

Speed Optimization Model for Reducing Fuel Consumption Based on Shipping Log Data

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Abstract—It is known that total operating cost of a vessel is dominated by the cost of fuel consumption. How to reduce the fuel cost of ship so that the operational costs of fuel can be minimized is the question that arises. As the basis of these kinds of problem, sailing speed determination is an important factor to be considered by a shipping company. Optimal speed determination will give a significant influence on the route and berth schedule of ships, which also affect vessel operating costs. The purpose of this paper is to clarify some important issues about ship speed optimization. Sailing speed, displacement, sailing time, and specific fuel consumption were obtained from shipping log data to be further analyzed for modeling the speed optimization. The presented speed optimization model is expected to affect the fuel consumption and to reduce the cost of fuel consumption.

Keywords—Maritime transportation, reducing fuel, shipping log data, speed optimization.

I. INTRODUCTION

DEVELOPMENT of economic globalization and the rapid growth of international trade make maritime transport play a more important role in the international supply chain. Consistent with this trend, shipping by container ships has experienced rapid growth in recent years, and the global container trade volume in 2009 reached 124 million TEUs [1]. About 8 billion tons of goods are transported annually in international trade [2].

Considering sailing speed of ship is an important factor that is determined by a shipping company, and this gives a significant influence on the route and berth schedule of ships, which also affects vessel operating cost. Sailing speed also affects the shipping time and quality of services provided by a shipping company [3].

The most substantial operational cost of ship is fuel cost. It is known that the cost of fuel consumption is normally over 50% of the total operating costs of a vessel [4]. Because of the fuel costs incurred, the question arises about how to reduce the fuel cost of ship so that the operational costs for fuel can be minimized. Speed optimization will affect the sailing speed which is related to amount of fuel consumption.

Non-linear relationship between speed and fuel consumption makes it clear that a ship that is running slower would consume far less fuel than the same ships that sail at higher speeds. This shows that changing the ship's speed has a quite dramatic

impact on operating costs of ships and ship emissions [5].

By reducing the speed of the ship by a few knots, it will impact both on the shipping company and the environment. Fagerholt et al. stated that, if the ship's speed is reduced by 10%, the ship will remain until at destination during the time windows [6]. If the optimum speed is operated during the voyage, the fuel consumption can be reduced by 24.3% [6].

These reasons make most shipping companies implement the management efficiency of fuel on ships in some way [7]. In practice, shipping company will continue to be involved in monitoring the efficiency of fuel on every ship, to find out how the amount of fuel used per day. This is done by looking at the logbook ship data because the logbook recording the ship sailing ship in the ocean profiles is reported by the captain of the ship every day. From the logbook data, shipping companies can find out the fuel efficiency of each vessel and it helps to identify if there are some oddities.

In this study, fuel consumption data from ship logbooks will be used as a comparison when the ship sailed at the speeds below the speed of service in one trip of a ship.

II. LITERATURE REVIEW

A. Shipping Logbook Data

In the shipping world, shipping logbook is very important. Any crews on board are required to write the logbook precisely because if something happens later, it will help the crew.

In the Commercial Law article 348, the implementation of shipping logbook should be pursued. Captain does himself/herself or assigns a crew (first deck officer) but charging remains under the supervision of the captain correctly, completely, and based on the regulations.

Logbook is a legal original and official document that shows the journey records and production vessels, and it must be noted carefully and strictly in accordance with the facts. Sentences in the logbook should be written clearly, accurately and avoid ambiguity. The words must be appropriate, clear, and easy to understand. Everything that is ambiguous can lead to misunderstandings and can even cause operational losses on ships [8].

Vessel which has 500 GT or more must hold the shipping logbook, while the vessel is equipped with radio telegraphy/ telephony with radio logbook.

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B. Relation between Vessel Speed, Duration of Sailing and Fuel Consumption

Theoretically, the speed and distance is inversely proportional. Ships sailing on the same route at high speed will arrive at their destination in a shorter time than the ships that sail at low speed. Ships sailing at low speed does consume less fuel, but each ship has a time window that must be obeyed. So, there are times when a ship sails at low speed, and when the ship sails at high speed.

Speed sailing also affects the round-trip time of a ship. In the previous study, if the round-trip time of a ship's route is 56 days, that is when the vessel is sailing at 24 knots. When the ship sailing under that speed, round-trip time may be increased to 63 days. Because the shipping companies generally provide delivery services weekly, the number of container ships which are placed on these ships will increase by 8-9 [9].

To calculate the duration of sailing boats, refer to (1).

$$t = S / v \quad (1)$$

where: t: Trip duration of ship (hour), S: Distance between ports in nautical mile (NM), v: Speed of the ship (km/h).

C. Estimation of Fuel Consumption

Ships consume fuel on three conditions; at the time of sailing ships, maneuver, and at port. At zero speed, the vessel also consumes less fuel, for example electricity generated by the ship auxiliary engines, in this case if the electricity is not supplied by the port. At port, ship fuel consumption is proportional to the total time the ship was in port [5].

The calculation of fuel consumption of engines refers to (2):

$$FC = BHP \times SFOC \times t \quad (2)$$

where: FC: Fuel consumption (gr), BHP : Main engine power (kW), SFOC: Specific Fuel Oil Consumption (g/kWh), t: Time (hours).

This paper examines the ways to reduce fuel consumption in container ship operations through speed optimization. Calculation for fuel consumption per time unit when sailing refers to (3) [10]:

$$FC(v) = (FC_0/v_0^3)v^3 \quad (3)$$

where $FC(v)$ is the fuel consumption at sailing speed v , and FC_0 is the fuel consumption at design speed v_0 . In addition, ship consumes fuel when waiting and performing loading/unloading activities at port.

III. RESEARCH DATA

The research methods contain some steps that will be described in the following section as below. The objective of this study is to use MV. Meratus Malino. This ship sails from Tanjung Perak Surabaya to port of Makassar, Indonesia.

Table I shows the principle dimension of MV. Meratus Malino, while Table II shows the fuel consumption based on shipping log data in one trip at May 23th 2016.

Table III shows the fuel consumption of MV. Meratus

Malino during loading – unloading activity of 573 TEU's, while Table IV shows the fuel consumption at departure-arrival maneuver.

Table V shows the port distance between Tanjung Perak port and Makassar port. Data from shipping logbook data show that total fuel consumption of MV. Meratus Malino in one trip is 40215 liters.

TABLE I
PRINCIPAL DIMENSION OF MV. MERATUS MALINO

Ship's Name/ Type	MV. Meratus Malino
Dimension (LoA; B; H; T)	149.6 m; 23.1 m; 12.8 m; 8.6 m
Service Speed	12.65 kn
M/E (Unit, Type, Power, SFOC)	MAN B & W, 7S 50 – MC, 13610 HP, 167
GT	11964
Routes	Surabaya – Makassar, Indonesia

TABLE II
FUEL CONSUMPTION OF MV. MERATUS MALINO AT SAILING CONDITION

Date (dd/mm/yyyy)	Duration of Sailing	Distance (NM)	Speed (kn)	Fuel Consumption (ltrs)
23/05/2016/ BOSV	0H 0M	0	0	0
23/05/2016	4H 0M	50	12.5	3120
23/05/2016	23H 0M	279	12.13	20220
23/05/2016/ EOSV	8H 0M	94.5	11.68	6160
Total	35H 0M	423.5	12.1	29500

TABLE III
FUEL CONSUMPTION OF MV. MERATUS MALINO AT LOADING-UNLOADING CONDITION

Date (dd/mm/yyyy)	Condition	Duration	Fuel Consumption (ltrs)
22/05/2016	Loading	12H 8M	1967
23/05/2016	Unloading	7H 24M	1183
Total		19H 32M	3150

TABLE IV
FUEL CONSUMPTION OF MV. MERATUS MALINO AT DEPARTURE-ARRIVAL MANEUVER

Date (dd/mm/yyyy)	Speed (kn)	Condition	Duration	Fuel Cons. (ltrs)
23/05/2016/	5	Departure	2H 30M	2635
24/05/2016	8	Arrival	23H 0M	4930
Total			19H 32M	7565

TABLE V
PORT DISTANCE

Port	Port Area 1 (Tj. Perak)	Sea Area	Port Area 2 (Makassar)
Tj. Perak - Makassar	7.5 NM	423.5 NM	25 NM

IV. RESULTS AND DISCUSSION

In this study, ship's speed will be varied in order to see the effect of difference speed on duration of sailing ship and fuel consumption of ships. After that, it will be compared with fuel consumption based on shipping logbook data. Speed variation is based on the area of cruise ships, the speed of the port area 1, the speed of the sea area, and the speed of the port area 2. Speed variations can be seen in Table VI.

As we know, every ship in shipping industry such as container ship has time windows schedule that must be obeyed.

Fig. 1 shows the time window of Makassar's port. When a ship arrives at the destination port before the time, the ship will be fined, and vice versa, if the ship arrived at the port of destination exceeds the schedule could be fined as well. Therefore, the ship's speed can be set when the ship running at high speed and when the ship running at low speed.

TABLE VI
FUEL CONSUMPTION OF MV. MERATUS MALINO

Speed Variation (kn)		
Port Area 1 (kn)	Sea Area (kn)	Port Area 2 (kn)
5	11.19	8
5	11.26	8
5	12.12	6



Fig. 1 Time windows MV. Meratus Malino from Surabaya - Makassar

It is known that service time of Makassar port is 24 h, with a demand of port 7080 TEUs in 2014 [11].

Below is the result of the calculation of fuel consumption using the equation that is already mentioned above. Table VII shows the fuel consumption at sailing time. Table VIII shows the fuel consumption at loading - unloading condition, and Table IX shows the fuel consumption while the ship maneuver.

From Table VII, it can be concluded that at lower speeds, ships consume less fuel. This is consistent with previous theory that the ship with lower ship will consume less fuel than ship with highest speed.

In Table VIII, the duration and fuel consumption is assumed to be the same as the data obtained from the logbook of the ship. So, there is no change in the duration or the amount of fuel consumption.

Table IX shows the variations of speed and fuel consumption at departure - arrival maneuver time. When the ship maneuver at a speed of 6 knots, the vessel consumes more fuel.

TABLE VII
FUEL CONSUMPTION OF MV. MERATUS MALINO AT SAILING CONDITION WITH VARIOUS SPEED

Speed (kn)	Duration of Sailing	Distance (NM)	Fuel Consumption (liters)
11	37H 36M	423.5	26330
11.28	37H 30M	423.5	26940
11.92	27H 18M	423.5	27850

TABLE VIII
FUEL CONSUMPTION OF MV. MERATUS MALINO AT LOADING-UNLOADING CONDITION

	Loading	Unloading
Duration	12H 8M	7H 24M
Fuel Consumption	1967	1183

TABLE IX
FUEL CONSUMPTION OF MV. MERATUS MALINO AT DEPARTURE-ARRIVAL MANEUVER

Speed (kn)	Condition	Duration	Fuel Consumption (liters)
5	Departure	2H 30M	2635
8	Arrival	23H 0M	4930
6	Arrival	27H 18M	5620

TABLE X
TOTAL SAILING TIME AND FUEL CONSUMPTION OF MV. MERATUS MALINO IN ONE TRIP WITH SOME VARIATION SPEED

Speed Variation (kn)	Total Duration	Distance (NM)	Fuel Consumption (liters)
5 - 11 - 8	82H 38M	423.5	37045
5- 11.28 - 8	82H 32M	423.5	37655
5 - 11.92 - 6	76H 38M	423.5	39255

TABLE XI
TOTAL SAILING TIME AND FUEL CONSUMPTION OF MV. MERATUS MALINO IN ONE TRIP WITH SOME VARIATION SPEED

Speed (kn)	N (Rpm)	BHP (HP)	BHP (%)
12.5	117.9	13000.3	95
12.13	114.2	111654.2	85
11.92	111.9	10858.2	80
11.58	108.5	9749.4	70
11.28	105.4	8699.9	64
11	102.3	7867.9	58

From the calculation results, it can be concluded that the scenario with ship running at speed 11 knots will consume less fuel than others scenario. However, that speed is not applicable yet on the ship operation. From the scenario mentioned above, after calculating the fuel consumption, the impact of the ship speed on the engine performance is analyzed. Table XI shows the power released by the engine in each speed scenario.

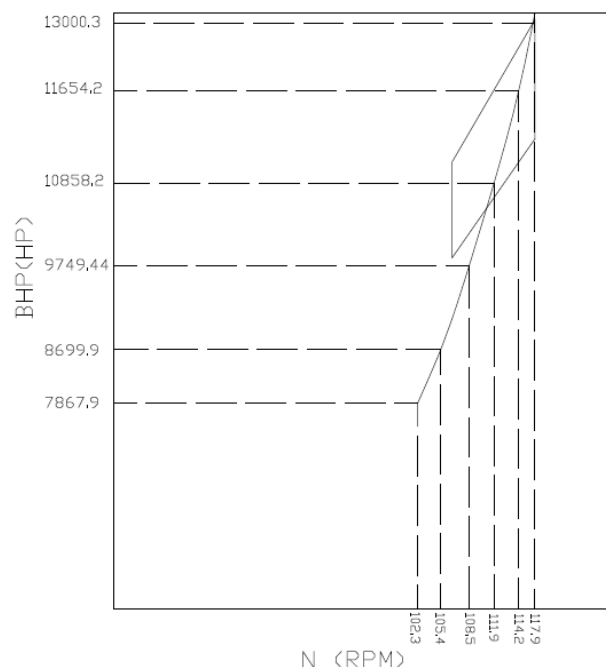


Fig. 2 Engine Performance Curve

It can be concluded that sailing with a speed of 11 knots can save more fuel than sailing at service speed, 12.5 knots. But, the speed of 11 knots will greatly affect engine performance. Engine only works 58% of the 100% engine power. Therefore, the speed of 11 knots cannot be used by ship in sailing condition.

From Table XI, it can be concluded that the speed of 11.92 knots is the optimum speed. At this speed, the boat can still be sailed not at the service speed and it reduces fuel consumption by not giving a considerable influence of engine performance. Fig. 2 shows the engine performance curve at any speed models.

V.CONCLUSION

It is known that the most substantial operational cost of ship is fuel cost. The cost of fuel consumption is normally over 50% of the total operating costs of a vessel. This paper examines the ways to reduce fuel consumption in ship operations through speed optimization and compared to the data based on shipping logbook of MV. Meratus Malino. The ship's speed varied, so it can be seen the effect of speed changes on ship fuel consumption. Based on calculations, MV. Malino Meratus can sail under the design speed without imposing a major influence on engine performance.

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