Computational Analysis of a Multi-Cylinder Four Stroke SI Engine Exhaust Manifold System

Girish L, Gowreesh S S, Kousik S

Abstract: ***In an internal combustion engines exhaust system plays a vital role in the enhancement of the combustion efficiency. A well designed exhaust manifold increases the performance of an IC engines. The designing of exhaust manifold is a complex procedure and is dependent on many parameters. The present work is fundamentally based on the investigation of modelling of exhaust manifold of a multi-cylinder four stroke SI engine using computational analysis. The work is majorly focused on reducing the backpressure at the outlet and also by increasing the velocity of the exhaust gases at the outlet of exhaust manifold system, which is leading to increase the performance of the engine. Commercially available CFD software tool is used for carrying out the present analysis. Flow through the exhaust manifold is analyzed using pressure and mass flow boundary conditions.***

Keywords: ***internal combustion, IC engines, CFD software, fundamentally***

I. INTRODUCTION

In IC engine exhaust manifold is the main important component of the exhaust system and exhaust manifold is the one of the key component of the exhaust system on vehicle. Exhaust manifold work is collecting the exhaust gases from the multiple engine cylinder, it's will send into the single pipe, which usually converge into one tube called collector. The exhaust manifold commonly made up of cast iron or stainless steel. When engine starts in exhaust stroke piston moves up the cylinder bore, in that the total volume of chamber will decrease, the exhaust valve open, the high pressure exhaust gas enter into the header or exhaust manifold. Exhaust manifold is also known as "header". When its high pressure exhaust gas entering into the header , is creating the exhaust pulse its includes three parts, high pressure head is created pressure difference between the combustion chamber exhaust and atmospheric pressure outside the exhaust system. Exhaust gas equalizing between the combustion chamber and atmosphere, so that the pressure difference, the pressure will decreases and also exhaust velocity deceases. Tail component initially matches the ambient atmospheric pressure, but momentum of high pressure and low pressure it will be reduce the combustion chamber pressure to lower than the atmospheric.

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The low pressure is the backpressure its helps to extract the engine combustion products from cylinder. The exhaust gas is not freely moves to the tail, when high pressure in the outlet of the manifold. out let exhaust gas not escape easily, Because the same pressure in outlet of the manifold and entering the exhaust gas into the inlet is very high pressure,
there will be a same inlet and outlet pressure, so that exhaust gas not moves freely, backpressure will be created. When increasing the backpressure also increasing the fuel consumption and increasing the emission level and also negative effect of the engine performance. So that proper exhaust manifold design is required to the engines. Exhaust manifold design is very complex procedure and its design is carefully, exhaust manifold design is depends on many parameters like, exhaust velocity, pressure, turbulence, volumetric efficiency, backpressure. Many work and research are done for the study of any exhaust manifold. The exhaust manifold is analyzed using CFD fluent with the help of velocity contours, pressure contour, turbulence kinetic energy and velocity stream lines using these parameters we can analyze and study the flow distribution in exhaust manifold. Purpose of the study is to understand the exhaust manifold working and operation and flow distribution of an exhaust manifold. The back pressure of the exhaust manifold outlet must be less in order to have optimum engine performance.

When increasing the backpressure decreasing engine performance or economy for domestic vehicles. The proper design of the exhaust manifold we can eliminate the unnecessary eddied and turbulence. Maximum backpressure is required for race cars to achieve the maximum speed in very short time. The race cars not bother about the fuel consumption, knock and emission. Race cars the main aim is to achieve the higher speed in very short time. Literature survey lot of work has been done for the design and improvement of an exhaust manifold because in order to improve the engine performance. For using the CFD method we can reduce the manufacturing cost and production time. Some of the literature as follows.

Table 1: Engine specification

Engine	4-stroke 4 cylinder SI Engine
Make	Maruti-Suzu ki wagon-R
Bore and stroke	69.05mm*73.40mm
Swept volume	1100cc
Compression ratio	7.2:1
Dynamometer constant	2000
Diameter of orifice	29mm
Coefficient discharge of orifice	0.65

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Mohdsajid Ahmed,Kailash BA, Gowreesh SS, In this work five different models of exhaust manifold are designed and analyzed. The major work is improve the design of an exhaust manifold because lowering the backpressure in the exhaust manifold it will be increases the engine efficiency and performance. They analyzed the easy flow of an exhaust with the help of an velocity contours and pressure contours for five different designed models and compare the all five models using pressure and velocity contour then select the best one model. They concluded that model number five is the best model because minimum backpressure in that model and also easy flow of an exhaust without recirculation and almost zero turbulent kinetic energy is observed in the best model, velocity of outlet in that model is more, compare to other models. Higher the exhaust velocity and minimum back pressure achieved using the exhaust manifold.

Vivekanand Navadagi, siddaveer Sangamad Have studied the flow through two different models of an exhaust manifold are analyzed using CFD. They analyzed the two models one model is base geometry of exhaust manifold and another one is modified geometry of the exhaust manifold, both models are analyzed using the pressure contour and velocity contours. The main aim of this paper is increase the outlet velocity, when minimum back pressure in exhaust manifold increases the volumetric efficiency and engine efficiency. They have concluded that existing model is modified by changing its geometry under the same boundary conditions. The results of the modified model is better compare to the existing model, because in the modified model they analyzed velocity and pressure contours the minimum back pressure is observed and increasing the volumetric efficiency of the engine.

KS Umesh, VK Pravin, K Rajagopal, Have presented both the CFD analysis and experimental verification of effect of exhaust manifold geometry. They have designed and analyzed two different model, existing model and modified model, they changed the geometry of the existing model of an exhaust manifold then analyzed using the parameters like velocity contours and pressure contours and then both models are constructed and experimentally conducted. In CFD analysis modified model is achieved the better result, minimum backpressure in exhaust manifold and increasing the volumetric efficiency of the engine. Then same results were obtained the experimental conducting the both model. It can be easily concluded that experimental results match the results of CFD analysis. The results of CFD analysis were proved by experimental analysis.

PL.S. Muthaiah, Dr.M. Senthil kumar, Dr. S. Sendilvelan He has analyzed the exhaust manifold in order to decrease the backpressure in exhaust manifold and increases the exhaust gas filtration. He has changing the geometry exhaust manifold he is varying the size of the conical area of exhaust manifold and also different grid size meshed wire packed through the exhaust manifold. When the increases the grid size decreases the filtration level, when the decreasing the level of filtration more exhaust emission comes from the exhaust system. When the deceasing the grid size backpressure will be created in the exhaust manifold, so that reason engine efficiency will decreases. CFD is used for study exhaust manifold and chose the best designed model with minimum backpressure and maximum PM filtration.

II. METHODOLOGY

Five models are designed including base model using the computer aided drawing software. The five models are analysed using CFD tool. The models are prepared and discretized using CFD-grid generation tool.

2.1 Design models of exhaust manifold using CAD software

2.1.1 Base model

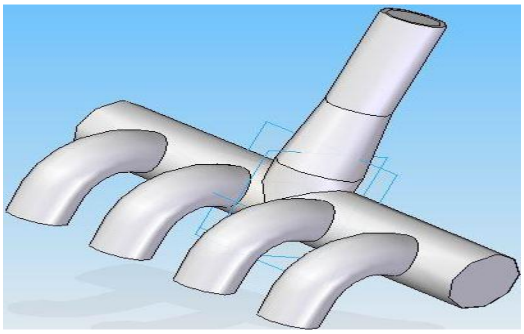

Fig 1 Base model

Table 2: Dimensions of Base model

Length of the header	365mm
ID and OD of the header	52.48mm and 60.30mm
Bend radius of the inlet	48mm
ID and OD of the inlet bend	38.29mm and 42.20mm
Length of the exhaust outlet	210mm

2.1.2 Model 1

In this model 1 shape of the inlet has been modified from eliminate inlet bend radius into straight inlet as shown in below figure 2

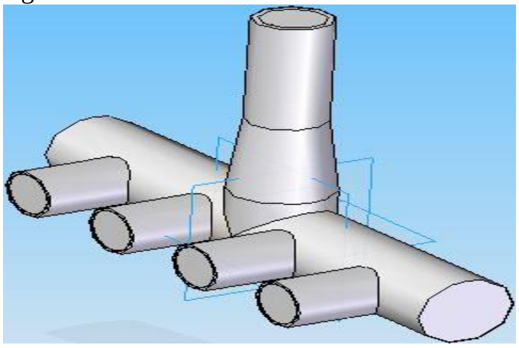

Fig 2 Model 1

2.1.3 Model 2

In model 2 inlet of exhaust manifold bend radius is increases up to 48mm to 90mm.

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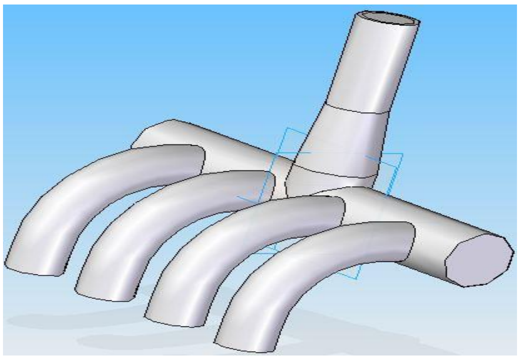

Fig 3 Model 2

Table 3: Dimensions of Model 1 and Model 2

Model 1 dimension	Model 2 dimension
Header length 365mm,	Exhaust outlet length 210mm
ID&OD header 52.48mm & 60.30mm	ID & OD of inlet 38.29mm & 42.20mm
Straight inlet length 49.85mm	Bend radius of the inlet 90mm

2.1.3 Model 3

In model 3 inlet and outlet of the exhaust manifold is modified from converging outlet to diverging-straight-convergent outlet and inlet bend radius increases up to 45mm to 90mm.

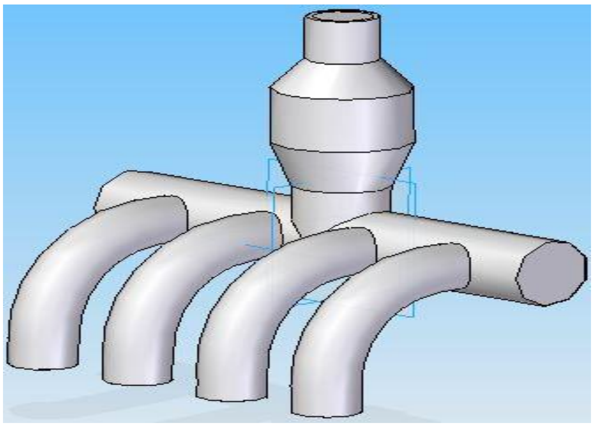

Fig 4 Model 3

2.1.4 Model 4

In this model 4 outlet of an exhaust manifold from convergent to straight-convergent outlet.

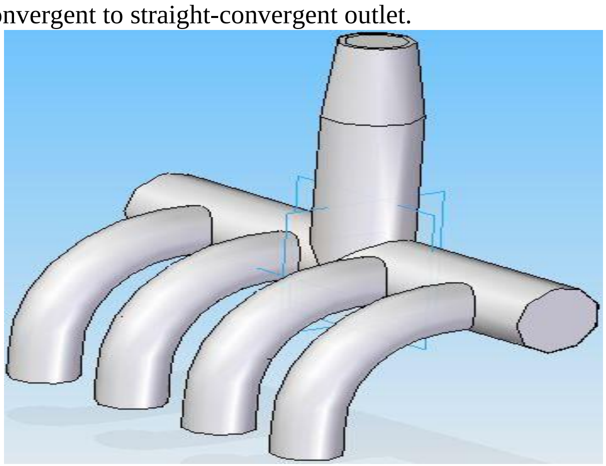

Fig 5 Model 4

Table 4: Dimensions of Model 3

Exhaust outlet overall length	210mm
First strigth length from header centre	50mm
Divergent length and angle	43.76mm & 72.26^0
Then strigth length	50mm
Convergent length and angle	35mm & 126^0
Then strigth length	40mm

Table 5: Dimensions of Model 4

Outlet overall length	210mm
First strigth length from header	140mm
Convergent length and angle	70mm & 95.91^0
Bend radius of inlet	90mm

2.2 Boundary condtions are used

Mass flow boundary condtions are used Inlet 1-0.00188kg/s, inlet 2-0.00188kg/s, inlet 3-0.00188kg/s, inlet 4-0.00188kg/s Outlet-0bar.

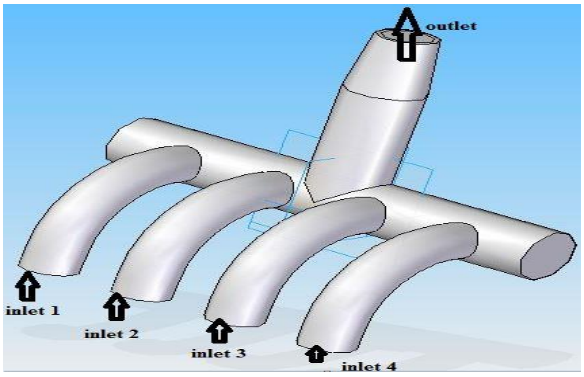

Fig 6 Boundary condition

2.3 Meshing of designed models

Figure 7 to 11 shows the meshed models

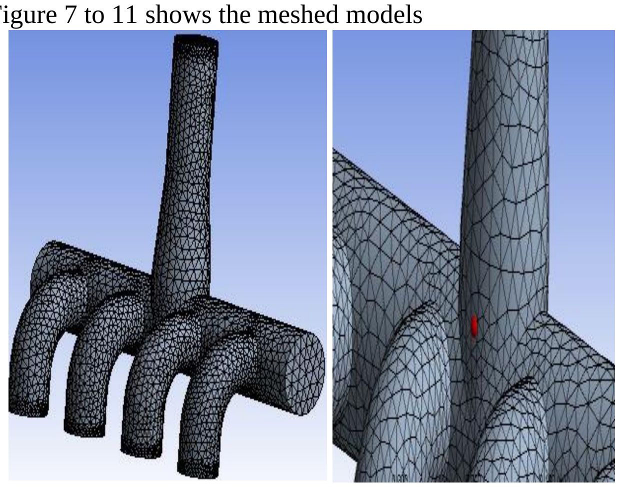

Fig 7 Base model

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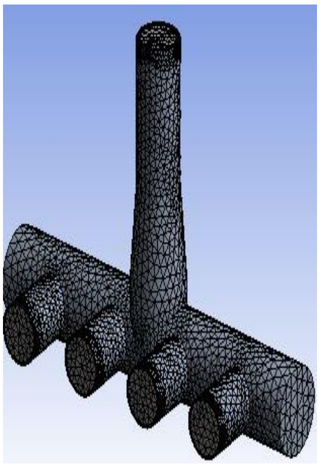

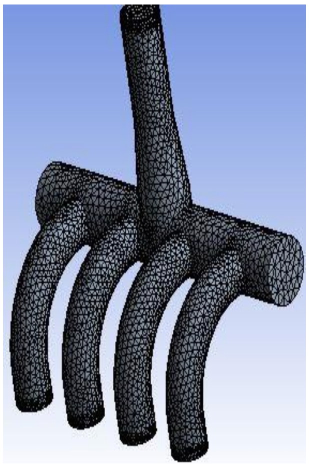

Fig 8 Model1 **Fig 9 Model 2**

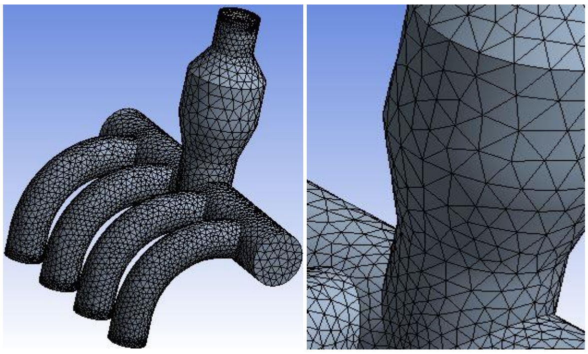

Fig 10 Model 3

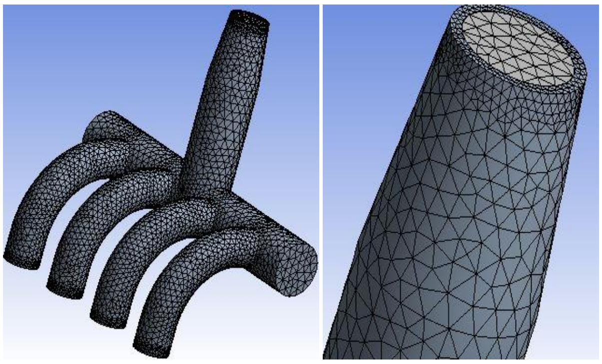

Fig 11 Model 4

Table 6: Meshing details of all models

	Elements	Nodes	Mesh type
Base model	74897	19434	Triangular
Model 1	58868	15201	Triangular
Model 2	90402	23418	Triangular
Model 3	88690	22955	Triangular
Model 4	88664	22994	Triangular

2.4 Planes are created for post-processing

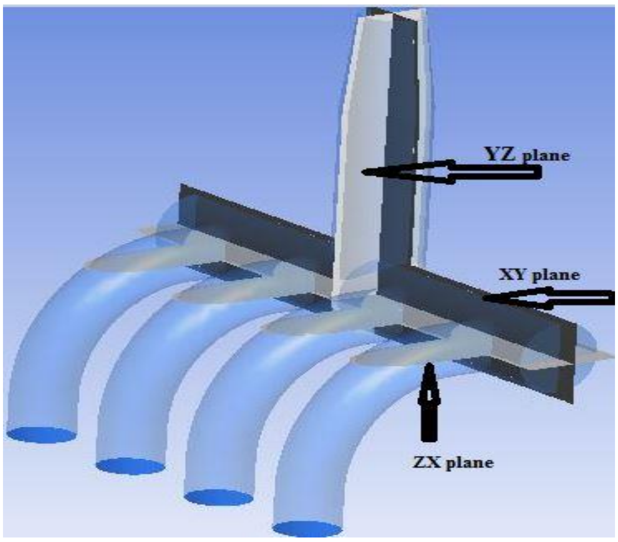

Fig 12 Planes for post-processing

Totally three planes created, XY plane, YZ plane and ZX plane for the analysis of exhaust manifold as shown in below figure 2.11, Understanding the velocity contour, pressure contour, turbulence kinetic energy and velocity streamline these parameters are better understanding using these planes and also results and discussion these planes are very helpful.

III. RESULTS AND DISCUSSIONS

3.1 Velocity contour for base model

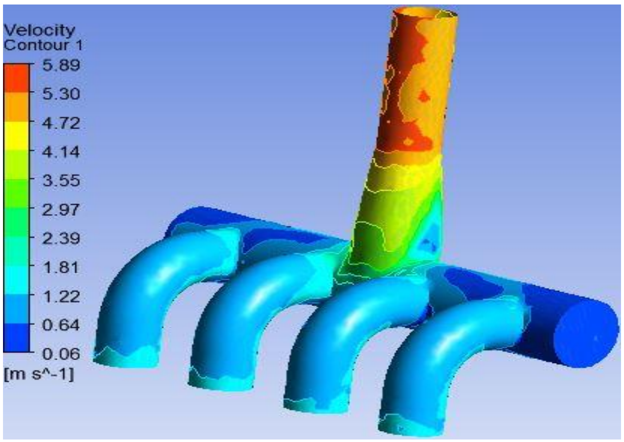

Fig 13 Velocity contour

The above Fig 13 shows the velocity contour of an base model of an exhaust manifold. In this model inlet port of the exhaust manifold we observe the minimum velocity and convergent shape of the top of the outlet manifold 5.89m/s maximum velocity. The low velocity results in high backpressure.

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3.2 velocity contours for all modified models

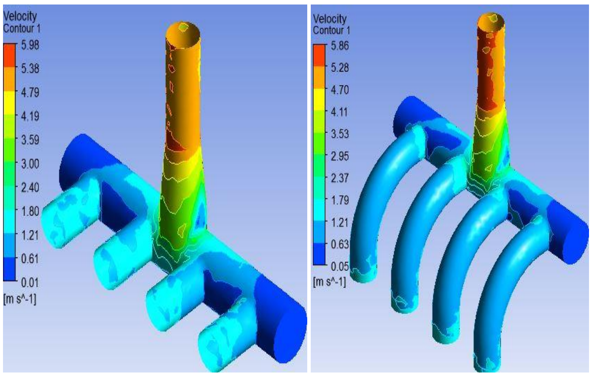

Fig 14 Velocity contour Model 1 and Model 2

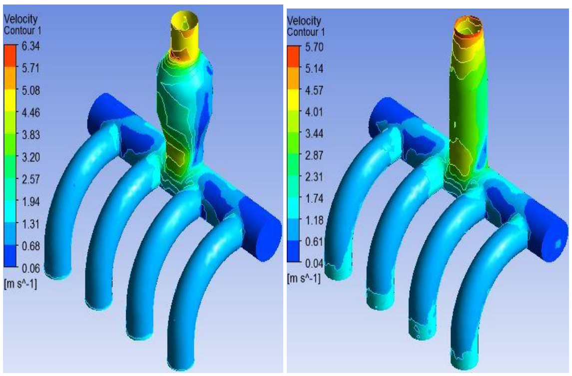

Fig 15 Velocity contour Model 3 and Model 4

The above figures Model 1, Model 2, Model 3 and model 4 shows the velocity contours for exhaust manifold. The figure 15 gives the velocity contour of the model 3. It is observed that, the outlet of the manifold shape divergent convergent shape of the velocity is higher, compare to the all 4 models including base model. It is observed that compare to the other model velocity is considerably increases by designing the exhaust manifold, by reducing the manifold outlet straight length and minimum backpressure is achieved compare to other models.

3.3 Pressure contour for base model

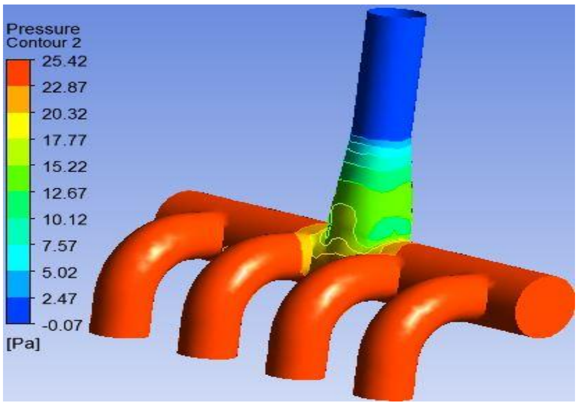

Fig 16 Pressure contour

The above figure 16 shows the pressure contour for base model. In this model top outlet of the exhaust manifold pressure is less, this indicates the more backpressure.

3.4 Pressure contours for all modified models

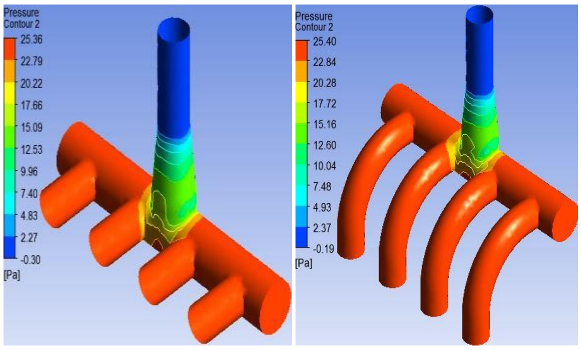

Fig 17 Pressure contour Model 1and Model 2

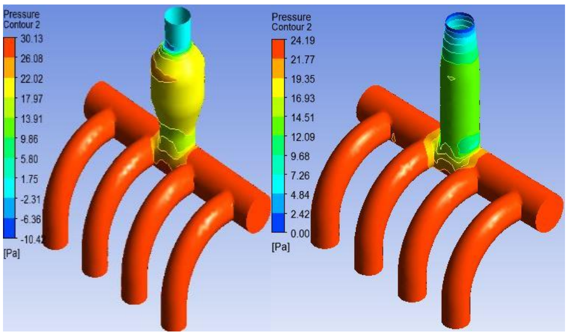

Fig 18 Pressure contour Model 3 and Model 4

The above figure model 1, model 2, model 3, and model 4 gives the pressure contours for all four modified models. The pressure of the exhaust manifold outlet is higher compare with other four models including base model. Model 3 higher pressure is observed in the inlet of the exhaust manifold.

3.5 Turbulence Kinetic energy contours for all models

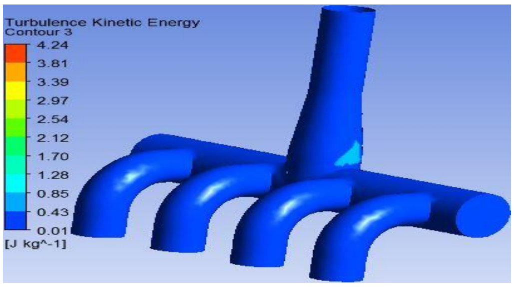

Fig 18 Turbulence kinetic energy contour

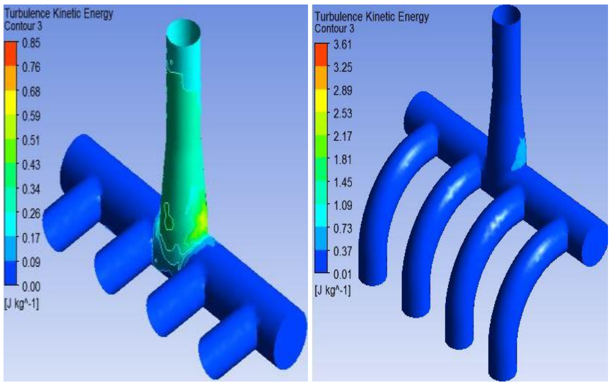

Fig 19 Turbulence kinetic energy contour for model 1 and model 2

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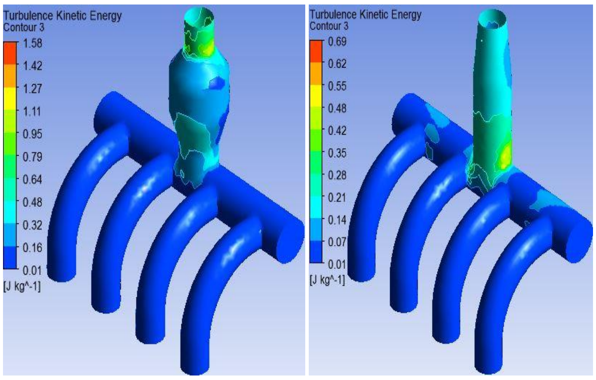

Fig 20 Turbulence kinetic energy contour for model 3 and model 4

The turbulence kinetic energy of the model 3 is little bit higher compare to the other models but almost negligible turbulence is observed and there are no flow recirculation were observed.

3.6 Velocity streamline for all models

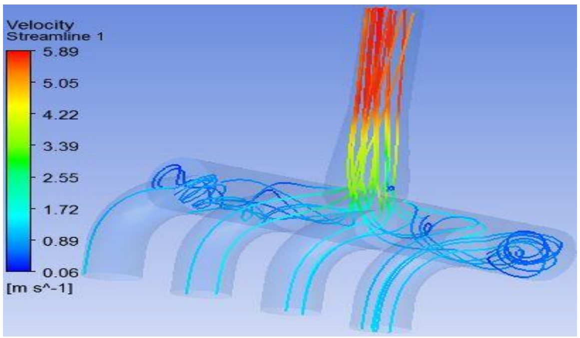

Fig 21 Velocity streamline Base model

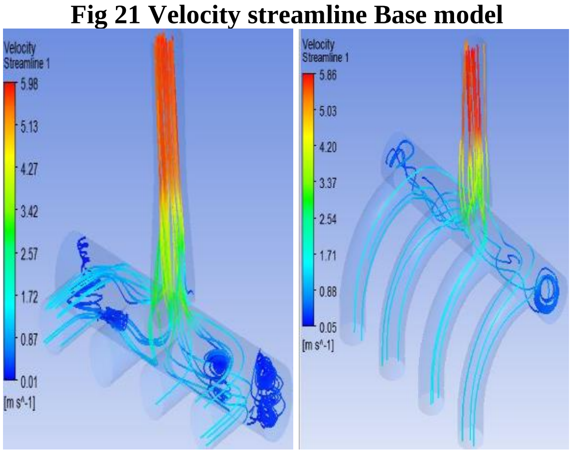

Fig 22Velocity Streamline Model1 and Model 2

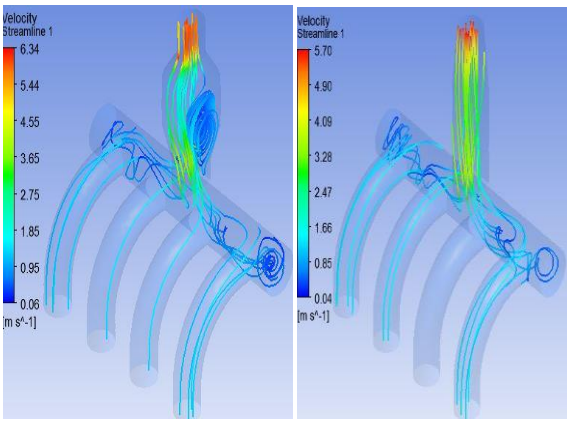

Fig 23Velocity Streamline Model 3 and Model 4

The velocity streamline of the model 3 flow is uniform and no recirculation are observed in this model and compare to the all the models almost same flow.

IV. CONCLUSIONS

Four different shapes of exhaust manifold are designed and analyzed using CAE and CFD tools. Pressure and velocity distribution along the exhaust manifold is analyzed by using numerical simulation and following conclusions were observed from the CFD analysis.

- Analysis is carried out for four different models by keeping the base model as a reference.
- The analyzed four models model-3 found to be best, since the flow of exhaust gas is observed to be less turbulent and minimum backpressure is achieved.
- For Model-3 maximum velocity is observed at the outlet of the exhaust manifold compared to the other models and hence backpressure is considerably decreases.
- The exhaust gas velocity at outlet found to be 6.34m/s for Model-3.
- The turbulence kinetic energy is almost negligible, and there are no flow recirculation were observed.

REFERENCES

1. Mohd Sajid Ahmed, Kailash B A, Gowreesh, " Design and analysis of a multi-cylinder four stroke SI engine exhaust manifold using CFD technique", volume:02 Issue:09 Dec-2015
2. Vivekanand Navadagi, Siddaveer Sangamad. "CFD analysis of exhaust manifold of multi-cylinder petrol engine for optimal geometry to reduce back pressure", volume: 3 Issue :3 March-2014
3. Rajesh Bisane, Dhanajay katpatal, "Experimental investigation and CFD analysis of single cylinder four stroke CI engine exhaust system", volume:03 Issue:06 Jun-2014
4. KS Umesh, VK Pravin, K Rajagopal, " CFD analysis and experimental verification of effect of manifold geometry on volumetric efficiency and back pressure for multi-cylinder SI engine", volume:3, Issue:7 July-2013
5. KS Umesh, VK Pravin, K Rajagopal, "CFD analysis of exhaust manifold of multi-cylinder SI engine to determine optimal geometry for reducing emission", volume:3 Issue:4 Oct- 2013
6. PL.S. Muthaiah, Dr.M. Senthil kumar, Dr. S. Sendilvelan, "CFD analysis of catalytic converter to reduce particulate matter and achieve limited back pressure in Diesel engine", volume:10 Issue:5 Oct-2010
7. P. Seenikannan, V. M. Periasamy and P. Nagaraj, " A design strategy for volumetric efficiency improvement in a multi-cylinder stationary diesel engine its validty under transient operation",volume:5 issue:3, 2008
8. Yasar Deger, Bukhard simperl, Luis P. Jimenez, "Coupled CFD-FE-Analysis for the exhaust manifold of a diesel engine 2004

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