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An Experimental Study on the Application of Fish Oil as Fuel

Scope

As the earth's population and peoples standard of living increases, the global society is faced with an increasing energy demand. Fossil fuels have been a reliable source of energy in the past and will continue to be so in the future, but fossil energy sources are finite and new energy sources must be investigated to ensure energy security in the future.

It is therefore of great interest to study alternative fuels, and biofuel have shown to be a promising alternative. Biofuels have similar properties and energy content as fossil fuels and this makes them applicable in existing engine technology. These biologically derived fuels has the advantage of being produced from organic material and are hence renewable. Biofuels are also carbon neutral and their use will prevent further build-up of carbon dioxide in the atmosphere.

This master thesis will investigate the injection and combustion characteristics of two fish based bio oils and their blends with MGO. The results will be compared with pure MGO to see if fish oil is a possible alternative to the conventional marine fuels used today.

Introduction

The diesel engine has been the preferred prime mover of the merchant fleet since it gradually started replacing the coal firing steam engines in the 1920's. When looking at emissions per tonne cargo kilometre, maritime transportation is by far the most environmentally friendly way of transporting goods, but the merchant fleet is still a huge source of pollutants that are causing global warming and in general are harming our planet. Up until recent years, the maritime transportation sector has consumed cheap, low quality fuel and has not been subject to particularly strict emission regulations. The introduction of global caps on emissions of sulphur dioxides and nitrogen oxides has forced the industry into using more processed, cleaner fuels and to adopt exhaust gas cleaning systems. Within the next 5 to 10 years, the maritime air emission regulations will require further reduction of air emissions and the industry will be needing more clean-burning fuel. When taking into account that the fuels derived from petroleum oil are finite and will run out within foreseeable future, it is inherent that new sources of energy are investigated.

The focus of this master thesis is to investigate fish oils potential as fuel for compression ignition engines. Two fish based oils in blends with MGO will be tested in a Constant Volume Combustion Chamber (CVCC), and spray and combustion characteristics will be compared to those of pure MGO (Marine Gas Oil). The CVCC has optical access and it is hence possible to capture images of the injection and combustion processes. These images together with acquired data from pressure and temperature sensors will be analysed to obtain information used for comparison.

A problem with biofuels in the past is that they have been in direct competition with food production and this has caused heated debates. The fish oils used in this study is hence chosen with this in mind. The first fish oil is a product produced from farmed fish that has died or been killed for other reasons than human consumption. Norwegian rules and regulations prohibits the use of these products for human consumption and its current application is as a dietary supplement for animals not intended as food, including pets and animals in the fur industry. This oil is termed Crude Fish Oil (CFO) and it is a dark brown viscous liquid with a strong fish smell. Due to its high viscosity, it has not been tested pure.

The second fish oil is a by-product from the omega fatty acid extraction. This oil has been subject to deeper processing and it is a transparent liquid with similar viscosity as MGO and only a slight fish odour. When looking at the chemical composition of this oil it is defined as biodiesel, but it is not prepared according to any biodiesel fuel specification and it fails on some of the fuel characteristic requirements. This oil has been transesterified, which is the most common process of producing biodiesel from fatty oils. In the transesterification process the triglycerides in the CFO is broken down to fatty acid alkyl esters, which is the chemical name of biodiesel. Depending on the alcohol used in the process one ends up with either fatty acid ethyl ester (FAEE) or fatty acid methyl ester (FAME). The latter is the most common, but FAEE has been tested in this study. Table 1 shows the fuel matrix with blends by volume.

Table 1: Fuel Matrix

	Fuel 1	Fuel 2	Fuel 3	Fuel 4	Fuel 5	Fuel 6
MGO	100%		50%	93%	50%	93%
FAEE		100%	50%	7%		
CFO					50%	7%

Experimental Setup

The CVCC is located in the engine laboratory at MARINTEK. It is a handy tool when studying the combustion properties of various fuels and can also be used to study different injector and spark plug technologies. The rig is equipped with a common rail fuel injection system with a maximum pressure of 1800 bar, a spark plug, air and gas inlet valves and an exhaust outlet valve. The combustion rig is computer controlled, and sensors sends data to the computer which than is recorded and used in further analysis. Figure 1 shows the flow plan of the CVCC and figure 2 shows the working principle. The CVCC is filled with 10 bars of an ignitable gas mixture composed of Oxygen, Nitrogen and Carbon Monoxide. This gas is ignited with the spark plug to achieve the right pressure and temperature conditions inside the vessel. This process of preparing the test environment, and to obtain test conditions where auto ignition of diesel fuels are possible is called the pre-combustion. Just after the pre-combustion, the pressure and temperature is too high for the environment to simulate an actual engine and one has to wait for heat losses to reduce the chamber conditions. When the conditions are as desired, the fuel is injected, and the main combustion occurs.

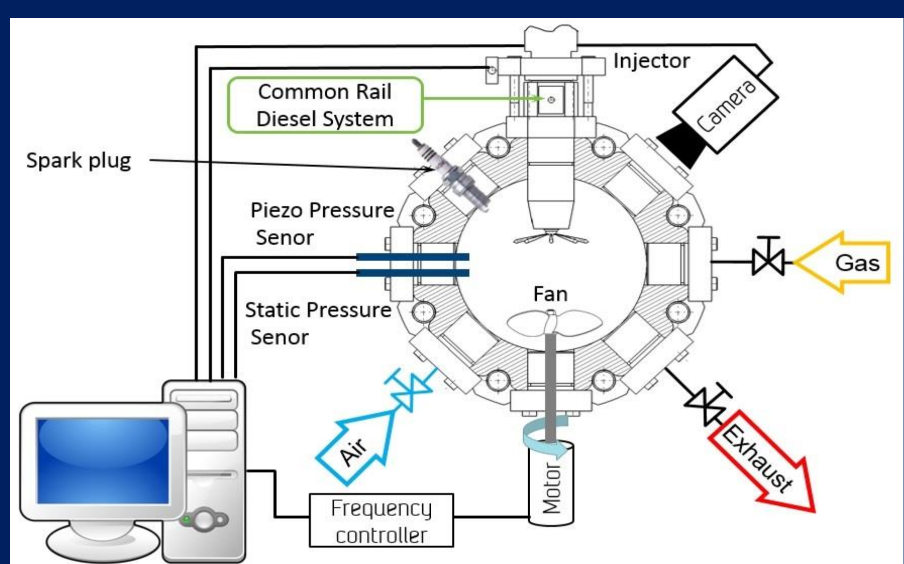

Figure 1: Schematic flow plan of the CVCC

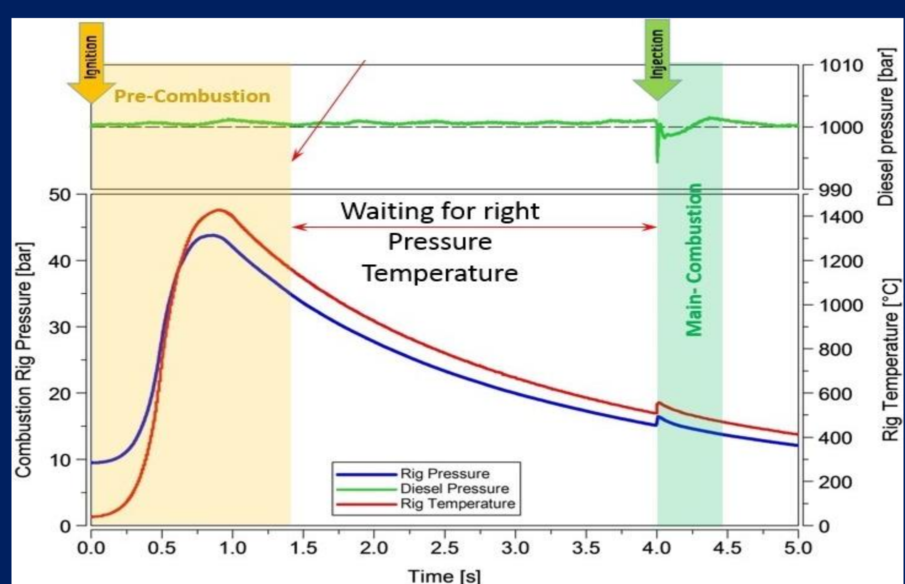

Figure 2: Working principle of the CVCC

Method

The fuels has been injected at three injection pressures; 800, 1000 and 1400 bars. Eight injections was done at each injection pressure to limit the risk of drawing conclusions based on faulty experiments. Three different imaging techniques has been used to capture images in this study; direct imaging, shadowgraph imaging and schlieren imaging. The fuels will be evaluated based on spray characteristics and combustion characteristics. The spray characteristics includes spray penetration, cone angle and lift-off length, whilst the combustion characteristics includes ignition delay, rate of heat release and combustion intensity. The intensity is used for qualitative determination of soot formation. Figure 3, 4 and 5 shows raw images captured with the different imaging techniques. A Matlab script reads the raw images, analyses them and wrights the spray characteristics to an Excel spreadsheet for further analysis. Figure 6 shows a Matlab processed image. Ignition delay and rate of heat release is analysed directly in excel based on pressure and temperature data from the sensors .

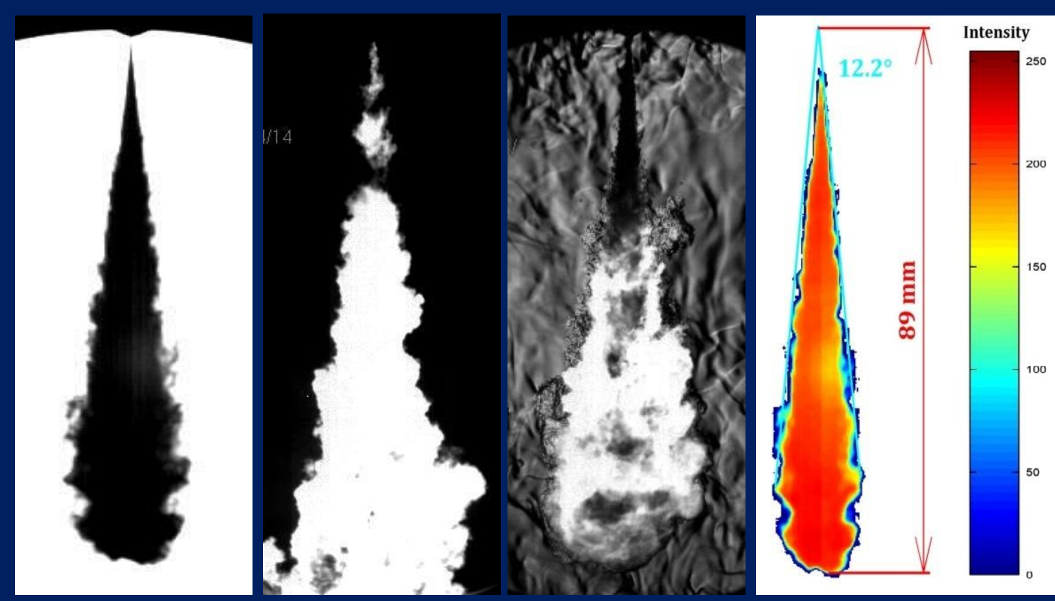

Figure 3: Shadowgraph *Figure 4: Direct Imaging* *Figure 5: Schlieren* *Figure 6: Matlab Analysis*

Results

The results are work in progress and so far there are not so much to show for. However, figure 7 shows the radiation intensity when combusting the different fuels with 1000 bar injection pressure. Higher intensity means more soot formation and the results are as expected. The fuel bound oxygen in the fish oils are improving the combustion process causing decreased soot formation. There are also possible to identify some differences in ignition delay by looking at the start of intensity detection along the time axis. No thermodynamic results are available at this time and the spray characteristics are somewhat contradictory and needs further in-depth studies to evaluate them against expectations and theory.

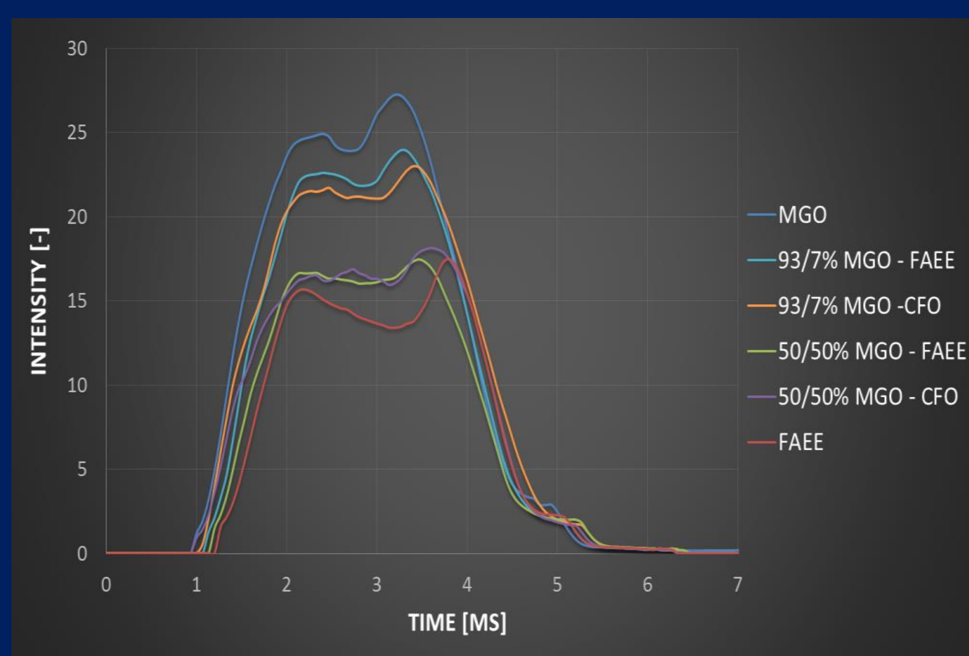

Figure 7: Combustion radiation intensity

Conclusion

No conclusion has been drawn yet.

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ScanBio
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