APPLICATION OF SLOW STEAMING ON 100 TEUs CONTAINER SHIP ON THE TANJUNG PERAK-BELAWAN ROUTE

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ABSTRACT

Sea transportation is a vital component of international trade, constituting over 80% of global cargo movement. As the shipping sector anticipates a promising future amid economic liberalization and enhanced operational efficiency, the focus on reducing fuel consumption becomes paramount. This paper investigates the potential benefits and drawbacks of implementing slow steaming, a strategy involving reduced ship speeds, to curtail operational costs, particularly fuel expenses that constitute 47% of total ship operational costs. The liner shipping industry in Indonesia is examined as a case study, evaluating the impact of slow steaming on fuel consumption, emissions, and overall financial performance. Ship that was used in this paper is a 100 TEUs container ship with 2 x 1550 HP engine Yanmar 12AYM-WET which had a voyage route that is assumed to be direct from Tanjung Perak Port to Belawan Port without any transit at other ports. There are 6 speed variations from sea trial data to calculating fuel consumption. Another assumption used is that the dwelling time at Belawan port as of December 2023 is 2.89 days. Considering the dwelling time at Belawan Port, Medan, the speed chosen is 7.6 knots with a travel time of 8.16 days. The assumption is that the fuel used is Diesel Oil B35 with a price of Rp. 22,300/litre. The fuel savings with a travel time of 8.16 days is 19,283.13 litres. The RPM ratio in existing conditions is 1:1.3. So the conversion is carried out into a graph to get the existing FOC. Next, the FOC calculation is carried out by interpolating the fuel consumption diagram against RPM. The CII value at a speed of 7.6 knots shows 0.593 with an A rating. The EEXI value when the speed is 7.6 knots shows the number 7.1235 which is compliant.

Keyword: Consumption, Container, EEXI, Fuel Oil, Saving

Introduction

Sea transportation is currently the most significant method of cargo transportation as it involves more than four-fifths of international trade. With more than 50,000 merchant ships worldwide displacing more than 1,000 gross tons and a total deadweight of around 2 billion tons, maritime transportation plays an important role in the world economy. The future of the shipping industry is quite promising due to increasing economic liberalisation and increasing efficiency of shipping as a means of transportation.

In shipping, the best way to reduce operational costs is to reduce fuel consumption. The reason is that fuel consumption costs reach around 47% of the total ship operational costs. One strategy to reduce fuel consumption is to use slow steaming. In slow sailing, container ships usually sail at a speed of 20-24 knots, reduced to only 12-19 knots. At lower speeds, less fuel is consumed by the ship, which also impacts emissions.

It is hoped that the liner shipping industry in Indonesia can save significant costs by implementing slow steaming, taking into account how many operational costs can be saved by reducing ship speed. Reducing ship speed by 20.63% results in fuel consumption savings of around 49.01% (Anye et al. 2013). Slow steaming has a positive impact on ship owners and operators because they get benefits in the form of fuel cost savings and also reduce a number of emissions. However, slow steaming has negative impacts such as reducing the number of ship trips in one year which can reduce company revenues.

In this paper, the author selects the most efficient ship speed which can help in company decision-making. In this paper it is assumed to compare the speed of the ship at full speed, slow steaming, extra slow steaming and super slow steaming by considering technical, financial and environmental aspects.

Methodology

Voyage Route

Voyage route is assumed to be direct from Tanjung Perak Port to Belawan Port without any transit at other ports. The distance between Tanjung Perak port to Belawan port is 1488 nm.

Figure 1. Voyage Tanjung Perak (SBY) - Belawan (Medan)

Principal Particular

Ship that used in this paper is a Container ship with principal particular:

Table 1. Ship Particular

Details	Dimensions
Length Overall	74.05 m
Length Between Perpendicular	69.20 m
Breadth Mould	17.20 m
Moulded Depth	4.90 m
Draught	3.50 m
Gross Tonnage	1787 Ton
Net Tonnage	537 Ton

Engine Specification

Engine that used in that Container ship 100 TEUs are 2 x 1550 HP engine Yanmar 12AYM-WET.

Figure 2. Engine Yanmar 12AYM-WET

Table 2. Engine specification

Model	Type
Type	4-cycle diesel eng
No. of cyl, bore x stroke (mm)	12.155 x 180
Displacement (lt)	40.76
Rated Output (kW (hp)/rpm)	M: 1220 (1659)
Emission	IMO Tier II
Fuel Consumption (gr/kW hr)	M: 217 at rated output
Dry weight	4950 (w/o marine gear)

Sea Trial Data

Ship speed and RPM data obtained from the ship's sea trials, used to calculate the fuel oil consumption. For the purposes of calculating real fuel consumption, sea trial data for the relevant ship is obtained which shows the speed produced in each engine RPM trial. This data will be used to determine SFOC (Specific Fuel Oil Consumption Engine) by interpolating the fuel consumption diagram against RPM.

Table 3. Sea trials data

Tenaga Mesin (% MCR)	25%	25%	50%	50%	75%	75%	85%	85%	90%	90%	100%	100%
RPM M/E (P)	750	750	800	800	1000	1000	1100	1100	1200	1200	1350	1350
RPM M/E (S)	750	750	800	800	1000	1000	1100	1100	1200	1200	1350	1350
Kecepatan (knot)	5,9	4,4	6,7	5,7	8,3	6,9	8,8	7,7	9,4	8,6	11,0	9,9
Arah Kapal												
Arah Arus	⇨	⇦	⇨	⇦	⇨	⇦	⇨	⇦	⇨	⇦	⇨	⇦
Kecepatan Rata-Rata (knot)	5,15		6,2		7,6		8,25		9		10,45	

Voyage Scenario

There are 6 speed variations from sea trial data to calculating fuel consumption, the speed used is the average speed as presented in the table.

Table 4. Speed variations

No. Scenario	Engine RPM	Velocity (kn)
1	750	5.15
2	800	6.2
3	1000	7.6
4	1100	8.25
5	1200	9
6	1350	10.45

Another assumption used is that the dwelling time at Belawan port as of December 2023 is 2.89 days. The assumption is that the fuel used is Diesel Oil B35 with a price of Rp. 22,300/litre (regions 1 and 2 as of 1 December 2023).

Figure 3. Dwelling time at Belawan Port in Dec 2023

Energy Efficiency Index

The International Maritime Organization (IMO) has played a crucial role in addressing environmental concerns related to the shipping industry. Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Ship Index (EEXI) have been established to enhance energy efficiency and reduce greenhouse gas emissions from ships. The instrument aims to achieve significant GHG emission reductions from ships through enhanced energy efficiency measures [1]. Stakeholders across various sectors contribute to this effort, providing technical insights to refine the EEDI and EEXI. The EEDI and EEXI formula is designed specifically for the largest and most energy-intensive segments of the global merchant fleet. It covers ship types such as oil and gas tankers, bulk carriers, general cargo ships, refrigerated cargo carriers, and container ships [2].

The mechanism provides a flexible and nonprescriptive framework for achieving energy efficiency. The introduction of EEDI for new ships represents a significant step towards reducing CO2 emissions in the shipping industry. On the other side, EEXI is used for reducing CO2 emissions for existing ships. The coordinated efforts of the IMO and stakeholders have resulted in a comprehensive framework that addresses existing and new vessels, ensuring a sustainable and environmentally conscious future for international shipping. As the industry evolves, ongoing discussions and refinements to regulations like EEXI and EEDI will be essential to meet the challenges of a rapidly changing maritime landscape [3][4].

In this study, the calculation focuses on the emission produced by the main engine. Carbon emission will be calculated as following approach [5]:

$$\left\{\left(\prod_{j=1}^{n} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} C_{FME(i)} SFC_{ME(i)}\right)\right\}$$

Where C_{FME} is the conversion factor fuel oil to CO2 and depends on the fuel type documented in the NOx Technical File, which for diesel/gas oil, are 3,206 [6]. SFC_{me} is the specific fuel consumption of the main engine at 75% MCR. fj is the correction factor for ship specific design elements which if no ship specific design elements are installed, the factor is set to 1. PME could be obtained using following equation:

$$P_{ME(i)} = 75\% \left(MCR_{(i)} - P_{PTO}\right)$$

The MCR (The maximum continuous rated power output) is as specified in the Technical File of the marine diesel engine.

To estimate the EEDI and EEXI which have the same formula, the following equation could be conducted:

$$EEDI \text{ or } EEXI = \frac{CO^2\ Emission}{Transport\ Work}$$

$$EEDI \text{ or } EEXI = \frac{P_{ME(i)} C_{FME(i)} SFC_{ME(i)}}{C_V}$$

TWhere, C is the capacity and v is the EEDI or EEXI speed.

Though the EEDI and EEXI formulas are the same, some parameter definitions are different.

Result and Discussion

Fuel Oil Consumption Estimation (FOC)

The RPM ratio in existing conditions is 1:1.3. So the conversion is carried out into a graph to get the existing FOC. Next, the FOC calculation is carried out by interpolating the fuel consumption diagram against RPM.

Table 5. FOC calculation

RPM Exist	Engine RPM	Velocity (kn)	FOC (lt/hr)
750	1024.51	5.15	48.02
800	1092.81	6.2	57.68
1000	1366.013	7.6	111.23
1100	1502.614	8.25	147.18
1200	1639.216	9	191.94
1350	1844.118	10.45	288.36

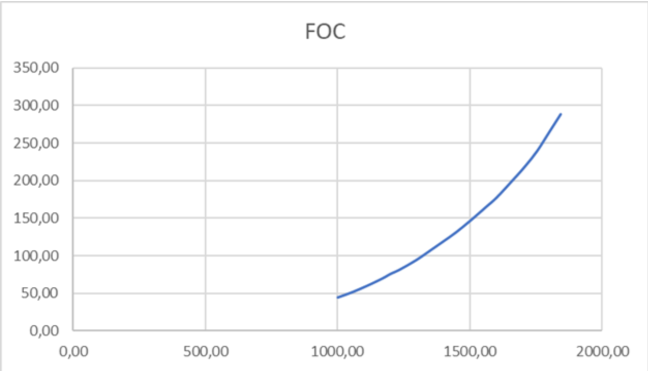

Figure 4. The RPM ratio in existing conditions

Analysis of Fuel Oil Needs

The calculation results can be seen at Table 6 below:

Table 6. Fuel Oil Needs

RPM Exist	Velocity (kn)	Time (hr/day)	SFOC (lt/hr)	FO Needs
750	5.15	288.93/12.04	48.02	13.874
800	6.2	24.00/10.00	57.68	13.843
1000	7.6	195.79/8.16	111.23	21.775
1100	8.25	180.36/7.52	147.18	26.546
1200	9	165.33/6.89	191.94	31.732
1350	10.45	142.39/5.93	288.36	41.058

The calculation results show that in the lowest speed scenario (5.15 kn) the fuel required is greater than in the second-speed scenario (6.2 kn), then the higher the ship speed, the greater the fuel required for the same voyage (Tanjung Perak-Belawan).

Table 7. Fuel Oil Value

RPM Exist	Velocity (kn)	FO Needs	Value (Rupiah)
750	5.15	13.874	Rp. 309.401.718.06
800	6.2	13.843	Rp. 308.703.360.00
1000	7.6	21.775	Rp. 485.598.227.37
1100	8.25	26.546	Rp. 591.990.104.44
1200	9	31.732	Rp. 707.633.114.67
1350	10.45	41.058	Rp. 915.611.965.55

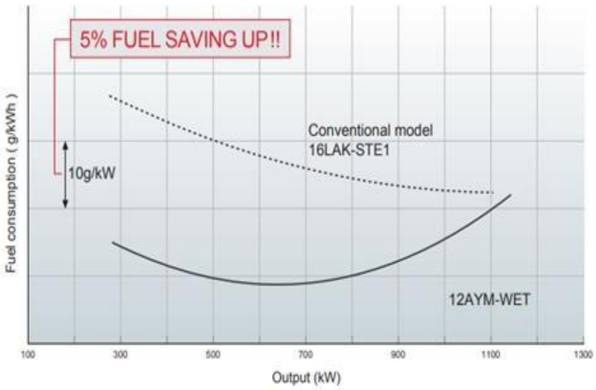

Figure 5. Fuel Saving

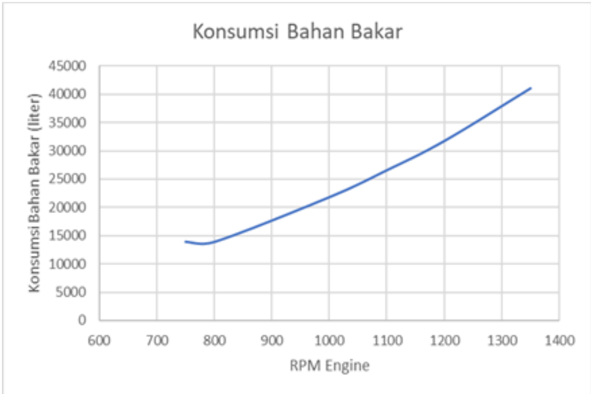

Figure 6. Fuel Oil Consumption Needs

Analysis of Fuel Oil Savings

By considering the results of calculating fuel requirements and dwelling time at Belawan Port, which is 2.89 days, shipping options with fuel savings are designed as table 8.

Energy Efficiency Existing Ship Index (EEXI)

To calculate the EEXI, we need to know the carbon intensity indicator. the carbon intensity indicator at RPM 1350, speed 10.45 kn and RPM 1000, speed 7.6 knot can be seen in the figure 7 and 8.

Table 8. Fuel Oil Savings

V (kn)	Time (day)	FO Needs	Dwelling Time + Day	Slow Steaming V Option (kn)	Dwelling Time + Day	FO Needs (1)	FO Needs (Slow Steaming) (2)	FO Savings (1-2)
7.6	8.16	21.775	11.05	6.2	11.05	21.775	13.843.20	7.932.51
8.25	7.52	26.546	10.41	6.2	10.41	26.546	13.843.20	12.703.44
9	6.89	31.732	9.78	7.6	9.78	31.732	21.775.71	9.956.72
10.45	5.93	41.058	8.82	7.6	8.82	41.058	21.775.71	19.283.13

Ship Particular	IMO Number	9863601
	Ship Name	Container 100 TEUS
	Ship Type	Container ship
	Deadweight	1500
	Gross Tonnage	1787
Fuel Consumption (ton)	Diesel/Gas Oil	288
	LFO	
	HFO	
	LPG(Propane)	
	LPG(Butane)	
	LNG	
	Methanol	
	Ethanol	
Distance Travelled (nm)		1488
CO2 Emission		924
Attained CII		414.18
CII ref		55.52
Rating Year		2023
Required CII		52.74
Attained CII / Required CII		7.853
CII Rating		E

Figure 7. Carbon intensity indicator at RPM 1350, speed 10.45 kn

Ship Particular	IMO Number	9863601
	Ship Name	Container 100 TEUS
	Ship Type	Container ship
	Deadweight	1500
	Gross Tonnage	1787
Fuel Consumption (ton)	Diesel/Gas Oil	22
	LFO	
	HFO	
	LPG(Propane)	
	LPG(Butane)	
	LNG	
	Methanol	
	Ethanol	
Distance Travelled (nm)		1488
CO2 Emission		70
Attained CII		31.28
CII ref		55.52
Rating Year		2023
Required CII		52.74
Attained CII / Required CII		0.593
CII Rating		A

Figure 8. Carbon intensity indicator at RPM 1000, speed 7.6 kn

Based on the calculations that have been carried out, it is found that with a shipping scenario where the ship applies slow steaming at a speed of 7.6 knots, the ship meets the EEXI with a value of 7.1235, where the requirement is 40.0593 (Compliant).

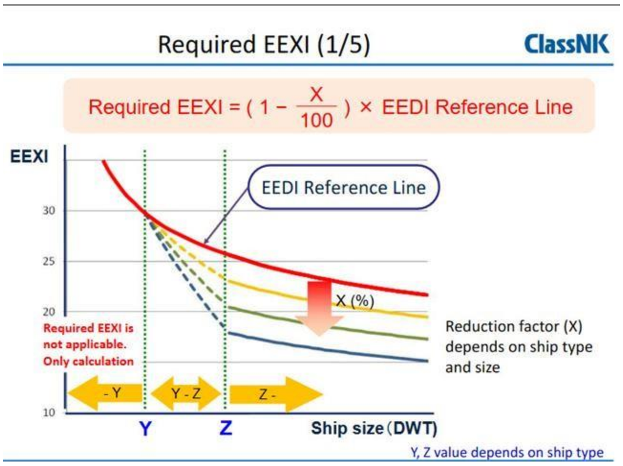

Figure 9. Required EEDi Reference Line

Required EEXI (3/5) ClassNK

EEDI Reference Line

✓ Required EEXI is set based on the EEDI reference line

Type of ship		Reference Line
Bulk carrier	DWT ≤ 279,000	$961.79 \times DWT^{-0.477}$
	DWT > 279,000	$961.79 \times 279{,}000^{-0.477}$
Gas carrier		$1120.00 \times DWT^{-0.456}$
Tanker		$1218.80 \times DWT^{-0.488}$
Containership		$174.22 \times DWT^{-0.201}$
General cargo ship		$107.48 \times DWT^{-0.216}$
Refrigerated cargo carrier		$227.01 \times DWT^{-0.244}$
Combination carrier		$1219.00 \times DWT^{-0.488}$
Ro-ro cargo ship (vehicle carrier)	DWT/GT < 0.3	$(DWT/GT)^{-0.7} \times 780.36 \times DWT^{-0.471}$
	DWT/GT ≥ 0.3	$1812.63 \times DWT^{-0.471}$
Ro-ro cargo ship	DWT ≤ 17,000	$1686.17 \times DWT^{-0.498}$
	DWT > 17,000	$1686.17 \times 17{,}000^{-0.498}$
Ro-ro passenger ship	DWT ≤ 10,000	$902.59 \times DWT^{-0.381}$
	DWT > 10,000	$902.59 \times 10{,}000^{-0.381}$
LNG carrier		$2253.7 \times DWT^{-0.474}$
Cruise passenger ship having non-conventional propulsion		$170.84 \times GT^{-0.214}$

Figure 10. Required EEXI set based on the EEDI reference Line

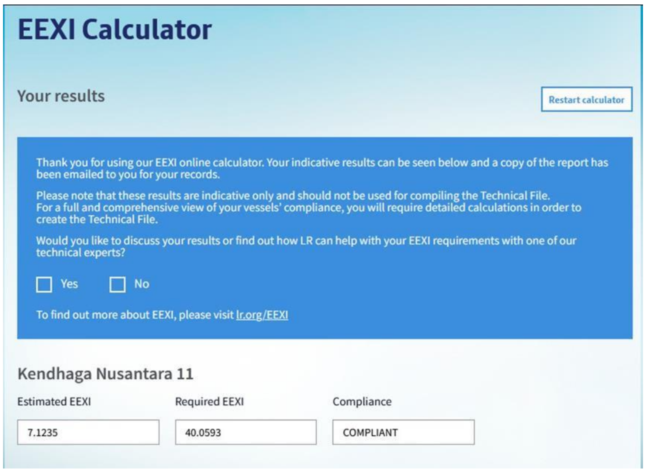

Figure 11. EEXI Compliance

Conclusion

The conclusions of the studies are:

1. Considering the dwelling time at Belawan Port, Medan, for 3 days, the speed chosen is 7.6 knots with a travel time of 8.16 days
2. The result of fuel savings with a travel time of
3. 8.16 days is 19,283.13 litres
4. The CII value at a speed of 7.6 knots shows 0.593 with an A rating
5. The EEXI value when the speed is 7.6 knots shows the number 7.1235 (COMPLIANT)

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