RESEARCH ARTICLE OPEN ACCESS

An Experimental Investigation of the Effect of Wind Speed and its Direction on the Marine Diesel Engine Fuel Consumption

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Abstract:
Generally, marine diesel fuel has become the highest effective parameter in shipping cost where, it has more than 45% of travelling cost. Since 2000, the fuel cost got high. Consequently, a lot of ships owners and engine manufacturers tried to develop and enhance the fuel consumption in order to increase the travelling revenue. But, the wind loads has a significant effects on the shipping resistance and relative wave direction. An example to show the importance of this research; considering 300 running days yearly with consumption of 40 ton/day "for small ships" in fuel cost of 500 USD/ton. If you neglect a 4% increasing in fuel calculations (that changes with the winds loads), it will accumulate 240,000 USD/year. So, a minor deviation in the fuel calculations will change the operational cost. Hence, the shareholders will decrease their expected profit. This study perform an experimental investigation and analysis of the wind speed effect and direction on the ship and its relative impact on the fuel consumption. The research methodology is based on studying the fuel consumption against the speed curve for selected different marine model (Panamax and Geared Supramax); and identify the most effective parameter that has to be enhanced in order to decrease the fuel consumption
Key words: Marine diesel engine, fuel consumption, wind speed, wind direction, fuel speed curve, ship head, beam and tail.

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I. INTRODUCTION

Designing a marine diesel engine efficiency is reflected with the fuel price. Between 1975 and 1982, there was increasing in fuel price significantly, making the ships owners to monitor the high fuel consumption. But, during the period 1983 to twenty century ends, prices of fuel down. Research and development on energy efficiency was unimportant regarding to the marines manufacturers.

However, since 2000, the fuel cost got high. Consequently, a lot of ships owners and engine manufacturers tried to develop and enhance the fuel consumption in order to increase the travelling revenue. The aim of experimental analysis is to predict the propulsion power, or calculating the wave resistance during sailing. It was recommended to install sensors onboard, along the marine diesel engine and ship deck to transmit all the required information, continuous monitoring to be gained with an analysis. This research study uses a similar approach, with the clear goal of gather all data to plot an real speed to fuel consumption curves at certain operating conditions depending on the changes in wind loads.

Ship's fuel consumption vs. speed curve was monitored during the traveling. Moreover, the resistance increases with increasing the ship speed due to high turbulence in the ship beam. Also, the fuel consumption increases by the selected two parameters as below:

- Increased displacement
- Worsening of weather conditions

Most studies were based on experimental investigations taken from practical tests and specific types of ships. Therefore, a statistical analysis was implemented to gather data and measure the influence of ship's weather loads to calculate the fuel consumption vs. speed curve that represents real and accurate curve.

The existing power-speed curve has negative effect; where the entire ship's lifetime effect on the fuel consumption. An example; considering 300 running days yearly with consumption of 40 ton/day "for small ships" in fuel cost of 500 USD/ton. If you neglect a 4% increasing in fuel calculations (that changes with the winds loads), it will accumulate 240,000 USD/year. So, a minor deviation in the fuel calculations will effect on the operational cost. Hence, the shareholders will decrease their expected profit.

Therefore, it is mandatory to have better and accurate fuel consumption calculations and identify the most effective and optimum parameters that reflect on the consumption in order to increase the profit margin of the shipping business.

II. MATERIALS AND METHODOLOGY

2.1. Research Methodology

The research methodology is to study the fuel consumption against the speed curve for selected different marine model as below:

- Panamax
- Geared Supramax

And consequently, the most optimum parameter that has to be enhanced in order to decrease the fuel consumption can be identified.

Fig. 2.1 presents an outline of the research developed in knowing the fuel consumption against speed curve. For this purpose, three parameters were evaluated:

1. Which model has higher fuel consumption
2. Weather force (wind speed)
3. Weather direction (wind attack angle)

Where, the fuel consumption was measured for each marine model and at each parameter shown above. The results will be presented on results and discussion section.

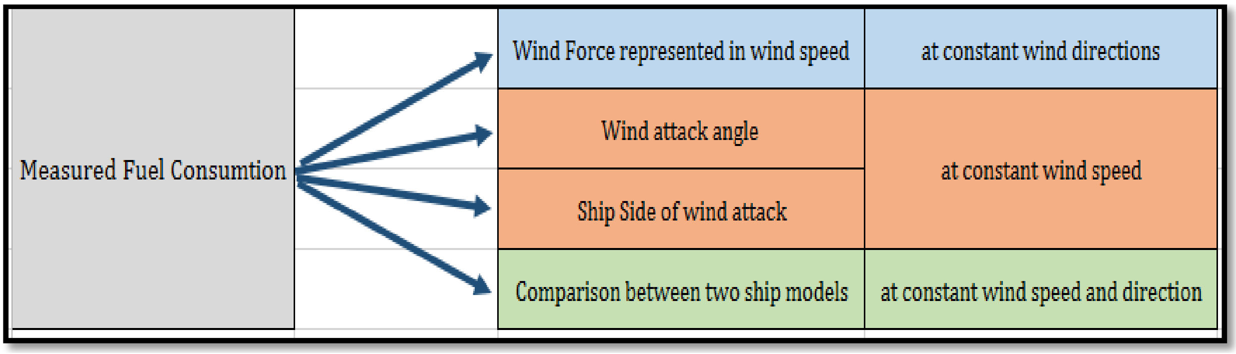


Figure 2.1. Research methodology to evaluate the optimum marine engine condition

Weather loads has to be used to measure the wind force (represented in speed) and its direction. Also, the date of the travelling is also required for the fuel consumption calculations. It is possible to guess the fuel consumption in a future travels, based on predetermined data.

2.2. Instruments Used

All parameters will be measured by installing different instruments devices onboard, along with equipment and on the ship dick to transmit the information and continuous monitoring**.**

a)Steaming distance (Km)

It is the shortest distance between two ports and it was measured in (Km) using the global positioning system (GPS).

b)Ground speed (Knot)

The ground speed is the ship speed that was calculated by dividing the main distance over the steaming time. It was measured in Knot (1 Knot is equivalent to 1.8 Km/hr).

c)Ship's Course (degree)

The ship's course is identify to know the ship direction. It was distinguished from the ship heading along the compass direction. It was measured used GPS.

d)Wind direction (Compass Card)

An anemometer was used. It is a device that measures wind speed and directions. It counts the cup rotation cycles, which is used to referred to the wind speed. Compass was used to determine the wind direction by using compass card as shown in figure 2.2. It is as rotating and circular card with magnetic compass showing the principal directions.

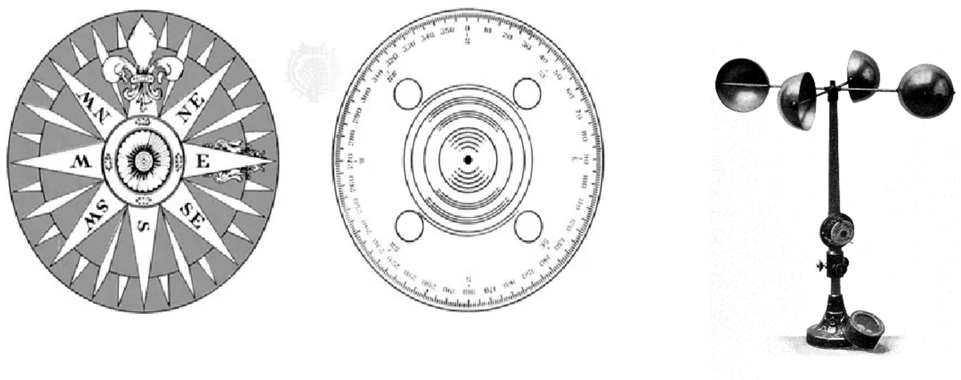


Figure 2.2. Compass Card and anemometer

e)Wind force (Speed) (Beaufort Scale)

Also, an anemometer was used. The scale is named for Sir Francis Beaufort (BF). It is determining the wind force depending on the procedures for setting sails on a warship. The Beaufort scale is a table. It describes the wind speed by a numbers (0 to 12) as per table 2.1. As increasing the BF number, the wind speed increases.

Table 2.1 Beaufort Wind Scale.

BF1	**Calm and still (wind speed < 1mph)**
BF2	**Light winds (wind speed is 1 to 3 mph).**
BF3	**Light breeze (wind speed is 4 to 7 mph).**
BF4	**Gentle breeze (wind speed is 8 to 12 mph).**
BF5	**Gentle breeze (wind speed is 13 to 18 mph).**
BF6	**Fresh breeze (19 to 24 mph).**
BF7	**Strong breeze (wind speed is 25 to 31 mph).**
BF8	**Moderate gale (wind speed is 32 to 38 mph).**
BF9	**Fresh gale (wind speed is 39 to 46 mph).**
BF10	**Strong gale (wind speed is 47 to 54 mph).**
BF11	**Whole gale (wind speed is 55 to 63 mph).**
BF12	**Herricane (wind speed is 74 to 136 mph).**

f)Fuel consumption

Differential pressure flow meter was used to measure the fuel mass flow rate depending on the pressure drop across the orifice install inside the flow meter body. Its model No. 8800DW020 Rose mount. It measured the marine diesel fuel in ton along the engine running time.

Figure 2.3. PDI Flow meter

2.3. Ships model and specifications

There are two ships model that were selected to study the relation between the fuel consumption against the speed curve experimentally as below:

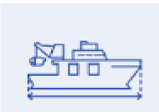
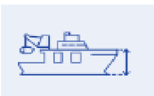
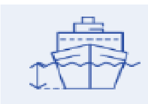
a)Panamax

b)Geared Supramax

Both ships were exposed to almost the same conditions along the voyage travel time. Note that they are the same DWT (52,500); Deadweight tonnage is a measurement of total contents of a ship including cargo, fuel, crew, passengers, food, and water aside from boiler water.

The ships specifications are listed as below in table 2.2:

Table 2.2 Ships Spec.

Parameter		Geared supramax bulker	Panamex	Unit
	Length	190	280	m
	Beam	32	32	m
	Depth	17	57	m
	Draft	12	12	m
Avg. Engine Fuel Consumption		36	240	Ton/day

III.RESULTS AND DISCUSSION

All measured parameters were based on the same wind speed (Beufort No. 3, 4, and 5). Comparison was applied according to the following:

- Comparison between two ships model according to fuel consumption increasing percentages at different ship speed at the same wind direction and attack angle.
- For both ships model; comparison between the fuel consumption against ship speed at different wind speed with the same wind direction.
- For both ships model; comparison between the fuel consumption against ship speed at different wind direction with the same wind speed.

3.1.Which model has higher fuel consumption

Based on figure 3.1; it was concluded that for the same weather loads; the fuel was increased with increasing the ship speed for both models due to increasing in wave resistance against the ship head. In addition, Panamex model has higher fuel consumption compared with supramex because it has higher length and depth as per table 2.2.

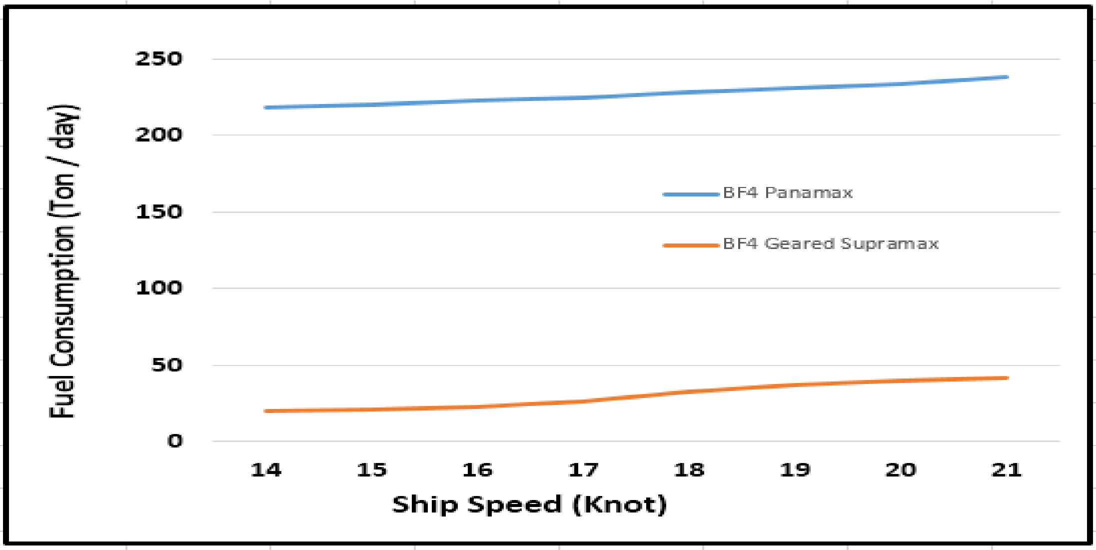


Figure 3.1. Fuel consumption for both models against ship speed

On the other hand and based on table 3.1; it was concluded that the rate of increasing in fuel consumption for large bulk carrier is less than the medium/ small bulk carrier because the effect of turbulence that produced from high ship speed will be significant on the medium or small carrier compared with the large one. So, it I much recommended to use large bulk carrier in high speeds respect to fuel consumption.

Also, large bulk carrier have high inertia due to high weight. This help the ship to sail with low fuel consumption at different speeds and weather conditions.

Table 3.1 Rate of increasing in Fuel Consumption for two ship models

Speed (Knot)	BF4 Panamax		BF4 Geared Supramax	
	Fuel Consumption	Fuel rate of increasing	Fuel Consumption	Fuel rate of Increasing
14	218	----	20	----
15	220	0.9	21	5.0
16	223	1.4	23	9.5
17	225	0.9	26	13.0
18	228	1.3	33	26.9

19	**231**	**1.3**	**37**	**12.1**
20	**234**	**1.3**	**40**	**8.1**
21	**238**	**1.7**	**42**	**5.0**

3.2.Fuel consumption at different wind speed with the same wind angle

According to figure 3.2 and 3.3; it was concluded that; at lower wind speed "BF3"; there is a minor changes on the fuel consumption at different ship speed. On the other hand; at bad weather "BF5"; there is significant changes in the fuel consumption especially at high ship speeds.

Hence, it is recommended to optimize the fuel consumption; to drive fast "up to 21 Knot" at low wind speed "BF3" and drive slow "up to 16 Knot" at higher wind speed "BF6".

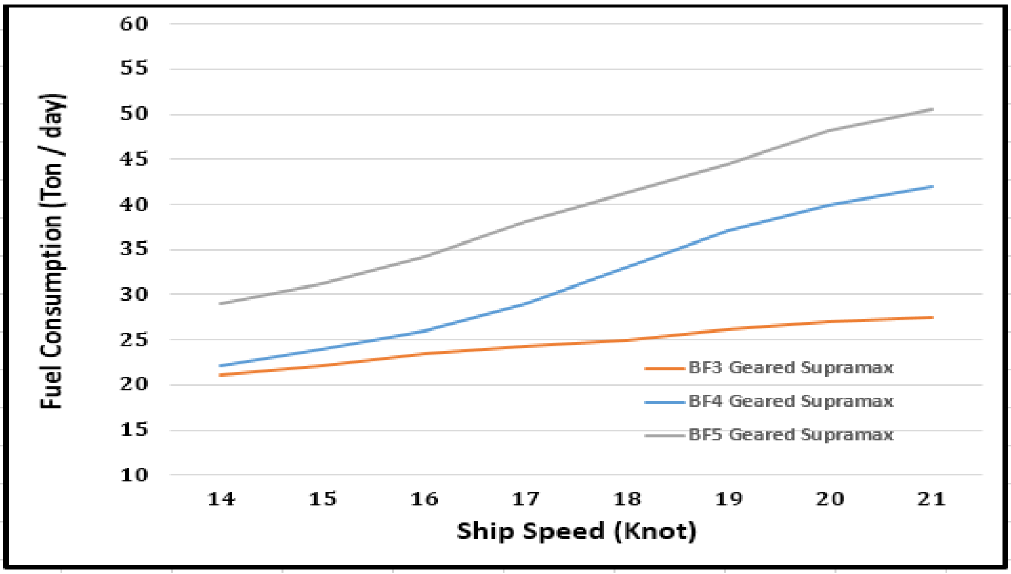


Figure 3.2. For Supramax; Fuel consumption at different wind speed against ship speed at constant wind angle

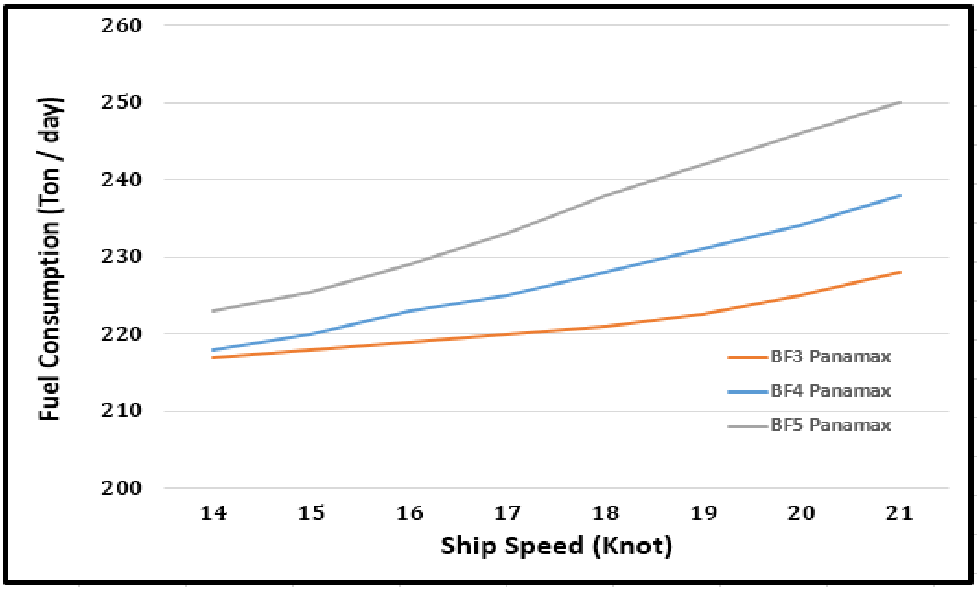


Figure 3.3. For Panamax; Fuel consumption at different wind speed against ship speed at constant wind angle

3.3.Fuel consumption at different wind angle with the same wind speed

As shown in figure 3.4 and 3.5 and for both models; it was concluded that; generally; the highest significant change in fuel consumption occurred when the attack angle was toward the head and vice versa in case of tail attack angle. This is due to higher ship resistance at head attack.

On the other hand, it is much recommended to lower the ship speed in case of beam side attack angle because it consumed much fuel at higher ship speed. This is due to high moment generated at the beam side from the wind load which cause high turbulence at the ship side.

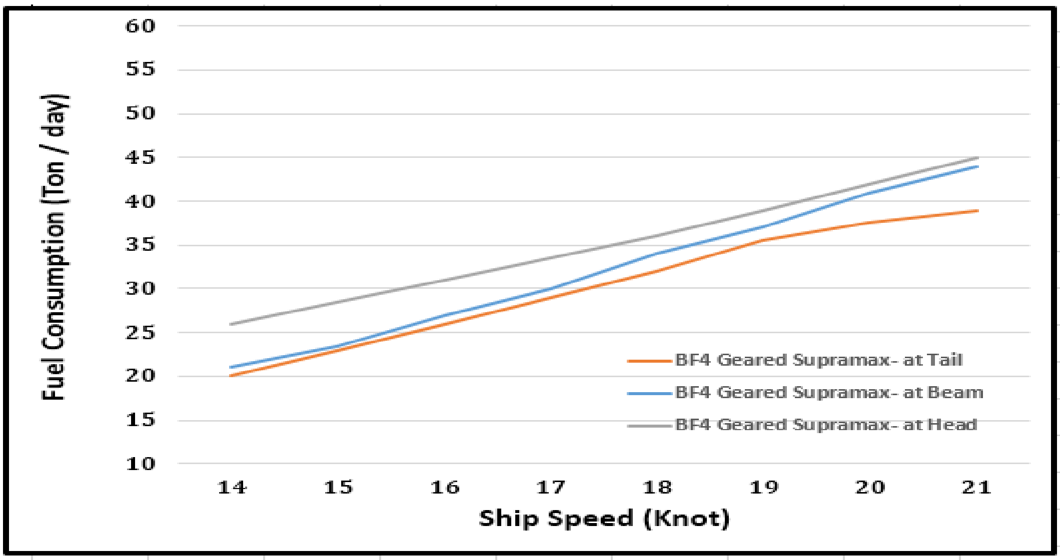


Figure 3.4. For Supramax; Fuel consumption at different wind angle against ship speed at constant wind speed

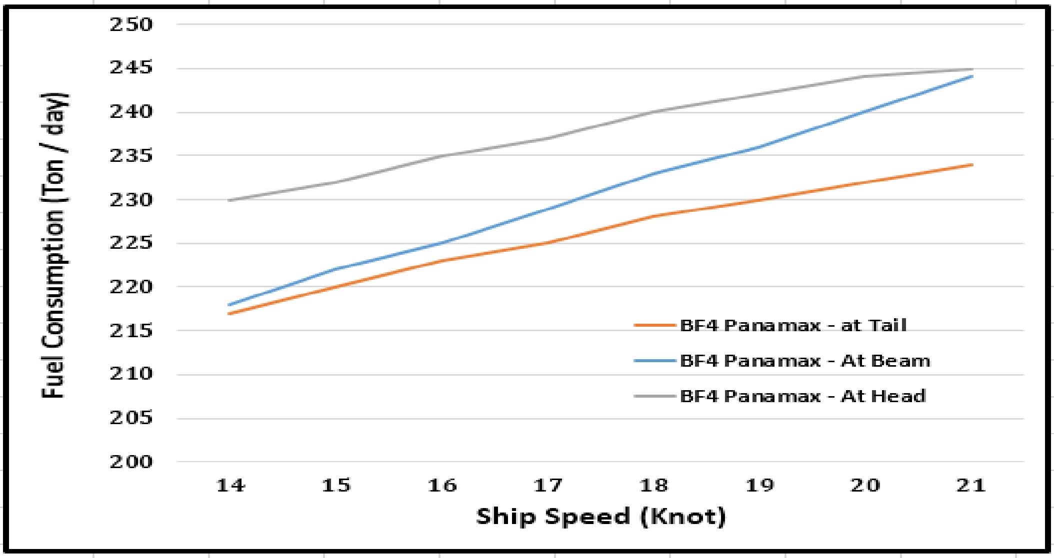


Figure 3.5. For Panamax; Fuel consumption at different wind angle against ship speed at constant wind speed

IV.CONCLUSION

From before, it was concluded that: for the same wind condition; the fuel was increased with increasing the ship speed for any ship model. Moreover, it is much recommended to use the large bulk carrier for high ship speed because it is more efficient and low fuel consumption compared with medium carrier.

At lower wind speed "BF3"; It is much better to raise the ship speed above 21 Knot because it will decrease the travelling time and will not consume high fuel quantities. But, at higher wind speed "BF5 and more"; it is much better to lower the ship speed below 16 Knot because it will save fuel quantities.

When the attack angle become toward the head or the beam side; it is much recommended to lower the ship speed but when the attack angle become toward the tail side, it is much recommended to raise the ship speed because it will decrease the travelling time and will not consume high fuel quantities.

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