Review on Diesel Water Emulsion as an Additive in Marine Diesel Engine to Reduce Nox Emission

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ABSTRACT

In September 1997, the Protocol of 1997 to MARPOL 73/78 was adopted to introduce the new Annex VI - Air pollution from ships. When the Protocol enters into force, the requirements of the NOx will be applied to each diesel engine with a power output of more than 130 kW which is installed on a ship, or which undergoes major conversion, on or after 1 January 2000. Annex VI deals with a wide range of air pollution control matters including regulations on halons, Hydro- chlorofluorocarbons (HCFCs) and other ozone depleting substances, Nitrogen oxides (NOx), Sulphur oxides (SOx), Volatile organic compounds (VOCs), shipboard incinerators and fuel oil quality. However, the main focus has so far been on reducing the NOx.

The NOx Technical Code introduces a new concept of engine family, engine group, parent engine and the technical file to be determined before issuing the Engine International Air Pollution Prevention Certificate (EIAPP Certificate) and the International Air pollution Certificate (IAPP Certificate). Because the new Annex VI has not yet come into force, guidelines have been introduced to issue a Statement of Compliance (SOC Certificate).

NOx formation builds up by reaction between nitrogen and oxygen in the combustion air (thermal NOx), by reaction between exhaust gas hydrocarbon and combustion air oxygen (prompt NOx) and by reaction between nitrogen bindings in fuel (fuel NOx).

Thermal NOx is decisive for total emission and all the reducing methods are targeted to reduce that component. NOx emission can be reduced by primary methods such as retard injection, fuel nozzle modification, change of compression ratio, water direct injection, water emulsification, exhaust gas recirculation (EGR) and secondary method such as selective catalytic reduction (SCR).

KEYWORD: - Air Pollution, Nitrogen Oxides (NOx), Emission, Diesel engine. Certification.

1. INTRODUCTION

Environmental issues have been more topical than ever. Recently, the emission control legislation, focused on reducing air pollution from the shipping industry is now contemplated by many regulatory agencies and authorities around world. The shipping industry has been excepted from legislation. Also, the relatively moderate amounts of air pollution generated by ship, on a global scale, compared to many other sources of air pollution has been considered.

As for marine diesel engines, they have been developed under two major technologies of thermal efficiency and reliability for the past 20 years. At the present time, with the various legislation of air pollution, the marine diesel engine is facing another major theme, the environment problem, and most of the technological efforts concentrate on this matter.

In September 1997, the Protocol of 1997 to MARPOL 73/78 was adopted to introduce new Annex VI. This Annex requires that survey of engines and equipment shall be conducted in accordance the NOx Technical Code. When the Protocol of 1997 enters into force, the requirements of the NOx emission restriction apply to each diesel engine with a power output of more than 130 kW which is installed on a ship on or after 1 January 2000, or which undergoes major conversion on or after 1 January 2000 except for lifeboat engine and emergency generator.

Annex VI of MARPOL 73/78 deals with a wide range of air pollution control matters including ozone depleting substances, acid deposition materials, volatile organic compounds, incineration and fuel oil quality. However, the main focus has so far been on reducing the NOx emissions because NOx regulation will be retrospectively applied to each engine installed on board a ship.

2. SCOPE, OBJECTIVES METHODOLOGY OF THE STUDY

The aim of this dissertation is to provide information on NOx problems to those who are concerned, such as ship owners and operators as well as surveyors, designers and manufacturers of marine diesel engines and equipment. There will naturally be some questions. Why is the air pollution from a ship so important? What is the content of the new Annex VI and NOx Code? When will this regulation enter into force? What is NOx and How is NOx formed? Then, how to reduce NOx emission?

The objectives of this dissertation are:

- To introduce the background of the legislation of the International Convention for the Prevention of Air Pollution from Ships and the major contents of the Convention
- To provide rationale behind the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines (NOx Code) by summarizing and analyzing it.
- To research and review various possible NOx reduction methods for marine diesel engines.
- To make proper proposals and recommendations to meet IMO goals concerning the prevention of air pollution from ships efficiently.

The background of Annex VI is introduced which includes the process of adoption of 1997 Protocol to MARPOL 73/78. The content of Annex VI is reviewed carefully in relation to the NOx Technical Code such as the entry into force versus application date. The purpose of this chapter is to identify those regulations in the new Annex which require to be addressed immediately as well as those which should be considered in the medium to long term.

The NOx Technical Code is summarized and also some new concepts in the NOx Technical Code such as engine family, engine group, parent engine and the technical file are introduced. Furthermore, the procedure of survey and certification for the Engine International Air Pollution Prevention Certification (EIAPP Certificate) and the International Air pollution Certificate (IAPP Certificate) is examined in relation to the Statement of Compliance Certificate (SOC Certificate).

The evaluation and contribution of air pollution from the marine diesel engine is introduced. This includes the different kinds of pollutants such as carbon monoxide (CO), Sulphur oxides (Sox), nitrogen oxides (NOx), hydrocarbons and particulate material from marine diesel engines. In the last part of this chapter, the formation of NOx i.e. thermal NOx, prompt NOx and fuel NOx are studied in light of Zeldovich's mechanism for thermal NOx formation.

The development of engineering technology and various methods for controlling NOx formation are discussed. Practical methods for marine NOx reduction can be divided into post-combustion (secondary method) such as Selective Catalytic Reduction (SCR) and combustion methods (primary method) of which more than several options exist. Some of them are: retard ignition, fuel modification, Exhaust Gas Recirculation (EGR), fuel emulsification and water direct injection. The concentration is put on the discussion of advantages and disadvantages regarding the cost, maintenance, efficiency and practical application of different options.

This study reviews and analyses the current design concept of the marine diesel engine concerning NOx reduction as well as the new Annex VI and the NOx Technical Code. Research papers submitted by various national and international institutions to the MEPC committee of IMO are widely used and cited in this study. Many other valuable books and periodical articles were searched through the WMU library system and Internet. Interviews with knowledgeable people such as professors, experts on engine manufacturers and colleagues were made

3. LITERATURE

Large amounts of fuels are consumed in off-road or road vehicles, shipping, agriculture, forestry, and industrial generators. In such cases, diesel engines are preferred over gasoline engines because of their low fuel consumption, high output, rigid structure, and high brake thermal efficiency (BTE). As such, diesel engines are an important power source for automobiles. However, they are associated with the emission of pollutants, such as carbon monoxide, hydrocarbons, nitrogen oxides, and smoke. Currently, the negative effects of such emissions on the human body such as pneumonia, breast and lung cancer will continue unless technologies for emission reduction are developed.

Investigated diesel engine performance and emission characteristics with oil-in-water emulsion fuel and emulsified fuel containing diglyme (a combination enhancer). They found that the CO level of water/diesel (W/D) emulsified fuel increased because of incomplete combustion caused by steam from water present in the emulsion fuel, but it can be reduced by adding diglyme, which assists combustion. The presence of moisture reduces NOx emissions. Investigated diesel engine performance using two-phase and three-phase emulsion fuels. They used moisture contents of 10% and 20% in preparing the emulsified fuel and found that emulsified fuel increased the CO level, but decreased NOx emissions by 56.82% compared to diesel fuel. Subramanian found that reductions in NOx and smoke in water–diesel emulsion fuel were lower compared to those of the injection method. However, the carbon monoxide and hydrocarbon levels were higher with emulsified oil.

Investigated the effects of NOx and smoke emission characteristic on the emulsion oil type in water-in-oil and oil-in-water multiple emulsions. The specific fuel consumption, CO emissions from the exhaust and the performance of this engine increased, whereas NOx emissions decreased. Yang et al used a novel emulsified fuel with organic addition and found that CO and HC emissions slightly increased, whereas NOx emissions decreased by 30.6%. Ogunkoya investigated the stabilization of emulsified oil with woody lignin. They stated that the emulsified oil increased the BTE, brake specific fuel, carbon monoxide and hydro carbon levels, whereas NOx emissions decreased. Sadhik used diesel oil and water/diesel (W/D) and WD as nanoparticle additives, and found that specific fuel consumption (SFC) increased for W/D fuel and nanoparticle mixture. Furthermore, NOx can be decreased by diesel water fuel and nanoparticles, but carbon monoxide and hydro carbon in the W/D fuel increased. These emissions can be reduced by adding alumina nanoparticles.

Research interests on additives of the main bases have continued to increase owing to improved combustion in the combustion process]. The additives mainly include copper, cerium, and platinum. Some researchers have reported that the addition of gold bases can improve the fuel quality and reduce BSFC and exhaust gas For example, Vellaiyan showed that HC, CO, and NOx emissions can be reduced by adding 50 ppm and 100 ppm of lead oxide to water diesel emulsion (WDE). Farfaletti et al. investigated the addition of CeO to new WDE mixed fuel and found that PM, HC, and CO emissions can be decreased [18]. In addition, Keskin investigated the effect of adding gold on the combustion and exhaust gas of a diesel engine and noted that carbon monoxide and soot release decreased by 56.4% and 30.4%, respectively.

4. CONCLUSIONS

In past time, the maritime industry paid little attention to air pollution. That attitude was changed when IMO adopted Annex VI to MARPOL 73/78. Annex VI is concerned with the prevention of air pollution from ships. Because of the transboundary effect of air pollution, and the compelling need for many countries to tackle the growing problems of its effects on human health and global environment, IMO agreed to recommend the early implementation to reduce the emission of NOx from new marine diesel engines. It has also been agreed that, in order to avoid unacceptably long delays in the entry into force of Annex VI, the MEPC will review the impediments to entry into force of the Protocol and any initiate necessary measures to alleviate those impediments, as a matter of urgency, if it has not entered into force by 31 December 2002. Therefore, there is no doubt that Annex VI will enter into force in the future.

Annex VI of MARPOL 73/78 deals with a wide range of air pollution control matters including regulations on halons, Hydrochlorofluorocarbons (HCFCs) and other ozone depleting substances, Nitrogen oxides (NOx), Sulphur oxides (SOx), volatile organic compounds (VOCs), shipboard incinerators and fuel oil quality. However, the main focus has so far been on reducing the NOx and SOx emissions, because the IMO regulations call for a 30% reduction in NOx emissions and a 50% reduction in SOx emissions compared with current levels.

Annex VI to MARPOL 73/78 requires the survey of engines and equipment to be conducted in accordance with the NOx Technical Code. When the Protocol of 1997 enters into force, the requirements of the NOx emission restriction will be retrospectively applied to each diesel engine with a power output of more than 130 kW, which is installed on a ship or which undergoes major conversion on or after 1 January 2000.

According to the NOx Technical Code all engines within Reg.13 need the Engine International Air Pollution Prevention Certification (EIAPP Certificate). This certificate will be one of the key requirements of issuing the International Air Pollution Certificate (IAPP Certificate) for the ship. However, the new Annex VI has not come into force yet, so guidelines have been introduced to solve this problem by issuing a sort of interim certificate. The authorized organization (e.g. Classification Societies) by the flag state can issue the Statement of Compliance (SOC Certificate). The SOC Certificate will be transformed into the EIAPP Certificate when the new Annex VI enters into force.

To avoid certification testing of every engine for serially manufactured engines, the engine family or the engine group concept may be applied. In such a case, the testing is required only for the parent engine, which is the representative of an engine family or engine group. If the NOx emission values meet the requirements, the NOx relevant engine parameters have to be documented in the technical file. This technical file of the parent engine has to be the same for all member engines. Within an engine family or engine group the SOC Certificates or EIAPP Certificate will be issued to the parent engine and to every member engine.

NOx formation occurs by reaction between nitrogen and oxygen in the combustion air (thermal NOx), by reaction between exhaust gas hydrocarbon and combustion air oxygen (prompt NOx) and by reaction between nitrogen bindings in fuel (fuel NOx). Thermal NOx is decisive for the total emission and all the abatement methods are targeted to reduce that component. The formation of NOx in the combustion chamber is mainly influenced by temperature and oxygen concentration: the higher the temperature and the longer the residence time at temperature, the more the thermal NOx will be created. Therefore, low speed engines with slow burning processes have the highest emission due to the long time the oxygen is allowed to react with nitrogen.

Since or even long before the time the Regulation 13 concerning emission limits of Annex VI to MARPOL 73/78 NOx were chosen, the marine industry has continuously researched emission control technologies for marine diesel engines. Engine manufactures are exploring various ways to develop practical NOx reduction technologies. There are the primary methods such as retard injection, fuel nozzle modification, compression ratio, water direct injection, water emulsification, electronic controls and exhaust gas recirculation (EGR) and secondary methods such as selective catalytic reduction (SCR).

Primary methods are aimed at reducing the amount of NOx formed during combustion. The basic aim of most of these measures is to lower the maximum temperature in the cylinder, since this results inherently in a lower NOx emission. The low NOx combustion process is based on a combination of compression ratio, injection timing and injection rate. Therefore, when considering the NOx reduction method, it should be taken into account that all the different NOx reduction methods may affect each other.

5. REFERENCES

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