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Experimental Investigation on Performance and Emission of IC-Engine by Modifying Inlet Manifold

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Abstract*—Turbulence means a random motion in 3D with varying size superimposed on one another and randomly distributed within the flow. An experimental investigation is carried out by modifying inlet manifold to understand the effects on performance and exhaust emission. For this research work, 4-stroke, air cooled, single cylinder, direct injection, natural aspirated diesel engine was used. Geometrical design of intake manifold is very important for the good performance of IC engine. Internal buttress threads were made in intake manifold of engine. Three such manifolds of same configuration with three different pitches and three different types of swirling devices are experimentally checked.*
To modify the intake manifold first a 3-D model of actual manifold is made in design software (PTC CREO 3.0) and then its 2-D sheet was prepared in AUTOCAD for its production in CNC machine. Brake specific fuel consumption (BSFC), brake thermal efficiency and emission including CO, unburnt HC and NOx is compared amongst the combinations of inlet manifold having same type of threads with three different types of pitch and three types of swirling device. All experiments are conducted at different loading conditions using an electric alternator generator and the exhaust analysis is carried out with the help of multi gas exhaust emission meter. The reported work aims for the selection of combination of optimum dimension of buttress threads and the optimum swirling device to get best improvement in performance and emission by producing maximum swirl in inlet air.

Keywords*-Inlet manifold, swirl, turbulence, IC-engine,brake thermal efficiency, brake power, emission.*

I. INTRODUCTION

IC Engines are being developed to obtain higher performance and gain the potential to fulfill the need of next generation. Engine plays very crucial role in vehicle operation. It produces and supplies the energy needed by the other car component to function. Engine transfers chemical energy of fuel into thermal energy and utilize this form of energy to perform useful work [1].

Flow of air through the manifold and mixing of the fuel with air inside the cylinder is more important in the case of diesel engine as all of these factors are directly affecting the volumetric combustion performance,efficiency, emission levels and output of the engine. Control of flow through the manifold is critical for meeting the emission regulations and fuel economy requirements. Parameters like engine speed, manifold and combustion chamber configuration directly influence the swirl in DI diesel engines and subsequently it plays a vital role in mixing air and fuel inside the cylinder. Optimization of swirl becomes an important aspect in the design of intake systems of diesel engines.[1]

An inlet manifold or intake manifold is the part of an engine that supplies the fuel/air mixture to the cylinder. The primary function of the intake manifold is to evenly allocate the combustion mixture (or just air in a direct injection engine) to each intake port in the cylinder head. Flow is scattered evenly to intake valve by ideal intake manifold. Even distribution is important to optimize the efficiency and performance of the engine. It may also serve as amount for throttle body,fuel injectors,carburetorand other components of the engine. The intake manifold has historically been manufactured from aluminum or cast iron but use of composite plastic materials is gaining reputation [1].

Today, major intention of engine designers is to attain the twin goals of best performance and lowest possible emission levels. Outstanding engine performance requires the simultaneous combination of good combustion and good engine breathing. Good combustion depends only in part on the characteristics of the flow within the cylinder. Good engine inhalation is strongly affected by the unsteady flow in the intake manifold, and to a lesser extent, that in the exhaust manifold. History tells us that correctly harnessing the flow in the intake manifold of a naturally aspirated I.C. (Internal Combustion) engine can yield improvements in engine torque of 10% or more, whereas performing the equivalent in the exhaust manifold yields a more modest 4-6%. To maximize the mass of air inducted into the cylinder during the suction stroke, design of intake manifold, which plays an important role, needs to be optimized. Design becomes more complex in a multi-cylinder engine as air has to be distributed equally in all the cylinders. Thus, configuration of manifold geometry becomes an important standard for the engine design [5].

II. LITERATURE REVIEW

Paulet al.[2]found the effectof helical configuration,spiral configuration,andhelical-spiral configurationcombinationmanifold configurationonairmotionandturbulence inside thecylinderofa DirectInjection(DI) diesel enginemotoredat3000rpm.By usingthe CFDtool(FLUENT), theycompared predictedCFD resultsofmeanswirlvelocity oftheengineatdifferentlocationsinsidethecombustionchamberat theendofcompressionandtheturbulencemodeledusing RNGk-ε modelstrokewithexperimental resultsavailableintheliterature.Thevolumetricefficiency ofthemodeled helical manifold was also compared.

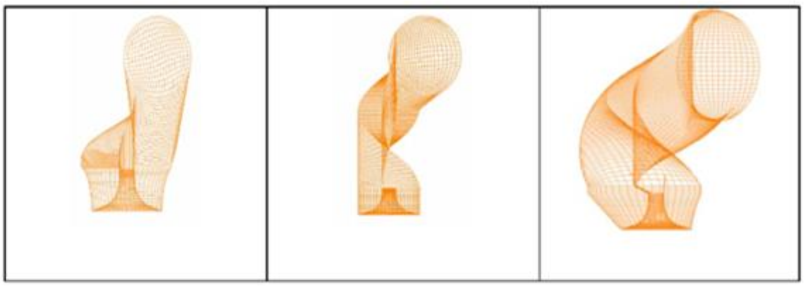
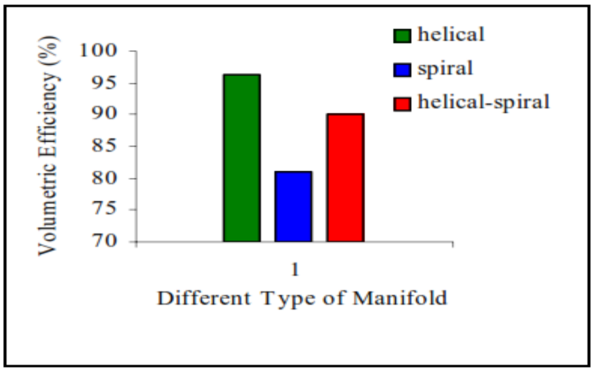


Figure 1:- Modelled(i)Spiral, (ii)Helical, (iii)Helical spiral manifold configuration[2]

Aftertheanalysismany things were noticed such ashighervelocity componentinsidethecombustionchamberattheendofcompressionstroke was created by thehelical-spiralmanifoldgeometry.Turbulentkineticenergy and swirl ratioinsidethe cylinderarehigher inspiralmanifold.In spiral-helicalcombinedmanifold, volumetric efficiencyis10%higherthanthatofspiralmanifold. Conclusionof resultshowsthatHelical-spiralcombinedmanifoldcreateshigher swirlinside the cylinderthanspiralmanifold. Highervolumetricefficiency is obtained in helicalmanifold.Helical-spiralcombinedmanifoldprovideshighermeanswirlvelocity atTDCofcompression.Hence,for better performanceahelical-spiral inlet manifoldconfiguration is recommendedbythem.



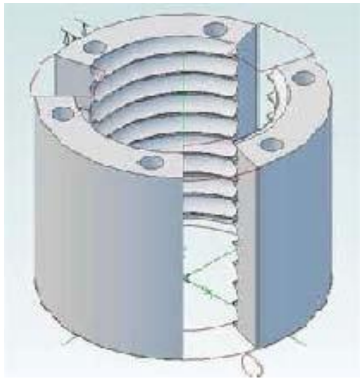


Figure 2:-Volumetric efficiency of different manifold Figure 3:-Internally ThreadedInlet Manifold[3] configurations at 3000 rpm.[2]

Dr.Pankaj et al. [3]worked upon the effects of swirl on the performance characteristicsoftheengine. It was done byinducingswirl ininlet manifolds. They did it withthree different types ofinternal threads viz. acme,buttressandknucklethreads. They kept constantpitchof2 mm in all three types of thread.They conductedexperiments on a single cylinder Kirloskarmakedirect injection four stroke cycle diesel engine.

It was concluded that theconfigurationinlet manifoldwithbuttress internal threadsenhancestheturbulenceandhenceresultsinbetter air-fuelmixingprocessamongall theconfigurationsofinlet manifolds.Asaresult,thethermalefficiency was increased andBSFC and exhaust emissions were reduced. Inlet manifoldwithbuttress internal threads was thebesttrade-offbetweenperformanceandemissions.

1.Itwasobservedthat11.62%ofreductioninBSFCat2.5kW loadforengine withinletmanifoldhavingbuttress internal threadscomparedtoengine with normal inlet manifold.

2.Theexhaustgastemperaturewashigherfordieselengine with inletmanifolds having all these threedifferent typesof internalthreads thanengine with normal inlet manifold.

3.Itwasobservedthat12.32%,26.66%and3.6%ofreduction inHC,COandNOxemissionsrespectively at 2.5kWload forenginewithinlet manifoldhavingbuttressinternal threadscomparedtoengine with normal inlet manifold.

4.The results indicatedthatinletmanifoldwithbuttress threadswereidentifiedasoptimum configurationbasedon performanceaswell asexhaust emissionsofdiesel engine.

III. NEW INLET MANIFOLD DESIGN

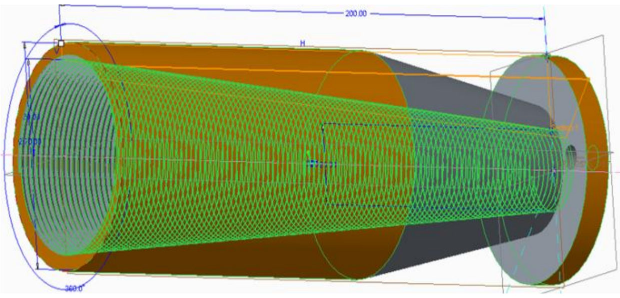
Inlet manifold includes design of two things. They are inlet manifold outer shell and swirling device kept at center.

3.1. Design of outer shell:

PTC CREO 3.0 software was used while designing new inlet manifold. Following notes were taken in consideration:

- ID at air outlet side should be minimum 25 mm as there is a hole of 25 mm on cylinder clock for air inlet.
- Length of inlet manifold should be 200mm and material used for construction is mild steel.

- In new design, internal surface is kept tapper for better volumetric efficiency and pitch of internal buttress thread is selected as 2mm, 4mm and 6mm for three different inlet manifolds of same configuration.
- Air inlet side of inlet manifold has internal diameter of 60 mm which gives tapper of 5º.
- Flange on air outlet side diameter is of 9mm thickness and
- Minimum thickness of material at any place should be at least 5mm.
- Two holes for fixing bolt should be there at distance of 50 mm from each other vertically opposite on radial axis of flange kept at air outlet end and for weight reduction, tapper on outer surface should also be done.
- Dimension of internal buttress thread is calculated on basis of following formula “D = ¾ P” and “f = 1/8P” where P is pitch, D is height and f is width of top and bottom flat surface of thread as shown in figure.



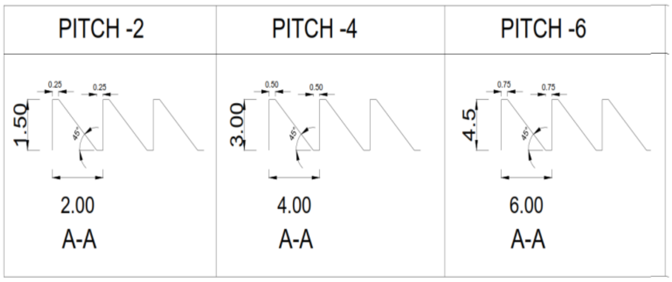


Figure 4:- 3-D model of new inlet manifold with internal view

Figure 5:- Dimensions of thread of pitch 2mm, 4mm and 6mm.

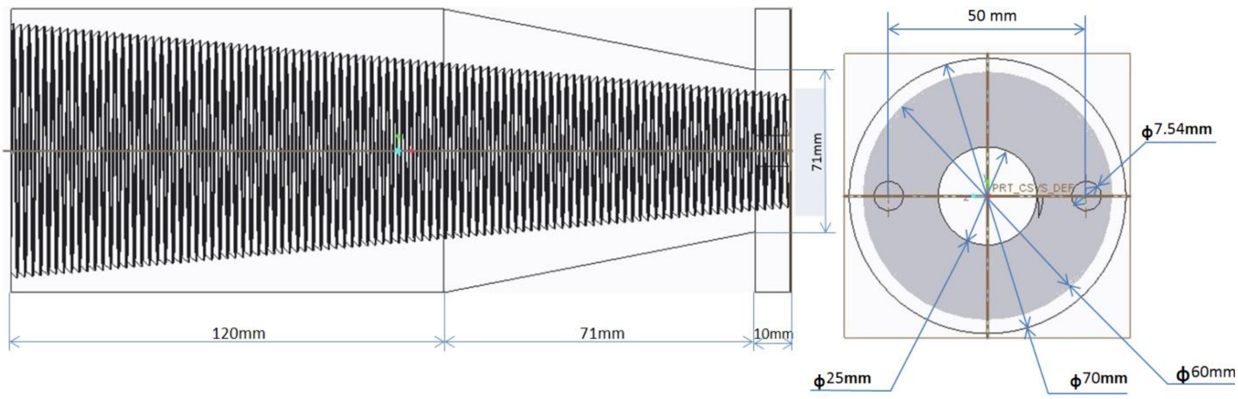


Figure 6:- 2-D Sketch of new inlet manifold with dimensions

Figure 7:- Newly designed internally threaded inlet manifold with swirling device at centre

3.2. Swirling Device.

50 mm is taken as width of swirling device so that it can be fixed inside the inlet manifold easily. Angle of tapper of swirling device is 8^o.Twisting in swirling device is kept such that it gets half of twist trough out its length. Hence its pitch becomes double of its total length. So we get pitch of twisting in swirling device as 360 mm.

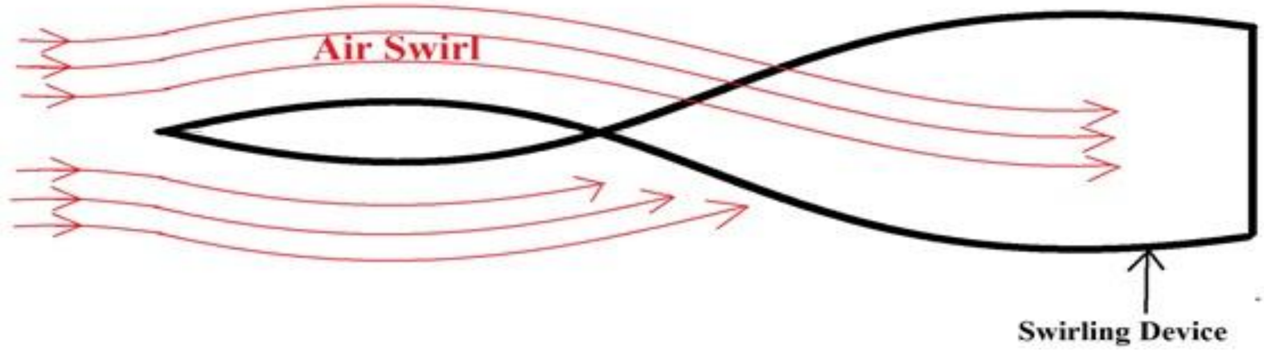


Figure 8:- Twisting in swirling device.

- Front face of swirling device are kept of three types

Type A: Flat front edge

Figure 9:- Flat front edge type swirling device.

Type B: Front edge straight bent in opposite direction

Figure 10:- Front edge straight bent in opposite direction type swirling device.

Type C: Front edge curve bent in opposite direction

Figure 11:- Front edge curve bent in opposite direction type swirling device.

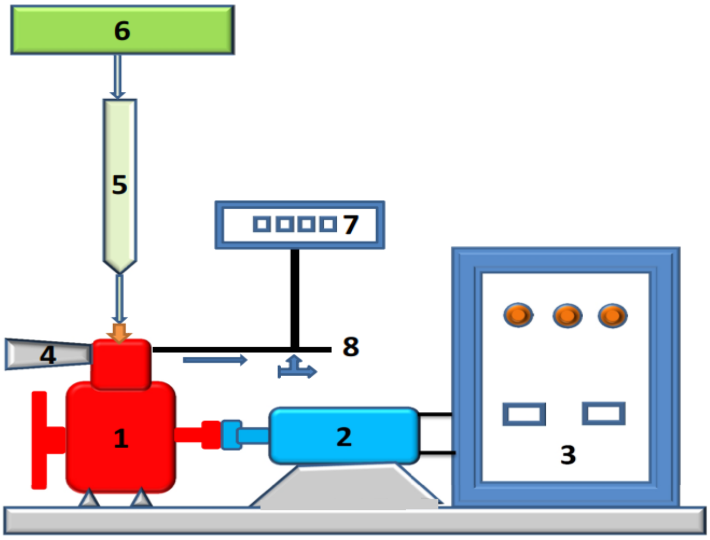
3.3:-Combinations of Swirling Device with Inlet Manifold Shell.

Table1:- Nomenclature of combinations of inlet manifold

Sr. No.	Pitch	Type	Combination	Nomenclature
1	2mm	Type A	2mm pitch; Type A	A2
2		Type B	2mm pitch; Type B	B2
3		Type C	2mm pitch; Type c	C2
4	4mm	Type A	4mm pitch; Type A	A4
5		Type B	4mm pitch; Type B	B4

6		Type C	4mm pitch; Type c	C4
7	6mm	Type A	6mm pitch; Type A	A6
8		Type B	6mm pitch; Type B	B6
9		Type C	6mm pitch; Type c	C6

3.4:-Expeerimentalsetup :



1. Engine
2.Electric Dynamometer
3.Dynamometer Panel
4.Modified Inlet Manifold
5.Burette
6. Fuel Tank
7. Exhaust Gas Analyzer
8.Exhaust

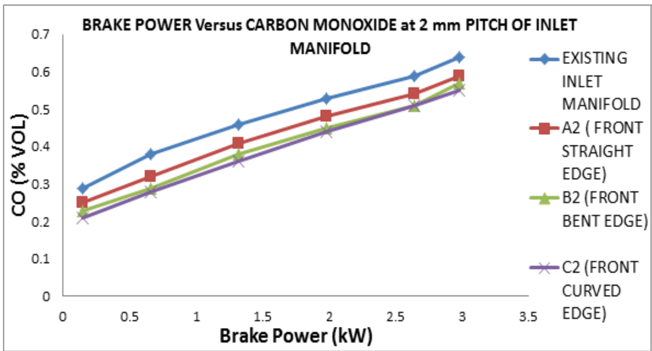
Figure 12:- Schematic view of experimental setup.

IV. RESULTS AND DISCUSSION

4.1:- Reduction in Carbon Monoxide:

There was reduction in carbon monoxide emission when newly designed inlet manifold replaced the existing inlet manifold. Figure 5.1 shows that while keeping 2mm of pitch in inlet manifold and comparing carbon monoxide proportion in flue gas, front straight edge has reduction of 7.81% (value-0.59 %vol), front bent edge has reduction of 10.97% (value- 0.57 % vol) and front curved edge has reduction of 14.06% (value-0.55% vol) as compared to existing inlet manifold (value-0.64%vol) at 2.98kW of brake power. Hence Swirling device of type- C (front curved edge) showed optimum emission of CO with pitch of 2mm inside inlet manifold.

It was found that swirling device with type of front curved face has optimum emission in carbon monoxide. By plotting the graphs of variation in percentage of pitch 2mm (14.06%), 4 mm (21.87%) and 6 mm (15.62%) in figure, it is found that optimum emission among them was found in 4 mm at brake power of 2.98kW.



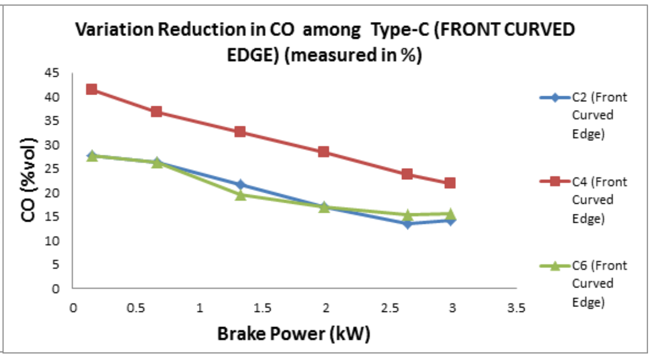


Figure13: Brake Power Vs COwith various faces of swirling device at 2 mm.

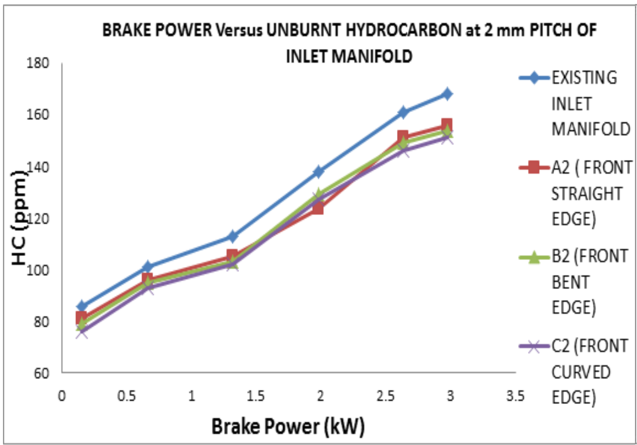
Figure14: Brake Power Vs CO with pitch 2mm, 4mm & 6mm with front curve edge.

Optimum combination obtained for reduction in carbon monoxide (CO) was with 4 mm pitch and front curved edge. Carbon monoxide was reduced to 0.5% vol from 0.64 % vol. Hence there was reduction up to 21.87% in carbon monoxide by using C4 (Pitch 4 mm and front curved edge) inlet manifold.

4.2:-Reduction in Hydrocarbon:

There was reduction in unburnt hydrocarbon emission when newly designed inlet manifold replaced the existing inlet manifold. Figure 5.5 shows that while keeping 2mm of pitch in inlet manifold and comparing unburnt hydrocarbon in ppm of flue gas, front straight edge has reduction of 7.14% (value-156 ppm), front bent edge has reduction of 8.33% (value- 154 ppm) and front curved edge has reduction of 10.11% (value-151 ppm) as compared to existing inlet manifold (value-0.64%vol) at 2.98kW of brake power. Hence Swirling device of type- C (front curved edge) showed optimum emission of Hydrocarbon with pitch of 2mm inside inlet manifold.

It was found that swirling device with type of front curved face has optimum emission in carbon monoxide. By plotting the graphs of variation in percentage of pitch 2mm (10.11%), 4 mm (14.28%) and 6 mm (9.52%) in figure 5.8, it is found that optimum emission among them was found in 4 mm at brake power of 2.98kW.



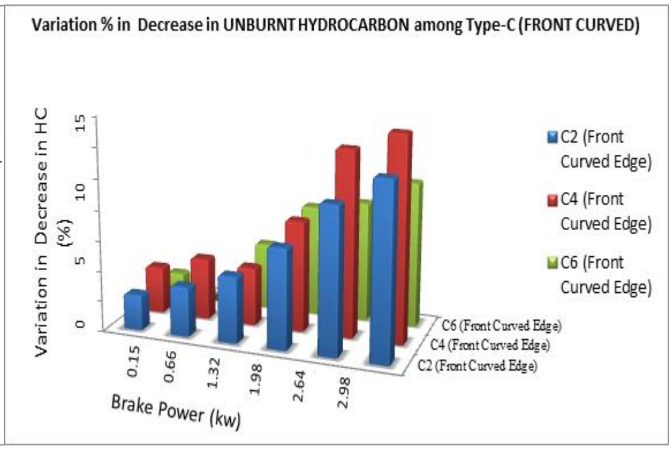


Figure15: Brake Power Vs HC with various faces of swirling device at 2 mm.

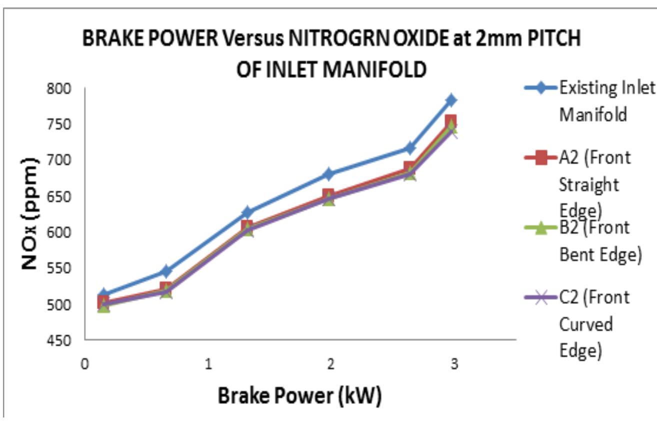
Figure16: Brake Power Vs HC with pitch 2mm, 4mm & 6mmwith front curve edge.

Optimum combination obtained for reduction in unburnt hydrocarbon (HC) was with 4 mm pitch and front curved edge. Hydrocarbon was reduced to 144 ppm from 168 ppm. Hence there was reduction up to 14.28% in hydrocarbon by using C4 (Pitch – 4 mm and front curved edge) inlet manifold.

4.3:-Reduction in Nitrogen Oxide:

There was reduction in nitrogen oxide emission when newly designed inlet manifold replaced the existing inlet manifold. Figure 5.9 shows that while keeping 2mm of pitch in inlet manifold and comparing nitrogen oxide in ppm flue gas, front straight edge has reduction of 3.95% (value-752 ppm), front bent edge has reduction of 4.59% (value-747 ppm) and front curved edge has reduction of 5.61% (value-739 ppm) as compared to existing inlet manifold (value-783 ppm) at 2.98kW of brake power. Hence Swirling device of type- C (front curved edge) showed optimum emission of NOx with pitch of 2mm inside inlet manifold.

It was found that swirling device with type of front curved face has optimum emission in carbon monoxide. By plotting the graphs of variation in percentage of pitch 2mm (5.61%), 4 mm (6.00%) and 6 mm (5.36%) in figure 5.12, it is found that optimum emission among them was found in 4 mm at brake power of 2.98kW.



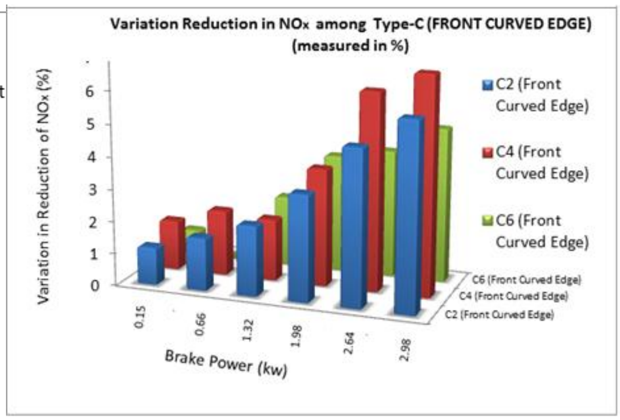


Figure17: Brake Power Vs NO_x with various faces of swirling device at 2 mm.

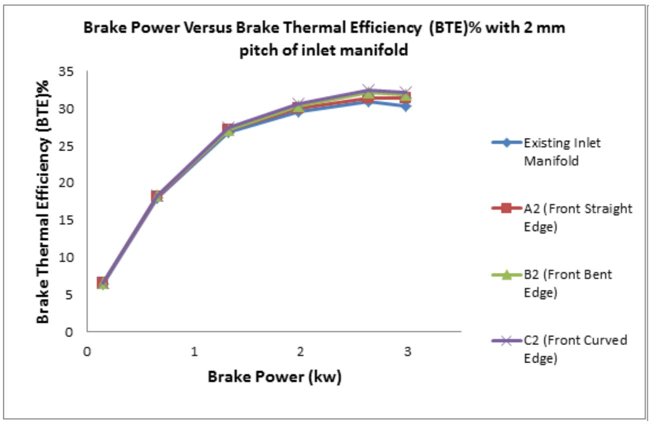
Figure18: Brake Power Vs NO_x with pitch 2mm, 4mm & 6mm with front curve edge.

Optimum combination obtained for reduction in nitrogen oxide (NOx) is with 4 mm pitch and front curved edge. Nitrogen oxide is reduced to 736 ppm from 783 ppm. Hence there is relative reduction up to 6.00% in nitrogen oxide by using C4 (Pitch – 4 mm and front curved edge) inlet manifold.

4.4:-Increase in Brake Thermal Efficiency (BTE %)

There is increase in Brake Thermal Efficiency when newly designed inlet manifold replaced the existing inlet manifold. Figure 5.13 shows that while keeping 2mm of pitch in inlet manifold and comparing Brake Thermal Efficiency percentage, front straight edge has increment of 3.88% (value-31.44 %), front bent edge has increment of 5% (value-31.78 %) and front curved edge has increment of 6.11% (value-32.11%) as compared to existing inlet manifold (value-30.26%) at 2.98kW of brake power. Hence Swirling device of type- C (front curved edge) showed optimum Brake Thermal Efficiency with pitch of 2mm inside inlet manifold.

It was found that swirling device with type of front curved face (type-C) has optimum Brake Thermal Efficiency. By plotting the graphs of variation in percentage of pitch 2mm (14.06%), 4 mm (21.87%) and 6 mm (15.62%), it was found that optimum Brake Thermal Efficiency among them was found in 4 mm at brake power of 2.98kW.



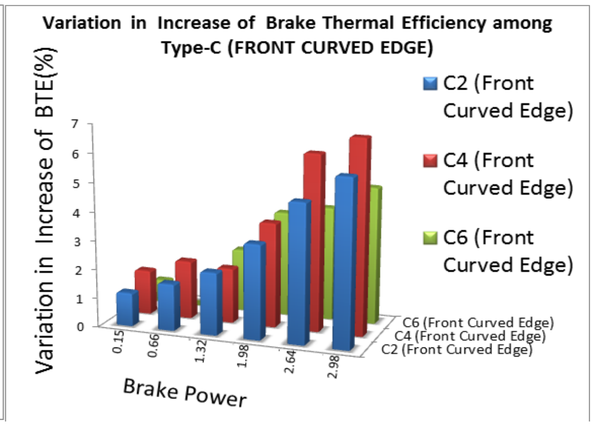


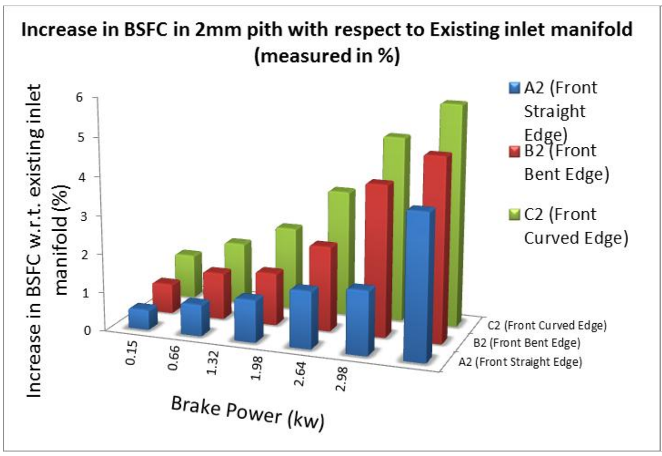
Figure19: Brake Power Vs BTE with various faces of swirling device at 2 mm.

Figure20: Brake Power Vs BTE with pitch 2mm, 4mm & 6mm with front curve edge.

Optimum combination obtained for increase in Brake Thermal Efficiency is with 4 mm pitch and front curved edge. Brake Thermal Efficiency is increased to 32.45% from 30.26%. Hence there is relative increment of 21.87% in Brake Thermal Efficiency by using C4 (Pitch – 4 mm and front curved edge) inlet manifold.

4.5:-Reduction in Brake Specific Fuel Consumption:

There was reduction in Brake Specific Fuel Consumption when newly designed inlet manifold replaced the existing inlet manifold. Figure 5.17 shows that while keeping 2mm of pitch in inlet manifold and comparing Brake Specific Fuel Consumption, front straight edge has reduction of 3.74% (value-0.268), front bent edge has reduction of 4.76% (value-0.265) and front curved edge has reduction of 5.75% (value-0.263) as compared to existing inlet manifold (value-0.279) at 2.98kW of brake power. Hence Swirling device of type- C (front curved edge) showed remarkable reduction in Brake Specific Fuel Consumption with pitch of 2mm inside inlet manifold



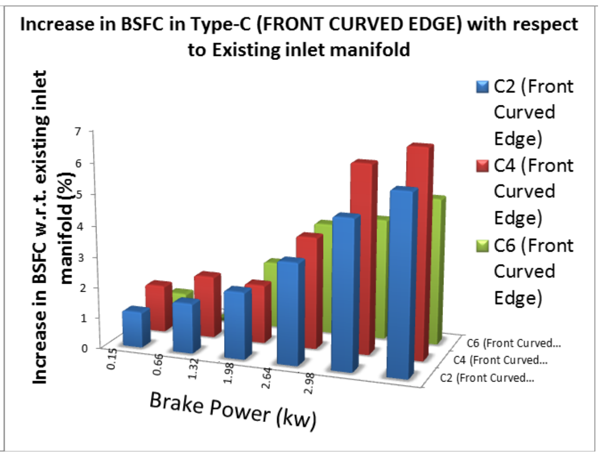


Figure21: Brake Power Vs BSFC with various

Figure22: Brake Power Vs BSFC with pitch 2mm, 4mm

faces of swirling device at 2 mm. ***& 6mm with front curve edge.***

It was found that swirling device with type of front curved face has proved to be optimum Brake Specific Fuel Consumption. By plotting the graphs of variation in percentage of pitch 2mm (5.75%), 4 mm (6.73%) and 6 mm (4.76%), it was found that optimum Brake Specific Fuel Consumption among them was found in 4 mm at brake power of 2.98kW. Optimum combination obtained for reduction in Brake Specific Fuel Consumption was with 4 mm pitch and front curved edge. Brake Specific Fuel Consumption is reduced to 0.260 from 0.279. Hence there was reduction up to 6.73% in Brake Specific Fuel Consumption by using C4 (Pitch – 4 mm and front curved edge) inlet manifold as shown in Figure 5.20.

V. CONCLUSION

Experimental investigation was concluded by following points:

a) **Brake Specific Fuel Consumption (BSFC)** was reduced to 0.260 from 0.279 at 2.98 kW brake power. Hence there was relative reduction up to 6.73% in BSFC by using inlet manifold of internal tapper threads of pitch 4 mm and front curved edge type swirling device.

b) **Brake Thermal Efficiency (BTC)** was increased to 32.45% from 21.87% at 2.98 kW brake power. Hence there was relative increment of 21.87% in BTE by using inlet manifold of internal tapper threads of pitch 4 mm and front curved edge type swirling device.

c) **Carbon Monoxide (CO)** emission was reduced to 0.5% vol. from 0.64% vol. at 2.98 kW brake power. Hence there was relative reduction up to 6.73% in CO emission by using inlet manifold of internal tapper threads of pitch 4 mm and front curved edge type swirling device.

d) **Nitrogen Oxide (NOx)** emission was reduced to 736 ppm from 783 ppm vol. at 2.98 kW brake power. Hence there was relative reduction up to 6.00% in NOx emission by using inlet manifold of internal tapper threads of pitch 4 mm and front curved edge type swirling device.

e) **Unburnt Hydrocarbon (HC)** emission was reduced to 144 ppm from 168 ppm vol. at 2.98 kW brake power. Hence there was relative reduction up to 14.28% in NOx emission by using inlet manifold of internal tapper threads of pitch 4 mm and front curved edge type swirling device.

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