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Performance Characteristics of an Four Stroke Compression Ignition Engine by Arranging Convergent Divergent Nozzle in the Intake Manifold

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Abstract - Growing demands on reduction of Internal Combustion Engine fuel consumption with increase of its performance new designs and optimization of existing ones are introduced. Air motion in CI Engine influences the atomization and distribution of fuel injected in the air charge. Better atomization of Injected fuel allows for a more complete burn and helps to reduce the engine Knock.

A four stroke compression ignition engine with power 9 H.P and rated speed 1500 rpm is selected for the present work to investigate the performance characteristics. The swirl motion of the air is an important parameter in optimizing the performance of the engine.

In order to increase the air velocity in the inlet manifold a convergent-divergent nozzle is used. The rise in velocity with the use of nozzle generates turbulence at the exit of the manifold which facilitates for better combustion of injected fuel. The Performance characteristics were calculated without nozzle and with out nozzle in the inlet manifold and compared.

I. INTRODUCTION

Thermal energy (heat) is one of the oldest forms of energy known to mankind. Thermal energy is usually evolved from energies such as chemical energy and electrical energy. The device for converting one form of energy to another is termed as engine. In an energy conversion process the conversion efficiency plays a vital role and it determines the efficient use of the supplied energy. Heat engine is the device that can transform chemical energy of a fuel into thermal energy and utilizes this thermal energy to perform useful work.

A diesel engine (also known as a compression-ignition engine) is one type of heat engine which comes under the category of internal combustion(I.C) engines uses the heat of compression to initiate ignition for burning the fuel injected into the combustion chamber during the final stage of compression. The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine due to its very high compression ratio [7]. In Direct injection diesel engines fuel is injected directly onto the compressed air and gets mixed depending upon the motion of the air in the chamber. Air is directed into the cylinder through the inlet manifold and this air flow is one of the important factors controlling the combustion process. It governs the fuel-air mixing and burning rates in diesel engines. Air enters the combustion chamber of an I.C engine through the intake manifold with high velocity. Then the kinetic energy of the fluid results in turbulence and causes rapid mixing of fuel and air, if the fuel is injected directly into the cylinder [9]. The increased turbulence causes better cooling of the cylinder surfaces thereby reducing the heat loss to the surroundings. The heat from the cylinder walls gets absorbed by the air supplied during suction and used for reducing the delay period thereby increasing the thermal efficiency of the engine.

Here, in this work we have implemented the helical threaded manifold by varying pitches for generating the swirl while entering the cylinder. The turbulence was achieved in the inlet manifold by threading the inlet manifold of size 4mm width and 3mm depth with different pitches to direct the air flow.

The tests are carried with different configurations by varying the pitch of the helical threads from 10mm to 25 mm in steps of 5mm inside the intake manifold. The measurements were done at constant speed of 1500 rpm. The results are compared among normal manifold and helically threaded manifold.

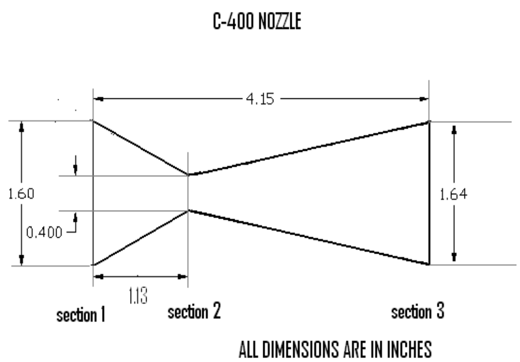
II. PRESENT WORK

In the present work the intake manifold of the CI Engine was modified by using nozzle with different throat. The Performance characteristics and the emission levels were verified by using manifolds with nozzle.

The time taken to fill the chamber would indeed depend on the inlet dimensions. There is enough time in each inlet stroke to allow the cylinder charge and atmosphere to gain a state of equilibrium, setting aside inlet rarefactions due to inlet obstacles, or compressions due to any turbo charging. Opening the valve for 1 nanosecond might let some air in, but (depending on the opening, and a couple of other things), the vacuum would be decreased. The amount by which the vacuum decreases will depend on how much air got back into the chamber. Although leaving the inlet valve open longer, having denser air or larger ports will allow more air into the cylinder.

The throat of the nozzle is about 19mm, length of the convergent section is 30mm and the length of the divergent section is 45mm, inlet diameter of the manifold and nozzle is 30mm and the outlet diameter of the nozzle is 28mm. The nozzle is manufactured by using mild steel as material.

The design of the convergent divergent nozzle is made based on the C-400 nozzle. The dimensions of C-400 nozzle were used for calibrating the dimensions of the required nozzle. The nozzles were made with constant length of 75mm, with convergent length of 30mm and divergent length of 45mm.



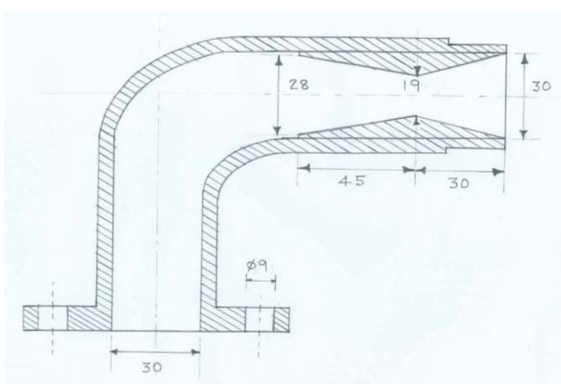


Fig.1 : Inlet Manifold with Nozzle

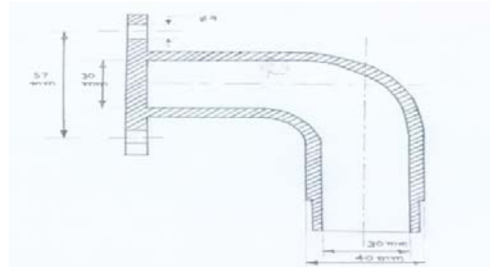


Fig. 2 : Normal manifold

III. OBSERVATIONS

TABLE1. Observations with Normal Inlet Manifold

Load (Watts)	Speed (revolutions Per minute)	Time taken for 20cc of fuel consumption (Seconds)	Voltage (volts)	Current (amperes)	Air Flow
0	1500	80.21	270	0	4.6
1000	1500	57.68	260	5.0	4.8
2000	1500	47.4	250	8.5	5.2
3000	1500	39.67	230	12.0	5.8
4000	1500	30.21	215	15.5	6.2
5000	1500	22.63	200	18.0	6.6

TABLE2. Observations with nozzle of throat 19 mm nozzle in the inlet manifold

Load (Watts)	Speed (revolutions Per minute)	Time taken for 20cc of fuel consumption (Seconds)	Voltage (volts)	Current (amperes)	Air Flow
0	1500	81.61	280	0	4.6
1000	1500	57.93	270	5.0	4.9
2000	1500	48.65	255	8.5	5.3
3000	1500	40.34	240	12	5.7
4000	1500	31.82	230	16	6.1
5000	1500	23.25	210	18	6.4

IV. RESULTS

The performance characteristics of engine without and with nozzle in the intake manifold were compared in the present work, and the results showed better performance with 19mm throat nozzle in the manifold than the remaining nozzles of throat 15mm, 17mm, 21mm and normal manifold. And the experimental results were tabulated for normal manifold and 19mm throat nozzle in the manifold:

TABLE 3 : EXPERIMENTAL RESULTS WITH NORMAL MANIFOLD

S. No	Item	Units	Load (%)					
			0	20	40	60	80	100
1	Total fuel consumption	kg/h	0.76	1.06	1.29	1.54	2.03	2.70
2	Brake power	kW	0.00	1.47	2.41	3.13	3.78	4.08
3	Brake specific fuel consumption	kg/kW h	0.00	0.72	0.54	0.49	0.54	0.66
4	Frictional power	kW	3.00	3.00	3.00	3.00	3.00	3.00
5	Indicated power	kW	3.00	4.47	5.41	6.13	6.78	7.08
6	Mechanical efficiency	%	0.00	32.94	44.54	51.05	55.75	57.64
7	Heat input	kW	8.90	12.38	15.06	18.00	23.63	31.55
8	Brake Thermal efficiency	%	0.00	11.91	15.99	17.39	16.00	12.94
9	Indicated Thermal efficiency	%	33.70	36.14	35.91	34.05	28.69	22.45
10	Volumetric efficiency	%	27.44	28.64	31.02	34.60	36.99	39.37
11	Brake mean effective pressure	kN/m^2	0.00	124.40	203.34	264.11	319.03	344.49
12	Indicated mean effective pressure	kN/m^2	253.20	377.60	456.54	517.31	572.23	597.69
13	Exhaust gas temp	^0C	118.00	165.00	216.00	280.00	330.00	351.00

TABLE 4 **:** EXPERIMENTAL RESULTS WITH 19mm THROAT NOZZLE IN THE MANIFOLD

S. No	Item	Units	Load (%)					
			0	20	40	60	80	100
1	Total fuel consumption	kg/h	0.74	1.05	1.29	1.53	1.92	2.63
2	Brake power	kW	0.00	1.68	2.45	3.26	4.17	4.28
3	Brake specific fuel consumption	kg/kW h	0	0.690	0.511	0.464	0.460	0.614
4	Frictional power	kW	3.25	3.25	3.25	3.25	3.25	3.25
5	Indicated power	kW	3.25	4.78	5.70	6.51	7.42	7.53
6	Mechanical efficiency	%	0.00	32.01	43.05	50.11	56.20	56.87
7	Heat input	kW	8.73	12.30	14.65	17.66	22.43	30.65
8	Brake Thermal efficiency	%	0.00	12.43	16.77	18.47	18.59	13.97
9	Indicated Thermal efficiency	%	37.21	38.85	38.95	36.87	33.08	24.58
10	Volumetric efficiency	%	27.44	29.23	31.62	34.01	36.39	38.18
11	Brake mean effective pressure	kN/m^2	0.00	129.18	207.40	275.58	351.95	361.71
12	Indicated mean effective pressure	kN/m^2	274.29	403.47	481.70	549.88	626.25	636.00
13	Exhaust gas temp	^0C	135	182	235	320	384	420

TABLE 5 : EXHAUST EMISSIONS WITH NORMAL MANIFOLD

S. No	Item	Units	Load (%)					
			0	20	40	60	80	100
1	Hydro carbons	Parts per million	25	26	29	30	32	33
2	Carbon monoxide	% volume	0.03	0.05	0.13	0.26	0.37	0.42
3	Carbon dioxide	% volume	0.8	0.9	1	1.3	1.4	1.5
4	Oxygen	% volume	19.45	19.28	19.02	18.55	18	17.4

TABLE 6**:** EXHAUST EMISSIONS WITH 19mm THROAT NOZZLE IN THE MANIFOLD

S. No	Item	Units	Load (%)					
			0	20	40	60	80	100
1	Hydro carbons	Parts per million	1	4	8	10	19	34
2	Carbon monoxide	% volume	0.02	0.03	0.04	0.12	0.34	0.51
3	Carbon dioxide	% volume	0.9	1.1	1.3	1.5	1.7	1.5
4	Oxygen	% volume	19.5	19.11	18.65	18.14	17.62	17.64

GRAPHS

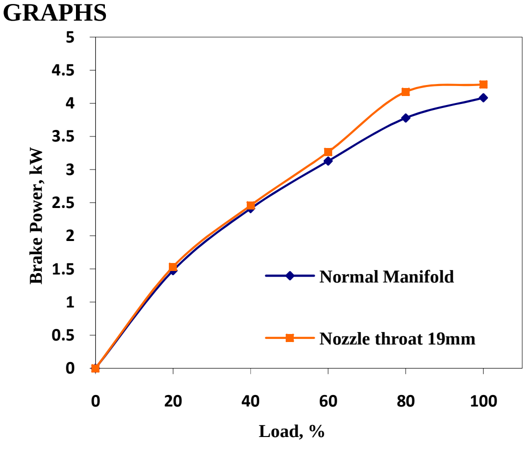


Fig. 3 : Load versus Brake Power

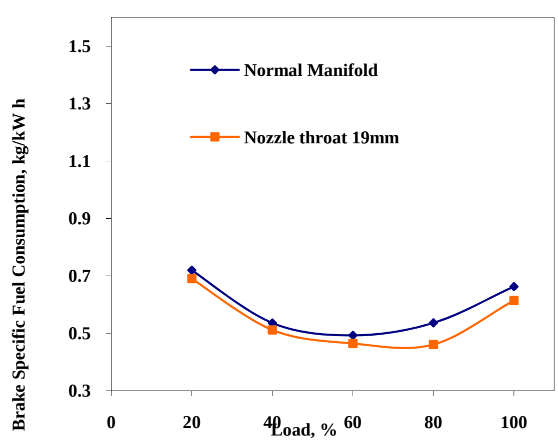


Fig. 4 : Load versus Brake Specific Fuel consumption

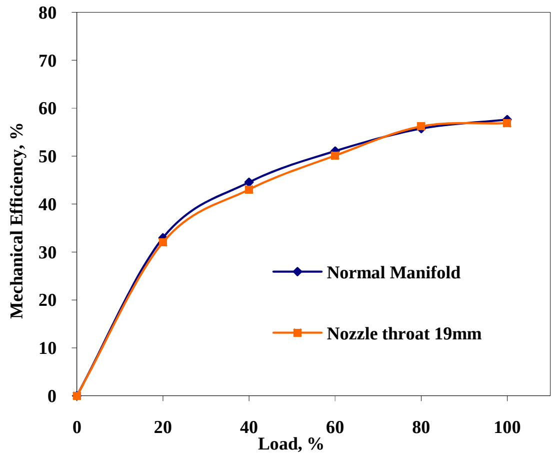


Fig. 5 : Load versus Mechanical efficiency

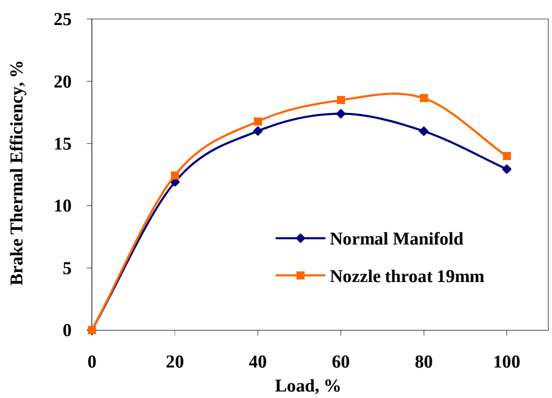


Fig. 6 : Load versus Brake Thermal efficiency

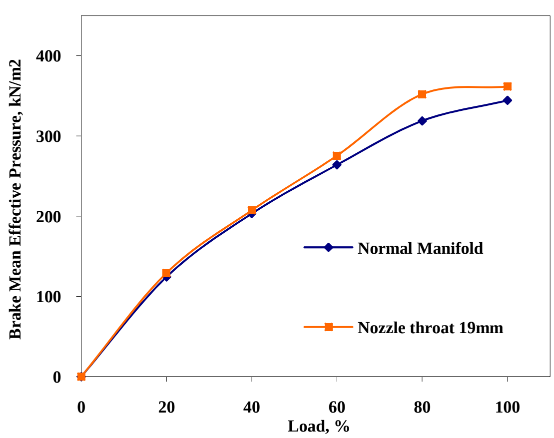


Fig. 7 : Load versus Brake mean effective pressure

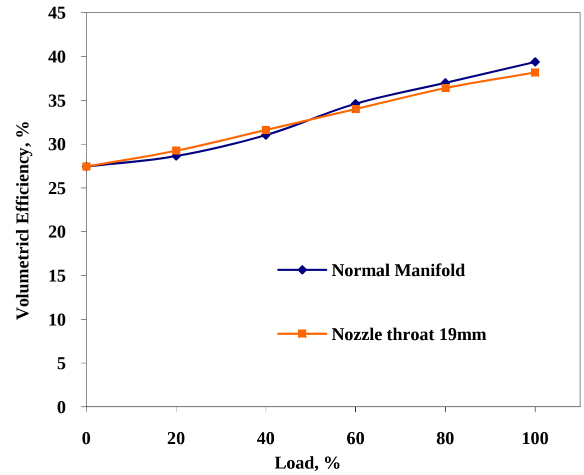


Fig. 8 : Load versus Volumetric efficiency

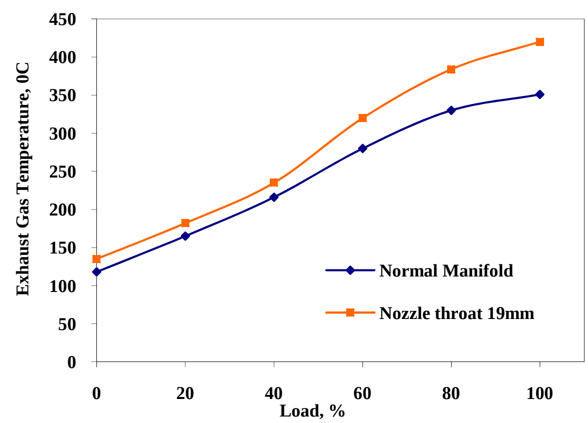


Fig. 9 : Load versus Exhaust Gas Temperature

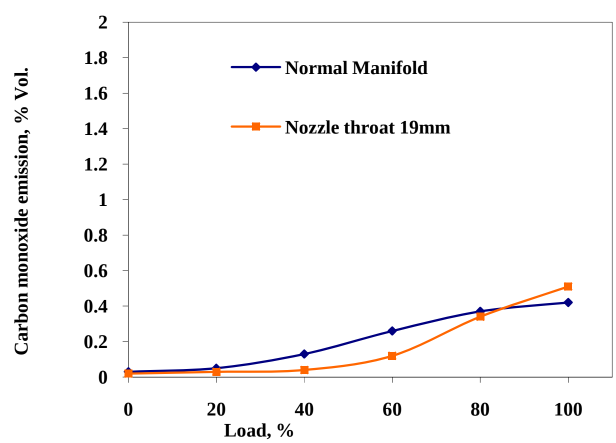


Fig. 10 : Load versus carbon monoxide emission

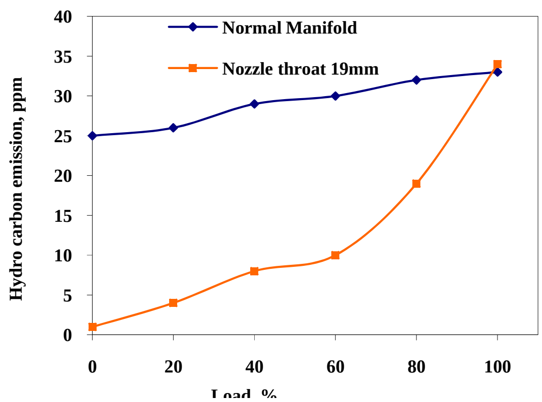


Fig. 11 : Load versus Hydrocarbon emission

CONCLUSION

The Performance characteristics of an engine without nozzle and with nozzle in the intake manifold were compared in the present work. A Convergent Divergent Nozzle of throat 15mm, 17mm, 19mm and 21mm in the manifold were used to evaluate the performance characteristics and among them it is found that 19mm throat nozzle showed better performance. The performance parameters are presented below at 4/5th of rated load (80%).

1. Brake power is increased by 2.38%.
2. Total fuel consumption is reduced by 2.91%
3. Specific fuel consumption is reduced by 5.55%
4. Indicated power is increased by 4.27%
5. Mechanical efficiency is reduced by 1.81%
6. Heat input is reduced by 2.58%
7. Brake thermal efficiency is increased by 5.13%
8. Indicated thermal efficiency is increased by 7.18%
9. Volumetric efficiency is reduced by 11.3%
10. Brake mean effective pressure is increased by 2.38%
11. Indicated mean effective pressure is increased by 4.28%
12. Exhaust gas temperature is reduced by 1.81%
13. Hydrocarbon emission is reduced by 12.5%
14. Carbon monoxide emission is reduced by 0.3%

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