ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

Energy Analyses of Diesel Engine Fuelled with 5% Butanol and 95% Diesel

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Abstract:

This study on the energy analysis of diesel engine that is fueled with alcohol-diesel blend. 5% butanol were used with 95% traditional diesel to achive this study. A blending (D95B5) is perfomed at different engine loads and different speeds. Brake specific fuel consumption, input energy, energy losses throught exhaust gases and cooling water is calculated for the traditional diesel and the (D95B5) blend. It was found that the brake specific fuel consumption increasing with using (D95B5) compared with traditional diesel (D100). Moreover, the blend (D95B5) gave high brake specific fuel consumption compared to the pure diesel (D100). The results also indicates that energy losess throught exhaust gases increases with fuelled the engine by he butanol-diesel compared with that of the pure diesel. Moreover, highest brake specific fuel consumption and energy losess throught exhaust gases of the he butanol-diesel is higher than that of the pure diesel (D100). The outcomes of the energy analysis have shown that he butanol-diesel can offer a competitive alternative instead of diesel fuel in diesel engines.

Keywords: Energy; Butanol; Consumption; Tranditional Diesel.

1. Introduction

Everyone is aware of the tremendous industrial development that the world has witnessed in the recent period, which led to an increase in the demand for fossil fuels, and because of global fears of its depletion, as well as the increase in the strictness of laws to reduce pollution globally, so attention was directed to finding alternatives to this fossil fuels. Alcohols which can be produced from plants and animal waste Açikkalp et al.[1]. Butanol is a mong alternative that use in internal combustion engines instead of diesel fuel because its properties closest to that of the diesel fuel.. Most of this alcohol type extract easily from many fossil and renewable sources including agricultural biomass products natural gas and coal [2]. Most previous studies dealing with adding various types of alcohol to gasoline in the spark ignition engines Nazzal et al.[3], Nazzal et al. [4]. Nevertheless, some studies has been dealt with effect of alcohol-diesel blends on performance and emissions of the diesel engines. Adding the alcohol to the diesel was investigated by Zhu et al.[5], Golmohammad et al.[6], Chaichan et al.[7] and Dube et al.[8]. They refer to there reduction in the emissions with using butanol-diesel blend insead of pure diesel. They found that CO_2 and UHC emssions decreased with using alcohol- diesel blends. They also found that the brake specific fuel consumption increased with using diesel-alcohol blends instead of pure diesel due to the decrease in the heating value of the butanol-fuel blends. They concluded that these blend of butanol-diesel can be used in stead of pure diesel in internal combustion engines because of the brake power is clost for both pure diesel and alcohol- diesel blends. Adding ethanol to the diesel with 5% volume were studied by Calam et al.[9] Their results revealed that, brake specific fuel consumption, maximum combustion temperature and heat release increase with using alcohol-diesel blends instead of diesel. Sarıkoç et al.[10] studied using blends of Ethanol-Diesel in the diesel engine. They found that the emisions decrease with using butanol- diesel and the brake thermal efficiency increased. Jamrozik et al.[11] investigated influence of adding Ethanol to the diesel engine on the emissions and combustion performance. They indicated that the specific fuel consumption increased with using ethanol-diesel blend instead of pure diesel. Panigrahi et al.[12] conducted that the biodiesel gave the highest value of the brake specific fuel consumption while pure diesel gave lowest values. Bahar et al.[13] introduced an investigation on a four-stroke single-cylinder diesel engine fuelled with various of blends involving 92% diesel- 5% bioethanol, the mixture consisting of 85% diesel and 5% bioethanol, 80% diesel- 15% biofuel- 5% bioethanol, 75% diesel- 20%

biofuel - 5 % bioethanol, and of pure diesel. She found that adding these types of alcohol to the diesel instead of traditional diesel cause to increase in the brake specific fuel consumption and brake thermal efficiency. Lei et al.[5] studied Emissions of a diesel engine operating on diesel and and diesel blended with ethanol. They found that the emissions reduced with adding methanol and ethanol to diesel compared with pure diesel. Moreover, they concuded that the 5% perctange of biodeseil is the best in terms of the eimmisions reducing.

Finding of previous studies on butanol-diesel Blend showed that adding alcohol to traditional diesel are attractive alternative fuels for the diesel engines. Moreover, it has indicated that alcohol- diesel blends has major affects the on the reducing UHC and CO emissions.. By taking advantages the properties of the various types alcohol-diesel blends, one can be expected the best type of the alcohol-diesel couild be selected with optimum percentage blends in diesel engines. Thus, energy analysis fuelled with butanol-diesel blend should be considered in a comprehensive study. In this work butanol-diesel were selected for energy analysis of diesel engines at different engine loads. In this manner, it can be observed the the diffrenec in energy distrubition. Therefore, this work aims to introduce an investiagtion of the influence of butanol-diesel and pure diesel, on the energy distribution in the diesel engine.

1. Description of Test Fuels and of the Experimental Installation

In the paper, a comparative investiagtion for butanol-diesel D95B5, under energy analysis was introduced. All used blend were prepared at same conditions. The butanol-diesel blend D95B5 consist of (5 vol.% butanol - 95 vol.% diesel). this type of the fuel blend separately were feulled into a test engine. The properites of the all the blend were obtained from laboratories ministry of oil, as shown in Table 1.

Table (1) the properties of fuel samples.

Property	D100	D95B5
Calorific value (MJ)	45.88	44.49
Sulphur content (%wt)	0.7506	0.7032
Cetane index.	52	49.5
K.Viscosity @ 40 ºC (Cst)	1.98	1.85
Density at 15 ºC (gmm/cc)	0.8164	0.8143
Aniline point (ºC)	68.5	65.6
A.P.I	41.9	42.3

To achieve this study a single-cylinder, four-stroke, diesel engine was used. The specification of the engine as shown in Table 2. The used engine was arrangment with generator to measure the engine load. To assess the performance of the engine, an instrumentation was set with the test engine. The air mass flow of the engine was measured using the consumption box viscous flow meter.

Table (2) the specification of the test engine.

Parameter	Size and feature
Engine Type	Field Marshall، Model FM-II، 1 cylinder، 4 stroke، compression ignition، Diesel fuel، Water cooled engine
Bore	114.3 mm
Stroke	139.7 mm
Engine capacity	1432 cc
Compression ratio	17
Rated power	5.9 kw at 850 rpm
Dynamometer	AC generator
Power transmission	v-belt
Air flow measuring	Air box MS fabricated with orifice meter and manometer (orifice dia. 35 mm)
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type pipe in pipe
Temp. sensor	PT100 and thermocouple،Type RTD
Fuel flow measuring	Glass fuel metering
Rotameter	Calorimeter 25-250 LPH،Engine cooling 100-1000 LPH

Stopwatch and calibrated glass tube was used to measure the fuel's mass flow rate. The mas fuel rate was estimated by calculating the time taken to consume fixed volumes into the engine. thermocouples of type K are utilized to measure the temperatures of the exhaust gas which were set at the ehxahust system. Figure (1) shows the schematics for the experimental set-up.

The engine load was adjusted for each test of the fuels blends with ranges from 10% to 60% and a 10% increase. Firstly, the research engine was perfomred with the pure diesel. The entire test was carried out under the same condition for fuel blends. Afterwards all engine tests for the alcohol-diesel fuel were completed at the same conditions. Before, it begins to the any test of the new blend, the engine runs for enough time in order to consume all the left fuel from the previous fuel. Similar measurements of experimental data were carried out for other blends of fuels. Moreover, in order to achieve the accuracy of the reading data of test, it was waiting until reaching the stabilizing of the operating conditions before the data were recorded. These reading parameters involved the temperature of the exhaust gas and envoroment, pressure drop, and the time required to consume constant qunantity of fuel.

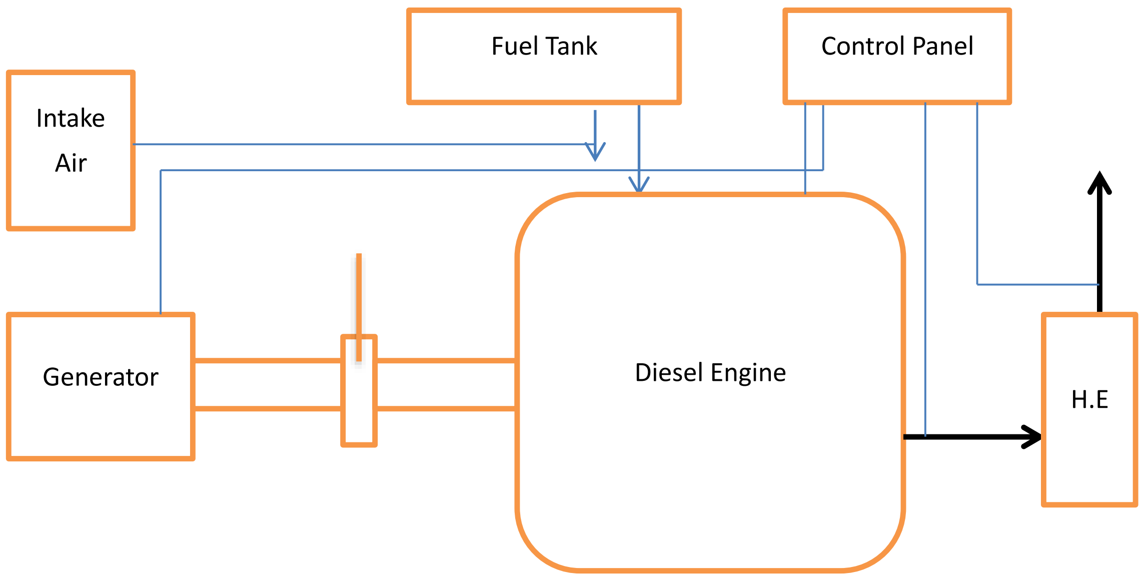

Figure (1) Schematic diagram of the experimental setup.

2. Energy analysis of the engine

The energy analysis provides insight into how the energy distribution within the system will be occured. The input energy into engine converts into useful energy (brake power) and energy losses throught cooling water and exhaust gase. Howerver, The analysis of these energies based on the first law of thermodynamics. Figure depicts engine balance for the used engie which is plotted in order to simplify and understand the mathematical model. However, there area important hypotheses which assumed to simplify the theoretical as follows:

1- The exhaust gases and fuel mixtures a have negligible potential and kinetic energy[14].

2- The combustion is completely burnt and the exhaust gases leave the engine at pressure Pp and temperature Tp.

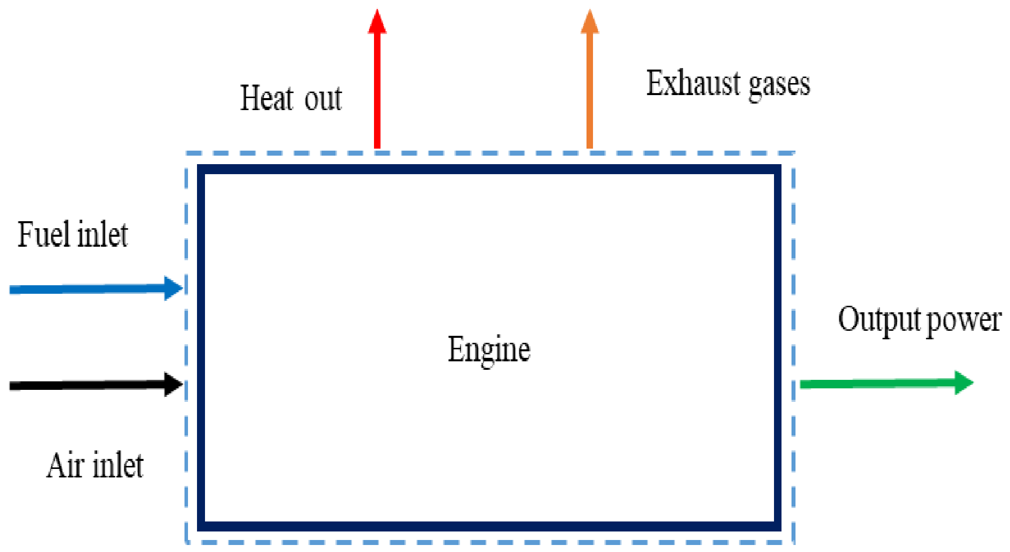

Figure 2 Schematic of the engine test.

The energy balance is estimated as[15]:

$$\sum \dot{Q}_{in} = \sum \dot{Q}_{out} \tag{1}$$

where $\dot{Q}_{in}$ and $\dot{Q}_{out}$ are the rate of energy for both the inlet and outlet respectively. While the energy balance of the engine was calculated as follows[16]:

$$\dot{Q} = \dot{E}_{fuel} - (\dot{W} + \dot{Q}_{exh}) \tag{2}$$

where $\dot{Q}$ and $\dot{W}$ are the rate of energy and work respectively while h_{out} and h_{in} are outlet and inlet specific enthalpy rate. The brake power was calculated based on the angular velocity and the torque (*T*) of the engine as[17]:

$$\dot{W} = T.\omega \tag{3}$$

lowering heating value of fuel (LHV) and the rate of fuel mass flow are utilized to calculated fule energy as follows[18]:

$$\dot{Q}_{in} = \dot{m}_{fuel} * LHV \tag{4}$$

Energy loss ($\dot{Q}_{loss}$) through cooling water to the surroundings is estimated as follows[19]:

$$Q_{cool} = \dot{m}_w \times C_{p,w}(T_{w,o} \quad T_{w,i}) \tag{5}$$

While the energy losses throught exhaust energy ($\dot{Q}_{exh}$) is estiamted as follows [20]:

$$Q_{exh} = \dot{m}_{exh} \times C_{p,exh} \times (T_{exh} \quad T_o) \tag{6}$$

While the brake specifc fuel comsumption (BSFC) is estiamted as follows[21]:

$$BSFC = \frac{\dot{m}_{fuel}}{Q_{BP}} \tag{11}$$

3. Results and Discussion

Energy balance was applied on the control volume of the diesel system. The analysis is based on the first law of thermodynamics. The fuel energy is input energy while brake power is the output of the useful energy. Moreover, there are energies lost throught exhuats gases and water cooling and unaccounted losses energies. The analyses were calculated for all the blend types of the fuel. All the obtained results were represented in terms of diesel and diesel-alcohol volume percentage at different engine loads. As shown in the Table 1, the lower heating value and cetane number of all the blends of diesel- alcohol are lower than that of diesel. Adding ethanol to the diesel led to an decrease in heating value and cetane number of the blend because of the lower heating value of the alcohol are lower than that of the diesel fuel. The cetane number and lower heating value influenced on the enrgy distribution in the engine especially the fuel energy.

Figure 3 shows fuel energiy of D95B5 blend and pure diesel versus engine load. As can be seen in this Figure, the fuel energy increase with increase in engine load increase for all the diesel fuel and ethanol-diesel fuel. The figure also indicates the highest fuel energy value for diesel fuel while the lowest value of the fuel enegy found for the D95B5. Moreover, to understand this behaviour, the implementation of a comparison between used the properties of used fuel which was diesel and D95B5 blend is necessary first. As can be seen in the Table, the cetane number and heating value of the pure diesel are higher than that of all the fuel blends, consequently, the the diesel has highest value of the input energy compare with other types of fuel blends. In addition, the D95B5 has lowest value of the heating value compare with other types of fuel blends, thus the input energy of the D95B5 is lowest compare with traditional diesel. Here engine load of 60% was selected as an example for comparison in terms of fuel type. It can be noticed that the fuel energy of D95B5 blends is lower that diesel fuel as 2.6 % at load (60%).

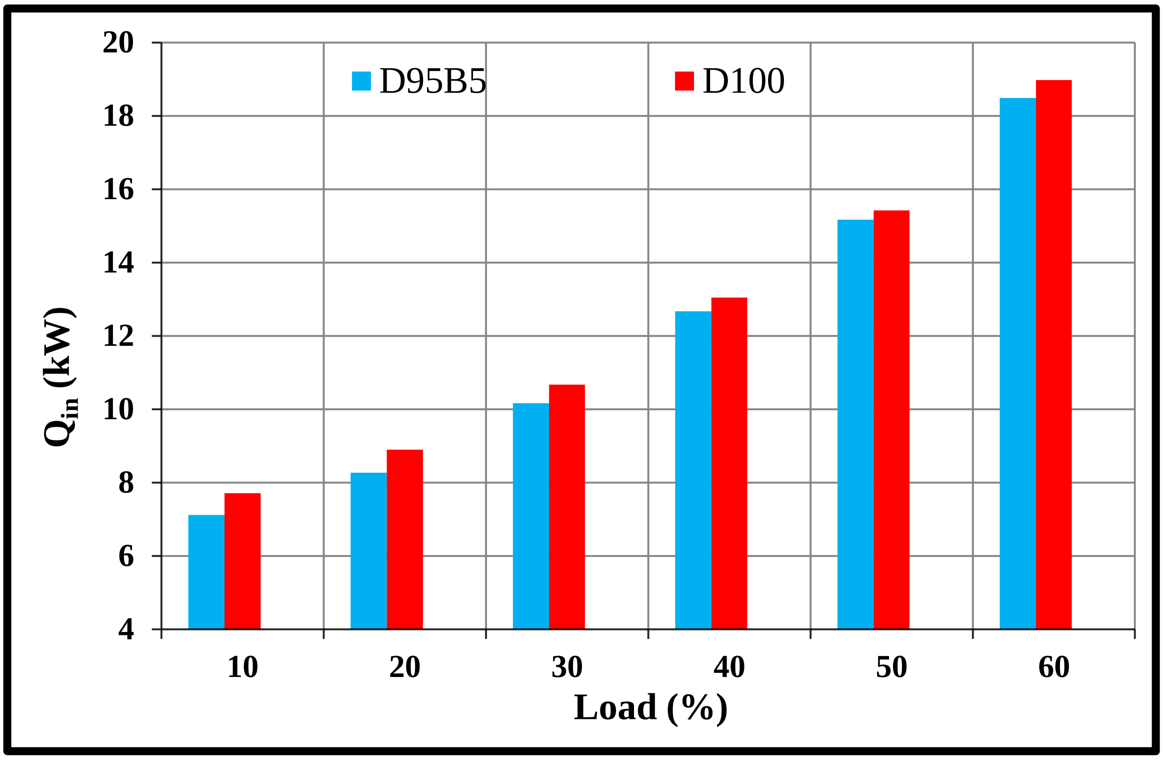

Figure (3) the variation of the fuel energy with an engine load for diesel and butanol-diesel blend.

Figure(4) depicts the brake specific fuel consumption for the D95B5 blend and D100 at different engine loads. As can be shown that, as engine load increased, the brake specific fuel consumption decreased before reaches minmum value and then it increases with increase in the engine load for each fuel types. In the comparison examination of the fuel-butanol blends, the D95B5 blend prrovides the highest brake specific fuel consumption while the lowest brake specific fuel consumption was obtained for that of the D100 fuel. This trends can be ascribed to decrease in the cetane numberand lowering heating value the alcohol was adding to the diesel [10]. It can be noticed from the ther Table 1, the D95B5 blend has lowest lowering heating value and D100 has highest lowering heating value. This trend is consistent with results of the previous studies such as[22].

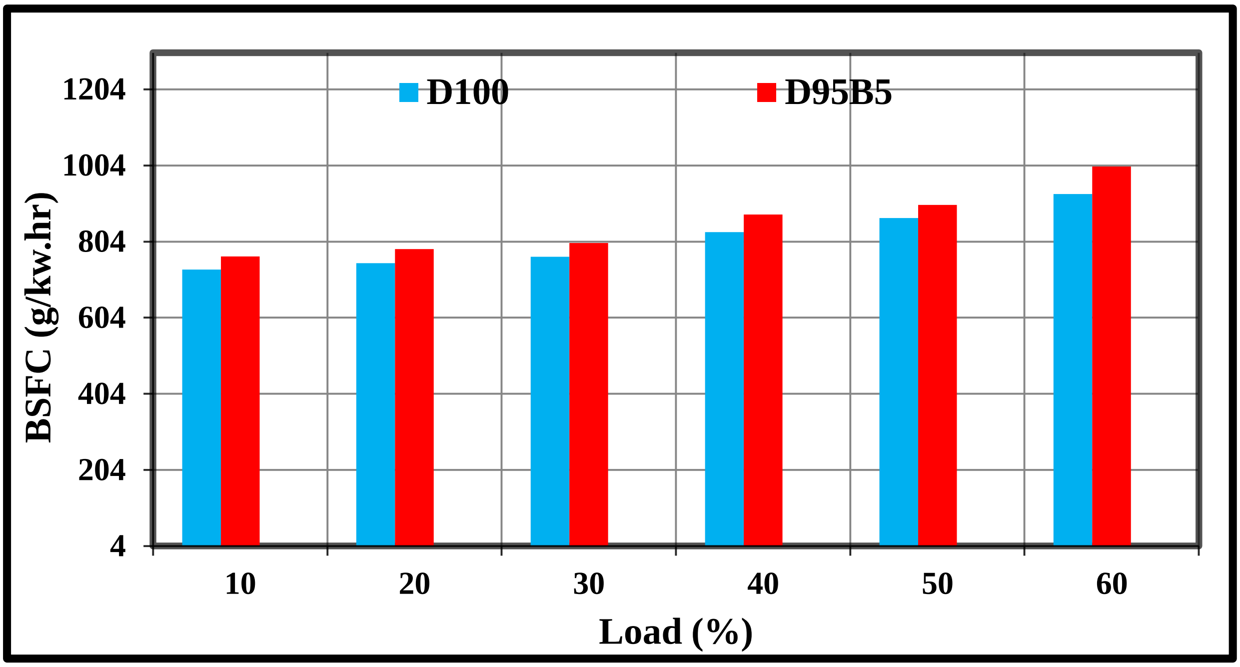

Figure (4) the variation of the brake specific fuel comsumption with an engine load for diesel and butanol -diesel blend.

Portion of the fuel energy is lost to the surroundings into exhaust gases is. The quantity of exhaust exergy is based on temperature and mass flow rate of exhaust gases. It can be noticed from the Figure 5, as the engine load increases, the energy lost throught exhaust gas increases for each types of fuel, as shown in Figure 5 . It can be also seen the highest exhaust gas energy values at high engine loads. Explanation of this trend can be attributed to an increase in temperature of combustion consquently an increase in exhaust gas energy [23]. Figure 4 also shows the part of energy transfer of exhaust through exhaust gases of D95B5 blend is higher than that of the D100. For example, at an engine load of 60%, the exhaust energy rate of D95B5 blend is higher than that of the D100 as 9.2% respectively. This behavior can be attributed to the fact, which was previously mentioned as adding alcohol to the diesel, the heating value and cetane number of the blend decrease compare with pure diesel. This trend was similar to the previous results of many studies such as[24].

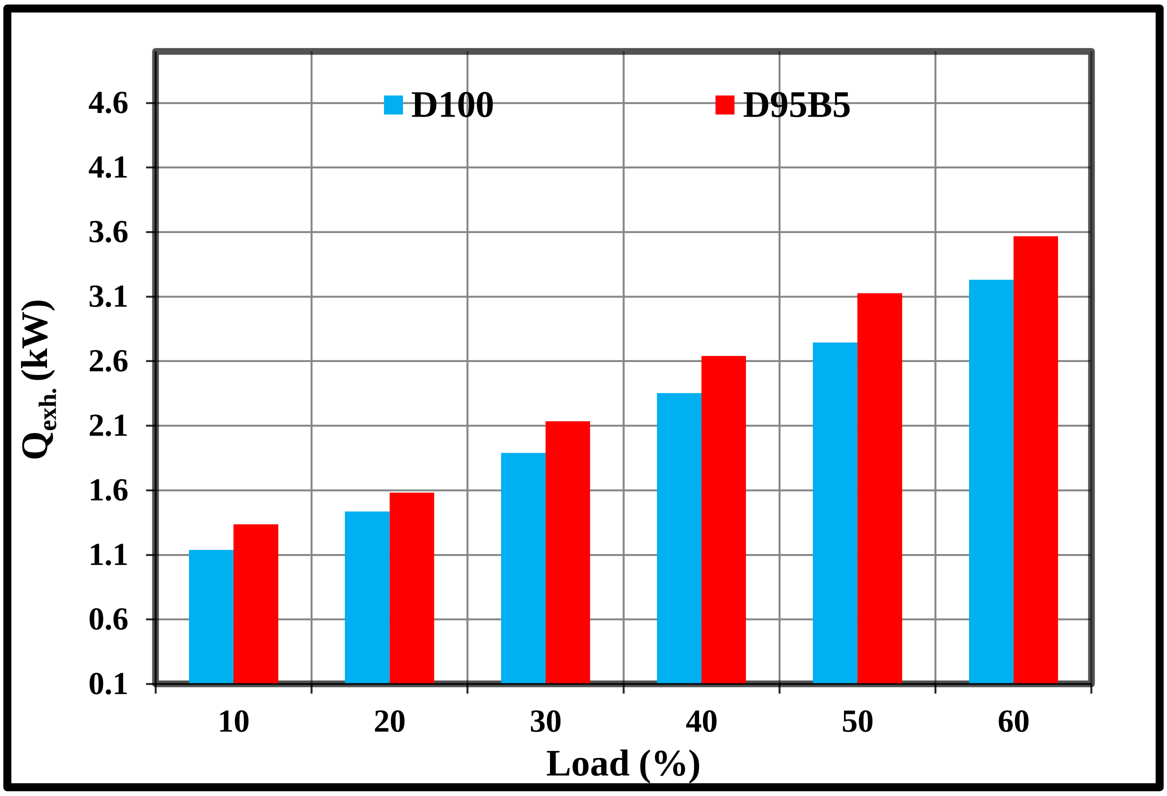

Figure (5) the variation of the energy rate through exhaust gases with an engine load for fuel of D100 and D95B5 blend.

portion of energy rejects to the environment through heat transfer which is based on several factors such as enthalpy change, combustion products and molar fraction of inlet fuel. Moreover, the energy of heat transfer is strongly affected by fuel type and engine load as shown in Figure 6. It can be seen from the Figure 6, the rate of energy losses to enviroment increases as engine load increase. This trend can be attributed to that fact as the engine load increases, the energy input flows into engine increases, i.e., energy losses throught cooling. In terms of the fuel type, it can be noted the highest energy rate of heat transfer losses with using diesel while the lowest value was noticed with using D95B5 blend at the same condition. For 60% engine load, the energy losses through cooling of diesel fuel are higher than that of D95B5, as 7.4%. As mentioned earlier, this trend is attributed to the fact that energy released by heat transfer increased with an increase in alcohol content in the diesel because of the decrease in heating value and cetane number of the diesel-alcohol blends compared to diesel, i.e., increase in combustion temperature. Moreover, due to increase in the temperature of exhaust gases for the alcohoh-diesel blends compare with pure diesel. This trend is consistent with results of the previous studies such as[10].

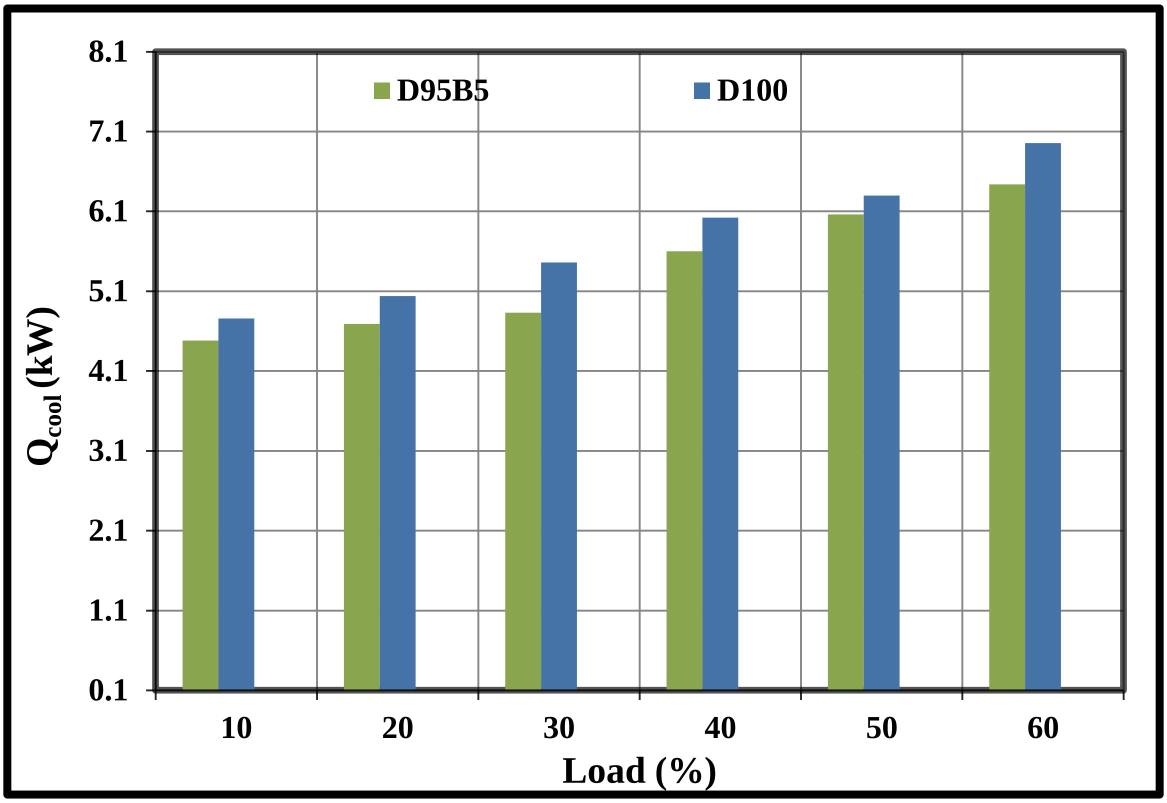

Figure (6) the variation of the energy rate through cooling water with an engine load for fuel blends of D100 and D95B5.

4. Conclusion

In this study, the energy analysis of compression ignition engine that was fueled with an butanol-diesel blend. The analyses were carried by calculating the brake power input energy, energy losses through exhaust gases and energy losses through a cooling.

The findings results indicated that engine load has a major affect on fuel energy, exergy loss throught to exhaust gas exergy and cooling fluid. It was found that as the engine load increases, the input energy increase for diesel and butanol-diesel blend. Similar trends were observed for the energy losses through exhaust gases and cooling fluid. It was also found that the adding butanol to diesel gave the highest value of brake specific fuel consumption compare with diesel fuel. The energy losses through a heat transfer and input fuel have the highest values when the engine was fueled with pure diesel compared with that of the butanol-diesel blend. While the lowest values of the energy losses through a heat transfer and input fuel were found for the butanol-diesel blend. In contrast, the butanol-diesel blend has provided the energy losses through exhaust gases compared with that of the pure diesel. These behavior due to the decrease in heating value and cetane number when the engine fuelled with butanol-diesel blend instead of diesel. The obtained results provided insight into how the input energy and energy losses and its location for the blends of the diesel and butanol-diesel blend.

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