BACHELOR THESIS & COLLOQUIUM – ME1841038

DEVELOPMENT OF A DECISION-SUPPORT TOOL FOR SUGGESTING THE OPTIMUM SHIP SPEED UNDER IRREGULAR SEA AND WEATHER CONDITIONS WITH DIFFERENT DRAFTS

FELIA NATASYA
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DOUBLE DEGREE PROGRAM
DEPARTMENT OF MARINE ENGINEERING
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APPROVAL SHEET

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BACHELOR THESIS

Submitted to Comply One of the Requirement to Obtain a Bachelor Engineering Degree

on

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Bachelor Program Department of Marine Engineering
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

Prepared By :

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SURABAYA

AGUSTUS, 2020

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Name	:	Felia Natasya
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Bachelor thesis Title	:	Development of a Decision-Support Tool for Suggesting the Optimum Ship Speed under Irregular Sea and Weather Conditions with Different Drafts

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Warnemünde, August 2020

Felia Natasya

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ABSTRACT

In shipping industry, energy efficiency has become a major attention to reduce the fuel consumption and emission. One of the way to create those fuel savings is by optimizing the voyage by choosing the optimum speed for each suitable water area. Many ships are passing through canal to cut the voyage time or sometimes ship travels through river area, which is common for inland water transport. The influence of restricted water can be an issue to optimize the voyage. Referring to a work by Hafidh, a tool has been developed using the ship design parameter from a general cargo ship, which operates in a canal. The modelling of ship calm water resistance and additional resistance due to restricted water are processed using MATLAB-Simulink software. The tool is able to optimize the voyage by giving out the value of power and fuel consumed (€/nm) for a certain speed value under different water depth and breadth. The result of the analysis show that when the ship is operated in restricted water area with water depth 5 m, and water breadth 50 m, the power needed to achieve speed 7 knots is 150 kW higher than the power needed to achieve the same speed on water depth 7 m and water breadth 50 m. For a ship to go lower by 0.5 knots at 6.0 knots with water depth 3 m and water breadth 50 m, 221 € of fuel cost can be saved with other economic parameters considered as constant.

Key words - Resistance Model, Restricted Water Area, Voyage Optimization

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PENGEMBANGAN ALAT BANTU PENGAMBILAN KEPUTUSAN UNTUK REKOMENDASI KECEPATAN OPTIMAL KAPAL PADA KONDISI LAUT DAN CUACA TIDAK TENTU DENGAN VARIASI SARAT KAPAL

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Dosen Pembimbing	**: Prof. Dr.-Ing. Axel Rafoth**
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ABSTRAK

Dalam industri pelayaran, efisiensi energi menjadi perhatian utama untuk mengurangi konsumsi bahan bakar dan emisi. Salah satu cara untuk menghemat bahan bakar tersebut adalah dengan mengoptimalkan pelayaran dengan memilih kecepatan optimal untuk setiap wilayah perairan yang sesuai. Banyak kapal yang melewati kanal untuk mempersingkat waktu pelayaran atau terkadang kapal melakukan perjalanan melalui wilayah sungai yang biasa digunakan untuk transportasi perairan darat. Pengaruh air yang terbatas bisa menjadi masalah untuk mengoptimalkan pelayaran. Mengacu pada karya Hafidh, alat dikembangkan dengan menggunakan parameter desain kapal dari kapal general cargo yang beroperasi di kanal. Pemodelan tahanan kapal pada air tenang dan tahanan tambahan akibat wilayah air terbatas diolah menggunakan software MATLAB-Simulink. Alat tersebut mampu mengoptimalkan perjalanan dengan memberikan nilai daya dan bahan bakar yang dikonsumsi (€ / nm) untuk nilai kecepatan tertentu pada kedalaman dan luas perairan yang berbeda. Hasil analisis menunjukkan bahwa pada saat kapal dioperasikan di daerah perairan terbatas dengan kedalaman air 5 m, dan lebar perairan 50 m maka daya yang dibutuhkan untuk mencapai kecepatan 7 knot adalah 150 kW lebih tinggi dari daya yang dibutuhkan untuk mencapai kecepatan yang sama pada kedalaman air 7 m dan lebar air 50 m. Untuk kapal yang melaju lebih rendah 0,5 knot pada 6,0 knot dengan kedalaman air 3 m dan lebar air 50 m, 221 € biaya bahan bakar dapat dihemat dengan parameter ekonomi lain yang dianggap konstan.

Key words - Resistance Model, Restricted Water Area, Voyage Optimization

PREFACE

Praises to God, for the opportunity, and strength to finish this bachelor thesis with the tittle "DEVELOPMENT OF A DECISION-SUPPORT TOOL FOR SUGGESTING THE OPTIMUM SHIP SPEED UNDER IRREGULAR SEA AND WEATHER CONDITIONS WITH DIFFERENT DRAFTS" in order to fulfill the requirements to get a Bachelor of Engineering degree in the Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Surabaya.

The author would like to express her gratitude to all those who helped, supported, and offered encouragement on this bachelor thesis writing:

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The author realizes that in writing this report there are many shortcomings, so the constructive criticisms and suggestions that the author hopes for. Hopefully this bachelor thesis can be beneficial for us.

Warnemünde, August 2020

Author

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NOMENCLATURES

B	Breadth
H	Depth moulded
T	Draught
L_{BP}	Length between perpendicular
L_{WL}	Length on water line
L_{OA}	Length overall
DWT	Deadweight tonnage
GRT	Gross tonnage
NT	Net tonnage
V_S	Service speed
C_B	Block coefficient
C_P	Prismatic coefficient
C_M	Amidships coefficient
C_{WP}	Water plane coefficient
LCB	Longitudinal center of buoyancy
F_N	Froude number
R_N	Reynolds number
C_F	Friction coefficient
S	Wetter surface area
ρ	Density
υ	Kinematic viscosity
∇	Volume displacement
Δ	Hull displacement
$R_{T,calm}$	Ship total resistance at calm water
R_f	Frictional resistance
R_{app}	Appendage resistance
R_w	Wave resistance
R_b	Additional pressure resistance of to bulbous bow near the water
R_{tr}	Additional pressure resistance due to transom immersion
R_a	Model ship correlation resistance
$(1+K_1)$	Form factor of the hull
$(1+K_2)_{eq}$	Appendage resistance factor
ΣS_{APP}	Appendage surface area
P_B	Break power
P_D	Delivered power
P_T	Thrust power
P_E	Effective power
η_H	Hull efficiency
T_m	Draugth at midship
H_{water}	Water depth below keel
$R_{shallow}$	Shallow water resistance
B_{water}	Water breadth
V_I	Schlichting's Intermediate Speed

V_∞	Speed in deep water
A_X	Maximum sectional area of ship hull
A_M	Midship area
Nm	Nautical mile

CHAPTER I
INTRODUCTION

1.1 Background

According to UNCTAD in 2018, Maritime transport takes about 80 percent volume of trading goods in the global trade [1]. Although shipping is by far the most energy-efficient means of transporting cargoes over long distances, shipping also has problems such as high energy consumption and substantial environmental pollution. Referring to the statement of World Shipping Council, the fuel costs are as much as 50-6-% of the total ship operating costs, depending on the type of ship and service. As per approximated value, the fuel cost is proportional to the fuel consumption, which is directly related to third power of ship speed [2]. Since the lower speed means reducing the fuel consumption, many shipping companies using slow steaming method (operating ship under slow speed) [2]. However, by doing slow steaming, the ship might not arrive at the arrival port in time and there must be penalties to be paid.

In this study, we consider voyage optimization is ideal to be applied for a ship with a given route, and specified deadline. As modern shipping industries tend to give more attention to the topic of energy saving and emission reduction, the International Maritime Organization (IMO) published a guidelines for the development of a Ship Energy Efficiency Management Plan (SEEMP) [3].

1.2 Research Problem

Voyage planning and optimization is important due to the aspects of energy saving. However, without sufficient knowledge and experience about the behavior of the ship, the crew onboard often face difficulties in determining the optimum speed under the influence of different water depth and water breadth along the route. A development of a decision-support tool is required to give possible suggestions to proceed an optimum voyage using a certain speed to have a forecast on how much fuel cost to be spent. The tool shows the power needed for the chosen speed under a certain water depth and water breadth, where the ship is passing through.

1.3 Research Limitation

The limitation of the thesis is as follows:

1. The ship condition is considered as clean hull and clean propeller
2. The engine and technical data is considered under good condition
3. There is no influence of trim
4. Use the water density where the ship was operated

5. Use the data from the shipping company and measurement data
6. The water area is restricted to depth and breadth

1.4 Research Objectives

The purposes of the study is as follows:

1. Develop a decision-support tool which help to optimize the voyage of the ship under restricted water depth, and water breadth;
2. Provide information about power needs for the selected speed of the voyage;
3. Show information about possible power and fuel saving.

1.5 Research Benefits

The expected results is as follows:

1. The tool shows the speed and the power needed for different water depth and breadth.
2. The tool can be used to demonstrate the power and fuel saving after a certain speed is chosen.
3. For ship operators, the tool will be a decision-making tool for the ship crew to decide the optimum speed.
4. For ship owners, the tool can be used to increase the economic profit from the power saving result which relate to fuel saving.
5. For environmental aspect, it will reduce the emission from fuel saving and result in more environmental friendly ship performance.

CHAPTER II
LITERATURE STUDY

2.1 Previous Research

In a latest research, Tong Cui presents a speed optimization model towards energy efficient shipping. In this model, stakeholders can get the information about the optimum ship operations in various weather to achieve minimum fuel consumption following the shipping schedule. The result of applying this model to a Bulk Carrier as a case study is resulting on almost 1.5% saving on fuel consumption, which prove that the speed optimization model works [4]. Previous research by Xiaohe Li, gives a result that by applying speed optimization to a 4800 DWT oil tanker, fuel saving rate is 1.07, which equal to 4.33 t per voyage or about 77.94 t fuel saving annually [5]. Another research by Xiaohe Li shows that in a case study of 4230 TEU container ship, the speed optimization model is minimizing the main engine fuel consumption and the total cost in a single voyage. After applying the model, the main engine fuel cost is reduced to 57% of the total cost [6].

2.2 Speed Optimization

The definition of speed optimization is the selection speed for the ship to optimize the specific objectives with various requirement during the ship's operation. The speeds that match to those profiles are called as optimum speeds. Those specifics objectives can be profit, cost, and emissions. And the requirements or constraints in speed optimization are the specified deadline/arrival time, scheduling requirements for specific port, and allowance speeds range (minimum and maximum) refers to main engine specifications [7]. According to MEPC 282 (70) point 5.2.6, Optimum speed means the speed at which the fuel used per tonne mile is at minimum level for that voyage. Reference should be made to the engine manufacturer's power curve and the ship's propeller curve [3].

2.3 Ship Resistance

A ship experiences a force acting opposite to its motion direction when passing through a calm water. The force is the water's resistance to the motion of the ship, which is called as total hull resistance in calm water (RT,calm) which is influenced by many components, such as: ship speed, hull form (draught, breadth, length, wetted surface area), and water temperature of ship sailing area. The total hull resistance is used to calculate a ship's effective horsepower. Total hull resistance increases as speed increases as shown in Figure 1.

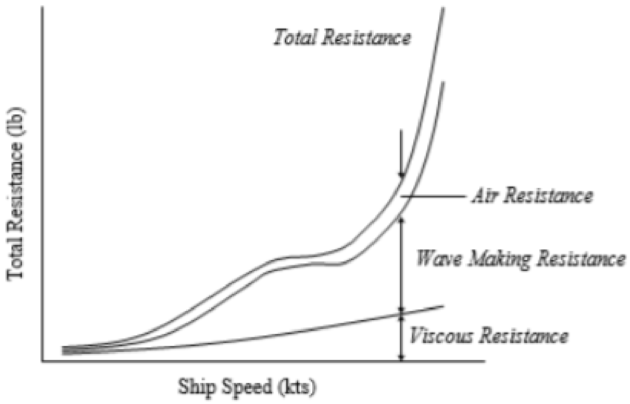

Figure 1 Curve of Total Hull Resistance over Ship Speed

Source: usna.edu

The total hull resistance in calm water (RT,calm) is influenced by many factors. As shown in Figure 1, the forces acting consist of:

1. Air resistance
2. Viscous resistance
3. Wave resistance

However, ship is not operating under constant calm water. Ship undergoes different operating condition, environment and water area. These situations contribute to additional resistance to the total hull resistance in calm water (RT,calm).

2.4 Ship Powering

On the ship, after a certain amount of power is generated in the Engine Room, the power will be transmitted through the shaft of the propeller and be delivered to the propeller. During the transmission of power, the term of power is different in several points as shown in Figure 2. Effective Power (PE) is required power for ship to overcome the total resistance at the given speed; this power is not including the required power to move the propeller. Delivered Power (PD) is power that is absorbed by the propeller to be able to produce thrust. Thrust Power (PT) is power from the propeller thrust, which equal to the product of advance speed and the thrust generated by the propeller. Break Power (PB) is power generated by the main engine at specified RPM value according to manufacture.

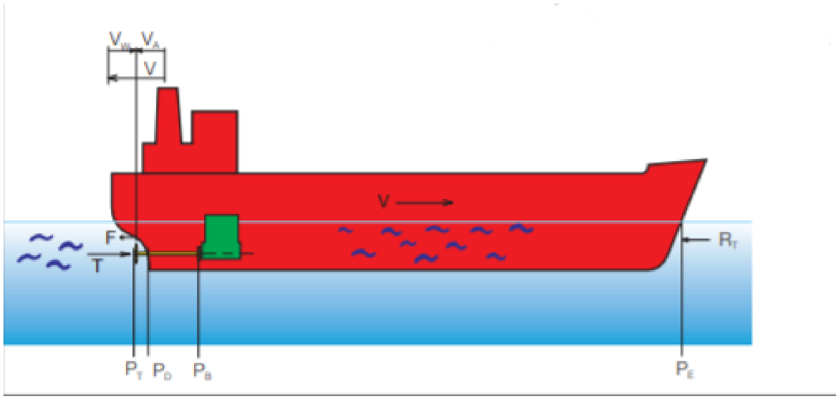

Figure 2 Ship Powering

Source: [8]

2.5 Restricted Water Effect

When a ship enters a restricted water which marked by shallow water depth and narrow water breadth, a number of changes occur due to the interaction between the ship and the seabed. There is an effective increase in resistance, backflow, decrease in pressure under the hull and significant changes in sinkage and trim. This leads to increases in potential and skin friction drag, together with an increase in wave resistance.

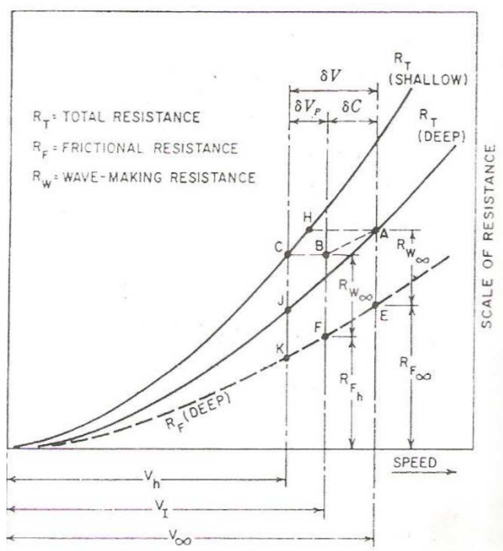

Figure 3 Resistance on Shallow Water from Schlichting's method

Source: [9]

Figure 3. Shows the increase resistance on shallow water compared to resistance in deep water.

When sailing in shallow waters, the residual resistance of the ship may be increased and, in the same way as when the ship accelerates, the propeller will be subjected to a larger load than during free sailing, and the propeller will be heavy running. In general, the shallow water will have no influence when the sea depth is more than 10 times the ship draught [8]. Based on ITTC 2017, the water is considered to experience shallow water effect when the value of H is smaller than the result of Eq. (1) [10].

$$Hwater = 3\sqrt{B.T_m} \qquad Eq.\ 1$$

2.6 Speed Reduction on Restricted Water

Schlichting assumed that based on Figure 3., wave-making resistance on the shallow water at speed V_I would be the same as the wave-making resistance on the deep water at speed V_∞ [9].

$$\frac{V_I}{V_\infty} = (\tanh gh/V_\infty^2)^{\frac{1}{2}} \qquad Eq.\ 2$$

From Figure 4. the ratio of V_h to V_I can be figured out by plotting the value of $\frac{\sqrt{A_x}}{h}$ to the curve of V_h/V_I to base of $\frac{\sqrt{A_x}}{h}$.

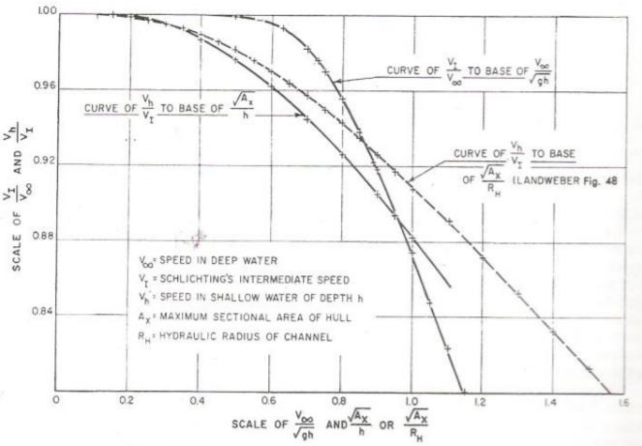

Figure 4 Curves of Velocity Ratios

Source: [9]

CHAPTER III
METHODOLOGY

3.1 Working Diagram

The following chart describe the process working of Bachelor Thesis

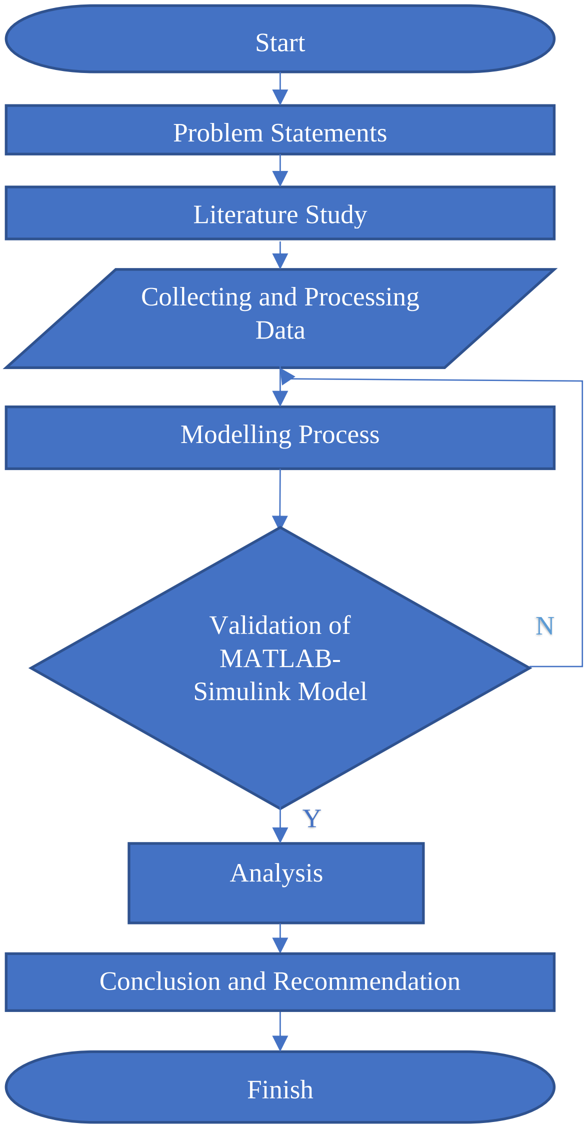

Figure 5 Working Diagram

3.2 Working Process

3.2.1 Literature Study

Collecting information from previous researches journals, academic literature about speed optimization, ship resistance and propulsion, restricted water effect (shallow water depth and narrow water breadth), and the effect of applying speed optimization in creating power saving potential for the ship.

3.2.2 Data Collection

The data used for this work were obtained from direct measurement on the ship and from shipping company. Several data such as coordinates, engine speed, ship speed over ground, fuel rack, draught, and water depth below keel were collected by the researchers by doing a measurement on the ship using related measuring equipment. The process of measurement took place on 02 July 2020 on MV Anouk at Kiel Kanal (Nord-Ostsee-Kanal). Other documental data were given from the shipping company. The data needed to make the simulations are:

Table 1 Data Collection

No.	Data	Source	Equipment
1.	Engine RPM	Measurement	RPM Meter (Bridge Deck), to be corrected by value from Tachometer (Engine Room)
2.	Fuel Rack	Measurement	Visual Reading (Engine Room)
3.	Speed Over Ground (SOG)	Measurement	Speed Log (Bridge Deck)
4.	Water Depth	Measurement	Echo Sounder (Bridge Deck)
5.	Water Breadth	Measurement	Openseamap.org
6.	Coordinates	Measurement	GPS Device
7.	Draught	Shipping Company	Given Information
8.	Ship General Dimension	Shipping Company	Given Information
9.	Engine Power Curve	Shipping Company	Given Information

3.2.3 Modelling Process

The modelling process is inspired by a prior research (master thesis) by Abdul Hafidh [11]. To input the simulation into the program, the modelling algorithm are prepared for these parameters:

1. Water density

2. Ship hull form
3. Ship general dimension
4. Resistance on calm water
5. Added resistance due to restricted water
6. Engine power

3.2.4 Model Validation

To make sure that the model is working, and the elements inside the model are giving the same effect as in real condition, the model shall be validated by comparing the result of the model with the real measured data from MV. Anouk.

3.2.5 Conclusion and Recommendation

Conclusions are given after the work is finished and the content of the conclusion about the result of the work and the result when applied to the problems. Recommendation are also listed to give information about the further development of the work.

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CHAPTER IV
MODELING AND ANALYSIS

4.1 Ship Data

Table 2 Ship Information

No.	SHIP INFORMATION	
1.	Ship Name	MV. Anouk
2.	Type	General Cargo
3.	IMO/MMSI	9196266 / 218856000
4.	Call Sign	DGME
5.	Flag	Germany
6.	Year Built	2000
7.	Home Port	HUSUM
8.	GT/ NT / DWT	2316 mts / 1295 mts / 3171 mts
9.	LBP	84.99 m
10.	LWL	86.69 m
11.	LOA	89.99
12.	Breadth	12.5 m
13.	Draught	4.2 m
14.	Depth Moulded	6 m
15.	Main Engine	MaK 8M20 750 kW/900 RPM
16.	Propeller	5-Blade FPP Diameter= 3.4 m

4.2 Modeling

4.2.1 Ship Route

The ship was sailing from Poland to Humus. However, since the measurement was started from Kiel Canal, the used route is only from KM 95 to KM 56 of Kiel Canal.

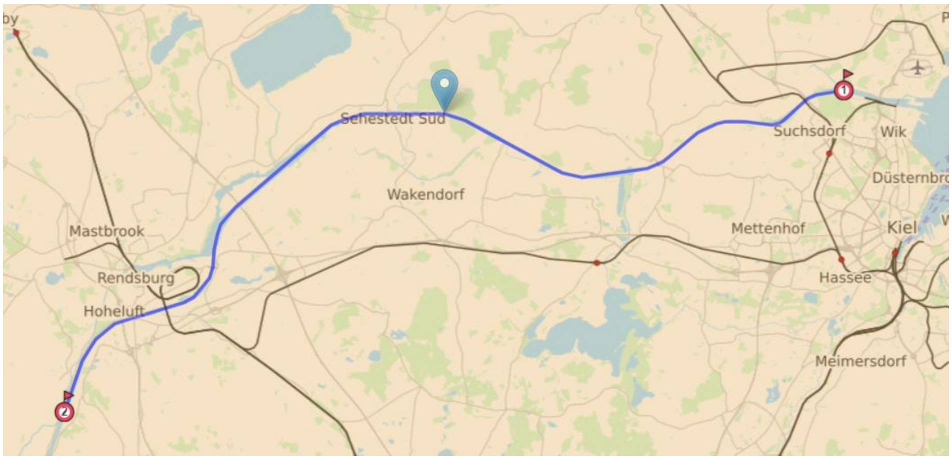


Figure 6 Ship Route

Source: searoutes.com

Table 3 Canal Information

No.	CANAL INFORMATION	
1.	Canal Name	Kiel Canal/Nord-Ostsee-Kanal
2.	Length	98.6 km
3.	Maximum Water Depth	11 m
4.	Maximum Water Breadth	162 m

4.2.2 Water Density Model

The water density value is different when the temperature of the water area where the ship is sailing is changing. The change in water density value will affect the water resistance from the ship. Using Eq. 2 from Kell's Formulation [12], the new water density can be obtained with the given temperature.

$$\rho = 999.84847 + 6.3375638 \times 10^{-2}t - 8.523829 \times 10^{-3}t^2 + 6.943248 \times 10^{-5}t^3 - 3.821216 \times 10^{-7}t^4 \quad \textit{Eq. 3}$$

To calculate the value of kinematic viscosity, Eq. (4) can be used by giving the input water densty, ρ, from Eq. (3) and dynamic viscosity,μ referring to IAPWS 2008 [13].

$$\upsilon = \frac{\mu}{\rho} \quad \text{Eq. 4}$$

The equation (2) and (3) are transferred to MATLAB as an algorithm. Then with the file "Water_Density.m", the water density and kinematic viscosity along the route can be defined.

According to the ship route, the average water temperature of Kiel Canal is 18°C. Therefore, value of water density, and viscosity at temperature 18°C are ρ=998.6 kg/m^3; υ=0.0000010541 m^2/s.

4.2.3 Ship Hull Form Model

Table 4 Ship Hull Form Model

Hull Form Coefficient	Reference	Formula	Note	Result
Block Coefficient (C_B)	Eric C. Tupper	$C_B = \frac{\nabla}{LBT}$	∇ is volume displacement in (m^3) L is L_{BP} in (m) V is V_s in knots	$C_B = 0.790$
Midship Coefficient (C_M)	HSVA	$C_M = \frac{1}{1 + (1 - C_B)^{3.5}}$		$C_M = 0.995$
Prismatic Coefficient (C_P)	General Formula	$C_P = \frac{C_B}{C_M}$		$C_P = 0.794$
Waterplane Coefficient (C_{WP})	Schneekluth	$C_{WP} = 0.95C_P + 0.17\sqrt[3]{1 - C_P}$		$C_{WP} = 0.825$
LCB (%)	Guldhammer & Harvald	$LCB = 8.9 - 45F_n$	$F_n = V_s/\sqrt{gL_{BP}}$ V_s in (m/s) g in (m/s^2) L_{BP} (m)	$LCB = 2.091$

The following coefficient for ship hull form need to be defined for the calculation in the model. The formula then transferred to MATLAB as algorithm. Using the algorithm, the value can be obtained from the calculation inside the MATLAB.

4.2.4 Calm Water Resistance Model

The estimation of ship resistance in calm water condition is conducted using the method from Holtrop and Mennen, which is shown in the following formula:

$$RT, calm = R_{F,calm}(1 + K_1) + R_{APP} + R_W + R_B + R_{TR} + R_A \qquad \text{Eq. 5}$$

Where:

R_{Tcalm} = Total resistance of the ship in calm water

$R_{Fc}(1+k1)$ = Frictional resistance considering the form factor of hull

R_{APP} = Appendages resistance

R_W = Wave resistance

R_B = Additional pressure resistance of bulbous bow

R_{TR} = Additional pressure resistance of immersed transom stern

R_A = Model-ship correlation resistance

Frictional Resistance (R_{Fcalm})

The frictional resistance can be expressed using Eq. 6.

$$R_{F,calm} = \frac{1}{2}\rho C_F S_{BH} V_S^2 \qquad \textit{Eq. 6}$$

ρ is the water density(kg/m^3); C_F is frictional resistance coefficient; S_{BH} is wetted surface area of ship hull (m^2); V_s is ship speed (m/s). The value of S_{BH} on Eq. 6 can be defined using Eq. 9. And the value of C_F can be calculated using the formula in Eq. 7 according to ITTC 1957.

$$C_F = \frac{0.075}{(logR_n - 2)^2} \qquad \textit{Eq. 7}$$

R_n is defined as Reynold number. The value of R_n is based on Eq. (8).

$$R_n = \frac{Vs \times L_{WL}}{\upsilon} \qquad \textit{Eq. 8}$$

Where, V_s is ship speed (m/s); and υ is kinematic viscosity of water (m^2/s) which already defined on water density model.

$$S_{BH} = L_{WL}(2T + B)\sqrt{C_M}\left(0.4530 + 0.4425C_B - 0.2862C_M - 0.003467\frac{B}{T} + 0.3696C_{WP}\right) + 2.38\frac{A_{BT}}{C_B} \qquad \textit{Eq. 9}$$

Where, L_{WL} is length at waterline (m); A_{BT} is transverse sectional area of bulb at the position where the water surface intersects the stern; C_M, C_{WP} are already defined on Table 4.2.

On Eq. 5, frictional resistance is multiplied by factor $(1+k_1)$ which is form coefficient of the naked hull. The value of $(1+k_1)$ can be estimated using Eq. 10.

$$1 + k_1 = 0.93 + \left(\frac{T}{L_{WL}}\right)^{0.22284}\left(\frac{B}{L_R}\right)^{0.92497}(0.95 - \mathrm{Cp})^{-0.521448}(1 - \mathrm{Cp} + 0.0225)^{0.6906} \qquad \textit{Eq. 10}$$

The length of the aft body, L_R, can be approximated by Eq. 11

$$L_R = \left[L_{WL}(1 - C_P + 0.06C_P\ {LCB}/{(4C_P - 1)}\right] \qquad \textit{Eq. 11}$$

Longitudinal center of buoyancy, LCB, is already calculated in Table 4.2.

Appendages Resistance (R_{APP})

The appendages resistance can be determined using Eq. 12.

$$R_{APP} = \frac{1}{2}\rho V_S^2 C_F(1 + k2)eq\Sigma S_{APP} \qquad \textit{Eq. 12}$$

The value of coefficient (1+k_2) is obtained from Table 5. according to the configuration of the hull appendages.

Table 5 1 + K2 Values

Approximate 1+k_2 values	
Rudder behind skeg	1.5 – 2.0
Rudder behind stern	1.3 – 1.5
Twin-screw balance rudders	2.8
Shaft brackets	3.0
Skeg	1.5 – 2.0
Strut bossings	3.0
Hull bossings	2.0
Shafts	2.0 – 4.0
Stabilizer fins	2.8
Dome	2.7
Bilge keels	1.4

Value of (1+k_2) is calculated by Eq. 13.

$$(1 + k_2)_{eq} = \frac{\sum(1+k_2)S_{APP}}{\sum S_{APP}} \qquad \textit{Eq. 13}$$

Where, S_{APP} is the wetted surface area of appendages.

Wave Resistance (R_W)

The wave resistance can be determined using Eq. 14.

$$R_W = c_1 c_2 c_5 \nabla \rho g exp\{m_1 F_n^d + m_2 \cos(\lambda F_n^{-2})\} \qquad \textit{Eq. 14}$$

Where, coefficient c_1 can be approximated using Eq. 15; c_2 using Eq. 18; c_5 using Eq. 20.

$$c_1 = 2223105 c_7^{3.78613} \left(\frac{T}{B}\right)^{1.07961} (90 - i_E)^{-1.37565} \qquad \textit{Eq. 15}$$

Where i_E represents the angle of waterline at the bow in degrees. i_E can be determined using Eq. 16, and coefficient c_7 using Eq. 17.

$$i_e = 1 + 89 exp\left\{-(\frac{L_{WL}}{B})^{0.80856}(1 - C_{WP})^{0.30484}(1 - C_P - 0.0225LCB)^{0.6367}\left(\frac{L_R}{B}\right)^{0.34574}\left(\frac{100\nabla}{L_{WL}{}^3}\right)^{0.16302}\right\} \qquad \textit{Eq. 16}$$

$$c_7 = \frac{B}{LWL} \text{ when } 0.11 < B/L_{WL} < 0.25 \qquad \textit{Eq. 17}$$

Coefficient c_2 is influenced by the value of c_3, as it is shown in Eq. 18. The value of c_3 can be approximated using Eq. 19.

$$c_2 = \exp\left(-1.89\sqrt{c_3}\right) \qquad \textit{Eq. 18}$$

$$c_3 = 0.56 A_{BT}^{1.5} / \left\{BT\left(0.31\sqrt{A_{BT} + T_F} - h_B\right)\right\} \qquad \textit{Eq. 19}$$

$$c_5 = 1 - 0.8 A_T / (BTC_M) \qquad \textit{Eq. 20}$$

Value of coefficient c_5 can be determined using Eq. 20, where A_T represents the immersed part of transverse sectional area of transom at zero speed. H_B is the position of the center of the transverse area A_{BT} above the keel line, the value of h_B can be approximated by using Eq.30. A_{BT} can also be approximated by using Eq. 31. T_f is draught at fore of ship.

$$m_1 = 0.0140407 \frac{L_{WL}}{T} - \frac{1.75254 \nabla^{\frac{1}{3}}}{L_{WL}} + 4.79323 \frac{B}{LWL} - c_{16} \qquad \textit{Eq. 21}$$

$$c_{16} = 8.07981 C_P - 13.8673 C_P^2 + 6.984388 C_P^3 \quad \text{when } C_p < 0.80 \qquad \textit{Eq. 22}$$

The value of m_1 is regulated by Eq. 21. Where the coefficient c_{16} can be defined from Eq. 22

$$F_n = V_s / \sqrt{g L_{WL}} \qquad \textit{Eq. 23}$$

$$D = -0.9$$

$$m_2 = c_{15} C_p^2 exp(-0.1 F_n^{-2}) \qquad \textit{Eq. 24}$$

$$c_{15} = -1.69385 \qquad \textit{Eq. 25}$$

$$\lambda = 1.446 C_P - 0.03 \, {}^{L_{WL}}/_{B} \quad \text{for } L_{wl}/B < 12 \qquad \textit{Eq. 26}$$

Additional Pressure Resistance of Bulbous Bow (R_B)

The additional pressure resistance of bulbous bow can be determined using Eq. 27.

$$R_B = 0.11 \exp(-3P_B^{-2}) F_{ni}^3 A_{BT}^{1.5} \rho g/(1 + F_{ni}^2) \qquad \textit{Eq. 27}$$

Where P_B is coefficient for the emergence of the bow (see Eq. 28) and F_{ni} (see Eq. 29) is the Froude number based on the immersion.

$$P_B = 0.56\sqrt{A_{BT}}/(T_F - 1.5h_b) \qquad \textit{Eq. 28}$$

$$F_{ni} = V_s/\sqrt{g\left(T_F - h_B - 0.25\sqrt{A_{BT}}\right) + 0.15V_s^2} \qquad \textit{Eq. 29}$$

The estimation of transverse bulb area (A_{BT}) is shown by Eq. 31, and the center area of A_{BT} above keel (h_B) is shown by Eq. 30.

$$h_B = 0.45T_F \qquad \textit{Eq. 30}$$

$$A_{BT} = C_{ABT}A_M \qquad \textit{Eq. 31}$$

Where,

$$C_{ABT} = 40F_n - 3.5 \qquad \textit{Eq. 32}$$

$$A_M = C_M BT \qquad \textit{Eq. 33}$$

Additional Pressure Resistance of Immersed Transom (R_{TR})

The additional pressure resistance of immersed transom can be determined using Eq. 34.

$$R_{TR} = \frac{1}{2}\rho V_S^2 A_T c_6 \qquad \textit{Eq. 34}$$

Where,

$$c_6 = 0.2(1 - 0.2F_{nT}) \quad \text{when } F_{nT} < 5 \qquad \textit{Eq. 35}$$

$$F_{nT} = V_s/\sqrt{2gA_T/(B + BC_{WP})} \qquad \textit{Eq. 36}$$

Model Ship Correlation Resistance (R_A)

The model ship correlation resistance can be determined using Eq. 37.

$$R_A = \frac{1}{2}\rho V_S^2 S_{BH} C_A \qquad \textit{Eq.37}$$

For the approximate value of hull roughness coefficient (C_A), Eq. 38 can be applied.

$$C_A = 0.006(L_{WL} + 100)^{-0.16} - 0.00205 + 0.003\sqrt{L_{WL}/7.5}\, C_B^4 c_2 (0.04 - c_4) \qquad \textit{Eq.38}$$

Where,

$$c_4 = 0.04 \qquad \text{when } T_F/L_{WL} > 0.04$$

4.2.5 Added Resistance due to Shallow Water ($R_{shallow}$)

The estimation of added resistance due to restricted water can be calculated by using the formula from ITTC 2017 (see Eq. 39).

$$R_{Shallow} = R_T \times 0.57(\frac{T_M}{H})^{1.79} \qquad \text{Eq. 39}$$

Where T_M is draught at midship (m); and H is water depth below keel (m).

Wake Fraction (w)

The wake fraction of ship with single screw propeller can be taken from Table 6. The table comes from Taylor averaged wake fraction value based on block coefficient (C_B) of the ship.

Table 6 Values of Wake Fraction from Taylor

Block Coefficient (C_B)	Wake fraction (Taylor)	
	Twin-screw ships	Single-screw ship
0.50	-0.038	0.230
0.55	-0.021	0.234
0.60	0.007	0.243
0.65	0.045	0.260
0.70	0.091	0.283
0.75	0.143	0.314
0.80	-	0.354
0.85	-	0.400
0.90	-	0.477

Thrust Deduction (t)

The value of thrust deduction for single screw propeller is approximated by Holtrop and Mennen is:

$$t = 0.10 \qquad \textit{Eq. 40}$$

Relative Rotative Efficiency (η_R)

According to Holtrop and Mennen, the value of relative rotative efficiency for single screw propeller is:

$$\eta_R = 0.98.$$

Hull Efficiency (η_H)

The value of hull efficiency can be determined using Eq. 41

$$\eta_H = \frac{1-t}{1-w} \qquad \textit{Eq. 41}$$

4.2.6 Power Model

Break Horsepower Model

In this model, power are determined using following equations that will calculate value of effective power using Eq. 42. Effective power is the product of total resistance (R_T) and service speed (V_s) in (m/s). Break power can be calculated in Eq. 43 with the influence of $\eta_H, \eta_R, \eta_O, \eta_S, \eta_G$. Where, η_H is hull efficiency, η_R is relative rotative efficiency, η_O is open-water propeller efficiency, η_S is shaft efficiency, and η_G is gearbox efficiency.

$$P_E = R_T V_S \qquad \text{Eq. 42}$$

$$P_B = \frac{P_E}{\eta_H \eta_R \eta_O \eta_S \eta_G} \qquad \text{Eq. 43}$$

Measured Power Model

The value of measured power is calculated using a formula on Eq. 44 made based on the performance diagram from the engine (see Appendix 2). The formula is a function of fuel rack (mm) and engine RPM which come from the measurement on the ship.

$$P_{Bmeasured} = \frac{RPM}{1000} \times \frac{FR}{25.5} \times 1350 \qquad \text{Eq. 44}$$

4.2.7 Speed Reduction Model

The water depth and water breadth of the water area where the ship is passing through influences the speed reduction. In this model, the ship is passing through canal with finite breadth less than 200 m.

The value of ship speed at canal (V_h) is shown by Eq. 44 [14].

$$V_h = V_\infty \left[1 - 0.09\left(\frac{\sqrt{A_M}}{R_H}\right)^{1.5}\right] \qquad \text{Eq. 45}$$

Where, V_∞ is the speed in deep water in (knots); V_h is the speed in canal of the depth h and breadth b. A_M is cross sectional area of midship. R_H is the hydraulic radius, which is the area of cross section of the canal divided by wetted perimeter of the canal (R_h) on Eq. 45.

$$R_H = bh/(b + 2h) \qquad \textit{Eq. 46}$$

4.3 Analysis

4.3.1 Speed Power Diagram

By running the file 'Resistance_Power.m', and then doing the calculation and simulation using the Simulink model 'Resistance_Power_Model.slx', the speed – power diagram on the Figure 7. can be obtained.

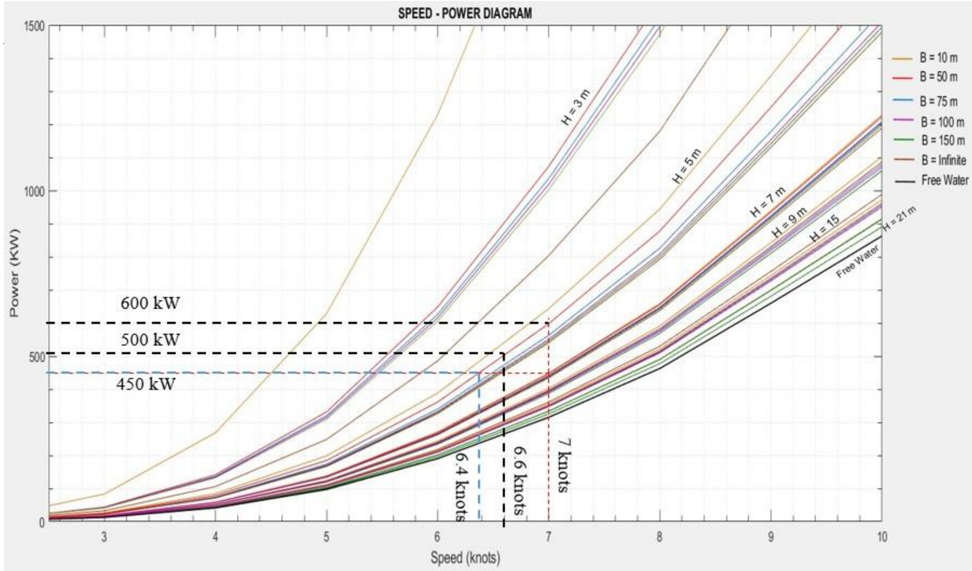


Figure 7 Speed - Power Diagram

From Figure 7, the value of power at the same speed can be seen higher as the value of water depth and water breadth becoming smaller. The influence of shallow water matches the formula of added resistance due to shallow water on Eq. 39. For example, from the diagram, if the ship is sailing with speed 7 knots on the water depth 7 m, and water breadth 50 m, the power used by the ship is around 450 kW. In the water depth 5 m, with water breadth 50m, the ship wants to maintain its speed at

7 knots. Then based on the diagram, the power used by the ship increasing to 600 kW. The ship has the choice to sail with the same power 450 kW by lowering the speed to 6.4 knots. The other choice, the ship can go with a small increase of power to 500 kW with the speed 6.6 knots.

The influence of water breadth is getting bigger when the water breadth is smaller. At water breadth 50 m and water depth 5 m, to achieve speed 7 knots, the power required is 600 kW. Meanwhile, with the same water depth and same power, when the water breadth is 75 m, the ship speed can achieve 0.15 knots higher to 7.15 knots.

4.3.2 Fuel Cost

Table 7 Estimation for Cost Calculation

No.	Name	Value	Unit
1.	Fuel Cost	300	€/ton
2.	Travel Distance	250	nm
3.	Fuel Consumption at 800 kW (From Appendix 2)	180	kg/h

From Figure 8, it can be seen for operation at 800 kW, the value of fuel cost 300 €/ton is converted to 54 €/h by dividing fuel cost with fuel consumption. At wide and deep water area, the speed is planned on 9.5 knots, which consequently make the fuel cost to be 5.7 €/nm. At narrow and shallow water area, the speed is planned on 6.5 knots, then the fuel cost is 8.31/nm. The fuel cost per nautical mile is the result of fuel cost per hour divided by ship speed.

The value of fuel cost per nautical mile (€/nm) is depending on the power and speed chosen. The higher the power, the higher the value of fuel consumption per hour (kg/h). However, as the diagram shows, it is not efficient to go on the same power for shallow and narrow water. To achieve a nearly same fuel cost per nautical mile, the ship must lower the speed to 6 knots. By operating at 6 knots, the power is becoming 600 kW. at At 600 kW, the fuel consumption is 120 kg/h, which resulting on 6 €/nm for the fuel cost at narrow and shallow water.

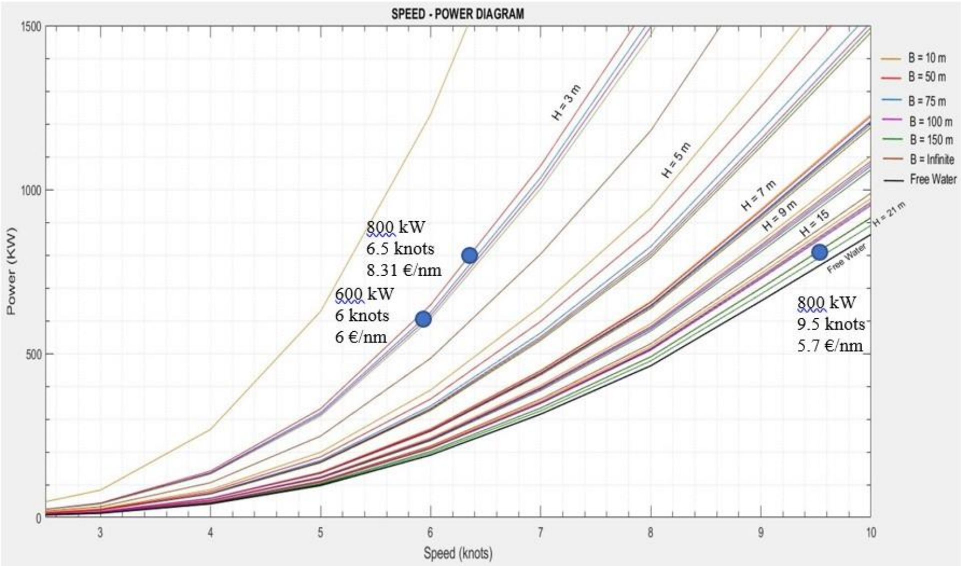


Figure 8 Speed- Power Diagram with Fuel Cost

From 250 nm voyage, the 100 nm is considered as travel through canal or river (restricted water area), and the 150 nm is considered as travel through wide and deep water area. The fuel cost for the total distance will be:

For constant 800 kW = (5.77 €/nm x 150 nm) + (8.31 €/nm x 100 nm)
= 1,686 €

For 800 kW to 600 kW = (5.77 €/nm x 150 nm) + (6 €/nm x 100 nm)

= 1,465 €

By reducing 0.5 knots at narrow and shallow water, the ship save 221 € per voyage.

4.4 Model Validation

Figure 9 shows the comparison between the results of model compared to the measured data. The comparison is proceed using the same power (measured power). This process is to validate that the model is working nearly the same as the real condition. From all measurement data, few specific data from KM ~63 to KM ~60 is taken into note where the ship is passing through the narrowing area and then continuing back to widening area. The detailed position can be look up on Figure 10.

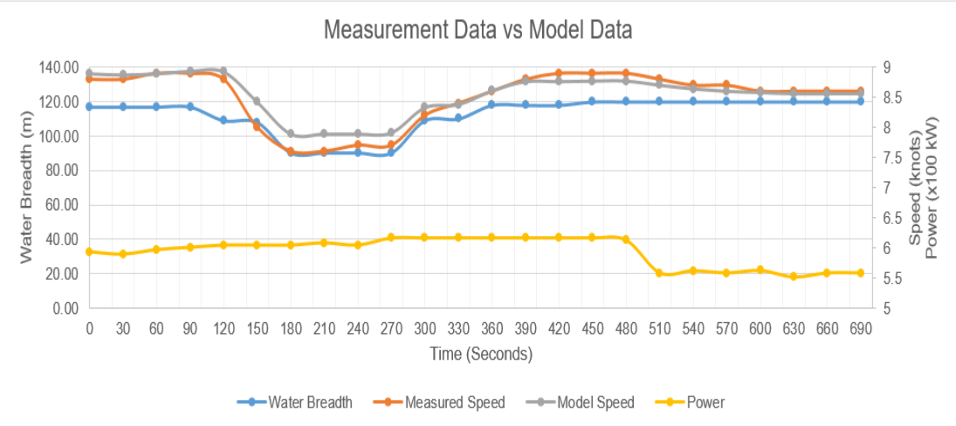


Figure 9 Model Data Compared to Measurement Data

From the set of data, it can be seen that the narrowing water breadth with the shallowing water contribute to the decreasing value of ship speed. From time 120 to 180 seconds, the canal breadth is going from 108 m to 90 m. Within the same timeline,

the measured speed is also going down from 8.8 knots to 7.6 knots. Using the model, if the applied power is same as the real condition, the ship speed of model is also going down from 8.92 knots to 7.89 knots together with the decreasing of water breadth at time 120 to 180 seconds. When the water breadth is widening to 110 m again (at time 270 to 300 seconds), both model speed and measured speed are increasing again.

After the narrowing (time 180 to 270 seconds), the ship speed is remarkable as nearly constant. Both model speed and measured speed give nearly same value. The constant value also happen after the ship is reaching the constant wide area 120 m (at time 600 to 690 seconds). These constant values also prove the existence of narrowing and shallowing water influence to the ship speed in both measured data and model data.

The model gives the same effect and result due to narrowing and shallowing water. However, the value is not perfectly match with the measured data. This can be the result of other influences, for example fouled propeller, fouled hull, the condition of the engine itself (the engine performance). These factors are considered as in a clean and good condition in the model, while in the real condition, this information are not available.

Figure 10 Map Showing Location for Model Validation

Source: openseamaps.org

CHAPTER V
CONCLUSION

5.1 Result

5.2.1 Mathematical Result

On mathematical side, the model is analyzing the potential energy and fuel saving by following the optimum speed showed by the resulted speed – power diagram. The Simulink model is calculating the total ship resistance including the calm water resistance, added resistance due to shallow water, added resistance due to narrow water. The total resistance then continued to be calculated as an input to power calculation. The resulted power from the Simulink calculation then provided to the MATLAB workspace. By variating the input of water depth and water breadth, a diagram for speed – power at various water depth and water breadth is obtained.

The application of speed – power diagram is giving an impact in term of energy saving. By going down 0.6 knots from 7 knots to 6.4 knots at water depth 5 m and water breadth 50 m, the power needed is cut down by 150 kW, which is around 30% compared to when it is sailing at the same speed 7 knots at water depth 7 m and water breadth 50 m.

5.2.2 Economical Result

On the economical side, the fuel cost can be reduced by following the speed – power diagram. When the ship is sailing on 6.0 knots instead of 6.5 knots at narrow and shallow water, the amount of fuel cost saved is 221 €. However, if it is compared to the payment received by the owner which roughly estimated as 10,000 € per voyage (250 nm travel distance), and considered the other cost -for example the daily operating cost allocated for daily maintenance of ship inventories, which can cost up to 2800 € per day- the fuel cost saved is relatively small to be counted as additional to the profit. In real condition, instead of following the optimum speed at the specified water depth and breadth, the shipping company tends to lower down the other possible cost.

5.2 Outlook

In order to make a more accuracy tool, the value of fixed cost, and other operational cost must following the real value from the shipping company. The one used in this analysis is following the rough estimation for the basic of helping tool. Further use of this tool must follow the actual fuel cost per metric tonnage; the density of the specific fuel oil used, and should follow the real schedule of the voyage. The future development of this tool is possible. For instant, in order to create a more useful tool, the work can be applied with using data from ship, which sails on seawater area. To achieve this, the density and the viscosity used must be adjusted to the seawater. And to make it more accurate, the influence of irregular sea and weather must be included. The improvement of MATLAB works shall be done to create a more efficient and easy-to-use tool for the user.

REFERENCES

[1] UNCTAD, "Review of Maritime Transport 2018," United Nations Publications, New York, 2018.

[2] H.-J. K. Jae-Gon Kim, "Optimizing Ship Speed to Minimize Total Fuel Consumption with Multiple Time Windows," Mathematical Problems in Engineering, vol. 2016, 2016.

[3] IMO, GUIDELINES FOR THE DEVELOPMENT OF A SHIP ENERGY EFFICIENCY MANAGEMENT PLAN (SEEMP), 2016.

[4] T. Cui, "Energy Efficient Ship Operation Through Speed Optimisation in Various Weather Conditions," Trends and Challenges in Maritime Energy Management, vol. 6, pp. 199-211, 2018.

[5] X. Li, "Model of speed optimization of oil tanker with irregular winds and waves for," Ocean Engineering, vol. 164, pp. 628-639, 2018.

[6] X. Li, "Speed optimization of a container ship on a given route considering voluntary speed loss and emissions," Applied Ocean Research, vol. 94, 2019.

[7] H. N. Psaraftis, "Speed Optimization vs Speed Reduction: the Choice between Speed Limits and a Bunker Levy," Sustainability, 2019.

[8] MAN Diesel & Turbo, "Basic Principles of Ship Propulsion," MAN Diesel & Turbo, Denmark, 2011.

[9] S. Prakash M.N, and B. Chandra, "Numerical Estimation of Shallow Water Resistance of a River-Sea Ship using CFD," International Journal of Computer Applications (0975 – 8887), vol. 71, no. 5, p. 33, 2013.

[10] International Towing Tank Conference, ITTC Quality System Manual Recommended Procedures and Guidelines, International Towing Tank Conference, 2017.

[11] A. H. Muhammad, "Automatic Detection of Fouling State of Ship Hulls," 2019.

[12] F. E. Jones and G. L. Harris, "ITS-90 Density of Water Formulation for Volumetric Standards Calibration," Journal of Research of the National Institute of Standards and Technology, vol. 97, p. 335, 1992.

[13] The International Association for the Properties of Water and Steam, IAPWS Formulation 2008 for the Viscosity of Ordinary Water Substance, Berlin: International Association for the Properties of Water and Steam, 2008.

[14] A. F. Molland, S. R. Turnock and D. A. Hudson, Ship Resistance and Propulsion, New York: Cambridge University Press, 2011.

[15] USNA Education, "Resistance and Powering of Ship.," in Course Objectives Chapter7,https://www.usna.edu/NAOE/_files/documents/Courses/EN400/02.

07%20Chapter%207.pdf (accessed on 2020-01-27).

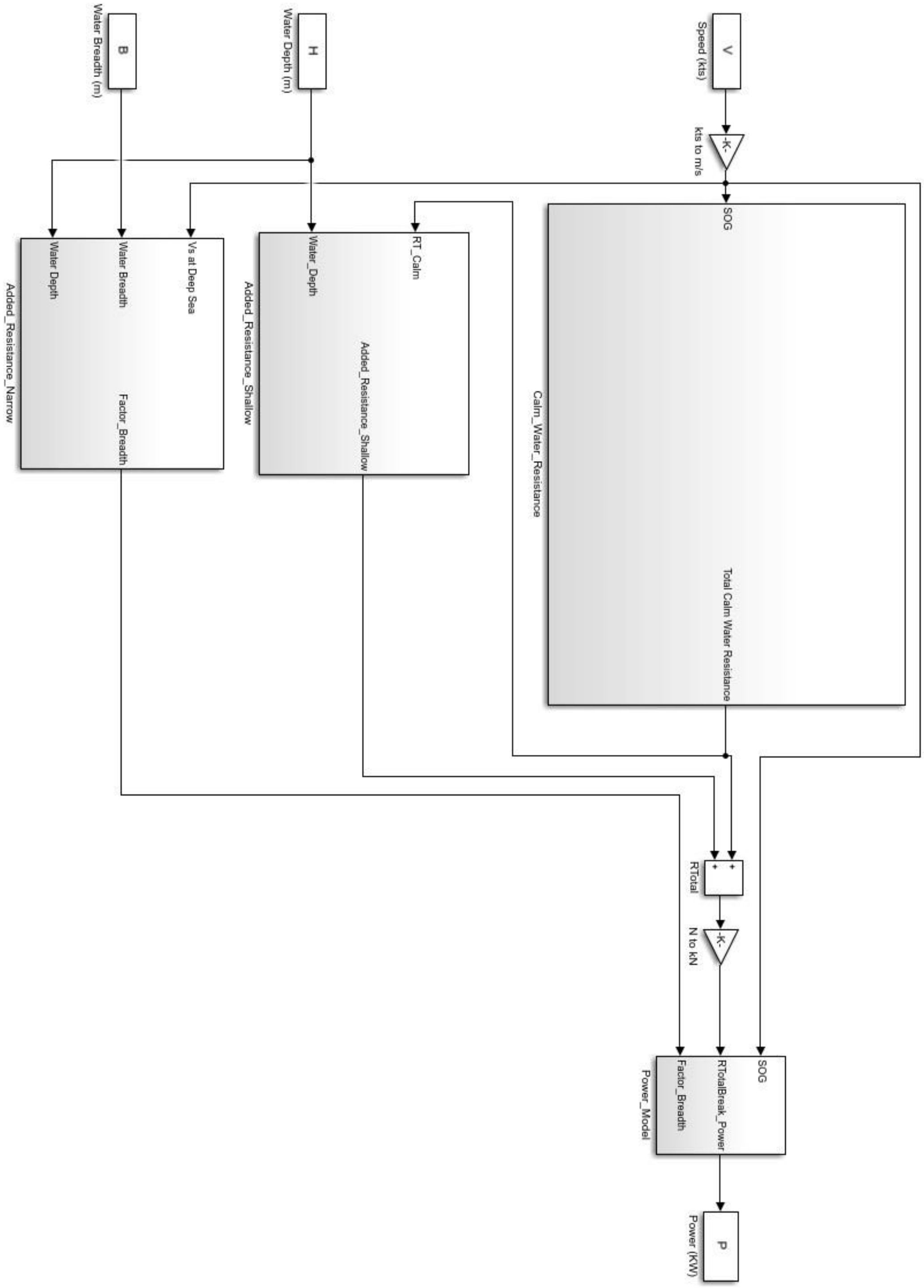
[16] "SeaRoutes," [Online]. Available: https://www.searoutes.com/routing/. [Accessed 27 07 2020].

[17] D. Taylor, Introduction to Marine Engineering, Oxford: Elsevier Ltd., 1996.

[18] E. C. Tupper, Introduction to Naval Architecture, Butterworth-Heinemann, 2013.

APPENDIX I

SIMULATION MODEL



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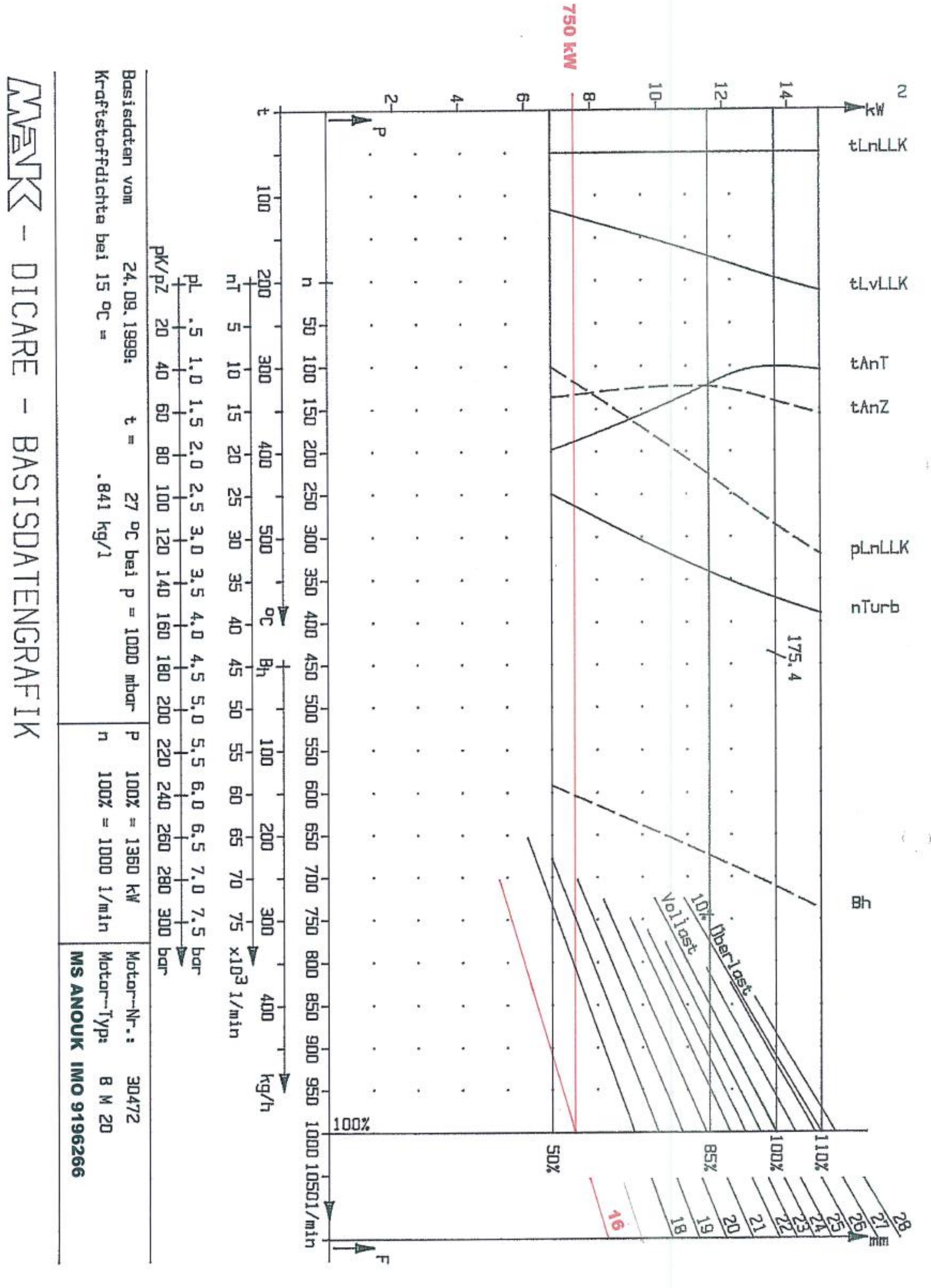
APPENDIX II
POWER CURVE DIAGRAM



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