

Studies on Various Performance, Combustion & Emission Characteristics of An IDI CI Engine With Multi-Hole Injector At Different Injection Pressures And Using SVO-Diesel Blend As Fuel

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Abstract— This paper includes various experimental tests and analysis carried out on an IDI CI Engine using SVO (Straight Vegetable Oil)-Jatropha & Diesel blend in 40:60 proportions. For this test the Conventional Single-hole Injector was replaced by newly fabricated & customized Multi-hole injector with four-hole nozzle.

The engine was run at constant rated speed (1000 rpm) and various performance, combustion and emission characteristics were measured at different engine load (10% to 100%) using an eddy current dynamometer as loading unit. The combustion characteristics (i.e, P- θ curve, differential heat release rate and integral heat release rate) were measured with the help of Advanced Combustion Analyzer unit. The performance characteristics (i.e, brake specific energy consumption and thermal efficiency) were calculated using mathematical relations. The emission characteristics (i.e, smoke opacity, HC, NO_x, O₂, CO₂ and CO) were measured with the help of Smoke meter and 5-Gas Analyzer set-up

The same methodology was adopted with different injection pressures (210, 250 & 270 bar).

Keywords—Diesel Engines, Alternate Fuel, Jatropha blends, Multi-hole Injetcor

I. INTRODUCTION

The idea of using vegetable oil as the fuel for diesel engine is not new. The original diesel engine that Rudolph Diesel designed ran with vegetable oil. He used peanut oil to fuel one of his engines at the Paris Exposition in 1900 [1]. Blending the Diesel fuel with Straight Vegetable Oil (SVO) is currently under research. This area is of wider interest since the petroleum crises in 1970s, the rapidly increasing prices and unavailability at certain places. Mixing SVO with Diesel and then using it in industrial and other applications will reduce the overall diesel fuel consumption without installing any other apparatus or using a different engine; thus giving a very economic approach towards conserving the fuel and sustainable development.

SVO has a little lower calorific value than diesel. But the viscosity of SVO is much higher than diesel fuel.[2] This high viscosity restricts SVO to be used directly in the diesel engine; unless a separate heating unit is provided. Due to the complexity of this heating unit, blending is by far the best method.

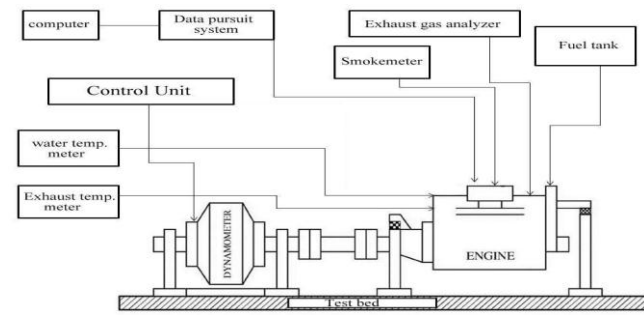
Vegetable oils have their own advantages: first of all, they are available everywhere in the world. Secondly, they are renewable as the vegetables which produce oil seeds can be planted year after year. Thirdly, they are “greener” to the environment, as they seldom contain sulphur element in them. This makes vegetable fuel studies become current among the various popular investigations. So does the evaluation of the performance of diesel engines when fuelled with vegetable oils. A number of investigations have been made, and the test results have proved that vegetable oils are feasible substitutes for diesel fuel [1,3,4,5].

Vegetable oils possess almost the same heat values as that of diesel fuel. But a major disadvantage of vegetable oils is their inherent high viscosity. Modern diesel engines have fuel-injection systems that are sensitive to viscosity changes. High viscosity may lead to poor atomization of the fuel, to incomplete combustion, to coking of the fuel injectors, to ring carbonization, and to the accumulation of fuel in the lubricating fuels[3]. A way to avoid these problems is to reduce the viscosity of vegetable oil in order to improve its performance. To reduce the viscosity there are various methods like heating, blending etc. According to the availability we have chosen blending as a method for this research.

According to our previous test results in [6-8] we selected blend containing 40% SVO & 60% diesel as our fuel for this test. The idea of using multi-hole injector was to increase the amount of charge entering into the combustion chamber, since SVO blend is more viscous and has less calorific value than diesel fuel[2].

Therefore either nozzle hole diameter should be increased or the number of holes. We preferred fabricating and replacing multi-hole injector in the engine. Different injection pressures were decided according to the existing single hole nozzle injection pressure range. Thus we considered the data of existing Single-hole injector as our baseline for comparison and analysis.

II. EXPERIMENTAL SETUP



The fig. shown is the layout for setup of the experimental study. The setup shows an engine and a dynamometer coupled together and mounted over a test bed, a fuel tank, a smoke meter, exhaust gas analyzer and a control unit. In addition to this various sensors are installed at different positions in order to obtain temperature and pressure and a data pursuit system to record it in a computer.

a) Engine

Model Lister	FMS-10 Type IDI
Number of cylinders	1
Swept volume	1580 cc
Compression ratio	17:1
Bore	120 mm
Stroke	139.7 mm
Aspiration	naturally aspirated
Speed	1000 rpm
Power output	7.35/10
kw/bhp	
Specific fuel consumption	255 g/kwh

b) Dynamometer: To apply different loads on the IDI compression ignition engine an eddy current dynamometer has been selected which is controlled by a controlling unit and provides an option to run the engine at either constant rpm or constant load.

c) Smoke meter: AVL 437 smoke meter is used to determine the smoke opacity of exhaust gases. Its range of measurement is 0-100% smoke opacity. It has an accuracy of $\pm 1\%$ of full scale and a resolution of 0.1%. It has been built with 7 segment LED digital display.

d) Exhaust gas analyzer: AVL 5-Gas analyzer is used to measure exhaust characteristics. It can calculate the amount of HC, NO_x, CO₂, CO and O₂ in the exhaust gases. Further, it can measure the stoichiometric ratio.

e) Data pursuit system: The AVL Indicom advanced combustion analyzer is a Complete combustion analysis platform covering pressure and optical signal measurement and conditioning, data acquisition and online and offline data evaluation - all crank angle based and cycle per cycle. Due to its high performance data acquisition this system is optimal for development and calibration at the test bed.

III. PARAMETERS TESTED

For this test we considered various performance, combustion & Emission parameters according to the requirement & availability of resources. Parameters tested are explained below.

1. Performance Parameters :

a) Thermal Efficiency : It is the ratio of useful output of the engine and the energy supplied (by fuel) to the engine. It is the measure of efficiency of conversion of energy from fuel to the output energy. [8]

b) Brake Specific Fuel Consumption : Amount of fuel consumed for each unit of brake power per hour [9]

c) Brake Specific Energy Consumption : Energy Consumed for each unit of brake power per hour.

$$bsec = bsfc \times \text{Calorific Value of fuel}$$

is used to compare performance of two different types of fuels in the same engine.

2. Combustion Parameters :

a) P- θ Curve: The P- θ curve indicates the amount of pressure inside the cylinder due to combustion of fuel with respect to the crankshaft position. As the fuel is desired to burn when piston reaches TDC, maximum pressure is also obtained about TDC.

b) Differential Heat Release Rate: It is the amount of heat released per unit volume per degree crank angle. This gives an overall mapping of the heat release inside the cylinder when combustion is taking place. Its unit is kJ/m³-degrees.

c) Integral Heat Release Rate: It is the total amount of heat released during the combustion. It gives the cumulative value of heat released per unit volume of combustion chamber. Its unit is kJ/m³.

3. Emission Parameters :

a) Nitrogen oxides (NO_x) are generated from nitrogen and oxygen under the high pressure and temperature conditions in the engine cylinder. NO_x consist mostly of nitric oxide (NO) and a small fraction of nitrogen dioxide (NO₂). Nitrogen dioxide is very toxic. NO_x emissions are also a serious environmental concern because of their role in the smog formation. [10]

b) Smoke opacity measurement is the only relatively low-cost and widely available method to measure a PM-related emission parameter in the field. For this reason, opacity limits are used in most inspection and maintenance programs for diesel engines. Smoke opacity limits may be also included as auxiliary limits in new engine emission standards. [10]

IV. EXPERIMENTAL PROCEDURE

The engine is started with supply of diesel as fuel, to ensure no clogging is there in filter & then the engine is run at idling condition for at least 15-20 min. to attain the run-in conditions. Then blend supply is switched ON and Diesel supply is cut OFF. The engine is run at idling condition for 20 min. with blend to ensure that there is no change in characteristics due to the use of diesel. After this the engine rpm is set to 1000 rpm (rated rpm) by using eddy-current dynamometer & the peak load is recorded. Now according to that, gradual increase in load with 10% difference is supplied and reading of fuel consumption, emission & combustion are recorded as per the standard test procedures of the measurement devices

V. RESULTS & DISCUSSION

The installation of Multi-hole injector decreased the torque capacity of the engine to about 9% than Single-hole injector. Moreover it increased the knocking of the engine. When we tested engine at 250 bar & 290 bar injection pressure a sudden increase in knocking was observed as compared to 210 bar injection pressure. Comparing all these important factors of engine life, 210 bar injection pressure was considered best for this test and further investigation was done at 210 bar injection pressure on Multi-hole injector. The data was compared to baseline diesel & SVO-40 with Single-hole injector.

1. Brake Thermal Efficiency :

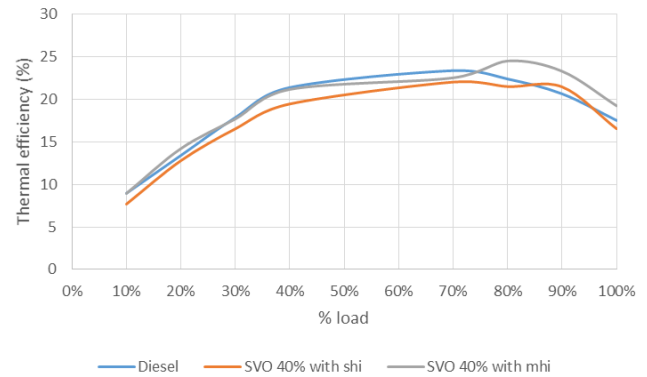


Figure 1 : BTE vs Load

Figure.1 shows that highest brake thermal efficiency was obtained with diesel due to low fuel consumption and proper combustion. Thermal efficiency improved when SVO 40% blend was used with multi hole injector than with single hole injector. Using SVO 40% blend with multi hole injector was found to give thermal efficiency higher than that of diesel at higher loads (80-100%).

2. BSEC :

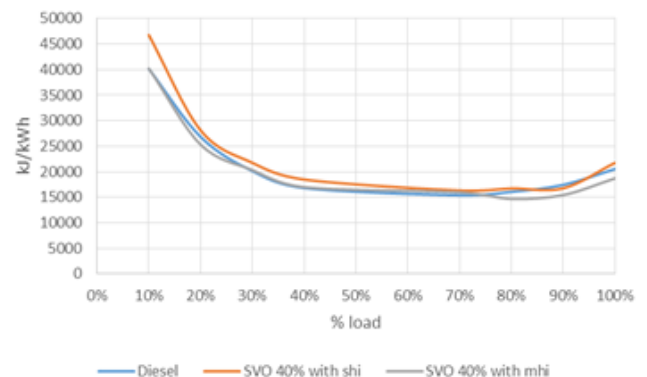


Figure 2 : BSEC vs Load

Figure.2 shows that bsec of SVO 40% blend with multi hole injector being less than that of diesel at low and at high loads. Using SVO 40% blend with single hole injector was found to have a higher level of bsec. Multi-hole injector has improved the fuel consumption.

3. P- θ Curve

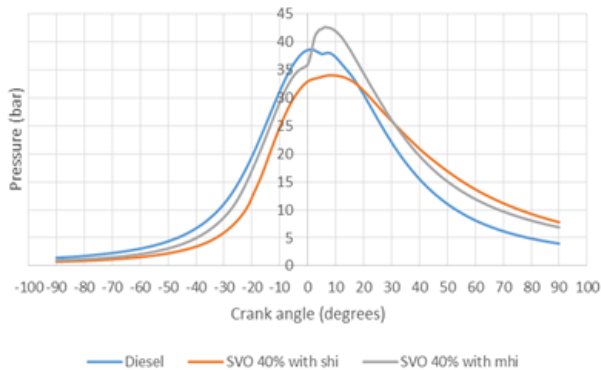


Figure-3 : P- θ Curve

Figure.3 shows the pressure-crank angle curve at 20% load of the engine, for all loads same type of observation in curve was obtained. The rise in peak pressure was observed by using Multi-hole injector than Single-hole injector & Diesel, but peak pressure was obtained 10-12o after TDC. This may be due to the fact that spray penetration is not good as the injection angle may have been effected & moreover the engine is not designed for Multi-hole injectors. This shows that there is a need to make ignition advance to achieve peak pressure at TDC.

4. Differential Heat Release Rate

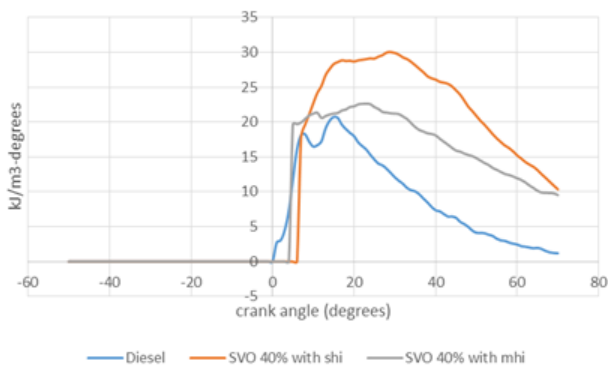


Figure-4 : DHRR

Figure.4 show DHRR for one cycle at 20% load of the engine. In case of pure diesel, maximum heat was released in between 0 to 20 degree crank angle. So, there was a sudden fall in the curve. Though, at all loads, differential heat release rate for diesel was found to be the lowest. This was because of low fuel consumption when operating on pure diesel. SVO 40% blend with multi hole injector was found to achieve highest heat release at any point.

There was an ignition lag in case of blends at all the loads and in case of diesel at loads above 50%.

5. Integral Heat Release Rate

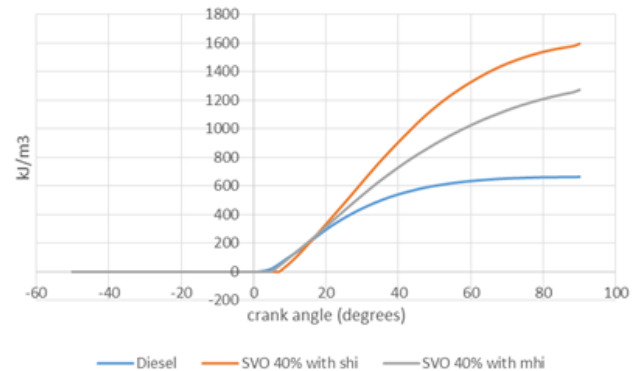


Figure-5 : IHRR

Figure.5 show IHRR for one cycle at 20% load of the engine. Same results as that for differential heat release rate were obtained in case of integral heat release rate. Diesel was found to have the lowest amount of integral heat release rate due to less fuel consumption. Highest integral heat release rate was obtained with SVO 40% blend with single hole injector. For SVO 40% blend with multi hole injector, integral heat release rate was found in the middle. It was higher than diesel due to high fuel consumption but at the same time, due to improper combustion than when used with single hole injector, it was less than SVO 40% blend with single hole injector.

6. Smoke Opacity

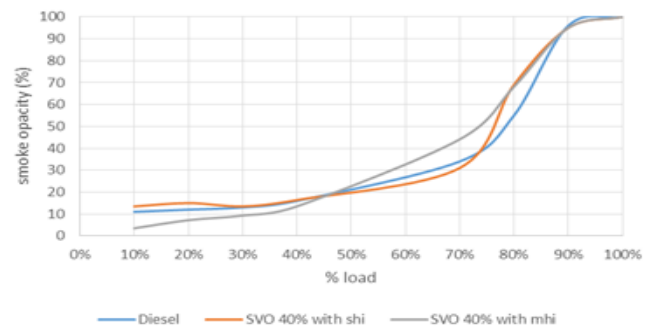


Figure-6 : Smoke Opacity vs Load

At lower loads, smoke opacity was the least for SVO 40% blend with multi hole injector. For medium load range, smoke opacity was least SVO 40% blend with single hole injector. At higher loads, diesel was found to have the least smoke opacity.

7. NOx Emissions

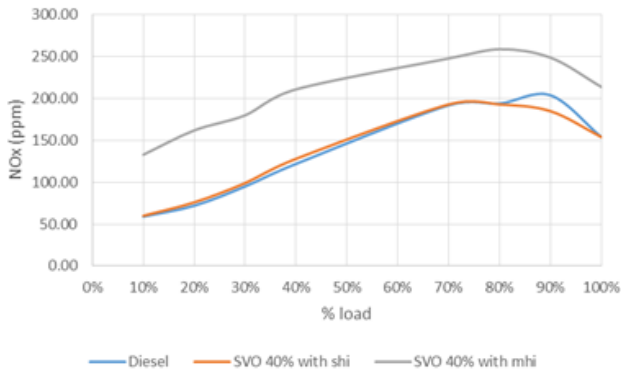


Figure-7 : NOx(ppm) vs Load

Diesel and SVO 40% with single hole injector was found to have least amount of NOx emissions. Replacing single hole injector with multi hole injector resulted in very high amount of NOx being emitted in the exhaust. This is one of the main reasons of not using multi hole injectors in conventional IDI CI engines.

VI. CONCLUSION

The installation of Multi-hole Injector decreased the torque capacity of the engine and increased knocking which may be due to the abnormal trend of pressure rise (peak pressure obtained 10-12o after TDC) and moreover it has increased NOx emission which is highly unlikely.

But improvement in thermal efficiency, bsfc, bsec, peak pressure & smoke opacity are some of the positive points for this test. Various problems like knocking, Torque capacity, etc. could be solved by application of some injection advance strategies, which is our ongoing research for the project.

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