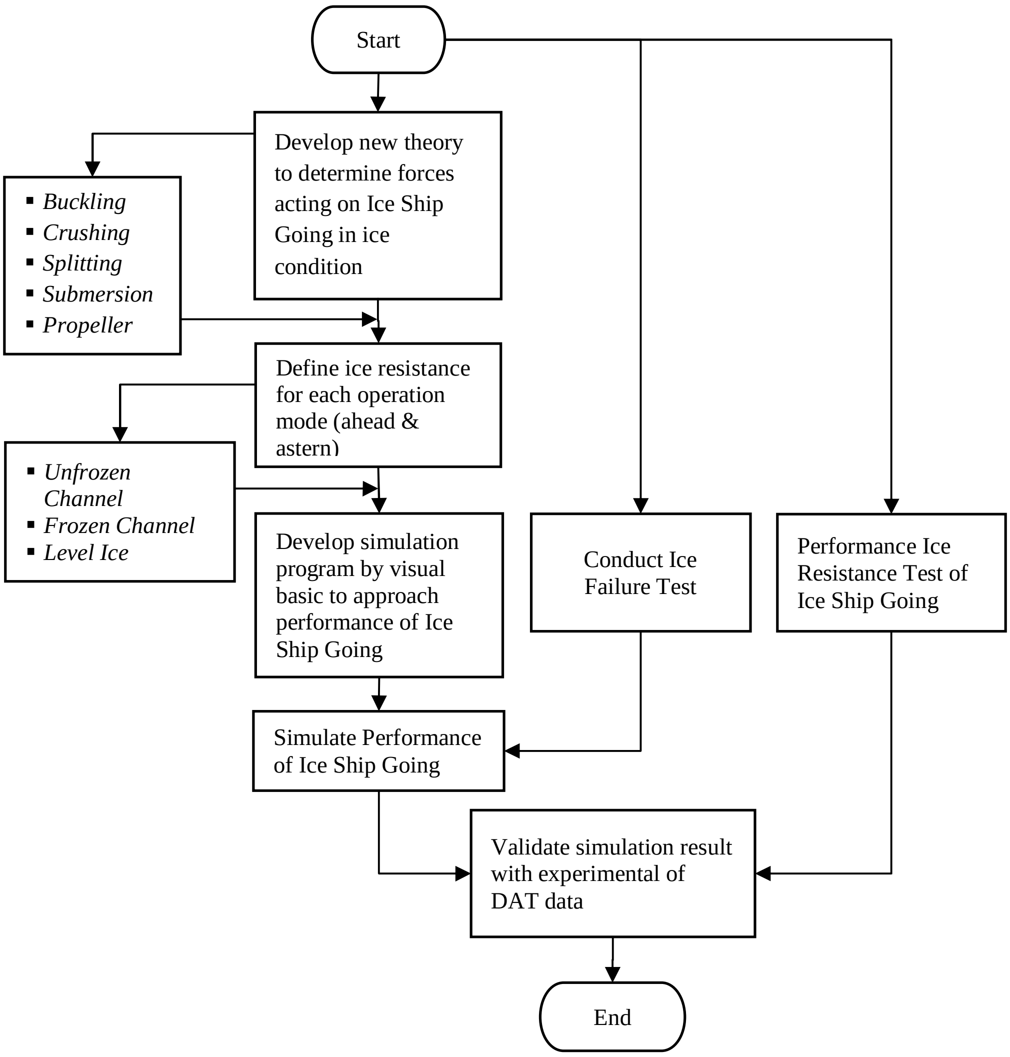

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Figure 3 Global flowchart of an ice ship investigation including simulation, experimentation and validation of calculation performance DAT ships while operating in icy conditions.

When an ice ship is sailing through the frozen seas, various forces were acting on the hull. Firstly, the ice would be breaking due to pushing force by ship. Some fragment piece of ice lead to up making a pile and any part are going to sinking rub against the hull body ship. It can be mentioned that forces are breaking the ice, submersion of ice and sucking by propeller. The latter continues to determine the force of others while contributing as ice resistance as friction resistance and water resistance.

3.3 Ice Failure Test

Sum all of resistance and amount of forces that were needed by ship to make a channel are as component in process on simulation program which is developed in this study. Bending strength as mechanical properties of ice were obtained from tensile experimental test together with dimension of DAT is an input for this program. In the experimental test, ice was pushed by tensile testing machine using punch which is placed on the jig and fixture.

Figure 4: Setup equipment test on Universal Testing Machine, Instron 5982

3.4 Ice Resistance Test

DAT performance was evaluated by the simulation program and then validated using experimental test scale model that was converted into a full-scale. This research is collaboration between Sumitomo Heavy Industries and Japan with Fortum Oil and Gas Oy Finnish and Mass-Yards-artic Research Center of Finland. The ship had been designed for handling trade operation at the area in Baltic seas.

3.5 Develop Simulation

Simulation program had been prepared using script code visual basic. In that section, every stage that involved in developed the simulation program is explained below.

3.5.1 Simulate Performance of Ice Ship

Simulation program that had been developed in this study aims to maintain complex parameters design well and also have been validated by experimental test. From Figure 4, Simulate flowchart briefly explained some input parameters were arranged in groups including; general input, special condition, FMA rules and ship dimension. Afterwards, these input data were used in calculation process to determine performance of ship on ice. Eventually the result can also be displayed as in graphical performance of characteristic curve of ship sailing on ice.

Other design hull form can be estimated repeatedly to other parameters using a simulation program that has been developed in this study. For instance, stern angle, bow angle, ship speed and thickness of ice. So that engine of ship was chosen as propulsion consider of economic value. Detail description of proposed method which had been developed to make simulation on this research was shown on Chapter 4.

3.5.2. Simulation Process for Proposed Method

Some equation which could be used to predict resistance occurs when ship was sailing on ice and open water has been explained section 4.2 to 4.3. On that section, two separate ideas were proposed to determine resistance happening at the ship on the open water and the ice condition.

For the open water, the ship was moving in the ahead mode. Some active resistance would be summarized into total resistance occurs. Likely **Equation 3.1** was used in an unfrozen channel that was contributed by water friction resistance, submersion resistance, friction resistance, and momentum resistance.

$$F_{ship-HUC} = F_{water-frict} + F_{sub} + F_{frict} + F_{moment} \quad (3.1)$$

Where: $F_{ship-HUC}$ is ice resistance at ahead for unfrozen channel, $F_{water-frict}$ is water friction resistance, F_{sub} is submersion resistance, F_{frict} is ice friction resistance and F_{moment} is ice momentum resistance.

Another equation was applied for a frozen channel is Equation 3.2. All resistance components in the unfrozen channel are still being participated in this situation with difference active coefficient and to be added by ice-breaking resistance.

$$F_{ship-HFC} = F_{water-frict} + F_{sub} + F_{frict} + F_{moment} + F_{ice} \quad (3.2)$$

Where: $F_{ship-HFC}$ is ice resistance at ahead for frozen channel

For the level-ice environment then represented by Equation 3.3 to define total resistance. According to other situation in the level-ice environment the resistance would have been coming from water resistance, submersion resistance, friction resistance, momentum resistance and ice-breaking resistance.

$$F_{ship-HLI} = F_{water-frict} + F_{sub} + F_{frict} + F_{moment} + F_{ice} \quad (3.3)$$

Where: $F_{ship-HLI}$ is ice resistance at ahead for level ice

Figure 5 and Figure 6 below of this could be giving illustrated happening in the simulation process which was developed in this study

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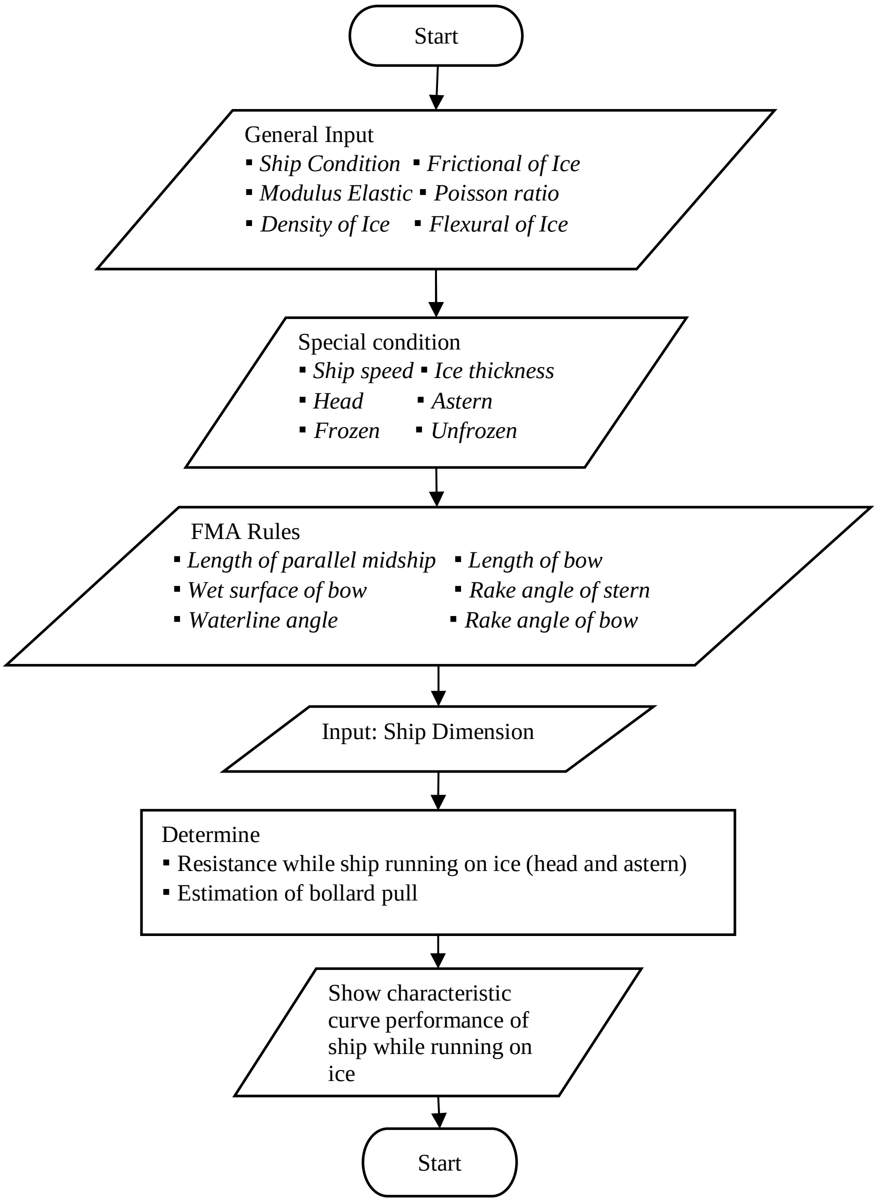

Figure 5: Main flowchart of simulation

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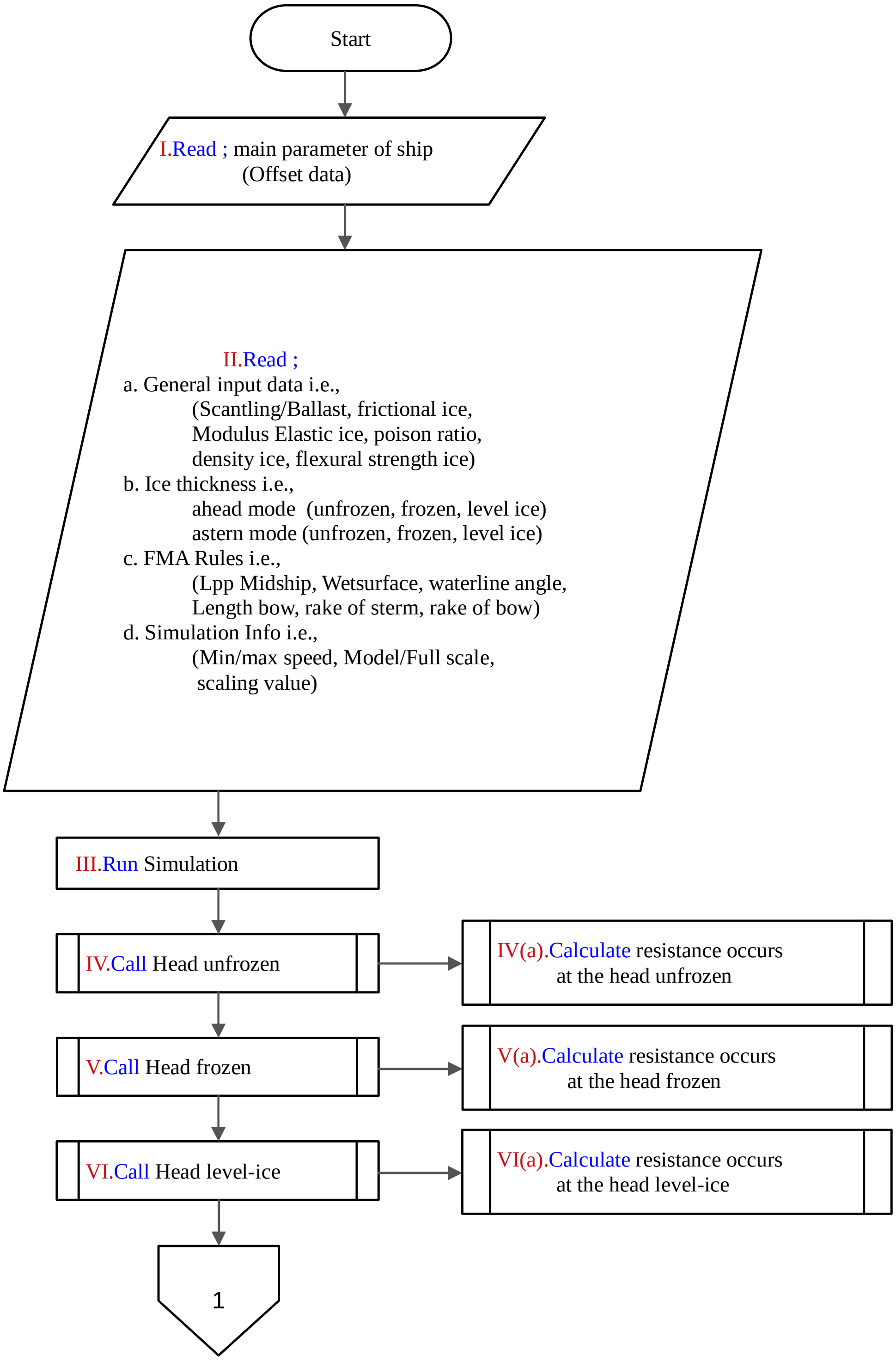

Figure 6: Simulation process for proposed method to predict resistance occurs when DAT travelling on ice at ahead mode

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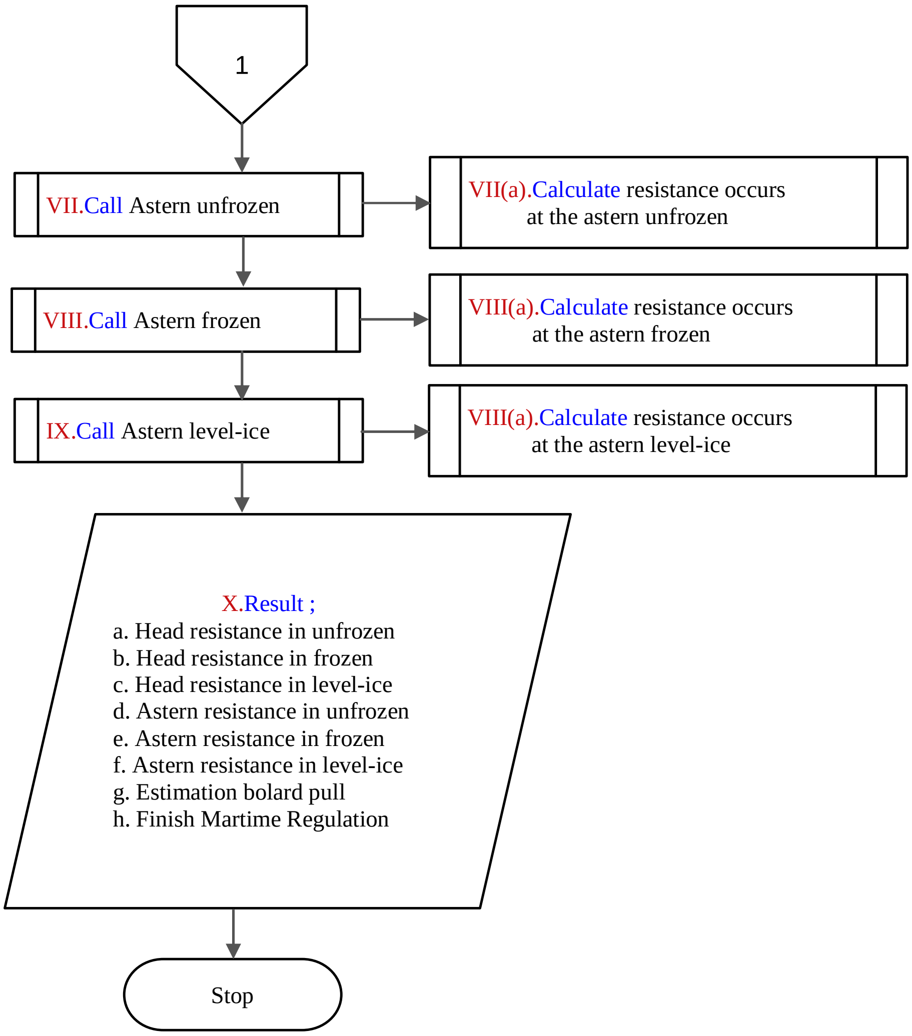

Figure 7: Simulation process for proposed method to predict resistance occurs when DAT travelling on ice at astern mode

The double acting ship will be acting astern on the ice sea environment. This way was chosen because the propeller would be giving additional force to ship, that make easy to break the ice for channel and passing its, at astern mode. In this study, that was called as suction of a propeller. Equation 3.4 introduced total resistance working in an unfrozen condition.

$$F_{ship-AUC} = F_{water-frict} + F_{sub} + F_{frict} + F_{moment} - F_{suction} \tag{3.4}$$

Where: $F_{ship-AUC}$ is ice resistance at astern for unfrozen channel.

Some resistance had been collected to arrange its including, water friction resistance, submersion resistance, friction resistance, momentum resistance and resistance of propeller effect. At a frozen condition, some resistances which were involved in calculating total resistance occurrence is same but in the difference of working coefficient and coupled with ice-breaking resistance, as to be shown in **Equation 3.5**.

$$F_{ship-AFC} = F_{water-frict} + F_{sub} + F_{frict} + F_{moment} + F_{ice} - F_{suction} \tag{3.5}$$

Where: $F_{ship-AFC}$ is ice resistance at astern for frozen channel.

For the level-ice condition, Equation 3.6 can be applied to define total resistance happening. This equation will be existing same way likely unfrozen, where supported by same resistance involved, but in the difference of working coefficient. So simulation program, which was developed in this study is a method chosen to solve the problem to determine exactly the working of coefficients.

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$$F_{ship-ALiC} = F_{water-frict} + F_{sub} + F_{frict} + F_{moment} + F_{ice} - F_{suction} \quad (3.6)$$

4.0 ICE–SHIP PERFORMANCE SIMULATION

The introduction interface for the developed simulation program is illustrated in Figure 8. In this screenshot, it displayed an illustration of double acting tanker, Tempera, was manoeuvring, followed by text as a program name, Ice-Ship Going Simulation. below that joining a picture in the graph form showing the results ice resistance working against velocity of ship after program simulation was sailing.

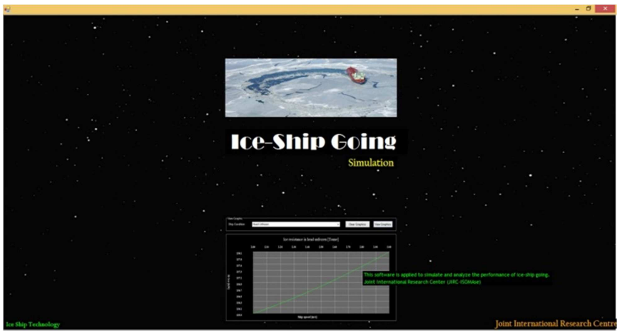

Figure 8: First screenshot arise after simulation program execute

By clicks at the introduction form, the program will enter the form for Ship Powering Completed Computation which as shown in Figure 9, while default tab active is Ship Information. In this section, series of parameter input data are readed by the program. And than, Read Input Data button can be pressed by user to initiate the execution process. A Back button designed in software to allow user cancel or return to the main screenshot. There are many parameter data input that would be used in the calculation, as example Principle Dimension, Hydrostatic Coefficient, Operational Condition, Control Surface, Stem-Stern Coefficient, Data Engine, Propeller, and Environmental Data.

Series of parameters data maintained in a text file (.txt) and default position of existence text file is displayed in the text-box at the left side to the Read Input Data button. when the Read Input Data button is clicked that ease for a user. After that, the result of parameter data readed by software from the text file (.txt) would appear in the text-box below of it.

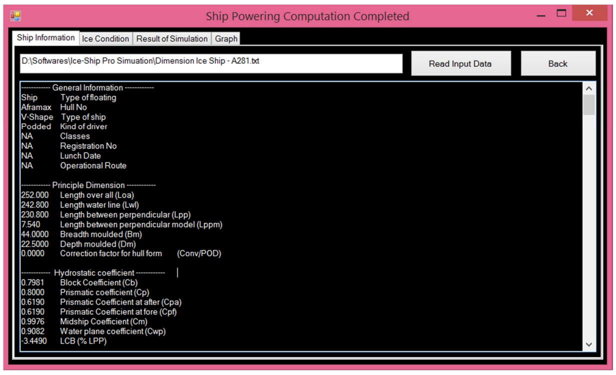

Figure 9: Ship dimension as input parameters

Figure 10 shows parameters of ship dimension to input simulation program that consists of main dimension of double acting tanker, such as Length over all (Loa), Length water line (Lwl), Length between perpendicular (Lpp), and Hydrostatic coefficient such as Block Coefficient (Cb), Prismatic coefficient (Cp), also draught, wet surface area, waterline angle, and stern angle.

After a series parameters of ship dimension was inserted next input about properties of ice can be filled thru a tab ice condition like a depicted in Figure 10. There are including of ice thickness, flexural strength of ice, ratio of model scale and either condition operating of ship like as scantling or ballast.

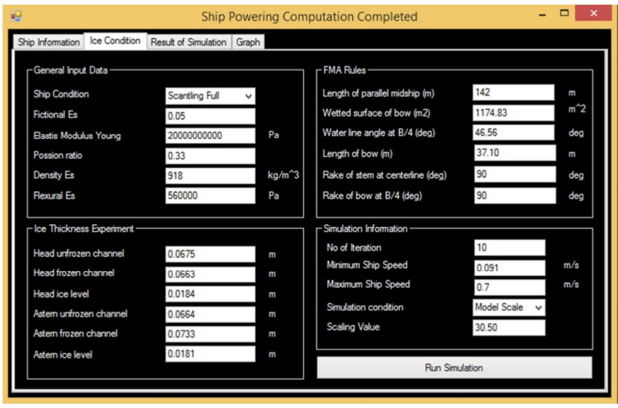

Figure 10: Ship dimension and Ice Condition to input parameters of ice.

After the data processed and simulation was run, the simulation results would be displayed in tab Result of Simulation, as shown in Figure 11. The simulation results will be clasified based on mode of ship sailing ahead and astern, each state will be varied according to environmental conditions of route to be traversed unfrozen, frozen and level ice.

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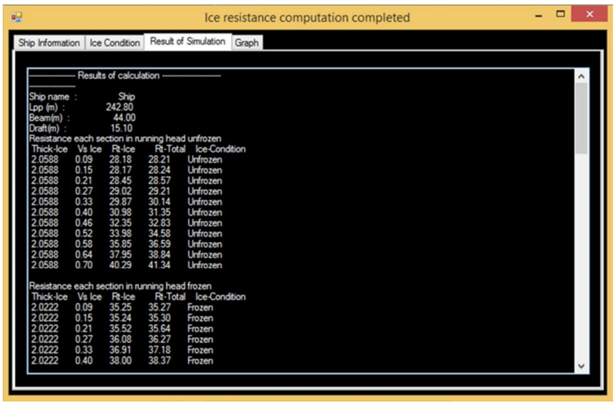

Figure 11: Tab Result of Simulation, shows classified result of simulation program

Figure 12 is an image of tab Graph, the tab will show the results of simulation in the form of a graph while illustrated ice resistance working related to ship speed reached when ships sailing a covered route with a certain of ice thickness.

Figure 12: Result simulation in Graph, ice resistance working related to ship speed

5.0 CONCLUSION

In conclusion, this paper discussed methodology to determine the Double Acting Tanker operated in ice condition such as: unfrozen and frozen channels and level ice conditions. The methodology consists of Ice failure test, ice resistance mathematical model and software development was carried out using VB language.

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