Experimental Study of using Recycled Lubricating Oil as a Diesel Engine Fuel

Mohamed Tarek Hamouda[1], Ahmed Taher Hussin[2], Mahmoud Mohamed Kamal[3], Gamal Mosaad Hennes[4]

[1]Mechanical Power Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt
[2]Assistant Mechanical Power Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt
[3]Professor, Mechanical Power Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt
[4]Professor, Mechanical Power Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt

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Abstract - *A Twin-cylinder, naturally-aspirated, direct-injection (DI), compression-ignition engine was used to perform a comparative study on the effect of using different blends of Recycled Waste Lubricating Oil (RWLO) and petroleum diesel (W0) on engine performance and emissions. Different blends of RWLO were used [10% RWLO + 90% diesel (denoted as W10), 20% RWLO + 80% diesel (denoted as W20), 30% RWLO + 70% diesel (denoted as W30) and 40% RWLO + 60% diesel (denoted as W40)] to operate the engine at fifteen engine loads in addition to test the effect of varying the injection pressure on the same parameters. The engine was operated at 2400 lb/in² (~ 165 bar) injection pressure. The injection pressure was raised to 2800 lb/in² (~193 bar) in order to eliminate the undesirable effect of RWLO when used as a fuel and it was not appropriate to raise the injection pressure further more due to technical difficulties regarding the engine. The brake specific fuel consumption (BSFC), exhaust gas temperature (EGT), nitrogen oxides (NOx), carbon monoxide (CO) and unburned hydrocarbons (HC) emissions increased by about 14, 17, 39, 22 and 60 % respectively in addition to a reduction in the brake thermal efficiency (BTE) and carbon dioxide emissions (CO2) by 12 and15 % respectively upon switching from W0 to W40. Increasing the injection pressure enhanced the engine performance by increasing the BTE and reducing both BSFC and HC emissions.*

Keywords: Recycled Waste Lubricating Oil, Injection pressure, Compression-ignition engine

1. INTRODUCTION

The increasing impact of air pollution caused by using fossil fuels, fossil fuels depletion, being concentrated in certain places in the world and their high costs make alternative fuel sources more attractive [1, 2, 3]. Therefore, most researchers have focused on finding alternative waste energy sources. These wastes can be anything around us such as waste frying cooking oils, waste lubricating oils, trees, plastics, tires, etc. They cannot be used as a fuel directly and burned inside an engine without processing. Waste processing includes filtration and purification to remove undesirable particles which may harm the engine and then being converted into the fuel to be used.

Waste engine oil loses its physical properties due to its exposure to high temperatures in addition to the fact that it holds many suspended matters resulted from the engine operation. About 40 million metric tons of waste lubricating oils are produced per year all over the world. Around 60% of the production becomes waste and most of them, which is improper, disposed or lost in use [4]. One liter of waste lubricating oil being improperly disposed to the environment contaminates about 810,000 liters of water and about 5,000,000 tons of clean water not usable [5]. Such numbers show the importance of converting the waste oil into a usable fuel [6].

The production of a fuel which can be used to operate diesel engines from waste engine oil offers a triple-facet solution: economical, environmental and waste management. The new technologies developed during the last years made it possible to produce diesel fuel from recycled waste lubricating oils with an added attractive advantage of being lower in price.

2. MATERIALS AND METHODS

In order to convert RWLO into fuel, there are several processes that need to be done in order to have a high quality fuel. These processes are filtration, acid treatment and neutralization. The RWLO passed through several filters in order to ensure that there are no suspended particles or metals inside it which may cause damage to the engine when used as a fuel. The oil was then heated for one hour, for the purpose of evaporating the water and the volatile substances in the used oil.

Sulphuric acid was then added at a percentage of 10 % by volume of the oil and then the whole mixture was stirred for 10 minutes. It was, then, left for 24 hours in order to allow the additives to settle down at the bottom of the container forming a semi solid substance (sludge) in order to separate it from liquid oil. Sulphuric acid was added to the RWLO after the filtration process in order to remove the additives found in the oil after its break down. Such process helps to lower the oil viscosity to the appropriate level to be used as a fuel in diesel engines.

The extracted oil from the above step was placed in a container containing 10 % of its weight sodium hydroxide in order to neutralize the effect of any remaining acid to avoid any damage to the injection system [7].

3. EXPERIMENTAL EQUIPMENTS AND PROCEDURES

A Twin-cylinder, air-cooled, four-stroke, diesel engine type DEUTZ F2L-511 with a maximum power of 13.6 kW operating at a constant speed of 1500 rpm and 2400 lb/in^2 (~ 165 bar) injection pressure was used in the experiment operated by W0, W10, W20, W30 and W40. The engine is connected to a 3-phase electric generator used to supply electricity to three rows of lamps (3L), each containing three lamps (100 W each) and three rows of heaters (3H), each containing three heaters (≈1200 W each) representing about 90 % of full load. An exhaust gas analyzer (LANCOM Series II) was employed to measure the EGT as well as the percentage of NOx, HC, CO and CO2 emissions.

To ensure the accuracy of the measured values, the gas analyzer was calibrated before each measurement. The fuel consumption was calculated by measuring the time during which the engine consumed a certain quantity of fuel. The injection pressure was regulated at 2200 lb/in^2(~152 bar) and 2800 lb/in^2(~193 bar) by using the nozzle tester as shown in Figure 1 and the values were compared with 2400lb/in^2 (~ 165 bar) which is the rated injection pressure of the engine.

Before running the engine with a different fuel, it was allowed to run for sufficient time to consume the remaining fuel from the previous experiment. To evaluate the engine performance, the important operating parameters such as power output, fuel consumption and exhaust emissions were measured. Significant engine performance parameters such as the BSFC and BTE when using RWLO and its blends were calculated.

Fig 1: BOSCH H-S/KDEP 99A nozzle tester

4. RESULTS AND DISCUSSION

The results of the experimental work of this research including the engine performance and emissions are discussed in the following sections.

4.1. BRAKE SPECIFIC FUEL CONSUMPTION (BSFC)

Chart 1 shows the BSFC variation of the RWLO blends versus the brake power of the engine at 2400 Ib/in^2 (~ 165 bar). In general, it was observed that the BSFC values of the RWLO blends were higher than those of W0 under all the range of engine loads. Among the blends, the highest percentage increase in BSFC was about 14 % for W40 at 0.53 kW engine power when compared to W0at the same engine load. More RWLO blends are needed to produce the same amount of energy due to the low calorific value when compared with W0.

The injection pressure was increased to 2800 lb/in^2 (~193 bar) which improved the BSFC when compared to the results obtained at the rated pressure at all cases. Such improvement may be due to the complete combustion of the fuel due to the improvement in spray atomization at higher injection pressure which leads to better mixing between air and fuel. Such behavior matches with the results obtained by Sarada [8], Prabhahar [9] and Keerthi [11].Increasing the injection pressure helped to overcome the undesirable effect resulted from using RWLO. Using high injection pressure helped to restore the BSFC for W10 at 0.53 kW when compared to W0 at rated injection pressure.

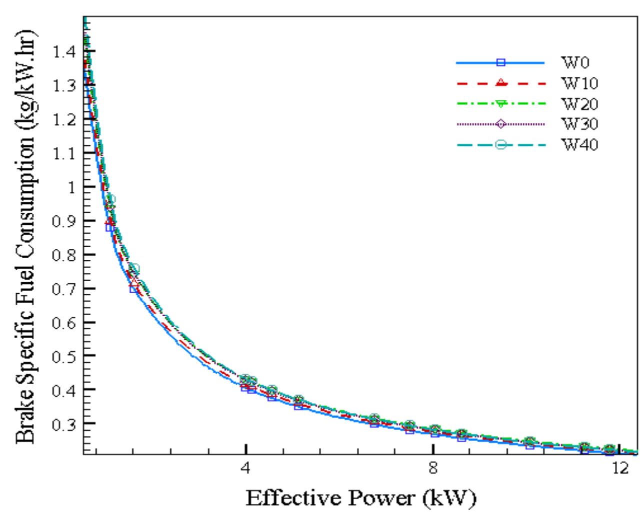

Chart-1: Variation of BSFC versus brake power at 2400 lb/in^2 (~ 165 bar) injection pressure

After that, the injection pressure was decreased to 2200 lb/in^2 (~152 bar) which increased the BSFC. These results are may be due to the bad atomization of the spray. Chart 2 and Chart 3 show the variation of the BSFC at 2800 lb/in^2 (~193 bar) and 2200 lb/in² (~152 bar) injection pressure versus the brake power when compared to the rated pressure for W0, W10, W20, W30 and W40.

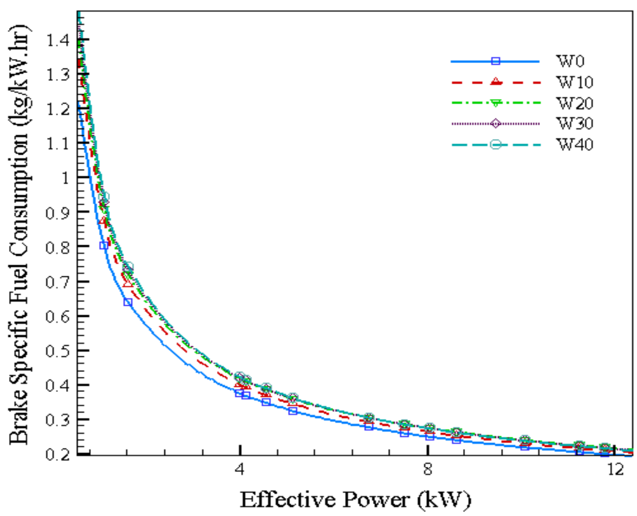

Chart-2: Brake specific fuel consumption versus the brake power at 2800 lb/in² (~193 bar) injection pressure

4.2. BRAKE THERMAL EFFICIENCY (BTE)

The BTE values calculated for RWLO blends with the diesel fuel are shown in chart 4. It was observed that as the RWLO content increased, the BTE decreased. The highest percentage reduction for BTE was 11 % for the W40 blend at 0.53 kW engine power when compared to W0. Such reduction may be due to low calorific value of RWLO when compared to diesel in addition to the increase in fuel consumption and the incomplete combustion occurred due to the high viscosity of the fuel.

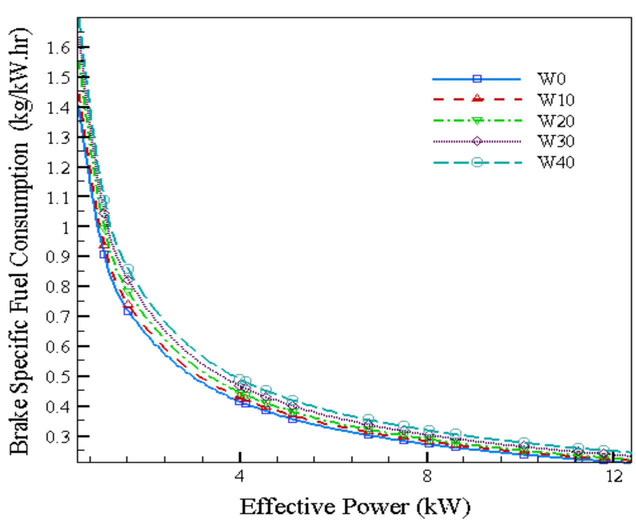

Chart-3: Brake specific fuel consumption versus the brake power at 2200 lb/in² (~152 bar) injection pressure

As the injection pressure increased, the BTE increased. Using high injection pressure improved the BTE for W10 at 0.53 kW and eliminated the effect of high viscosity fuel to the same values obtained when using W0. The highest percentage increase in BTE when the injection pressure increased to 2800 lb/in² (~193 bar) was about 15 % at 8.62 kW brake power while the highest percentage reduction in BTE when the injection pressure was reduced to 2200 lb/in² (~152 bar) was about 13 % at 5.14 kW brake power.

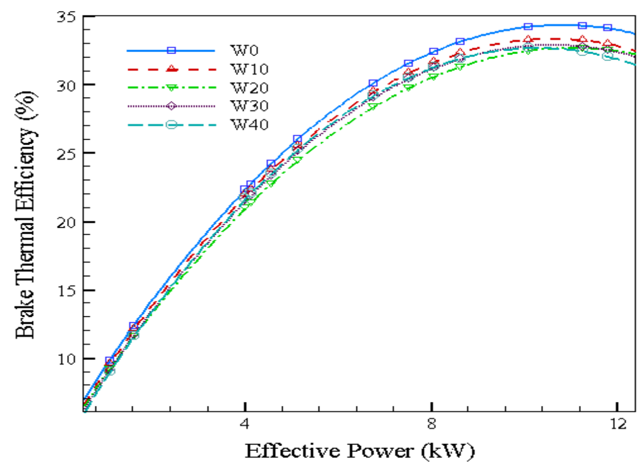

Chart-4 Variation of BTE versus brake power at 2400 lb/in² (~ 165 bar) injection pressure

The reason for such behavior may be due to the reduction of the diameter of the fuel droplets as the injection pressure increases which means better atomization and better formation of fuel - air mixture during the ignition delay period which improves the combustion process and, in turn, improves the efficiency. These results meet with the results observed by Sarada [8], Prabhahar [9], Kumar [10], Keerthi [11] and Pugazhvadivu [12]. Chart 5 and Chart 6 show the variation of the BTE at 2800 lb/in2 (~193 bar) and 2200 lb/in² (~152 bar) injection pressure versus the brake power when compared to the rated pressure for W0, W10, W20, W30 and W40.