Study on Performance of Double Acting Tanker in Ice Condition

Efi Afrizal,[a,c] and Jaswar Koto,[a,b,*]

[a)]Department of Aeronautics, Automotive and Ocean Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia
[b)]Ocean and Aerospace Research Institute, Indonesia
[c)]Mechanical Engineering, Universitas Riau, Indonesia

*Corresponding author: jaswar.koto@gmail.com

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ABSTRACT

An optimum procedure of hull form design for ice ship going "Double Acting Tanker" is introduced. The procedure orderly consist of hull form design, analyses of performance of a ship in open water and ice condition, maneuverability performance, ice loading effect on propeller and torsional shaft, and economical and environmental societies. In the present study, only two topics are mainly discussed, which are hull form design and then continued with performance analysis in ice condition and open water. For the hull form design the objective parameter are considered as follows; stem and the stern angles, upper and lower fore bulbous angles, entrance angles, and spreading angles. All those angles are investigated for both full loaded and ballast condition in ahead and astern. Special concern is needed for stern part due to existing propeller effect on ice breaking performance. The hull form is firstly investigated without installation of propeller to avoid the effect of pressure from propeller and then continued by installation of propeller to find the optimum propeller design and propeller immersion. Research in ice condition is compromised with open water. The optimum hull form, propeller design and propeller immersion is when the hull form gives better performance for both open water and ice condition. The selected hull form then is compared with existing DAT tanker "Tempera".

KEY WORDS: *Double Acting Tanker; Ice Load; Ahead; Astern.*

1.0 INTRODUCTION

The development of pod drive brought highly advantage of diesel electric power for improvement maneuvering capability and icebreaking performance in astern mode during heavy ice condition for ice ship going. Application of pod drive on ship is firstly on icebreakers to have good capability to run astern. Combination of icebreaking and bulbous bow and pod drive brought possibility for a tanker to operate astern in ice condition and ahead in open water, which is called Double Acting Tanker "DAT" concept. Figure 1 to 2 shows Double Acting Tanker Tempera in open water and ice condition, respectively, which is built by Sumitomo Heavy Industries Japan.

The propulsion drive of the ship is provided by an Azipod unit, which contains the electric motor and the fixed pitch propeller. This is pod can rotate at 360o and has a maximum rating of 16 MWatt and the nominal output is 15 MWatt. This gives the tanker a speed of 15.2 knots in open water at 90 % of maximum continuous rating. In ice the tanker can go at 3 knots in 1 meter thick.[(1)] . The hull structure features a specially reinforced double skin with a fatigue life of 40 years. 1 This present study discusses and optimum procedure for optimization hull form for ice ship going "DAT". The performance of selected hull form design in ice condition and then is compared with the existing DAT "Tempera" from publishing data.

Figure 1: Double Acting Tanker Tempera in open water (1)

Figure 2: Double Acting Tanker Tempera in ice condition (1)

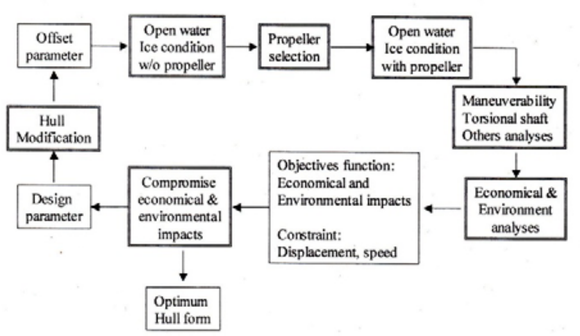

Figure 3: Hierarchy of optimization of hull form for ice ship going

2.0 OPTIMIZATION OF HULL FORM

A procedure for optimization of hull form for ice ship going is presented in (Fig. 1). The procedure mainly consist of hull form design, to open water, and ice condition performance with and without propeller, maneuverability, torsional shaft due to effect of ice loading and economical and environmental impacts on user and societies.The objective function are economic and environmental impact on user and societies. This means that the ship is selected based on satisfaction of user and societies. The viewpoint of user mean the ship owner view from profit and the societies viewpoint mean the local and international requirement such as regulation. This economic and environmental impact is investigated by using the economic and environmental model.[1]Since the topic is constrain the present study only discusses the performance of hull form in open water and ice condition.

The constraint parameter in present study is 106000 ton of deadweight and 15.5 knot of speed. The optimization condition of hull form is designed to have capability to operate in both open water and ice condition in scantling and ballast draft. The fore part of vessel is fitted with bulbous bow as shown in (Fig. 2). The bow shape is designed to be capable to operate in light ice condition. The modification of the fore profile is divided into three sections which is stern angle, upper and lower bulbous angles. The constrain of hull form design is as follows stem angle 55, upper bulbous angle 36.0-44.0 and lower bulbous angles 76.0-84.0, entrance angle at full loaded draft 54.0-64.0, entrance angle at ballast draft 26.0-38.0.

Modification of fore hull is shown in Figure 4. The hull is modified into two parts, which is upper part (α1F and α2F) for full loaded and lower part for ballast condition (α3F).

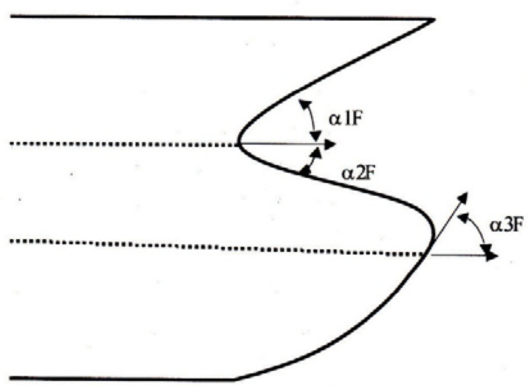

Figure 4: Two part of fore hull form modification.

Modification of hull form in the x direction can be expressed as where X_{oi} is station of parent hull form, X_{mi} is station of required hull form, X_1 is maximum station and X_0 is minimum station.

Then the modification of the hull form in the y direction can be expressed as where X_{FL} is fixed station of the minimum point, and X_{FU} is fixed station in the maximum point.

The modification of bulbous bow for ballast condition can be expressed as where z_{FL} is fixed waterline of minimum point and z_{FU} is fixed waterline of the maximum point.

The stern ice breaking type is designed to be able to operate independently in the most severe ice condition. After bulbous bow was modified similar to fore bulbous bow to reduce resistance as shown in Figure 5. The modification procedure of the stern part is same as the fore part.

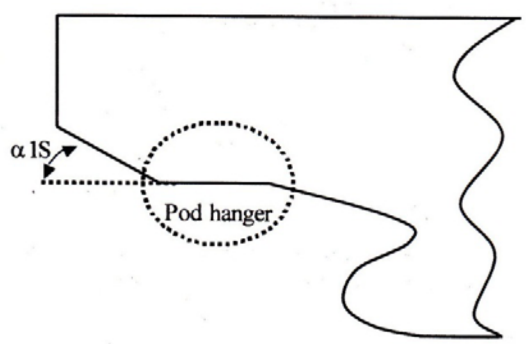

Figure 5: Stern part modification

3.0 PERFORMANCE ANALYSIS IN ICE CONDITION

The hull form of an ice ship going is analyzed in both open water and ice conditions. For each condition, the hull form is investigated with and without installing propeller. The investigation procedure is firstly start from fore part, and then continued to after part.

As the ship make an advanced progress to move forward into an unbroken ice field, the ship put forth sufficient amount of force to against the ice sheet. During the ice breaking process, two forces act on the same time, which are force given by the unbroken ice sheet and forced procedure by the ship. The force procedure by the ship can be classified into two component is procedure by thrust and vertical component provides ice breaking force.

The vertical force is incessantly transmitted to the ice sheet through the forward bow hull structure. When the vertical force and pressure go over in certain value, firstly, radial cracks propagate from loading point. Since loading of the ice continues, series of radial crack appear which as followed by one or more rows of circumferential cracks to ice failure. Then the ice failure is manifest in the formation of broken cusps or wedges. For the reason that the ship moves forward, the broken cusps become upended due to the hull flare. These cusps near the centerline of the ship and bow are simultaneously submerged and given a velocity that pass underneath the hull. In the case, the ship spend it force to against the submerging force from the ice cusps and frictional force between ice and hull.

The total acting force by the ice to resist the ship may be classified into four components, which are resistance for breaking and submerging ice, frictional ice hull, and loss momentum. The resistance can be expressed as

$$F_{ship} = F_{ice} + F_{sub} + F_{frict} + F_{moment} - F_{eff} \quad (1)$$

where; F_{ice} is resistance for breaking ice, F_{sub} is submersion resistance, F_{frict} is frictional resistance between ice and hull, F_{moment} is resistance due to loss momentum and F_{effect} is reduction resistance due to propeller effect, which is considered when the ship moves astern.

$$F_{ice} = C_1 . \sigma . h^2 . \mu . f(a, b) \quad (2)$$

where; C_1 is an icebreaking coefficient, σ is ice flexural strength, h is ice thickness, μ is coefficient of kinetic friction of ice and hull and a, b are component angles fore or after parts

The submersion resistance is assumed arise from work required to tip and submerge the broken an ice cusps. The submersion resistance depends on buoyancy of force of the ice cusp due to different density between the ice cusp and seawater.

$$F_{sub} = C_2 . (\rho_{water} - \rho_{ice}) . g . D . B \quad (3)$$

where; C_2 is submersion coefficient, ρ_{water} is water density 1.025 ton/m^3, ρ_{ice} is ice density 0.918 ton/m^3, g is acceleration of gravity 9.81 m/s^2, D is depth of ice cusp and B is width of the ice cusp.

The frictional resistance is developed when buoyancy force of the broken ice is against the hull and underside of the broken ice field as well as the effect of hull form such as friction between ice and hull and broken ice piece and under surface of the broken ice cover. The frictional resistance can be expressed as

$$F_{frict} = C_3 . \rho_{ice} . g . r . h . B . V / \sqrt{\quad} . f(a, b, C \quad (4)$$

where; C_3 is frictional coefficient, L is ship length, C_W is water plane area coefficient of entrance part, V speed of ship in m/s.

Loss momentum resistance is developed when resistive force attributable to extract momentum from the ship and imparting it to broken ice pieces. The time rate of change momentum of the ship is equal to resultant force on ship, which can be expressed as

$$F_{moment} = C_4 . \rho . B . h . V^2 . f(a, \quad (5)$$

The propeller effect is assumed due to pressure created from propeller which can be expressed as

$$F_{effect} = f(A_W, A_I, I_P, \quad (6)$$

where; A_W is working area, A_I is un-working area, I_P is propeller immersion and T_P is propeller thrust.

The principal dimension of ship which is evaluated in present study is shown in Table 1.

The fore and after part of ship are modified under constraint condition as follows: stem angle 55, upper bulbous angle 36.0-44.0 and lower bulbous angle 76.0-84.0 entrance angle at scantling draft 54.0-64.0 entrance angle at ballast draft 26.0-38.0. Propeller diameter is ranged from 7.4 to 7.6 m.

Table 1: Main principal dimension

Items	
Length, Lpp (m)	230
Beam (m)	44
Draft (m)	14.5
Deadweight (ton)	106100

Result of calculation are shown in Figure 6-13 in which Figure 6-9 show ice resistance of ship in full loaded and ballast draft in ahead without propeller, and Figure 10-13 show ice resistance of ship in fill loaded and ballast in astern without propeller. In figure w mean waterline angle and b mean bulbous angle at fore part and stern angle at stern part. The result show that resistance increase with increasing of entrance angle and bulbous angle. After compromising with open water condition and without propeller 36 and 54 degree are the suitable angle for upper bulbous and entrance angle at ballast draft, respectively and 76 and 28 degree are suitable for lower bulbous and entrance angle at ballast draft, respectively. For stern part 30 and 40 degree are suitable for stern and stern angle for both full and ballast condition, respectively.

In order to evaluate hull form ice resistance by the selected hull form are compare with existing DAT tanker "Tempera" as shown in Figure 14-17. The result show that selected ship has lower ice resistance than Tempera in unfrozen and frozen channels in full load and ballast conditions.

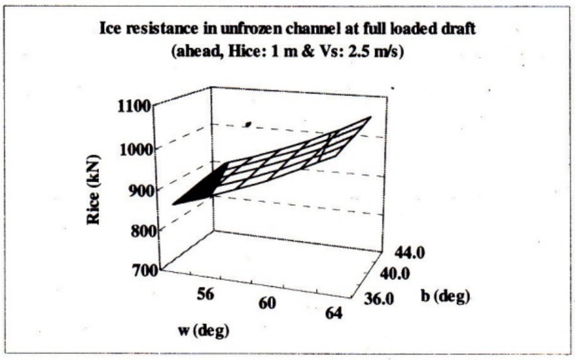

Figure 6: Ice resistance in unfrozen channel at full loaded draft, ahead, H-ice: 1.0 m and Vs: 2.5 m/s

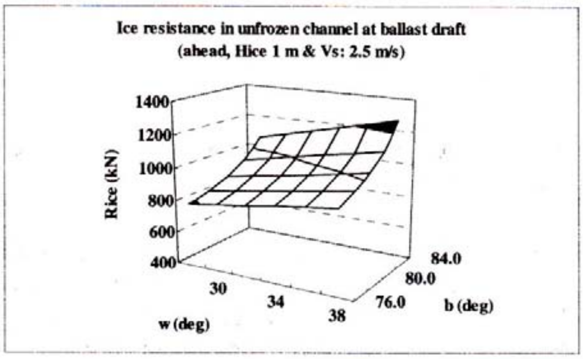

Figure 7: Ice resistance in unfrozen channel at ballast draft, ahead, H-ice: 1.0 m and Vs: 2.5 m/s

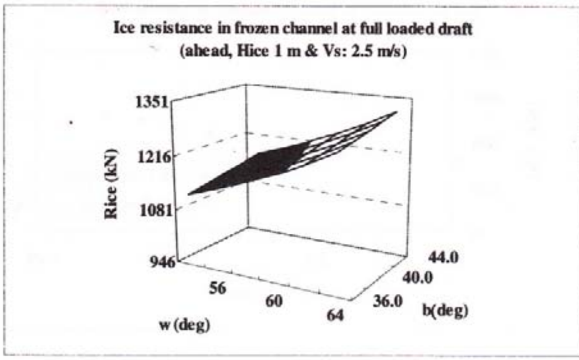

Figure 8: Ice resistance in frozen channel at full loaded draft, ahead, H-ice: 1.0 m and Vs : 2.5 m/s

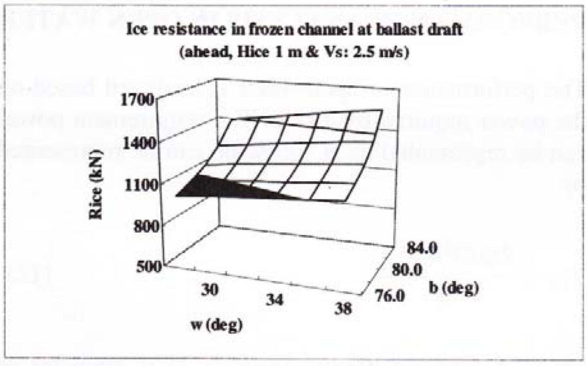

Figure 9: Ice resistance in frozen channel at ballast draft, ahead, H-ice: 1.0 m and Vs: 2.5 m/s

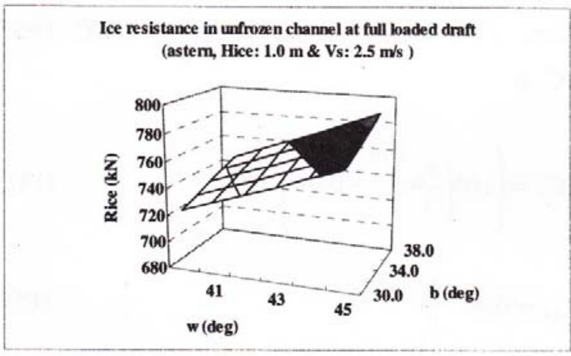

Figure 10: Ice resistance in unfrozen channel at full loaded draft, astern without propeller, H-ice: 1.0 m and Vs: 2.5 m/s.

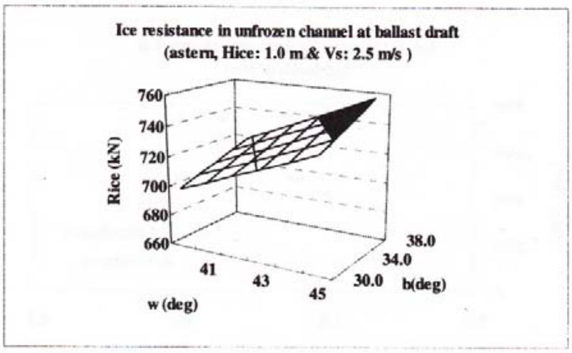

Figure 11: Ice resistance in unfrozen channel at ballast draft, astern without propeller, H-ice: 1.0 m and Vs: 2.5 m/s.

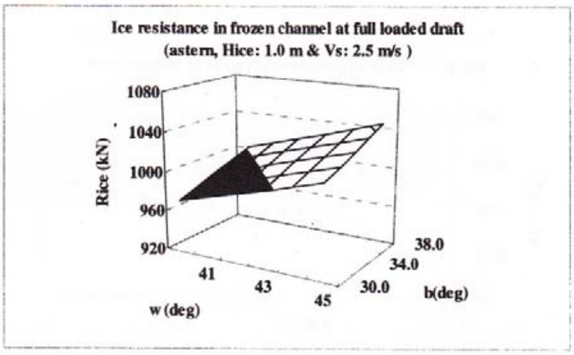

Figure 12: Ice resistance in frozen channel at full loaded draft, astern without propeller, H-ice: 1.0 m and Vs: 2.5 m/s

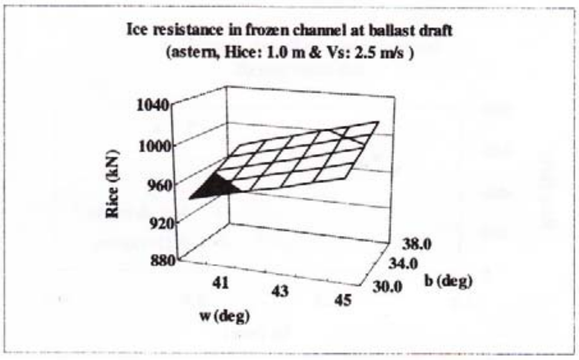

Figure 13: Ice resistance in frozen channel at ballast draft, astern without propeller, H-ice: 1.0 m and Vs: 2.5 m/s.

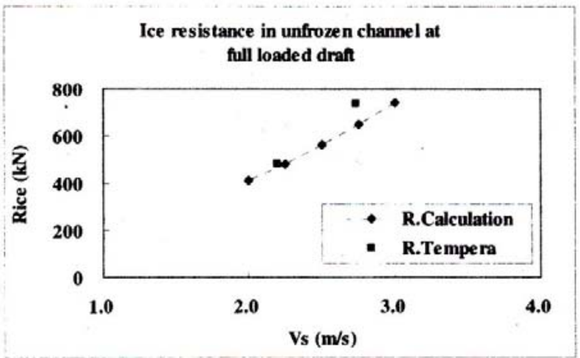

Figure 14: Comparison ice resistance of selected hull form in unfrozen channel at full loaded draft in astern with existing DAT "Tempera" (4)

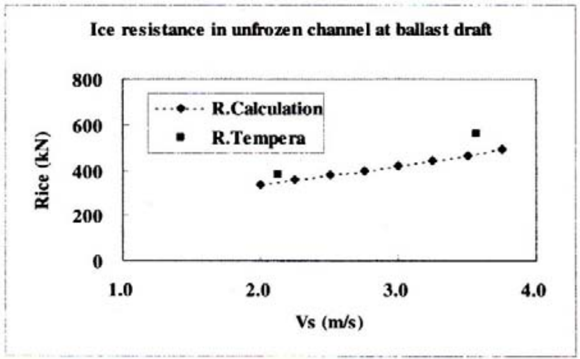

Figure 15: Comparison ice resistance of selected hull form in unfrozen channel at ballast draft in astern with existing DAT "Tempera" (4)

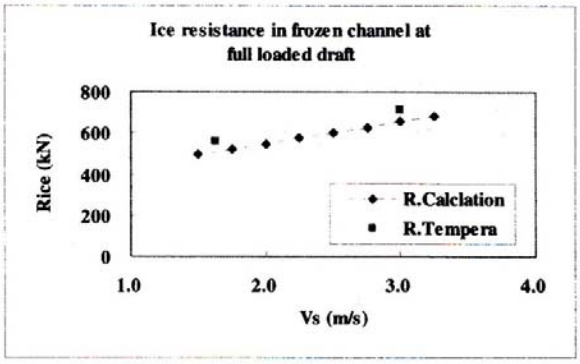

Figure 16: Comparison ice resistance of selected hull form in frozen channel at full loaded draft in astern with existing DAT "Tempera" (4)

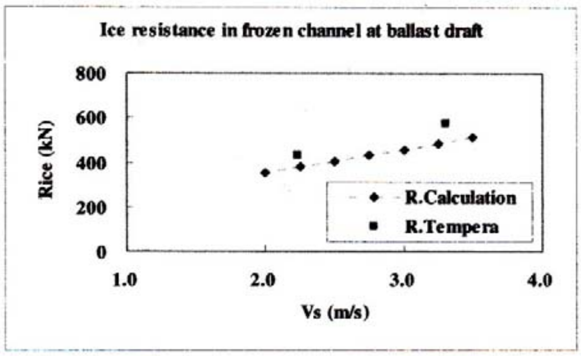

Figure 17: Ice resistance in frozen channel at ballast draft astern with propeller and then compare with existing DAT "Tempera" (4)

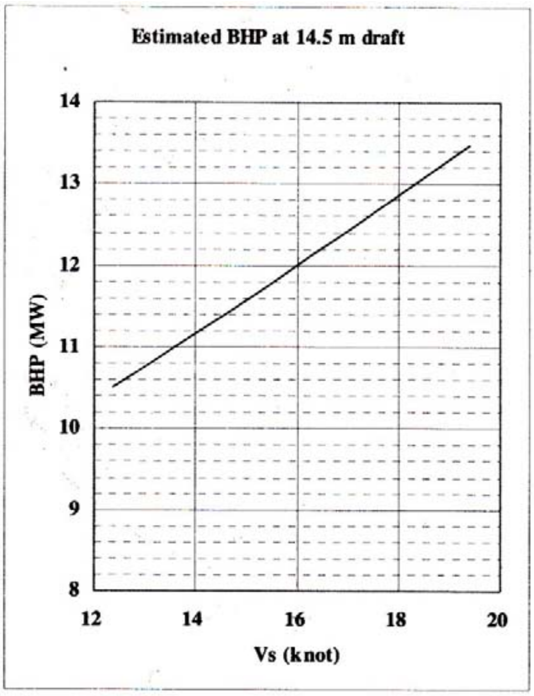

Figure 18: Estimated break horse power in open water of the selected ship

4.0 PERFORMANCE ANALYSIS IN OPEN WATER

The performance in open water is analyzed base on the power required by ship. The requirement power at the full scale can be represented by

$$P_{DS} = \frac{\text{[illegible]}}{\eta} \quad (7)$$

where seawater density (kg/m^3), D is diameter of propeller, n_s is revolution per second, K_t torque coefficient and η relative rotate efficiency.

Total resistance in open water can be represented as

$$C_{Total} = (1 + k)C_f + \Delta C_f + C_W + C \quad (8)$$

where is frictional coefficient of ITTC 1957, Δ is

$$\Delta C_f = \left[105 \left(\frac{\text{[illegible]}}{\text{[illegible]}} \right) - 0.64 \right] . 10^3$$
$$C_{AA} = 0.001 \frac{\text{[illegible]}}{\text{[illegible]}}$$

The estimated power curve of the selected hull form is shown in Figure 18.

4.0 CONCLUSION

The conclusions are obtained as follows: A method for optimization of hull for ice ship going is introduced. Using the method Double Acting Tanker is taken as a case study, and then obtain result are compare with existing DAR "Tempera". The obtained result show that for fore hull form 36 and 54 degree are the suitable angle for upper bulbous and entrance angle at full loaded draft, respectively, and 76 and 28 degree are suitable angle for lower bulbous and entrance angle at ballast draft, respectively. For stern part 30 and 40 degree are suitable angle for stern and stern angle for both full and ballast condition respectively. The performance of selected hull form show better performance than existing DAT "Tempera" in ice condition such as unfrozen and frozen channels.

REFERENCES

1. The Website for Cruise and http://www.ship-technology.com/
2. Jaswar. 2002. *A Prediction Method of Ice Breaking of an Icebreaker*. Presented at Seminar of Applied Physic 2002. ITS Surabaya
3. Jaswar. Ikeda Y. 2002. *A Feasibility Study of Double Acting Tanker Project Report Osaka Prefecture University and Sumitomo Heavy Industries*. Japan.
4. Jaswar,
5. Sasaki N., Laapio J., Fagerstrom B., Juurma K., and Wilkman G. 2005. *Full Scale Performance of Double Acting Tanker "Tempera and Mastera"*. 1st International conference on Technology Advances in Podded Propulsion. UK.
6. Mewis F., 2001. *The efficiency of Pod Propulsion HADMAR 22nd International Conference*. Bulgaria.