A Brief Background Based on Recent IMO MEPC on Performance and Emissions of Marine Diesel Engines*

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Abstract

Among the energy sources nowadays, fossil fuels are the most popular being utilized but have a huge impact and contribute negatively on the environment. Along with vast economic benefit, maritime transportation industry and stakeholders in particular are facing a serious challenge of addressing environment pollution protection due to the impacts of engine emissions to populace in general. Currently, state authorities have also become more vigilant on the implementation of environmental pollution policies especially on the energy industry sector that plays a vital role.

The 71st session of the IMO MEPC was held in London from 3rd to 7th July 2017. Exhaust emissions such as CO₂, PM and VOC have been discussed at the meeting and regulations will possibly be in effect in the near future. The first mandatory measure on energy efficiency was entered into force on 1 January 2013 while the Tier III NOx emission regulations became effective last 1st January 2016. This keynote speech describes the performance and emissions of Marine Diesel Engines as well as the results of MEPC 71st session.

Keywords: MEPC (Marine Environment Protection Committee), PM (Particulate Matters), VOC (Volatile Organic Compounds), NOx (Nitrogen Oxides)

1. Introduction

Environmental pollution has been an issue lately, especially on the energy industry sector, making governing bodies more vigilant. Fossil fuels are continually being utilized as prime source of energy, along with the advancement of human knowledge and technology and development of society, plays as factors contributing to this issue. These factors present two-faced scenario – additional comfort on human life and its impact on the environment in terms of pollution. Further, merchant vessels as means of sea transport have a big role in the modern world as indicated by the growth of the global fleet in terms of ship's type and tonnage.

The IMO MEPC (Marine Environment Protection Committee) conducted its 71st session in London last 3 ~ 7 July 2017^{[1]-[9]}. During the past twelve years, IMO MEPC has been discussing on CO₂ emissions and proposed regulations will possibly be in effect in the very near future. Discussions on particulate matters (PM) and volatile organic compounds (VOC) were also included. On the other hand, the first mandatory measures on energy efficiency was entered into force on 01 January 2013 while implementation of the Tier III NOx emissions regulations will be postponed from 2016 to 2021^[10]. Tier III NOx emission regulations became effective last 1st January 2016.

This paper discusses the effect of ship's emissions on air pollution along with the development of diesel engine designs. Actual performance and emission analysis on a two-stroke low speed diesel engine was conducted for this study. Additionally, result of MEPC 71st session which includes Tier III NOx emission

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standards under MARPOL Annex VI is presented.

2. Marine Diesel Engines

2.1 Performance of Marine Diesel Engines

Fig. 1 Ships impact on air and water pollution problems.

Ships contribute to both air and water pollution as can be seen in Figure 1. One factor affecting the emission quantity is the diesel engine design and configuration. Basically, marine diesel engines are configured according to its operation speed being low, medium, or high speed. They are also classified according to cylinder volume and rated power. Table 1 below shows the improvement of diesel engines in terms of specific fuel consumption. The reduction of specific fuel consumption can be attributed to progression of engine designs.

Table 1. Specific fuel consumption (sfc) of marine engine

Specific fuel consumption				
Engine year built	2-stroke low speed	4-stroke medium/high speed (> 5,000 kW)	4-stroke medium/high speed (1~5,000 kW)	4-stroke medium/high speed (< 1,000 kW)
1970-1983	180-200 g/kWh	190-210 g/kWh	200-230 g/kWh	210-250 g/kWh
1984-2000	170-180 g/kWh	185-195 g/kWh	180-200 g/kWh	200-240 g/kWh
2001-present	165-175 g/kWh	175-185 g/kWh	180-200 g/kWh	190-230 g/kWh
After 2020	160-10 g/kWh	170-180 g/kWh	175-185 g/kWh	180-220 g/kWh

Fig. 2 Emissions from a typical two-stroke low-speed turbocharged large marine diesel engine

Figure 2 illustrates the exhaust gas emission component from a typical two-stroke diesel engine.

2.2 Emission Data of Marine Diesel Engine

Table 2. Exhaust gas emissions analysis for an engine maker

Engine type		Ambient and gaseous emission data			
Mode	-	1	2	3	4
Engine Power	%				
	kW	31640.0	23730.0	51820.0	7910.0
Engine Load	%	100	91	80	63
Engine Speed	rpm	80.0	80.0	80.0	80.0
T/C Speed	rpm	9980	8879	7008	4173
Fuel					
Fuel consumption	kg/h	6200.0	4250.0	2950.0	1500.0
Air Fuel Ratio		49.7	55.3	59.2	63.9
Sfc	g/kWh	196.0	179.1	186.5	189.6
Scavenge Air					
Air flow	kg/h	308.405	234.866	174.643	95.845
Exhaust gases					
Gas flow	kg/h	314.605	239.116	177.593	97.845
Exh. Gas temp.	°C	281.0	225.3	252.3	258.7
Gaseous Emission Data					
CO (Dry)	ppm	47.0	51.0	115.0	327.0
CO ₂ (Dry)	%	4.28	3.85	3.59	3.39
HC (Wet)	ppmC	59.0	60.5	50.0	46.5
O ₂ (Dry)	%	15.05	15.70	16.00	16.40
NO _x	ppm	878	818	736	688
NO _x Mass flow	kg/h	396.49	286.28	196.06	98.10
NO _x Specific	g/kWh	12.53	12.06	12.39	12.40
IMO Tier II NO _x limits : 14.4 g/kWh @ 80 rpm					

An analysis was conducted on a maker test engine to substantiate the base value of exhaust gas emission. Table 2 shows the result of the emission analysis conducted on four different modes at constant speed of 80 rpm. NOx concentration at different loads ranges between 690 ppm to 880 ppm while the mass flow at full load is approximately 400 kg/hr or 10 tons/day. The fuel oil sulfur content is specified at 2,500 ppm but SOx analysis was not carried out. However, SOx value can be estimated based on the AFR (50 at full load).

3. IMO MEPC Regulations for NOx and SOx

3.1 Emission Control Areas (ECAs)

The global map for existing, planned and future Emission Controlled Areas for international shipping NOx and SOx emissions is shown on Figure 3. SOx emission regulations have been regulated in EU SECAs since 2006 while implementation of these regulations was adopted on planned ECAs on August 2012. On the other hand, NOx Tier III regulations became effective in last 1st January 2016 in the gray color area and will be in effect on 2021 in the green color area (SECAs).

Fig. 3 Emission Control Areas (ECAs) for NOx and SOx for international shipping

The allowable limit for sulfur content of fuel oils entering the SECAs is 0.1% from 2015 and 0.1% once the ship entered the territorial waters or ports in EU SECAs. Hence, there is a need for ships to switch over from high sulfur content fuels to lower sulfur content fuels. The North America ECAs also adopts the same

limit value and covers a 200 nautical mile distance from land and has been effective since August 01, 2012. The current global limit for fuel oil sulfur content is 3.5% and this will be reduced to 0.5% after 2020.

3.2 IMO MEPC NOx and SOx Emissions Timeline

Fig. 4 IMO NOx emissions standard

Table 3. IMO Tier I and Tier III NOx emissions standard

Details		IMO Tier I	IMO Tier III	Remarks
Limit	< 130 rpm	17.0 g/kWh	3.4 g/kWh	80 % decrease (at SECAs of ECAs)
	130 ~ 2000 rpm	45.0 n ^(0.2) g/kWh	9.0 n ^(0.2) g/kWh	
	> 2000 rpm	9.8 g/kWh	2.0 g/kWh	
Effective date		-	Jan. 01, 2016	(at IMO MEPC 66 th)
Application standard		-	Ship Keel Laying	-
Application techniques		-	SCR or other technologies	Modify engine room
Application area		Global	Emission Control Areas

Fig. 5 IMO NOx and SOx emissions timeline

The NO_x emissions regulations are being covered at present by Tier II standards being in place from 2011. The previous Tier I was in place from 2005 to 2010 while Tier III NO_x emission regulations became effective last 1st January 2016. Comparing the NO_x limits for Tier I and Tier III standards, the NO_x emission will be reduced by almost 80% as can be seen on Figure 4 and Table 3. Due to the stringent standards of Tier III, SCR (Selective Catalytic Reduction) or EGR (Exhaust Gas Recirculate) systems are required to be installed on ships. Figure 5 is the general overview of NO_x and SO_x emissions limit implementation schedule according to IMO MARPOL 73/78 Annex VI.

4. Conclusions

This paper presents the ongoing development on IMO emission regulations on both global and ECAs. Ships, usually powered by large diesel engines, contribute greatly to this emission; hence measures are curved to address its impact on the environment.

Important aspects of this paper are enumerated as follows:

First: NO_x emissions values for large marine diesel engines are extremely high.

Second: SCR or EGR systems are to be installed on all ocean-going ships after 2016.

Third: The sulfur content of fuel oils is too high which can have an adverse effect on planned SCR systems. Hence, further investigation is deemed necessary to identify its effect on SCR catalyst system.

Fourth: Increasing a use of the dual fuel engines for reducing emissions.

Fifth: CO₂ emissions have been discussed at the IMO/MEPC meetings for the past twelve years and implementation of regulation for this matter is expected in the near future. Likewise, PM and VOCs are included in the discussion.

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