Effect Of Inlet Valve Modification Using Converging Tube For Single Cylinder Diesel Engine Using Biodiesel

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Abstract: Biodiesel has become one of the promising alternative fuels. Various strategies are applied to improve the engine performance and emission characteristics. Most research works suggested that B20 (blend of 20% of biodiesel and 80% of diesel) could serve effectively, which can replace only 20% of the diesel requirement without any engine modifications. Very few researchers have worked in engine modification for improving the engine performance and emissions. The objective of this work is to propose a design modification of the intake manifold to improve engine performance and emissions. In this work, the influence of modified intake manifold with a Converging tube of varying ratio of outer to inner diameter (1, 1.25, 1.5 and 1.75) was investigated on the engine performance and emission characteristics. The experiments were carried out in a single cylinder diesel engine and the measurements were taken to determine engine performance and emissions. The results suggest that the addition of Converging of ratios of outer to inner diameter increased the engine performance while reducing the emissions of CO and HC. However, there was no significant reduction in NOx emissions.

Keywords: diesel, biodiesel, Converging, environment, performance, emissions.

1. INTRODUCTION:

Biodiesel is fatty acid alkyl esters extracted produced through various techniques, such as, transesterification reaction, supercritical fluid method, ultrasound assisted transesterification, membrane technology, and reactive distillation technology, transesterification reaction (Aransiola et al., 2004; Fazal et al., 2011; Abbaszaadeh et al., 2012; Sharma et al., 2008; Murillo et al., 2007; Yusuf et al., 2011; Agarwal, 2007). The major sources of biodiesel are vegetable oils, animal fats and waste cooking oils. Food crops and edible oils are the first generation biodiesel sources; nonfood crops and nonedible oils are the second generation biodiesel sources; and other feedstock that does not require fresh water and large land are the new or third generation biodiesel sources (Verma et al., 2016). Various strategies, such as Exhaust gas recirculation, Emulsification, Low-temperature combustion, Selective catalytic reduction, DOC and EPF, Lean nitrogen traps, Fuel additives, Fuel composition, etc., are applied to improve the engine performance and emission characteristics. Most of these techniques do not require any engine modification. Moreover, most research works suggested that B20 (blend of 20% of biodiesel and 80% of diesel) could serve effectively. This can replace only 20% of the fuel needs and there is a great dependency of diesel. Therefore it also important to concentrate on engine modifications so that the full use of pure biodiesel could be achieved with improved engine performance and emission characteristics. The properties of biodiesel B20 under initial condition and before use condition are given in Table. The properties of biodiesel considered in experiment are density at 15ºC, viscosity at 40ºC, acid value and water content.

***Table 1**. Properties of B20 biodiesel*

Properties	Units	Initial Conditions	Before Use Condition
Density at 15ºC	Kg/m3	843	852
Viscosity at 40ºC	mm2/s	3.205	3.308
Acid Value	mg IOD/g	0.59	0.61
Water Content	mg/kg	265	334

The basic function of the intake manifold of an Internal combustion (IC) engine is to deliver the fresh air from the atmosphere into the engine cylinder(s) and distributing air flow uniformly among the cylinders (Benajes, 1997). In the work of Paul and Ganesan (2010), the effects of the shape of intake manifold (helical threaded, spiral and helical-spiral combined) on swirl velocity was investigated numerically. The findings suggested that the combined helical-spiral intake manifold produced higher swirl velocity than the other configurations. Intake manifold of the diesel engine connects the air intake system with the inlet valve of the cylinder through which air is drawn into the cylinder. The flow taking place in the intake manifolds is really complex. Most of engine companies, recently, focus on variable intake manifold technology. Variable intake manifold are increasingly becoming popular as it increases the torque and thus engine performance at low speed without any penalty at high speed. However, design factors, such as low air flow resistance, good air distribution in fuel and sufficient heating of air, are important for determining the effective burning. In the work of Ceviz (2007), the influence of intake plenum volume on engine performance and emissions was investigated and found that the engine performance increased and the emissions of CO, CO2 and HC reduced at speeds about between 1700 and 2600 rpm with the increase of plenum volume. When the inlet valve of the cylinder is open, air available in the intake runner moves rapidly into the cylinder. When the inlet valve closes, this air stops abruptly and the air remaining in the runner stacks up, producing a high pressure area inside. Unless the intake runner is maintained just the right length, building up of this high pressure will not be helpful for the right air delivery into the cylinder. The air delivery may be improved by appropriately choosing the right length of the intake runner. In the work of Khan and Jahanzaib (2011), computational investigation of the flow behaviour of inner plenum was discussed for optimum torque. Simplified straight runners, smooth bends and the increase in the depth of plenum chamber were suggested for improving the engine performance. However, this technique is effective only for a narrow range of engine speeds. In smaller automobiles, many approaches are applied to increase the airflow of an IC engine system. Among them, turbochargers and superchargers mechanically force more air. These devices, however, additional mechanical load/friction and increase the inlet air temperature which may make add sensitivity to knocking problem. Proper design of an intake system and exhaust system can improve the low and midrange torque without affecting the compression ratio. Tabaczynski (1982) evaluated intake and exhaust system designs that could predict the tuning effects. However, these simple models could not effectively improve the volumetric efficiencies. In the work of Kumar et al. (2012), the influence of fuel injection pressure (160, 180 and 200 bars) and intake manifold inclination (0, 30, 60 and 90 degrees) on engine performance was investigated. The results showed that the 60 degrees intake manifold inclination at 160 bar produced the maximum engine power, better volumetric efficiencies and less pollutant emissions. One way of improving the air flow rates is the reduction of the air flow restriction through the Converging element. In the work of Abdullah et al. (2014), the influence of air intake pressure produced due to the absence of Converging was investigated. The results showed that the engine performance and fuel consumption were improved with the increased exhaust emissions in the case of intake system without filter.

2. METHODOLOGY:

2.1. Preparation of Biodiesel Blends:

Diesel is purchased from the local petrol bank. Biodiesel was prepared from the waste cooking oil collected from the local restaurants in Chennai, India. The chemicals, such as methanol and catalyst (sodium hydroxide) required for the esterification were purchased from the local market in Chennai, India. The collected waste oil was first filtered using micro filter that removes the unwanted solid particles. The heating then removes the moisture content. Transesterification process was used for the preparation of biodiesel with the molar ratio of methanol to waste cooking oil of 1:3 with the catalyst of about 1%. Biodiesel was then produced by using alkaline transesterification process and the prepared biodiesel is mixed with diesel to make B20 blends by adding 20% of biodiesel by volume with 80% diesel. Diesel was considered to be the reference fuel. From the beginning of raw material to the final product is explained in block diagram, where waste is collected separated finally. The block diagram for the preparation of biodiesel is given below:

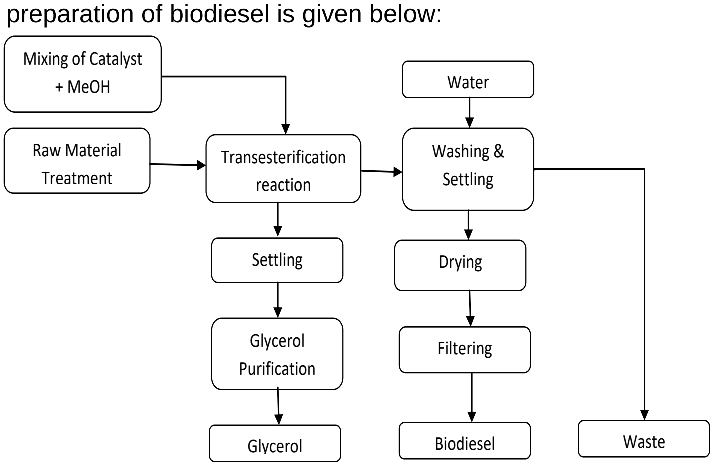


Figure 1: *Biodiesel production process*

2.2. Experimental Setup:

The proposed method is explained simply in block diagram as shown in figure 2, in which the air is entered into the engine intake manifold through Converging for the combustion process and after the combustion, the exhaust is released into the channel where it is tested for exhaust gas emission.

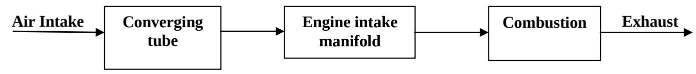


Figure 2: *Block diagram explaining theproposed modification*

[The experimental setup is given in the figure 3. In this work, a single cylinder and four stroke diesel engine of Kirloskar make (Model No. 10.101-2) was used. The intake manifold was modified with a Converging setup. Three kinds of Converging setup is used here with varying the ratios of outer and inner diameter while maintaining the length fixed. Three Converging diameter ratios were used in the work with 1.25, 1.50 and 1.75. Converging diameter ratio of 1 (regular pipe of same diameter) was considered as the reference. The Converging setup is threaded into the intake manifold so that the outer to inner diameter can be varied. The engine's power rating and maximum speed are 3.7 KW and 1500 rpm respectively. The engine is connected to eddy current dynamometer for the load to be applied. The load conditions (0, 20, 40, 60, 80 and 100 % of the full load rating) were considered in the experiment. The operating parameters were adjusted electronically with a control panel attached to the engine. It can be operated through a display unit attached to the control panel. The display unit could be used for displaying the values of those parameters. An exhaust pipe was connected to an EPM 1601 i3sys gas analyzer that can measure the emissions of various gases up to plus or minus 1 ppm accuracy.

Figure 3: *experimental setup (right)*

2.3. Engine Specification:

The engine used for the experiment is constant speed single cylinder diesel engine. The specifications of engine are given below including the compression ratio, spray angle, aspect ratio of orifices and displacement. The specification of constant speed single cylinder diesel engine is tabulated below:

***Table 2**. Specifications of constant speed diesel engine.*

Type	Diesel, direct injection, 4 stroke
Combustion Chamber	Quiescent(low turbulence)
139.Chamber diameter	97.8mm
Intake values	2
Exhaust values	2
Injection system	Electronic Unit Injector(UIS)
Displacement	2.333dm3
Bore / stroke	139.7mm/152.4mm
Connecting rod length	304.8mm
Nozzle orifice	8
Nozzle orifice diameter	0.200mm
Aspect ratio of orifices	4.1(length/diameter of orifices)
Spray angle	152º
Compression ratio	13.1

2.4. Experimental Procedure:

Before start of the test, the right Converging type of a particular outer to inner diameter ratio (for example 1) was fixed into the intake manifold. After fixing the Converging in the intake manifold, the measured quantity of fuel (B10 or diesel) was poured in a burette. Using the control panel, the engine was started and allowed to run for about 5-10 minutes so as to warm up and to become steady. After maintaining engine speed of the engine at 1500 rpm, experiments are conducted and measurements were observed. The engine performance (brake thermal efficiency and emissions characteristics (CO, HC and NOx) were then plotted in graphical form. The experiments were repeated for other Converging outer to inner diameter ratios (1.25, 1.5 and 1.75). The results were compared and discussed.

3. RESULTS & DISCUSSION:

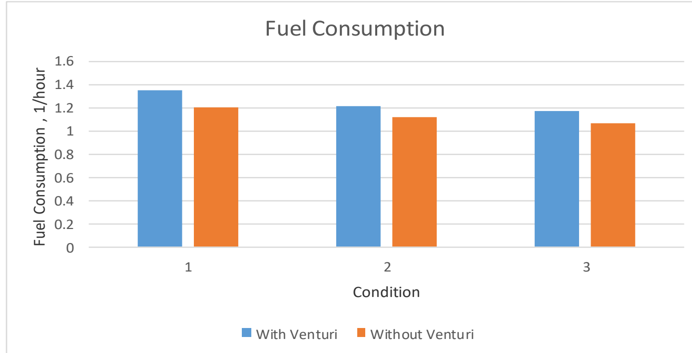
The analysis is carried out based on constant engine speed. This approach is to analysis output characteristics of biodiesel towards manipulation of load.

*[**Table 3**. The constant loads and engine speed*

Condition	Engine speed, rpm	Torque, Nm.	Power, Kw
Constant 1	3000	1	0.315
Engine 2	3000	2	0.625
Speed 3	3000	4	1.260

3.1. Fuel Consumption:

As from the fig 2, fuel consumption by engine is decreed for both the variables under constant engine speed analysis. Approximately 13.64% of fuel consumption is decreased when the Converging takes place. That is at condition 1 the fuel consumption (with Converging) is 1.356 1/hr, but at the condition 3 the fuel consumption is around 1.171 1/hr. For without Converging approximately 11.07% of fuel consumption is decreased. Comparison between with and without Converging, the fuel consumption is decreased for with Converging.



***[[[Fig 4**. Graph of fuel consumption*

Air fuel ratio will pays effect on fuel consumption. Whereas, in leaner air fuel ratio, the fuel consumption is less but in rich air fuel ratio, fuel consumption rate is high. As per load increases, the fuel consumption will also increase in order to maintain the same speed.

3.2 Air Intake Gauge Pressure:

The differences between both variables can't see in condition 1, because intake gauge pressure for both the variables are same. The difference can be seen in condition 2 and condition 3, where the intake air gauge pressure for (with Converging) is high and for (without Converging) is less. The air intake pressure at condition 1 for both the variables are at same level 18Pa, reason for this is, at initial the engine is running at 3000rpm even the load of 1Nm is applied. Because load is comparatively very small as considering with maximum load in which engine can withstand.

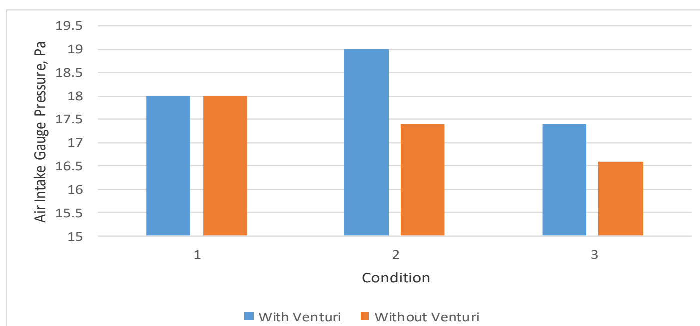


***Fig 5**. Graph of Air intake pressure gauge*

In condition 2 and condition 3, the load will affect the engine speed, because engine speed is the main parameter which affects the air intake gauge pressure. As the load applies, the engine speed will decreases, in order to maintain constant engine speed, engine will undergoes forced induction. So, the air intake gauge pressure is increased for with Converging, but for without Converging, the air intake gauge pressure is less, in which it's can't maintain same speed for applied loads. Forced induction is achieved with the help of compressor.

3.3 Exhaust Gas Temperature:

The fluctuation of exhaust gas temperature seen from condition 1 to condition 3 in without Converging is at higher rate. But, with Converging, fluctuation seen from condition 1 to condition 3 but at lower rates comparatively. In without Converging, the exhaust gas temperature is fluctuated at improper manner based on loads. In with Converging, fluctuation occurs at decreased rate at every condition of load.

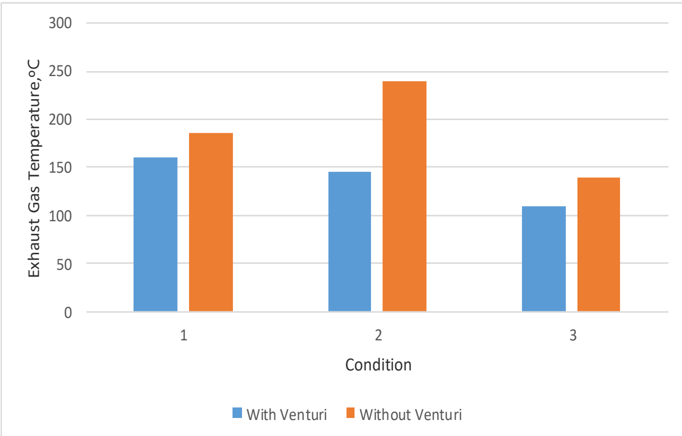


***Fig 6**. Graph of exhaust gas temperature*

Energy is in different form and heat is a type of energy in which during combustion, it releases. More efficient combustion will releases more heat energy in the form of exhaust gas temperature. The temperature of exhaust gas will reflects on the injection pressure. As exhaust temperature increases, the injection pressure will increases. In which the complete combustion will achieves due to injection pressure increases even for lean mixture.

3.4 Brake Thermal Efficiency (BTE):

Figure 7 shows the brake thermal efficiencies of various conditions. The BTE of diesel was higher than all other combinations. This was because of the lowered energy content of the biodiesel blends (B20). The calorific value of B20 is normally lower and was therefore expected to produce the lower engine performance. In addition, the kinematic viscosity of B20 was higher as compared to diesel, which makes poor atomization of B20 through the fuel injector. When the Converging was added to the intake manifold, the swirling of intake air was enhanced and, because of the Converging effect, the velocity and pressure increased. This in turn improved the combustion efficiency better. Due to the increased combustion, the torque developed would be higher and the BTE would be higher. As the ratio of outer to inner Converging diameter increased, the swirl velocity and mixing increased to produce higher BTE.

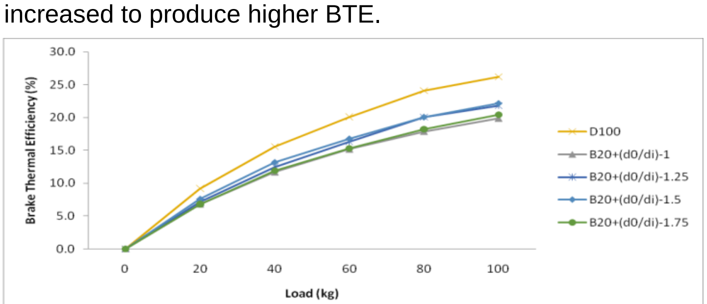


***Figure 7:** Brake thermal efficiency*

3.2. CO Emissions:

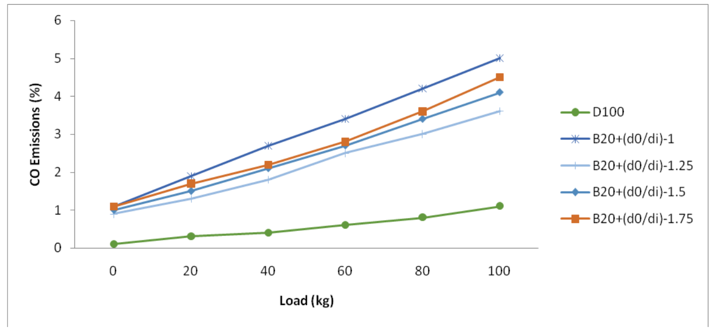


***Figure 8:** CO Emissions*

Figure 8 shows the carbon monoxide (CO) emissions. The CO emissions of diesel would be lower than B20 and other configurations. As the oxygen presence was higher in biodiesel, more CO concentration was converted into carbon dioxide (CO_2) and therefore the emissions of CO would be lower in case of B20. But, as opposed to this belief, due to high kinematic viscosity and the poor atomization causing improper burning, combustion efficiency would be lesser and CO emissions was found to be higher. However, with the Converging introduction, the mixing and heat distribution improved and therefore the more complete combustion than it was with B20 with no Converging. Hence, the addition of Converging reduced the CO emissions. As the ratio increased, the CO emissions reduced in accordance with the increase in the CO emissions.

3.3 HC Emissions:

Figure 9 shows HC emissions of the test conditions. HC emissions of diesel was found to be higher than the rest of the test configurations and blends. Biodiesel generally contains lower hydrogen content than that of diesel. Also some amount of hydrogen would react with oxygen to form water vapors. Therefore the HC emissions of biodiesel would be lower than diesel fuel. As expected, the HC emissions of B20 was found to be lower than diesel. The Converging effect further reduced the emissions of HC. As the ratio of outer to inner Converging diameter increased, due to the swirling velocity and proper mixing of air with B20, the burning of fuel blends was more complete and the unburnt HC emissions was lesser.

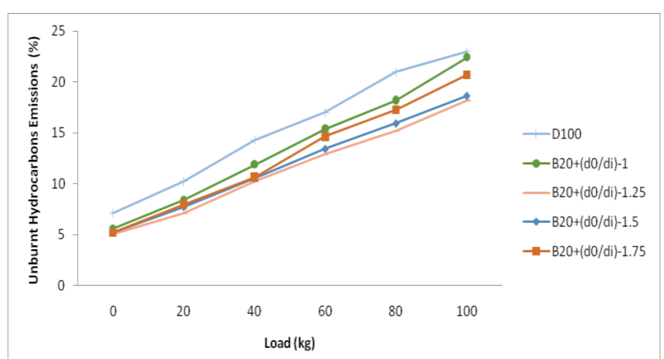


***Figure 9:** HC Emissions*

3.4 NOx Emissions:

Figure 10 shows the emissions of oxides of nitrogen (NOx). NOx forms only at higher temperatures. At lower temperatures, nitrogen and oxygen do not react to form NOx. From the results obtained, it was observed that NOx emission of diesel was lower than the remaining blends and configuration. The burning of diesel was considered to be more complete than biodiesel due to higher viscosity and poor atomization of B20. Due to higher oxygen presence, the flame temperature increased sharply and, due to high temperature, formation of NOx emissions would be higher. As the Converging effect was added, the swirl velocity of air was improved and the air pressure would also slight be improved. Due to the Converging effect, the temperature distribution was uniform and the pressure and consequently the temperature of air increased. The increased swirl velocity improved the uniform heating of fuel blends, and due to this, the NOx emissions initially reduced slightly lower than that of B20 for a ratio of 1.25. However, as the ratio increased to 1.5 and 1.75, the pressure improved significantly high due to reduced cross section of the Converging tube. Due to increased pressure, the temperature and consequently the combustion temperature would increase high and formed NOx higher than the other configurations. Thus, the Converging effect has only a little effect on NOx reduction.

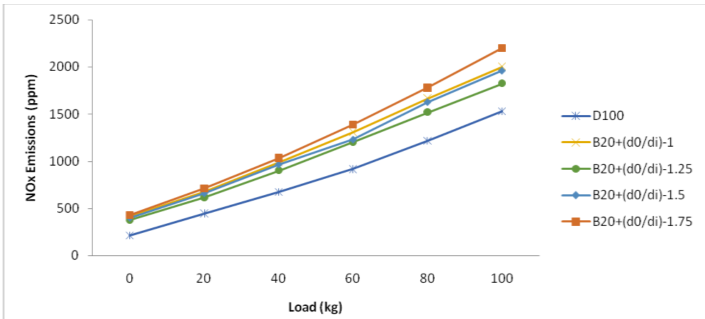


Figure 10: *NOx Emissions*

CONCLUSION:

In this work, the influence of modified intake manifold with a Converging tube of varying ratio of outer to inner diameter was investigated on the engine performance and emission characteristics. The ratios of 1, 1.25, 1.5 and 1.75 were considered for the Converging design in the intake manifold. The experiments were carried out in a single cylinder diesel engine of Kirloskar make of 3.7 kW power rating running at a constant speed of 1500 rpm. The measurements were taken for various load conditions, from no load, 20%, 40%, 60%, 80% to full load (100%), to determine engine performance and emissions. EPM 1601 i3sys gas analyzer was used to measure the emissions of exhaust gases such as CO, HC and NOx. From the results, it was observed that that the addition of Converging of ratios of outer to inner diameter increased the engine performance while reducing the emissions of CO and HC. On the whole, the diameter ratios of venture tube upto 1.5 would be promising for improving the engine performance and emissions characteristics of biodiesel blends in a single cylinder diesel engine.

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