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

International Journal of Mechanical Engineering

Computation of Alcohol Exhaust Stream in a 1-D Engine Cylinder

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Abstract

The objectives of this article are to mimic engines running on alcohol as an additional energy source. To mimic running the vehicle using alcohol, a normal consumer engine application is developed. To design the complete combustion during a combustor, the fuel characteristics from some kind of standardized excel spreadsheet will indeed be utilized. To create the enormous ability among alcohol fuels versus conventional fuel oil, the machine simulation is performed at maximum engine loads. The diesel engine is taken which is having a single-cylinder and a one-dimensional simulation is performed. During the simulation, alcohol is used as the alternative fuel and with this simulation characteristics and performance of the engine are studied. The results obtained with this simulation are then compared with the data which is for the diesel engine. The observance makes it clear that, when we use ethanol for operating the diesel engine, it will be lower in efficiency and performance. For ethanol-operated engines and conventional diesel engines, these simulations are carried out by taking the conditions of full load. With the results, it can be said that for the ethanol-operated engine, there will be a reduction in brake torque and power of about 37.67% and 38.84% respectively as compared to the conventional diesel engine. This shows that now the ethanol-operated engine can compete with the standard engines and their production is also economic and favorable. At full load, the thermal efficiency of the engine gets reduced and the specific value of the fuel used is increased with the decrease in heating value.

Keywords: Diesel Engine, 1-D (single-dimensional), Ethanol, bio-diesel, combustion, hydrocarbons.

1. Introduction

Since the invention of internal combustion engine, air pollution from vehicles has been rising at a significant level, and this phenomenon has gotten worse, particularly after major commercial viability. The combustion of fossil fuels in car engines produces the majority of exhaust emissions [1]. Diesel is poisonous and has the potential to damage the marine ecosystem in the long run. Biofuels are those fuels which are already available as an optional fuel and they also have a good scope in future as a good replacement of diesel. Cottonseed, coconut oil, jatropha seed, Soybean, sunflower, waste cooking oil, corn, groundnut, safflower, rapeseed, sunflower, palm oil, tallow (animal fat), are all acceptable feedstocks. For producing biodiesel rapeseed is the largest producer in Europe while if we talk about US then soybean is used to derive biodiesel [2-4]. In the Asian countries having tropical environment, the majorly used and produced vegetable oil is palm oil. According to Bozbas, 2008, the production of biodiesel was around 1.8 billion liters [5-7]. In this production Germany emerged as the leader and France and Italy followed it. Also, there was the contribution of around 1.5 million tons by the European Union Countries. For the transport sector, the public is encouraged to make use of biodiesel as an alternative fuel by the European Union council and European Parliament. Worldwide around 21% of CO2 emmissions are specially accounted by the transportation sector [8-13] . According to Kreithand Goswami, 2007 approx 95% of energy comes from fossil fuels for the transportation sector.For the transport sector use of biodiesel will not only reduce emmission but also reduce the dependance on the energy sources which are imported and this will in turn results in secured energy supply and influenced market of fuel [14-16]. Also biodiesel is carbon neutral fuel so it is the main advantage of using biodiesel. During analysis(Mamat et al., 2008) found that if carbon cycle is includedit is observed that engines running on biodiesel produce more CO2 but they are responsible in less emmission of CO2 in the environment. As biodiesel and diesel have comparable properties so we can use biodiesel alone or by combining it with the conventional fossil fuels and this process can eb achieved without the need of any changes (Agarwal, 2007).

In order to find the emission impact and performance of biodiesel various researches have been conducted. According to (Demirbas, 2007), there will be around 75-90% decrease in polycyclic aromatic hydrocarbons(PAHs) and around 90% decrease in unburnt hydrocarbons with the combustion of biodiesel itself. By analysing the experiments which are conducted earlier on single cyclinder engine by using biodiesel and its blend with mineral diesel, it is observed that amount of Nox will be increased with the increase in proportion of biodiesel blend, increase in brake specific fuel consumption and value of smoke will gets reduced (Chuepeng at al., 2007). Many researchers (Bozbas, 2008,Mamat et al., 2009, Labeckas and Slavinskas, 2006) have reported that biodiesel is advantageous and it can also be the source of renewable energy which is also biodegradable, non toxic, sulphur free .Also , by blending standard diesel and fuel, the friction of cylinder will gets reduced and this will improve the lubricating property of the fuel as well (Nwafor, 2004). There are several properties of biodiesel which includes lower value of heating, flash end combustion points, viscosity, cloud and pour points, cetane number, density, distillation characteristics etc [17-21].

Rakopoulos et al., 2006 suggested that we can reduce the calorific value of fuel by mixing biodiesel with mineral diesel and this will also increase the fuel consumption. According to (Labeckas andSlavinskas, 2006) higher NOx levels can be produced along with the boost in temperature of combustion as the cetane number of Biodiesel and mineral diesel are almost similar but this will also affect ignition delay as the volatility of biodiesel is slightly higher [22-24]. In agricultural areas some purposes like water pumping are extensively used for single cylinder engine. This will become the effective and economic alternative as the fuel used is diesel and it will make use of single cylinder , which results in lower cost and milited consumption of fuel. Thus for rural areas , these engines become important auxiliary tool in agriculture. (Bayrakceken et al., 2007) suggested that these engines can also be used for driving purposes in some areas. Despite of excess in crude oil , alcohol gets the attention as the alternative fuel globally. Engines which are alcohol-fuelled are more viable when the world's crude oil suppliesstop meeting the consumption requirement. For a great many yearsengines that operate on pure alcohol are likely to become more viableas world's crude oil reserves fail to meet global demand. The countries where there is the shortage in supply of crude oil, must be ready with some alternative plans such as liquid fuels so that it will become easier to fulfil the demands in agricultural and transport sectors. The supply of diesel fuel must be expanded as it is becoming the main and significant concern.

As a result, the compression-ignition engines which are using ethanol has gotten a lot of attention, with a lot of emphasis on stiching the fuel to the engine's needs (Ajav et al., 2000). The researcher Hansen et al. (1989) used a heat release model to investigate the ethanol's combustion and ethanol blends with diesel fuel. They discovered that adding ethanol to diesel fuel resulted in increased ignition delay, higher premixed combustion rates, higher thermal performance, and lower exhaust smoke.Czerwinski (1994) contrasted the heat release curves of ethanol,rapeseed oil, and diesel fuel blend with those of diesel fuel. At all operating conditions, he noticed that adding ethanol triggered longer ignition lag. Considering full and higher loads, it is observed that the speed during combustion is higher when the phases include premixed solids. Ali et al. (1996) used 12 fuels made by mixing methyl soy ate,fuel ethanol and methyl tallow ate, and with diesel fuel in a Cummins N 14-410 engine. This addition of fuel blends and ethanol will not show any effect on ignition delay. If the diesel content of fuel gets reduced then the charge temperature also gets decreased, according to the reports. In table 1 (Chen et al., 2008), typical fuel properties for ethanol, diesel, and ester are shown. These properties includes oxygen content, boiling point, heating value, cloud point, flash point, viscosity, carbon, cetane number, hydrogen etc.

Table 1: (Rakopoulos et al., 2007)Characteristic Table of Both Fuels Diesel and Ethanol

Fuel properties	Diesel Fuel	Alcohol
Density	838	785
Cetane number	51	6-9
Kinematic viscosity	2.8	1.3
Surface tension	0.024	0.016
Lower calorific value	44	27.8
Specific heat capacity	1851	2200
Boiling point	190-350	79
Oxygen	0	35.8
Latent heat of evaporation	255	841
Bulk modulus of elasticity	17000	13201
Stoichiometric air-fuel ratio	16.0	10
Molecular weight	171	47

MODEL SETUP:

Variable geometry turbocharger system (VGT) intake system, exhaust system, compressor, valve train, exhaust gas recirculation systems, common rail fuel injection systems,engine cylinders, and exhaust gas recirculation systemsare all included in a one-dimensional (1D) simulation of an engine model. This paper describes the advancement of single cylinder modelling in 1-D simulation by taking diesel engine which is direct-injection (DI)type and consists of 4-strokes.Table 2 contains the specifications of the engine which is used in this model. Figure 1 displays the GT-POWER programme used to model a diesel engine. The intake system in the chosen diesel engine has a variety of components, sizes, and details. The machine was started from the outside in and worked its way up to the intake valve. In the model of GT-POWER, all of the intake system components are intrunner air filter, atmosphere, in runner, import, and intvalve. In order to fill the form consisting all the data and run the model, the components in this framework need a few pieces of information.

Engine cylinder and fuel injection system output is based on diesel fuel from the fresh air intake system, fuel injection system, and exhaust gas to the exhaust system. The elements, dimensions, and data must all be recorded and entered into the GT-POWER form. Cylinder, engine and Injector are all components included in the system of fuel injection and engine cylinder. The diesel engine's exhaust system is the final system. The system began with an exhaust valve and ended with a finish in the setting. Exhvalve, exhport, exhumer, muffler, exhumer exit, and atmosphere are some of the parts which are contained in the exhaust systemof GT-POWER.

Table 2: Table Showing single cylinder diesel engine parameters

NO	Description	Value
1	Fuel	Diesel
2	Engine Type	Single cylinder
3	Displacement	405.6cc
4	Piston pin offset	1mm
5	Number of cylinder	1
6	Bore	87.0mm
7	Stroke	71mm
8	Connecting Rod length	119.1mm
9	Compression Ratio	18.3
10	Maximum Intake valve open	8.09mm
11	Maximum exhaust valve open	8.09mm
12	Intake duration	250 CAD
13	Exhaust duration	290CAD

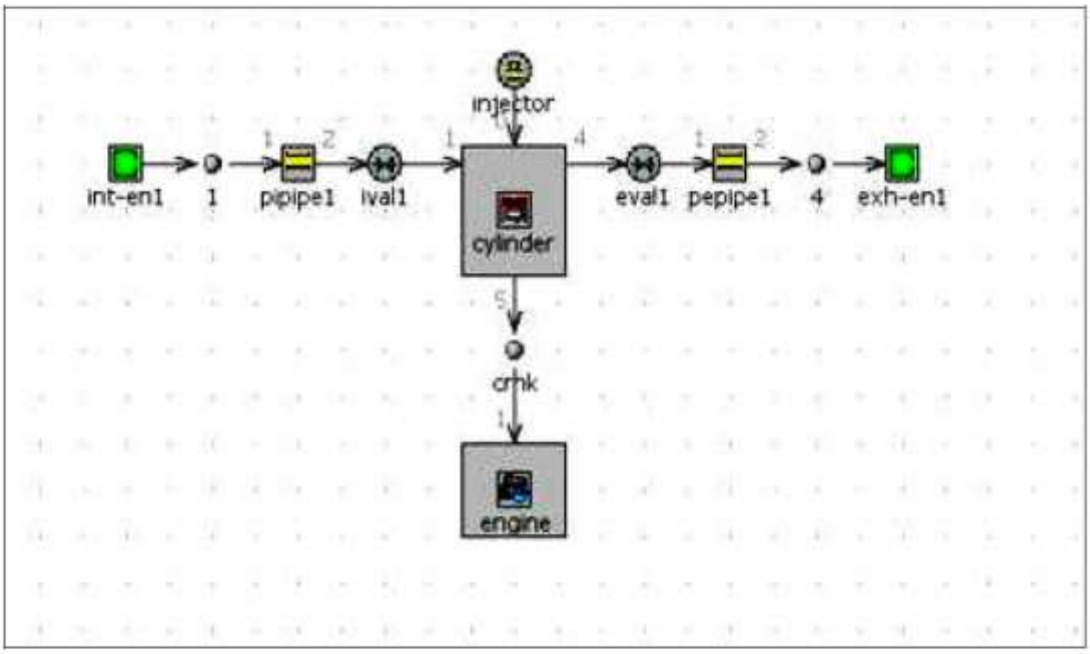

Figure 1: Figure Showing GT POWER Model of Diesel Engine with single-cylinder

During modelling of diesel engine , the GT-power compuattional model is used and it consists of engine cylinder, exhaust system model, intake system model and fuel injection system model. The engine cylinder,fuel injection system and the intake system are connected with the orrifice connection. Figure 1 shows that by using GT-Power software we can develop the model for the diesel engine and the data provided above plays an important role during build up of engine model. Its library will consist all the information which is required during model build up in GT-power. Sometimes more information is needed apart from that what is provided in the library and for some models all the items listed are not required.The simulation can be used to determine optimal values for some of the items described if the model is being designed at an early design point. If this is the case, those specific attributes should be specified as parameters and run through a series of scenarios to find the best value. Inline or V configuration, Compression ratio, V-angle (optional), 2 or 4 stroke, firing order, are all necessary engine characteristics. Piston area, pin offset, stroke, head bowl geometry, piston TDC clearance height, connecting rod length, pin offset, head area, piston area, and Boreare all necessary in cylinder geometry. Geometry of all components is needed in the intake and exhaust systems. Throttle position and discharge coefficients versus throttle angle in both flow directions are the data in throttles. The piston , the number of holes in the nozzle, and nozzle diameter of nozzle, the injection rate, the LHV, the fuel type, and number of injectors, are all stored in fuel injectors.Diameter of lift profile for valve ,valve lash and discharge coefficient, are data in intake and exhaust valves. Pressure, temperature, and humidity are the variables in the ambient environment. When tuning a model after it has been designed, performance data can be extremely useful. Prior to running the model simulation, it was important to prepare. The complete model is then reviewed and plot requests, run setup, plot setup , case setup and run setup are included in this . All these parameters are itself specified in setup and during the first case of simulation , each one is described. In steady state simulations, computation time is usually reduced by preparing the order of simulations and using the initialization state in running setup. There are plot options available within each folder and when we chose one plot which is appropriate then it will request for time and/or cycle plots. In this all plots requested individually will automatically be saved irrespective of the fact that whether the user is interested in using the plot setup.If a simulation model has been developed, the GT-POWER simulation can be launched, and the simulation will begin to run. A window will show the simulation's progress as scrolling text. We can start the simulations when the input data has been readed carefully and the progress reports of the simulations can also be generated.

Engine Performance Parameters

Some parameters are there which are usually considered in order to characterize the operation of engine. The fuel, air, combustion, emission, efficiency etc required at the input, some output parameters like torque, power, work etc; are some mechanical parameters included along with the measurement of emission from the exhaust (Heywood, 1988, Pulkrabek, 2004).

Volumetric Efficiency: For measuring the effectiveness of four stroke cycle , its volumetric efficiency is used. Exhaust system and its intake are taken as the devices for the pumping of air. Equation 1 (Pulkrabek, 2004)expresses the volumetric efficiency-

$$\eta_v = \frac{\dot{m}_a}{\rho_a V_{disp} N/2}$$

Where,

$\dot{m}_a$= flow of air into engine at steady state

V_{disp}= displacement volume

ρ_a = density of inlet air (1)

Brake Engine Torque: The ability of engine to perform is indicated by the torque and it is basically the force which acts on the moment distance. Its unit is lbf-ft or N-m.Pulkrabek (2004) gives the expression which says about the relation between Torque (τ) and work.

$$2\Pi\, \iota = Wb = (bmep)\, V_d/n \quad (2)$$

where Vd= displacement volume

n denotes per cycle revolutions

Wb = brake work of one revolution

The expression given below is for the engine having 4-strokes and which takes 2 revolutions for each cycle-

$$\iota = (bmep)V_d/4\Pi \quad (3)$$

Brake Power: The rate at which the engine performs the work is termed by the Power. Brake power is expressed in equation (4) where N denotes the speed of engine , N denotes the number of revolutions per cycle.

$$\dot{W} = WN/n$$

$$\dot{W} = 2\,\Pi N\zeta$$

$\dot{W} = \left(1/_{2n}\right)(mep)A_p\bar{U}p$

$\dot{W} = \left(1/_{2n}\right)(mep)A_p\bar{U}p / 4$ (4)

where

U p = average speed of piston

W = work per cycle

Ap = face area of all pistons

Brake Thermal Efficiency: wecan define the brake thermal efficiency as the ratio of brake power (bp)to fuel energy at input in appropriate units (Ganesan, 2003) and it is denoted byη_{bth}. Expression of thermal efficiency is given below-

$$\eta_{bth} = \frac{bp}{mass\ of\ fuels \times calorific\ value\ of\ fuels} \quad (5)$$

Brake Mean Effective Pressure: This is the parameter which is taken to compare engines in respect of design, output etc as it does not depend on size and speed of engine. We can obtain brake mean effective pressure if brake work is used.

bmep= $w_b/_{\Delta V}$

bmep= $2\pi n\zeta/V_d$ (6)

where $\Delta\nu = \nu_{bdc}/_{\nu_{tdc}}$

Brake Specific Fuel Consumption: Brake specific fuel consumption is occurred with thebrake power:

bsfc= $\dot{m}_f/_{\dot{W}_b}$ (7)

where $\dot{m_f} = rateoffuelflowintoengine$

RESULTS AND DISCUSSION

The effects of both the fuels viz. diesel and ethanol on engine efficiency were addressed in this report. The experiments were carried out by increasing the engine speed by 500 rpm from 500 to 4000 rpm. Brake mean effective pressure, brake engine torque, volumetric efficiency, brake strength, thermal efficiency of brake, engine air flow , brake specific fuel consumption, and in-cylinder pressure were all addressed as variations of engine output. The simulation model's findings were compared to the patterns in diesel and ethanol fuel.

The effect of air flow in engine with respect to speed of engine is shown in figure 2. The trends found similar for both the fuels i.e. ethanol and diesel. With the increase in engine speed, the air flow of engine also increased. Ethanol has 40% lower value of Stoichiometric Air-fuel Ratio (AFR) than diesel. This results in lower air flow of engine which is operated on ethanol as compared to that of diesel which is having less conducted air.

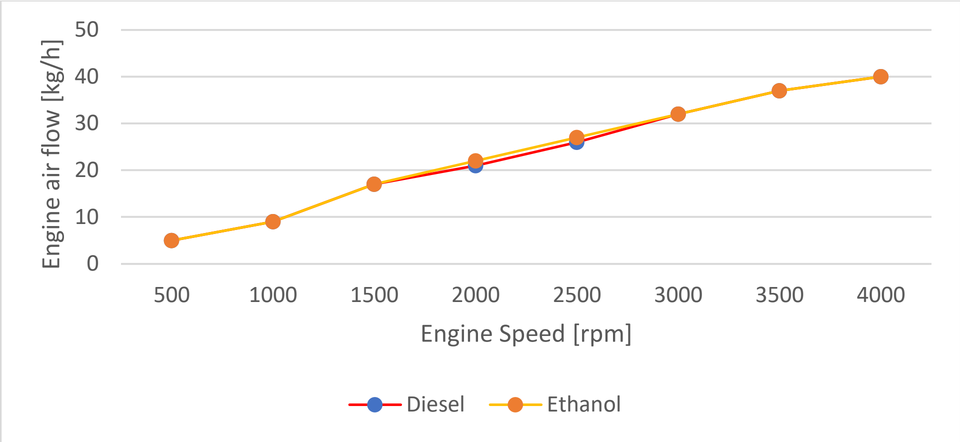

Figure 2: Figure Showing Engine Speed v/s Air Flow in Engine

In Figure 3 the variation of engine speed is shown with respect to the volumetric efficiency. At 2000 rpm of engine speed, it is observed that maximum efficiency of engine can be achieved. The higher volumetric efficiency leads to higher speed of engine and high production of overall power. It is due to the fact that during in and out movement of air the loss of parasitic power is less. There occurs the turning point in the volumetric efficiency when the speed of engine is around 2500rpm. With the increase in engine speed , there occurs the sharp decrease in volumetric efficiency .This sharp reduction is because after the higher speed there occurs the phenomenon which shows negative influence on η_{υ}. In this phenomenon, then charge heating occurs in manifold which results in the higher value of friction losses. This, in turn would increase as the square of engine speed increases (Rahman et al., 2009).

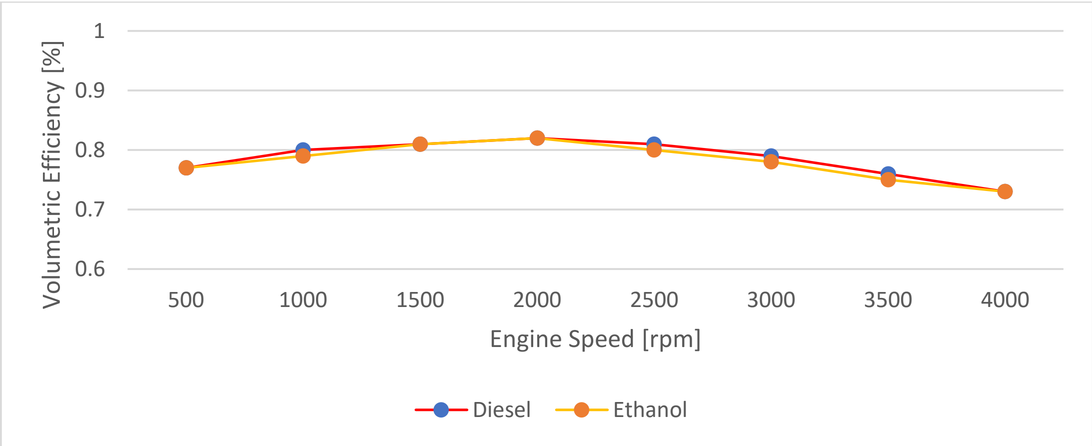

Figure 3: Figure Showing Engine Speed v/s Volumetric Efficiency

Figure 4 depicts the difference in braking power for diesel and ethanol as a function of engine speed. The outputs of the engine at full load are depicted in the diagram. The ignition delay decreased as brake power increased and the delay in injection of diesel fuel was found to have more in value than that of ethanol. At low speeds, there was a striking similarity, indicating a slight difference in output between the fuels. At higher speeds, however, a distinct difference between both the fuels i.e. diesel and ethanol fuels emerged.Diesel and ethanol have maximum brake power of 6.86 kW and 4.20 kW, respectively. At the highest speed, there is the maximum decreasein brake power registered was 38.84% approx. It is well understood that the heating value of a fuel has an impact on an engine's efficiency. According to Ozer et al., 2004, in diesel engines if ethanol is taken without any upgradation , then it is founded that power of engine is reduced and for this reduced energy level of fuel is responsible.

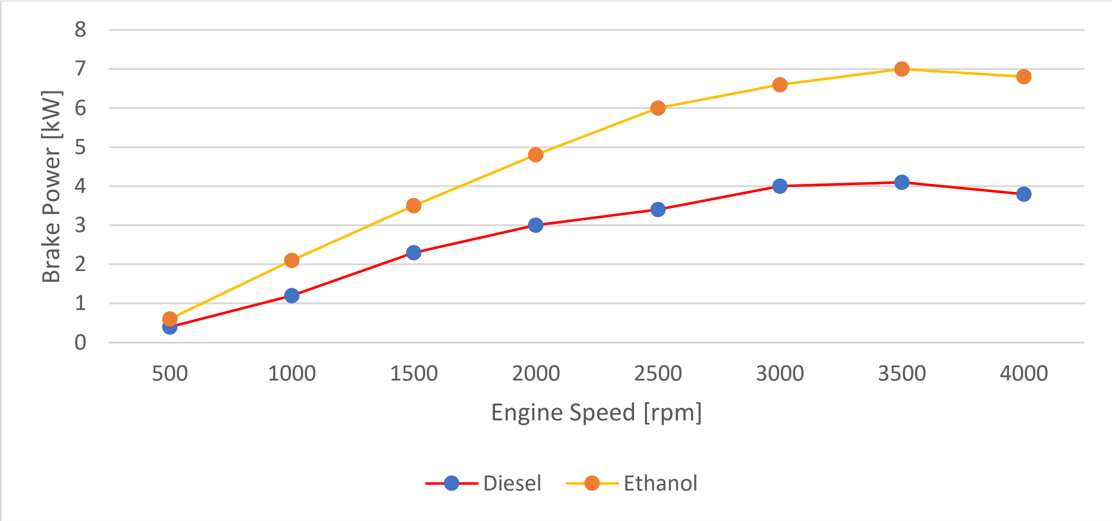

Figure 4: Figure Showing Engine Speed v/s Brake Power for Diesel & Ethanol

The variation shown in figure 5 is of engine speed and thermal efficiency of brake system. It's a useful metric for determining how well the energy which the fuel contains gets to convert into mechanical output. They seem to follow similar patterns and are very similar to one another. The thermal efficiencies of ethanol brakes were lower than those of diesel fuel. For engine speeds of 1500rpm and 2000rpm, the maximum reductions were around 1.2 percent and 0.9 percent, respectively. Since ethanol has a lower calorific value than diesel, its brake thermal efficiency is lower. The thermal efficiency of the brakes was reduced with the increase in the amount of ethanol within the blend. (Rakopoulos and colleagues, 2008)

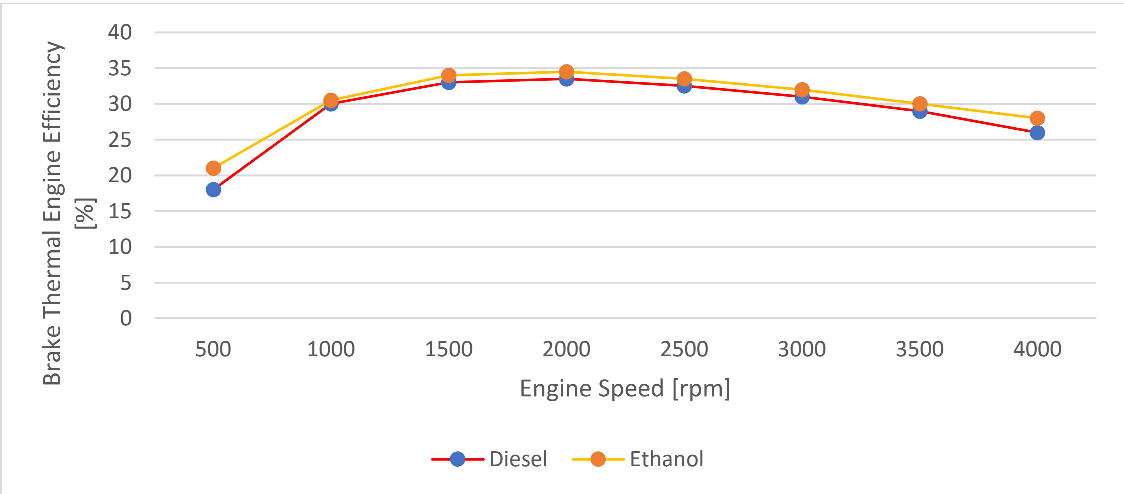

Figure 5: Figure Showing Engine Speed v/s Brake Thermal Efficiency

Figure 6 depicts the influence of both the fuels viz. ethanol and diesel on brake engine torque at different speeds. The torque is proportional to the engine's rpm (Abu-Zaid, 2004). The value of torque gets increase with the increase in speed of engine at low speeds, it will then reached to a limit, and then this curve will further decreases as speed of engine increases, as seen in Figure 6. Since the engine can't ingest a complete charge of air at the higher rpm, the torque drops. The difference between diesel fuel and ethanol can be seen clearly in Figure 6. When the engine speed was set to 2000 rpm, around 37.67% of maximum reduction in brake engine torque was observed.

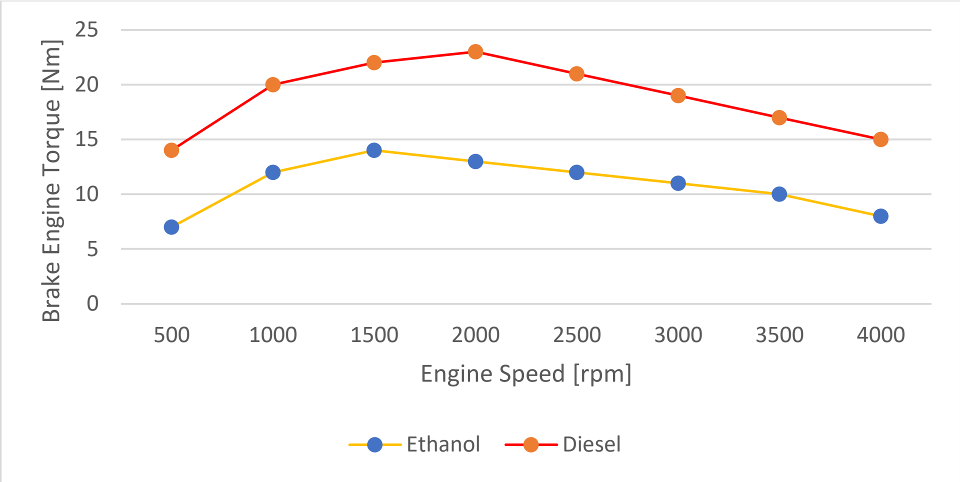

Figure 6: Figure Showing Engine Speed v/s Brake Engine Torque

The variation of engine speed with the mean effective pressure in brake is shown in Figure 7. For both the fuels this graph will have the similar trend. The reduction occurred during brake engine torque brake mean effective pressure are approximately same.

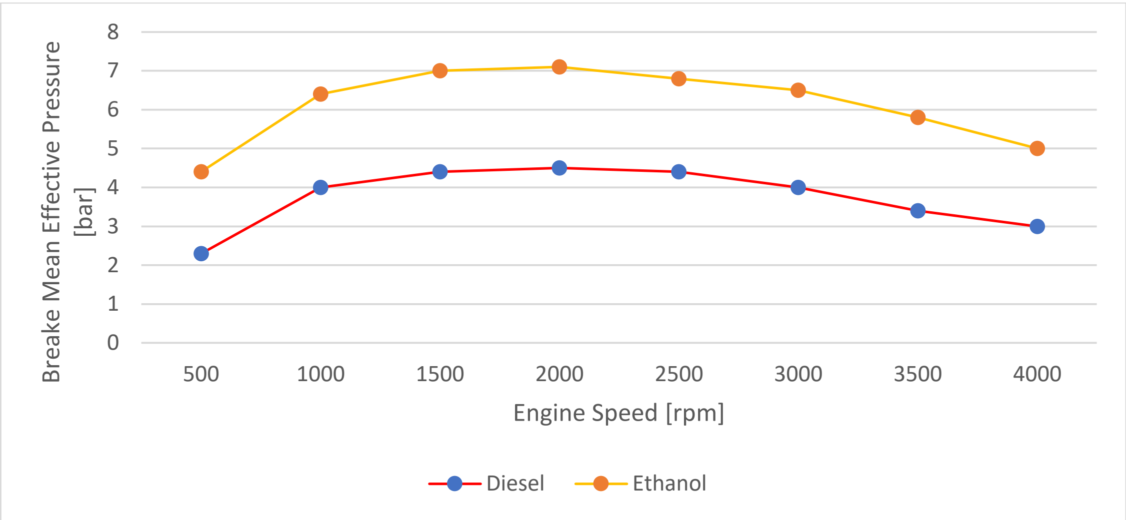

Figure 7: Figure Showing Engine Speed v/sBrake Mean Effective Pressure

For diesel fuel and ethanol the effect of engine's variation of speed with brake specific consumption of fuel (BSFC) is shown in Figure 8. Both the fuels show almost similar characteristic behaviour. The minimum value of BSFC obtained is (388.882) g/kWhr for ethanol and for diesel this value is (241.484 g/kWhr). From Table 1 it is clear that the diesel fuel has higher number of cetane number than that of ethanol and also the calorific value of diesel is higher than ethanol which is (43 MJ/kg) while ethanol has (26.8 MJ/kg). Longer ignition delay cause the higher value of BSFC for ethanol and it is observed with figure 8 and table 1, and it is due to the lower value of cetane number. With the decrease in cetane number , the value of ignition delay increases. According to (Rakopoulos et al., 2008) , the brake specific fuel consumption gets increased by increasing the amount of ethanol in the blend of fuel.

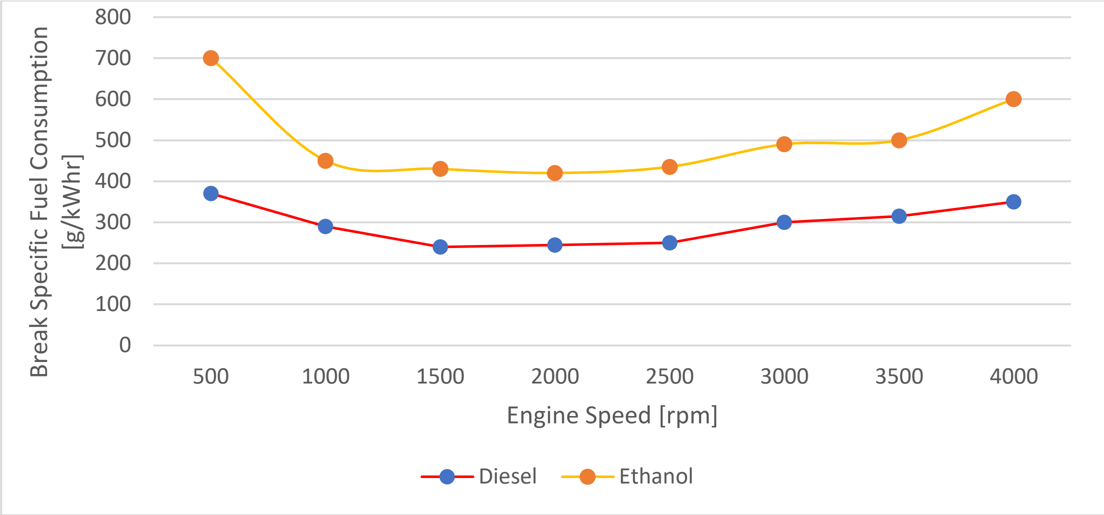

Figure 8: Figure Showing Engine Speed v/s Brake Specific Fuel Consumption

In figure 9 the variation shows the speed of engine within cylinder's pressure by taking boththe fuels which are diesel and ethanol. The value of peak pressure is more with diesel as compared to that of ethanol. The higher value of cetane number leads to the lower ignitiondelay and higher peak in pressure of cylinder, for the diesel using as fuel. When the engine is operating there occurs the start of combustion at the early stage which is suggested by the rise and drop of pressure graph. At the end of the compression, the transfer of work from piston to gas is very large if the combustion process starts at an early stage. On the other hand if this process will start too late then there occurred the reduction in peak pressure of cylinder and also there will be the reduction in the work transfer of expansion stroke (Alla, 2002).

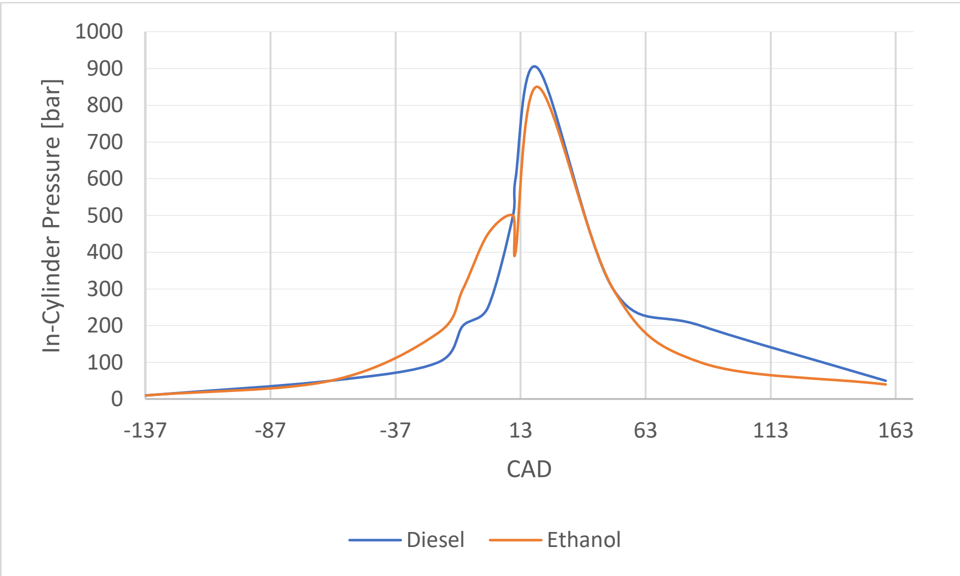

Figure 9: Figure showing CAD v/s In-Cylinder Pressure

Conclusion

The conclusions reached after researching the effects of different fuels and engine efficiency by taking the single cylinder diesel engine for the investigation; are as follows-

1. 1.When the heating value is low, the brake thermal efficiency also gets reduced. Out of Two fuels taken into consideration ethanol have the low value of brake thermal efficiency.
2. With the lower value of heating there is an increase in the brake specific consumption of fuel and o comparing the two fuels, ethanol will have the higher value than that of diesel engine.
3. The lower value of cetane number results inincrement within the ignition delay for ethanol and in turn the peak-in pressure of cylinder will also have the lower value.
4. The value of ethanol(in %age) which is present in the blend, is the factor affecting the energy content of ethanol which is less when the specific fuel consumption gets increased.

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