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Performance & Emission Analysis of CI Engine under the Influence of two different Injecting Nozzles

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Abstract: *The performance of any engine can be determined by the efficiencies of engine. The research work in the field of performance includes the calculation and analysis of efficiencies and fuel consumption. The overall idea about the performance can be achieved by conducting the experiment. Moreover the study regarding the nozzle is also integrated in the research so that the main working principle and design of nozzle can be studied in detailed. Also the pollution is a major problem in today's life so this paper also includes the study and analysis regarding the exhaust gas emission created by the vehicles on road. Thus the integration of performance and emission study gives the perfect idea about the actual CI engine.*

Keywords: *CI engine, Efficiency, Emission, Nozzles, Performance, Combustion, Analysis*

I. Introduction

All the engines have their own specific performance level to which they can work. This differs from manufacturer to manufacturer, types of engine, capacity of engine. Here the focus is made on automobile diesel engine. The various parameter which are the core of performance of engine are mechanical efficiency, thermal efficiency, air-fuel ratio, fuel consumption and specific fuel consumption. The detailed study of above mentioned parameter will integrate into the performance of engine. This paper includes the analysis carries out regarding performance of engine. The paper also includes the methodology which is carried out to analysis the survey. The paper also includes the experimental setup and working of engine with view of performance which is the core part of the survey. The study of performance will give the general idea of the engine at which the engine give its best performance so that the mean working condition for the economy point of view is decided. Moreover the idea regarding the modification in the engine can also be came into the field for research work [8]. The modification is costly for the initial level but once it is ready it may be helpful to the field. Here in this research work the set of experiment is carried out for two-hole nozzle and then by single-hole nozzle. The performance achieved by these both level of experiment is achieved in the form of specific fuel consumption, fuel consumption, air-fuel ratio, indicated thermal efficiency, brake thermal efficiency and mechanical efficiency. Those values achieved by the experiment is to be presented into the form of graph to get the complete and proper idea regarding the performance.

One of the biggest energy sources in India is coal, followed by petroleum and routine biomass and waste. The diesel is imported from the foreign countries such as Iran, Iraq, and Saudi Arabia. There the diesel is available in abandon quantity and are rich in the petroleum fields [2]. The filtration processes are carried out an ultimately the petrol and diesel are obtained at particular temperatures according to the law of distillation. Peoples now a days prefer diesel car more as compared to that of petrol cars. The core reason for this excess demand of diesel vehicles is its running cost with respect to petrol engines. Everything having the positive sides also have some negative sides too. Diesel engine produces more amount of pollution as compared to petrol engines. With increase in demand of diesel vehicles there is increase in exhaust gases also. This paper includes the analysis carries out regarding the emission gases. The paper includes the methodology which is carried out to analysis the survey. The paper also includes the experimental setup and working of the gas analyser system which is the core part of the survey [3]. Now a day's government is also trying to reduce the emission by various rules and regulations. Recently in Delhi, the capital of India the rule was implemented of odd – even car series system which was also a steeping step toward the reduction and control over the harmful emission in the surrounding atmosphere [4].

II. Experimental Setup

The setup consists of single cylinder, four stroke, multi-fuel, research engine connected to eddy type dynamometer for loading and DC five gas analyzer connected measures five emission gases, including Hydrocarbons (HC), Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxygen (O2) and Oxides of Nitrogen (NOX) [10]. The operation mode of the engine can be changed from diesel to Petrol of from Petrol to Diesel with some necessary changes. The specification of the research engine is given in table-3. The operation mode of the engine can be changed from diesel to petrol of from petrol to diesel with some necessary changes. In both modes the compression ration can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement [1]. The injection point and spark point can be changed for research tests. Setup is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements [5]. The set-up has stand-alone panel box consisting of air box, two fuel flow measurements, process indicator and hardware interface. Rota meters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement. The setup enables study of VCR engine performance for brake power, indicated power, frictional Power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio[6]. Laboratory view based engine performance analysis software package "Engine soft" is provide for performance of experiment. Figure 2.1 shows the experimental set-up [7].

Fig.1: Experimental setup [9]

Table 1: Technical specification of the engine [11]

No. of cylinder	Single cylinder
No. of stroke	4
Cylinder dia.	87.5 mm
Stroke length	110 mm
C.R. length	234 mm
Orifice dia.	20 mm
Dynamometer arm length	185 mm
Fuel	Diesel
Power	3.5 kW
Speed	1500 rpm
C.R. range	12:1 to 18:1
Inj. Point variation	0 to 25 BTDC

III. Experimental Procedure

- First of all the water flow for the cooling of engine is turned on and then the engine is cranked with the handle and started.
- During this testing the two-hole nozzle having two holes for the fuel supply is fitted in the engine assembly along with the injector.
- Then the fuel line in the filled with the diesel and allowed to stable.
- The knob for the load is set at load 1 and the pressure is set at the high level by adjusting the pressure adjusting screw on the injector.
- Then the "Enginesoft" software is attached to the engine setup and the start of reading is done.
- The software takes 60 seconds for taking the reading of any specific reading.
- Then the load and pressure is adjusted as per the table and 21 readings were taken as per table and individual software files are saved.
- Then the engine is stopped and the injector bolts are loosen and the nozzle with two holes is removed from injector and nozzle with single hole is fitted in the injector and the engine is again started.
- The same procedure is followed again for the single-hole nozzle having the single hole for the fuel supply.

IV. Observation

Table 2: Observation Table for Two-hole nozzle

Ex. No	Injection Pressure	Load	Speed rpm	FC cc/min	Air mmwc	O_2 %	CO_2%	HC ppm	CO %	No_x ppm
1	High	1	1534	8	59.17	19.28	0.9	10	0.07	88
2	High	3	1529	10	58.49	19.23	1.1	25	0.05	184
3	High	5	1496	12	55.81	18.66	1.3	27	0.03	321
4	High	7	1468	14	53.74	18.13	1.7	34	0.03	535
5	High	9	1468	16	53.17	17.98	1.8	45	0.03	769
6	High	11	1453	18	51.89	17.52	2	29	0.02	837
7	High	13	1456	21	51.22	17.33	2.1	54	0.03	992
8	Medium	1	1544	8	59.94	18.87	1	25	0.06	119
9	Medium	3	1527	10	58.5	18.91	1.1	27	0.04	201
10	Medium	5	1517	12	57.65	18.66	1.3	32	0.03	339
11	Medium	7	1462	13	53.39	18.14	1.6	41	0.03	531
12	Medium	9	1472	16	53.16	18	1.8	49	0.02	795
13	Medium	11	1460	18	52.06	17.48	2	36	0.02	874
14	Medium	13	1461	20	51.57	17.31	2.1	65	0.03	1050
15	Low	1	1554	8	60.54	19.27	1	26	0.05	137
16	Low	3	1551	10	59.92	18.87	1.1	29	0.04	222
17	Low	5	1485	11	55.79	18.56	1.4	20	0.04	333
18	Low	7	1497	14	55.99	18.44	1.5	34	0.03	539
19	Low	9	1493	16	54.94	17.98	1.8	48	0.02	830
20	Low	11	1467	18	52.67	17.57	1.9	45	0.02	904
21	Low	13	1449	21	50.85	17.27	2.1	73	0.03	1066

Table 3: Observation Table for Single-hole nozzle

Ex. No	Injection Pressure	Load	Speed rpm	FC cc/min	Air mmwc	O_2 %	CO_2%	HC ppm	CO %	No_x Ppm
1	High	1	1503	12	56.88	19.47	1	37	0.15	12
2	High	3	1505	10	56.97	18.92	1.3	31	0.04	256
3	High	5	1406	11	51.43	18.22	1.4	33	0.03	387
4	High	7	1442	14	53.79	18.17	1.6	38	0.03	460
5	High	9	1462	16	52.37	17.66	1.8	33	0.02	542
6	High	11	1464	18	51.85	17.45	1.9	45	0.02	807
7	High	13	1454	21	51.12	17.14	2.1	50	0.02	951
8	Medium	1	1484	11	55.45	19.26	1	22	0.06	80
9	Medium	3	1486	10	55.63	18.72	1.1	26	0.05	123
10	Medium	5	1414	12	49.55	18.29	1.3	32	0.04	275

11	Medium	7	1458	14	52.24	17.98	1.6	37	0.03	455
12	Medium	9	1455	16	52.25	17.69	1.8	37	0.02	612
13	Medium	11	1468	18	52.06	17.43	2	48	0.02	853
14	Medium	13	1458	20	51.38	17.18	2.1	56	0.02	983
15	Low	1	1504	8	57.48	19.23	1	28	0.08	67
16	Low	3	1498	10	56.52	18.76	1.1	28	0.05	117
17	Low	5	1460	11	53.43	18.41	1.4	35	0.04	279
18	Low	7	1454	14	52.47	17.99	1.6	41	0.03	480
19	Low	9	1464	16	52.55	17.71	1.8	41	0.02	644
20	Low	11	1459	18	51.77	17.47	1.9	51	0.02	856
21	Low	13	1477	20	52.56	17.2	2	59	0.02	990

Table 4: Nozzle specifications

Two Hole Nozzle	Single Hole Nozzle
	
Nozzle 1	Nozzle 2
Two fuel Holes One Leak-off port	One fuel Hole One Leak –off port

V. Result And Discussion

Table 5: Result table for two-hole nozzle

SFC kg/kWh	FC kg/hr	Air kg/hr	A/F ratio	Torque Nm	IP kW	BP(kW)	FP kW	ITHE %	BTHE%	Mech. Eff. %	Vol. eff.%
1.41	0.4	25.35	63.4	1.76	4.92	0.28	4.64	103.34	5.88	5.69	69.28
0.57	0.5	25.2	50.42	5.46	5.65	0.87	4.78	94.94	14.62	15.4	69.11
0.43	0.6	24.62	41.05	9	6.23	1.41	4.82	87.23	19.74	22.63	69
0.36	0.7	24.16	34.53	12.78	6.4	1.96	4.44	76.81	23.52	30.63	69
0.32	0.8	24.03	30.05	16.47	6.83	2.53	4.3	71.73	26.57	37.04	68.63
0.28	0.9	23.74	26.38	21.14	7.13	3.22	3.91	66.56	30.06	45.16	68.49
0.29	1	23.58	22.47	23.66	7.53	3.61	3.92	63.26	30.33	47.94	67.91
1.41	0.4	25.51	63.8	1.76	5.04	0.28	4.76	105.86	5.88	5.56	69.28
0.58	0.5	25.2	50.43	5.41	5.7	0.86	4.84	95.78	14.62	15.09	69.21
0.42	0.6	25.02	41.72	9.05	6.13	1.44	4.69	85.83	20.16	23.49	69.15
0.34	0.6	24.08	37.06	12.44	6.27	1.91	4.36	87.79	26.74	30.46	69.05
0.31	0.8	24.03	30.04	16.52	6.69	2.54	4.15	70.26	26.78	37.97	68.43
0.29	0.9	23.78	26.43	20.09	7.05	3.07	3.98	65.81	28.66	43.55	68.28
0.28	1	23.66	23.67	23.61	7.55	3.61	3.94	63.43	30.33	47.81	67.91
1.41	0.4	25.64	64.13	1.75	5.13	0.28	4.85	107.75	6.09	5.46	69.18
0.57	0.5	25.51	51.04	5.45	5.69	0.88	4.81	95.61	14.95	15.47	68.96

0.4	0.5	24.61	44.77	8.89	5.9	1.38	4.52	99.14	23.19	23.39	69.49
0.35	0.7	24.66	35.24	12.62	6.44	1.98	4.46	77.29	23.76	30.75	69.06
0.31	0.8	24.43	30.54	16.4	6.77	2.56	4.21	71.1	26.88	37.81	68.59
0.29	0.9	23.92	26.58	20.12	6.98	3.09	3.89	65.16	28.84	44.27	68.35
0.29	1	23.5	22.39	23.51	7.55	3.56	3.99	63.43	29.99	47.15	68

Table 6: Result table for two-hole nozzle

SFC kg/kWh	FC kg/hr	Air kg/hr	A/F ratio	Torque Nm	IP kW	BP(kW)	FP kW	ITHE %	BTHE%	Mech. Eff. %	Vol. eff.%
2.19	0.6	24.85	41.44	1.75	4.68	0.27	4.41	65.53	3.78	5.77	69.33
0.56	0.5	24.87	49.77	5.67	4.77	0.89	3.88	80.15	14.95	18.66	69.29
0.42	0.52	23.63	42.98	8.85	4.95	1.3	3.65	83.17	21.84	26.26	70.47
0.37	0.7	24.17	34.54	12.55	6.13	1.9	4.23	73.57	22.8	31	70.27
0.32	0.8	23.85	29.82	16.42	6.2	2.51	3.69	65.11	26.36	40.48	68.39
0.3	0.9	23.73	26.38	19.77	6.63	3.03	3.6	61.89	28.28	45.7	67.96
0.29	1	23.56	22.45	23.98	7.25	3.65	3.6	60.91	30.67	50.34	67.94
2.03	0.5	24.54	44.63	1.73	4.64	0.27	4.37	77.96	4.54	5.82	69.33
0.57	0.5	24.58	49.17	5.61	4.59	0.87	3.72	77.12	14.62	18.95	69.34
0.46	0.6	23.2	38.68	8.89	4	1.32	2.68	56.01	18.48	33	68.78
0.37	0.7	23.82	34.04	12.55	5.56	1.92	3.64	66.73	23.04	34.53	68.49
0.33	0.8	23.82	29.79	16.16	6.19	2.46	3.73	65.01	25.83	39.74	68.64
0.3	0.9	23.78	26.43	19.71	6.52	3.03	3.49	60.86	28.28	46.47	67.91
*0.27	1	23.62	23.63	23.94	7.28	3.65	3.63	61.16	30.67	50.14	67.92
1.16	0.4	24.98	62.48	2.2	3.91	0.35	3.56	82.12	7.35	8.95	69.64
0.57	0.5	24.77	49.57	5.59	4.58	0.88	3.7	76.96	14.79	19.21	69.34
0.4	0.5	24.09	43.81	8.94	5.01	1.36	3.65	84.18	22.85	27.15	69.17
0.37	0.7	23.87	34.11	12.51	5.58	1.9	3.68	66.97	22.8	34.05	68.83
0.32	0.8	23.89	29.87	16.18	6	2.48	3.52	63.01	26.04	41.33	68.41
0.3	0.9	23.71	26.36	19.6	6.49	2.99	3.5	60.58	27.91	46.07	68.14
0.27	1	23.89	23.9	24.09	7.32	3.72	3.6	61.5	31.25	50.82	67.81

Discussion of Results for Performance

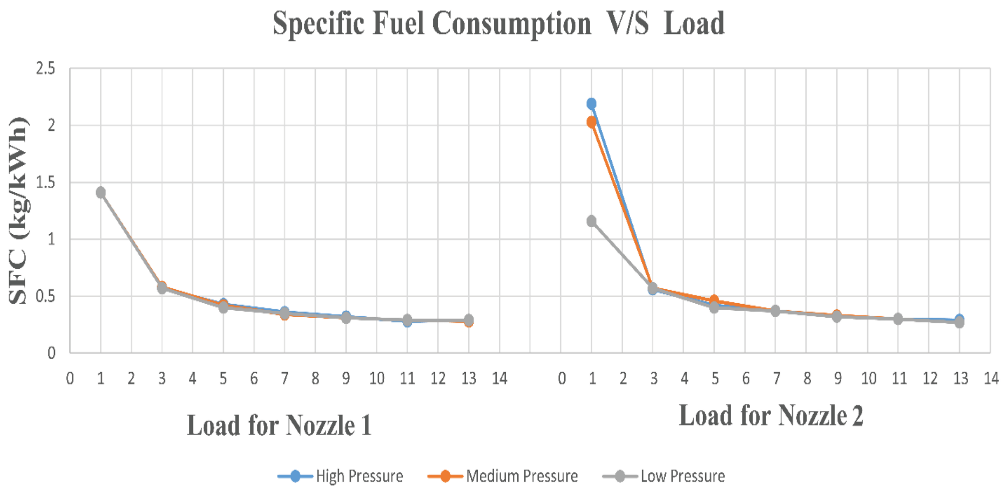

Fig.2: Specific fuel consumption V/S Load

Figure 2 shows the Specific Fuel Consumption V/S Load graph for two-hole nozzle and single-hole nozzle. Specific fuel consumption is same for the loading condition of load 3 to load 13.But the Specific Fuel Consumption is more for load 1 for both nozzle, moreover the Specific Fuel Consumption for load 1 in single hole nozzle is more as compared to two-hole nozzle with a huge fluctuations for all the three injection pressure.

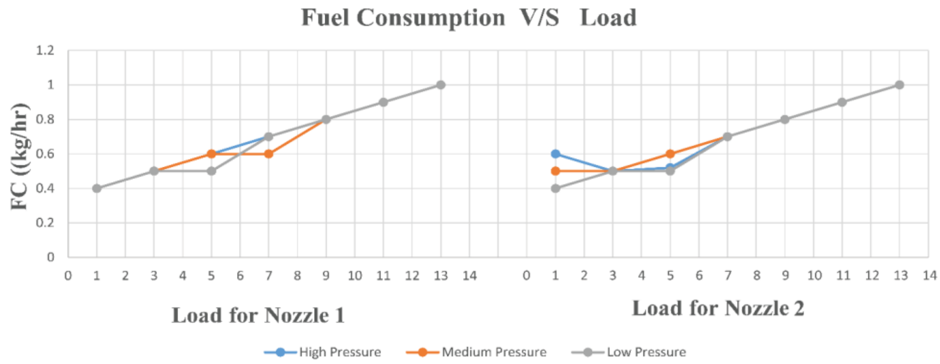

Fig.3: Fuel consumption V/S Load

Figure 3 shows the Fuel Consumption V/S Load graph of two-hole nozzle and single-hole nozzle. The Fuel consumption for single-hole nozzle and two-hole nozzle is same for the load condition 9 to 13 is same for all the three injection pressure. The Fuel consumption vary for load 3 to 8 in both the nozzle, but at the same time Fuel consumption becomes constant for all the three injection pressure at load 1 only of single-hole nozzle whereas two hole nozzle shows a drastically change at all the three pressure at load 1.

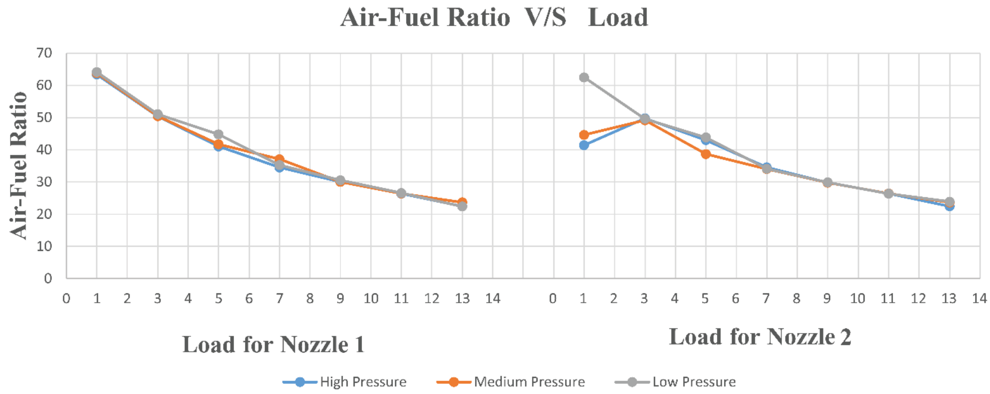

Fig.4: Air-Fuel Ratio V/S Load

Figure 4 shows the graph for Air-fuel Ratio V/S Load, from the graph we can conclude that the air - fuel ratio is inversely proportional to the load. In other words as the load increases the air-fuel ratio is decreased. For both the nozzle the air-fuel ratio is almost same at all the load condition of both the nozzles. But for single-hole nozzle the air fuel ratio is reduced at load 1 for high and medium pressure.

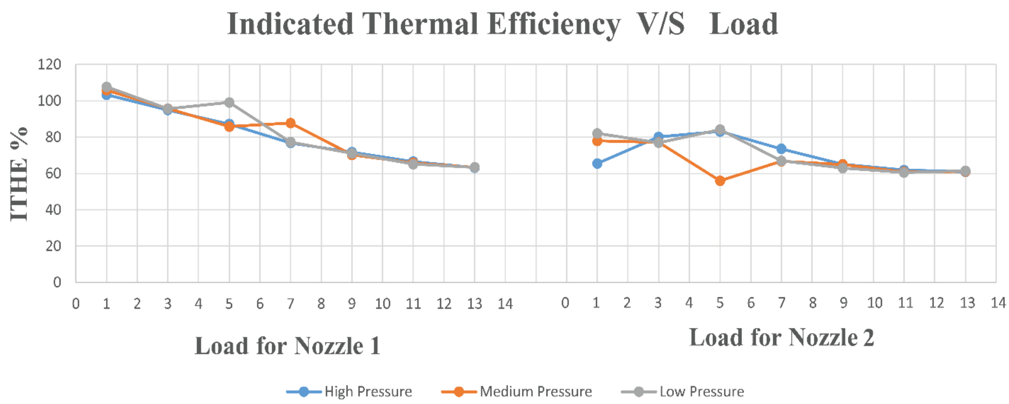

Fig.5: Indicated thermal efficiency V/S Load

Figure 5 shows the graph for Indicated Thermal Efficiency V/S Load for two-hole nozzle and single-hole nozzle. The indicated thermal efficiency for single-hole nozzle and two-hole nozzle is same at higher load from 9 to 13. But the fluctuation occurs from load 1 to 7. For two-hole nozzle the Indicated thermal efficiency is reduced for medium pressure whereas for single-hole nozzle it is increased for medium pressure.

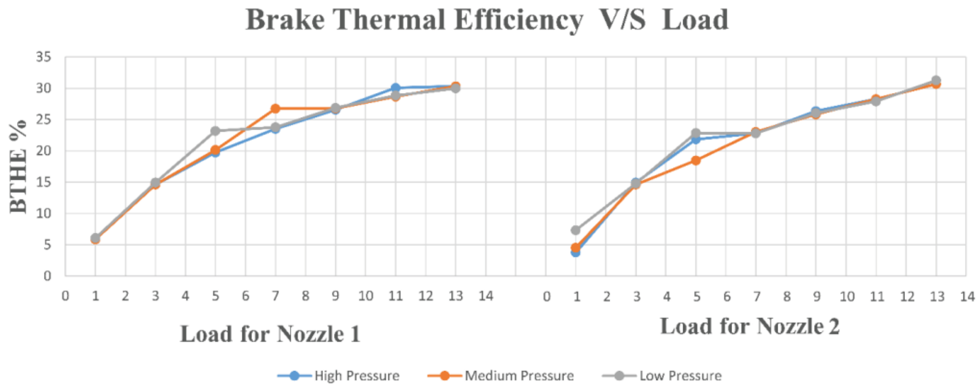

Fig.6: Brake thermal efficiency V/S Load

Figure 6 shows the Brake thermal efficiency V/S Load for two-hole nozzle and single-hole nozzle. Brake thermal efficiency for single-hole nozzle and two-hole nozzle are same for load 7 to load 13.But fluctuate occurs for load 1 to load 5. Moreover it is concluded that brake thermal efficiency fluctuation for two-hole nozzle in same manner for different injection pressure whereas fluctuation for single-hole nozzle in different manner for different injection pressure.

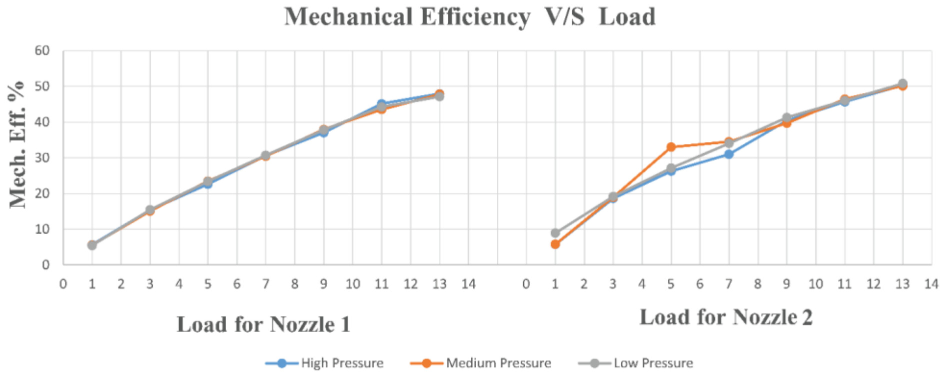

Fig.7: Mechanical Efficiency V/S Load

Figure 7 shows the graph of Mechanical efficiency V/S Load for two-hole nozzle and single-hole nozzle .Mechanical efficiency if same for two-hole nozzle and single-hole nozzle for load 9 to load 13. But for load 1 to load 8 the mechanical efficiency is fluctuated for single-hole nozzle for all the three injection pressure. Whereas for two-hole nozzle the mechanical efficiency is increasing linearly with the increase in load without any fluctuation

Discussions of results for Emission

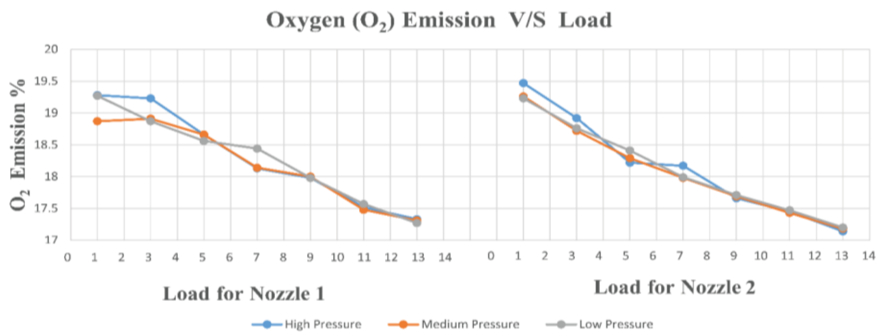

Fig.8: Oxygen V/S Load

Figure 8 shows the graph for Oxygen emission V/S Load. The Oxygen gas emission for diesel engine is decreasing linearly with the increase in the load on engine. In other words Oxygen emission is inversely proportional to the load. The amount of oxygen emission for two-hole nozzle is little bit of more amount as compared to the single-hole nozzle. The amount of oxygen varies from 19.5% to 17 % for load range of 1 to 13.

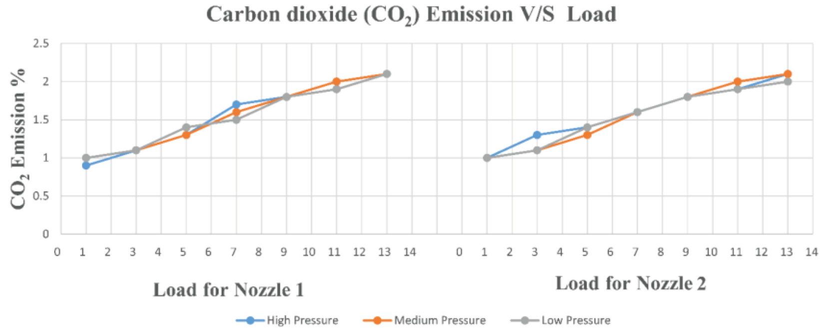

Fig.9: Carbon dioxide V/S Load

Figure 9 shows the graph for Carbon dioxide emission V/S Load. The Carbon dioxide gas emission for diesel engine is increasingly linearly with the increase in the load on engine. In other words carbon dioxide emission is directly proportional to the load. The amount of carbon dioxide emission for two-hole nozzle is same as for single-hole nozzle. The amount of carbon dioxide varies from 0.5 % to 2.5 % for load range of 1 to 13.

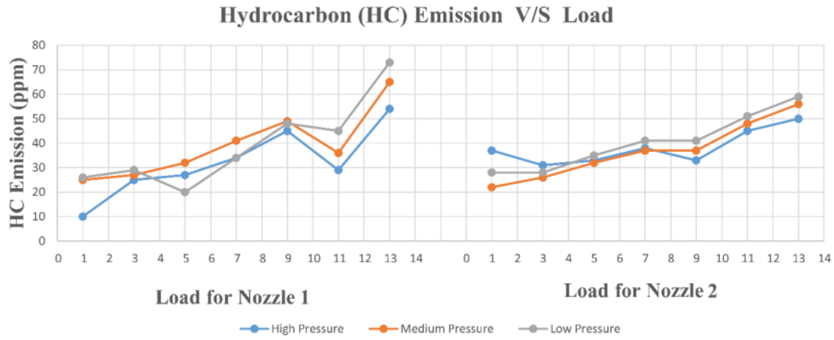

Fig.10: Hydrocarbon V/S Load

Figure 10 shows the graph for Hydrocarbon emission V/S Load. The amount of hydrocarbon emission for diesel engine is increasingly having slight variation with the increase in the load on engine. In other words amount of hydrocarbon is proportional to the load. The amount of hydrocarbon emission for two-hole nozzle is almost same as for single-hole nozzle. The amount of carbon dioxide for two-hole nozzle is varies from 10 ppm to 75 ppm and for single-hole nozzle it varies from 30 ppm to 60 ppm for load range of 1 to 13. Thus we can conclude that the amount of hydrocarbon is more in case of two-hole nozzle as compared to single-hole nozzle.

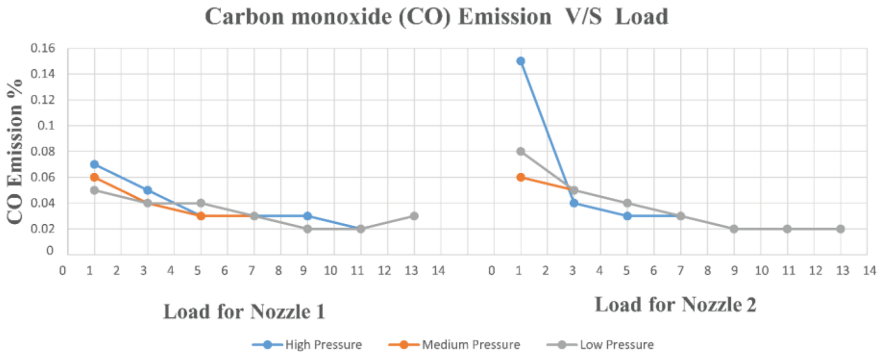

Fig.11: Carbon monoxide V/S Load

Figure 11 shows the graph for Carbon monoxide emission V/S Load. The amount of carbon monoxide emission for diesel engine is decreasing having slight variation with the increase in the load on engine. In other words amount of carbon monoxide is inversely proportional to the load. The amount of hydrocarbon emission for two-hole nozzle is almost same as for single-hole nozzle. The amount of carbon dioxide for two-hole nozzle is varies from 0.01 % to 0.08% and for single-hole nozzle it varies from 0.016% to 0.01% for load range of 1 to 13.

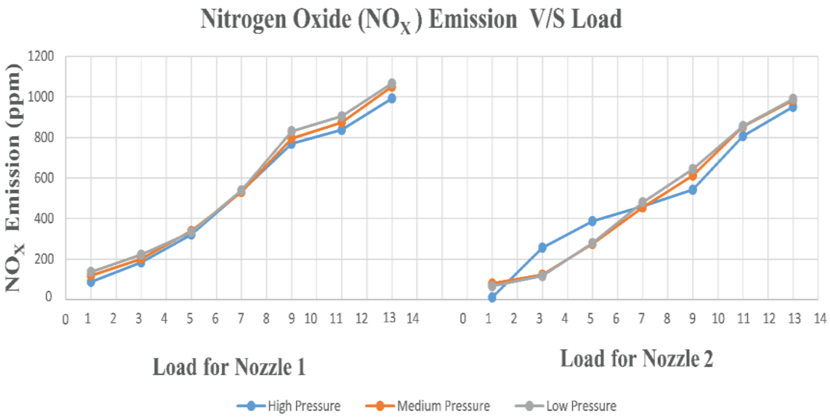

Fig.12: Nitrogen Emission V/S Load

Figure 12 shows the graph for Nitrogen oxide emission V/S Load. The amount of nitrogen oxide emission for diesel engine is increasing linearly with the increase in the load on engine. In other words amount of nitrogen oxide is directly proportional to the load. The amount of nitrogen oxide emission for two-hole nozzle is almost same as for single-hole nozzle. The amount of nitrogen oxide for two-hole nozzle is varies from 100 ppm to 1100 ppm and for single-hole nozzle also it varies from 50 ppm to 1000 ppm for load range of 1 to 13.

VI. Conclusion

After conducting the experiment the results were obtained and those results were shown in the graphical form for better understanding and getting the conclusion in more precise level.

The Conclusion which can be make out from the experiments are as listed below

- The performance of the two-hole nozzle is better at as compared to single nozzle.
- The performance of single-hole nozzle is same as that of the two-hole nozzle at high load.
- The performance of the single-hole nozzle is not up to the mark when it is used at lower load condition.
- The specific fuel consumption of single-hole nozzle is more as compared to the two-hole nozzle only at the lower load condition.
- The fuel consumption is more in single-hole nozzle as compared to two-hole nozzle when engine is allowed to run at low load.
- The Air-fuel ratio required in single-hole nozzle is less than the two-hole nozzle.
- The amount of fuel used in single-nozzle is more than two-hole nozzle.
- The working of single-hole nozzle tries to cope up with the working of two-hole nozzle as the load increases.
- The indicated thermal efficiency of two-hole nozzle is decreasing from higher level to lower level with the increase in load while for the single-hole nozzle the indicated thermal efficiency increases with from low level to higher level with the increase in load.
- The brake thermal efficiency varies for lower load but as the load increases the brake thermal efficiency also increases and its amount also same as the load increases.
- The Mechanical efficiency of the single-hole nozzle is more as compare to two-hole nozzle.
- There is no variation in volumetric efficiency as the amount of inlet air is not changed by any constrain.
- The emission of both the nozzles vary with very little range.
- The emission of carbon dioxide, hydrocarbon and nitrogen oxide is directly proportional to the load
- The emission of oxygen, carbon monoxide are directly proportional to the load.
- Thus we can conclude that the working of single-hole nozzle is not up to the mark for low load while the working of single-hole nozzle tries to become same as two-hole nozzle with the increase in load.
- The noise produced by the engine during the operation of single-hole nozzle is ok detonation type noise.
- The fuel leaks off from the leak-off port during the operation of the single-hole nozzle.

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