REVIEW OF CO_2 EMISSION AND REDUCING METHODS IN MARITIME TRANSPORTATION

by

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Despite the lowest CO_2 emission in terms of payload per unit mile, commercial marine fleet transport is responsible for approximately 1 billion tonnes of CO_2 emissions per year and 2.7% of the total global CO_2 emission. To keep the world's surface temperature below critical +2 °C, International Maritime Organization works with alternative methods on a ton / mile basis to reduce existing CO_2 emissions. In this study, these methods are analyzed and their advantages and disadvantages are discussed. The future of CO_2 emissions was also investigated.

Key words: *ship emissions, Beaufort scale, CO_2 emission*

Introduction

According to the general agreement reached by the world's leading meteorological experts, the surface temperature of the earth has increased by 0.6 °C in the last 100 years [1]. According to the work of the United Nations Framework Convention on Climate Change (UNFCCC), the average world surface temperature has increased by 0.74 °C since the late 1800s, and in 2100 it is between 1.8 °C and 4 °C unless the necessary measures are taken. It is estimated that there will be a larger increase than expected in any 100 year period [2, 3].

In the globalizing world economy, the need for transportation is constantly increasing, and as a result of the reliance on fossil fuels, the increases in GHG emissions bring about many environmental impacts such as global warming, climate change and ocean acidification. The most environmentally-friendly mode of transport of the transported unit cargo per ton of gas per ton is considered as shipping [4]. However, due to the fact that the global trade demand of up to 90% of the world trade has been carried by sea and the increasing global trade demand also increases the demand for maritime transport in the following years, the limitations and sanctions on the CO_2 emissions from man-made GHG as well as other sectors are the necessity to take control with the application has come to light.

Until 2050, if no emission control is applied and mitigation policies are not established, the IMO's medium-term emission scenarios predict that in 2050, merchant-ship emissions would increase from 150-250% as a result of growth in world trade [5].

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The future emission scenarios of the IPCC suggest that ship-based CO_2 emissions will be higher than twice the value of the existing one in 2050 if no measures are taken [6].

It is predicted that world trade will be accounted for 6% of total global CO_2 emissions by exceeding 1.4 millionnnes by 2020 and increasing ship-source CO_2 emissions in line with increasing transport capacities by 90% and increasing transport capacities [7]. As a result of the study conducted on a statistical approach on the fuel consumption and emissions of the international maritime trade fleet, total global anthropogenic emissions were reported to be 2.7% CO_2, 11% NO_x, and 2% SO_x [8].

As stated in the United Nations report prepared in the 2007 Intergovernmental Panel on Climate Change in Paris, France, the UN report stated that the world will be a hotter place in 2100, increasing temperatures and their possible effects are listed [2]:

- +2.4 °C: Water shortage will start and in North America the sandstorms can destroy agriculture. Sea levels will rise and 10 million people in Peru will suffer from water shortages. The coral reefs will disappear. The 30% of the species on the planet will be in danger of extinction.
- +5.4 °C: Sea 5 m and the sea level will be 70 meters. The world's food stocks will run out.
- +6.4 °C: Migrations begin. Hundreds of millions of people will fall on migration routes in the hope of living inappropriate climatic conditions [2]. To reduce global warming, CO_2 emissions from commercial vessels should be reduced urgently. Although the IMO clearly defines the rules for sulfur oxides released from ship machinery, the rules for CO_2 are still under development. The main reason is that the rules related to SO_x and NO_x are due to their negative effects on the health of the people living in the near environment, ie in the coastal regions, but the rules on their emission the global environment, such as CO_2, are not prioritized. However, despite the fact that SO_2 has remained in the atmosphere for about 10 days and the global climate has responded and repaired it over many decades, CO_2 has recovered itself over hundreds of years and the atmosphere has become old. As the percentage of sulfur in the atmosphere is low, SO_2 combined with water in the rain descends to the earth as sulfuric acid (H_2SO_4). However, since the CO_2 content in the atmosphere is much higher than that of sulphide, there is a lot more rain and land needed to reduce the amount of CO_2 in the atmosphere as carbonic acid (H_2CO_3) to the earth, in this context it is called as hundreds of years to clean the atmosphere. In fact, considering that CO_2 has been disposed of in this way, precautions should be taken in the years before the rules regarding SO_x and NO_x, since CO_2 has been spreading much longer in terms of the period of self-repair of the atmosphere.

Location of commercial ships in world transportation

Increased number of vessels and growing capacities and emissions caused by sea transport. The company is active in changing the air quality and the global climate. Commercial vessels are one of the most important fuel consumer groups in the world with their high-powered main machines and auxiliary machines and an average of 350 millionns of fuel is consumed [9].

Global climate change and GHG

The most important natural GHG are CO_2, CH_4, diazotmonoxide (N_2O), and troposphere ozone (O_3) gases in the stratosphere which is the major contributor to water vapor.

The observed increase in anthropogenic GHG emissions in the atmosphere has been continuing since the industrial revolution. Especially, considering the accumulation and residence time in the atmosphere, CO_2 emerges among these GHG. Of the most important gases causing greenhouse effect, CO_2 is the most abundant and dominant. The level of accumulation of CO_2 and other GHG in the atmosphere has increased rapidly since the industrial revolution. Increased GHG accumulation in the atmosphere has led to the use of fossil fuel, deforestation and other human activities. Economic growth and population growth have further accelerated this process [10].

The CO_2 has reached the highest value of the last 420000 years and even the last 20 million years with a value of about 375 ppm (one part per million) [2]. In the case that the human-induced increases in CO_2 emissions are maintained at the current rate, it is projected that CO_2 accumulation, which was about 280 ppm in the pre-industrial period, 368 ppm in 1998, 375 ppm in 2007, will reach 500 ppm by the end of the 21st century [2]. These increases in GHG accumulations weaken the cooling efficiency of the earth through long-wave radiation, resulting in a positive radiative forcing to warm the earth further. This positive contribution the energy balance of the earth and the atmosphere system is called the strengthening greenhouse effect. This means that the natural greenhouse effect, which has been working since hundreds of millions of years with the help of natural GHG (H_2O, CO_2, CH_4, N_2O, and O_3) in the Earth's atmosphere, in other words. The magnitude of the global warming that may be caused by the strengthening greenhouse effect depends on the extent of the increase in the accumulation of each GHG, the radiative properties of these gases, the atmospheric life span and the accumulation of other GHG in the atmosphere. The average temperature of the earth's surface near the atmosphere increased by 0.6 (±0.2) °C in the 20th century. The widespread scientific view on climate change is that the rise in temperature over the last 50 years has noticeable effects on human life and is indicated in fig. 1.

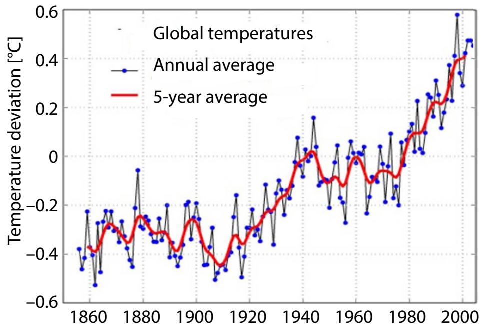

Figure 1. Global temperature values, between 1860 to 2000, http://data.giss.nasa.gov

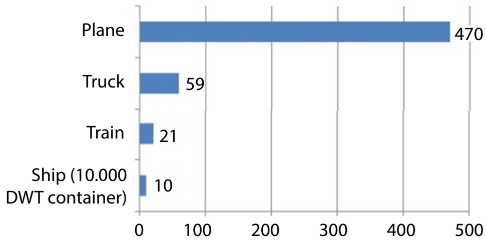

Figure 2. The comparison of the CO_2 amount carried for one kilometer carriage of one ton cargo in different transport modes (gram carbon), http://www.worldshipping.org

Commercial ship emissions

According to IPCC data for 2007 [2], international sea transport is responsible for 2.7% of total global GHG. In response to the question of the question of which of the long-haul goods it transports for long distances on ships, the transportation of locally produced goods at short distances produces more CO_2 emissions, the response to the question is given by the fact that the long-distance transported sea transportation produces less CO_2 [11]. This is because the ratio of cargo per ton/km is much higher than that of the airline or road, and in this context, the amount of CO_2 per ton/km per unit cargo is the lowest in maritime transport and is shown in fig. 2. To illustrate the situation that arises as a result of the literature screening.

According to a study by the wine industry, the CO_2 emissions during the transfer of a bottle of French wine sold in a restaurant in New York are less than that of a bottle of wine from California [12]. Similarly, studies on white paper trade for the World Economic Forum have also revealed that the amount of CO_2 emitted by a container from China to Europe is equal to a distance of 200 km in Europe [11]. According to the data of the Swedish Transport Office, a flying Boeing 747-400 airplanes produce 540 g of CO_2 per ton / km, while an 8000 Dwt vessel produces 15 g of CO_2 per ton/km of CO_2 [13].

Factors regulating ship-based CO_2 emissions

Alternative fuels

The fuels used in ships are mostly low quality HFO due to their cost reasons and these heavy fuels should be used with heating up to 140 °C and the remaining part of the unexposed fuel should be disposed of as well [14, 15].

The average sulfur content of these fuels is 2.5%. On the other hand, marine fuels containing 0.5% sulfur-containing marine diesel fuel or 0.1% sulfur are cleaner fuels. Switching to fuels with a lower sulfur ratio results in lower CO_2 emissions.

The IMO's work on this issue has shown that switching from heavy fuels to marine diesel or gaseous fuels and reducing CO_2 emissions by 4-5% in fuel per tonnnage [16]. Due to its low carbon content, liquefied natural gas (LNG) can be used as an alternative clean fuel. The main component of natural gas, which is abundant in nature, is CH_4 and, if used as fuel, it produces higher energy per unit of carbon compared to petroleum-derived diesel fuels. Natural gas, on the other hand, is a type of fuel that will significantly reduce SO_x and NO_x emissions. As it does not contain sulfur, it is less than 90% in NO_x emissions and particulate matter emissions are almost absent [1]. The carbon content and emission comparisons of the fuel types are given in tab. 1.

Table 1. Carbon amounts in different fuel types [17]

Fuel type	Reference	Carbon content
Diesel	ISO8217 Grades DMX	0.875
LFO	ISO8217 Grades RMD	0.860
HFO	ISO8217 Grades RME	0.850
LPG	Propane Butane	0.819 0.827
LNG		0.750

However, both the storage of the liquefied form of natural gas on the ships and the arrangement of the main machine according to the LNG fuel type and propulsion system instead of the diesel increase the cost. This means storage and storage in insulated cylindrical tanks for storage purposes. Since it can be stored three times more than liquid fuels, it does not seem to be widely used due to technical and safety standards. It has been reported that the use of potential LNG will reduce CO_2 emissions by around 25% [1].

Although nuclear propulsion systems are technically feasible, they are not eligible for commercial vessels. Since the carbon in the biofuels is derived from the decomposition of the CO_2 in the air, it is preferable to use biofuels instead of fossil fuels in order to prevent the increase of CO_2 in the atmosphere, since the burning of biofuels does not cause an increase in the net CO_2 in the world atmosphere. Due to the inadequacies to be produced in high quantities and to be sufficient for the entire sector, it does not seem economical to use in commercial ships because it is also used for human nutritional requirements. In addition, the technical infrastructure for the storage of ships is not yet ready for the first generation of biofuels [1].

Low speed cruising

In the maritime sector, especially in container ships, reducing the speed of navigation has been used as an application frequently used in ships in recent years. When the speed of a ship increases, the water resistance value of the boat increases, and on the contrary, the water resistance value decreases at low speeds, and even a small amount of speed reduction at certain rates contributes greatly to this. fuel economy and energy economy [5]. The CO_2 emissions from ships are directly proportional to fuel consumption.

In general, the high service speed has both advantages and disadvantages. The first advantage is the amount of cargo transported annually. For example, the distance between a ship operating between Algeciras-Barcelona-Valencia-Marseille-Genoa-Gioia Tauro-Istanbul is 4994 miles. The length of a ship with a capacity of 10000 tons at 15 knots is approximately 13 days. Assuming that loading and unloading operations at the ports take one day, the transport time of 10000 tons of cargo will be 24 days in total. This means that approximately 152083.33 tons of cargo are transported annually. If the ship had moved at 20 knots, the service time would have been 21 days in total, meaning 173809.52 tons of cargo would be transported a year.

High-speed fuel consumption also leads to increased CO_2 emissions. As a result, speed is reduced, which results in lower speeds, less energy and fuel consumption, and therefore, less CO_2 emissions. The IMO's work in the world maritime trade fleet has reduced this rate by 10% and reduced emissions by 23.3% on ships in maritime transport [16]. Reducing ship speed reduces CO_2 emissions. Hapag Lloyd, the world famous ship line, showed a 50% reduction in fuel consumption with a 20% speed drop on its ships, ie a 5-knot slowdown [16].

Since the amount of cargo to be transported on a certain route with the reduction of the cruising speed will result in fewer cruises per year as a result of the slow moving of the vessels, the low-speed course results in the operation of additional ships in that rotation. However, this does not mean slow speed, so low consumption. A ship that runs below the optimum speed consumes more fuel than the expected amount of fuel. Possible negative consequences of low-speed operation include vibration increase and problems of accumulation in combustion chambers and exhaust systems [18].

Weather routing

The weather conditions associated with wind and waves as well as the associated current affect the energy spent on ship dispatch. For this reason, many numerical methods have been developed for the estimation of wind power [19]. One of the methods used among these methods is the Beaufort wind scale. Wave height and wind speed are classified as 0-12. Table 2 shows the Beaufort scale.

Table 2. Beaufort scale

Beaufort number [BN]	Wind speed [Knot]	Estimated wave height [m]
0	1	–
1	1-3	–
2	4-6	0.7
3	7-10	1.2
4	11-16	2.0
5	17-21	3.1
6	22-27	4.0
7	28-33	5.5
8	34-40	7.1
9	41-47	9.1
10	48-55	11.3
11	56-63	13.2
12	64 and over	–

Let BN is Beaufort number. Townsin and Kwon [18] developed the aforementioned formula for the waves coming from the front:

$$\frac{\Delta\upsilon}{\upsilon}100\% = \left(0.7BN + \frac{BN^{6.5}}{22.\nabla^{\frac{2}{3}}}217.34\mathrm{e}^{-0.726\,BN}\right)$$

For ballast ships, the formula is (C_B = 0.75, 0.80, and 0.85):

$$\frac{\Delta\upsilon}{\upsilon}100\% = \left(0.7BN + \frac{BN^{6.5}}{2.7\nabla^{2/3}}\right)$$

For full ships (C_B = 0.75, 0.80, and 0.85):

$$\frac{\Delta\upsilon}{\upsilon}100\% = \left(0.5BN + \frac{BN^{6.5}}{2.7\nabla^{2/3}}\right)$$

This formula applies to vessels with a displacement of more than 20000 m^3 for container ships. Here, $\Delta\upsilon$ speed change, ∇ is the displacement volume of the ship [20].The CB is the coefficient of coefficient is the block coefficient.

Conclusion

According to 2007 data, transportation constitutes 3.3% of total global CO_2 emissions and 1046 millionns of CO_2 emissions [21]. Only sea transport is responsible for 2.7% of total global CO_2 emissions with 870 millionns of CO_2 emissions [22]. It is estimated that, if no measures are taken, the CO_2 emissions from sea transport will increase to 1475 millionns in 2020 and account for 6% of total global CO_2 emissions, despite the fact that there is the greenest transportation mode and the lowest CO_2 emission per unit load per unit [7]. In addition, if other sectors carry out their own improvements to keep the surface temperature of the earth below +2 °C below the critical temperature of 50%, sea transport is responsible for approximately 12-18% of global CO_2 emissions as of 2050 [5]. It aimed to reduce the GHG emissions from international transport to at least 40% of its value in 1990 by 2020 and to reduce it to values below at least 80% by 2050 [2]. The IMO's work also predicts that it is possible to increase efficiency and reduce CO_2 emissions by 25-75% per tonne/mile depending on the ship type and operation with the implementation of all measures [5].

During the journey of a ship between two harbors, the amount of CO_2 emissions emitted by the fuel produced by its main machine and auxiliary machines against the sea and air resistance that it is exposed to can be found with certain formulas. It can also be calculated for a continuing process under many other applications, such as taking into account all other external factors between the start of an expedition, the change of ship speed, change of trim and draft, switching to LFO in berthing maneuvers, and port operations. The amount of CO_2 released from a ship can also be measured by the carbon content of the fuel consumed on that ship. Approximately 3.17 ton CO_2 is emitted from the burning of one ton of ship fuel [21].

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