ENGINE-PROPELLER MATCHING FOR FISHING VESSEL AT KUALA PAHANG BAY

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I certify that the project entitled “*Engine-Propeller Matching for Fishing Vessel at Kuala Pahang Bay*” is written by *Muhammad Zarihan Bin Zakaria*. We have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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Report submitted in partial fulfilment of the requirements
for the award of the degree of
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SUPERVISOR’S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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STUDENT’S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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My kindly supervisor, Dr Agung Sudrajad
My beloved parent Adam Bin Ismail& Zainab Binti Ishak
My lovely, brothers and sisters
All my friends
May Allah bless all of you

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ABSTRACT

Fishing vessel is a transport for fishermen to catch fish at the sea. Ship propulsion normally occurs with the help of a propeller while the propeller absorbs power from the engine to move. The propeller is depending on the engine and the ships resistance. So, whatever source of propeller power used, but it's still depending on those factors. So, the factors will affect the speed or power performance. Thus, the right combination of engine and propeller are required to give good performance, fuel economy and others. The objective of this project is to calculate the engine-propeller matching for fishing vessel at Kuala Pahang bay. By surveying the fishing vessel at the bay, collecting some data required to proceed to other steps. From the data, the resistance of the ship and also the power of the ship are calculated. From the result, a propeller and an engine is selected to find the matching point. At the point, the power output from the engine equals to power absorb by the propeller. So, the fishing vessel was operated in high efficiency, high performance and reduces its fuel consumption.

ABSTRAK

Kapal nelayan adalah pengangkutan nelayan untuk menangkap ikan di laut. Pergerakan kapal biasanya berlaku dengan bantuan kipas sementara itu kipas tersebut menyerap kuasa dari enjin untuk berputar. Kipas itu juga bergantung kepada enjin dan rintangan kapal. Jadi, apa-apa sumber kuasa kipas yang digunakan tetapi ia masih bergantung kepada faktor-faktor tersebut. Oleh itu, kombinasi yang betul antara engine dan kipas diperlukan untuk memberikan prestasi yang bagus, jimat minyak dan lain-lain. Objectif projek ini adalah untuk mengira padanan engine dan kipas untuk kapal nelayan di Kuala Pahang. Dengan membanci kapal nelayan di sana, data yang diperlukan dikumpul untuk meneruskan langkah seterusnya. Daripada data tersebut, rintangan kapal dan kuasa kapal dikira. Hasilnya, satu enjin dan satu kipas dipilih untuk mendapatkan titik sepadan. Pada titik tersebut, kuasa keluar daripada enjin sama dengan jumlah kuasa yang diserap oleh kipas. Pada keadaan itu, kapal nelayan beroperasi dalam kecekapan dan prestasi yang tinggi dan boley mengurang penggunaan minyak.

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Δ	Displacement
ρ	Density
φ	Viscosity of sea water
β	Coefficient
ηH	Hull efficiency
ηrr	Relative rotative efficiency
ηP	Propeller efficiency
ηS	Shaft efficiency
ηB	Brake efficiency
ηG	Gear efficiency
γ	Coefficient

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

For the purpose of this project, the term “ship” is used to denote a vehicle employed to transport goods and persons from one point to another over water. Ship propulsion normally occurs with the help of a propeller.

Nowadays, the fishermen use fishing vessel to catch fish at the sea. Every day they go to the sea to catch the fish, the start the boat engine, then they pushing the throttle lever so hard that their hand numbs, without gaining an increase in speed, they vow to improve your boat's speed. Unfortunately, they just use the fishing vessel without care about the engine-propeller matching for their fishing vessel. So, by choosing the right propeller affect every phase of a ship performance, including handling, comfort of the ride, acceleration out of the hole, engine life, fuel economy, safety and the all importance element include top speed.

A propeller's relationship to a boat and forward motion in the water is directly related to a car's tire and the road. Matching the right traction to the available horsepower, load to be moved and top speed desired are just as important in the water as they are on land-based vehicles, or perhaps more so since water provides a liquid footing.

Today, the primary source of propeller power is the diesel engine, and the power requirement and rate of revolution very much depend on the ship’s hull form and the propeller design. Therefore, in order to arrive at a solution that is as optimal as possible, some general knowledge is essential as to the principal ship and diesel engine parameters that influence the propulsion system. Whatever source of propeller power used, but it's still depending on ship resistance and the propeller design.

A propeller is needed to generate adequate thrust to propel a vessel at some design speed with some care taken in ensuring some reasonable propulsive efficiency. Considerations are made to match the engine's power and shaft speed, as well as the size of the vessel and the ship's operating speed, with an appropriately designed propeller. Given that the above conditions are interdependent (ship speed depends on ship size, power required depends on desired speed). By following this to get understand the basic relationship between ship power, shaft torque and fuel consumption.

1.2 PROBLEM STATEMENT

In order to achieve the best of a ship performance, including handling, comfort of the ride, acceleration out of the hole, engine life, fuel economy, safety and the all importance element include top speed is about the boat resistance and propulsion. Before this, the fishermen just use the propeller without care about the characteristic of the propeller for their boat. The propeller is depending on the engine and the boat resistance. So, this problem will affect the speed or power performance. By achieving a best performance for the boat is designing the engine-propeller matching for fishing vessel.

1.3 OBJECTIVES

i. To calculate the engine-propeller matching for fishing vessel at Kuala Pahang Bay. From the calculation, the result will show the suitable engine power for certain diameter and fishing vessel size.

1.4 SCOPES OF PROJECT

There are three scope of the project as the limitation for the research. First, survey of fishing vessel type that has at Kuala Pahang bay. After that, the project scope is analysis of the general arrangement for that fishing vessel. Last, the calculation of engine-propeller matching for the fishing vessel.

1.5 PROCESS FLOW CHART

The processes of the project are based on the flow chart (refer next page Figure 1.1)

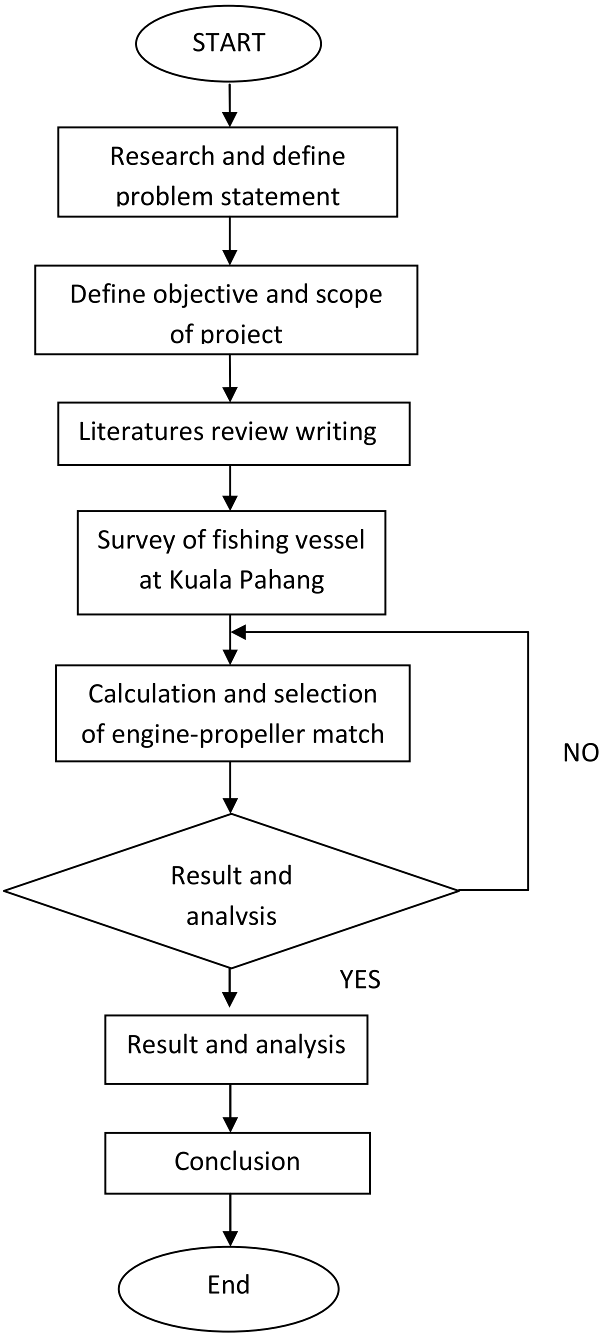


Figure 1.1: Process flow chart

CHAPTER 2

LITERATURE REVIEW

2.1 DESCRIPTION OF KUALA PAHANG

Figure 2.1: Location of Pekan

The figure above shows the location of Pekan, Pahang. The town is known as the City of Royal City as the place of residence and the Royal family and the central Pahang state government since time immemorial. In addition, the town is also famous as a center for trade and business. Its strategic location at the estuary of Sungai Pahang is a factor to this situation in view of the river to the main roads at that time.

Figure 2.2: Location of Kuala Pahang

Kuala Pahang area is about 3900 hectares while the water area is about 8022.52 hectares. Kuala Pahang also has about 4000 villagers which is the majority of the villagers' occupation is fisherman.

Figure 2.3: Location of Kuala Pahang Jetty

The Figure 2.3 shows the Kuala Pahang Jetty. This is where they stop and then unload their catch for the day.

Figure 2.4: Road to jetty

The arrows in the shows the way of the fishing vessel enter the estuary of Sungai Pahang to stop at the jetty.

2.2 Fishing Zone

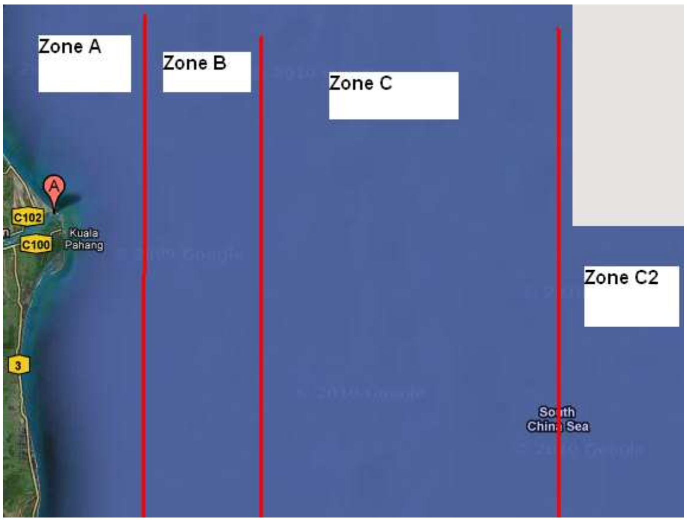


Figure 2.5: Fishing zones

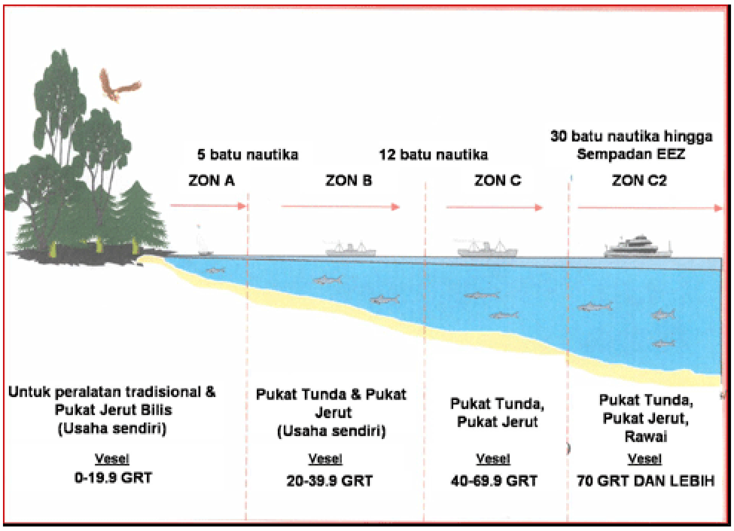


Figure 2.6: Fishing zones characteristic

Source: Jabatan Perikanan Malaysia

In Malaysia, there are four zones for fishing activities which are Zone A, Zone B, Zone C and Zone D. All zones is depends on their distance from the beach. Besides, each zone has their rules to follow by the fishermen like the trawl used and the size of fishing vessel use.

Zone A is about 5 nautical miles from the beach, using the traditional tools to fishing and tighten trawl with the size of fishing vessel is 0 to 19.9 GRT. Zone B’s distance is five to 12 nautical miles. The fishermen in Zone B using the drag trawl and tighten trawl to fishing by using 20 to 39.9 GRT of fishing vessel size.

The next distance is 12 to 30 nautical miles which is for Zone C. The fishermen from this zone also use the drag trawl and tighten trawl to fishing while they using 40 to 69.9 GRT of fishing vessel. The last zone is Zone C2. The distance is more than 30 nautical miles. They are using drag trawl, tighten trawl and line trawl to fishing. The size of fishing vessel used there is the biggest which is 70 GRT and above.

However, the fishermen from Zone A can go to another zones but no suitable with their size of the fishing vessel. But the fishermen from Zone C2 cannot come to nearer zone because they will conquer all the area with their big fishing vessel and disturb the smaller fishing vessel.

2.3 Fishing vessel

The type of fishing vessel used in Kuala Pahang is anchovy dragnetters. The dragnetters usually operated near the shore. The average age of the boats was 7.6 years. The non-powered boats and the outboard-powered boats were about 6.7 years old whereas the inboard-powered boats were 9–14 years old. By size of management, the fishing fleet is composed of powered boats and nonpowered boats at 95.4 and 4.5 percent, respectively. About 76 percent of the poweredboats are outboard powered and the rest are inboard powered with different classes of gross tonnage.

Of the inboard-powered boats, those with less than 10 GT, 10–50 GT and over 50 GT account for 47.3, 37.9 and 14.8 percent, respectively. It was found that most of the non-powered boats use lift nets and traps, especially crab portable lift nets and crab traps. The majority of the outboard-powered boats use shrimp gillnets, followed by crab gillnets and traps. The inboard-powered boats of less than 10 GT mostly use otterboard trawls, crab and shrimp gillnets; those of 10–49 GT use otterboard trawls, squid cast nets and pair trawls; and those of 50 GT and over mostly use otterboard trawls, pair trawls and purse seines.

2.4 General Description of Engine-Propeller Matching.

Actually, propeller operates by both pushing and pulling at the same time. As a blade rotates it is moving downward, which moves water back and downward. As water is pushed in those directions, more water more water rushes in behind the blade to feel the void left by the moving blade. (Harvald. Sv. Aa, Guldhammer.H.E,1974)The result is a pressure differential between the two sides of the blade, with positive pressure causing a pushing effect on the underside and a negative pressure, or pulling effect, on the top side. Since this action is created on all sides of the propeller, the push-pull effect is increased with the speed of the prop.

Basically, boat moves on the water with any velocity will have resistance which is opposite direction with the boat direction. The thrust force value must be higher than the resistance force to make the boat is moving. The thrust force is produce by propulsor. Delivered power, P_D to the propulsion is come from the shaft power while the shaft power is produce by brake power, P_B which is external force of ship propulsor.

2.5 Description of Hull Form

It is evident that the part of the ship which is significance for its propulsion is the part of the ship's hull which is under the water line. The dimensions below describing the hull form refer to the design draught, which is less than, or equal to the scantling draught. The choice of the design draught depends on the degree of load whether, the ship, the ship will be heavily loaded. Generally, the most frequently occurring draught between the fully-loaded and the ballast draught is used. (Harvald.Sv.Aa, 1986)

2.5.1 Ship's lengthsL_{OA}, L_{WL} and L_{PP}.

The overall length of the ship L_{OA} is normally of no consequence when calculating the hull's water resistance. The factors used are the length of the waterline, L_{WL} and the so-called length between perpendiculars,L_{PP}. The dimensions referred to are shown in Figure 2.7.

The length between perpendiculars is the length between the foremost perpendicular, i.e. usually a vertical line through the stem's intersection with the waterline, and aft most perpendicular which, normally, coincides with the rudder axis. Generally, this length is slightly less than the waterline length, and is often expressed as:

$$L_{PP} = 0.97 \times L_W$$

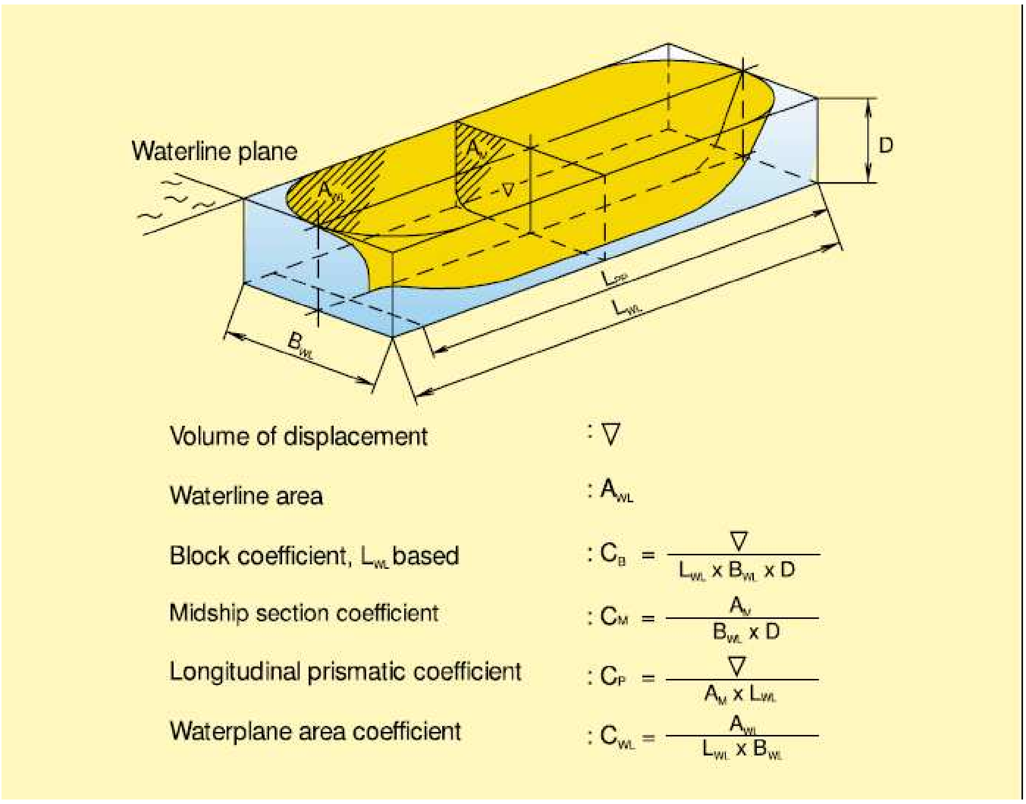


Figure 2.7: Hull coefficients of ships

Source: Harvald. Sv. Aa, Guldhammer.H.E, (1974)

2.5.2 Draught, D

The ship’s draught D is defined as the vertical displacement from the waterline to that point of the hull which is deepest in the water. (Harvald.Sv.Aa, 1983)

2.5.3 Breadth on waterline B_{WL}

Another important factor is the hull’s largest breadth on the waterline B_{WL}, see Figure 2.7.

2.5.4 Block coefficient C_B

Various form coefficients are used to express the shape of the hull. The most important of these coefficients C_B, which is defined as the ratio between the displacement volume V and the volume of a box with dimensions$L_{WL} \times B_{WL} \times \mathrm{D}$, see Figure 2.7.

$$C = \frac{V}{L_{WL} \times B_{WL} \times \mathrm{D}}$$

In the case cited above, the block coefficient refers to the length on waterlineL_{WL}. However, shipbuilders often used block coefficient $C_{B,PP}$ based on the length between perpendiculars, L_{PP}, in which case the block coefficient will, as a rule, be slightly larger because, as previously mentioned, L_{PP} is normally slightly less than L_{WL}.

$$C_{B,PP} = \frac{V}{L_{PP} \times B_{WL} \times \mathrm{D}}$$

A small block coefficient means less resistance and consequently the possibility of attaining higher speeds. (Harvald. Sv. Aa, Guldhammer.H.E, 1974)

Table 2.1: Examples of block coefficients

Ship type	Block coefficient, C_B	Approximate ship speed,V (knots)
Lighter	0.90	5 – 10
Bulk carrier	0.80 - 085	12 – 17
Tanker	0.80 - 085	12 – 16
General cargo	055 – 0.75	13 – 22
Container ship	0.50 – 0.70	14 - 26
Ferry boat	0.50 – 0.70	15 - 26

Table 2.1 shows some examples of block coefficient sizes and the pertaining service speeds on different types of ships. It shows that large block coefficient correspond to low speeds and vice versa. (Harvald.Sv.Aa, 1983)

2.5.5 Water plane area coefficient C_{WL}

The water plane area coefficient C_{WL} expresses the ratio between the vessel's waterline area A_{WL} and the product of the length L_{WL} and the breadth B_{WL} of the ship o the waterline, see Figure 2.7.

$$C_{WL} = \frac{A_{WL}}{L_{WL} \times B_{WL}}$$

Generally, the water plane area coefficient is some 0.10 higher than the block coefficient;

$$C_{WL} = C_B + 0.10$$

This difference will be slightly larger on fast vessels with small block coefficients where the stern is also partly immersed in the water and thus becomes part of the "water plane" area. (Harvald.Sv.Aa, 1983)

2.5.6 Midship section coefficient C_M

A further description of the hull form is provided by the midship section coefficient C_M , which expresses the ratio between the immersed midship section area A_M (midway between the foremost and the aft most perpendiculars) and the product of the ship's breadth B_{WL} and draught D, see Figure 2.7;

$$C_M = \frac{A_M}{B_{WL} \times D}$$

2.5.7 Longitudinal prismatic coefficient C_P

The longitudinal prismatic coefficient C_P expresses the ratio between displacement volume V and the product of the midship frame section area A_M and the length of waterline L_{WL} , see Figure 2.7;

$$C_P = \frac{V}{A_M \times L_{WL}} = \frac{V}{C_M \times B_{WL} \times D \times L_{WL}} = \frac{C_B}{C_M}$$

As can be seen, C_P is not an independent form coefficient, but is entirely dependent on the block coefficient C_B and the mid ship section coefficient C_M

2.5.8 Longitudinal Centre of Buoyancy LCB

The Longitudinal Centre of Buoyancy (LCB) expresses the position of the centre of buoyancy and is defined as the distance between the centre of buoyancy and the mid-point between the ship's foremost and aft most perpendiculars. The distance is normally stated as a percentage of the length between the perpendiculars and is positive if the centre of buoyancy is located to the fore of the mid-point between the perpendiculars, and negative if located to the aft of the mid-point. For a high speeds ship designed, it will normally be negative whereas for slow speed it will normally be positive. The LCB is generally between -3% and +3%. (Harvald.Sv.Aa.1983)

2.5.9 Fineness ratio C_{LD}

The length per displacement ratio or fineness ratio C_{LD} is defined as the ratio between the ship's waterline length L_{WL} , and the length of a cube with a volume equal to the displacement volume;

$$C_{LD} = \frac{L_{WL}}{\sqrt[3]{V}}$$

2.6 Ship resistance

The ship that cruises smoothly on the water is a thing that moves in the air and water mediums. It is means the thing will feel the resistance force from the medium it's passed through. (Harvald.Sv.Aa.1983)

The resistance force that experienced by the ship after pass through the air and water are:

a) Frictional resistance, R_F

It is happened because exist a layer or water volume that sticks to the wet body of the ship. So, there have an influence of the viscosity force on the part and cause the friction resistance.

b) Wave making resistance, Rw

The ship that moving on the water will feel the resistance until produce the wave that causes by variation of water tension to the ship hull when moving at a certain speed.

c) Eddy making resistance, Rp

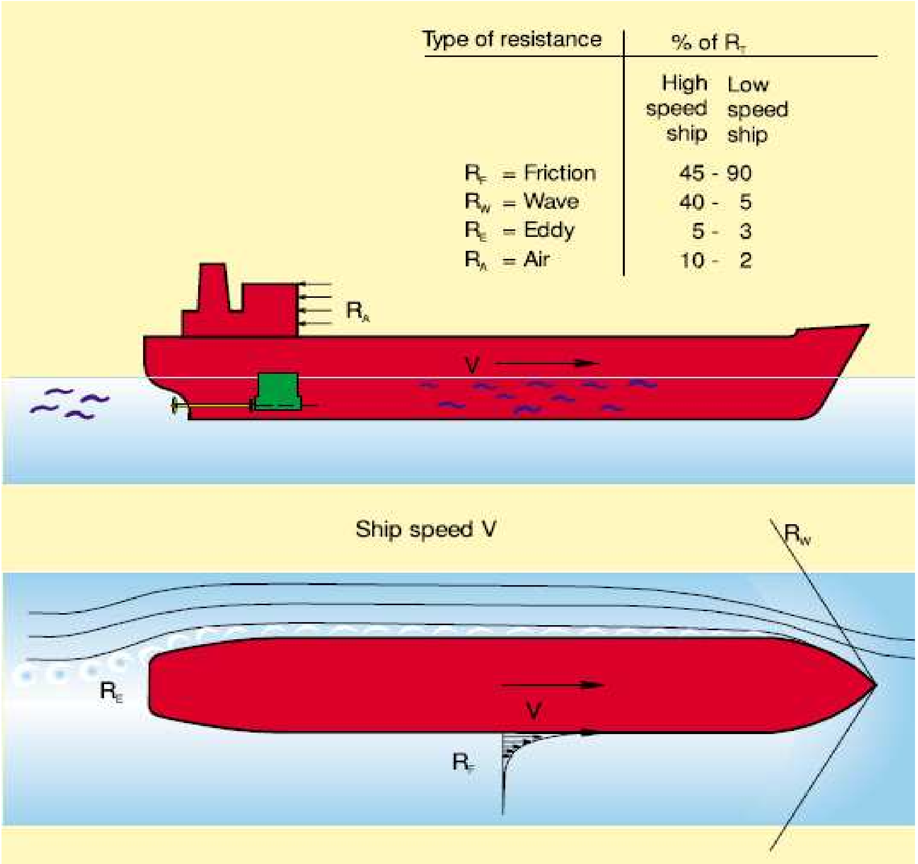
The particles of water moving across the ship hull will broke and form a volume of water where the water particles that moving in an eddy. When this phenomenon happened, thus water tension at the ship stern will decrease and form a force that oppose the moving direction of the ship

d) Air resistance, R_{A}

When the ship is moving, the upper parts (a part of hull and building on it) will fell the air resistance.

e) Appendage resistance, R_{AA}

The principal appendages in ships are the bilge keels, rudders, bossing or open shafts and struts. All these items give rise to additional resistance, which is best determined by model experiments. For rudders this can also be calculated from knowledge of their shape, using drag coefficients for airfoils of similar characteristics and Reynolds numbers appropriate to their speed and length.



Type of resistance	% of R_T High speed ship	 Low speed ship
R_F = Friction	45 -	90
R_W = Wave	40 -	5
R_E = Eddy	5 -	3
R_A = Air	10 -	2

Figure 2.8: Total ship towing resistance

Source: Harvald. Sv. Aa, Guldhammer.H.E, (1974)

Resistance, R and effective power for the ship can be calculated with these equations.

$$R = C_R \times \left(\frac{1}{2} \times \rho \times V^2 \times S\right)$$

$$P_E = R \times V_S$$

Total resistance coefficient

$$C_T = C_R + C_F + C_A$$

Where; $C_R = resistance\ resistance\ coefficient$

$C_F = frictional\ resistance\ coefficient$

$C_A = air\ resistance\ coefficient$

2.7 Propeller propulsion

The conventional agent to move a ship is a propeller, sometimes double and more in very rare case. The necessary propeller thrust T required moving the ship at speed V is greater than the pertaining towing resistance R_T and the flow-related reasons are, amongst other reasons, explained in the chapter. (Techet. A. H.2004)

2.7.1 Propeller types

a) Fixed pitch propeller

This propeller are cast in one block and normally made of a copper alloy. The position of the blades, and thereby the propeller pitch, is once and for all fixed, with a given pitch that cannot be changed in operation

b) Controllable pitch propeller

This type of propeller designed to give the highest propulsive efficiency for any speed and load condition. When the ship is fully loaded with cargo the propulsion required at a given ship speed is much higher than when the ship is empty. By adjusting the blade pitch, the optimum efficiency can be obtained and fuel can be saved. Also, the controllable pitch propeller has a “vane"-stance, which is useful with combined sailing or motor vessels as this stance gives the least water resistance when not using the propeller.

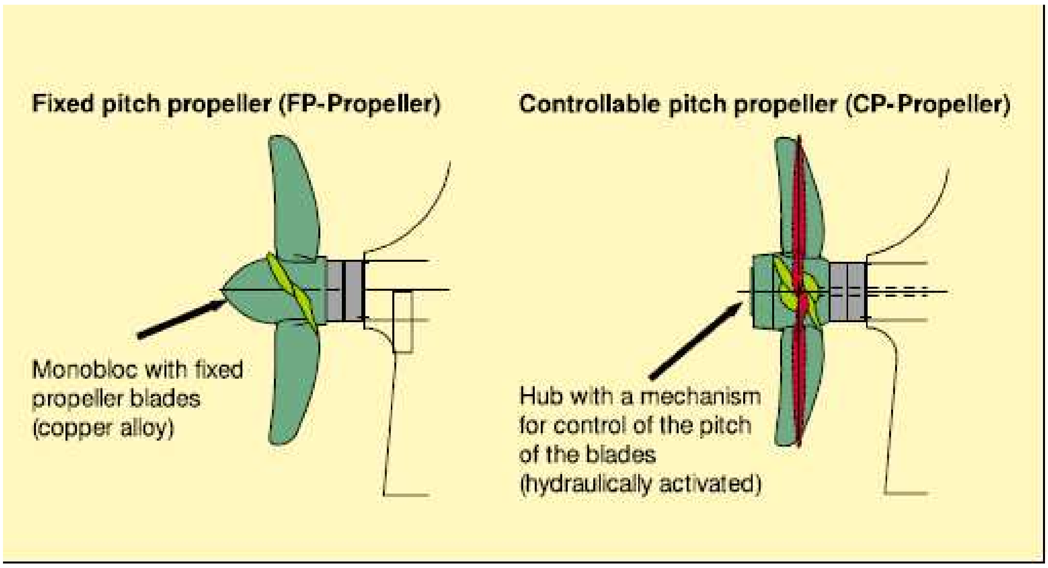


Figure 2.9: Propeller types

Source: Harvald. Sv. Aa, Guldhammer.H.E (1974)

2.7.2 Flow condition around the propeller

a) Wake fraction coefficient, ***w***

The friction off the hull will create a so-called friction belt or boundary layer of water around the hull when the ship is moving. For the friction belt, the velocity of the water on the surface of the hull is equal to that of the ship, but is reduced with its distance from the surface or the hull. At a certain distance from the hull and, per definition, equal to the outer surface of friction belt, the water velocity is equal to zero. (O’Brien, T.P, 2006)

The wake fraction, w is defined as

$$w = \frac{V - V_A}{V}$$

$$V_A = V(1 - w)$$

Where; $V = ship\ velocity$

$V_A = advance\ velocity$

The wake is due to three principal causes:

1. The frictional drag of the hull causes a following current which increases in velocity and volume towards the stern, and produces there a wake having a considerable forward velocity relative to the surrounding water.

2. The streamline flow past the hull causes an increased pressure around the stern, where the streamlines are closing in. This means that in this region the relative velocity of the water past the hull will be less than the ship's speed and will appear as a forward or positive wake augmenting that due to friction.

3. The ship forms a wave pattern on the surface of the water, and the water particles in the crests have a forward velocity due to their orbital motion, while in the troughs the orbital velocity is sternward. This orbital velocity will give rise to a wake component which will be positive or negative according to whether there is a crest or a trough of the wave system in the vicinity of the propeller.

4. The total wake is made up of these three components, and in the great majority of cases is positive, with the exception of high speed ships. The wake has other significant effects on the behavior of the ship.

2.7.3 Relative Rotating Efficiency

The propeller in open water, with a uniform inflow velocity at a speed of advance,V_A has an open water efficiency given by

$$\eta_0 = \frac{TV_A}{2\pi n Q_0}$$

Where; $Q_0 = the\ torque\ measured\ in\ open\ water$

$T = thrust$

$V_A = advance\ velocity$

$n = revolution$

The efficiency behind the hull, $\eta_B$will be

$$\eta_B = \frac{TV_A}{2\pi n Q}$$

The ratio of behind to open efficiencies under these conditions is called the relative rotative efficiency, being given by

$$\eta_R = \frac{\eta_B}{\eta_0} = \frac{Q_0}{Q}$$

The difference in torque found behind and in open is due to two main reasons: the heterogeneous wake, and the fact that the amount of turbulence in the water behind the hull is greater than in open water. The value of the relative rotative efficiency does not in general depart significantly from one, being in the range of 0.95 to 1.0 for most twin screw ships, and between 1.0 and 1.1 for single screw. (O'Brien, T.P, 2006)

2.7.4 Thrust Deduction.

When a hull is towed, there is an area of high pressure over the stern which has a resultant forward component reducing the total resistance. With a self propelled hull, however, the pressure over some of this area is reduced by the action of the propeller in accelerating the water flowing into it, the forward component is reduced, the resistance is increased and so is the thrust necessary to propel the model or ship. If R is the resistance and T the thrust, we can write for the same ship speed. (O’Brien, T.P, 2006)

$$R = (1 - t)T$$

Where; $(1 - t) = thrust\ deduction\ factor$

2.7.5 Hull efficiency

The work done in moving a ship at a speed V against a resistance, R is proportional to the product RV or the effective power, P_E. The work done by the propeller in delivering a thrust T at a speed of advance V_A is proportional to the product TV_A or the thrust power, P_T . The ratio of the work done on the ship by that done by the propeller is called the hull efficiency,η_H so that

$$\eta_H = \frac{P_E}{P_T} = \frac{RV}{TV_A} = \frac{1 - t}{1 - w}$$

For most ships this is greater than one. At first sight this seems an anomalous situation in that apparently something is being obtained for nothing. It can, however, be explained by the fact that the propeller is making use of the energy which is already in the wake because of its forward velocity.

Propulsive efficiency or overall efficiency becomes:

$$\eta_D = \frac{effective\ power}{delivered\ power} = \frac{P_E}{\eta_D}$$

$$P_E = RV$$

$$P_D = \frac{TV_A}{\eta_B}$$

Therefore,

$$\eta_D = \frac{RV}{TV_A}\eta_B$$

So,

$$\eta_D = \frac{1-t}{1-w}\eta_B = \frac{1-t}{1-w}\cdot\frac{\eta_B}{\eta_0}\eta_0$$

$$\frac{1-t}{1-w}\eta_R\eta_0 = \eta_H\eta_R\eta_0$$

The overall propulsive efficiency is then become as

$$\eta_P = \eta_D\eta_R\eta_0\eta_S$$

The division of the propulsive coefficient into factors in this way is of great assistance both in understanding the propulsion problem and in making estimates of propulsive efficiency for design purposes. (J.S.carlton, 2006)

2.8 Interaction of Hull and Propeller

Hull and propeller interaction is a theoretically on the paper to get the suitable characteristic of the propeller when operating behind the ship condition. So, the method is:

$$T_{SHIP} = \frac{\alpha V_A^2}{(1-t)(1-w)^2}$$

$$T_{\mathrm{Prop}} = K_T \times \rho \times n^2 \times D^4$$

$$T_{SHIP} = T_{\mathrm{Prop}}$$

$$K_T = \frac{\alpha V_A^2}{(1-t)(1-w)^2 \rho n^2 D^4}$$

$$if \beta = \frac{\alpha}{(1-t)(1-w)^2 \rho D^2}$$

$thus$

$$K_T = \beta \times \frac{V_A^2}{n^2 D^2}$$

$$K_T = \beta \times J^2$$

If the addition for hull service margin needs which is needs in the calculations, thus the ideal conditions between perfect surface (1) at the hull and propeller of the ships, and calm wind and seas (2) must be add the allowances about ±20% from the K_T value. So, it's become;

$$K_{T(SM)} = 120\% \times \beta \times J^2$$

From the figure above shows the interaction from propeller kinetic at behind of the ship condition where, curve 1 is the trendline of the propeller thrust coefficient for trial condition. By look at the x-axis show the J (3) line will get value of propeller torque, K_Q at trial condition. While the curve (2) is the trendline from propeller thrust coefficient at hull service margin condition and by make the line J (4) until intersect with point K_{T-SM}, thus will get the propeller thrust coefficient, K_{Q-SM} at the hull service margin. So, both unknowns, K_Q and K_{Q-SM} is used to determine the propeller load characteristics. (Adji. S. W, 2005)

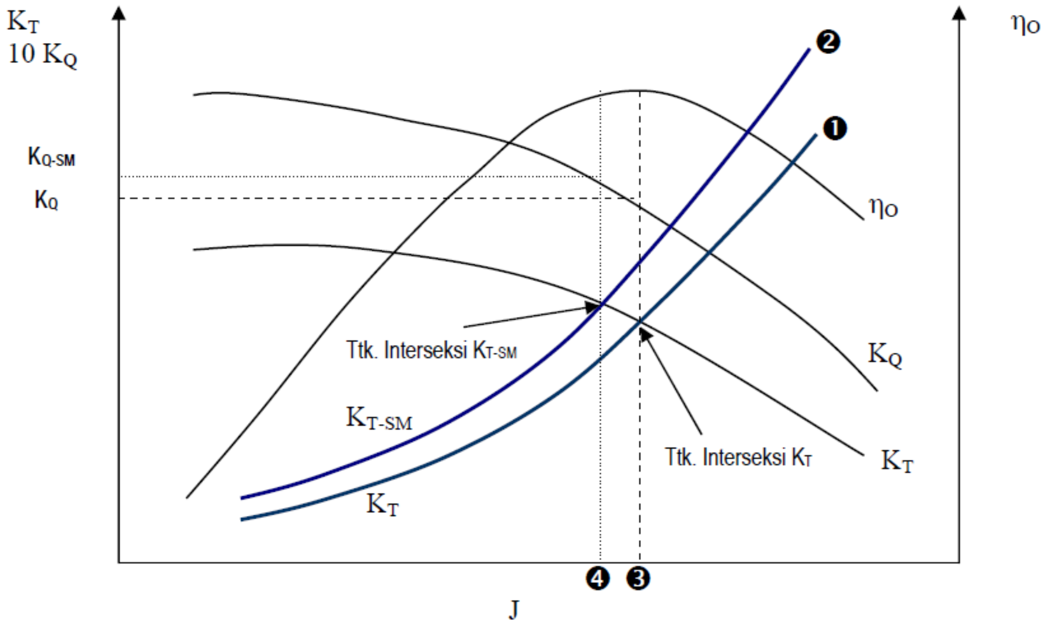


Figure 2.10: Example of plotting K_T & $K_{T(SM)}$ at openwater test propeller

Source: Adji. S. W. (2005)

2.8.1 Combination of engine characteristic and Propeller

a) Matching point

Matching point is an operation point from engine speed until match with the characteristic of propeller which is the power absorbed equals to power produced by the engine. (Adji. S. W.2005) The matching point will get from the Figure 2.11.

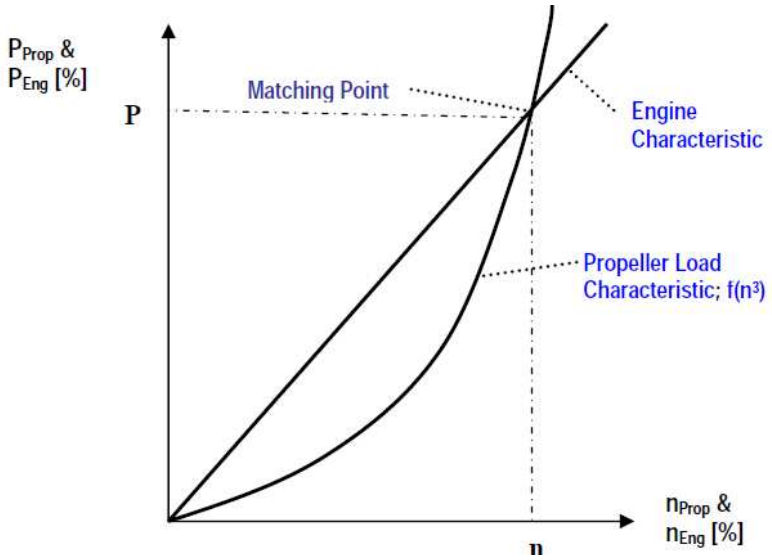


Figure 2.11: Matching point engine and propeller

Source: Adji. S. W. (2005)

At engine speed, n, is an operation point that suitable with propeller load because the power produced by the engine is equal with the power absorb by the propeller, P. So, the fuel consumption will become optimum towards the velocity of the ship. Overalls, rotational operation from the propeller are the key of the best propulsion system. (Adji. S. W.2005)

b) Effect of incorrect pitch

In the case of error in choose the pitch from propeller for the propulsion system, it will effect to the engine motor. One of the effects of the case, is the value of engine speed that achieved by the engine.

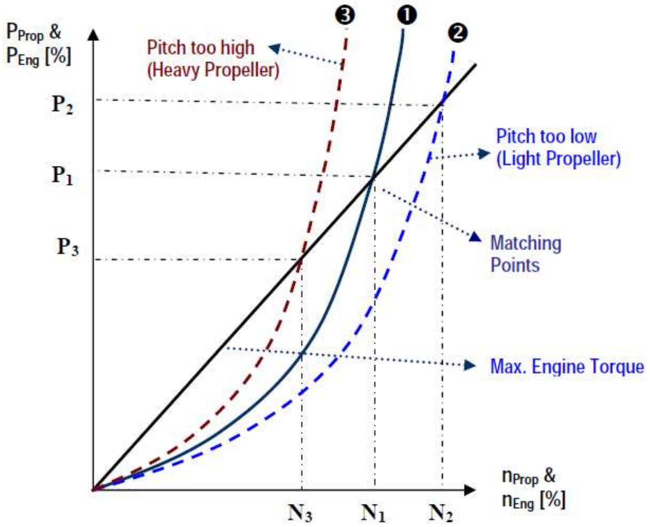


Figure 2.12: Engine torque vs propeller loads

Source: Adji. S. W. (2005)

From the graph, if the matching point for correct pitch is at {P_1 & N_1}, so the condition of pitch is not correct for the 2nd curve and 3rd curve. 2nd curve shows that the propeller load is very light and it is like the engine operating in over load condition. While for the 3rd graph shows the characteristic of load propeller for pitch condition is very high or heavy propeller. In this condition will damage the engine because the engine as operating in over speed.

c) Design for resistance change

For the long time operation, it will cause the ship hull will be rough surface which is cause by sea animal likes cockles, oyster and other. They will stick to the hull wall.

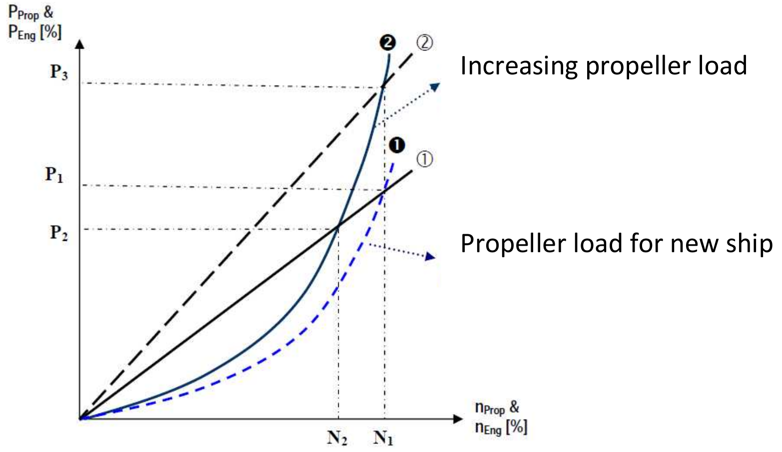


Figure 2.13: Engines torque vs propeller loads change

Source: Adji. S. W. (2005)

For the clean hull or smooth surface, the design speed for the ship was achieved at engine speed, N_1 condition. If, the propeller load is increasing, the engine speed will decrease from N_1 to N_2. So, the ship speed will decrease also. But, if the engine still has enough margins to increase the engine torque, thus the engine speed can be stay at N_1 condition. (Adji. S. W.2005)

d) Engine rating

When the engine is rated at 10000kW, its means, 10000kW power is supplied by engine to the propeller. At what condition also must be know how the engine affords to produce 10000kW power. As example, when the engine is rated, how about the value of power at the shaft. (Monk. J. C, 2000)

In defining the service rating power, there are some factors to be considered:

a) Rated power
b) Rated torque
c) Rated speed

d) Rated brake mean effective pressure

$$\{rated\ power\} = \{rated\ torque\} \times \{rated\ speed\}$$

$$rated\ torque\left[Q_{eng}\right] \propto rated\ brake\ mean\ effective\ pressure[bmep]$$

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The objective of this project is to analyze the engine propeller matching for the fishing vessel.

By achieving the objectives, the project start by gathering the information from all the source like journal, internet, technical paper and others about the ship resistance and propulsion to make some research and define the problem statement.

After getting all the information, define the introduction, and objectives and scope of the project to get clear about the project and also the limit of research. Next, the literatures review need to be done and followed by the research method that consist the flow chart of the project. The steps of the project process are;

i. Survey the general arrangement of ship construction, engine and transmission systems
ii. Calculate the ship resistance
iii. Calculate the propeller propulsion
iv. Calculate the engine-propeller matching
v. Choose the propeller
vi. Choose the engine

After getting the result and make the discussion, do the analysis. Then, make the conclusion and compile the proposal. Lastly, submit the proposal to the coordinator. If the report is accepted, the proposal can be presented. If not, define the introduction, objective and scopes of the project all the flow again until the proposal is accepted.

3.2 FLOW CHART OF METHODOLOGY

To achieve the objectives of the project, methodologies by flow chart purposely use to give the guidelines and direction to make this project work out successfully. Figure 3.1(refer next page) shows the flow chart of the project. So the project was based on the flow chart to keep the work inline.

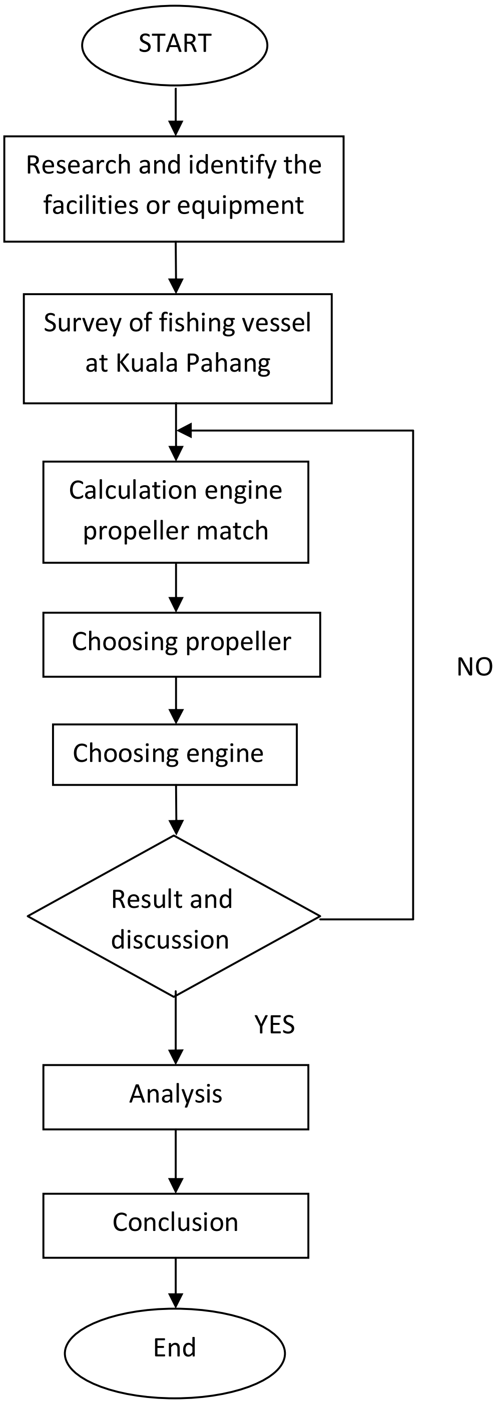


Figure 3.1: Flow chart

3.3 RESEARCH AND IDENTIFY THE FACILITIES OR EQUIPMENT

From the project of engine-propeller matching, the objective is to match the engine power to the propeller and depends on the size of fishing vessel. The results is to give good performance, including handling, comfort of the ride, acceleration out of the hole, engine life, fuel economy, safety and the all importance element include top speed. The fishing vessels needed is at the Kuala Pahang Jetty and it is not far from Universiti Malaysia Pahang (UMP) Pekan campus.

3.4 SURVEY OF FISHING VESSEL AT KUALA PAHANG

The data has been collected at the Kuala Pahang Jetty by surveying the general arrangement of ship construction, engine and transmission systems. The fishermen has been asked a few question about their fishing vessel like the overall length, breadth, height of fishing vessel and others and filled it in the data collection form.

3.5 CALCULATION OF ENGINE PROPELLER MATCHING

There are some steps to get the result of engine propeller matching.

3.5.1 CALCULATION OF SHIP RESISTANCE

The equations consisted in the calculations are:

a) Volume displacement($\forall$)

$$\forall = L_{WL} \times B \times D \times C_B$$

C_B of fishing vessel is 0.6

b) Displacement(Δ)

$$\Delta = \rho_{sea\ water} \times \forall$$

$\rho_{sea\ water}$ is 1.025 ton/m^3

c) Wetted surface area(A_S)

$$A_S = \rho \times L_{WL}[(C_B \times B) + (1.7 \times D)]$$

d) Froude number coefficient(F_n)

$$F_n = V_S/(g \times L_{WL})^{0.5}$$

First, the ship velocity (V_S) was set up to 6, 8, 10 and 12 knots for the calculation. 1knots = 0.5144m/s

e) Renould number(R_n)

$$R_n = V_S \times \frac{L_{WL}}{\Phi}$$

f) Resistance coefficient(C_R)

$$({L_{WL}}^3/\Delta)^{1/3}$$

Prismatic coefficient (C_P)

$$C_P = C_B/\beta$$
$$\beta = (0.08 \times C_B) + 0.93$$

Correction of C_R from B/D ratio, B/D = 2.5. So, the lower and higher the 2.5 must be corrected.

$$B/D$$

$$C_{Rnew} = 10 - 3(C_R \times 2.5) + 0.16(\frac{B}{D} - 2.5) \times 10^3$$

Correction of ship body:

Because of propeller, add 3%

$$C_R = (1 + X\%)C_{Rnew}$$

Because of shaft propeller, add 5%

$$C_R = (1 + Y\%)C_{Rnew}$$

g) Frictional resistance coefficient(C_F)

$$C_F = 0.075/(logR_n - 2)^2$$

The value happened at 15°C of sea water

For the east south area the sea water temperature is 18°C, so the equation becomes:

$$C_F = C_{Fstd} \times (1 + 0.0043(15 - T))$$

h) Advance coefficient(C_A)

LWL ≤ 100m ⟶ C_A = 0.4x10-3
LWL = 150m ⟶ C_A = 0.2x10-3

Interpolate:

$$C_A = 0.4 \ + [(L_{WL} \ - \ 100) \times (0.2 - 0.4)/(150 - 100)]$$

i) Air resistance coefficient(C_{AA})

$$C_{AA} = \ 0.006 \times (\ L_{WL} + 100) - 0.16 - 0.00205)$$

j) Propel resistance coefficient(C_{AS})

$$C_{AS} = 0.04 \times 10^{-3}$$

k) Total ship resistance(R_T)

$$C_T = [C_R + C_F + C_A + C_{AS}] \times 10^{-3}$$

$$R_{AA} = C_{AA} \times 0.5 \times P_{air} \times {V_S}^2 \times Compartement$$

$$compartement = B \times 2.5 \times 3$$

$$R_W = C_T \times 0.5 \times \rho_{sea\,water} \times {V_S}^2 \times A_S$$

$$R_T = R_W + R_{AA}$$

$$R_{T(service)} = R_T + shipping\ line$$

The shipping line for East Asia is 15-20%, in this case, 15% was used.

3.5.2 CALCULATION OF POWER

The equations consisted in the calculations are:

a) Effective horse power(EHP)

$$EHP = R_T \times V_S$$

b) Wake fraction(w)

$$w = (0.5 \times C_B) - 0.05$$

c) Thrust deduction factor(t)

$$t = k \times w$$

The range of k is 0.7-0.9. So the maximum value is taken, 0.9

d) Speed of advance(V_A)

$$V_A = (1 - w) \times V_S$$

e) Hull efficiency

$$\eta_H = (1 - t)/(1 - w)$$

f) Thrust(T)

$$T = R_T/(1-t)$$

g) Thrust horse power(THP)

$$THP = EHP/\eta_H$$

h) Propulsive coefficient(P_C)

$$P_C = \eta_H \times \eta_{rr} \times \eta_P$$

The relative rotative coefficient, η_{rr} range value is 1.02- 1.05. The maximum value is taken for this case.

i) Delivery horse power(DHP)

$$DHP = EHP/P_C$$

j) Shaft horse power(SHP)

$$SHP = DHP/\eta_S\eta_B$$

k) Brake horse power(BHP)

$$BHPSCR = SHP/\eta_G$$
$$BHPMCR = BHPSCR/0.85$$

3.5.3 CALCULATION OF K_T, K_Q, J

The equations consisted in the calculations are:

a) Calculation of advance coefficient(a)

$$a_w = 0.5 \times \rho_{sea\ water} \times A_S \times C_T$$
$$a_{AA} = 0.5 \times \rho_{air} \times A_S \times C_T$$

b) Calculation of K_T and J diagram

$$K_{T(AA)} = a_{AA} \times \frac{J^2}{1-t} \times (1-w)^2 \times \rho \times D^2$$

$$K_{T(w)} = a_w \times \frac{J^2}{1-t} \times (1-w)^2 \times \rho \times D^2$$

$$K_T = K_{T(AA)} + K_{T(w)}$$

$$J = \frac{V_A}{n \times D}$$

$$K_T = a \times \frac{J^2}{1-t} \times (1-w)^2 \times \rho \times D^2$$

$$K_{T(service)} = K_T \times J^2$$

c) Calculation of propeller characteristic

$$K_T = \frac{T}{\rho n^2 D^4}$$

$$K_Q = \frac{Q}{\rho n^2 D^5}$$

$$J = \frac{V_A}{nD}$$

$$\eta_o = \frac{K_T}{K_Q} \times \frac{J}{2\pi}$$

3.5.4 Choose a propeller and an engine

A propeller has been chosen for this project is B3-35 type. Then a graph for the propeller characteristic from the type of propeller will be constructed. After that, combine the K_T-J graph before with propeller characteristic graph. Then, the intersection point of $K_{T(trial)}$ $K_{T(sm)}$ and K_T is marked to get the value KT, 10KQ and η at both condition trial and sea margins.

Next, the values of $K_{Q(trial)}$ and $K_{Q(sm)}$ are use to determine the propeller load characteristics. In expanding the propeller load characteristic, the variable includes are propeller torque and propeller speed. For the propeller torque, the values are from the hull and propeller interaction graph which is $K_{Q(trial)}$ and $K_{Q(sm)}$. The substitute the values in equation below:

$$Q_{prop} = K_{Q(trial)} \times \rho_{sea\,water} \times n^2 \times d^5$$
$$Q^*{}_{prop} = K_{Q(sm)} \times \rho_{sea\,water} \times n^2 \times d^5$$

The value of $K_{Q(trial)}$, $K_{Q(sm)}$, $\rho_{sea\ water}$, d are constant, the equations become:

$$Q_{prop} = \gamma \times n^2 = f_1(n^2)$$
$$Q^*{}_{prop} = \gamma^* \times n^2 = f_2(n^2)$$

Then, from the both equation, the propeller load are results from:

$$[power] = [torque] \times [speed]$$
$$P_{prop} = Q_{prop} \times n = \gamma \times n^3 = f_1(n^3)$$
$$P^*{}_{prop} = Q^*{}_{prop} \times n = \gamma^* \times n^3 = f_2(n^3)$$

Next, tabulate the data for the propeller load with variable value of propeller speed which is from minimum to maximum speed. Then, construct a load propeller characteristic for condition, trial and sea margins.

For the matching point, an engine is selected first and gets the engine power curve. The power of selected engine is near with propeller power that calculated before. Next, combine the two data of propeller load characteristic and engine power curve in a graph. So, the matching point is at the intersection point of both trendlines.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter is aimed to show the engine-propeller matching for certain fishing vessel result. The calculation of the ship resistance, power and engine propeller matching was shown in this chapter also.

4.2 Data collected

Table 4.1: Data collection

	Fishing vessel 1	**Fishing vessel 2**	**Fishing vessel 3**
Lengthoverall(LOA)	12.2m	13.1064m	16.52m
Breadth(B)	3.2m	3.3258m	4.5m
Draught(D)	0.91m	1.0668m	1.12m
Engine Power(P)	37hp	103hp	145hp
Propeller diameter(d)	22inch	26inch	27inch

The table above shows the data of the fishing vessel at Kuala Pahang from the survey. There are three different size of fishing vessel.

4.3 Ship resistance calculation

All the equation that stated in chapter 3 was applied in this chapter. So, below is the result of the calculation for three fishing vessel which is different size of fishing vessel and different speed was calculated.

Fishing Vessel 1

From the calculations, (refer appendix A) the values of air resistance for the four speeds, 6 knots, 8 knots, 10 knots, 12 knots are 0.10841N, 0.1924N, 0.30115N and 0.43366N while the values of sea water resistance are 2570.53283N, 4536.62753N, 7050.81742N and 10110.49811N. By the formula above, the total resistance is the total of the air resistance and the water resistance. But the total resistance must be multiple by the East Asia shipping line, Z about 15%. So, the standard values of total resistance for each speed are 2956.23743N, 5217.34331N, 8108.44003N and 11627.07282N.

Fishing vessel 2

From the calculations, (refer appendix B) the values of air resistance for the four speeds, 6 knots, 8 knots, 10 knots, 12 knots are 0.101221N, 0.19948N, 0.31169N and 0.44883N while the values of sea water resistance are 3042.50953N, 5370.35091N, 8347.08313N and 11970.22199N. By the formula above, the total resistance is the total of the air resistance and the water resistance. But the total resistance must be multiple by the East Asia shipping line, Z about 15%. So, the standard values of total resistance for each speed are 3499.01500N, 6176.13295N, 9599.50404N and 13766.27144N.

Fishing vessel 3

From the calculations, (refer appendix C) the values of air resistance for the four speeds, 6 knots, 8 knots, 10 knots, 12 knots are 0.14948N, 0.26574N, 0.45121N and 0.59791N while the values of sea water resistance are 4549.68348N, 8032.5978N, 12487.14067N and 17909.69444N. By the formula above, the total resistance is the total of the air resistance and the water resistance. But the total resistance must be multiple by the East Asia shipping line, Z about 15%. So, the standard values of total resistance for each speed are 5232.30790N, 9237.79293N, 14360.68927N and 20596.83620N.

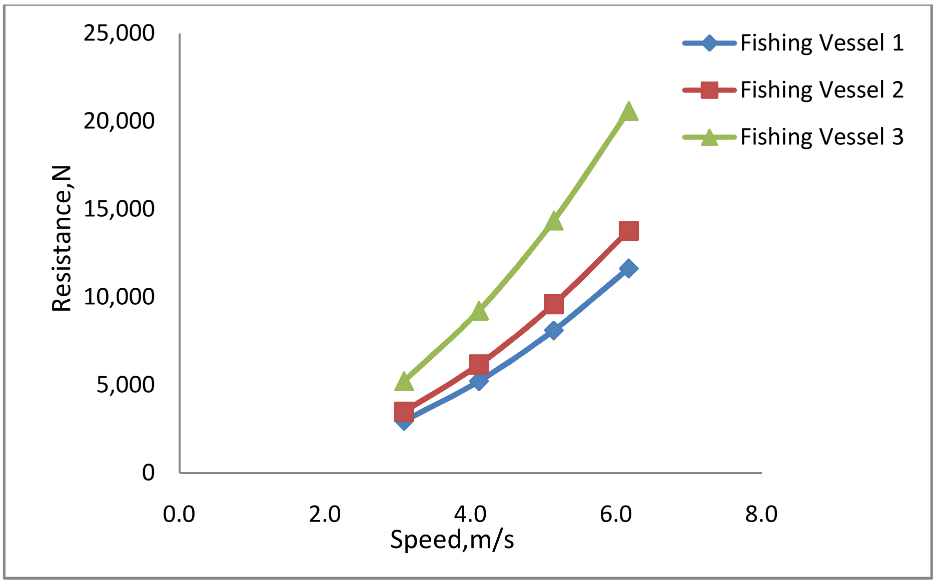


Figure 4.1: Ship resistance vs speed

From the above results, it shows that the bigger size of fishing vessel is the bigger ship resistance. Besides, the resistance of the fishing vessel increases when the speed increases by looking at the figures.

4.4 SHIP POWER CALCULATION

The steps to get the result are just like stated in chapter 3 and the results for the three fishing vessels are stated as follow.

Fishing vessel 1

Effective power (EHP) had been calculated for each speed by using the formula (refer appendix D) and the results are 12.23566Hp, 28.79229Hp, 55.93377Hp and

96.24728Hp. Next, the effective power was divided by hull efficiency to get the thrust horse power (THP) and the values are 11.84096Hp, 27.86351Hp, 54.12945Hp and 93.14253Hp. By dividing the effective power with prismatic coefficient (PC), the values 25.06024Hp, 58.97038Hp, 114.55969Hp and 197.12705Hp are for delivery horse power (DHP). Then, the brake horse power (BHPSCR) is divided by gear efficiency about 0.98 and get 26.69828Hp, 61.40190Hp, 119.28331Hp and 205.25515Hp. Lastly, the BHPSCR divided by power output at normal shipping to get the brake horse power (BHPMCR) values, 30.69828Hp, 72.23753Hp, 140.33331Hp and 241.47665Hp. To proceed to the next step, the value 72.23753Hp of BHPMCR from speed of 8 knots was used.

Fishing vessel 2

Effective power (EHP) had been calculated for each speed by using the formula (refer appendix E) and the results are 14.48323Hp, 34.08594Hp, 66.22433Hp and 113.96368Hp. Next, the effective power was divided by hull efficiency to get the thrust horse power (THP) and the values are 14.01603Hp, 34.08594Hp, 64.08806Hp and 110.28743Hp. By dividing the effective power with prismatic coefficient (PC), the values 29.66355Hp, 69.81267Hp, 135.63611Hp and 233.41256Hp are for delivery horse power (DHP). Then, the brake horse power (BHPSCR) is divided by gear efficiency about 0.98 and get 30.88667Hp, 72.69104Hp, 141.22877Hp and 243.03681Hp. Lastly, the BHPSCR divided by power output at normal shipping to get the brake horse power (BHPMCR) values, 36.33725Hp, 85.51887Hp, 166.15149Hp and 285.92566Hp. To proceed to the next step, the value 85.51887Hp of BHPMCR from speed of 8 knots was used.

Fishing vessel 3

Effective power (EHP) had been calculated for each speed by using the formula (refer appendix F) and the results are 21.65701Hp, 50.98145Hp, 99.06708Hp and 170.50452Hp. Next, the effective power was divided by hull efficiency to get the thrust horse power (THP) and the values are 20.95840Hp, 49.33689Hp, 95.87137Hp and

165.00437Hp. By dividing the effective power with prismatic coefficient (PC), the values 44.35640Hp, 104.41669Hp, 202.90237Hp and 349.21561Hp are for delivery horse power (DHP). Then, the brake horse power (BHPSCR) is divided by gear efficiency about 0.98 and get 46.18533Hp, 108.72209Hp, 211.26860Hp and 363.61475Hp. Lastly, the BHPSCR divided by power output at normal shipping to get the brake horse power (BHPMCR) values, 54.33569Hp, 127.90834Hp, 248.55130Hp and 427.78206Hp. To proceed to the next step, the value 127.90834Hp of BHPMCR from speed of 8 knots was used.

As a result, the power increases due to increasing of ship resistance and ship speed. So the higher engine speed was needed to overcome the ship resistance and move the fishing vessel.

4.5 ENGINE PROPELLER MATCHING

Fishing vessel 1

From results of ship resistance and ship power, a propeller was chosen to match with an engine. All the calculation in this part was using 8 knots or 4.1152 m/s as its speed

Propeller data

Type	: B3-35
ηpropeller	: 53.50%
P/d	: 0.643
Diameter (d)	: 0.5588
RPM	: 900

Calculation of advance coefficient (a):

$$a_w = 0.5 \times \rho_{sea\ water} \times A_S \times C_T$$
$$a_w = 267.809861$$
$$a_{AA} = 0.5 \times \rho_{air} \times A_S \times C_T$$

$$a_{AA} = 0.319542888$$

Where: $\rho_{sea\ water} = 1025\ kg/m^3$

$\rho_{air} = 1.223\ kg/m^3$

Calculation of K_T-J diagram

Table 4.2: Calculation of K_T-J diagram

Definition	Symbol	Equation	Value
		$(1-t) \times (1-w)^2 \times \rho_{seawater} \times d^2 /1000$	0.139527846
Thrust coefficient(air)	K_{TAA}	$a_{AA} \times J^2 / (1-t) \times (1 - w)^2 \times \rho \times d^2$	$2.290172873J^2$
Thrust coefficient(water)	K_{TW}	$a_W \times J^2 / (1-t) \times (1 - w)^2 \times \rho \times D^2$	$1919.400813J^2$
Thrust coefficient(trial)	$K_{T(trial)}$	$K_{TAA}+K_{TW}$	$1921.690986J^2$
Thrust coefficient(sea margins)	$K_{T(sm)}$	$K_{T(trial)}$+20%	$2306.029183J^2$

For the sea margins is usually ±20% and it is add as the allowances to the $K_{T(trial)}$ value. Next, all the values of K_T will multiply with the J value. The J value is set up like in the table below. So, the results are (refer Table 4.3 on next page):

Table 4.3: Result of $K_{T(trial)}$ and $K_{T(sm)}$

J	$K_{T(trial)}$	$K_{T(sm)}$
0.1	19.21691	23.06029
0.2	76.86764	92.24117
0.3	172.9522	207.5426
0.4	307.4706	368.9647
0.5	480.4227	576.5073
0.6	691.8088	830.1705
0.7	941.6286	1129.954
0.8	1229.882	1475.859
0.9	1556.57	1867.884
1.0	1921.691	2306.029
1.1	2325.246	2790.295

Then, applied it into the graph K_T vs J

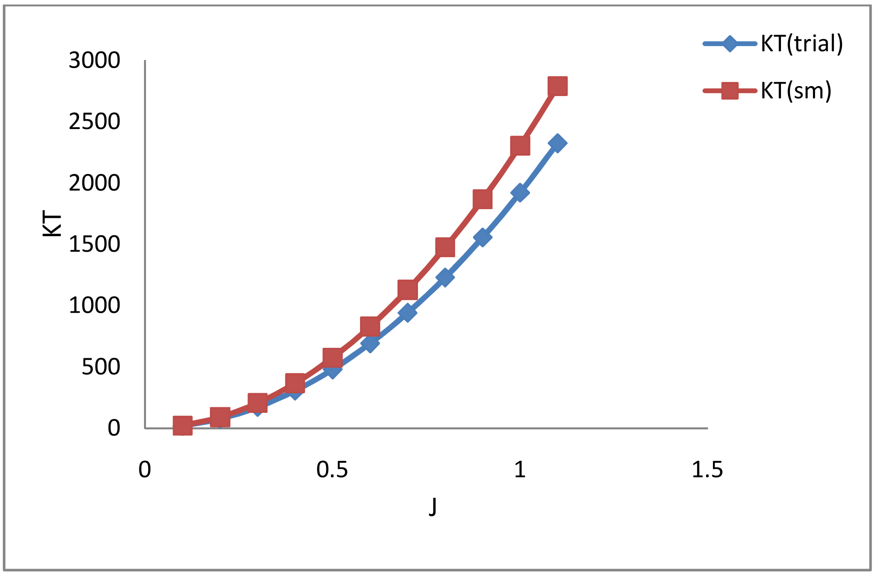


Figure 4.2: K_T vs J

Propeller Characteristic

The characteristic of propeller for fixed pitch propeller were given in constant of:

Thrust coefficient (K_T) = $T/\rho n^2 d^4$

Torque coefficient (K_Q) = $Q/\rho n^2 d^5$

Advance coefficient (J) = V_a/nd

Type : B3-35 P/d : 0.643

Table 4.4: Propeller data coefficients

J	KT	10 KQ	eff
0.000	245.000	277.000	0.000
0.100	235.000	265.000	150.000
0.200	215.000	243.000	280.000
0.295	192.000	222.000	400.000
0.400	160.000	190.000	486.000
0.500	127.000	160.000	545.000
0.600	90.000	128.000	541.000
0.700	45.000	90.000	350.000
0.800	0.000	45.000	79.000
0.900	0.000	0.000	0.000

From the table 4.4, the graph of KT, 10KQ, efficiency vs J was constructed.

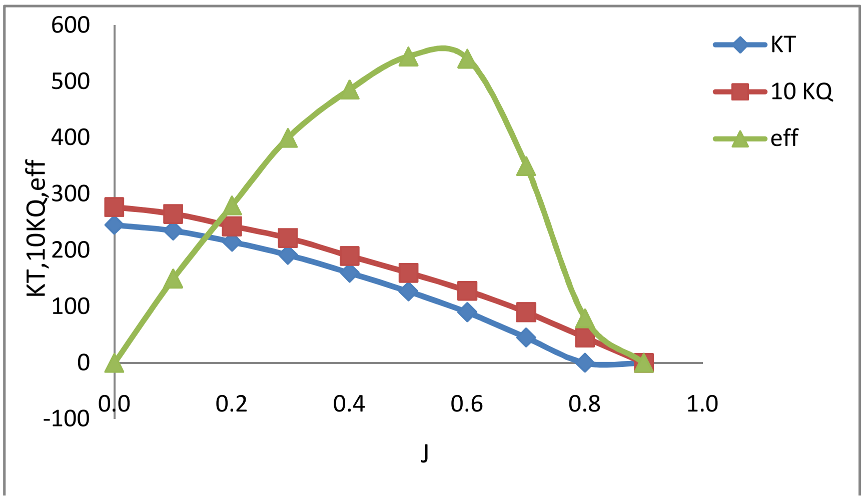


Figure 4.3: KT, 10KQ, efficiency vs J

Then, substitute the graph K_T-J into propeller characteristic graph to show the interaction from propeller kinetic at behind of the ship. So the graph becomes;

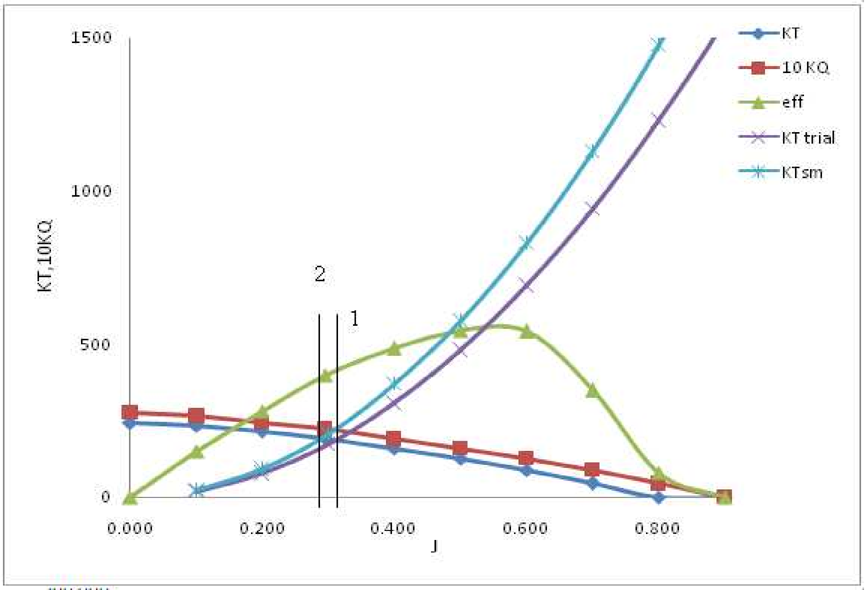


Figure 4.4: KT, 10KQ, efficiency vs J

For the trendline of the propeller thrust coefficient for trial condition, $K_{T(trial)}$. By look at the J(1) line would get the value of propeller torque at trial condition, $K_{Q(trial)}$. While the trendline from propeller thrust coefficient at hull service margin condition and by make the line J(2) until intersect with point $K_{T(sm)}$, thus would get the propeller torque coefficient, $K_{Q(sm)}$at the hull service margins. So, both unknowns, K_Q and $K_{Q(sm)}$ are used to determine the propeller load characteristics.

From the graph, the values are:

$10K_{Q(trial)}$: 216	$K_{Q(trial)}$: 21.6	$K_{T(trial)}$: 187	$\eta_{(trial)}$: 420
$10K_{Q(sm)}$: 224	$K_{Q(sm)}$: 22.4	$K_{T(sm)}$: 193	$\eta_{(sm)}$: 395

For the propeller load characteristic, the variable consist are propeller torque and propeller speed. For the propeller torque, it was from determination of hull and propeller interaction, $K_{Q\ (trial)}$ and $K_{Q(sm)}$.

Table 4.5: Propeller characteristic calculation

Definition	Symbol	Equation	Units	Value
γ		$K_{Q(trial)} x \rho_{(seawater)} x d^5$		1206.3188
γ*		$K_{Q(sm)} x \rho_{(seawater)} x d^5$		1250.99009
Propeller torque(trial)	Q_{prop}	$K_{Q(trial)} x \rho_{(seawater)} x n^2 x d^5$	Nm	977112620
Propeller torque(sm)	Q^*_{prop}	$K_{Q(sm)} x \rho_{(seawater)} x n^2 x d^5$	Nm	1013301977
Propeller power(trial)	P_{prop}	$\gamma\ x n^3$	W	
Propeller power(sm)	P^*_{prop}	$\gamma^* x n^3$	W	

The result of the propeller power calculated was tabulated in Table 4.6.

Table 4.6: Propeller power

Rpm,n_p	**rps**	**P_{prop},W**	**P^*_{prop},W**
0	0	0	0
100	1.666667	5584.77721	5791.62081
200	3.333333	44678.2177	46332.9665
300	**5**	**150788.985**	**156373.762**
400	6.666667	357425.741	370663.732
500	8.333333	698097.151	723952.601
600	10	1206311.88	1250990.09
700	11.66667	1915578.58	1986525.94
800	13.33333	2859405.93	2965309.85
900	15	4071302.58	4222091.57
1000	16.66667	5584777.21	5791620.81

Then, take the RPM at 300 as the reference point. At the condition, the propeller power is 150788.985 W. After that, an engine that produces power near the propeller power was chose.

Table 4.7: Engine specification

Engine Type	**YANMAR 4BY2-180Z 180 hp / kW 132**
Number of cylinder	4-inline
Output at crankshaft mhp/kW	180 - 132
Rated Speed rpm	4000
Displacement L / cu in	1.995 / 122
Standard drive	ZT350
Weight with gear/drive Kg (lbs)	370 (816)

Then, from the engine characteristic, tabulate the data for rpm value after reduction by gearbox and the power output.

Table 4.8: Engine power output

rpm	kW	W
0	0	0
100	19.68648	19686.48
200	39.37296	39372.96
300	59.059	59059
400	78.7459	78745.9
500	98.4324	98432.4

Lastly, plot a graph that combine the propeller load characteristic combine with the engine characteristic.

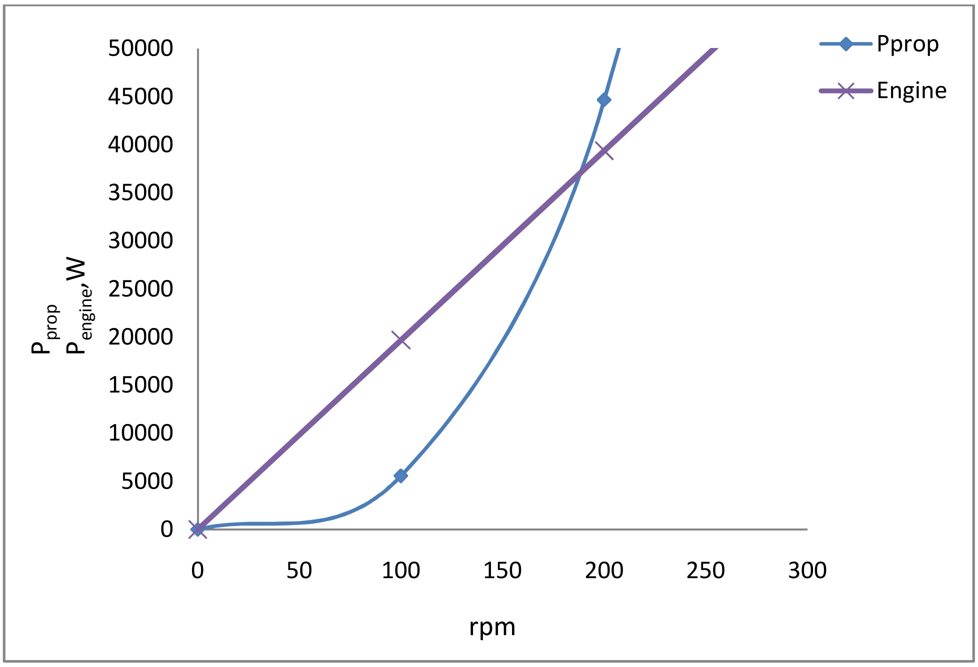


Figure 4.5: Matching point for engine and propeller

From the figure above, the values at the intersection point are 190rpm and 37kW or 49hp for propeller power absorb. From the data collected, the engine power for this fishing vessel 1 is 37hp. At the intersection point, there is a suitable operational point with the propeller load condition. This is because, the power produce by the engine are same with the power absorb by the propeller. Thus, that will give the optimal consequence toward the fuel consumption by the engine power with acquired speed.

Generally, only the engine speed (rpm) and fishing vessel speed (knots) can be seen in the indicator. So, the setting of engine operation is the key of the operational propulsion system to make it effective.

Fishing vessel 2

From results of ship resistance and ship power, a propeller was chosen to match with a engine. All the calculation in this part was using 8 knots or 4.1152 m/s as its speed

Propeller data

Type	: B3-35
ηpropeller	: 53.50%
P/d	: 0.643
Diameter (d)	: 0.6604
RPM	: 940

Calculation of advance coefficient (a):

$$a_w = 0.5 \times \rho_{sea\ water} \times A_S \times C_T$$
$$a_w = 317.2053566$$
$$a_{AA} = 0.5 \times \rho_{air} \times A_S \times C_T$$
$$a_{AA} = 0.378480147$$

Where: $\rho_{sea\ water} = 1025\ kg/m^3$

$\rho_{air} = 1.223\ kg/m^3$

Calculation of KT-J diagram

Table 4.9: Calculation of KT-J diagram

Definition	**Symbol**	**Equation**	**Value**
		$(1-t) \times (1-w)^2 \times \rho_{seawater} \times d^2/1000$	0.194877735
Thrust coefficient(air)	K_{TAA}	$a_{AA} \times J^2 / (1-t) \times (1-w)^2 \times \rho \times d^2$	$1.942141553J^2$
Thrust coefficient(water)	K_{TW}	$a_W \times J^2 / (1-t) \times (1-w)^2 \times \rho \times D^2$	$1627.714711J^2$
Thrust coefficient(trial)	$K_{T(trial)}$	$K_{TAA}+K_{TW}$	$1629.656853J^2$
Thrust coefficient(sea margins)	$K_{T(sm)}$	$K_{T(trial)}+20\%$	$1955.588223J^2$

For the sea margins is usually ±20% and it is add as the allowances to the $K_{T(trial)}$ value. Next, all the values of K_T will multiply with the J value. The J value is set up like in the table below. So, the results are:

Table 4.10: Result of $K_{T(trial)}$ and $K_{T(sm)}$

J	$\mathbf{K_{T(trial)}}$	$\mathbf{K_{T(sm)}}$
0.1	16.29657	19.55588
0.2	65.18627	78.22353
0.3	146.6691	176.0029
0.4	260.7451	312.8941
0.5	407.4142	488.8971
0.6	586.6765	704.0118
0.7	798.5319	958.2382
0.8	1042.98	1251.576
0.9	1320.022	1584.026
1.0	1629.657	1955.588
1.1	1971.885	2366.262

Then, applied it into the graph K_T vs J

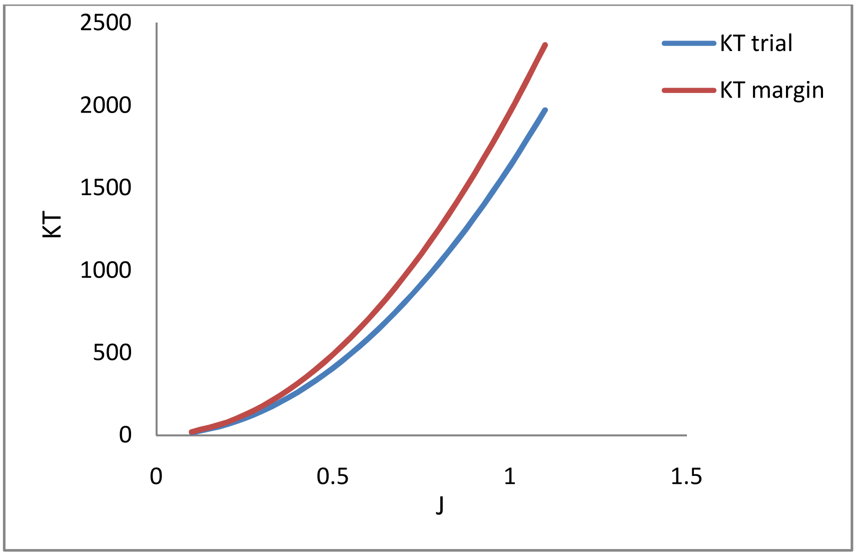


Figure 4.6: K_T vs J

Propeller Characteristic

The characteristic of propeller for fixed pitch propeller were given in constant of:

Thrust coefficient (K_T) = $T/\rho n^2 d^4$

Torque coefficient (K_Q) = $Q/\rho n^2 d^5$

Advance coefficient (J) = V_a/nd

Type : B3-35 P/d : 0.643

Table 4.11: Propeller data coefficients

J	KT	10 KQ	eff
0.000	245.000	277.000	0.000
0.100	235.000	265.000	150.000
0.200	215.000	243.000	280.000
0.295	192.000	222.000	400.000
0.400	160.000	190.000	486.000
0.500	127.000	160.000	545.000
0.600	90.000	128.000	541.000
0.700	45.000	90.000	350.000
0.800	0.000	45.000	79.000
0.900	0.000	0.000	0.000

From the table, the graph of KT, 10KQ, efficiency vs J was constructed.

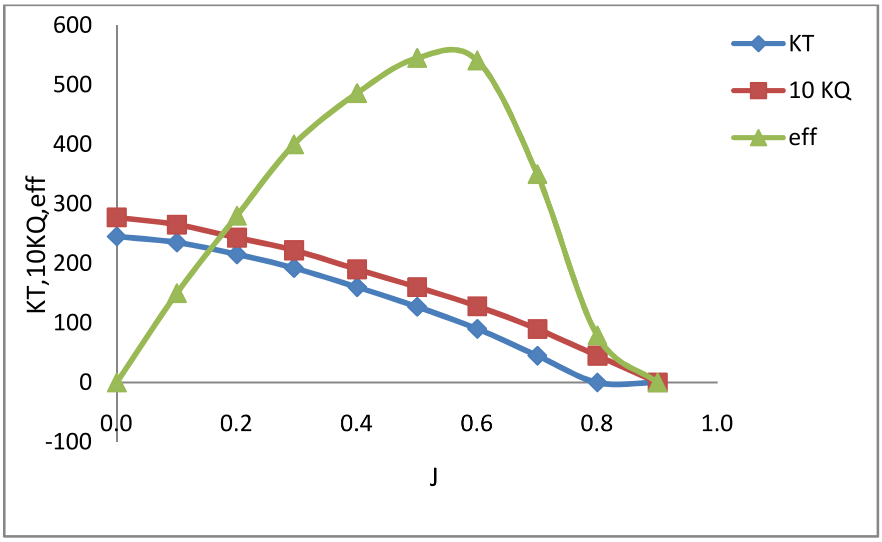


Figure 4.7: KT, 10KQ, efficiency vs J

Then, substitute the graph K_T-J into propeller characteristic graph to show the interaction from propeller kinetic at behind of the ship. So the graph becomes;

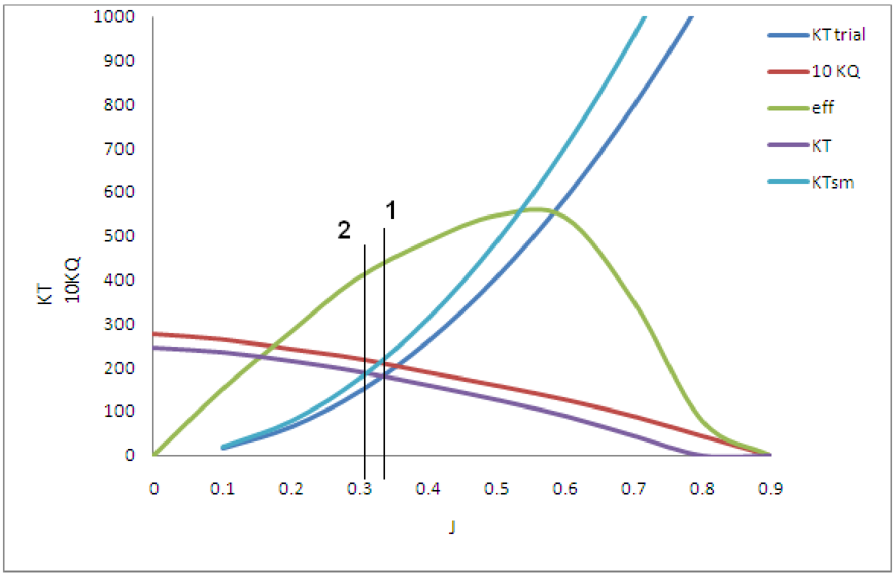


Figure 4.8: KT, 10KQ, efficiency vs J

For the trendline of the propeller thrust coefficient for trial condition, $K_{T(trial)}$. By look at the J(1) line would get the value of propeller torque at trial condition, $K_{Q(trial)}$. While the trendline from propeller thrust coefficient at hull service margin condition and by make the line J(2) until intersect with point $K_{T(sm)}$, thus would get the propeller torque coefficient, $K_{Q(sm)}$at the hull service margins. So, both unknowns, K_Q and $K_{Q(sm)}$ are used to determine the propeller load characteristics.

From the graph, the values are:

$10K_{Q(trial)}$: 210	$K_{Q(trial)}$: 21.0	$K_{T(trial)}$: 180	$\eta_{(trial)}$: 430
$10K_{Q(sm)}$: 219	$K_{Q(sm)}$: 21.9	$K_{T(sm)}$: 187	$\eta_{(sm)}$: 415

For the propeller load characteristic, the variable consist are propeller torque and propeller speed. For the propeller torque, it was from determination of hull and propeller interaction, $K_{Q\ (trial)}$ and $K_{Q(sm)}$.

Table 4.12: Propeller characteristic calculation

Definition	**Symbol**	**Equation**	**Units**	**Value**
γ		$K_{Q(trial)} x \rho_{(seawater)} x d^5$		2703.824
γ^*		$K_{Q(sm)} x \rho_{(seawater)} x d^5$		2819.703
Propeller torque(trial)	Q_{prop}	$K_{Q(trial)} x \rho_{(seawater)} x n^2 x d^5$	Nm	2389099241
Propeller torque(sm)	Q^*_{prop}	$K_{Q(sm)} x \rho_{(seawater)} x n^2 x d^5$	Nm	2491489208
Propeller power(trial)	P_{prop}	$\gamma\ x n^3$	W	
Propeller power(sm)	P^*_{prop}	$\gamma^* x n^3$	W	

The result of the propeller power calculated was tabulated in Table 4.13.

Table 4.13: Propeller power

Rpm,n_p	**rps**	**P_{prop},W**	**P^*_{prop},W**
0	0	0	0
100	1.666667	12517.70556	13054.17866
200	3.333333	100141.6445	104433.4292
300	**5**	**337978.0501**	**352462.8237**
400	6.666667	801133.1559	835467.434
500	8.333333	1564713.195	1631772.332
600	10	2703824.401	2819702.59
700	11.66667	4293573.007	4477583.279
800	13.33333	6409065.247	6683739.472
900	15	9125407.354	9516496.24
1000	16.66667	12517705.56	13054178.66

Then, take the RPM at 300 as the reference point. At the condition, the propeller power is 337978.0501W. After that, an engine that produces power near the propeller power was chose.

Table 4.14: Engine specification

Engine Type	**YANMAR** **6LY3-ETP 480 hp / kW 353**
Number of cylinder	6-inline
Output at crankshaft hp/kW	480 / 353
Rated Speed rpm	3300
Displacement L / cu in	5.813 / 354
Standard drive	
Weight with gear/drive Kg (lbs)	640 (1411)

Then, from the engine characteristic, tabulate the data for rpm value after reduction by gearbox and the power output.

Table 4.15: Engine power output

rpm	**kW**	**W**
0	0	0
100	71.5872	71587.2
200	143.1744	143174.4
300	214.7616	214761.6
400	286.3488	286348.8
500	357.936	357936

Lastly, plot a graph that combine the propeller load characteristic combine with the engine characteristic.

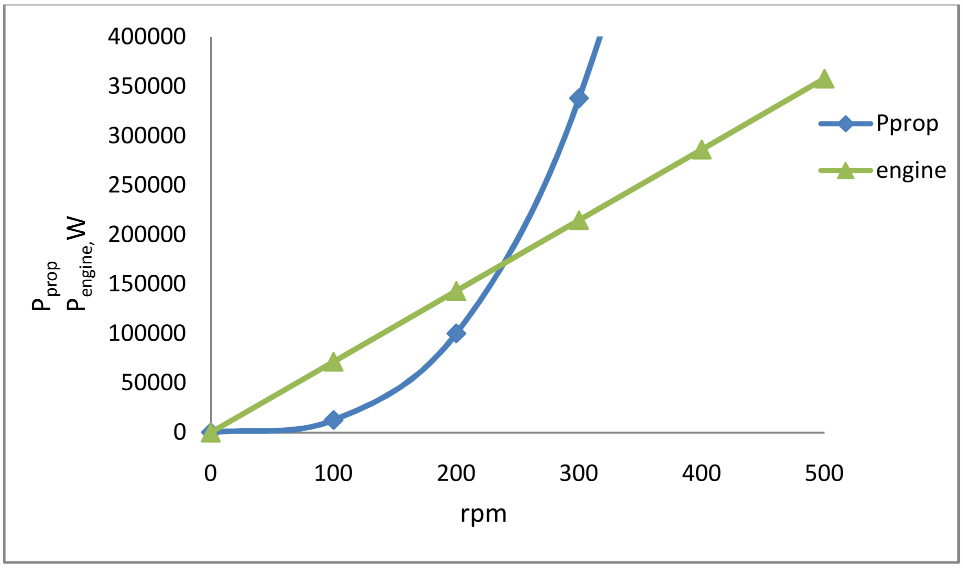


Figure 4.9: Matching point for engine and propeller

From the figure above, the values at the intersection point are 240rpm and 170kW or 225hp for propeller power absorb while the engine power from data collected is 103hp. At the intersection point, there is a suitable operational point with the propeller load condition. This is because, the power produce by the engine are same with the power absorb by the propeller. Thus, that will give the optimal consequence toward the fuel consumption by the engine power with acquired speed.

Generally, only the engine speed (rpm) and fishing vessel speed (knots) can be seen in the indicator. So, the setting of engine operation is the key of the operational propulsion system to make it effective.

Fishing vessel 3

From results of ship resistance and ship power, a propeller was chosen to match with a engine. All the calculation in this part was using 8 knots or 4.1152 m/s as its speed

Propeller data

Type	: B3-35
ηpropeller	: 53.50%
P/d	: 0.643
Diameter (d)	: 0.6604
RPM	: 975

Calculation of advance coefficient (a):

$$a_w = 0.5 \times \rho_{sea\ water} \times A_S \times C_T$$

$$a_w = 483.2667536$$

$$a_{AA} = 0.5 \times \rho_{air} \times A_S \times C_T$$

$$a_{AA} = 0.576619746$$

Where: $\rho_{sea\ water} = 1025\ kg/m^3$

$\rho_{air} = 1.223\ kg/m^3$

Calculation of KT-J diagram

Table 4.16: Calculation of KT-J diagram

Definition	**Symbol**	**Equation**	**Value**
		$(1-t) \times (1-w)^2 \times \rho_{seawater} \times d^2 / 1000$	0.210156611
Thrust coefficient(air)	K_{TAA}	$a_{AA} \times J^2 / (1-t) \times (1-w)^2 \times \rho \times d^2$	$2.743762109J^2$
Thrust coefficient(water)	K_{TW}	$a_W \times J^2 / (1-t) \times (1-w)^2 \times \rho \times D^2$	$2299.555324J^2$
Thrust coefficient(trial)	$K_{T(trial)}$	$K_{TAA}+K_{TW}$	$2302.299087J^2$
Thrust coefficient(sea margins)	$K_{T(sm)}$	$K_{T(trial)}$+20%	2762.758904

For the sea margins is usually ±20% and it is add as the allowances to the $K_{T(trial)}$ value. Next, all the values of K_T will multiply with the J value. The J value is set up like in the table below. So, the results are:

Table 4.17: Result of $K_{T(trial)}$ and $K_{T(sm)}$

J	$K_{T(trial)}$	$K_{T(sm)}$
0.1	23.02299	27.62759
0.2	92.09196	110.5104
0.3	207.2069	248.6483
0.4	368.3679	442.0414
0.5	575.5748	690.6897
0.6	828.8277	994.5932
0.7	1128.127	1353.752
0.8	1473.471	1768.166
0.9	1864.862	2237.835
1.0	2302.299	2762.759
1.1	2785.782	3342.938

Then, applied it into the graph K_T vs J

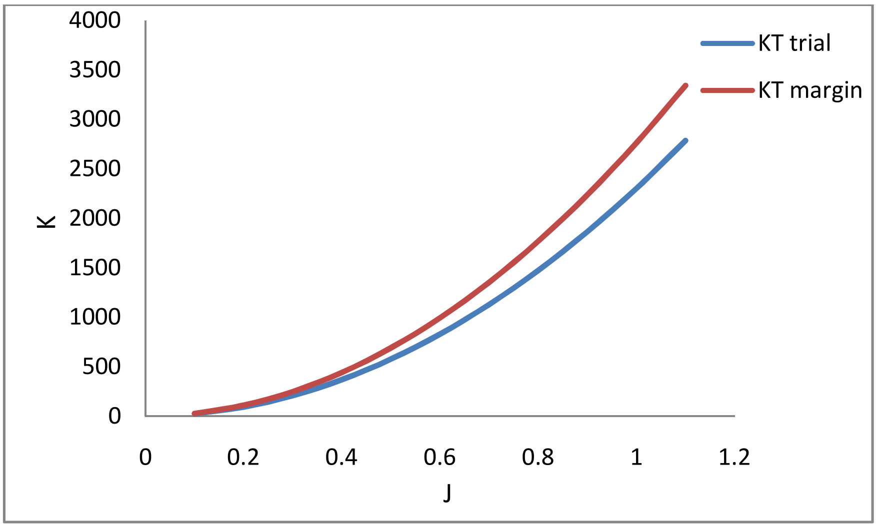


Figure 4.10: KT vs J

Propeller Characteristic

The characteristic of propeller for fixed pitch propeller were given in constant of:

Thrust coefficient (KT) = $T/\rho n^2 d^4$

Torque coefficient (KQ) = $Q/\rho n^2 d^5$

Advance coefficient (J) = V_a/nd

Type : B3-35 P/d : 0.643

Table 4.18: Propeller data coefficients

J	**KT**	**10 KQ**	**eff**
0.000	245.000	277.000	0.000
0.100	235.000	265.000	150.000
0.200	215.000	243.000	280.000
0.295	192.000	222.000	400.000
0.400	160.000	190.000	486.000
0.500	127.000	160.000	545.000
0.600	90.000	128.000	541.000
0.700	45.000	90.000	350.000
0.800	0.000	45.000	79.000
0.900	0.000	0.000	0.000

From the table 4.18, the graph of KT, 10KQ, efficiency vs J was constructed.

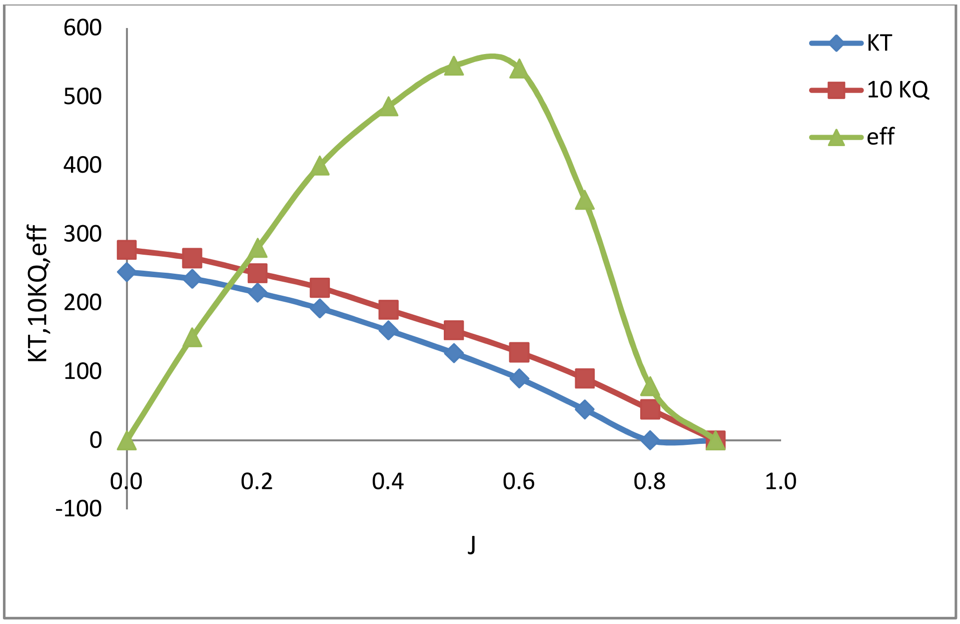


Figure 4.11: KT, 10KQ, efficiency vs J

Then, substitute the graph K_T-J into propeller characteristic graph to show the interaction from propeller kinetic at behind of the ship. So the graph becomes;

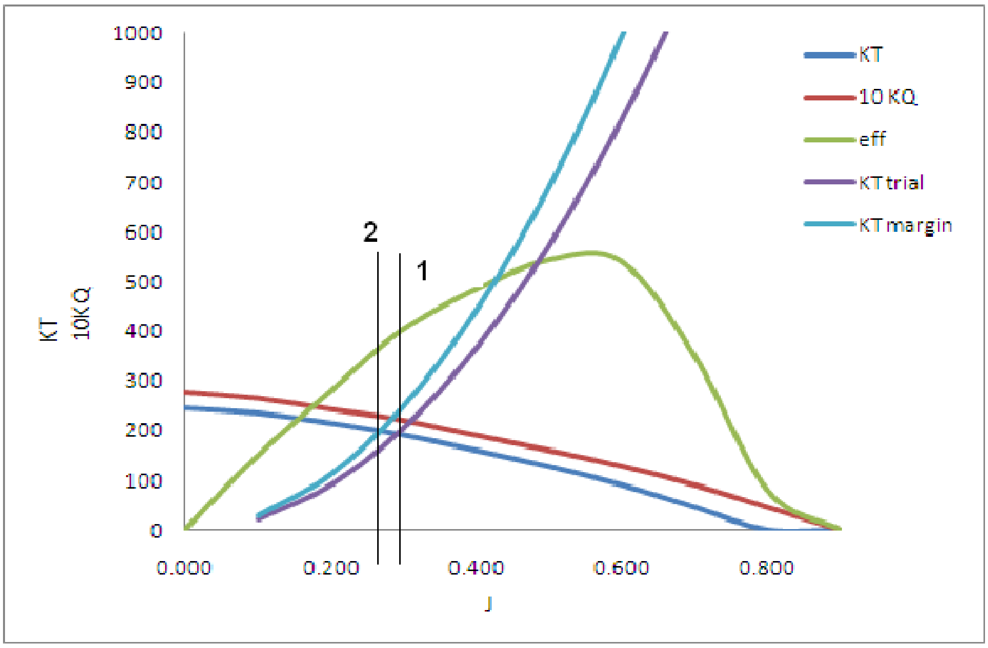


Figure 4.12: KT, 10KQ, efficiency vs J

For the trendline of the propeller thrust coefficient for trial condition, $K_{T(trial)}$. By look at the J(1) line would get the value of propeller torque at trial condition, $K_{Q(trial)}$. While the trendline from propeller thrust coefficient at hull service margin condition and by make the line J(2) until intersect with point $K_{T(sm)}$, thus would get the propeller torque coefficient, $K_{Q(sm)}$at the hull service margins. So, both unknowns, K_Q and $K_{Q(sm)}$ are used to determine the propeller load characteristics.

From the graph, the values are:

$10K_{Q(trial)}$: 225	$K_{Q(trial)}$: 22.5	$K_{T(trial)}$: 191	$\eta_{(trial)}$: 400
$10K_{Q(sm)}$: 230	$K_{Q(sm)}$: 23.0	$K_{T(sm)}$: 199	$\eta_{(sm\ )}$: 360

For the propeller load characteristic, the variable consist are propeller torque and propeller speed. For the propeller torque, it was from determination of hull and propeller interaction, $K_{Q\ (trial)}$ and $K_{Q(sm)}$.

Table 4.19: Propeller characteristic calculation

Definition	**Symbol**	**Equation**	**Units**	**Value**
γ		$K_{Q(trial)} x \rho_{(seawater)} x d^5$		3498.595937
γ*		$K_{Q(sm)} x \rho_{(seawater)} x d^5$		3576.342513
Propeller torque(trial)	Q_{prop}	$K_{Q(trial)} x \rho_{(seawater)} x n^2 x d^5$	Nm	3325852762
Propeller torque(sm)	Q^*_{prop}	$K_{Q(sm)} x \rho_{(seawater)} x n^2 x d^5$	Nm	3399760601
Propeller power(trial)	P_{prop}	γ xn	W	
Propeller power(sm)	P^*_{prop}	γ*xn	W	

The result of the propeller power calculated was tabulated in Table 4.20.

Table 4.20: Propeller power

Rpm,n_p	rps	P_{prop},W	P^*_{prop},W
0	0	0	0
100	1.666667	16197.20341	16557.14126
200	3.333333	129577.6273	132457.1301
300	**5**	**437324.4921**	**447042.8141**
400	6.666667	1036621.018	1059657.041
500	8.333333	2024650.426	2069642.658
600	10	3498595.937	3576342.513
700	11.66667	5555640.77	5679099.453
800	13.33333	8292968.146	8477256.327
900	15	11807761.29	12070155.98
1000	16.66667	16197203.41	16557141.26

Then, take the RPM at 300 as the reference point. At the condition, the propeller power is 437324.4921 W. After that, an engine that produces power near the propeller power was chose.

Table 4.21: Engine specification

Engine Type	**YANMAR** **6SY-720 720 hp / kW 530**
Number of cylinder	6-inline
Output at crankshaft mhp/kW	720 / 530
Rated Speed rpm	2300
Displacement L / cu in	11.7 / 714
Standard drive	
Weight with gear/drive Kg (lbs)	1150 (2536)

Then, from the engine characteristic, tabulate the data for rpm value after reduction by gearbox and the power output.

Table 4.22: Engine power output

rpm	kW	W
0	0	0
100	107.3808	107380.8
200	214.7616	214761.6
300	322.1424	322142.4
400	429.5232	429523.2
500	536.904	536904

Lastly, plot a graph that combine the propeller load characteristic combine with the engine characteristic.

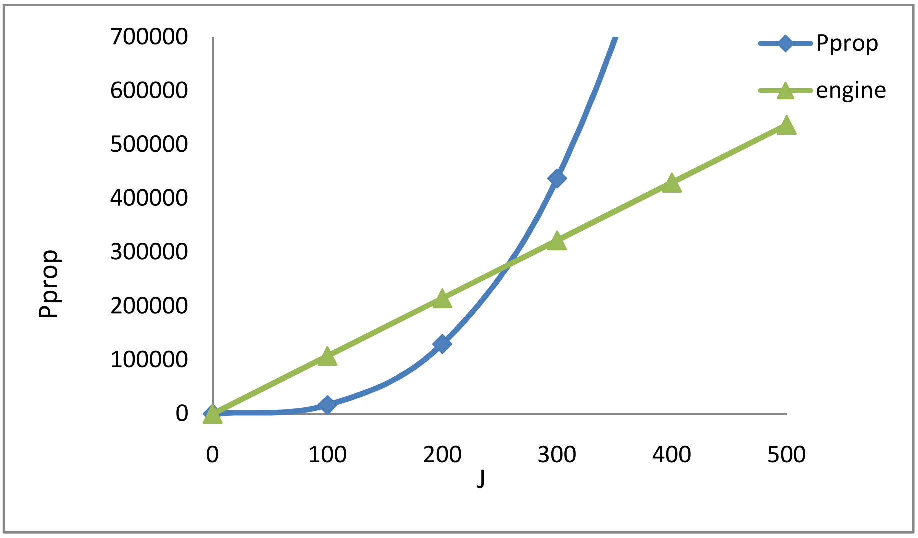


Figure 4.13: Matching point for engine and propeller

From the figure above, the values at the intersection point are 260rpm and 280kW or 375hp for propeller power absorb while the engine power from data collected is 145hp. At the intersection point, there is a suitable operational point with the propeller load condition. This is because, the power produce by the engine are same with the power absorb by the propeller. Thus, that will give the optimal consequence toward the fuel consumption by the engine power with acquired speed.

Generally, only the engine speed (rpm) and fishing vessel speed (knots) can be seen in the indicator. So, the setting of engine operation is the key of the operational propulsion system to make it effective.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

As a conclusion for this project, learning, researching and problem solving process based on calculation are achieved as well. The objective is achieved when all the calculation have done.

For the fishing vessel 1 that its length overall is 12.2m, operated with speed 8knots, the total resistance is 5.217kN. The type of propeller chose is B3-35 and the engine is Yanmar 4BY-180Z 180hp. Thus, the result for the matching point is 190rpm for propeller speed and 49hp for the engine power. Then, for the fishing vessel 2 that its length overall is 13.11m, also operated with speed 8knots, the total resistance is 6.176kN. The propeller type chose is B3-35 and the engine is Yanmar 6LY-ETP 480hp. As the result for the matching point is 240rpm for propeller speed and 225hp for the engine power. While, for the Fishing Vessel 3 that its length overall is 16.52m and operated with speed 8knots, the total resistance is 9.237kN. The propeller type chose is B3-35 and the engine is Yanmar 6SY-720 720hp. So, the matching point is 260rpm for propeller speed and 375hp for the engine power.

At the matching point, the operation of engine and propeller is in good combination. As the result from the literature review, theoretically the combination will give good performance, economical fuel consumption and better for engine life

5.2 RECOMMENDATION

For the recommendation, I suggest that, the engine-propeller matching point finding must be continued by using software like computational fluid mechanics (CFD).it is because, the comparison of calculation result can be seen after using the software. Next, the way of taking data, by surveying only, the data are not very accurate. Furthermore, the technical drawing of fishing vessel is hard to get even at the fishing vessel factory. From the registration of boat also it lack of data required. As a suggestion, the researcher must go to the fishing vessel factory to get the exact data and luckily when the fishing vessel is not in the water.

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APPENDICES

APPENDIX A

CALCULATION OF SHIP RESISTANCE FOR FISHING VESSEL 1

DEFINITION	SYMBOL	EQUATION	UNIT	SPEED 1	SPEED 2	SPEED 3	SPEED 4
Length overall	L_{OA}		m	12,20000	12,20000	12,20000	12,20000
Length between perpendiculars	L_{PP}	0.85L_{OA}	m	10,37000	10,37000	10,37000	10,37000
Length waterline	L_{WL}	L_{PP}/0.97	m	10,69072	10,69072	10,69072	10,69072
Block coefficient	C_B			0,60000	0,60000	0,60000	0,60000
Density of sea water	ρ		ton/m^3	1,02500	1,02500	1,02500	1,02500
Breadth on waterline	B_{WL}		m	3,20000	3,20000	3,20000	3,20000
Draught	D		m	0,91000	0,91000	0,91000	0,91000
	H	3xD	m	2,73000	2,73000	2,73000	2,73000
Volume displacement	?	L_{WL} x B_{WL} x D x C_B	m^3	18,67883	18,67883	18,67883	18,67883
Displacement	Δ	? x ρ	ton	19,14580	19,14580	19,14580	19,14580
Wetted surface area	A_S	ρ x L_{PP} x ((C_B x B_{WL}) + (1.7 x D))	m^2	36,85161	36,85161	36,85161	36,85161
Ship velocity	V_S		knots	6,00000	8,00000	10,00000	12,00000
Ship velocity	V_S	V_S x 0,5144	m/s	3,08640	4,11520	5,14400	6,17280
Gravity	g		m/s2	9,81000	9,81000	9,81000	9,81000
Froude number coefficient	Fn	VS/(g x LWL)^0.5		0,30138	0,40184	0,50230	0,60276
Viscousity of sea water@15°C	ϕ	8.493*10^0.5		0,00000	0,00000	0,00000	0,00000
Renould number	Rn	VS x LWL/ϕ		38.850.633,81487	51.800.845,08649	64.751.056,35812	77.701.267,62974
		(LWL^3/?)^(1/3)		4,02925	4,02925	4,02925	4,02925
	β	(0.08 x CB)+0.93		0,97800	0,97800	0,93000	0,93000
Prismatic coefficient	C_P	CB/β		0,61350	0,61350	0,64516	0,64516
	a			4,00000	4,00000	4,00000	4,00000
	2a			4,02925	4,02925	4,02925	4,02925
	3a			4,50000	4,50000	4,50000	4,50000
	b			0,00830	0,00830	0,00830	0,00830
	3b			0,00750	0,00750	0,00750	0,00750
interpolation of CR		(b+(2a-1a)x(3b-1b))(3a-1a)		0,00825	0,00825	0,00825	0,00825
ratio		B/D		3,51648	3,51648	3,51648	3,51648
correction depend on B/T		(CR(2.5)+0.16(B/D-2.5)		0,00978	0,00978	0,00978	0,00978
		e%		0,00700	0,00700	0,00700	0,00700
Longitudinal centre of bouyancy	LCB	e%xLdisp		0,07484	0,07484	0,07484	0,07484
propeller percentage		X	%	3,00000	3,00000	3,00000	3,00000
correction because of propeller		(1+X%)CR		0,01007	0,01007	0,01007	0,01007
shaft percentage		Y	%	5,00000	5,00000	5,00000	5,00000
correction because of shaft		(1+Y%)CR		0,01057	0,01057	0,01057	0,01057
Coefficient of residual resistanc	C_R			0,01109	0,01109	0,01109	0,01109
		log Rn		7,58940	7,71434	7,81125	7,89043
Coefficient of frictional resistan	C_F	0.075/(log Rn-2)^2		0,00240	0,00230	0,00222	0,00216
temperature	t		°C	30,00000	30,00000	30,00000	30,00000
CF @ 30		CF(std) x (1+0.0043(15-t))		0,00225	0,00215	0,00208	0,00202
Coefficient of Advance	C_A	0.4+[(LWL-100)x(0.2-0.4)/(150-100)]x10^-3		0,00076	0,00076	0,00076	0,00076
Coefficient of air resistance	CAA	0.006x(LWL+100)^(-0.16)-0.00205		0,00078	0,00078	0,00078	0,00078
propel	CAS	0.04x10^-3		0,00004	0,00004	0,00004	0,00004
Total Coefficient	CT	(CR+CF+CA+CAS)x10^-3		0,01429	0,01418	0,01411	0,01405
Air pressure	Pair		kg/m3	1,22300	1,22300	1,22300	1,22300
air resistance	RAA	CAAx0.5xPairxVS^2xcompartment		0,10841	0,19274	0,30115	0,43366
Water resistance	RW	CTx0.5xρxVS^2xAS		2.570,53283	4.536,62753	7.050,51627	10.110,06445
Total Resistance	RT	RW+RAA	N	2.570,64125	4.536,82027	7.050,81742	10.110,49811
East asia shipping line		Z	%	15,00000	15,00000	15,00000	15,00000
Total Resistance (std)	RT(std)	RTxZ	N	2.956,23743	5.217,34331	8.108,44003	11.627,07282
Effective power	EHP	RT(std)xVS	kW	9,12413	21,47041	41,70982	71,77160
Effective power	EHP	1Hp=0.7457kW	Hp	12,23566	28,79229	55,93377	96,24728

APPENDIX B

CALCULATION OF SHIP RESISTANCE FOR FISHING VESSEL 2

DEFINITION	SYMBOL	EQUATION	UNIT	SPEED 1	SPEED 2	SPEED 3	SPEED 4
Length overall	L_{OA}		m	13,1064	13,1064	13,1064	13,1064
Length between perpendiculars	L_{PP}	$0.85L_{OA}$	m	11,14044	11,14044	11,14044	11,14044
Length waterline	L_{WL}	$L_{PP}/0.97$	m	11,48499	11,48499	11,48499	11,48499
Block coefficient	C_B			0,60000	0,60000	0,60000	0,60000
Density of sea water	ρ		ton/m^3	1,02500	1,02500	1,02500	1,02500
Breadth on waterline	B_{WL}		m	3,3258	3,3258	3,3258	3,3258
Draught	D		m	1,0668	1,0668	1,0668	1,0668
	H	3xD	m	3,2004	3,2004	3,2004	3,2004
Volume displacement	?	L_{WL} x B_{WL} x D x C_B	m^3	24,44899	24,44899	24,44899	24,44899
Displacement	Δ	? x ρ	ton	25,06022	25,06022	25,06022	25,06022
Wetted surface area	A_S	ρ x L_{PP} x ((C_B x B_{WL}) + (1.7 x D))	m^2	43,49524	43,49524	43,49524	43,49524
Ship velocity	V_S		knots	6,00000	8,00000	10,00000	12,00000
Ship velocity	V_S	V_S x 0,5144	m/s	3,08640	4,11520	5,14400	6,17280
Gravity	g		m/s2	9,81000	9,81000	9,81000	9,81000
Froude number coefficient	Fn	VS/(g x LWL)^0.5		0,29077	0,38770	0,48462	0,58154
Viscousity of sea water@15°C	ϕ	8.493*10^0.5		0,00000	0,00000	0,00000	0,00000
Renould number	Rn	VS x LWL/ϕ		41.737.044,83862	55.649.393,11817	69.561.741,39771	83.474.089,67725
		(LWL^3/?)^(1/3)		3,95710	3,95710	3,95710	3,95710
	β	(0.08 x CB)+0.93		0,97800	0,97800	0,93000	0,93000
Prismatic coefficient	C_P	CB/β		0,61350	0,61350	0,64516	0,64516
	a			4,00000	4,00000	4,00000	4,00000
	2a			4,02925	4,02925	4,02925	4,02925
	3a			4,50000	4,50000	4,50000	4,50000
	b			0,00830	0,00830	0,00830	0,00830
	3b			0,00750	0,00750	0,00750	0,00750
interpolation of CR		(b+(2a-1a)x(3b-1b))(3a-1a)		0,00825	0,00825	0,00825	0,00825
ratio		B/D		3,11755	3,11755	3,11755	3,11755
correction depend on B/T		(CR(2.5)+0.16(B/D-2.5)		0,00984	0,00984	0,00984	0,00984
		e%		0,00700	0,00700	0,00700	0,00700
Longitudinal centre of bouyancy	LCB	e%xLdisp		0,08039	0,08039	0,08039	0,08039
propeller percentage		X	%	3,00000	3,00000	3,00000	3,00000
correction because of propeller		(1+X%)CR		0,01013	0,01013	0,01013	0,01013
shaft percentage		Y	%	5,00000	5,00000	5,00000	5,00000
correction because of shaft		(1+Y%)CR		0,01064	0,01064	0,01064	0,01064
Coefficient of residual resistance	C_R			0,01116	0,01116	0,01116	0,01116
		log Rn		7,62052	7,74546	7,84237	7,92155
Coefficient of frictional resistance	C_F	0.075/(log Rn-2)^2		0,00237	0,00227	0,00220	0,00214
temperature	t		°C	30,00000	30,00000	30,00000	30,00000
CF @ 30		CF(std) x (1+0.0043(15-t))		0,00222	0,00213	0,00206	0,00200
Coefficient of Advance	C_A	0.4+[(LWL-100)x(0.2-0.4)/(150-100)]x10^-3		0,00075	0,00075	0,00075	0,00075
Coefficient of air resistance	CAA	0.006x(LWL+100)^(-0.16)-0.00205		0,00077	0,00077	0,00077	0,00077
kemudi	CAS	0.04x10^-3		0,00004	0,00004	0,00004	0,00004
Total Coefficient	CT	(CR+CF+CA+CAS)x10^-3		0,01433	0,01423	0,01415	0,01409
Air pressure	Pair		kPa	1,22300	1,22300	1,22300	1,22300
air resistance	RAA	CAAx0.5xPairxcompartment		0,11221	0,19948	0,31169	0,44883
Water resistance	RW	CTx0.5xρxVS^2xAS		3.042,50953	5.370,35091	8.347,08313	11.970,22199
Total Resistance	RT	RW+RAA	N	3.042,62174	5.370,55039	8.347,39481	11.970,67082
East asia shipping line		Z	%	15,00000	15,00000	15,00000	15,00000
Total Resistance (std)	RT(std)	RTxZ	N	3.499,01500	6.176,13295	9.599,50404	13.766,27144
Effective power	EHP	RT(std)xVS	kW	10,79936	25,41602	49,37985	84,97644
Effective power	EHP	1Hp=0.7457kW	Hp	14,48218	34,08344	66,21946	113,95526

APPENDIX C

CALCULATION OF SHIP RESISTANCE FOR FISHING VESSEL 3

DEFINITION	SYMBOL	EQUATION	UNIT	SPEED 1	SPEED 2	SPEED 3	SPEED 4
Length overall	L_{OA}		m	16,5200	16,5200	16,5200	16,5200
Length between perpendiculars	L_{PP}	0.85L_{OA}	m	14,04200	14,04200	14,04200	14,04200
Length waterline	L_{WL}	L_{PP}/0.97	m	14,47629	14,47629	14,47629	14,47629
Block coefficient	C_B			0,60000	0,60000	0,60000	0,60000
Density of sea water	ρ		ton/m^3	1,02500	1,02500	1,02500	1,02500
Breadth on waterline	B_{WL}		m	4,5000	4,5000	4,5000	4,5000
Draught	D		m	1,1200	1,1200	1,1200	1,1200
	H	3xD	m	3,3600	3,3600	3,3600	3,3600
Volume displacement	?	L_{WL} x B_{WL} x D x C_B	m^3	43,77630	43,77630	43,77630	43,77630
Displacement	Δ	? x ρ	ton	44,87070	44,87070	44,87070	44,87070
Wetted surface area	A_S	ρ x L_{PP} x ((C_B x B_{WL}) + (1.7 x D))	m^2	66,26560	66,26560	66,26560	66,26560
Ship velocity	V_S		knots	6,00000	8,00000	10,00000	12,00000
Ship velocity	V_S	V_S x 0,5144	m/s	3,08640	4,11520	5,14400	6,17280
Gravity	g		m/s2	9,81000	9,81000	9,81000	9,81000
Froude number coefficient	Fn	VS/(g x LWL)^0.5		0,25899	0,34532	0,43166	0,51799
Viscousity of sea water@15°C	ϕ	8.493*10^0.5		0,00000	0,00000	0,00000	0,00000
Renould number	Rn	VS x LWL/ϕ		52.607.579,55915	70.143.439,41220	87.679.299,26525	105.215.159,11830
		(LWL^3/?)^(1/3)		4,10750	4,10750	4,10750	4,10750
	β	(0.08 x CB)+0.93		0,97800	0,97800	0,93000	0,93000
Prismatic coefficient	C_P	CB/β		0,61350	0,61350	0,64516	0,64516
	a			4,00000	4,00000	4,00000	4,00000
	2a			4,02925	4,02925	4,02925	4,02925
	3a			4,50000	4,50000	4,50000	4,50000
	b			0,00830	0,00830	0,00830	0,00830
	3b			0,00750	0,00750	0,00750	0,00750
interpolation of CR		(b+(2a-1a)x(3b-1b))(3a-1a)		0,00825	0,00825	0,00825	0,00825
ratio		B/D		4,01786	4,01786	4,01786	4,01786
correction depend on B/T		(CR(2.5)+0.16(B/D-2.5)		0,00970	0,00970	0,00970	0,00970
		e%		0,00700	0,00700	0,00700	0,00700
Longitudinal centre of bouyancy	LCB	e%xLdisp		0,10133	0,10133	0,10133	0,10133
propeller percentage		X	%	3,00000	3,00000	3,00000	3,00000
correction because of propeller		(1+X%)CR		0,00999	0,00999	0,00999	0,00999
shaft percentage		Y	%	5,00000	5,00000	5,00000	5,00000
correction because of shaft		(1+Y%)CR		0,01049	0,01049	0,01049	0,01049
Coefficient of residual resistanc	C_R			0,01099	0,01099	0,01099	0,01099
		log Rn		7,72105	7,84599	7,94290	8,02208
Coefficient of frictional resistan	C_F	0.075/(log Rn-2)^2		0,00229	0,00219	0,00212	0,00207
temperature	t		°C	30,00000	30,00000	30,00000	30,00000
CF @ 30		CF(std) x (1+0.0043(15-t))		0,00214	0,00205	0,00199	0,00193
Coefficient of Advance	C_A	0.4+[(LWL-100)x(0.2-0.4)/(150-100)]x10^-3		0,00074	0,00074	0,00074	0,00074
Coefficient of air resistance	CAA	0.006x(LWL+100)^(-0.16)-0.00205		0,00076	0,00076	0,00076	0,00076
kemudi	CAS	0.04x10^-3		0,00004	0,00004	0,00004	0,00004
Total Coefficient	CT	(CR+CF+CA+CAS)x10^-3		0,01406	0,01397	0,01390	0,01384
Air pressure	Pair		kg/m3	1,22300	1,22300	1,22300	1,22300
air resistance	RAA	CAAx0.5xPairxcompartment		0,14948	0,26574	0,41521	0,59791
Water resistance	RW	CTx0.5xρxVS^2xAS		4.549,68348	8.032,59768	12.487,14067	17.909,69444
Total Resistance	RT	RW+RAA	N	4.549,83296	8.032,86342	12.487,55588	17.910,29235
East asia shipping line		Z	%	15,00000	15,00000	15,00000	15,00000
Total Resistance (std)	RT(std)	RTxZ	N	5.232,30790	9.237,79293	14.360,68927	20.596,83620
Effective power	EHP	RT(std)xVS	kW	16,14900	38,01537	73,87139	127,14015
Effective power	EHP	1Hp=0.7457kW	Hp	21,65616	50,97944	99,06314	170,49772

APPENDIX D

CALCULATION OF SHIP POWER FOR FISHING VESSEL 1

DEFINITION	SYMBOL	EQUATION	UNIT	SPEED 1	SPEED 2	SPEED 3	SPEED 4
Length overall	L_{OA}		m	12,20000	12,20000	12,20000	12,20000
Length between perpendi	L_{PP}	0.85L_{OA}	m	10,37000	10,37000	10,37000	10,37000
Length waterline	L_{WL}	L_{PP}/0.97	m	10,69072	10,69072	10,69072	10,69072
Block coefficient	C_B			0,60000	0,60000	0,60000	0,60000
Breadth on waterline	B_{WL}		m	3,20000	3,20000	3,20000	3,20000
Draught	D		m	0,91000	0,91000	0,91000	0,91000
Ship velocity	V_S		knots	6,00000	8,00000	10,00000	12,00000
Ship velocity	V_S	V_S x 0,5144	m/s	3,08640	4,11520	5,14400	6,17280
Total Resistance (std)	RT(std)	RTxZ	N	2.956,23743	5.217,34331	8.108,44003	11.627,07282
Effective power	EHP	RT(std)xVS	Hp	12,23566	28,79229	55,93377	96,24728
Wake fraction	w	(0.5xCB)-0.05		0,25000	0,25000	0,25000	0,25000
	k			0,90000	0,90000	0,90000	0,90000
Thrust deduction factor	t	k x w		0,22500	0,22500	0,22500	0,22500
advance velocity	Va	(1-w)xVS	m/s	2,31480	3,08640	3,85800	4,62960
Hull efficiency	ηH	(1-t)/1-w)		1,03333	1,03333	1,03333	1,03333
Thrust	T	RT/(1-t)	N	3.814,49991	6.732,05588	10.462,50326	15.002,67461
Thrust horse power	THP	EHP/ηH	Hp	11,84096	27,86351	54,12945	93,14253
relative rotative efficiency	ηrr			1,05000	1,05000	1,05000	1,05000
Propeller efficency	ηP			0,45000	0,45000	0,45000	0,45000
Propulsive coefficient	PC	ηHxηrrxηP		0,48825	0,48825	0,48825	0,48825
Delivery horse power	DHP	EHP/PC	Hp	25,06024	58,97038	114,55969	197,12705
Shaft & Brake efficiency	ηSηB			0,98000	0,98000	0,98000	0,98000
Shaft horse power	SHP	DHP/ηSηB	Hp	25,57167	60,17386	116,89765	201,15005
Gear efficiency	ηG			0,98000	0,98000	0,98000	0,98000
Brake horse power	BHPSCR	SHP/ηG	Hp	26,09354	61,40190	119,28331	205,25515
Brake horse power	BHPMCR	BHPSCR/0.85	HP	30,69828	72,23753	140,33331	241,47665

APPENDIX E

CALCULATION OF SHIP POWER FOR FISHING VESSEL 2

DEFINITION	SYMBOL	EQUATION	UNIT	SPEED 1	SPEED 2	SPEED 3	SPEED 4
Length overall	L_{OA}		m	13,1064	13,1064	13,1064	13,1064
Length between perper	L_{PP}	$0.85L_{OA}$	m	11,14044	11,14044	11,14044	11,14044
Length waterline	L_{WL}	$L_{PP}/0.97$	m	11,48499	11,48499	11,48499	11,48499
Block coefficient	C_B			0,60000	0,60000	0,60000	0,60000
Breadth on waterline	B_{WL}		m	3,3258	3,3258	3,3258	3,3258
Draught	D		m	1,0668	1,0668	1,0668	1,0668
Ship velocity	V_S		knots	6,00000	8,00000	10,00000	12,00000
Ship velocity	V_S	V_S x 0,5144	m/s	3,08640	4,11520	5,14400	6,17280
Total Resistance (std)	RT(std)	RTxZ	N	3.499,26922	6.176,58489	9.600,21020	13.767,28831
Effective power	EHP	RT(std)xVS	Hp	14,48323	34,08594	66,22433	113,96368
Wake fraction	w	(0.5xCB)-0.05		0,25000	0,25000	0,25000	0,25000
	k			0,90000	0,90000	0,90000	0,90000
Thrust deduction factor	t	k x w		0,22500	0,22500	0,22500	0,22500
advance velocity	Va	(1-w)xVS	m/s	2,31480	3,08640	3,85800	4,62960
Hull efficiency	ηH	(1-t)/1-w)		1,03333	1,03333	1,03333	1,03333
Thrust	T	RT/(1-t)	N	4.515,18609	7.969,78695	12.387,36800	17.764,24298
Thrust horse power	THP	EHP/ηH	Hp	14,01603	32,98639	64,08806	110,28743
relative rotative efficie	ηrr			1,05000	1,05000	1,05000	1,05000
Propeller efficency	ηP			0,45000	0,45000	0,45000	0,45000
Propulsive coefficient	PC	ηHxηrrxηP		0,48825	0,48825	0,48825	0,48825
Delivery horse power	DHP	EHP/PC	Hp	29,66355	69,81247	135,63611	233,41256
Shaft & Brake efficiency	ηSηB			0,98000	0,98000	0,98000	0,98000
Shaft horse power	SHP	DHP/ηSηB	Hp	30,26893	71,23722	138,40419	238,17608
Gear efficiency	ηG			0,98000	0,98000	0,98000	0,98000
Brake horse power	BHPSCR	SHP/ηG	Hp	30,88667	72,69104	141,22877	243,03681
Brake horse power	BHPMCR	BHPSCR/0.85	HP	36,33725	85,51887	166,15149	285,92566

APPENDIX F

CALCULATION OF SHIP POWER FOR FISHING VESSEL 3

DEFINITION	SYMBOL	EQUATION	UNIT	SPEED 1	SPEED 2	SPEED 3	SPEED 4
Length overall	L_{OA}		m	16,5200	16,5200	16,5200	16,5200
Length between perper	L_{PP}	$0.85L_{OA}$	m	14,04200	14,04200	14,04200	14,04200
Length waterline	L_{WL}	$L_{PP}/0.97$	m	14,47629	14,47629	14,47629	14,47629
Block coefficient	C_B			0,60000	0,60000	0,60000	0,60000
Breadth on waterline	B_{WL}		m	4,5000	4,5000	4,5000	4,5000
Draught	D		m	1,1200	1,1200	1,1200	1,1200
Ship velocity	V_S		knots	6,00000	8,00000	10,00000	12,00000
Ship velocity	V_S	V_S x 0,5144	m/s	3,08640	4,11520	5,14400	6,17280
Total Resistance (std)	RT(std)	RTxZ	N	5.232,51334	9.238,15815	14.361,25933	20.597,65795
Effective power	EHP	RT(std)xVS	Hp	21,65701	50,98145	99,06708	170,50452
Wake fraction	w	(0.5xCB)-0.05		0,25000	0,25000	0,25000	0,25000
	k			0,90000	0,90000	0,90000	0,90000
Thrust deduction factor	t	k x w		0,22500	0,22500	0,22500	0,22500
advance velocity	Va	(1-w)xVS	m/s	2,31480	3,08640	3,85800	4,62960
Hull efficiency	ηH	(1-t)/1-w)		1,03333	1,03333	1,03333	1,03333
Thrust	T	RT/(1-t)	N	6.751,63012	11.920,20406	18.530,65720	26.577,62316
Thrust horse power	THP	EHP/ηH	Hp	20,95840	49,33689	95,87137	165,00437
relative rotative efficie	ηrr			1,05000	1,05000	1,05000	1,05000
Propeller efficency	ηP			0,45000	0,45000	0,45000	0,45000
Propulsive coefficient	PC	ηHxηrrxηP		0,48825	0,48825	0,48825	0,48825
Delivery horse power	DHP	EHP/PC	Hp	44,35640	104,41669	202,90237	349,21561
Shaft & Brake efficiency	ηSηB			0,98000	0,98000	0,98000	0,98000
Shaft horse power	SHP	DHP/ηSηB	Hp	45,26163	106,54765	207,04323	356,34246
Gear efficiency	ηG			0,98000	0,98000	0,98000	0,98000
Brake horse power	BHPSCR	SHP/ηG	Hp	46,18533	108,72209	211,26860	363,61475
Brake horse power	BHPMCR	BHPSCR/0.85	HP	54,33569	127,90834	248,55130	427,78206

APPENDIX G

ENGINES SPECIFICATION

Engine Type	**YANMAR 4BY2-180Z 180 hp / kW 132**	**YANMAR 6LY3-ETP 480 hp / kW 353**	**YANMAR 6SY-720 720 hp / kW 530**
Number of cylinder	4-inline	6-inline	6-inline
Output at crankshaft mhp/kW	180 - 132	480 / 353	720 / 530
Rated Speed rpm	4000	3300	2300
Displacement L / cu in	1.995 / 122	5.813 / 354	11.7 / 714
Standard drive	ZT350		
Weight with gear/drive Kg (lbs)	370 (816)	640 (1411)	1150 (2536)