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Introduction of the HFO-MGO dual fuel system in marine engines

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Abstract
Nowaday, aproximately 0.8% of mass of fuels used in global maritime transportation are heavy fuels with the sulphur less 0.5% and light fuels with the sulphur less 0.1%. Hence, the SO_x emission at the sea regions or port where are not Sulphur Emission Control Areas (SECA) is quite high. It is necessary to reduce the sulphur content in fuels less 0.1% and use these fuels in global maritime transportation, especially the requirement of sulphur emission control is perform in the beginning of 2018. The paper presents the study of charactericstic and the methods of using marine gas oil MGO in marine engines. The results are the ground to orientate the design, fabrication and installation the dual fuel system HFO-MGO or DO-MGO used in marine engines in order to reduce the SO_x emission and the environment pollution.

Keywords: MGO fuel, marine engines, SO_x emission

1. Introduction

Currently, marine diesel engines often use HFO or DO diesel fuel or simultaneously use HFO and DO fuels. The sulfur content of these two fuels is usually greater than 3.5%. In response to strict requirements for SOX emissions, vessels operating in the emission control area (ECA) such as the North Sea, Baltic Sea or the English Channel have to use fuels with a sulfur content of less than 0, 5% (according to Annex VI, MARPOL). Thus, the transfer of marine diesel engines to use light marine MGO fuel would be the most viable option when meeting SOx emission standards. The fuel use roadmap for marine diesel engines under MARPOL 73/78 has a mandatory sulfur content shown in Figure 1 [4].

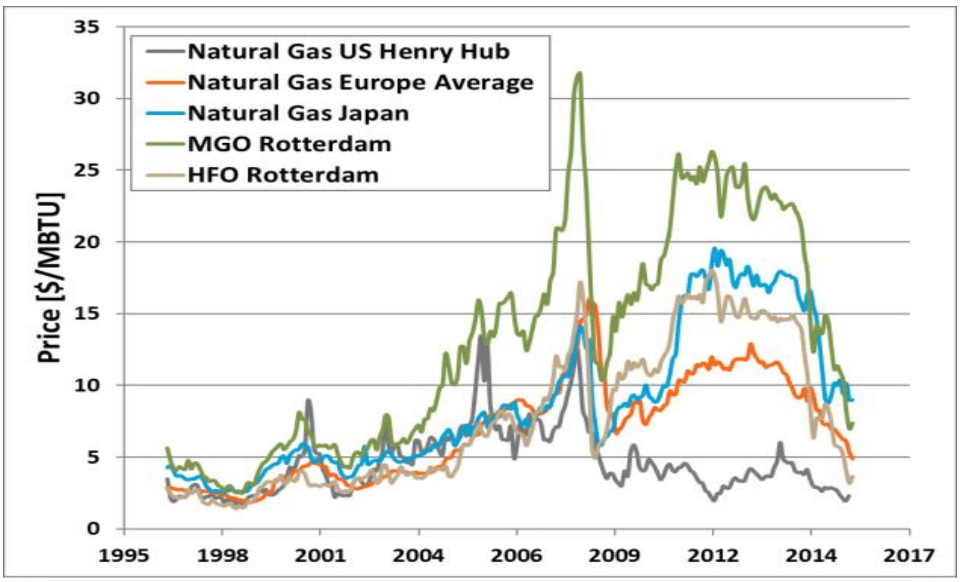

Fig.1: The sulfur content limit has been applied

The conversion of marine diesel engines from the use of HFO fuel to the use of MGO fuel when entering emission control areas requires ship owners and operators to have reasonable exploitation methods because of operating temperatures. The difference of these two fuels is, therefore, at risk of adversely affecting the engine and service system. When the extraction temperature of HFO and MGO fuel is too different, it can pose a risk of thermal shock to fuel equipment and systems as well as can cause leaked fuel. Thus, the conversion of marine diesel engines to use MGO fuel to replace HFO or DO fuel when entering ECA area should take into account the thermal adaptability of the engine and equipment of the engine.

The sulfur content in the fuel affects the SOx emission content. Emission of SOx on ships originates mainly from fuel. The process of forming SOx is very complex and depends on many factors such as temperature, pressure, element in fuel. In engines, sulfur acts with oxygen under suitable temperature and pressure conditions to form SOx combustion products in response to:

$$S + O_2 \leftrightarrow SO_2 \quad (1)$$

$$2S + 3O_2 \leftrightarrow 2SO_3 \quad (2)$$

After that, SO3 will combine with air vapor to form sulfuric acid according to the reaction:

$$SO_3 + H_2O \leftrightarrow H_2SO_4 \quad (3)$$

SOx is an emission gas that has a very serious impact on the environment, ecosystem and especially human health. SOx can adversely affect the process and respiratory system as well as circulatory system in the human body. With SOx content, it can cause death. In addition, the concentration of SOx in the air is also one of the causes of blurred vision and decreased vision. In addition, NOx and SOx emissions are a major cause of acid rain due to the interaction with water vapor in the air forming nitric acid and sulfuric acid [6]. The relationship between SO2 content and dew point temperature forming sulfuric acid is shown in Figure 2.

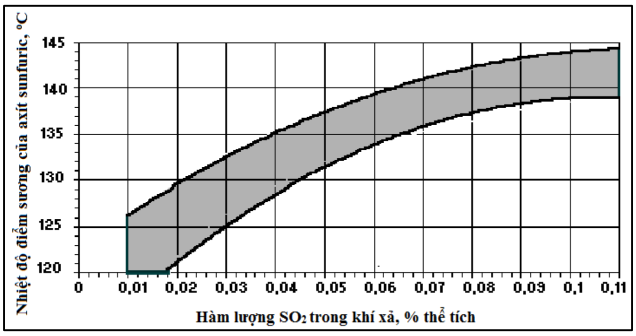

Fig.2: Relationship between SO2 content and temperature of sulfuric acid dew point

1.1. Effect of sulfur content on emissions

According to the results of some studies, when the sulfur content decreases to about 150ppm, the emission content of CO, HC, NOx decreases for gasoline-fueled engines and PM emissions decrease for dynamic diesel engine. When the sulfur content is low, about 50 ppm, NOx emissions decrease by more than 80% [7,8]. When the sulfur content in the fuel is very low, about 10ppm, it allows NOx emission control to more than 90% in both diesel and gasoline engines, especially the dust filter achieves maximum efficiency, thus allow access to full control of PM emissions.

1.2. Effect of sulfur content on lubrication ability

Sulfur is not a self-lubricating substance, but it can combine with nickel elements in some alloys to form an alloy with Ni-S crystals with a low melting point and therefore can increases lubrication. Sulfur is known as an additive component to increase lubrication. Lubrication of the fuel also plays an important role in reducing abrasive friction of the fuel pump piston and cylinder pair, which is a measure of the ability of fuel to lubricate and protect other parts of the fuel system against abrasion. The lubrication process of the piston and cylinder pairs is adversely affected when using extremely low sulfur fuels. Handling to reduce sulfur content in low fuel also eliminates the natural lubricating agents of diesel fuel. The sulfur removal process also reduces aromatic hydrocarbon content and fuel density, resulting in a 1% reduction in calorific value [3]. Some studies show that when the sulfur content in the fuel is lower than 50 ppm can cause lubrication problems. However, it is possible to reduce the sulfur content but it is necessary to add other lubricants to meet the standards for fuel.

1.3. Effect of sulfur content on flash point

Due to the risk of an explosion involving the use of fuels on board ships, the International Maritime Organization IMO banned the use of fuels with flash points lower than 60 ° C [2,4]. However, some studies show that ultra-low sulfur fuel oils often have a flash point lower than 60 ° C. Fuel oils should not be used on board and must be handled according to the instructions of SOLAS Convention.

2. MGO properties

Properties of fuel MGO, DO and HFO are given in Table 1.

Table 1: Fuel properties MGO, DO and HFO

Properties	Unit	MGO	DO	HFO
ρ	kg/m³	890	893	930
μ	cSt	1,5	4	87
T_f	ºC	60	63	66
Suphur content	%	0,1	0,25	5
Ash content	%	0,01	0,15	0,2
Heating value	MJ/kg	41	43	42
Cetane number		42	45	42

For marine diesel engines, to ensure the working conditions of the hydrodynamic oil film between the pump and piston pair to avoid fuel pump damage, the viscosity of the fuel is measured at the top. The fuel pump is allowed no less than 2 cSt. This limit provides the necessary safety margins for fuel pumps. At the start of the engine and stopping the engine, with long-term fuel pumps, the viscosity recommended by designers is greater than 3 cSt. However, the fuel temperature is always increasing during the exploitation of marine diesel engines, so it is difficult to maintain the low temperature at the inlet of the fuel pump to increase the viscosity of MGO fuel to a value greater than 2. cSt at 400C temperature [6].

From Table 1 shows, to increase the viscosity of MGO fuel to the allowed value, it is necessary to reduce the temperature of the fuel to the appropriate value. The viscosity value of MGO fuel according to the temperature is given in Figure 3.

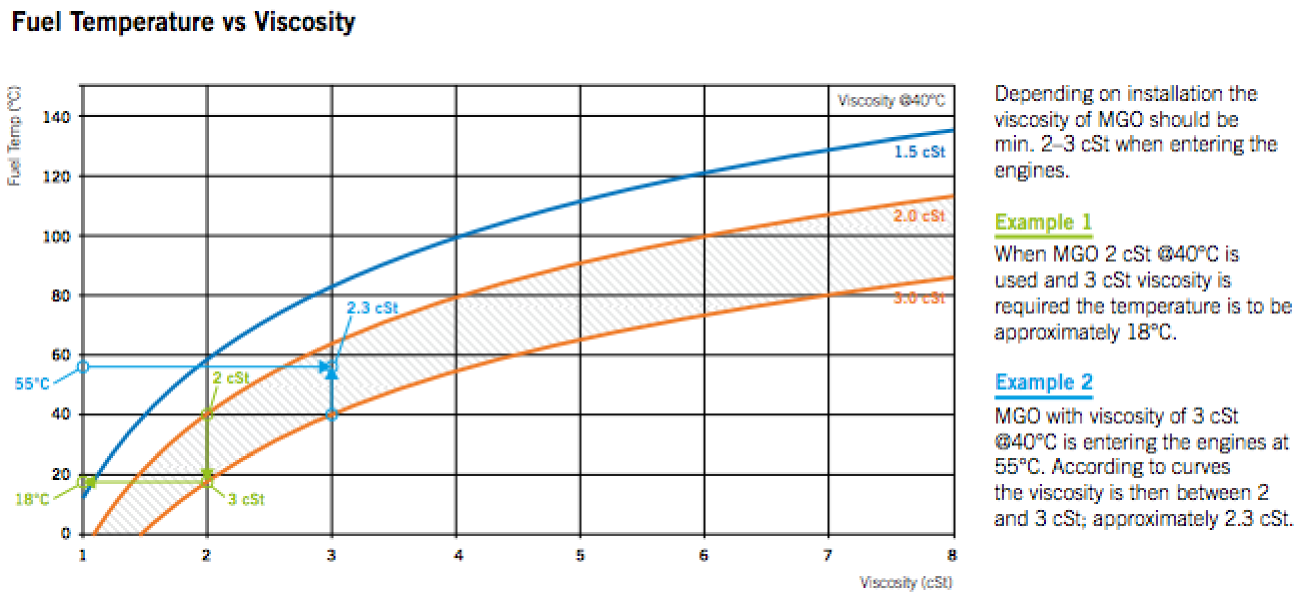

Fig.3: MGO properties

3. MGO fuel solution on board ships

Figure 4 shows a schematic diagram of the HFO – MGO dual fuel system on board. Normally, in the process of exploiting and operating diesel engines, the main fuel used is HFO fuel. However, when ships move into some of the emission control waters, the fuel system allows to switch to MGO fuel while ensuring fuel viscosity as well as adaptability to change. temperature of fuel. With the mixer set at the output of 2 HFO tanks and MGO and before the fuel pump, HFO and MGO fuels are mixed to gradually reduce the temperature of HFO fuel to the temperature and viscosity values of MGO.

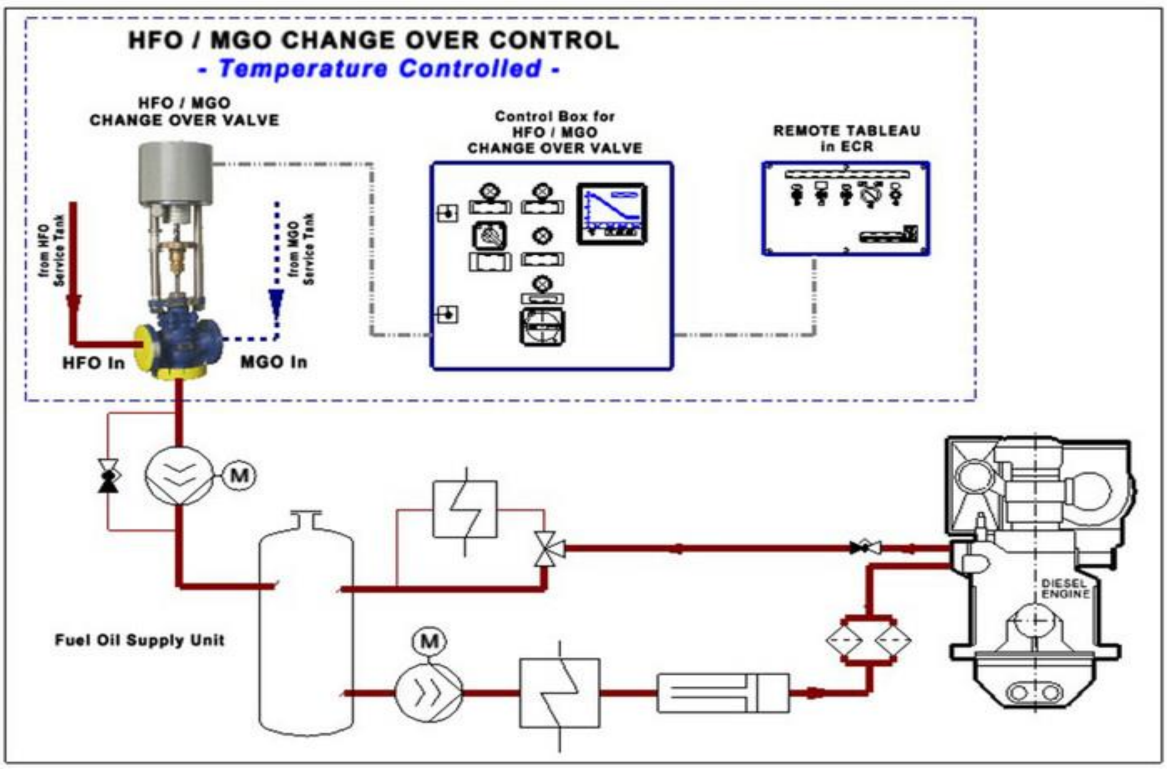

Fig.4: The principle diagram of the HFO-MGO dual fuel system

In order to maintain the MGO fuel temperature in the range of 10-15oC, a cooling system is installed at the MGO fuel output before being fed into a diesel engine. MGO fuel cooling system can be designed to use electrical energy from generators on ships or use air conditioning systems to absorb exhaust gas energy. However, the cooling system by electric energy is more commonly used due to its quick cooling capacity and easier control over the cooling system by the exhaust gas energy. Figure 5 shows Auramarine's MGO fuel system [1].

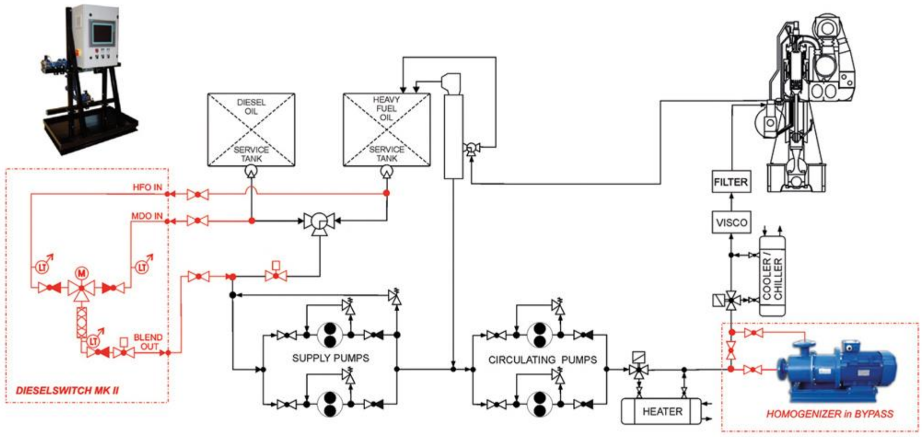

Fig.5: Fuel system converts to lightweight MGO for Auramarine vessels

Manufacturer of Auramarine liquid fuel systems has designed and built a fast, reliable HFO heavy oil transfer system for MGO light oil based on automatic control. According to Auramarine, the fuel selector is programmed to ensure the transition from one fuel to another is fully automated. The system also ensures that the temperature change process is slow enough to not cause heat stress in the engine's transport equipment and fuel system. The rate of temperature increase of fuel supplied to a marine diesel engine must not be greater than 2 (° C / min). Especially, Auramarine's fuel selector also allows setting up data, data is stored on PLC device and can be transferred to a report for shipping companies and units. Relevant use.

Consclusion

Environmental pollution is an urgent problem for countries around the world, replacing traditional diesel fuel with low sulfur fuels used on marine diesel engines is of interest. In order to meet SOx emissions requirements from 2020, all ships must be equipped with MGO fuel systems or low sulfur fuel when moving into special ports or waters. The article presented the benefits and solutions when using MGO fuel to replace traditional diesel fuel on ships. In subsequent studies, the authors will present trials using MGO fuel on diesel engines in the laboratory to provide more specific assessments.

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