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Investigation of Biogas Flow Analysis in Mixing Chamber by Using CFD, Performance and Emission Characteristics of Single Cylinder SI Engine

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Abstract-In this work, Design and fabrication of mixing chamber for biogas supply to the engine and CFD analysis of the mixing Chamber. Biogas is used as fuel for SI engine by the help of pressure conversion kit, study of different fuels like biogas blended with petrol, biogas blended with ethanol and 100 % biogas as fuel in single cylinder SI engine. Studied the performance, emission characteristics of single cylinder SI engine.
Keywords-Anaerobic digester, Biogas, Methane content, Quality, CFD, SI engine

I. INTRODUCTION

The world has been confronted with an energy crisis due to exhaustion of finite resources of fossil fuel, difficulties in their extraction and processing, leading to an increase of its cost. Also fossil fuels contribute an important role in accumulation of greenhouse gases which can ultimately pollute the environment. Fossil fuels are being used for the production of fuel, electricity and other goods. Excessive consumption of these fossil fuels has resulted in high levels of pollution during the last few decades. To overcome these problems the one of prominent resource is biogas. This biogas is produced from the waste food, fruit waste. In this work biogas is used as fuel for the SI engine.

II. ENGINE STUDY

Figure II-1. Computerized 4 stroke, single cylinder petrol engine test rig

1) Engine
2) Vaporizer
3) Emission analyzer
4) Biogas cylinder
5) Weighing machine
6) U tube manometer (air)
7) Speed encoder
8) Computer for p-ø curve
9) Fuel measuring burette
10) exhaust gas temp
11) pressure gauge

Engine spcifications

Table II-1. spcifications engine

Name	KIRLOSKER	Speed	3000rpm
Type	4 stroke single cylinder petrol engine	Swept volume / capacity	661.45cc
Power	2.2 kw	Displacement	256cc
Bore	75mm	SFC	500g/kwh
Stroke	166.7mm	AFR	14.7:1
Cooling	Air cooling	Compression ratio	4.87

Table 3-2. Properties of 5 samples taken for test

Fuel Sample	**Sample I Petrol**	**Sample II Pet + BG**	**Sample III BG**	**Sample IV Ethanol**	**Sample V Eth + BG**
% Petrol	100	50			
% Ethanol	00			100	50
%Biogas		50	100		50
Auto-ignition temperature (°C)	240	---	650-720	320	----
Calorific Value (kJ/kg)	42000	39500	37000	38800	37900
Density (kg/m^3)	747	----	0.720	780.5	------

III. THE CFD ANALYSIS OF MIXING CHAMBER

The CFD analysis of mixing chamber is carried out using CFD tool FLOWVISION. The 3D flow analysis is carried out to find out the mixing pattern of air and biogas before it entering in to the engine cylinder. In the mixing chamber, there two pipe mixing chamber has been taken 1)single input with an angle 0f 30^0 for biogas input 2) Two input biogas mixing chamber and elbow mixing chamber having one input with 3 different input angles for biogas supply. The angles are 10^0, 20^0, 30^0, Different models are analyzed in flow vision as follows.

A. *Single Pipe Mixing Chamber*

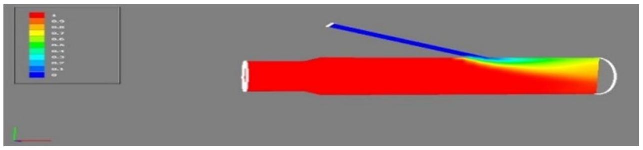

Figure III-1. Single pipe mixing chamber with boundary conditions

Model is created in UG modeling and taken in to the flow vision and assigning the boundary conditions.

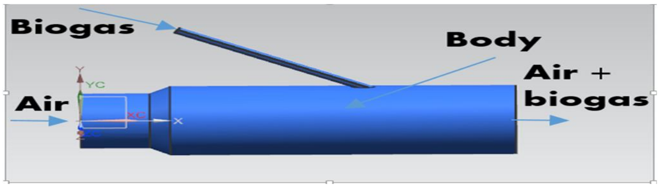

Figure III-2. Mixing pattern colored contour in sectional view.

Figure 3-2. Show that mixing of air and biogas when biogas input by the single inlet. In fig red color indicates as air and blue is

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biogas, in the front view it is clear that mixing is happening in upper layer as shown in fig where yellow indicates that mixing in proportion of 70% air and 30% biogas and light indicates that 50% air and 50% biogas.

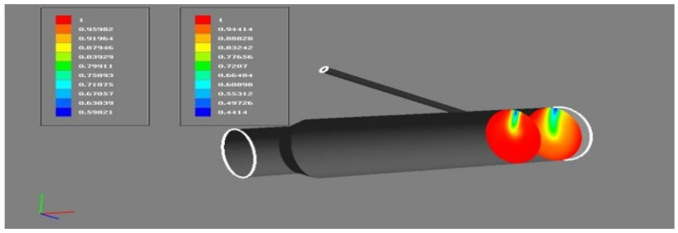

Figure III-3. Mixing pattern in the both circular plane.

Figure 3-3. Mixing of air and biogas is in circular planes it show that mixing of air and biogas is not homogeneous due to flow air due to suction pressure and biogas is more concentrated in middle and upper layer of the mixing chamber.

B. Pipe Mixing Chamber With Two Input

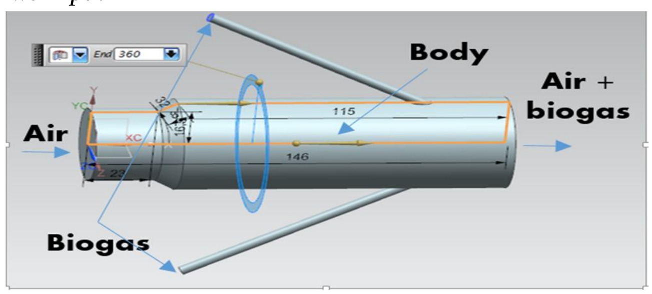

Figure III-4. Pipe mixing chamber with two inlets

Model is created in UG modeling and taken in to the flow vision and assigning the boundary conditions.

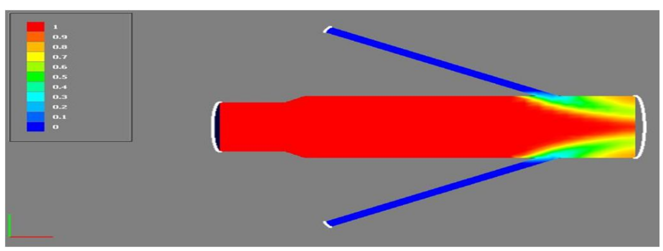

Figure III-5. Mixing pattern colored contour in sectional view.

The Figure 3-5. Show that mixing of air and biogas when biogas input by the two inlet. In fig red color indicates as air and blue is biogas, in the front view it is clear that mixing is happening in upper and bottom layer as shown in fig. where yellow indicates that mixing in proportion of 70% air and 30% biogas and light indicates that 50% air and 50% biogas.

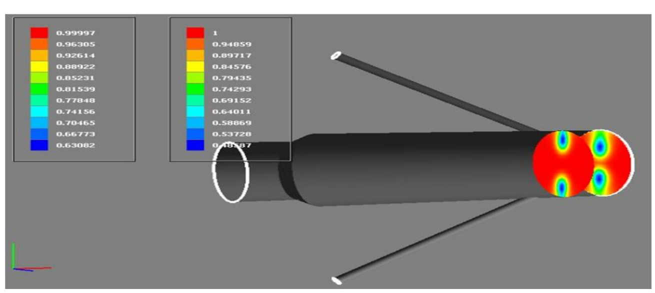

Figure III-6. Mixing pattern in the both circular plane.

From the figure 3-6. Mixing of air and biogas is in circular planes it show that mixing of air and biogas is slightly homogeneous due

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to flow of biogas is in the two inlet and it much better than the single pipe mixing chamber .

C. Elbow Mixing Chamber With Input Angle 10^0

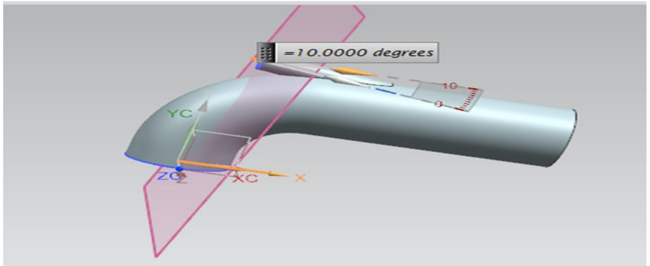

Figure III-7. Elbow mixing chamber with one inlet of angle 10^0.

Model is created in UG modeling and taken in to the flow vision and assigning the boundary conditions.

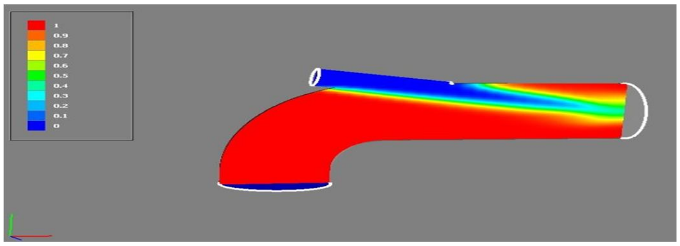

Figure III-8. Mixing pattern colored contour in sectional view

Figure 3-8. Show that mixing of air and biogas when biogas input by the one inlet with an angle 10^0. In fig red color indicates as air and blue is biogas, in the front view it is clear that mixing is happening in upper and middle layer as shown in fig. where yellow indicates that mixing in proportion of 70% air and 30% biogas and light indicates that 50% air and 50% biogas.

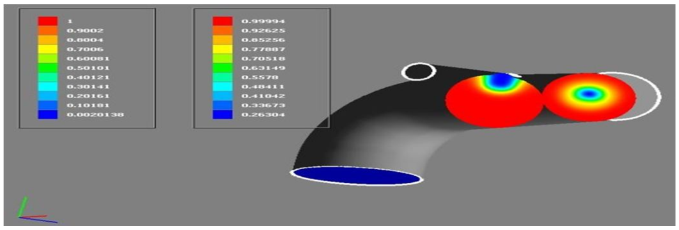

Figure III-9. Mixing pattern in the both circular plane.

From the figure 3-9. Mixing of air and biogas is in circular planes it show that mixing of air and biogas is slightly good mixture at the middle due to flow of biogas is in the two inlet and it much better than the angle of 10^0 inlet mixing chamber.

D. 20^0 Biogas Input

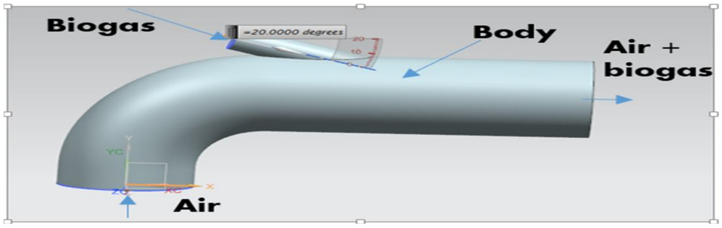

Figure III-10. Elbow mixing chamber with one inlet of angle 20^0

Model is created in UG modeling and taken in to the flow vision and assigning the boundary conditions.

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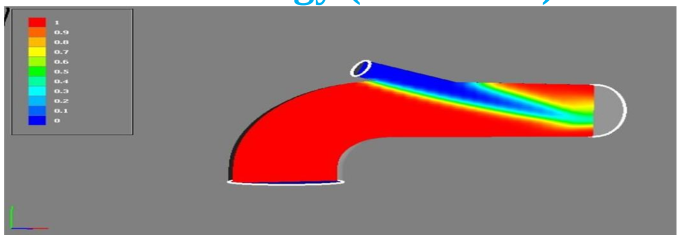

Figure III-11. Mixing pattern colored contour in sectional view.

The figure 3-11. Show that mixing of air and biogas when biogas input by the one inlet with an angle 10^0. In fig red color indicates as air and blue is biogas, in the front view it is clear that mixing is happening in upper and slightly middle layer as shown in fig. where yellow indicates that mixing in proportion of 70% air and 30% biogas and light indicates that 50% air and 50% biogas.

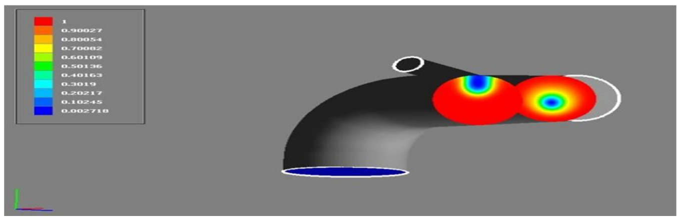

Figure III-12. Mixing pattern in the both circular plane.

From the figure 3-12. Mixing of air and biogas is in circular planes it show that mixing of air and biogas is slightly homogeneous due to flow of biogas is in the angle of 20^0 inlet mixing chamber. And it much better than the angle of 10^0 inlet mixing chamber.

E. 30^0 Biogas Input

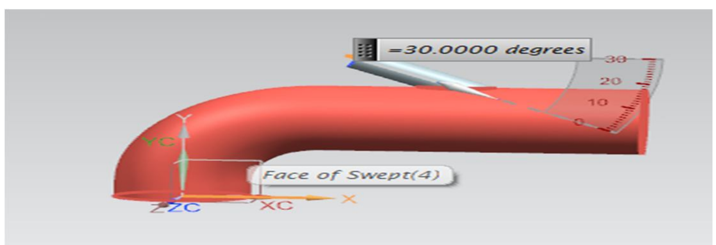

Figure III-13.Elbow mixing chamber with one inlet of angle 30^0.

Model is created in UG modeling and taken in to the flow vision and assigning the boundary conditions

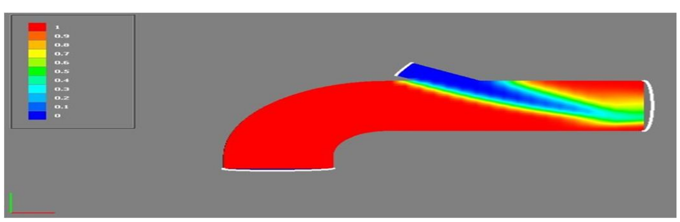

Figure III-14. Mixing pattern colored contour in sectional view.

The figure 3-14. Show that mixing of air and biogas when biogas input by the one inlet with an angle 10^0. In fig red color indicates as air and blue is biogas, in the front view it is clear that mixing is happening in upper and middle layer as shown in fig. where yellow indicates that mixing in proportion of 70% air and 30% biogas and light indicates that 50% air and 50% biogas.

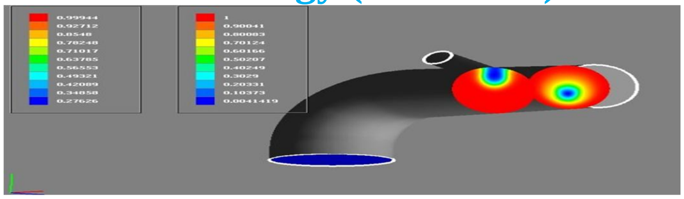

Figure III-15. Mixing pattern in the both circular plane.

From the figure 3-15. Mixing of air and biogas is in circular planes it shows that mixing of air and biogas is slightly homogeneous but the biogas pressure is 1 to 1.5 bar that will make to hit the gas at bottom of elbow that may cause damage of mixing chamber. Due to flow of biogas is in the one inlet with an angle of 30^0 and it not much better than the angle of 20^0 inlet mixing chamber.

F. Study Of Engine Performance

1) Brake Thermal Efficiency

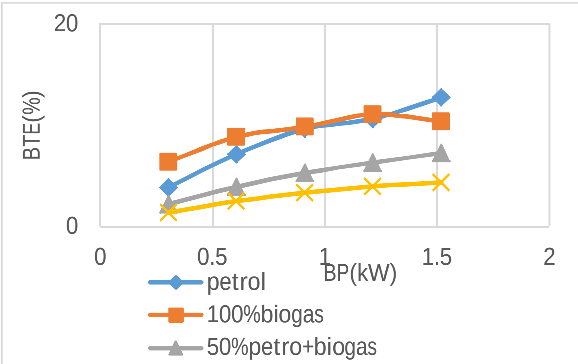

Figure III-16. The variation of BTE with BP of petrol, Ethanol and biogas and its blends.

From the figure 3-16. As brake power increases the BTE is increases for almost all fuels. This is by reason of decrease in heat loss and growth in power with growth in brake power. It is observed that petrol has higher thermal efficiency than biogas, biogas + petrol and biogas + ethanol. For the 100% biogas has initially more BTE compared with the petrol due to the complete combustion of mixture but it is decreases at the full load as result of increase of air suction the biogas will entered more this will decrease, other blends has less heating value. BTE it is inversely proportional to BSFC.

2) Brake Specific Fuel Consumption

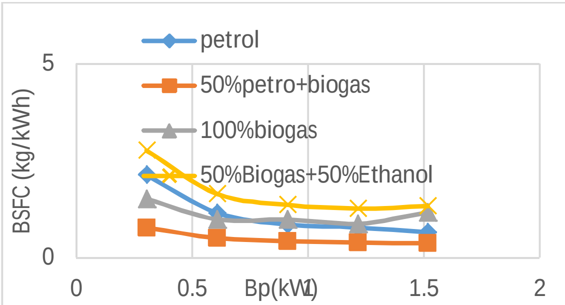

Figure III-17. The variation of BSFC with BP of Petrol, Ethanol and biogas and its blends

From the figure 3-17. For All the blends the BSFC decreasing of with respect to BP. The 50% blend of Ethanol-biogas fuel shows slightly higher BSFC compare to Petrol and other blends. This performance is attributed to the Heating Value per unit mass i.e. Calorific Value of the 50% blend of Ethanol-biogas fuel, which is clearly lower than that of the Petrol fuel ,which is higher value 1.32834(kg/kWh) of BSFC 1.51836 BP(KW). By taking the biogas as fuel the fuel consumption is slightly similarly up to load

1.21468728kw and bsfc is 1.1633(kg/kWh) and at full load BSFC is increases result of heating value is compared with the petrol.

3) ***B**rake Mean Effective Pressure*

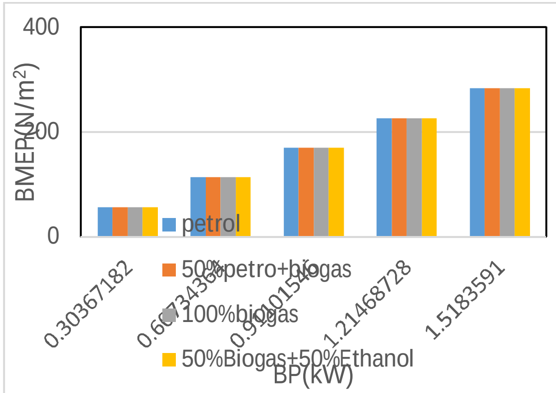

Figure III-18. The variation of BMEP with BP of Petrol, Ethanol and biogas and its blends

From the figure 3-18. The pressure variation is same in all loads as seen from the graph.

4) *Air Fuel Ratio*

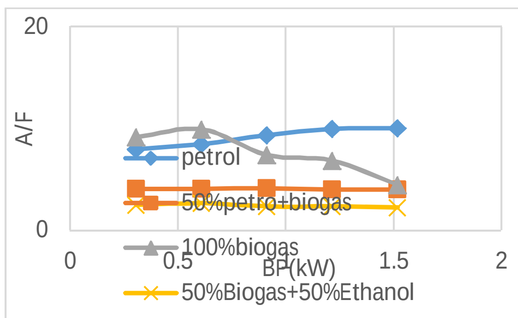

Figure III-19. The variation of Air fuel ratio with BP

From the figure 3-19. The A/F is increases with the increases in the BP for the petrol it is uniformly increases with respect load but for the 100%biogas the A/f ratio is decreases in the trend due to the as suction increase the fuel flow is increases due to the biogas is supplied with inlet air and the biogas has less heating value so at load increase amount of fuel required increase. For the other blends the A/f ratio is uniform. The stoichiometric A/F ratio for the petrol engine is 14.5.

5) *Air Flow Rate*

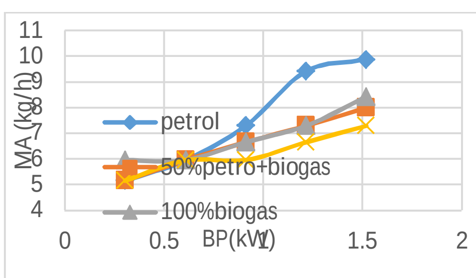

Figure III-20. The variation of mass air flow rate with BP

From the figure 3-20. Air flow rate is increases with increases in the BP and for petrol it is uniformly increases and similarly all blends air flow rate increases but compared to petrol it less in the biogas as seen above figure.

6) Fuel Flow Rate

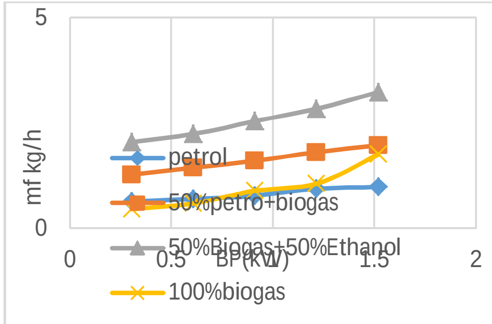

Figure III-21. The variation of (mf) fuel flow rate with BP.

From the figure 3-21. For all type of fuel the fuel consumption is increases with load in kW for the bland ethanol and biogas the fuel consumption is comparatively more due to very less heating value and for the 100% biogas the heating value is 37000kj/kg that is will near to petrol but at full load the flow rate increases due engine operate at the rich in mixture, similarly to the other blend the fuel flow rate is increases with load.

G. Emission Analysis

1) HC Emission

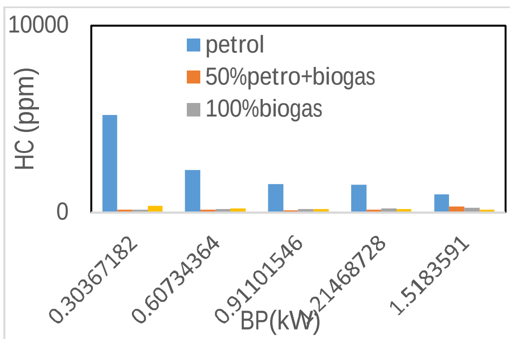

Figure III-22. Hydrocarbon emission with respect to BP.

From the figure 3-22. The HC emission is due incomplete combustion, richer mixture operating or misfire. The HC emission for petrol is more at initial staring due to the engine operating in riche mixture and as load increase it shifted to the lean mixture that will decreases the HC emission as seen in fig. the HC emission in 100% biogas is less in all loads for the 50% Ethanol + 50%biogas the HC emission is very low at the full load due to the presence of OH group in the Ethanol that will lead to sufficient oxygen for the complete combustion of fuel. For the blend 50%petrol+50%biogas the HC emission is less at the initial but as load increases the HC emission increase due increase in rich ness of the mixture.

2) CO% Emission

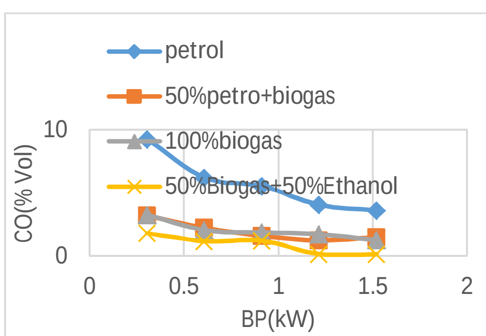

Figure III-23.Carbon monoxide emission with BP.

From figure 3-23. CO is the produce due to imperfect combustion due to inadequate amount of air in the air- fuel mixture. Ethanol have (OH) oxygen is mixed with biogas that will lead to complete combustion this will help in the reduction of CO emission, for 100% biogas and 50% biogas and 50% petrol presence of the gasses fuel and complete combustion will take place that will decrease the HC emission. HC emission of the petrol is more due to in complete combustion.

3) *CO_2 Emission*

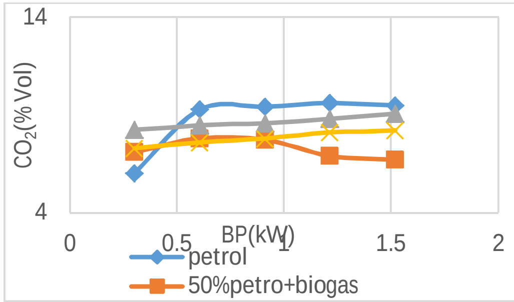

Figure III-24. Carbon dioxide emission with respect to BP.

From the figure 3-24. Widespread of oxidation of fuel outcomes in complete ignition to CO_2 rather than leading to the development of CO. From Fig 4-14, it is come know that the CO emissions for ethanol-biogas blend are lesser than the all other blended fuel. The stoichiometric air–fuel ratio of ethanol is about 2/3 that of petrol, hence the essential amount of air for complete combustion is lesser for ethanol-biogas, similarly for other fuels. Consequently CO_2 emission is reduced. Both CO and CO_2 are inversely related to each other.

4) *NOx Emission.*

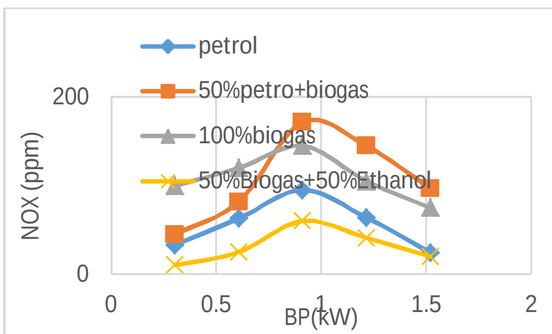

Figure III-25. Nitrogen oxides emission with respect to BP.

From the figure 3-25. Main reason contributing to NOx emissions take account of high flame temperature and presence of oxygen during combustion. Due to much lower flame temperature the ethanol -biogas contributes its NOx emissions are usually lower than that petrol. It apparent that any HC oxidation process that takes place during combustion of alcohol blends provides leaning of mixtures that lead lower NOx emissions.

5) *Exhaust Gas Temp In ^{0}C.*

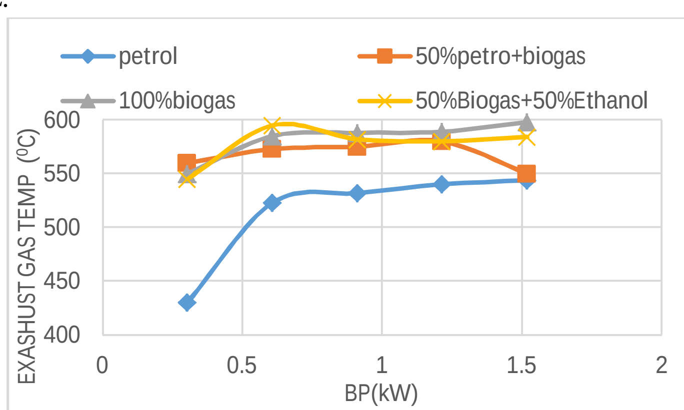

Figure III-26. Exhaust gas temp in 0C with respect to BP.

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From the figure 3-26. Exhaust gas temp is lower for petrol compared to other blends due to complete combustion may lead to the exhaust gas temp more at full load the exhaust gas temp is varies 550 to 600^{0}C

IV. CONCLUSIONS

From this experimental work main conclusions have been summarized about the biogas generation, gas flow analysis on CFD and its engine studies as follows

From the CFD analysis it is come to know that, mixing chamber have two inputs at angle of 30^0 will be the best for better mixing of biogas and air entering into the cylinder. In the mixing chamber having one input will also less mixing capacity.

From the CFD analysis given mixing capacity of elbow having one input with an angle 0f 20 degree will be better in mixing of biogas and air as compared with the inlet angle of biogas on elbow10^0 ,30^0.

We have been used fuel as Biogas, having 16% CO_2 and 82% of CH_4 for the SI engine. And compared with the petrol and blends like50% ethanol-50%biogas and 50%petrol-50%biogas.

It very easy to start the engine in petrol mode and shift to the biogas mode by cutting off the petrol manually or automatically. With the small modifications in inlet system and using extra unit vaporizer.

From the performance it is come know that BTE of the biogas is same as petrol engine but at full load it slightly decrease due to rich mixture operation which leads in complete combustion and for other blends BTE is comparably less. And petrol have BTE 11% and biogas will produce 10.23% up to part load, and at full load it will for petrol it will be 12% for biogas 10%.

BSFC for the 100% biogas is same as petrol up to part load at full load it will increases dude less heating value but in the blend 50%petrol-50%biogas is comparably lesser then petrol and other blends.

By exhaust gas emission analysis it is clear that biogas and its other blends are burns completely. Where the emission like HC, CO, CO_2 are very less as compared with petrol and HC emission is 60 to 70% less in biogas and its blends. And these blends are eco-friendly.

NO_X emission of the blend 50% ethanol-50%biogas is comparably less than petrol but for other blend it is slightly more compared with petrol. Exhaust gas temp is also more for biogas and its blends compare to petrol which is the region for the greenhouse effect.

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