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Performance Evaluation of Variable Compression Ratio for Diesel Engine Using Convergent-Divergent Nozzle in the Intake Manifold

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Abstract

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(C-D) 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. In this project, we have designed and fabricated a turbulence device with convergent-divergent nozzle. A single cylinder four stroke variable compression ratio diesel engine with 5 H.P and rated speed 1500 rpm is selected for the present work. In order to find optimum compression ratio for both Normal and C-D Nozzle manifolds, test were carried out to investigate at different loads (0kg, 2kg, 4kg, 8kg) & compression ratios(12.0, 14.0, 16.0 and 18.0) the performance characteristics of engine like Brake power (BP), Mechanical Efficiency(ME), Brake Specific Fuel Consumption (BSFC) etc. From the compared values the Convergent-Divergent nozzle manifold leads to the better efficiency than normal inlet manifold. Results shows that engine yields better performance at 16.0 compression ratio.

Keywords: *Convergent-Divergent Nozzle, Variable Compression Ratio Diesel Engine, etc***.**

1.Introduction

Compression ignition engines are employed particularly in the field of heavy transportation and agriculture on account of their higher thermal efficiency and durability. However, there is large development in CI engine in last few decades but it is still lagging in the performance in its fuel economy & emission. It is due to the ineffective use of air in engine causes the improper atomization air fuel mixture results in the poor combustion, which affects engine performance characteristics in terms of fuel economy & emissions at part load conditions. Hence search for the modification of intake manifolds has intensified.

1.1 Need for Convergent Divergent Nozzle

The present day energy crisis and ever increasing demands of energy in addition to global pollution brought us into a situation where there is an urgent need for energy conservation, efficient utilization and eco-friendly techniques to be implemented in day to day use. These needs lead us to an idea of modified design in a CI engine without any additional energy requirement and with no complicated variations in design. There are various other methods to improve the efficiency of engine such as super charging, turbo charging, varying stroke length, varying injection pressure, fuel to air ratio, additional strokes per cycle and so on. Many of them require additional design (stroke length, injection pressure etc.,) and some of them load to increase environmental effect. Here in this project affords were made to increase the velocity (physical parameter) of air entering the inlet manifold of the engine by inserting a convergent divergent nozzle at the inlet manifold. There by increasing the mixture quality of air & fuel in the combustion chamber before the initialization of ignition.

1.2 Types of Intake Manifolds

Intake manifold plays an important role in the better atomization of air fuel-mixture which results in the good combustion in I.C engines and also increases the performance characteristics of the engine in term of fuel economy.

The following are some of the different types of intake manifolds;

- Convergent intake manifold
- Divergent intake manifold
- Convergent divergent intake manifolds
- Convergent intake manifold with internal blades
- Threaded manifold
- Hallow cylindrical manifold

2. Literature Review

K.Satyanarayana [13] et al, Experiments conducted on a single cylinder four stroke variable compression ratio diesel engine. Tests were carried out at compression ratios of 16.5, 17.0,17.5, 18.0 and 19.0 at different loads the performance characteristics of engine like Brake power (BP), Brake Thermal Efficiency (BTE), Brake Specific Fuel Consumption (BSFC). Results show a significant improved performance at a compression ratio

19.0. The compression ratios lesser than 19.0 showed a drop in break thermal efficiency, rise in fuel consumption.M. Chandramouli [6] et al, Selected a four stroke compression ignition engine with power 9 H.P and rated speed 1500 rpm 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 with nozzle and without nozzle in the inlet manifold and compared [6].In this project a single cylinder four stroke variable compression ratio diesel engine with 5 H.P and rated speed 1500 rpm is selected. The present work to investigate the performance characteristics of engine with and without convergent-divergent nozzle at compression ratios of 12.0,14.0,16.0 and 18.0 at different loads.

3. Fabrication of Convergent – Divergent Nozzle

The manifold is fixed in a 3-jaw chuck lathe machine to perform drilling operation, in order to drill a hole at the center of required diameter. Next boring operation is performed on already drilled hole from both the ends by using boring tool.

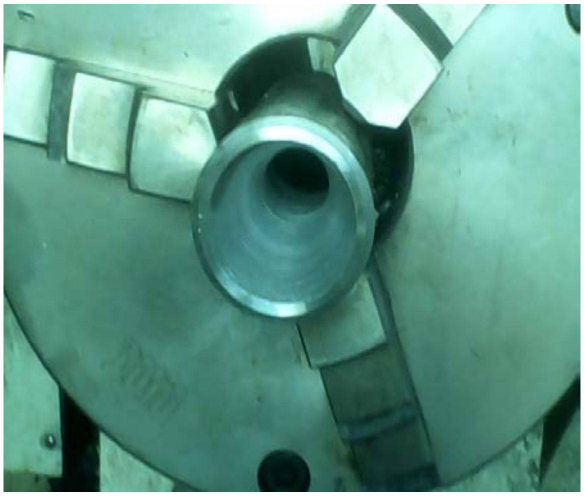

Fig .1 Convergent-Divergent Nozzle manifold

- All the operations like facing, drilling and boring is performed by using same setup.

Fig .2 preparation of Convergent- Divergent Nozzle manifold flange

- By using four jaw chuck facing is performed on a flange, four jaw chuck is used in order to grip properly.

Fig .3 Prepared Convergent- Divergent Nozzle manifold with flange

- Arc welding is carried out to join flange and manifold. The above figure shows final convergent divergent manifold.

4. Experimental setup and Procedure

Engine Specifications:

Fig.4 Kirloskar made diesel engine

The engine which is supplied by M/s Kirloskar Company. The engine is single cylinder vertical type four stroke, Water-cooled, Variable compression ignition engine type diesel engine. The engine is of self-governed type whose specifications are given below are used in the present work.

- Engine : Four stroke single cylinder
- Bp : 5hp
- Rpm : 1500
- Compression Ratio : 12:1 TO 20:1
- Fuel : Diesel
- No of cylinders : Single
- Bore : 80mm
- Stroke length : 110mm
- Starting : Cranking
- Work cycle : Four stroke
- Method of cooling : Water cooled
- Method of ignition : Compression ignition

Variable compression ratio:

Fig.5 Variable compression ratio in diesel engine

The overhead cylinder head made of cast iron is water cooled internally & has a counter piton which helps in varying the clearance volume. The counter piton is actuated by a screw rod mechanism to change the clearance volume for different compression ratios.

Observations:

Table no:1 Observations with Normal Manifold at different Compression ratios & Loads:

COMPRESSION RATIO	LOAD (kg)	SPEED (N) rpm	T1 (℃)	T2 (℃)	T3 (℃)	T4 (℃)	T5 (℃)	TIME (sec) 10cc	H1 mm	H2 mm
12	0	1544	26	37	29	247	119	48	26	23
	2	1548	26	37	29	248	121	42	26	23
	4	1536	26	37	30	264	126	38	26	22.6
	6	1520	26	37	30	286	134	32	26	22.5
	8	1498	25	37	30	300	145	28	26	22.2
14	0	1564	27	43	32	291	129	44	25	24
	2	1560	27	39	31	263	126	36	26	23
	4	1540	27	38	31	276	132	32	26	23.5
	6	1532	26	39	30	305	141	29	26	22
	8	1528	26	40	29	325	148	24	26	22
16	0	1577	27	35	29	172	79	51	23	24
	2	1544	27	45	30	223	114	45	23	25
	4	1540	27	44	31	261	114	38	23	25
	6	1532	27	46	33	313	134	32	23	27
	8	1528	27	45	34	323	154	26	23	27
18	0	1582	27	35	30	234	118	52	25	23
	2	1560	26	36	30	257	123	46	25	22.5
	4	1540	26	36	30	283	131	38	25	22.2
	6	1532	26	37	30	314	142	31	25	22
	8	1520	26	37	30	320	145	24	25	21.8

Table no:2 Observations with Convergent-Divergent Nozzle Manifold at different Compression ratios & Loads:

COMPRESSION RATIO	LOAD (kg)	SPEED (N) rpm	T1 (℃)	T2 (℃)	T3 (℃)	T4 (℃)	T5 (℃)	TIME (sec) 10cc	H1 mm	H2 mm
12	0	1548	29	39	32	236	117	52	21	22
	2	1542	29	39	33	235	120	48	21	22.5
	4	1530	29	39	33	240	124	39	21	22.8
	6	1512	28	39	33	252	128	34	21	23
	8	1488	28	39	33	280	132	30	21	23.5
14	0	1564	29	39	32	230	111	51	22	24
	2	1544	29	39	32	225	113	47	21	24
	4	1516	29	39	32	235	120	40	21	25
	6	1498	29	39	33	250	127	35	21	25.5
	8	1458	29	39	33	275	134	30	21	25.8
16	0	1576	30	33	31	139	83	58	23	24
	2	1564	29	36	31	190	95	55	23	26
	4	1556	29	38	32	217	107	45	23	27
	6	1546	29	39	32	250	120	38	23	27
	8	1542	29	39	32	275	130	30	23	28
18	0	1572	28	39	33	235	118	53	22	24
	2	1554	28	40	33	239	122	47	22	24.5
	4	1540	28	40	34	252	128	41	21	24
	6	1530	28	40	33	276	136	36	21	24.4
	8	1520	28	40	33	295	148	29	21	24.6

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5. RESULTS:

Experiments were conducted when the engine was fuelled with diesel and run at different compression ratio's namely 12.0,14.0,16.0 and 18.0 at different loads (i.e., 0, 2, 4, 6, 8) respectively with two different inlet manifolds such as normal inlet manifold and convergent divergent nozzle inlet manifold for air suction. And the experimental results were tabulated for both manifolds.

Table no:3 Experimental Results with Normal Manifold at different Compression ratios & Loads:

COMPRESSION RATIO	Load (kg)	Brake thermal efficiency (η)	Mechanical efficiency (η)	Indicated thermal Efficiency (η)	Volumetric efficiency (η)	MFC (Kg/hr)	SFC (Kg/KW hr)
12	2	4.98	25.62	19.43	19.5	0.7114	1.72
	4	8.94	40.6	22.02	20.55	0.7863	0.958
	6	11.18	50.37	22.19	22.19	0.9337	0.766
	8	12.85	57.14	22.49	22.8	1.0671	0.666
14	2	4.3	22.93	18.76	18.99	0.83	1.992
	4	7.55	37	20.4	20.8	0.93375	1.135
	6	10.21	46.72	21.85	22.3	1.0303	0.839
	8	11.24	53.83	20.87	22.4	1.245	0.762
16	2	5.32	27.26	16.5	15.68	0.664	1.61
	4	8.966	42.78	19.3	19.26	0.7863	0.956
	6	11.26	52.74	20.03	22.33	0.933	0.76
	8	12.17	59.74	21.55	22.4	1.149	0.704
18	2	5.97	39.09	14.07	17.34	0.649	1.558
	4	9.438	51.12	17.53	18.58	0.7863	0.956
	6	10.56	56.01	19.48	19.34	0.9638	0.785
	8	11.64	56.6	19.75	20.13	1.245	0.766

Table no:4 Experimental Results with Convergent-Divergent Nozzle Manifold at different Compression ratios & Loads:

COMPRESSION RATIO	Load (kg)	Brake thermal efficiency (η)	Mechanical efficiency (η)	Indicated thermal Efficiency (η)	Volumetric efficiency (η)	MFC (Kg/hr)	SFC (Kg/KW hr)
12	2	5.66	25.87	21.9	21.4	0.6225	1.511
	4	9.14	40.9	22.34	23.65	0.7661	0.937
	6	11.81	50.64	23.32	25.16	0.8788	0.7256
	8	13.67	57.38	23.82	28.5	0.996	0.6268
14	2	5.56	32.66	17.02	30	0.6357	1.541
	4	9.29	48.79	19.04	35	0.747	0.922
	6	12.05	58.54	20.58	38.6	0.8537	0.711
	8	13.4	64.69	20.72	38.8	0.996	0.639
16	2	6.59	34.3	19.21	30.37	0.543	1.3
	4	10.729	50.95	21.056	35.16	0.664	0.798
	6	13.5	60.76	21.9319	35.35	0.7863	0.634
	8	15.59	67.31	22.82	39.63	0.905	0.549
18	2	5.59	29.7	18.8	27.42	0.6357	1.532
	4	9.67	45.6	21.2	30.43	0.7287	0.886
	6	12.66	55.5	22.78	32.56	0.83	0.677
	8	13.5	62.36	21.66	33.76	1.0303	0.634

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6. Graphs:

At 16 Compression Ratio:

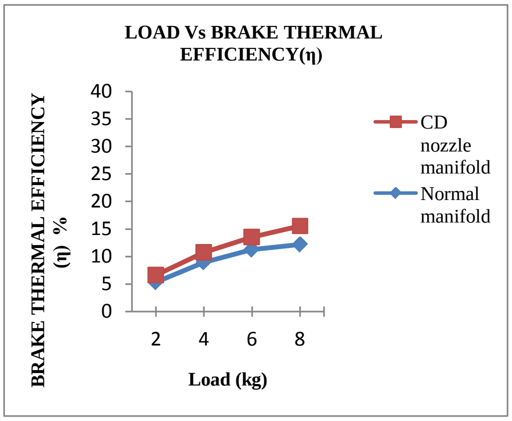

Fig .6 Variation of Brake thermal efficiency with Load

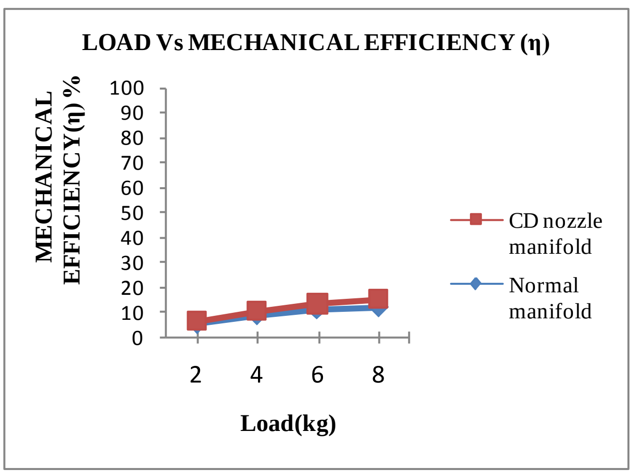

Fig.7 Variation of Mechanical efficiency with Load

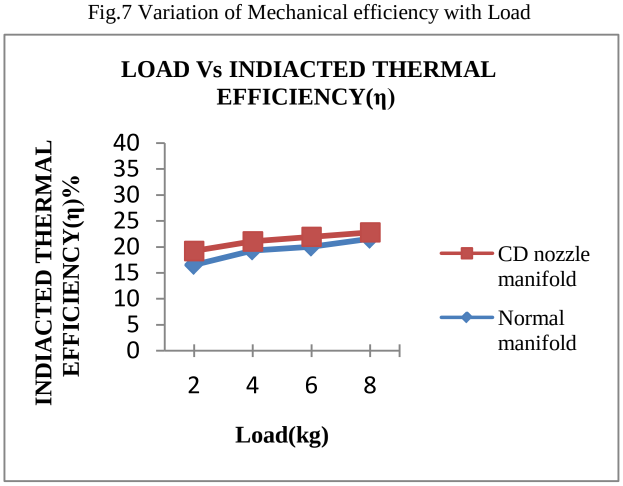

Fig.8 Variation of Indicated thermal efficiency with Load

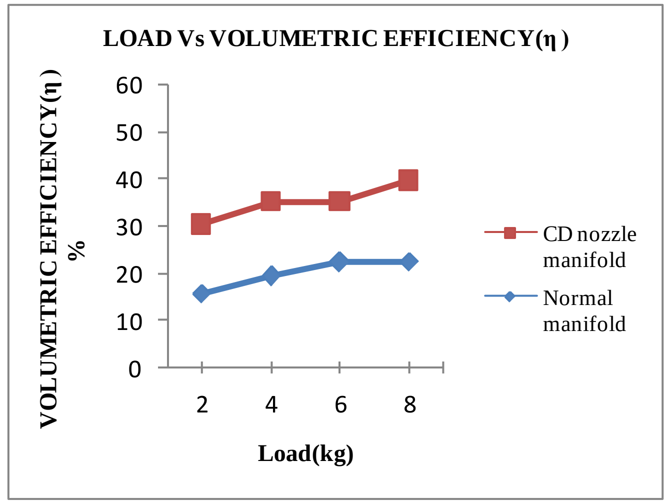

Fig.9 Variation of Volumetric efficiency with Load

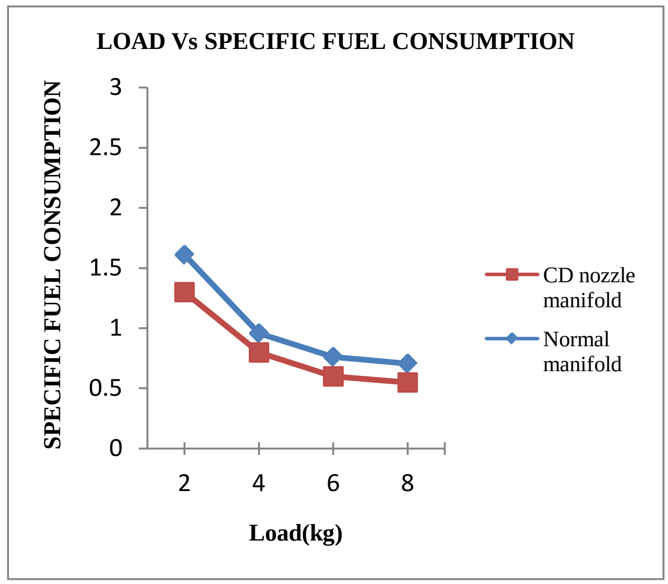

Fig.10 Variation of Specific Fuel Consumption with Load

7. Results and Discussion:

A Convergent-Divergent Nozzle manifold were used to evaluate the performance characteristics and among them it is found that 16.0 compression ratio showed better performance.

The performance of the engine was evaluated in terms of Brake thermal efficiency, Mechanical efficiency, Indicated thermal efficiency, Volumetric efficiency and Specific fuel consumption. By using these terms the efficiency of the engine is compared between normal inlet manifold and convergent-divergent nozzle inlet manifold at different compression ratios.

7.1 Specific Fuel Consumption

The result for the variations in the specific fuel consumption (SFC) was presented in the figure. For both the manifold the specific fuel consumption falls with increasing load. The difference of specific fuel consumption is small when using different loads and compression ratios. The maximum SFC is 1.610 kg/kw-hr at 16.0 compression ratio with normal manifold and 1.300 kg/kw-hr at 16.0 CR with Convergent-Divergent nozzle inlet manifold. The higher SFC for normal manifold due to variation of air pressure, velocity and thereby less atomization of fuel.

7.2 Brake Thermal Efficiency

The variation of brake thermal efficiency with load is shown in figures Brake thermal efficiency gives an idea of the output generated by the engine with respect to heat supplied in the form of fuel. For all the compression ratios break thermal efficiency increases with load. The maximum BTE is 12.17% at 16.0 compression ratio with normal manifold and 15.59% at16.0 CR with C-D Nozzle manifold. The efficiency values for normal manifold are less when compared to Convergent-Divergent nozzle manifold. This is due to the less heat input requirement for higher power output at given load.

7.3 Volumetric Efficiency

The figures shows the variation of volumetric efficiency with load for two different manifolds. Volumetric efficiency is a measure of success with which air supply, and thus the charge is inducted to the engine. It indicates the breathing capacity of the engine. From the figure it is evident that the volumetric efficiency is varying with normal manifold is less than the Convergent-Divergent nozzle.

7.4 Mechanical Efficiency

The figures shows the mechanical efficiency for different loads and manifolds. Mechanical efficiency indicates how good an engine is inverting the indicated power into the useful power. The maximum Mechanical efficiency is 59.74% at 16.0 compression ratio with normal manifold and 67.31% at 16.5 CR with C-D Nozzle manifold. The efficiency values for normal manifold are less when compared to Convergent-Divergent nozzle manifold. Because higher fuel injection pressures increases the decrease of atomization. The fitness of atomization reduces the ignition lag.

7.5 Indicated Thermal Efficiency

The figures indicates variation of indicated thermal efficiency at different loads for both the manifolds. Indicated power is the power developed at the engine cylinder, it can be noted from fig. that the indicated thermal efficiency is more for Convergent-Divergent nozzle manifold when compared to normal manifold for different compression ratios.

8.Conclusions:

The Performance characteristics of an variable compression ratio diesel engine without nozzle and with nozzle in the intake manifold were compared in the present work. The following are the conclusions based on the experiment results obtained while operating the single cylinder water cooled variable compression ratio diesel engine with normal inlet manifold and Convergent-Divergent nozzle inlet manifold at different compression ratios 12.0,14.0,16.0 and 18.0 respectively. By tabulating obtained values and those values are compared with load applied. Finally performance characteristic curves are drawn and efficiencies are identified.

When the obtained results are compared at different compression ratios (12.0,14.0,16.0 and 18.0) and among them it is found that 16.0 compression ratio showed better performance for both manifolds. From the compared values at 16.0 compression ratio the Convergent-Divergent nozzle manifold leads to the better efficiency than normal inlet manifold for air suction.

- The Brake thermal efficiency is increased by 3.42%.
- The Mechanical efficiency is increased by 7.57%.
- The volumetric efficiency is increased by 17.23%The Indicated thermal efficiency is increased by 1.27%
- The Specific fuel consumption is decreased by 0.155%

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