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PERFORMANCE ANALYSIS OF CI ENGINE EMISSION BY ADMITTING STEAM WITH AIR

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Abstract - *To reduce the NO_xharmful gas from the CI engine by admitting steam with inlet air. The steam will be produced by using exhaust heat energy. For producing steam, shell and tube heat exchanger (counter flow) has been used in the project. The percentage of steam admitting with air will varying 3% and 5% by using pressure gauge. The steam flow position will vary without disturbing the air flow in the engine and it has analyzed by using CFD. And also pressure will be vary in steam admitted with air 0.5 bar, 1 bar, 1.5 bar. According to pressure vary the inlet temperature and velocity also vary in the inlet of engine and also easily analyzed the air-steam mixture in inlet by using CFD. The result showed that in combination of air-steam flow will reduces the harmful gas like CO, CO2, HC, NOx. Unfortunately the specific fuel consumption increased, brake thermal efficiency slightly decreased in the engine.*

Key Words*: *Brake thermal efficiency,Specific fuel consumption, emission rate (HC,CO_2,CO,NO_X)

1.INTRODUCTION

Several hazardous gases are generated when a combustion process takes on irrespective of the fact whether the process is efficient or not. These injurious gases include HC, CO, CO2 and NOx. In this project, particular attention has been focused on diesel engine performance combustion and pertaining to emission from automobiles because diesel engines emit more pollutants than gasoline engines. It is heartening to note that the performance and emission from automobile engines have attracted the attention of many investigators. Experiments conducted concerning performance and emission from diesel engines using steam flow. Normally all the literature shows that additive fuels with diesel which controls emission and also brake thermal efficiency increased, fuel consumption will be decreased while using additive fuel with diesel. This project mainly focused on diesel engine to reduce or control emission. Now a days, due to pollution we cannot able to breathe natural air in the atmosphere and also pollution damaging the earth's environment. In this project, we have only using single cylinder diesel engine and steam admitted to engine and to analyse the level emission. Now a days, some other companies moved from diesel engine cars to solar cars. Some other vehicle like trucks, buses. Heavy vehicle are not easily switched to any renewable resources, so that we used to flow steam to reduce the emission in single cylinder diesel engine.

2. METHODOLOGY

This chapter explains the concept of the exhaust and steam line setup. The ideas collected from literature review by studying various journals. By these ideas the setup was fabricated. Also explaining the materials used and design of the components.

2.1 Concept of the project

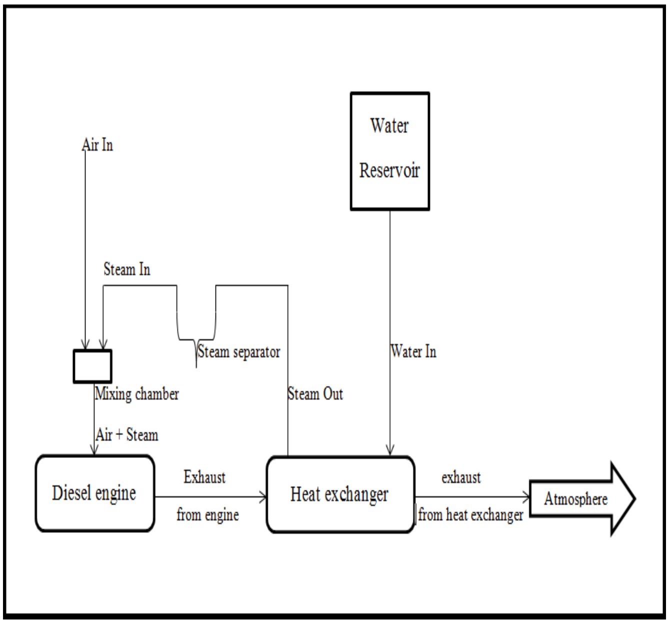

Fig. 2.1 Flow diagram

By the flow diagram, engine exhaust was sent into the heat exchanger. After losing some heat to water, that released into atmosphere. Same time the water is supply into the heat exchanger and take the steam out from another end of heat exchanger. Then the steam is enter into the mixing chamber through steam separator. Finally air + steam mixture was sent into the inlet of engine.

2.2 Heat exchanger

Fig. 2.2 Heat exchanger

In the project heat exchanger is one of the main component to produce steam. It is a counter flow shell and tube type heat exchanger. The water and exhaust gas is flow in the opposite direction. There are to reducer couplings are connected in each ends. One is used to increase the diameter and another is reducing the diameter. Then the copper coil is fixed inside the shell. Two ends of the coils are projected outside the shell. It will easy to connect water line and steam line with heat exchanger. Also additionally one valve is provided for safety purpose when the exhaust heat energy is more.

2.3 Copper tube coil

Fig. 2.3 Copper tube coil

In the project copper tube was used for producing steam. Copper is a good conductor of heat. This means that if heat one end of a piece of copper, the other end will quickly reach the same temperature. Thermal conductivity of copper is 394w/mk.Copper tube was made as a coil shape by manual bending. It shown in the fig. 2.3.

2.4 Engine specification

Table 2.1 Engine specification

Specification	Type/Range
Manufacturing	Texvel
Fuel	High speed diesel
No of cylinder	1
Power	4.8kw / 6.5hp
Speed	1500 rpm
SFC	250 g/kw
Bore diameter	85 mm
Stroke length	110 mm

2.5 Fabrication of the prototype

The main component of our project is heat exchanger. It is fixed in the exhaust manifold of diesel engine. The copper tube coil is fixed inside the steel pipe. This is counter flow heat exchanger. So the hot and cold particles are moving in an opposite direction. The water is stored in a reservoir. Then it is connected to rotameter through nylon tube. Flow control valve is fixed in outer end of rotameter. It is directly connected to the water inlet of heat exchanger through copper tube. Then the water outlet is going to steam separator. It has a U shape bend to drain the water particles from steam by gravity. Then the steam is send to the inlet manifold of engine through steam control valve. Orifice setup is fixed to measure the mass flow rate of engine inlet air and the air filter as well fixed before this. There are four thermocouples are fixed. First one is fixed in air and steam mixing area. Second one is fixed in exhaust gas before the heat exchanger. Third one is in exhaust gas after heat exchanger. And fourth is fixed to measure the steam temperature. These all ends are connected to temperature indicator switch.

2.6 Testing procedure

When an engine starts running, the hot exhaust gas is come out from the engine is sent to the heat exchanger. In the heat exchanger the heat energy is observed by the water. The continuous heat supply is used to convert the water into steam. After converted as a steam, the steam will flow to the U shaped steam separator to drain the water from steam. Then the steam send to the combustion chamber with mixing of air. Air steam mixer flow is controlled by the steam FCV. Pressure gauge is used to know quantity of steam entering into an engine. Same time the required amount of water is supplied by water control valve from reservoir. The water flow is measured by rotameter. The experimental testing was conducted for six different loading conditions out of six readings three readings were without steam and next three readings were with steam. Gas analyser setup is used as emission content measuring equipment. For performance test reading are taken from pressure gauge, thermocouple, etc,. Then the calculations are enclosed. Working condition is mainly taken from the literature in steam injection.

2.17 Conceptual design

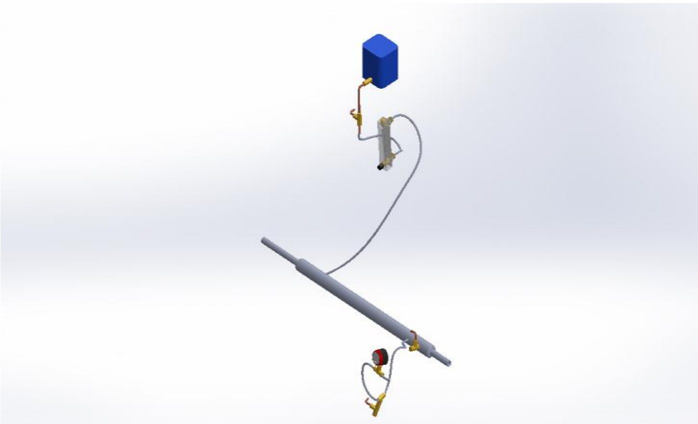

Fig. 2.5 Conceptual design

2.8 Project setup

Fig. 2.6 Project setup

3. RESULTS AND DISCUSSION

3.1 Experiment

The test was mainly conducted for reducing emission of diesel engine. So it tested under some experimental methods. The following things are explaining the procedure held and result.

3.1.1 Procedure

i. First the entire project setup had to fix in the engine.
ii. Then start the engine.
iii. All six readings are taken in constant speed and that should check and correct every single readings by using speedometer.
iv. Load of the engine was increased five kilograms for each using brake drum setup.
v. The emission test was conducted by AVL gas analyser for all six variables.
vi. And four temperatures, fuel consumption time, water flow rate and manometer heights are noted.
vii. Then required parameters are calculated using various formulas and tabulated.
viii. There are two set of readings taken and calculation as well. First three was without steam supply and another three was with steam supply.

3.1.2 Tabulations and graphs

S. No	Load (kg)	Time (s)	TFC (kg/s)	BTE (%)	CO (%)	CO2 (%)	HC (PPM)	NOX (PPM)
1.	0	84	0.35	0	0	0.06	32	622
2.	5	69	0.43	58	0	0.19	21	928
3.	10	57	0.52	83	0	0.33	17	1112

3.1.2.1 Result of emission test (without steam)

Table 3.1 Result of emission test (without steam)

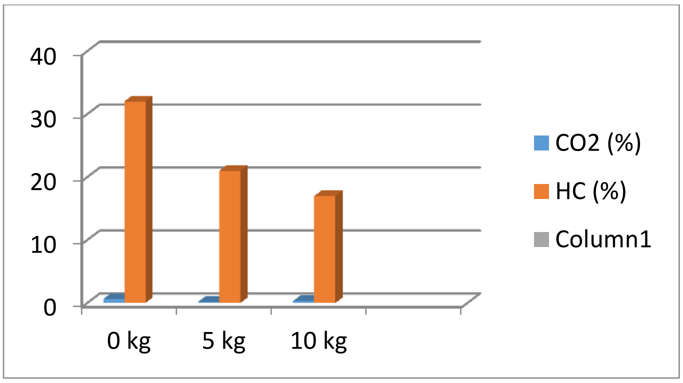

Fig. 3.1 Without steam

The bar chart 3.1 shows the emission level on without steam. When the load increase, the emission level also increased. Because the total fuel consumption was increased. The emission values of different gases are mentioned in the table.

Table 3.2 Result of emission test (with steam)

S. No	Load (kg)	Time (sec)	TFC (kg/s)	BTE (%)	CO (%)	CO2 (%)	HC (PPM)	NOX (PPM)
1.	0	73	0.40	0	0	0.01	0	195
2.	5	67	0.44	57	0	0.03	0	280
3.	10	53	0.56	77	0	0.07	0	669

3.1.2.2 Result of emission test (with steam)

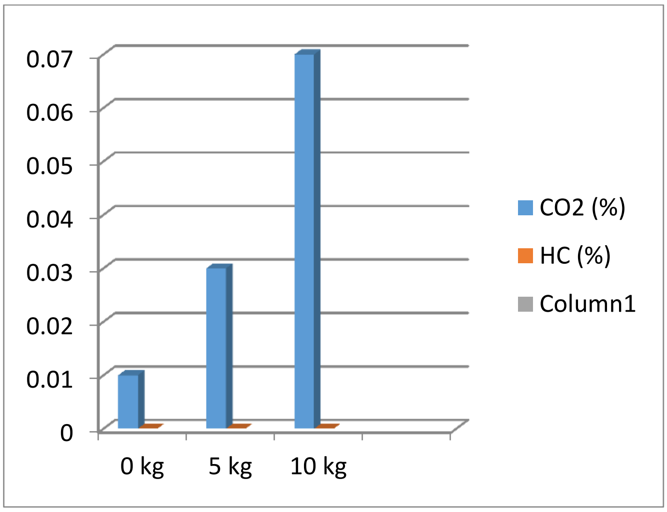

Fig. 3.2 With steam

Chart 4.2 shows the emission level of exhaust gas on with steam. After admitting the steam the emission level reduced. Other values are tabulated in table 3.1 and 3.2.

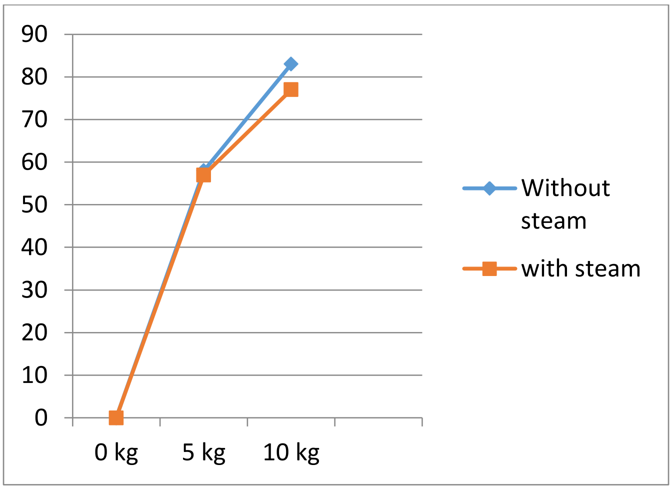

Fig.3.3 Brake thermal efficiency (%)

The line chart 3.3 is shown brake thermal efficiency for three different loads. When comparing these two lines the efficiency slightly reduced after adding the steam. While steam adding the efficiency is reduced 83% to 77% in 10 kg of load and 1% is reduced in 5 kg of load applied. There is no big drop in efficiency. It might come by manual errors.

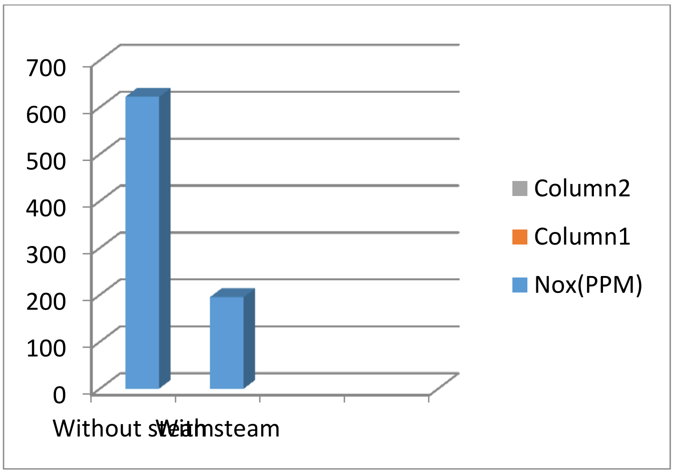

Fig.3.4 NO_xComparision

The main gas $NO_x$is reduced almost 622 PPM to 195 PPM on no load condition. Other load conditions values are given in the table 3.1 and 3.2.

3.1.2.3 Parameters

i. Load (kg)
ii. Time taken of fuel for 10 cm (sec)
iii. Total fuel consumption (kg/s)
iv. Brake thermal efficiency (%)
v. Carbon monoxide (%)
vi. Carbon dioxide (%)
vii. Hydro carbons (PPM)
viii. Nitres oxide (PPM)

3.1.3 Calculations

The main parameter brake thermal efficiency had to find. It is used to compare the efficiency level of the project. So, many additional formulas are used to find the brake thermal efficiency.

3.1.3.1 Without steam

For 0 kg:

$$Va = Cd\times A\times\sqrt{2gh}\times 6$$

$$h = (h1-h2)(\text{density of water}/\text{density of air})$$

$$= (35-29)(1000/1.16)$$

$$h = 5$$

$$Va = 0.62\times(\pi/4)\times(0.025)^2\times\sqrt{(2\times 9.81\times 51.72)}\times 60$$

$$Va = 0.58 m^3/min$$

Mass flow rate of air (assumption)

$$ma = \text{density of air}\times\text{volume of air}\times 60$$

$$= 1.16\times 0.58\times 60$$

$$ma = 40.36 kg/s$$

Total fuel consumption

$$TFC = Vcc\times\text{specific gravity of fuel}/(t\times 1000)$$

$$= 10\times 0.83\times 3600/(84\times 1000)$$

$$TFC = 0.339 kg/s$$

Mass flow rate of exhaust:

$$mg = ma + TFC$$

$$= 40.36+0.3559$$

$$mg = 40.719 kg/s$$

Brake thermal efficiency:

The load was zero, so the brake thermal efficiency also zero for first reading.

For 5kg:

Va = Cd× A×√2gh×6o

h = (h1-h2)(density of water/density of air)

= (35-29)(1000/1.16)

h = 51.72m

Va = 0.62×(π /4) ×$(0.025)^2$ ×√(2×9.81×51.72) × 60

Va = 0.58m^3/min

Mass flow rate of air:

ma = density of air× volume of air ×60

= 1.16×0.58×60

ma = 40.36 kg/s

Total fuel consumption:

TFC = Vcc×specific gravity of fuel/(t×1000)

= 10×0.83×3600/(69×1000)

TFC = 0.43kg/s

Mass flow rate of air (original):

mg = ma + TFC

= 40.36+0.43

mg = 40.79 kg/s

Brake thermal efficiency:

$$BTE = \frac{\text{brake power}}{Mf + Cv}$$

$$\text{Brake power} = \frac{2\pi N T}{60}$$

$$= \frac{2\pi \times 1500 \times 5 \times 14}{60}$$

Brake power = 10995.5 W

$$BTE = \frac{10995.5}{0.43\ (43350)}$$

= 58 %

3.1.3.2 With steam

For 0kg:

V = ($\pi \times D^2/128\mu$)(pressure of steam /length of pipe)

= ($\pi \times 0.008^2/128\times0.023$)(1bar/0.14)

V = 48.78m/s

Mass flow rate of steam:

ms = A×V

$=\left(\frac{\pi}{4}\right) \times d^2 \times 48.78$

ms = 2.45kg/s

Total fuel consumption:

TFC = Vcc×specific gravity of fuel/(t×1000)

= 10×0.83×3600/(73×1000)

TFC = 0.40kg/s

Brake thermal efficiency:

There is no load applied here. So the brake thermal efficiency was zero.

For 5kg:

V = ($\pi \times D^2/128\mu$)(pressure of steam /length of pipe)

= ($\pi \times 0.008^2/128\times0.023$)(1bar/0.14)

V = 48.78m/s

Mass flow rate of steam:

ms = A×V

$=\left(\frac{\pi}{4}\right) \times d^2 \times 48.78$

ms = 2.45kg/s

Total fuel consumption:

TFC = Vcc×specific gravity of fuel/(t×1000)

= 10×0.83×3600/(67×1000)

TFC = 0.44kg/s

Brake thermal efficiency:

$$BTE = \frac{\text{brake power}}{m_f + Cv}$$

$$\text{Brake power} = \frac{2\pi N T}{60}$$

$$= \frac{2\pi \times 1500 \times 5 \times 14}{60}$$

Brake power = 10995.5 W

$$BTE = \frac{10995.5}{0.43\,(43350)}$$

= 57 %

3.1.4 Additional calculations

The amount of heat energy released from engine exhaust gas and amount of heat energy gained from heat exchanger are additionally calculated. The percentage of steam supplied also calculated. Calculated values are taken from load five kilo gram in with steam.

3.1.4.1 Heat energy

Heat energy of exhaust gas:

$$Q_{exhaust} = m_g . C_p(\Delta T)$$

= 40.769×1.005× (148-30)

= 4837 kj/s

$Q_{exhaust}$ = 80.62 kw

Heat energy gained by water:

$$Q_{gained} = m_g C_p(\Delta T) + M(\text{latent heat})$$

latent heat of steam =2256 kj/kg

= 4.186(112-30)+2256

Q_{gained} =43.32 kw

3.1.4.2 Quantity of steam addition

Percentage of steam admitted in engine,

$$= \frac{\text{mass flow rate of steam}}{\text{mass flow rate of steam + mass flow rate of air}}$$

$$= \frac{2.45}{40.76 + 2.45}$$

steam admitted = 5.6 %

3.2 CFD Analysis:

This analysis is on flow of fluids and condition of fluids using CFD analysing software. It is used to know the conditions of fluids, while the air and steam mix at different positions. The parameters are get by varying the pressure of steam. That is 0.5bar, 1bar, 1.5bar. There two direction of steam flow has analysed. One is parallel to air flow another is inclined to air flow.

4.2.1 CFD results

For 0.5 bar pressure at parallel flow,

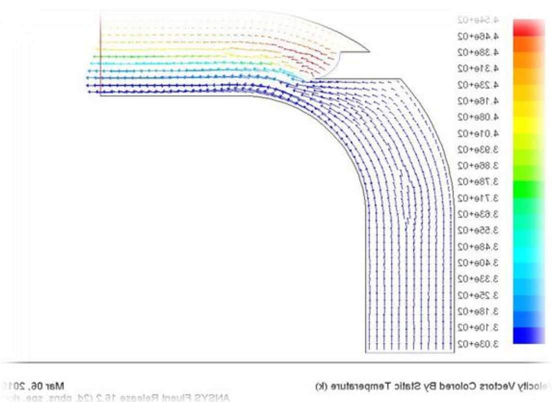

Fig 3.5 temperature diagram

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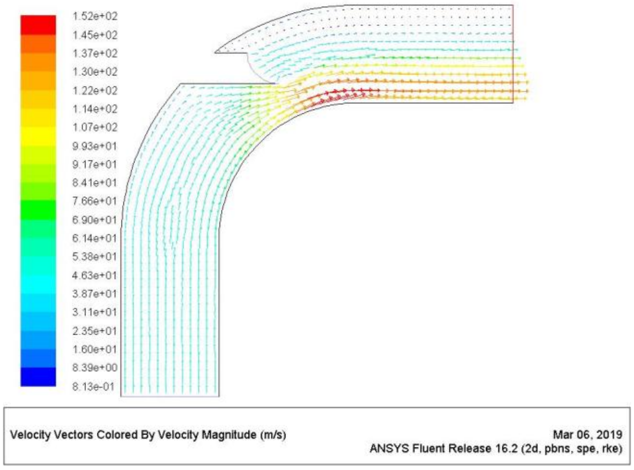

Fig 3.6 velocity diagram

For 0.5 bar pressure at inclined flow,

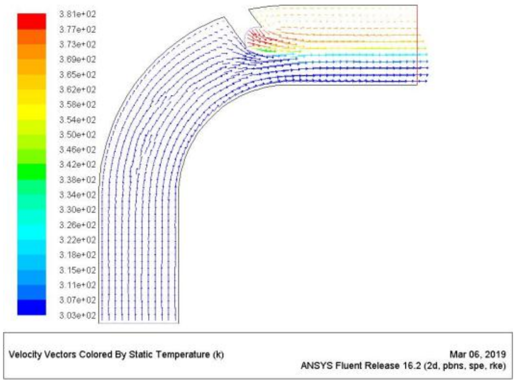

Fig 3.7 temperature diagram

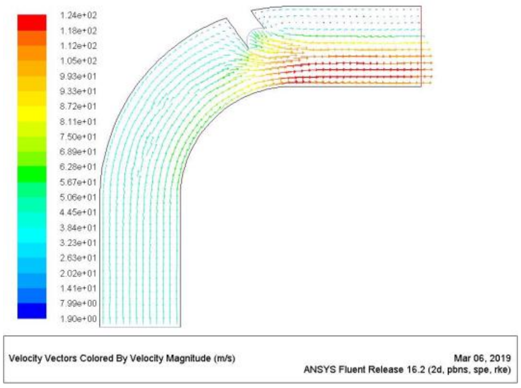

Fig 3.8 velocity diagram

3.2.2 Value table

Table 3.3 Parallel flow

S. No	Pressure (bar)	Velocity (m/s)	Temperature (K)
1	0.5	152.3	453.51
2	1	152.3	453.51
3	1.5	152.3	453.51

Table 3.4 Inclined flow

S. No	Pressure (bar)	Velocity (m/s)	Temperature (K)
1	0.5	123.7	381.14
2	1	123.7	381.14
3	1.5	123.7	381.14

The above two tables are shows the analysed vales of air steam mixing and flow values. Table 3.3 is for parallel flow of air and steam. Table 3.4 is for mixing angle of steam at inclined position.

4.CONCLUSIONS

So the project was concluded that, after admitting the steam, the emission level was reduced to half of it's normal emission level. But the brake thermal efficiency of the engine is reduced some percentages. So it have advantages and disadvantage as well. But the project main objective was achieved by reducing emission level. This project mostly run inside the components. So we can't exactly know what is happening inside. If want to improve this further, we have to go for advanced technologies.

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