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Experimental Investigation of Surface Ignition Using Ethanol in Di-Disel Engine

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Abstract

In present scenario, a rapid increase in usage of automobiles for transportation and the depletion of fossil fuel had forced researchers to find suitable alternative fuels to be used in Internal Combustion (IC) engines. The paradox of soot-NOx is an incredibly difficult unsolved problem in compression ignition engines. One of the most viable alternatives for combustion combining the advantages of SI and CI modes, Homogeneous Load Compression Ignition (HCCI). Similar to compression ignition engines, it gives high heat efficiency and resolves the associated problems of high NOx and PM levels at the same time. The homogeneous mixture of air and fuel spontaneously burns in the combustion chamber in the HCCI combustion cycle, minimizing the overall burning time due to a high heat release rate. In this experiment ethanol was used as sole fuel in conventional CI engine by inserting a glow plug in the engine. It was performed on unmodified constant speed single cylinder direct injection diesel engine and based on the results brake thermal efficiency at the maximumload is 23.85% for ethanol, that of diesel is 27.3%, respectively, that is lower for ethanol as fuel. The reduction in the efficiency is due to the lower heating value and inferior combustion of ethanol. Thus, This Paper outcomes draw on effective utilization of ethanol with diesel and also in the aspects of economy effective.

Keywords: DI-diesel engines, Surface Ignition, Combustion characteristics, Ethanol Blend Fuel

1. Introduction

In current years, the demand for energy around the world is continuously increasing, specifically the demand for petroleum-based energy. 90% of energy consumption of the world is from the petroleum fuels [1]. So, the demand and the price of these fuels are increasing at an alarming rate. Facing the increasing consumption of petroleum fuels and the stringent emission regulations, biofuels, have been explored to reduce fuel consumption and engine emissions [2].

According to International Energy Outlook bulletin published by the Energy Information Administration, the world consumption for petroleum and other liquid fuel increased from 97 million barrels/day in 2015 and will increase to 118 million barrels/day in 2025. Under these increase in consumption, approximately half of the world's total resources would be exhausted by 2025. Also, many studies estimated that the world oil production would peak upto 2025. Therefore, the future petroleum based energy availability will be a serious problem for the mankind [3]. Another major global concern is environmental concern or climate change such as global warming. Global warming is related with the greenhouse gases which are mostly emitted from the combustion of petroleum fuels. In order to control the emissions of greenhouse gases [4]. Now, Kyoto Protocol covers more than 160 countries globally with the target to reduce the greenhouse gas emission by a collective average of 5% below. The Inter-Governmental Panel on Climate Change (IPCC) concluded that the global surface temperature is likely to increase about 1.1°C to 6.4°C between 1990 and 2100 because of global warming effect. Igniting combustible liquids in automobile or manufacturing industries is proven hazardous to environment. Recent studies have shown that it is a primary need to focus on considering alternative fuels for combustion in engines [5]. But the problem is only limited research has been conducted on this. Few studies have shown that ignition of fluids and other hydrocarbons in Combustion Ignition engines. This experimental have used "Ethanol" as the fuel to run the 4-stroke CI engine [6]. Ethane is clean high octane and carbon neutral fuel. Ethanol produces clean emissions; also, ethanol is less harmful for the environment. This can be better used as an alternative for the engines. For using ethanol alone as the fuel, there are few modifications and Exhaust gas recirculation systems are used for better performance of the experiment. Exhaust gas recirculation systems helps in analyzing and controlling the NOx and HC gases emitted into the atmosphere also effective for reducing the nitrogen oxides into the environment. Using EGR at upto one particular range is very useful. Higher use of EGR systems can reduce the oxygen contents. Different analyzers are used for different gas emissions [8]. QROTECH exhaust analyzer helps in knowing the NOx emissions and Carbon monoxide emissions are measured by NDIR exhaust analyzer. Also, NOx analyzer helps in analyzing the amount of NOx released. Further modifications taken are coupling an eddy current dynamometer with the 4-stroke diesel engine, glow plug installation for easy ignition, pre-ignition chamber for faster propagation, also a charge amplifier for getting voltage [9]. Low thermal conductivity and higher heat resistant materials are used for improving the efficiency of the engine. Ceramic coatings also help in reducing the negative effects of wear and friction. Low Heat Rejection Engines is also preferred. Increasing useful work can be achieved by decreasing the losses of energy for cooling systems and friction [10]. This Research deals to solve the energy and environmental concerns, the renewable energy sources with lesser environmental pollution is necessary also to verify the analysis of performance in a CI engine when ethanol is used alone and compared with biofuels and this also helps as a reference for further study of Ethanol fuels.

2. EXPERIMENTAL SETUP

The experimental set up used in this investigation with and without EGR is shown in the Figure1 respectively. It consists of a single cylinder four stroke, constant speed, water cooled, direct compression injection engine with compression ratio of 16.5:1, developing 4.4 kW at 1500 rpm, coupled to a generator loaded by variable resistance. The rated injection pressure of the engine was 200bar and static injection timing was 23° BTDC. The fuel level in the fuel tank, flow of cooling water, level of lubricant oil in the engine oil sump were checked before starting the engine. The engine was started and warmed up. The engine speed was maintained at rated speed. The power developed by the engine was calculated by measuring the current and voltage. Thermo couple with digital temperature indicator was used to measure cooling water temperature. The cylinder pressure was measured by a piezo electric pressure sensor. The exhaust emission such as CO, NOx and HC were measured by QROTECH exhaust gas analyzer. TI Diesel Tune smoke meter was used to measure the smoke emission. The experiments were repeated for various loads from no load to full load.

MEASURING INSTRUMENTS AND METHODS

The following instruments and procedure were adopted for measuring the current flow,fuel flow, air flow and exhaust emissions.

Properties	Ethanol	Diesel
Density(kg/m^3, at 20°C)	811.5	820
Flash point(°C)	13	68
Auto ignition temperature(°C)	425	300-340
Lower heating value(MJ/kg)	27	43
Cetane number	8	42
Vapor pressure (kPa at 38°C)	17	0.34
Latent heat of vaporization (kJ/kg)	921.1	620

Table.1 Properties of Ethanol & Diesel

Eddy Current Dynamometer

An electrical dynamometer was used for measuring the brake power of the engine. The electrical dynamometer consists of an alternator mounted on the bearings. The output power was directly obtained by measuring the reaction torque. A water rheostat was used to dissipate the power generated.

NOx Emission

An oxide of nitrogen (NOx) in the exhaust emission contains nitric oxide (NO) and nitrogen dioxide (NO2). The formation of NOx is highly dependent on in-cylinder temperature, the oxygen concentration and residence time for the reaction.

Make	:	KANE – MAY U.K.
Range	:	0-5000 ppm
Resolution	:	1 ppm
Accuracy	:	± 5 ppm
Sensor type	:	Electrochemical
Response time	:	30 to 40 seconds
Operating temperature	:	0 to 40°C

Table.2 Specification of NOx Analyser

Pressure Transducer

The pressure transducer was located in a hole drilled through the cylinder head into the combustion chamber. The sensing element consists of a metal diaphragm, which deflects under pressure. This deflection was converted into voltage, which is proportional to pressure. The charge output of the pressure transducer is amplified by using a Kistler charge amplifier. The amplified signals were correlated with the signal from crank angle encoder and the data were stored on a personal computer for analysis.

Model	:	KISTLER Switzerland. 601 A,
Range	:	0-250 bar
Acceleration sensitivity	:	< 0.001 bar/g
Operation temperature range	:	-50ºC to 300°C

Table.3 Specification of Pressure Transducer

Charge Amplifier

The charge amplifier is used to convert the electrical charge output of the pressure transducer into proportional voltage. It consists of an operational amplifier with a feedbackthrough a variable capacitor, which is changed according to the range selected. This combination acts as an integrator for the current inputs from the transducer and the integral of the change variation appears as the output voltage. This voltage output is proportional tothe total charge at any instant. To ensure the accuracy of the pressure measurement, the charge amplifier is allowed to warm up for four hours before the measurements are taken.

Fig.1. Modifications in Cylinder Head

RESULTS & DISCUSSION

3. EFFECT OF ETHANOL IN DI DIESEL ENGINE

Brake Thermal Efficiency

Brake thermal efficiency is defined as break power of a heat engine as a function of the thermal input from the fuel. Brake thermal efficiency indicates the ability of the combustion system to accept the experimental fuel and provides comparable means of assessing how efficient the energy in the fuel was converted to mechanical output. Figure 3.1 shows the comparison of the brake thermal efficiency with respect to brake power for ethanol and diesel fuels. It can be observed from the figure that the brake thermal efficiency at the maximum load is 23.85% for ethanol, while that of diesel is 27.3%, respectively. The brake thermal efficiency of ethanol is lower compared to neat diesel. Thereduction in the efficiency is due to the lower heating value and inferior combustion of ethanol. Besides, the brake thermal efficiency of diesel is higher than that of ethanol especially at higher load, the possible reason for improved brake thermal efficiency is due to more complete combustion and additional lubricity of diesel.

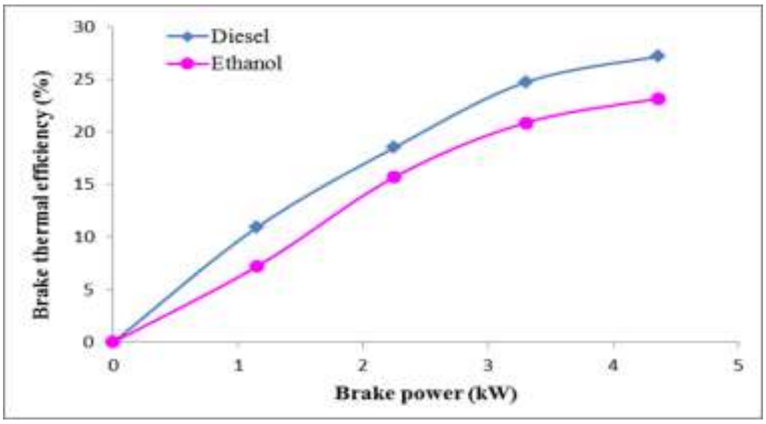

Fig. 3.1 Brake Thermal Efficiency

Brake Specific Energy Consumption

Figure 3.2 shows the test results of the brake specific energy consumptions at various loads for ethanol and neat diesel. From the graph, it can be seen that for ethanol more energy consumption was found when compared with those fuelled by neat diesel. From the figure, it was seen that at maximum load, the brake specific energy consumption was 6.8% high by using ethanol when compared to neat diesel fuel. This behavior was attributed to heating valueper unit mass of ethanol, which was noticeably lower than that of the diesel. Therefore, the amount of fuel introduced into the engine cylinder for a desired fuel energy input has to be greater with ethanol. This is due to the low volatility which affects the mixture formation of the ethanol fuel and leads to slow combustion.

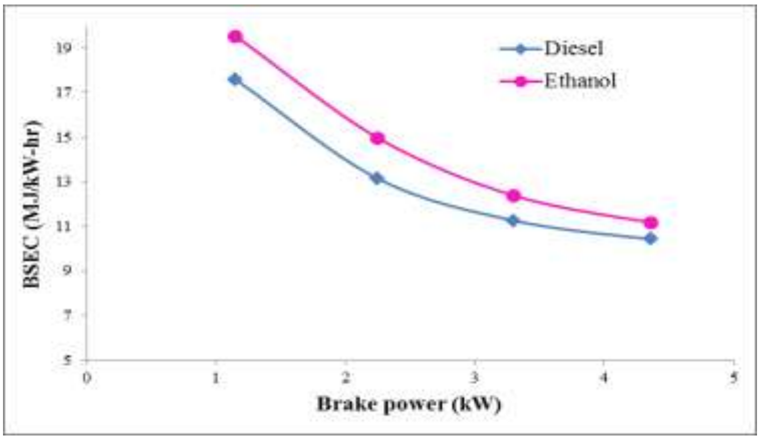

Fig. 3.2 Brake Specific Energy Consumption

Exhaust Gas Temperature

Figure 3.3 shows the variation of exhaust gas temperature for ethanol and diesel at various loads. The exhaust gas temperature increases with load for both ethanol and diesel. At the maximum load, the exhaust gas temperature of ethanol was found to be 12.21% lower thanthat of diesel, due to release of low thermal energy. Another reason may be due to the higher latent heat of vaporization of ethanol, the exhaust gas temperature of the ethanol fueled conventional CI engine was lower than the diesel operation.

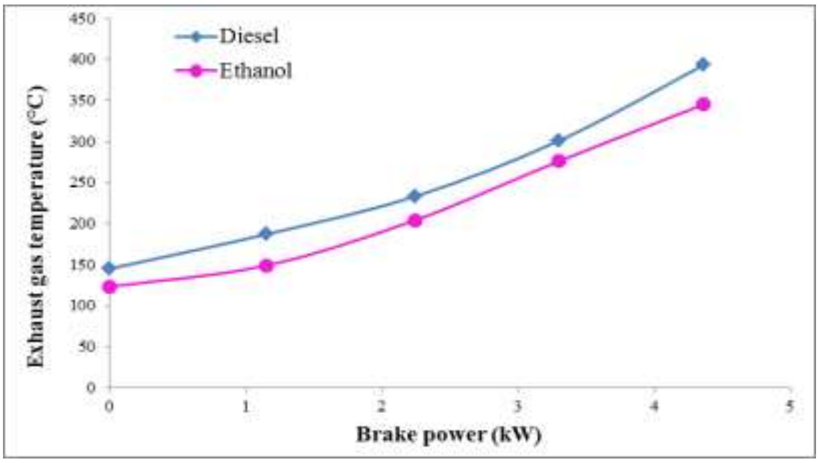

Fig. 3.3 Exhaust Gas Temperature

Carbon Monoxide Emission

Generally, carbon monoxide (CO) is generated when there is insufficient available oxygen to convert all carbon atoms to carbon dioxide (CO2). The other factor of CO emission is poor fuel air mixing and hence causes incomplete combustion. Figure 3.4 shows the variation of CO emission at different load for ethanol and diesel. Emission of carbon monoxide from CI engine mainly depends upon the fuels physical and chemical properties. The main difference in ethanol compared to diesel is the oxygen content and cetane number. As the ethanol fuel contains some oxygen, which acts as combustion promoter inside the cylinder result better combustion than diesel. Hence carbon monoxide, which was present in the exhaust due to incomplete combustion, reduces drastically. From the figure it was seen that, the reduction of CO in case of ethanol was 24.3% lower compared to diesel at the maximum load.

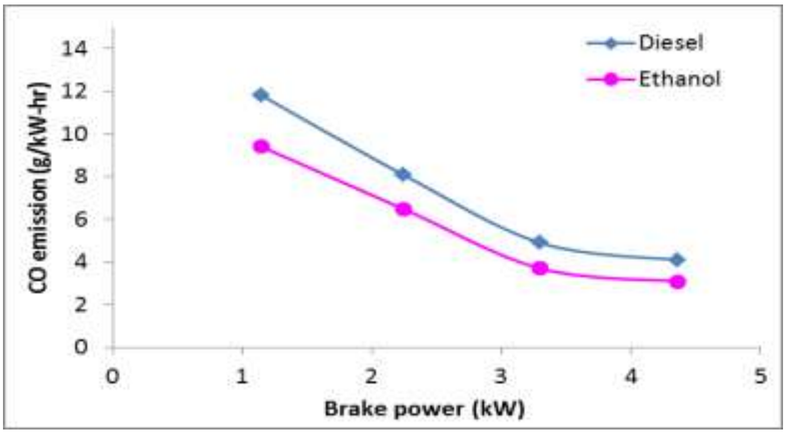

Fig. 3.4 Carbon Monoxide Emission

Unburnt Hydrocarbon Emission

Unburnt hydrocarbon (HC) emissions are formed mainly due to the presence of gaseous hydrocarbons in the relatively stagnant low temperature boundary layer along the cylinder wall and in crevices. Hydrocarbons remain unburned in these areas because the flame does not wholly propagate into these areas. Generally, diesel

(CI) engines produce lesser HC emission as they are operated with overall lean fuel air equivalence ratios. Hydrocarbon isa useful measure of combustion inefficiency and consists of fuel that is not completely burned. At light loads, due to large amounts of excess air and low exhaust temperature,lean fuel-air mixture regions may survive to escape into the exhaust. Figure 3.5 shows the variation of HC emission at maximum load. It was very clear from the graph that at maximum load, there was 9.8% lower HC emission for ethanol compared to diesel. For efficient combustion, the fuel has to atomize, mix and ignite properly. Atomization and mixing of fuel again depends on the physical property of the fuel. Here oxygen content of the ethanol fuel comes into the picture as it enhances the combustion process. Therefore overall result of oxygen content in the ethanol fuel leads to low HC emission.

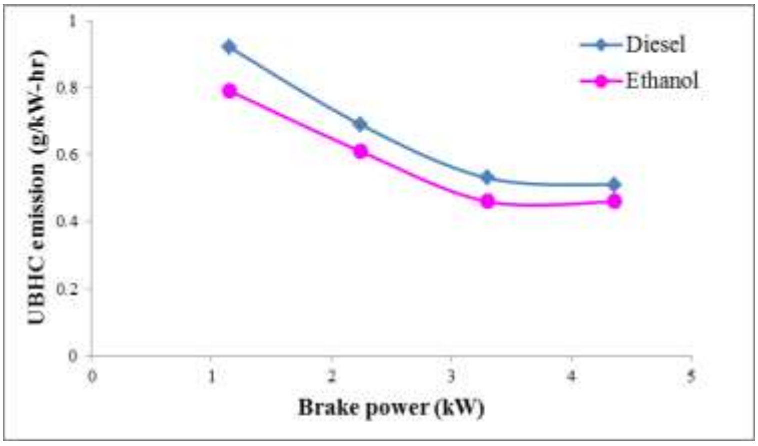

Fig. 3.5 Hydrocarbon emission

Oxides of Nitrogen Emission

Figure 3.6 shows that the NOx concentration decreases with increasing engine load for both diesel and ethanol. However, at high loads they decreased significantly. It was seen that NOx emission for ethanol was 24.1% higher compared to that of diesel at maximum load. For ethanol, cetane number and oxygen content are more effective than thelower heating value and latent heat of vaporization for the peak temperature increase in the cylinder. Therefore, the concentration of NOx emission increased when ethanol was used as the fuel. Increased ignition delay of ethanol promotes premixed combustion, by allowing more fuel injected prior to ignition, may also be another reason for increased NOx.

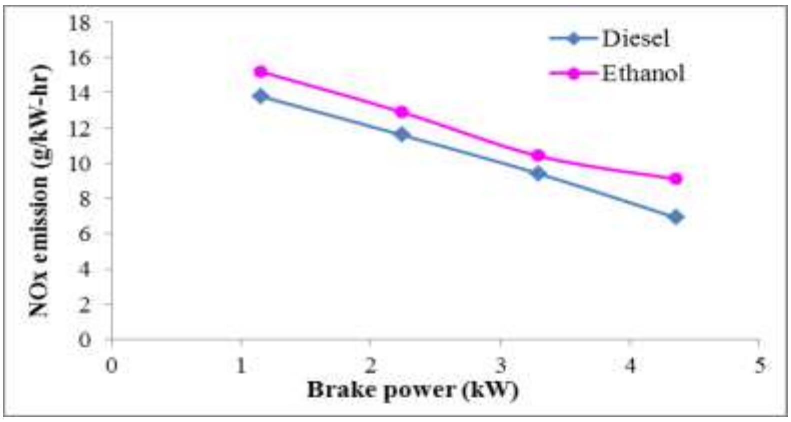

Fig. 3.6 Oxides of Nitrogen Emission

Smoke Opacity

Smoke is nothing but solid soot particles suspended in the exhaust gas. Figure 3.7 shows the variation of smoke emission at various loads. From the graph it is seen that the smoke emission increases with load. At the maximum load, the smoke density for ethanol was 8.7% lower when compared to diesel. The reason may be due to the higher latent heat of ethanol increases the ignition delay period. Hence proper mixing of ethanol and air was enhanced. So, the smoke emission decreased.

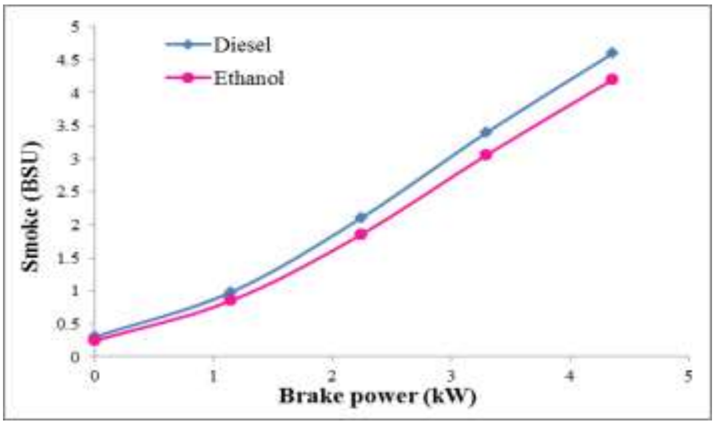

Fig. 3.7 Smoke Emission

Ignition Delay

Ignition delay is defined as the time delay (expressed in crank angle) between the start of injection and start of combustion. The start of injection was taken as the static injection timing of the engine (i.e. 23°bTDC) for comparison. Even though the density of ethanol is marginally lesser than neat diesel fuel, the same injection timing was adopted for both the tested fuels. Delay period was taken from the point of fuel injection to the start of combustion, the point at which the heat release rate curve starts rising from zero. Ignition delay of any fuel is a significant parameter in determining the knocking characteristics of CI engine. The cetane number of a fuel, which indicates the self-igniting capability, has a direct impact on ignition delay. The Figure 3.8 compares the ignition delays between neat diesel and ethanol at various loads. It was seen from the figure that the delays were consistently longer for ethanol, varying between 16.3° to 11.7°CA which is higher than diesel. The reason may be due to low cetane number and higher self-ignition temperature of the ethanol in the conventional CI engine. Another possible reason may be due to the inferior atomization and vaporization, ignition delay of ethanol became larger as compared to neat diesel fuel.

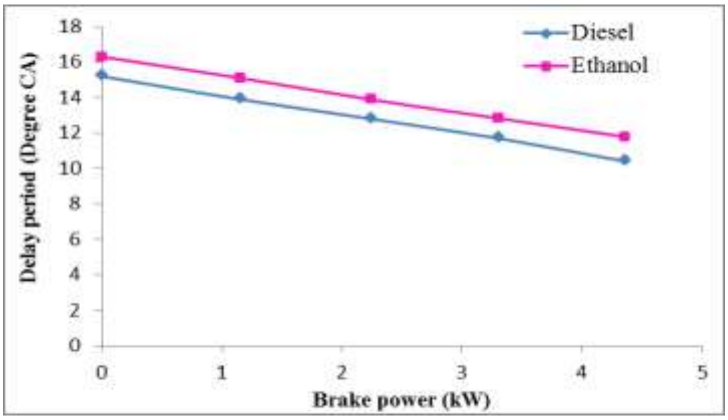

Fig. 3.8 Ignition delay

Heat Release

Figure 3.9 shows the variation of heat release rate for diesel and ethanol at maximum load. Because of the vaporization of the fuel accumulated during ignition delay, at the beginning a negative heat release was observed. After combustion was initiated, this became positive. It can be seen from this figure that the maximum heat release rate occurred for pure diesel was at 10°CA before TDC and for ethanol it was at 12°CA before TDC. It can also be seenfrom the figure that the maximum heat release rate of ethanol was lower (66 J/°CA) than that of diesel (90 J/°CA). Since the overall heating value of pure ethanol was low, the heat release rate was also low compared to the pure diesel. The premixed combustion heat release was higher for diesel due to higher volatility and better mixing of diesel with air.

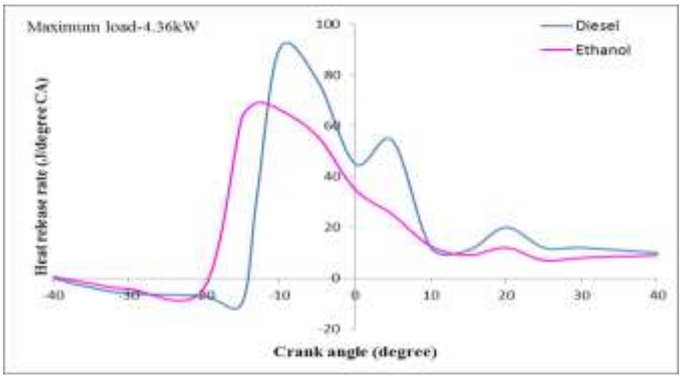

Fig. 3.9 Heat release

Cylinder Pressure Measurement

The engine cylinder pressure was measured using a water-cooled Kistlerpiezo electric pressure sensor. The pressure transducer was located in a hole drilled through the cylinder head into the combustion chamber. The sensing element consists of a metal diaphragm thatdeflects under pressure. This deflection was converted into voltage that is proportional to pressure. The charge output of the pressure transducer is amplified by using a Kistler charge amplifier. The amplified signals were correlated with the signal from crank angle encoder and the data were stored on a personal computer for analysis. The specifications ofpressure transducer are given in Table 1.3With the help of cylinder pressure measurements, the heat release rate was determined.

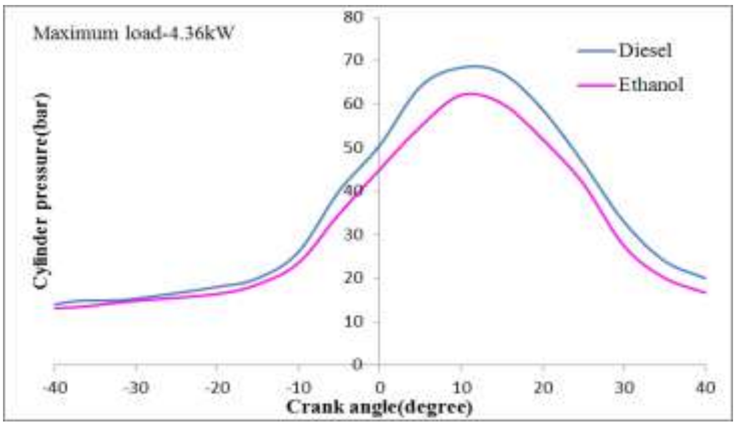

Fig. 3.10 Cylinder Pressure Vs. Crank Angle

DISCUSSION & CONCLUSION

In this research work, ethanol was extracted by grinding the feedstock for converting starch or cellulose into sugar, that is then fed to microbes, producing ethanol and carbon dioxide in the process. A final step purifies the ethanol to the desired concentration. Experiment was performed on unmodified constant speed single cylinder direct injection diesel engine and based on the results the following conclusions were drawn:

1. Brake thermal efficiency at the maximum load is 23.85% for ethanol, while that of diesel is 27.3%, respectively, which is lower for ethanol as fuel. The reduction in the efficiency is dueto the lower heating value and inferior combustion of ethanol.
2. Brake specific energy consumption was 6.8% high by using ethanol when compared to neat diesel fuel, which is due to lower heating value per unit mass of ethanol than diesel and also due to, low volatility which affects the mixture formation of the ethanol fuel and leads to slow combustion
3. The exhaust gas temperature increases with load for both ethanol and diesel. At the maximum load, the exhaust gas temperature of ethanol was found to be 12.21% lower than that of diesel, due to release of low thermal energy and also due to higher latent heat of vaporization of ethanol.
4. Ethanol fuel contains some oxygen, which acts as combustion promoter inside the cylinder result better combustion than diesel. Hence carbon monoxide, which was present in the exhaust due to incomplete combustion, reduces drastically up to 24.3% for ethanol, compared to diesel at the maximum load. In this research found that 9.8% lower HC emission for ethanol was obtained at maximum load when compared to diesel, which is mainly due to the higher oxygen content in ethanol fuel.
5. NOx concentration decreases with increasing engine load for both diesel and ethanol. However, at high loads they decreased significantly. For ethanol, cetane number and oxygen content are more effective than the lower heating value and latent heat of vaporization for the peak temperature increase in the cylinder. Therefore, the concentrationof NOx emission increased when ethanol was used as the fuel. Increased ignition delay of ethanol promotes increased NOx.
6. Peak pressure increases as the engine load increases, pure diesel has maximum pressure of 69.5 bar occurred at 10ºCA after TDC and use of ethanol as sole fuel results in a decrease of the maximum pressure of 62.1 bar occurred at 12ºCA after TDC, due to low range of cetane number of ethanol.

   Maximum heat release rate occurs for pure diesel at 10°CA before TDC and for ethanol it was at 12°CA before TDC and the maximum heat release rate of ethanol was lower (66 J/°CA) than that of diesel (90 J/°CA), due to higher volatility and better mixing of diesel with air.

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References

[1]M ElKelawy, El-Shenawy, A.E., Mohamad, H.A.E.D. and Abd Al Monem, S.K., Experimental Investigation on Spray Characteristics of Waste-Cooking-Oil Biodiesel/Diesel Blends at Different Injection Parameters.
[2]Kannan, M., Balaji, R., Babu, R.S., Bennita, M. and Kuppili, P., 2020. Computational analysis on combustion, characteristics and ignition analysis on IC engine using mahua oil. Materials Today: Proceedings.
[3]Kumar, A.J.P., Sivakumar, S., Balaji, R. and Nadarajan, M., 2021. A Novel Banana Leaf Waste-Based Activated Carbon for Automobile Emission Control. Trends in Manufacturing and Engineering Management, pp.977-989.

[4]P.Nautiyal, K.A.Subramanian, M.G. Dastidar, and A.Kumar, 2020. Experimental assessment of performance, combustion and emissions of a compression ignition engine fuelled with Spirulina platensis biodiesel. Energy, 193, p.116861.
[5]R.Niculescu, A.Clenci, and V.Iorga-Siman, 2019. Review on the use of diesel– Biodiesel–Alcohol blends in compression ignition engines. Energies, 12(7), p.1194.
[6]M.Mofijur, M.M.Hasan, Mahlia, T.M.I., S.M.Rahman, A.S.Silitonga, and H.C.Ong,, 2019. Performance and emission parameters of homogeneous charge compression ignition (HCCI) engine: a review. Energies, 12(18), p.3557.
[7]Adnan Parlak, HalitYasar & BahriSahin 2003, 'Performance and exhaust emission characteristics of a lower compression ratio LHR Diesel engine', Energy Conversion and Management, vol. 44, pp. 163–175.
[8]A.K. Agarwal, 2007, ' Biofuels (alcohols and biodiesel) applications as fuels internal combustion engines', Journal of Energy and Combustion Science, vol. 33, pp. 233–71.
[9]Yuan Zhuang & Guang Hong 2014, 'Effects of direct injection timing of ethanol fuel on engine knock and lean burn in a port injection gasoline engine, Fuel, vol. 135, pp. 27– 37.
[10]K.Venkateswarlu, Murthy, BSRC & V.V Subbarao, 2013, 'The Effect of Exhaust Gas Recirculation and Di-Tertiary Butyl Peroxide on Diesel-Biodiesel Blends for Performance and Emission Studies', International Journal of Advanced Science and Technology, vol. 54, pp. 49-60.