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Reducing the viscosity of Jojoba Methyl Ester diesel fuel and effects on diesel engine performance and roughness

Mohamed Y.E. Selim *

Mech. Eng. Dept., UAE University, Al-Ain, Abu Dhabi 17555, United Arab Emirates

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ABSTRACT

An experimental investigation has been carried out to test two approaches to reduce the viscosity of the Jojoba Methyl Ester (JME) diesel fuel. The first approach is the heating of the fuel to two temperatures of 50 and 70 °C as compared to the base ambient temperature and to diesel fuel too. The second approach is adding one chemical which is considered by its own as alternative and renewable fuel which is Diethyl Ether (DEE). The viscosity has been reduced by both methods to close to diesel values. The performance of a diesel engine using those fuels has been tested in a variable compression research engine Ricardo E6 with the engine speed constant at 1200 rpm. The measured parameters included the exhaust gas temperature, the ignition delay period, the maximum pressure rise rate, maximum pressure, and indicated mean effective pressure and maximum heat release rate. The engine performance is presented and the effects of both approaches are scrutinized.

1. Introduction

In addition to diesel's inherent energy efficiency, use of renewable fuels can reduce petroleum consumption even further [1]. Diesel drivers have the option to fill up with blends of biodiesel – a domestically produced renewable fuel. Biodiesel fuels are derived from a variety of biomass sources such as vegetable oil, animal fat, and cooking oil. Biodiesel is made through a chemical process called transesterification, where glycerin is separated from methyl esters derived from the fat or oil. The methyl ester product is what is known as biodiesel and must meet the standards set forth by the American Society of Testing and Materials (ASTM) for fuel grade biodiesel, specifically ASTM D6751 (or EN14214 in Europe) [2].

Technically, any hydrocarbon distillate material derived from biomass that meets the appropriate ASTM specification can be defined as diesel, or as biodiesel. Feedstocks for diesel fuels derived from biomass include soybean [3], rape seed [4–6], and waste cooking oils, along with animal fats [7]. Vegetable oils can be used directly as diesel fuels, but their properties such as high viscosity and low volatility cause durability problems in fuel systems [2,3,5].

Various processes convert biomass to diesel fuels. Among these is transesterification of triglycerides, which produces esters. The resulting fuel fits into the definition of biodiesel. Other processes include hydrothermal processing, hydroprocessing, and indirect liquefaction. These processes yield distillates that are not esters.

Biodiesel is defined as the mono alkyl esters of long-carbon-chain fatty acids derived from renewable lipid feedstocks. It is produced by transesterification of triglycerides (fatty acids) contained in oil-rich biomass and animal fats. The triglycerides can be converted to esters that have properties more compatible with petroleum diesel fuel. In the base-catalyzed transesterification process, the triglycerides are reacted with an alcohol, either methanol or ethanol, in the presence of an alkaline catalyst, normally potassium hydroxide. This reaction forms methyl or ethyl esters, and glycerin is a byproduct.

Use of biodiesel can also result in some reduction in fuel economy depending on the blend due to biodiesel's slightly lower energy content. The primary concern is one of quality assurance. While many people can produce biodiesel, the production of biodiesel that meets the ASTM standard is more difficult. As the percentage of biodiesel in the blend increases, the sensitivity to quality of the biodiesel increases proportionately [8,9].

Of the several biodeisel sources that started to appear in the literature by the current author is Jojoba oils [10–12]. It appears to be first published as a fuel in shock tube experiments [12], followed by another article about diesel engine burning this fuel [11] and it has been then used in a dual fuel engine [10]. Another article has been also published from the same laboratory [13]. Jojoba oil comes from very promising plant that lives for more than one hundred and fifty years and has unique properties. This is due to many factors [13] such as its high contents of oil per seed, its molecules contains a carbon chain of 20–22 carbon atoms and its chemical stability. The plant itself is very promising for cultivation in hot weather as it resists salinity and dryness. It gives acceptable

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* Tel.: +971 504494723; fax: +971 37623158.
E-mail address: mohamed.selim@uaeu.ac.ae

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production per acre and is currently used for cosmetics applications. The properties of Jojoba Methyl Ester (JME) are unique as will be shown later. However, so far only the viscosity needs to be reduced so that it will be accepted by fuel properties standards, hence it should be reduced from more than 19 cSt. to lower than 7 cSt. All previous publications about this fuel were for high viscosity version and no work has been reported about the long term effects of the high fuel viscosity. The current high viscosity affects negatively the injection, atomization and mixing process of the fuel with air.

Atomization is the breakup of bulk liquid jets into small droplets by using an atomizer. Adequate atomization enhances mixing and complete combustion in a direct injection (DI) engine and therefore is an important factor in engine emission and efficiency. According to Lefebvre [14], the physical properties of a liquid fuel that affect its atomization in a diesel engine are viscosity, density, and surface tension. For a DI diesel injector at fixed operating condition, use of fuel with higher viscosity delays atomization by suppressing the instabilities required for the fuel jet to breakup. An increase in fuel density adversely affects atomization, whereas higher fuel surface tension opposes the formation of droplets from the liquid fuel [14]. Hence a suitable diesel fuel in a DI engine requires balanced values of viscosity, density, and surface tension, for a given atomizer to function properly.

Therefore the objectives of the present work are to reduce the viscosity of the Jojoba Methyl Ester so that its properties will be acceptable by fuel properties standards and it is acceptable as a good fuel for diesel engines. The reduction of viscosity will be carried out by different approaches to match the required viscosities for diesel fuels. Two approaches are used here of heating the JME fuel to different temperatures and the second is by adding very low viscosity renewable fuel to the JME. The effect of using the new reduced-viscosity fuel on a real diesel engine will also be presented.

2. Experimental engine test RIG

The research engine used in the present study is the Ricardo E6 single cylinder variable compression indirect injection diesel engine. The specifications of the engine are listed in Table 1. The engine cylinder head has a Ricardo Comet Mk V compression swirl combustion chamber. This type of combustion system consists of two parts. The swirl chamber in the head has a top half of spherical form and the lower half is a truncated cone, which communicates with the cylinder by means of a narrow passage or throat. The second part consists of special cavities cut into the crown of the piston.

The engine is loaded by an electrical dynamometer rated at 22 kW and 420 V. The engine is fully equipped for measurements of all operating parameters and noise data. The pressure time history is measured by a water-cooled piezo-electric pressure transducer and crankshaft degree angle sensor connected to the relevant amplifiers. The liquid fuel flow rate is measured digitally by a multi-function microprocessor-based fuel system, Compuflow System. Two data acquisition systems are used to collect the important data and store it in a personal computer for offline analysis. The following parameters are fed into the computer: cylinder pressure, crank angle degrees, liquid fuel flow rate data, engine speed and torque, and air/oil/coolant/oil/exhaust temperatures. A computer program in μMACBASIC language is written to collect the data and manage the system and a workstation operating system has been used to run the program.

Table 1
Engine specifications.

Model	Ricardo E6
Type	IDI with the pre-combustion chamber
Bore × stroke (mm)	76.2 × 111.1 – 1 cylinder
Cycle	4-stroke
Compression ratio	Variable, max. 22
Maximum power (kW)	9, naturally aspirated
Maximum speed (rpm)	3000
Injection timing	Variable, 20 to 45° BTDC

The pressure signal is fed into a charge amplifier then to a data acquisition card linked to the personal computer and the crank angle signal is fed into a degree marker shape channel and the output is fed into the acquisition card. The acquisition card could collect data at the rate of 250 kHz. The pressure and crank angle data are stored in the computer disk for further analysis. A MS Excel computer program is written to find the pressure rise rate, combustion maximum pressure of the cycle, ignition delay, the heat release and the indicated mean effective pressure data at all cycle points from mid compression stroke to mid expansion stroke. The maximum value of pressure rise rate is obtained and recorded. This value will be used to represent the combustion noise level at that operating condition. The typical combustion pressure history may be seen in Fig. 1 with the corresponding pressure rise rate. The maximum combustion pressure has also been calculated for the all operating conditions. Another program has been written to calculate the heat release rate [15–17] during the combustion process and the maximum value only has been presented here. The ignition delay period has been also calculated from the start of injection to the onset of pressure deviation from the motoring pressure values; Fig. 2. Experiments have been carried out after running the engine for some time until it reaches steady state and oil temperature is at 60 ± 5 °C, and cooling water temperature is at 60 ± 5 °C.

Data are presented as exhaust gas temperature, ignition delay period, maximum pressure rise rate $(dP/d\theta)_{max}$, maximum pressure (P_{max}), maximum heat release rate (HRR_{max}), and indicated mean effective pressure (*imep*) for the following operating parameters:

a. The brake mean effective pressure (*bmep*) and it is varied from 50 to 450 kPa.
b. The liquid fuel inlet temperature to the pump and it is varied at 25, 50 and 70 °C.
c. The DEE concentration (viscosity reduction additive) and it is varied at 5%, 10%, and 15% of the JME mass used.

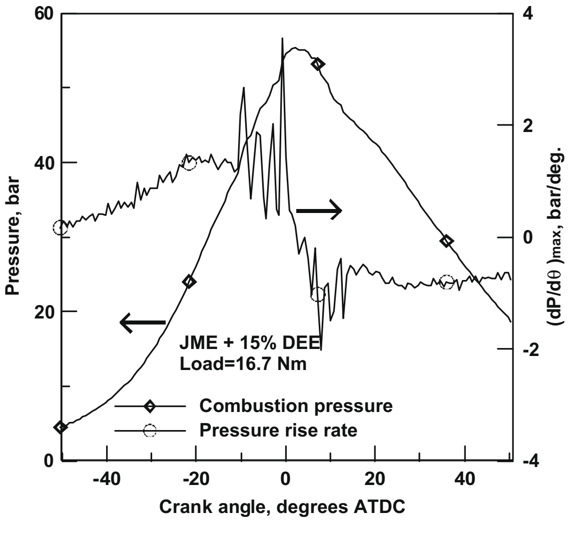

Fig. 1. Typical pressure and pressure rise rate for the diesel engine.