Effect of advancing fuel injection point on performance of Low speed IDI engine fueled with Jatropha straight vegetable oil

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Abstract

The diminishing reserves of fossil fuels coupled with spiraling prices and higher environmental degradation has led to the interest in development of environment friendly alternate fuel. This has led to increasing interest in alternative sources of energy. One of the sources is Straight Vegetable Oil (SVO). Many researchers have reported that the brake thermal efficiency of engine with JSVO fuel is lower than the diesel fuel under design operating parameter for almost all the engine. This effect is due many reasons; one prime reason is very high viscosity of JSVO in comparison with diesel. The surface tension is also almost twice than the diesel where as the calorific value of JSVO (39000kJ/kg) is comparable with diesel (42000 kJ/kg). The high viscosity leads to poor atomization characteristics because of release of bigger fuel particle from fuel injector in the combustion chamber. The bigger fuel particles need more time for getting atomized properly. This can be attained by advancing the fuel injection point thereby increasing the time delay. In this work low speed IDI engine is used for investigation. The experiment was done in two phases, first the engine was run with diesel fuel and second it was run with neat JSVO. The design fuel injection point with diesel fuel for this engine is 20^0 BTDC. During the experiments the fuel injection advance angle in changed to 22^0 BTDC, 24^0 BTDC and 26^0 BTDC and the performance was evaluated. The BTE of engine with diesel fuel at its design operating parameter 20^0 BTDC and fuel injection pressure 175 kgf/cm^{2}was found 32.96% in comparison with BTE with JSVO 30.62% at same operating parameters. As the advance angle of fuel injection was increased to 22^0, 24^0 and 26^0 BTDC the BTE of diesel fuel was decreased to 31.25% where as the BTE of JSVO was increased to 31.04% at 24^0 BTDC but decreased to 30.21% at 26^0 BTDC. Substantial improvement in BTE is achieved by changing the fuel injection point of this engine to 24^0 BTDC for JSVO. There are possibilities of even changing the fuel injection pressure which will also enhance the efficiency. One of the prominent modification as suggested by many researchers is to preheat the fuel. These aspects of modifications will be the extended work of this investigation. The JSVO as alternate fuel for engine will make the farmers self dependent and improve their economy. This will also reduce or may eliminate the trouble of running to the market and paying the high cost of diesel.

Key words: Jatropha straight vegetable oil (JSVO), IDI engine, inlet valve opening pressure (IVOP)

1. Introduction

The energy security is global objective to secure the availability of energy for use to one and all in the present scenario of rapid development all around. The fossil fuel reserves are limited and the demand is enormously increasing. The cost of fuel is ever increasing. The search for the alternative fuel becomes most essential under these circumstances to gain energy security. The use of locally grown, non edible, plant oil to fuel slow speed diesel engine has potential to provide low cost, sustainable solution [1]. The search of alternate energy sources become more important for the countries whose energy demand is met by foreign sources. The global concern about environmental pollution resulting from exhaust of internal combustion engines also attracted the attention of researchers to work in this area. The replacement of petroleum diesel by vegetable oil is one important potential initiative. There are so many sources of vegetable oil e.g. forest, vegetable oil crop and oil bearing biomass material. An important concern about it is that many of the straight vegetable oils are edible oils, if we make use of these oils for this purpose then the cost of edible oil and its direct effect on human food materials will be very adverse which can not be acceptable. Thus there is need to focus research and development on utilizing non-edible seeds from oil bearing trees. The farmers who are the potential target in this study and using the IDI engine for their agricultural applications, power generations, pumping the water etc are to be dependent upon market once again and pay the cost of biodiesel fixed by industries. Apart from the cost and affordability, the availability is another problem especially for remotely established places. The utilization of Straight Vegetable Oils (SVOs) has not founded favor due to various technical limitations imposed primarily because of its high viscosity. It has been reported that in addition to inferior output performance the injector choking, gum formation, piston sticking etc are encountered under endurance test. The prime cause of these results are high viscosity and density of SVO [2,3]. However, SVOs could be advantageous in certain specific application areas such as remote village electrification and energizing pump-set for rural irrigation needs due to lower cost and simpler production technology.

One needs to differentiate between the energy security of rural and urban areas because energy dynamics of both the areas are quite different. Energy security perhaps is more important for the rural people because they are very vulnerable, marginalized and lack access to most of the basic resources. Majority of rural households in developing countries like India depend on traditional fuels like firewood to meet most of their energy requirements, supplemented by small amounts of kerosene and electricity for lighting.

In this work we have explored the possibility of Jatropha oil expelled from seeds and filtered to be used in low speed IDI engine. This engine is taken for study because of versatile use of this engine in agricultural applications and otherwise too. The schematic diagram of experimental test set up is shown in figure 1. The engine was run with diesel fuel in first phase and then same engine was run with JSVO in second phase to find out the comparative deviations in engine performance. The cause of these deviations and its long term effects on engine is discussed. The use of SVO in long term causes the filter chocking because of high viscosity and insoluble present in SVO [4]. The NL Panwar [5] reported that the dilution of lubricating oil is also a problem in addition to injector choking and deposits. One of the important causes is high viscosity of JSVO; because of high viscosity the size of fuel particles released in combustion chamber by the injector is more. The bigger size of fuel particle need more heat and time to get atomized efficiently [6, 7]. The fuel atomization has high bearing on brake thermal efficiency (BTE), so second aspect about fuel atomization i.e. time duration is taken in consideration in this work. The delay period in gradually increased by advancing the fuel injection point. The effect of advancing the fuel injection point there by increasing the delay period is studied. The preheating the fuel to 70^0 C is also another method to improve the efficiency because it reduces the viscosity substantially [8,9,10]. The engine is tested with JSVO as test fuel at fuel injection advance angle 20^0 BTDC, 22^0BTDC, 24^0BTDC and 26^0BTDC.

The parameters taken for study are brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) and emission parameters like CO, CO_2, NOX, HC and smoke. The NOx and HC emission was reported to be high in case of SVO in comparison to diesel fuel [11,12]. It has been found that the substantial improvement in these parameters is obtained.

2. Methodology

2.1 Experimental test set up

The low speed IDI diesel engine manufactured by Field Marshal (model F- 4) was taken for experiment due to large scale utilization of such engine in agricultural and small scale industries. The rated power output of this engine with diesel fuel is 10 HP/7.35 kW. It is single cylinder, water cooled, vertical engine having forced lubrication system. The engine designed for compression ratio 17:1, it is 1580 cc engine with bore x stroke 120 mm x139.7 mm. The engine is self governed and designed to operate at 1000 rpm. The advance angle of fuel injection for diesel fuel is 20^0 and the fuel injection pressure is 175 kgF/ cm^2. The engine is coupled with single phase AC alternator having rated capacity 7.5 kW at 1500 rpm. The efficiency of the alternator as quoted by the manufacturer is 80%. The alternator was coupled with engine with v-belt power transmission system. The main components of experimental set up are alternator, hydraulic loading unit, fuel consumption measuring unit, voltmeter, ammeter, temperature measuring thermocouples, AVL - 437 smoke meters and AVL gas analyzer used for emission measurement. The engine rpm was measured with digital tachometer. The engine was mounted on vibration isolators to minimize the vibrations.

The necessary arrangements were required to find out the TDC, BDC positions and subsequently the angle of fuel injection. For that the 360^0 dial was made and it was pasted on fly wheel. The TDC, BDC positions were marked with the help of magnetic dial indicator and arrow indicator.

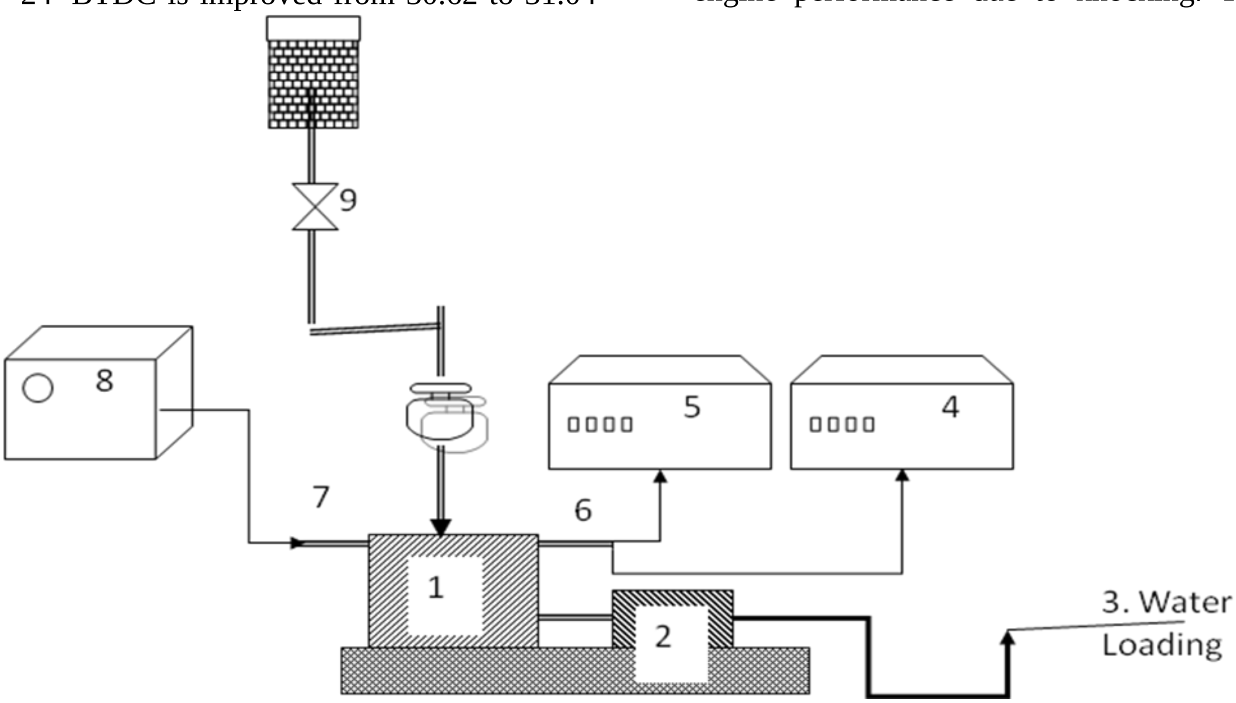
2.2 Experimental Procedure

Initially the fuel injection point was set to 20^0 BTDC with the help of drop test. This value of fuel injection point is the design value for this engine with diesel fuel. After integrating all the sub systems to enable data collection, the engine was started with diesel as test fuel for 30 minutes to get the engine stabilized and then the data was observed at 20^0 BTDC. Then the fuel injection angle were changed one by one to 22^0 BTDC, 24^0 BTDC and 26^0 BTDC and the observation parameters were recorded at all these operating points. After completing one cycle of the experiment the diesel fuel was drained and the fuel pipes, filters were also drained and flushed with JSVO. The engine was started with JSVO fuel for 30 minutes to ascertain that no traces of diesel are available in engine system. After that the performance parameters were collected again on same fuel injection points. The data observed were processed for finding out the BTE, BSFC. The emission parameters recorded were CO, CO_2, NO_x, HC and smoke. The graphs were plotted to compare the results and to draw the conclusion.

3. Result and discussion

The BTE of engine with test fuel diesel decreases as the advance angle of fuel injection is increased from 20^0 BTDC. The design fuel injection point for diesel fuel for this engine is 20^0 BTDC. It shows that the best BTE is at design point. The BTE of engine with diesel fuel at 20^0 BTDC is 32.96% in comparison with BTE of JSVO at same injection angle 30.62%. The BTE of JSVO increases as the advance angle of fuel injection is increased to 22^0 BTDC and 24^0 BTDC but the BTE decreases as the advance angle is further increased to 26^0 BTDC [fig.2 (a)]. The BTE due to increase in advance angle of fuel injection from 20^0 BTDC to

24^0 BTDC is improved from 30.62 to 31.04



%. This increase in BTE is due to increase in delay period. Because of delay period the fuel atomization becomes more efficient, therefore the BTE gets increased. On increasing the angle further to 26^0 BTDC the BTE is reduced to 30.21%. This is because increase in BTE due to increase in advance angle of fuel injection is dominated by the decrease in BTE due to knocking

1. Single cylinder 4-stroke diesel engine, 6 kW
3. Hydraulic load
5. Smokemeter
7. Intake manifold
9. Control valve

period beyond a limit causes the ill effect on

engine performance due to knocking. The BSFC of engine fuelled with diesel increases as the advance angle is increased but the BSFC of JSVO increases up to 24^0 BTDC but start decreasing beyond that [fig.2(b)].The BSFC at 20^0 BTDC for diesel is 0.260 kg/kWh in comparison with BSFC of JSVO at same fuel injection point as 0.301 kg/kWh. The BSFC of JSVO is reduced to 0.297 kg/kWh as the advance angle is increased to 24^0 BTDC where as the BSFC increases 0.306 kg/kWh on increasing the angle further to 26^0 BTDC. This shows that optimum utilization of energy input for brake output at 24^0 BTDC. The CO emission by this engine with diesel fuel and JSVO is shown in fig.3(a). It shows that the CO emission in increasing gradually in case of diesel fuel as the angle is increased from 20^0 BTDC to 26^0 BTDC. This indicates that the combustion efficiency is decreasing as the fuel injection point is increased from its design value for this engine which is 20^0 BTDC. The CO emission for JSVO fuel in this engine which is 0.10 % vol. at 20^0 BTDC is reduced to 0.07 % vol. at 24^0 BTDC nd this value is increased to 0.9 % vol. as the fuel injection point is further advanced to 26^0 BTDC. The CO_2 emission has reducing trend for diesel fuel continuously from 20^0 BTDC to 26^0 BTDC but the trend in case of JSVO is to increase from 20^0 BTDC to 24^0 BTDC which further decreases as the angle is advanced to 26^0 BTDC [fig.3(b)].The NO_x emission for JSVO is higher than the diesel at the design angle of fuel injection i.e. 20^0 BTDC but the NOx emission of JSVO reduces as the angle is advanced up to 24^0 which further increases as the angle is increased to 26^0 BTDC [fig.3(c)]. The reduction in NO_x emission from angle 20^0 BTDC to 24^0 BTDC in case of JSVO fuel is from 430 ppm to 417 ppm which further increase to 420 ppm at 26^0 BTDC. The HC emission of engine with diesel fuel at 20^0 BTDC is 18 ppm which increases to19.9 ppm at 26^0 BTDC as the advance angle of fuel injection is increased [fig.3(d)]. The HC emission at 20^0 BTDC was found to 21.5 ppm which quiet high in comparison with diesel at 20^0 BTDC. The HC emission of engine with JSVO fuel is observed to be decreasing to 20.85 ppm. The HC emission is improved as the advance angle is increased but it is still quite high in comparison with HC emission at 20^0 BTDC. The Smoke emission is continuously increasing for diesel as the angle of fuel injection is increased from 20^0 BTDC to 26 ^{0} BTDC in step of 2^0 . The smoke opacity of diesel fuel at 20^0 BTDC is 9.7% which increases to 11.6% at 26^0 BTDC. The JSVO has more smoke emission at all the fuel injection point in comparison with diesel. The smoke opacity of JSVO at 20^0 BTDC is 17.9% which is quite high with diesel fuel smoke opacity. The value of smoke opacity incase of JSVO in reduced to 16% at 26^0 BTDC [fig.4].

4. Conclusion

The experimental investigation in the direction of search for the alternate fuel for diesel as JSVO has been carried out. The results were showing that the JSVO is not an efficient alternative fuel for diesel at the existing design operating parameter. There are many methods to improve the performance. Some of the possible methods are modification in advance angle of fuel injection, modification in fuel injection pressure and pre heating the fuel. These modifications do not include much financial implications. There can be some more major modification but they have huge financial implications and a fresh design of major engine components. In this study one of the minor modification i.e. modification of fuel injection point was undertaken. The tests were carried out at 20^0BTDC, 22^0 BTDC,

24^0 BTDC and 26^0 BTDC fuel injection advance angles keeping all other parameters unchanged. The results obtained show that the BTE of engine with diesel fuel at its design operating parameter 20^0 BTDC fuel injection point and fuel injection pressure 175 kgf/cm^2 was found 32.96% in comparison with BTE with JSVO 30.62% at same operating parameters. As the advance angle of fuel injection was increased to 22^0, 24^0 and 26^0 BTDC the BTE of diesel fuel was decreased to 31.25% where as the BTE of JSVO was increased to 31.04% at 24^0 BTDC but decreased to 30.21% at 26^0 BTDC. Substantial improvement in BTE is achieved by changing the fuel injection point of this engine to 24^0 BTDC

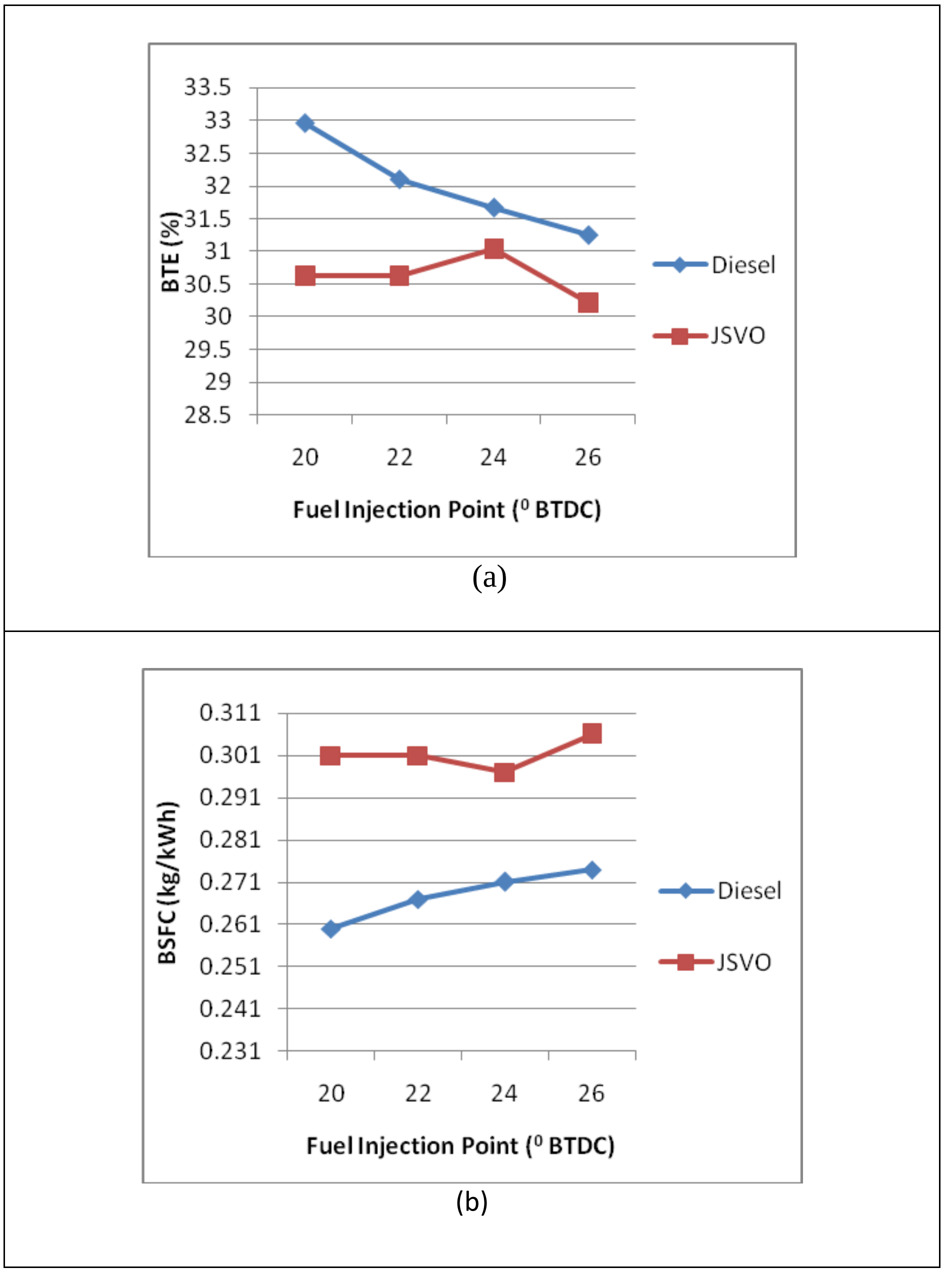


Fig. 2: Performance parameters vs Fuel Injection Point

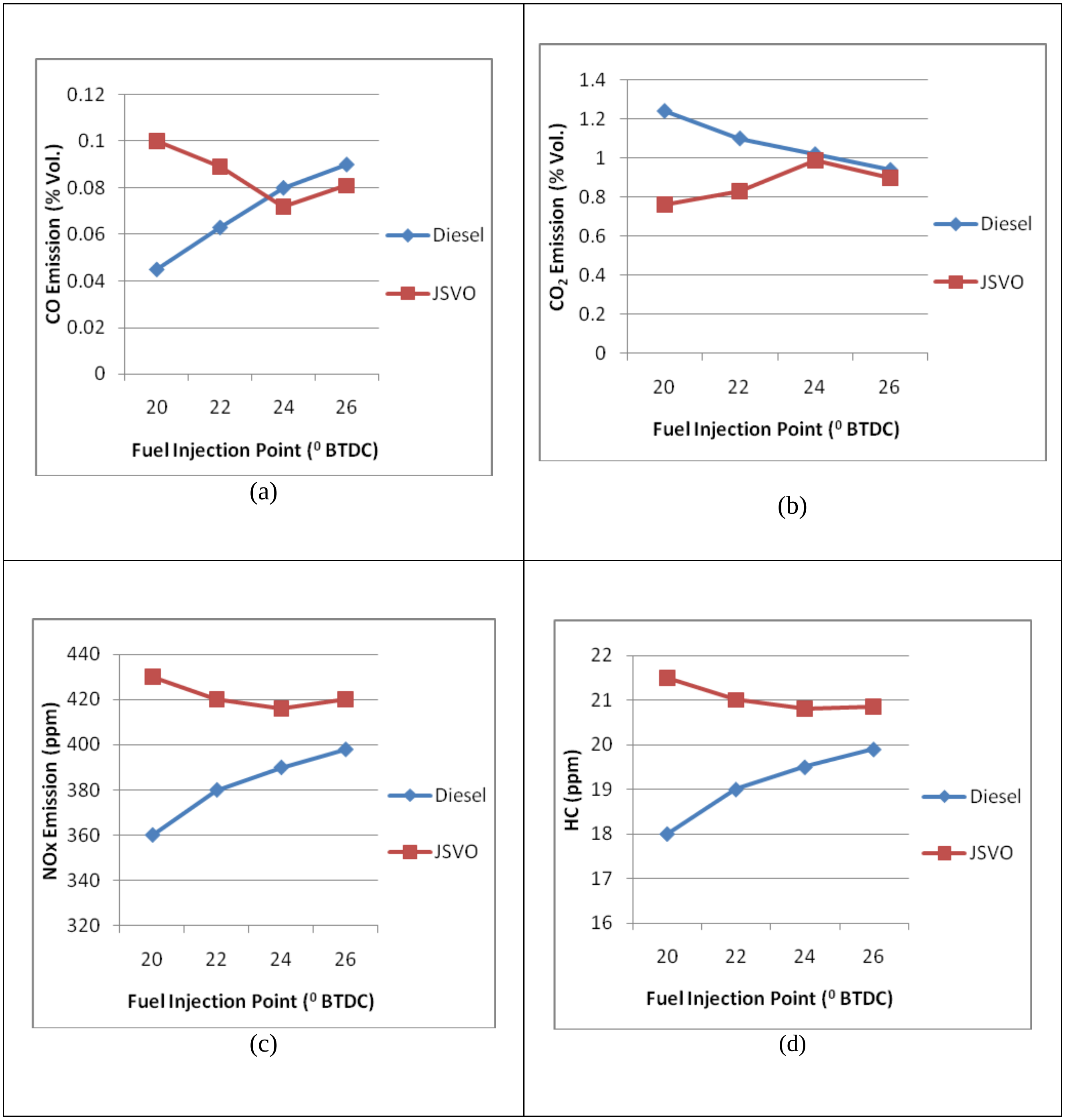


Fig. 3: Emission characteristics vs Fuel Injection Point

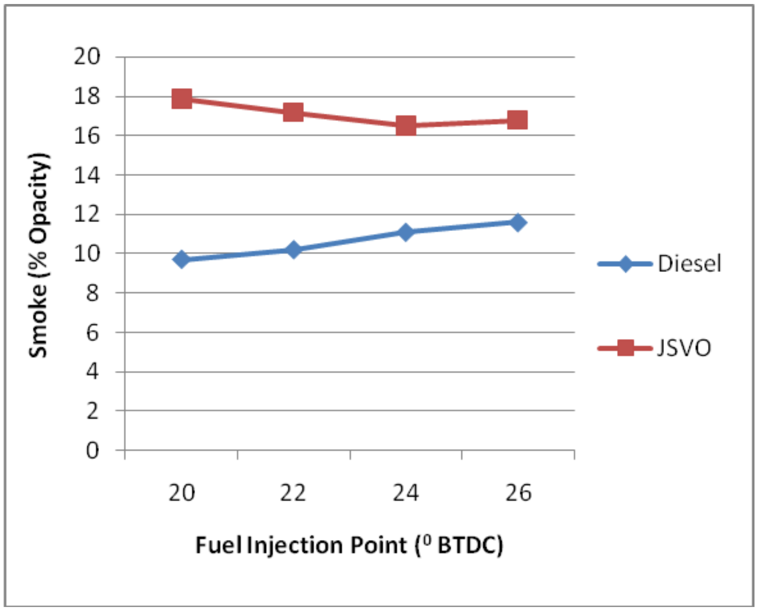


Fig. 4: Line chart Smoke emission vs Fuel Injection Point

for JSVO. There are possibilities of even changing the fuel injection pressure which will also enhance the efficiency. One of the prominent modification as suggested by many researchers is to preheat the fuel. These aspects of modifications will be the extended future work of this investigation. The JSVO as alternate fuel for engine will make the farmers self dependent and improve their economy. This will also reduce or may eliminate the trouble of running to the market and paying the high cost of diesel.

The injector chocking , carbon deposit, gum formation, dilution of lubricating oil and the piston sticking consequences which was reported by different researchers will definitely be reduced by the modifications because combustion efficiency of the engine is improved. However it needs to be investigated by conducting the endurance test with incorporating the modifications. The modified maintenance schedule chalked out based upon the endurance test result analysis may also be advisable solution to counteract the impacts of these ill effects.

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