International Journal of Engineering Innovation & Research
Volume 3, Issue 3, ISSN: 2277 – 5668

Experimental Study on the Performance of Diesel Engine using Different Alternative Fuels

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***Abstract* – The experimentations conducted in this paper concentrated on alternative sources by developing new mixtures of fuels to reduce the fuel consumption and to reduce the environmental impact of combustion emissions. It describes the experimental results of different mixtures of diesohol (Diesel+ alcohol). To investigate the performance of the diesel engine at different mixtures percentages of ethanol and methanol with diesel. Different diesohol mixtures (5%, 10%, 15%, 20%, and 25% of ethanol and methanol with diesel) were tested and compared with pure diesel samples. The experimentations were conducted using four strokes (1400 cc) 8 hp and 1 cylinder diesel engine test bed (Lester P-8-1). Remarkable results were obtained regarding different operating conditions such as torque, thermal efficiency and specific fuel consumption. The experimental results obtained concluded that the disohol mixtures improved the torque and the thermal efficiency of the engine compared to the pure Diesel samples**

***Keywords* – Diesel Engine, Alternative Fuel, Diesohol, BioDiesel.**

I. Introduction

As a result of consuming oil with much faster than it's naturally produced, studies on energy resources showed that the oil depletion point has been reached [1]. In addition, energy demands are increasing at alarming rate that wants the world Energy Research Centers to present alternative energy sources to keep the world economies being running smoothly. Wide spread of national energy centers worldwide were to attempt this urgent energy problem. Jordan is no exception; The National Energy Research Center (NERC) has been established in Jordan for the purposes of research, development and training in the fields of new and renewable energy to rise up the efficiency of using energy in different economic sectors [2].The alarming rate at which the Earth's atmosphere is getting polluted, the increased impact of global warming on the weather conditions on Earth and the stringent anti-pollution laws imposed in certain countries are among the main reasons for the search for alternatives to gasoline and diesel fuels [3,4].The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. The indiscriminate extraction and consumption of fossil fuels have led to a reduction in petroleum reserves. Petroleum based fuels are obtained from limited reserves. These finite reserves are highly concentrated in some certain regions of the world. Therefore, those countries not having these resources are facing a foreign exchange crisis such as Jordan, mainly due to the import of crude petroleum oil. Hence it is necessary to look for alternative fuels, which can be produced from resources available within the country. Although vegetative oils can be fuel for diesel engines, but their high viscosities, low volatilities and poor cold flow properties have led to the investigation of its various derivatives. The use of alcohols provides an attractive alternative fuel for internal combustion engines. Moreover, alcohol can be produced by biorefineries, thus reducing the consumption of fossil resources. Therefore research related to the use of alcohols as alternative fuels for internal combustion or diesel engines has been focused on the employment of short chain alcohols, mainly methanol and ethanol, blended with fossil fuels. BioDiesel is a clean burning alternative fuel, produced from domestic, renewable resources. It is petroleum free, but it can be blended at any level with petroleum diesel to create a BioDiesel combination. It can be used in compression-ignition (Diesel) engines with little or no modifications. BioDiesel is simple to use, recyclable, harmless, environmental and essentially free of sulfur and aromatics [5, 6]. BioDiesel can also help meet national goals for the net reduction of atmospheric carbon. As a renewable fuel, derived from organic materials, BioDiesel and blends of BioDiesel reduce the net amount of carbon dioxide in the Biosphere [6, 7]. BioDiesel helps preserve and protect natural resources. For every one unit of energy needed to produce BioDiesel, 3.24 units of energy are gained. This is the highest energy balance of any fuel. Because of this high energy balance and since it is domestically produced, BioDiesel use can greatly contribute to domestic energy security [5, 6 and 7]. In 2000, BioDiesel became the only alternative fuel in USA to have successfully completed the EPA-required Tier I and Tier II health effects testing under the Clean Air Act. These independent tests conclusively demonstrated BioDiesel's significant reduction of virtually all regulated emissions, and showed BioDiesel does not pose a threat to human health [7, 8].Blends of BioDiesel higher than B5 require special handling and fuel management as well as vehicle equipment modifications such as the using of heaters and changing seals/gaskets that come in contact with fuel, according to the National Renewable Energy Laboratory [9].Rahimi et al [10] added bioethanol to diesel to enhance the oxygenated component in the fuel, while the sunflower methyl ester was added to maintain the fuel stability at low temperatures. The parameters considered for investigation are the engine power, torque, specific fuel consumption and exhaust emissions for various mixture proportions. Their experimental results showed that bioethanol plays an important role in determining the flash point of the blends. By adding 3% bioethanol to diesel and sunflower methyl ester, the flash point was reduced by 16 °C. The viscosity of the blend was also reduced by increasing the amount of bioethanol. Their experimental measurement and observation of smoke concentration, NO*x*, CO and HC concentration indicated that both of these pollutants reduced by increasing the biofuel composition of diesterol throughout the engine operating range. Ozener et al [11] compared the combustion, performance and emission characteristics of conventional diesel fuel and biodiesel produced from soybean oil and its blends (B10, B20, B50). Their tests were performed at steady-state conditions in a single-cylinder direct injection diesel engine over the entire rpm range (1200–3000 rpm). Their experimental results, showed that, relative to diesel, biodiesel had a 1–4% decrease in the torque and an approximately 2–9% increase in the brake-specific fuel consumption (BSFC) due to the lower heating value (LHV) of the biodiesel. However, biodiesel significantly reduced carbon monoxide (CO) (28–46%) and unburned total hydrocarbons (THCs), while the nitric oxides (NO*x*) (6.95–17.62%) and carbon dioxide (CO2) emissions increased slightly 1.46–5.03%. Their combustion analyses showed that the addition of biodiesel to conventional diesel fuel decreased the ignition delay and reduced the premixed peak. Their results indicated that biodiesel could be used without any engine modifications as an alternative and environmentally friendly fuel. Torres-Jimenez et al [12] proved that, for all operating regimens tested, the addition of bioethanol to biodiesel reduces fuelling, injection timing, injection duration, mean injection rate and maximum injection pressure and increases injection delay compared to pure biodiesel. Meanwhile, increasing bioethanol in diesel fuel shows no significant variations or a slightly increase in fuelling, injection timing, injection duration, and mean injection rate and a decrease in injection delay and maximum injection pressure, compared to pure diesel fuel. While Abu-Qudais et al [13] investigated experimentally the effects of ethanol fumigation (i.e. the addition of ethanol to the intake air manifold) and ethanol–diesel fuel blends on the performance and emissions of a single cylinder diesel engine. Their results showed that both the fumigation and blends methods have the same behavior in affecting performance and emissions, but the improvement in using the fumigation method was better than when using blends. Their optimum percentage for ethanol fumigation is 20%. This percentage produces an increase of 7.5% in brake thermal efficiency, 55% in CO emissions, 36% in HC emissions and reduction of 51% in soot mass concentration. Their optimum percentage for ethanol–diesel fuel blends is 15%. This produces an increase of 3.6% in brake thermal efficiency, 43.3% in CO emissions, 34% in HC and a reduction of 32% in soot mass concentration. Sayin [14] studied the effects of methanol–diesel (M5, M10) and ethanol–diesel (E5, E10) fuel blends on the performance and exhaust emissions experimentally. For his work, a single cylinder, four-stroke, direct injection, naturally aspirated diesel engine was used. The tests were performed by varying the engine speed between 1000 and 1800 rpm while keeping the engine torque at 30 Nm. His results showed that brake specific fuel consumption and emissions of nitrogen oxides increased while brake thermal efficiency, smoke opacity, emissions of carbon monoxide and total hydrocarbon decreased with methanol–diesel and ethanol–diesel fuel blends. Lapuerta et al [15] experimental results were obtained by testing two different alcohol-derived biodiesel fuels: methyl ester and ethyl ester, both obtained from waste cooking oil. These biodiesel fuels were tested pure and blended (30% and 70% biodiesel content, volume basis) with a diesel reference fuel, which was tested too, in a 2.2 l, common-rail injection diesel engine. The operation modes were selected to simulate the European Driving Cycle. Pure biodiesel fuels, compared to the reference fuel, resulted in a slight increase in fuel consumption, in very slight differences in NOx emissions, and in sharp reductions in total hydrocarbon emissions, smoke opacity and particle emissions (both in mass and number), despite the increasing volatile organic fraction of the particulate matter. The type of alcohol used in the production process was found to have a significant effect on the total hydrocarbon emissions and on the particulate matter composition. As the alcohol used was more volatile, both the hydrocarbon emissions and volatile organic fraction of the particulate matter were observed to increase. Pan and chiu [16] found that the addition of alcohol in a diesel–biodiesel mixture could enhance the burning rate, reduce the preheating delay, and mitigate pollution of soot particles as well as the tendency to form rigid layers. Furthermore, they found that the introduction of micro explosion through the mixing with alcohol of much higher volatility may lead to substantial disintegration and faster combustion of fuel droplets. Campos-Fernandez et al [17] concluded from their field trial that a diesel engine, without any modifications, can run successfully on a blend up to 30% butanol/70% diesel fuel or 25% pentanol/75% diesel fuel without externally apparent damage to the engine parts. Nevertheless, they recommend that its use as a substitute of straight diesel fuel, long-term durability tests are needed.

II. Mechanical Analysis

The following sets of equations where used for calculating the mechanical parameters for the engine performance [18, 19, and 20]:

$$T = F.L \quad [N.m] \tag{1}$$

Where T is the torque, F is the force, and L arm length of dynamometer. The brake horse power (B.P) can be found by:

$$B.P = \frac{F.N}{K_1}\ [kW] \tag{2}$$

So $K_1 = 43388.4$, and N is speed in rpm. The mass flow rate of fuel (mf) equal to:

$$m^0{}_f = \frac{V}{t} \times \rho \times \frac{3600}{1000} \quad [Kg\ /\ hr] \tag{3}$$

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Where V is the volume of fuel and t is time, and ρ is the density of fuel. The specific fuel consumption will be:

$$S.F.C = \frac{m^{\circ}_{f}}{B.P} \quad [Kg / kW.hr] \qquad (4)$$

And the thermal efficiency will be:

$$\eta_{th} = \frac{B.P \times 3600}{m^{\circ}_{f} \times cv} \qquad (5)$$

The air mass flow rate ma equal to:

$$m^{\circ}_{a} = 0.00001232 \times D^{2} \times \sqrt{\frac{P_a \times H_a}{T_a}} \times 3600 \; [Kg / hr] \qquad (6)$$

Where Pa and Ta is the atmospheric pressure and temperature respectively. The volume of air flows is;

$$V_a = 0.003536 \times D^2 \times \sqrt{\frac{T_a \times H}{P_a}} \quad Lit/sec \qquad (7)$$

While the volumetric efficiency ηvol will be:

$$\eta_{vol} = 83.74 \times \frac{V_a}{N} \times 100 \; \% \qquad (8)$$

$$F/A = \frac{m^{\circ}_{f}}{m^{\circ}_{a}} \qquad (9)$$

III. Experimental Set-up

Experiments were conducted using: 1000 rpm, 4 strokes, (1400 cc), 8 hp and 1 cylinder Lester P-8-1 Diesel engine, at the Power Plant Lab in the Faculty of Engineering Technology/Al-Balqa Applied University. The diesel engine was tested under different mixtures of diesohol. To compare the performance of the engine at variable percentages of ethanol and methanol, the mixtures of Diesohol was tested according to the experimental matrix shown in table 1.

Table 1: Experimental matrix (the percentages of the added Ethanol and methanol to the main diesel fuel)

Mixture	Percentages of the added alcohol by volume
1-diesohol (Diesel+ ethanol)	5, 10, 15, 20, 25
2-diesohol (Diesel+ methanol)	5, 10, 15, 20, 25

An overview has been given in this work for the blend of diesohol to evaluate the performance of the engine at the variable percentages of ethanol and methanol and at different operational conditions (i.e. speed). The experimental investigations were conducted using the experimental matrix listed in table 1. The effects of various mixtures and their percentages on the operational functions and parameters (i.e. torque, thermal efficiency, volumetric efficiency, and S.F.C) are also reviewed in a view to improve operational effectiveness and enhance engine performance.

IV. Results and Discussion

From the experimental results the following observations have been found; Figures 1 to 8 shows the experimental results of a pure Diesel and Diesohol mixtures (Ethanol and Methanol– Diesel) of 5 % to 25 % by volume tested at variable speed engine between 1000 to 1500 rpm. All operating functions, Torque, Specific fuel consumption, thermal efficiency and volumetric efficiency are investigated. Most diesohol mixtures (Figures 1 and 5) gave higher torque compared with the pure Diesel over the lower range of running speeds (less than 1200). The results showed that the torque of pure diesel is lower than most of diesohol mixtures for low speeds up to 1300 rpm while the pure diesel is higher for speeds more than 1200 rpm, because the mixtures of the alternative fuel with diesel gave higher start up than pure diesel while at higher speeds the stability of diesel gave higher torque than diesohol mixtures. Also it was noticed that the highest torque occurred at E5 (5% Ethanol and 95% Diesel), followed by E10 and E15 (Figure 1) While for methanol and diesel mixture the highest torque at low speed was for M5 then followed by M10 (Figure 5). Figure 5 shows the specific fuel consumption for both pure Diesel and Diesohol mixtures (Diesel and Ethanol) for variable running speed. The results showed significant variations between the different diesohol mixtures and pure diesel. The pure diesel result showed higher values than diesohol mixtures for all speed ranges, this due to the homogenous viscosity of pure diesel compared to diesohol. For the diesohol mixtures the better results of SFC was noticed at higher percentages of (E25) and (M25) (Figures 2 and 6). For the Ethanol-Diesel and Methanol-Diesel mixtures the best thermal efficiency was noticed at higher percentage of 25 % (Figures 3 and 7) In the operational parameter (such as thermal efficiency) it was found that the Diesohol mixtures showed much higher thermal efficiency than pure Diesel. This attributed to the higher calorific values (high Cetan number) of the mixtures compared with pure diesel. The best results were found at mixtures percentages between 25 % to 20 %, having an increase of the thermal efficiency of about 55 % compared to pure Diesel, Figures 5 and 8 shows the volumetric efficiency for both pure Diesel and Diesohol mixtures for variable speeds. The results show no significant difference between the different Diesohol mixtures with better results for pure diesel which attributed to the homogeneity of fuel, and the viscosity stabilization. While for the Diesohol mixtures the low viscosity and the nonhomogenity of the fuel contributed to the lower volumetric efficiency.

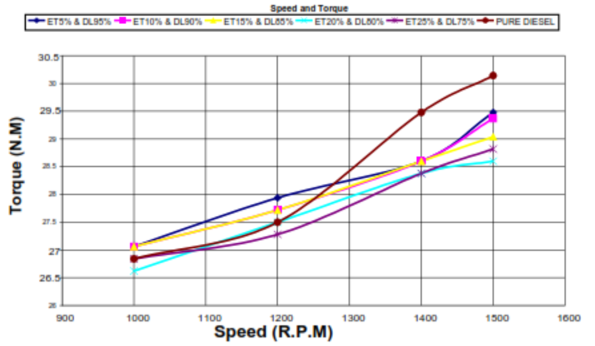

Fig.1. Torque versus engine speed using various Ethanol-Diesel blends

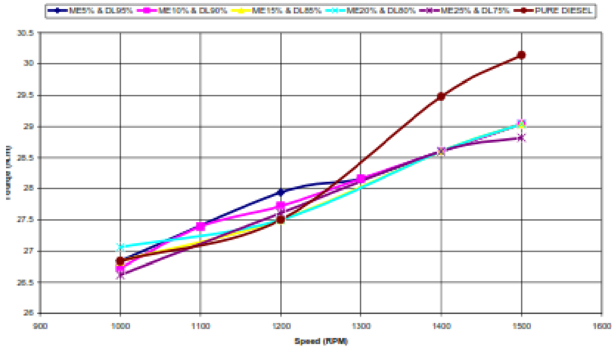

Fig.5. Torque versus engine speed using various Methanol-Diesel blends.

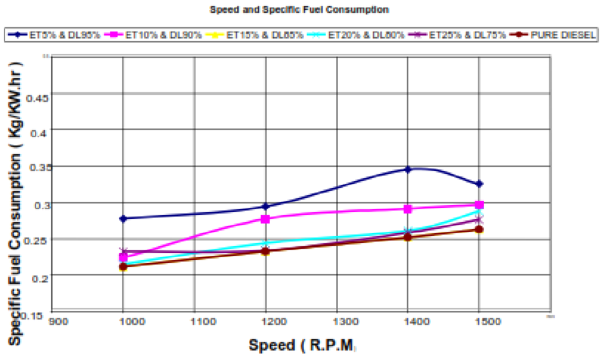

Fig.2. Specific fuel consumption versus engine speed

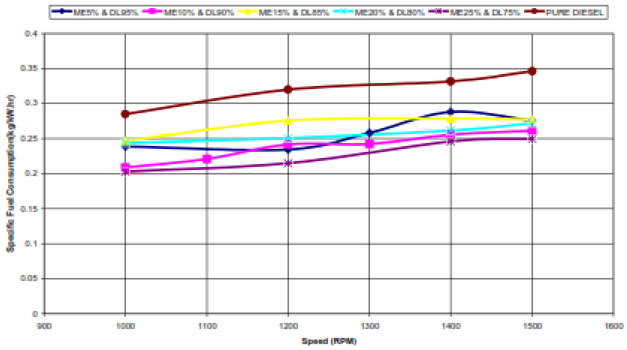

Fig.6. Specific fuel consumption versus engine speed using various Methanol-Diesel blends.

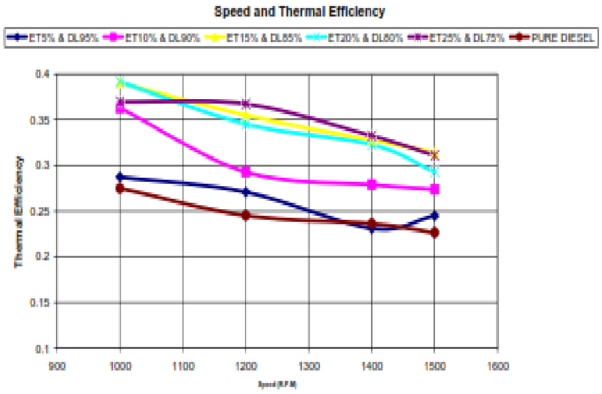

Fig.3. Thermal Efficiency versus engine speed using

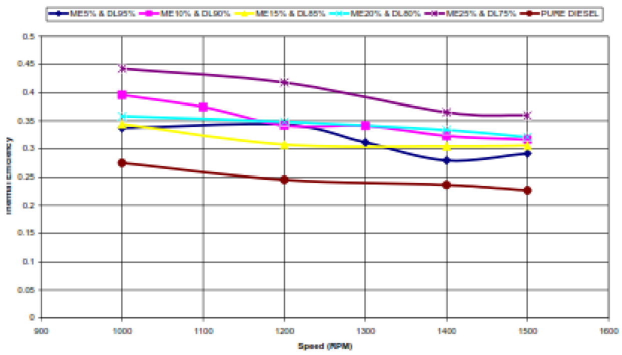

Fig.7. Thermal Efficiency versus engine speed using various Methanol-Diesel blends.

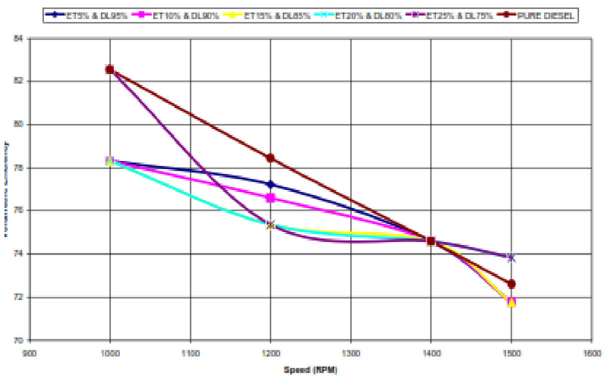

Fig.4. Volumetric efficiency versus engine speed

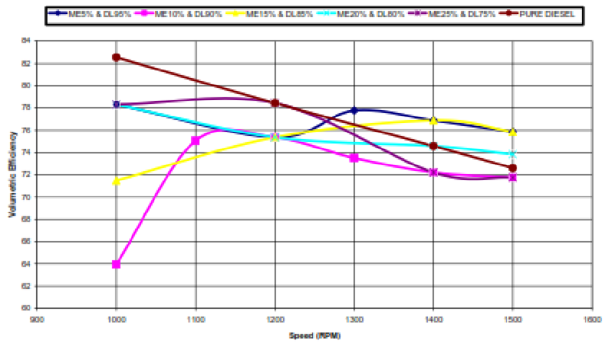

Fig.8. Volumetric efficiency versus engine speed using various Methanol-Diesel blends.

V. CONCLUSIONS

The experimental result obtained from the tests at different operating conditions and under different engine speeds gives the following concluding remarks:

Most diesohol mixtures gave higher torque compared with the pure Diesel over the lower range of running speeds (less than 1200). It was found also that the diesohol mixtures showed higher thermal efficiency than pure Diesel. This attributed to the higher calorific values (high Cetan number) of the mixtures compared with pure diesel. The best results were found at diesohol percentages between 25 % to 20 %, having an increase of the thermal efficiency of about 55 % compared to pure Diesel. The specific fuel consumption results showed significant variations between the different Diesohol mixtures and pure diesel. The pure diesel result showed higher values than diesohol mixtures for all speed ranges, this due to the homogenous viscosity of pure diesel compared to diesohol. For the diesohol mixtures the better results of SFC was noticed at higher percentages of (E25) and (M25). The volumetric efficiency results showed no significant difference between the Diesohol mixtures, with better results for pure diesel, this attributed to the homogeneity of diesel fuel, and its viscosity stabilization.

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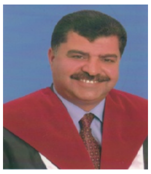

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