Impact of EEDI and EEXI on Bulk Carriers

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Synopsis

The bulk carrier fleet faces a lot of challenges to cope with the strict GHG emissions implemented by IMO. The EEDI rules for the newly designed ships and EEXI regulations for the existing ships are considered to be the strictest for the bulk carriers and operating efficiently as well as comply with the rules can be very difficult. A comparative study of the EEDI values for bulk carriers and container vessels are carried out to depict the limitations faced by newly designed and existing bulk carriers. Also, the lowering of speed of the bulk carrier to reduce maximum power output of the vessel is discussed and how it may not be effective on a long-term basis is discussed with respect to the Minimum Power Requirement guidelines for a bulk carrier. Furthermore, the alternative options for replacing the conventional bulk carrier design are discussed which includes usage of alternative fuel instead of heavy fuel oil, usage of wind power and implementation of hybrid systems onboard the ship. The economic aspect of these alternatives is discussed. As for the existing bulk carrier fleet the compliance with EEXI regulations is checked and suggested alternative is discussed, which mainly includes retrofitting or decommissioning of the vessel, based on the evaluation of profit margin. From the respective analysis, a suggested solution is provided which includes a hybrid system utilization as well as encourage short voyages instead of a long one which is typical for bulk carriers in order to minimize the limitations faced by the bulk carrier fleet.

Keywords: Bulk Carrier, EEDI, EEXI, LNG, LPG, Methanol, Hybrid Propulsion System, Carbon Capture System, Wind Energy, Flettner Rotor

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1. Introduction

In this paper, the effect of Energy Efficiency Design Index (EEDI) and Energy Efficiency Existing Index (EEXI) on bulk carriers is discussed. A number of alternative methods which includes use of Liquified Natural Gas (LNG) as the alternative fuel or using wind energy as a complimentary system along with the conventional heavy fuel oil operated bulk carrier. Also, operating the vessel at lower speed in order to comply EEDI regulations, is another viable option. But all the alternative methods have limitations which are discussed in detail.

1.1 Background

The EEDI is a measure implemented to reduce carbon footprint introduced by Maritime Environment Protection Committee (MEPC). The term was adopted and brought into effect in the 62nd session of MEPC in July 2011, which is applicable to new ships or ships which has undergone major conversion. In accordance with the EEDI regulations, the required EEDI must be less than the attained EEDI. The EEDI regulations are implemented in phases and with each advancing phase, the required EEDI value reduces, which further restricts the emission from ships. The recent phase is phase 2, initiated from 2020 to 2025 (MEPC, 2011). The required EEDI is different for different ships, determined from previous ship data. As for attained EEDI, it is a function of maximum power output, deadweight, specific fuel consumption and service speed of the ship. It also depends on the carbon factor of the fuel used and the factors applicable to the designed vessel. In short, the EEDI can be defined as a measure to calculate the damage done due to CO2 emission with respect to the effective transport work done.

The EEXI on the other hand is applicable to existing ships above 400 Gross Tonnage (GT), which is adopted in June 2021 and possible entry into force in January 2023 (DNV GL, 2021). It is applicable to all pre EEDI and post EEDI launched vessels. The EEXI calculations are similar to that of EEDI, and modifications are mandatory to be made to the existing ships if it doesn’t comply with the EEXI regulations.

2. The Problem

So, the question is, why a measure initiated to restrict CO_2 emissions is a problem for large bulk carriers, operating on a long-distance voyage?

A number of factors can be considered to be disadvantageous, when considering EEDI calculations for ships. They can be pointed out as follows:

EEDI/EEXI uses only one operating profile, i.e., they take into consideration only the design speed of the ship. It may not be the case for all types of ship. For example, a cruise ship usually operates at a lower speed and involves a lot of manoeuvring. As for bulk carriers, they usually operate at a lower speed than the designated design service speed.

The attained EEDI calculation is given by the equation 1.1.

$$\text{Attained EEDI} = \frac{75\%\text{MCR} \times \text{CF} \times \text{SFOC} \times \text{SF}}{\text{Capacity} \times \text{Service Speed}}$$

Equation 1.1

MCR is the Maximum Continuous Rating of the vessel, which is maximum power of the Main Engine installed in the ship. CF is the carbon factor of the fuel being used, SFOC is the Specific Fuel Oil Consumption of the M/E and SF represent s Specific Factors depending on the type of ship. The capacity refers to the deadweight (DWT) or the GT of the ship, depending on the type of ship. For large conventional bulk carriers, the ship specific factors do not have effective influence on the attained EEDI, especially for those carrying heavy cargo.

The required EEDI calculation is based on the previous ship data, i.e., a regression line developed based on the emission from previous ships, the formula being a function of deadweight. The equation is given as:

Required EEDI=a* [DWT]^{-c}

Equation 1.2

The coefficients a and c depend on the type of the ship taken into consideration. Therefore, the data cannot be said to be an absolute measure for determining a margin. For bulk carriers, the required EEDI becomes quite rigid with increasing deadweight. For the same deadweight, the required EEDI margin for bulk carriers is stricter in comparison to container ships, though one can argue that the time factor plays a big role for container ship operations.

Operating the bulk carrier at slower speed to reduce power requirement cannot be taken as a long-term solution as the rules will get stricter, with each passing phase and in accordance with the Minimum Power Requirement guidelines (ClassNK, 2013) for the ship, the installed propulsion unit cannot have less than the power determined based on the minimum power requirement assessment. So, even if the bulk carrier complies with the EEDI/EEXI regulations by reducing service speed but doesn’t comply with rules for minimum power required by the ship, then it will be unworthy for any commercial application.

To cope up with the GHG regulations and also maintain optimal operation efficiency, use of alternative fuels for main propulsion and subsequent use of renewable energy, such as utilization of wind energy for auxiliary power are considered as a potential option. Use of carbon capture system is also considered to be an option but have many restrictions.

3. EEDI Calculation for Conventional Bulk Carriers

EEDI is applicable to newly built ship and depending on the period during which the ship is built or is to be build, the EEDI regulations for that particular phase will be applicable for the new vessel. For example, a ship built in 2019 having a gross tonnage more than 400 GT must comply with EEDI regulation of phase 1, i.e., between 1st January 2015 to 31st December 2019 (MEPC, 2011).

A comparative graph between the required EEDI curve for bulk carrier and container ship is shown in figure 1. As it can be seen from the figure 1, for the same deadweight, the required EEDI margin is considerably lower for a bulk carrier in comparison to a container ship.

Thus, the bulk carrier operates at a low design speed, so that the power required for the ship is reduced. Power shares a cubic relationship with the speed of the ship. And as the attained EEDI calculation is dependent on the MCR of the installed engine and service speed, therefore less the service speed, less will be the power required and thus reduction in Attained EEDI.

Shaft power limitation is already initiated in ships in order to reduce the Attained EEDI and has been approved by MEPC (MEPC, 2021) But as stated earlier, it is not a long-term solution.

Another explanation for containerships having high required EEDI margin is that it operates at high speed and highly dependent on the time factor, i.e., the cargo is to be delivered within stipulated time to the destination. For bulk carriers, it can be said that the time factor is not as important as container ships and thus can be allowed to operate at a lower speed. But as the problem is stated, lowering the speed to reduce power requirement is not a long-term solution as minimum power is required for the sufficient manoeuvrability in adverse weather conditions, and thus when the EEDI margin gets stricter over coming years, a conventional bulk carrier won't be able to operate even at lower speed to comply with EEDI rules in case it doesn't comply with Minimum Power Requirement Regulations.

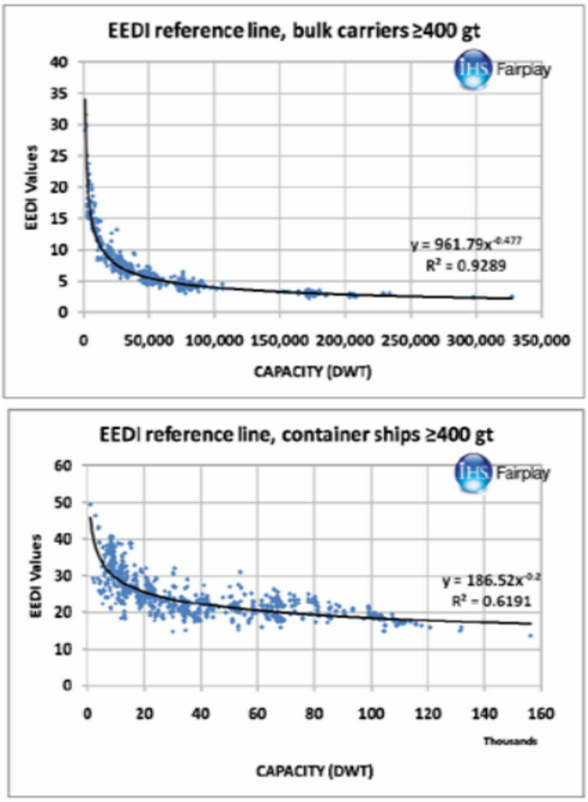

Figure 1: Required EEDI margin for Bulk Carriers and Container Ships (IMO, n.d.)

A comparative graph between required EEDI for container ships and bulk carriers for different phases are shown in figure 1 (IMO, n.d) and figure 2. Phase 0 refers to a period between 2013 to 2015, phase 1 includes the period between 2015 to 2020 and phase 2 is between 2020 to 2025.

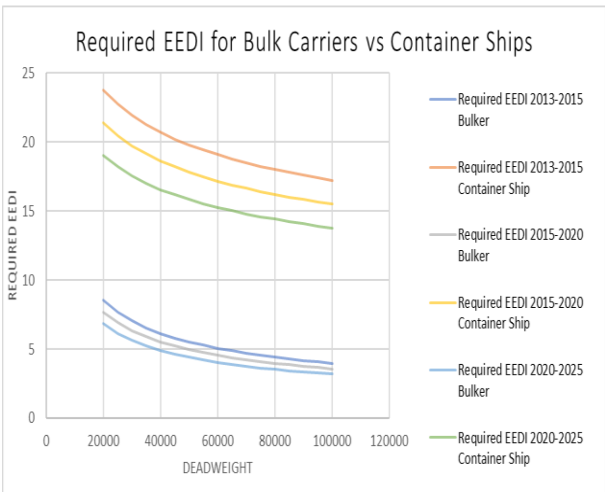

Figure 2: Required EEDI for Bulk Carriers vs Container Ship

Ship Particulars	Value
Length overall (L_{OA}) [m]	228.99
Length between perpendiculars (L_{PP}) [m]	222.0
Moulded Breadth (B) [m]	32.26
Moulded Depth (D) [m]	20.05
Moulded Design Draft (T_D) [m]	12.20
Deadweight at scantling draft [tonnes]	82026
Maximum Continuous Rating M/E [kW]	9710
Service Speed (Vs) [knots]	13
Auxiliary Engine (A/E) Power (Paux) [kW]	486
SFOC M/E (g/kWh)	165
SFOC A/E (g/kWh)	200

Table 1: Main Dimensions and Power Rating of a typical Panamax Bulk Carrier

The ship particulars of a typical Panamax bulk carrier are shown in table 1. The attained EEDI calculation was performed for the Panamax bulk carrier using equation 1.1, and it was evaluated that the bulk carrier complied with phase 0 and phase 1 of the EEDI regulations, but it doesn't comply with the phase 2, as seen in figure 3 and table 2. In this case, the bulk carrier uses heavy fuel oil (HFO) or marine diesel oil (MDO) as the main fuel.

Therefore, it can be said that a conventional bulk carrier has to be operated at a lower speed to comply with EEDI regulations.

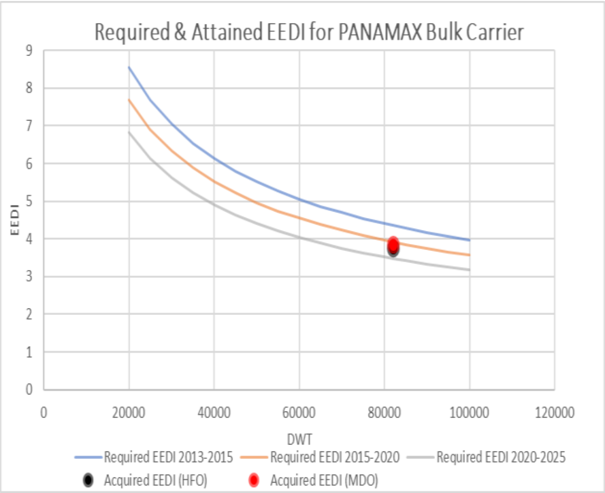

Figure 3: Required EEDI vs Attained EEDI for Panamax Bulk Carrier

75% of MCR	7282,5	7282,5
Paux	485,5	485,5
Vs	13	13
Fuel Used	HFO	MDO
Cf	3,11	3,21
SF	1,01	1,01
Attained EEDI	3,75	3,86
Required EEDI phase 0	4,36	4,36
Required EEDI phase 1	3,92	3,92
Required EEDI phase 2	3,14	3,14

Table 2: Attained EEDI vs Required EEDI for the Panamax Bulk Carrier

3.1. Problems Regarding EEDI Compliance

Though by reducing the service speed, the vessel can be made compliant with the EEDI 2020 regulation, but the conflict lies with the compliance of the bulk carrier with Minimum Power Requirement regulations. In accordance with assessment level 1 of the Interim Guidelines for Minimum Power Requirement (ClassNK, 2013), the minimum power required for the Panamax bulk carrier is 9632 kW approximately, whereas the MCR of the installed engine is 9710 kW. Now let us assume that the service speed is reduce to 12 knots. Therefore, the power required will be reduced to approximately to 7630 kW, therefore the calculated attained EEDI is approximately 3.085 gCO_2/tnm, which is lowered than the required EEDI 2020 value of 3.49 gCO_2/tnm. In order to comply with the EEDI rules, we can reduce the power to operate at lower speed, but it won't comply with the Minimum Power Assessment and therefore it can't be utilized commercially.

Another example of a typical Capesize bulk carrier is taken into consideration, having a DWT of 120000 tonnes, a service speed of 14.0 knots and MCR of 13600 kW. The Capsize bulker uses HFO and MDO as fuel, having SFOC 161 g/kWh and 190 g/kWh for M/E and A/E respectively. Though the vessel complies with the Minimum Power Requirement in accordance with assessment level 1, the Capesize bulk carrier doesn't comply with the EEDI 2020 regulations.

75% of MCR	10200	10200
Paux	680	680
Vs	14	14
Fuel Used	HFO	MDO
Cf	3,11	3,21
SF	1,01	1,01
Attained EEDI	3,25	3,35
Required EEDI phase 0	3,63	3,63
Required EEDI phase 1	3,27	3,27
Required EEDI phase 2	2,62	2,62

Table 3: Attained EEDI vs Required EEDI for a typical Capesize Bulk Carrier

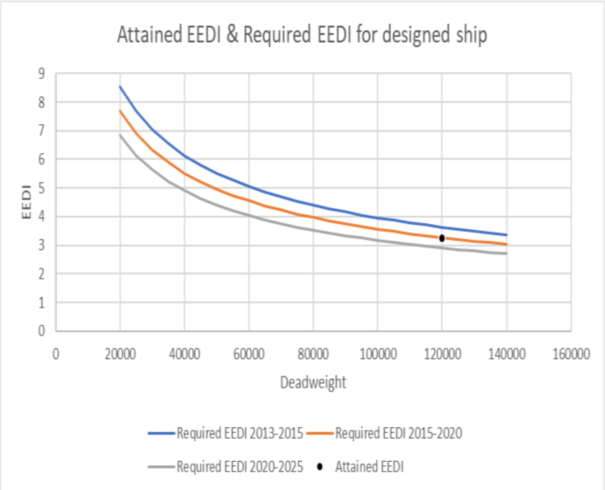

Figure 4: Attained EEDI vs Required EEDI for designed ship for different EEDI phases

In accordance with table 3 and figure 4, it can be seen that the Capesize bulk carrier complies with EEDI phase 1 but not with phase 2.

Thus, even if the bulk carrier propulsion power is reduced by reducing service speed to comply with EEDI regulations, it may not comply with Required Minimum Power and vice versa.

3.2. Suggested Technical Modifications and Limitations

Hull optimisation of bulk carriers for reducing power requirement is not a desirable option as the reduction in power requirement is not nearly sufficient.

Some of the famous alternatives taken into consideration for complying with the recent emission regulations are the use of alternative fuels such as LNG, LPG, methanol, ammonia, and hydrogen.

Furthermore, utilization of carbon capture system onboard ship and use of wind energy are other prospective solutions.

i. Use of Liquified Natural Gas (LNG) as a fuel:

LNG has low carbon content having a carbon factor of 1.75 gCO_2/t-fuel (MEPC, 2011). Also, LNG has negligible NOx emission and no SOx emission making it one of the suitable options for replacing HFO and MDO as the main marine fuel oil. The advantages of using LNG as a fuel are:

- Existing and proven technology to be commercially utilized in the maritime sector (SEA-LNG, 2022)
- High growth in the LNG bunkering facilities worldwide (SEA-LNG, 2022).

But the problems associated with LNG can be listed as follows:

• LNG has a low volumetric energy density, thus requires more space for storage (DNV GL, 2019). For ships such as bulk carriers which go for long voyages, this can be a problem.

• LNG is a low flashpoint fuel, thus the vessel needs to comply with International Code of Safety for Ships Using Gases or Other Low-flashpoint fuels (IGF code) (DNV GL, 2019).

• The problem of ‘methane slip’ is associated with usage of LNG as a fuel (Riviera, 2020). Unburned methane is released in the exhaust, which can effectively contribute to global warming.

LNG is considered to be a transition fuel, which depicts the fact that it is not a permanent solution but an intermediate solution, in order to lead to a cleaner future for the deep-sea maritime industry (SEA-LNG, 2022)

One of the retrofitted Capesize bulk carrier operating on LNG has the storage tanks on aft part of the ship above the weather deck, thus making it compliant with the IGF code (Tam, et al., 2019). The diagram of the retrofitted Capesize bulk carrier is given in figure 5 and 6.

The design is relatively simple but requires structural assessment for the aft part of the deck. Also, the capacity of the designated tanks are 1500 m3, which may not be enough for long voyages and may require frequent bunkering operations, thus making expensive operations.

Another problem is the allocated tanks for HFO and MDO in a conventional bulk carrier may not be used if LNG is used. Though MDO tanks are required for storage of pilot fuel, HFO tanks may either be used as ballast tanks. These can in turn be expensive, as the ballast tanks require coating for corrosion prevention due to sea water storage. On the other hand, keeping the tanks empty is a waste of space and may not be economical. The tanks can be filled with HFO and can be used as a secondary fuel but keeping HFO in a tank requires heating.

Development of the bio or e-based fuels are gaining momentum and popularity in the fuel market, but it can be said that those fuels will take a considerable long time to become available in the maritime market (DNV GL, 2020).

Also, use of bio-MDO or e-MDO can contribute to achieve net zero CO_2 emission, but bulk carriers will have EEDI restrictions as well as pertain with the expected high price of the bio or e fuel.

Therefore, compromise is to be made on way or the other keeping in mind the most economical and viable option to approach.

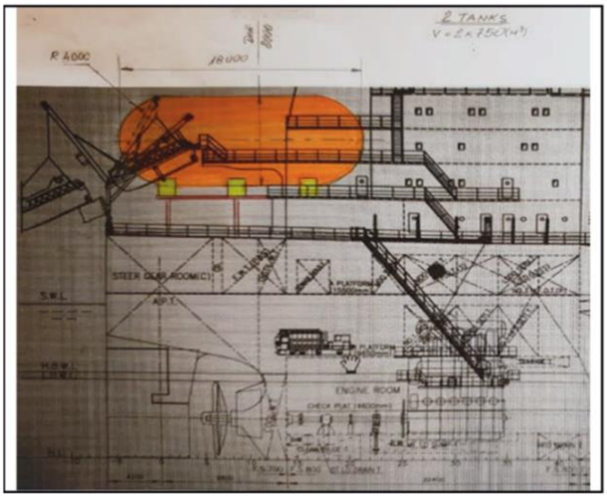

Figure 5: General Arrangement of retrofitted bulk carrier (Tam, et al., 2019)

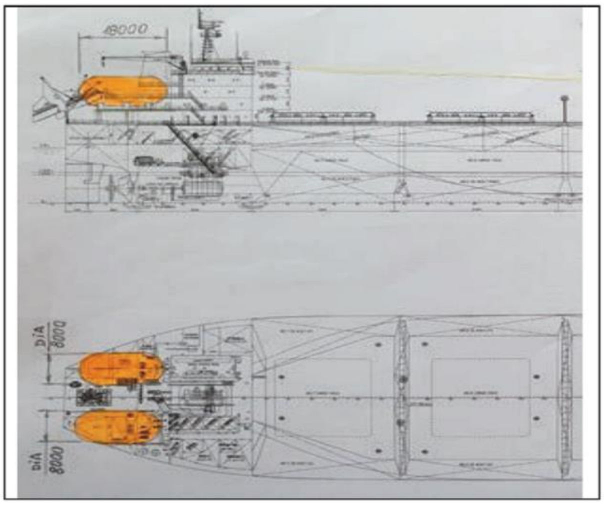

Figure 6: General Arrangement of the retrofitted Bulk Carrier (Tam, et al., 2019)

Using LNG as a secondary fuel is not a viable option as the design and construction of the vessel will require the same cost and also not comply with the upcoming EEDI and EEXI regulations.

ii. Use of Liquified Petroleum Gas (LPG) as a fuel:

LPG is another viable option to be used as an alternative fuel. Its carbon factor is almost similar to LNG and the problem associated with methane slip is not there. But in this case, there are other limitations. They are:

• LPG also has low volumetric energy density, thus requires more storage space (DNV GL, 2019).

• The number of bunkering facilities for LPG is not yet developed.

• Increment in the number of bunkering operations.

iii. Use of Methanol (CH3OH) as an alternative fuel:

Another alternative fuel is methanol, special e-methanol, which is a viable option to be used. The limitations for using methanol as a fuel are:

• Methanol has low gravimetric and volumetric energy density, thus requires more storage as well as adequate amount of pilot fuel (DNV GL, 2019).

• Usage of methanol is in development phase and not fully compliant for commercial use (DNV GL, 2019).

• Increase in the number of bunkering operations.

But methanol is considered to be a potential alternative fuel, gaining its importance in the European market (Bush, 2022). Shipping giants such as Maersk line and CMA CGM are considering methanol as a future fuel and already in the process of construction containerships operating on methanol (Mike Schuler, 2022).

Even some potential projects are in the market to implement usage of methanol as a fuel in bulk carriers. (Mike Schuler, 2022).

iv. Use of hydrogen and ammonia as potential fuel:

One of the upcoming potential fuels to be used in the shipping industry are hydrogen and ammonia, with zero carbon emission from its utilization. But the problem is its implementation in bulk carriers which has a low freight rate, and thus have a low profit margin. Whether it will be profitable to utilize hydrogen or ammonia as a fuel is to be seen.

Ammonia is considered to be a green solution with no carbon emission. But there are problems associated with it. Though a number of Approval in Principle (AiP) for newbuild ships are initiated, the ammonia to be used commercially is still a long way to go. Furthermore, it is a toxic product and thus the safety aspects are also to be taken into account (DNV GL, 2019).

As for bulk carriers meant for long voyages, the capacity requirement and storage problems still persist due to it low gravimetric and volumetric energy density.

Use of hydrogen as a fuel is critical, though a new engine operating with hydrogen as a fuel is emerging. But for ships meant for long voyages, hydrogen storage is of major concern (DNV GL, 2019).

v. Use of CCS system

A number of pilot projects are already initiated to utilize carbon capture system onboard ship. But the projects are mainly directed vessels transiting short voyages.

The prospect of using carbon capture onboard a vessel is restricted by the limited capacity of the CO_2 storage onboard and also the high capital cost involved in using the pre/post combustion carbon capture system (Wang, et al., 2017).

vi. Use of wind energy for auxiliary power generation:

Another suggested alternative, which is considered to be one of the most viable options is to use the wind energy for auxiliary power generation. Use of Flettner rotors and sky sails are utilized to reduce overall power consumption. Flettner rotors or sky sails utilize the wind power to create a lift force, and thus reduces the power required for propulsion (Seddiek & Ammar, 2021). Figure 7 shows the typical layout of wind powered bulk carrier.

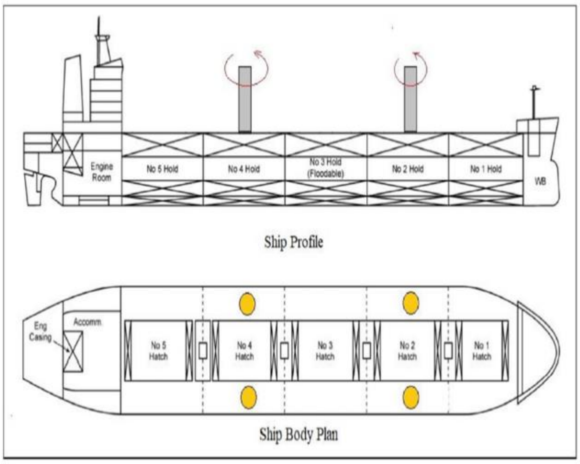

Figure 7: Typical layout of a bulk carrier powered by wind (Seddiek & Ammar, 2021)

But there are certain limitations pertaining to the utilization of wind power. They can be listed as:

• The utilization of wind power is heavily dependent on the weather conditions and the route of operation of the ship.

• The profit margin of the ships utilizing wind energy is dependent on the fuel price (Seddiek & Ammar, 2021). It won't be economic to utilize wind power if the fuel price drops as the initial investment will be higher.

• The maintenance of the rotors may not be familiar to the crew and therefore training of the crew is essential to operate or carry out maintenance of the rotors or sails.

• Better assessment of the ship structure is essential.

• With such tall structures, especially for Flettner rotors, it may not be viable for the vessel to enter all ports. But tiltable rotor structures are already being introduced.

Optimal designs for better usage of wind power are making its way into the maritime market for foreign going ships, as already a number of vessels fitted with Flettner rotors and sails are operating worldwide.

Another suggested technical modification suggested is the applying engine power limitations. It ponders on the fact that except for rough weather conditions, the ship can operate at lower service speed and thus reduce the CO_2 emission. Engine power limitation concept reduces the value of attained EEDI by a good margin and also helps the vessel to comply with Minimum Power Requirement guidelines. Operating the engine at part load condition causes decrease in operational efficiency but latest intelligent engines are said to operate efficiently at part load conditions.

3.3. Overall Assessment

From the above-mentioned alternatives, it can be deduced that for immediate compliance of EEDI regulations, LNG, LPG, or methanol can be used as an alternative fuel, but at the expense of payload reduction or increased initial investment. The route of operation, current market price of the bulk cargo and the operating cost can be considered as important aspects for determining which alternative method to reduce CO_2 emissions is to be considered.

Use of the low flashpoint fuels mentioned requires additional safety requirements and compliance of the IGF code and thus involve higher initial investment and lower profit margin. Also, the space dedicated for HFO tanks can't be utilized. If the space is not used for HFO, one can suggest it to be used as a ballast tank, but it will require additional cost. As for the bulk carriers making long voyages, it will be interesting to see the number of bunkering operations required for the entire voyage. An example is explained to further evaluate the problem.

Considering a Panamax bulk carrier carrying coal from Australia to Japan. The distance between Japan and Australia is approximately 4800 nautical miles (Anon., n.d). Considering a service speed of 15.5 knots, the required number of days for completion of a single voyage with coal laden is 13 days. Considering a buffer period of 5 days, the amount of LNG required is approximately 1675 m3. For the designed vessel, the overall capacity of the LNG tanks was 2090 m3 (Tam, et al., 2019). Though it can complete one side voyage without any additional bunker requirement, it will require bunker for the return voyage.

Now for the same vessel, if the operating route is changed and the vessel is required to ply for a longer voyage, then a number of bunkering operations is required even for a single voyage, which may not be viable in the long term.

For methanol, the frequency of the bunkering operations is even more. Due to low gravimetric and volumetric energy density, the amount and space required for methanol for the same distance covered is much higher in comparison to LNG, LPG, HFO or MDO.

Use of low flashpoint fuels for EEDI compliance can require decrease of payload capacity and better structural analysis of the ship.

As for utilizing wind power, it's having a good possibility for being a potential alternative.

4. EEXI calculation for existing Bulk Carrier fleet

The calculation of attained and required EEXI is similar to that of EEDI regulations and considered to have the strictest required curve for bulk carriers among all ship types (DNV GL, 2021). The compliance of EEXI for the existing bulk carrier fleet, especially the ones with high deadweight capacity (60000 tonnes and above) will be quite tough. The conventional bulk carriers running on HFO are either required to be retrofitted or operate at a lower speed. If both the options are not viable, the only option is decommissioning of the ship.

More than 50% of the existing bulk carrier fleet around the globe is comprised of Panamax and Capesize bulk carriers and most of them have a conventional bulk carrier design running on HFO as the primary fuel (MAN, n.d). The typical layout of a bulk carrier is given as in figure 8.

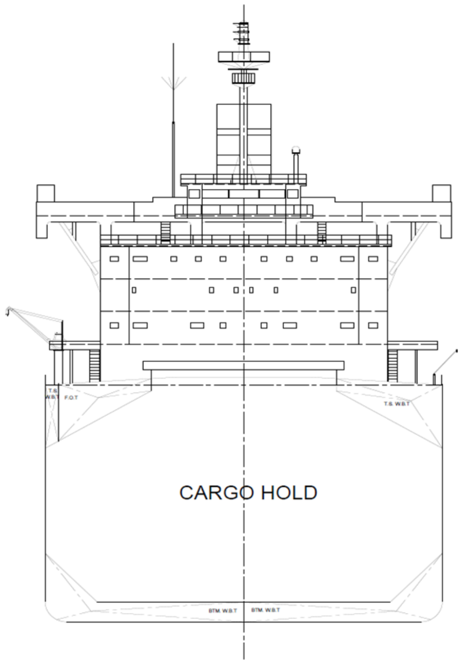

Figure 8: Front view a typical bulk carrier using HFO as primary fuel

The bulk carrier retrofitted with LNG, or any other low flashpoint fuel can't be stored in the dedicated HFO tanks.

Now, for bulk carriers with existing EEDI Technical File but has higher attained EEDI than the required EEDI, then an Engine Power Limitation (EPL) management plan may be implemented to reduce the value of attained EEDI. The existing bulk carriers is then required to operate at a lower speed to lower power consumption. But part load operation of the existing engines may cause loss of propulsive efficiency and lead to loss of fuel and as well as increment in the maintenance cost. Now, if fitted with new engines which operates at part load condition with acceptable efficiency, it can be taken into consideration.

Another option for complying with the EEXI regulations, these bulk carriers are required to be retrofitted with LNG or methanol tanks and dedicated machinery systems to be utilized onboard ship. But the problem is associated with the capital cost and whether the option is economically viable or not. The operational cost should also be taken into account.

5. Suggested Solution

i. *Route Optimisation along with wind power utilization*

For newly built bulk carriers, route optimisation along with wind power installation can be considered as the one of the most suitable option to be taken into account. By the term route optimisation, it can direct to the fact that a definite route is established and take in account the cargo in demand. As the bulk carrier carries loose cargo such as coal, iron ore, cement, or grain, it is very important to understand the cargo in demand. Based on the frequency of operation of the bulk carrier and the route in which it is operating the technical modification can be made accordingly. This is essential because it will help the to determine what is the profit margin that can be expected during its lifetime of operation during the design phase of the vessel.

Now, installation of rotor sails can be considered as an option to be used as it a clean source of energy and can be used effectively to reduce CO_2 emission. Also, the EPL management plan can be implemented so that the vessel complies with the EEDI regulations. But it is crucial to implement the cost effectiveness of these installations. Use of LNG or methanol as a potential fuel is a good alternative but with the IMO's aim to reduce CO_2 emission by 70% by 2050 and with increasing restrictions of EEDI over the coming years, it may not be considered as the only alternative but installing a hybrid system may become mandatory.

As for the existing bulk carrier fleet, the same technical modifications are desirable. If the profit margin expected from the operation of the vessel is not achieved, decommissioning of the vessel is the viable alternative.

ii. Shortening of voyage

Shortening of voyages can be implemented to reduce the capacity required for LNG, LPG or methanol storage tanks if used onboard the bulk carrier as the primary fuel. If used along with rotor sails, it can effectively reduce the CO_2 emission.

Another advantage of this option is the increment of the number of bulk carriers in operation as well as reduction in GHG, NOx and SOx emissions. Also, the bunkering operation frequency for a bulk carrier will effectively reduce. Therefore, the problem associated with utilization of low flash point fuel having low volumetric energy density can be used effectively along with wind energy.

6. Conclusion

With the world moving towards net zero carbon emission policy in the maritime industry, it is very difficult to attain both operational efficiency of the bulk carriers as well as effectively lower CO_2 emission. It is evident that merging of EPL management plan, hybrid propulsion system and wind power utilization is essential to effectively reduce GHG, NOx, SOx and particulate matter emission.

As discussed, the matter of concern is the determination of the profit margin for the newly designed bulk carrier or retrofitted bulk carrier to comply with EEDI and EEXI regulations. For getting a positive output to utilize technical modifications, usage of alternative fuels as well as use of wind power in bulk carriers, route optimisation and shortening of voyage length for these bulk carriers are essential.

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