CFD Analysis of Exhaust Manifold of Multi- Cylinder SI Engine

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Abstract— In present century, spark ignition engines have become a non-separable part of the society, and are used in many sectors of energy. They act as backbone for transportation systems, but, as a bitter truth they behave like a major source of air pollution. There are basically three types of emissions, emerged from a SI engine; exhaust emissions, evaporative emission, and crankcase emission, and the major pollutants emerged from these engines are CO, CO2, SOX, NOX. Present project work aims at reducing emissions. It is a well-established fact that smooth combustion minimizes the emissions, and exhaust process contributes a lot in accomplishing smooth combustion process. In present project work, different designs of exhaust manifold for a multi cylinder spark ignition engine are optimized for reducing emissions, by evaluating back pressures and exhaust velocities. For this purpose four different designs, namely, short bend center exit, short bend side exit, long bend center exit with reducer, and long bend side exit with reducer are considered, and their performance is evaluated for different loading conditions. As a result performance scores of different models based on back pressure and exhaust velocity are evaluated, and on the basis of these scores, overall performance score is investigated. In next step, on the basis of overall performance score, ranking of different models is carried out. The results show the suitability of short bend centre exit model for the purpose, as it scores better rank in the analysis. The analysis is carried out on virtual models of manifolds. Models of manifolds are developed on CATIA v5 modelling software, and for the purpose of analysis ANSYS Workbench is used.

Keywords: CFD, Multi- Cylinder SI Engine, IC Engine

I. INTRODUCTION

An internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal-combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy. The first commercially successful internal combustion engine was created by Etienne Lenoir around 1859 and the first modern internal combustion engine was created in 1864 by Siegfried Marcus.

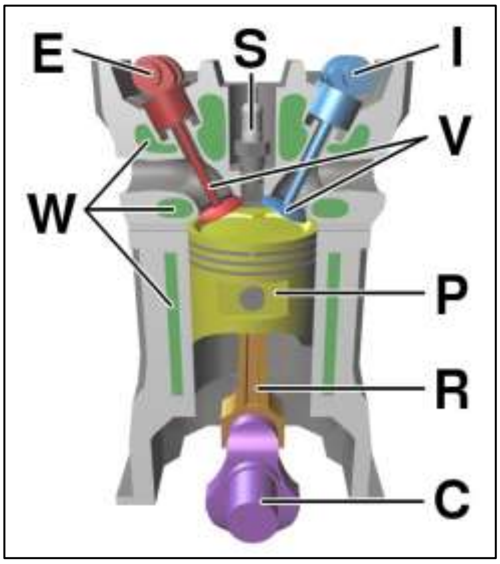

Fig. 1: IC Engine

C – Crank shaft.
E – Exhaust camshaft.
I – Inlet cam shaft.
P – Piston.
R – Connecting rod.
S – Spark plug.
V – Valves red: exhaust, blue: intake.
W – Cooling water jacket.
gray structure – engine block

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar stroke and two-stroke piston engines, along with variants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described. Firearms are also a form of internal combustion engine. Internal combustion engines are quite different from external combustion engines, such as steam or Stirling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized or even liquid sodium, heated in a boiler. ICEs are usually powered by energy-dense fuels such as gasoline or diesel, liquids derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for vehicles such as cars, aircraft, and boats. Typically an ICE is fed with fossil fuels like natural gas or petroleum products such as gasoline, diesel fuel or fuel oil. There's a growing usage of renewable fuels like bio-diesel for compression ignition engines and bi-ethanol for spark ignition engines. Hydrogen is sometimes used, and can be made from either fossil fuels or renewable energy.

A. Exhaust manifold

The exhaust manifold is a pipe, receives the exhaust gases from the combustion Chamber and leaves it to the atmosphere. Exhaust manifolds are mounted to the cylinder head. V- Type engines have two exhaust manifolds, and an in-line engine usually has one. When intake and exhaust manifolds are on opposite sides of an in-line engine, the head is called a cross-flow head. This design improves breathing capacity of an engine. Exhaust manifolds are typically made of cast iron or steel, although some latest-model cars use stainless steel manifolds. Cast iron is a good material for exhaust manifolds. Like the frying pan on a stove, it can tolerate fast and severe temperature changes. Exhaust gas temperature is related to the amount of load on the engine.

Fig. 2: Exhaust Main-fold

II. LITERATURE REVIEW

Backpressure is one of the common problems associated with the exhaust manifold. The literature review reveals that the lots of work have been done for the improvement of the exhaust manifold in order to improve the working of the engine. CFD method reduces the cost of manufacturing and production time. Literature review shows that lots of exhaust manifold study have been done using the CFD technique. Some of the literature reviews are as follows.

A. PL. S. MUTHAIAH He has analyzed the exhaust manifold in order to reduce the

Back pressure and also to increase the particulate matter filtration. He has modified the different exhaust manifold by varying the size of the conical area of the exhaust manifold and varying the size of the grid wire mesh packed throughout the exhaust manifold. When size of the grid mesh packed decreased the backpressure increases which leads to lower the performance of the engine due to more fuel consumption and hence low volumetric efficiency. When size of the grid mesh packed increased the backpressure decreases the filtration of the particulate matter also reduces which will not satisfy the standards of the pollution control. Computational fluid dynamics is used for the study of the exhaust manifold and best possible design of the exhaust manifold with minimum backpressure and maximum particulate matter filtration efficiency is suggested.

B. K.S. Umesh, V.K. Pravin and K. Rajagopal

In this work eight different models of exhaust manifold were designed and analyzed to improve the fuel efficiency by lowering the backpressure and also by changing the position of the outlet of the exhaust manifold and varying the bend length. The eight different modified models are short bend centre exit (SBCE), short bend side exit (SBSE), long bend centre exit (LBCE), long bend side exit (LBSE), short bend centre exit with reducer (SBCER), short bend side exit with reducer (SBSER), long bend centre exit with reducer (LBCER), long bend side exit with reducer(LBSER).After analysis they included that the exhaust manifold with long bend centre exit with reducer (LBCER), gives the highest overall performance

C. Kulal Et Al. (2013)

work comprehensively analyzes eight different models of exhaust manifold and concluded the best possible design for least fuel consumption. CFD is the current trend on automotive field in reducing the cost effect for analysis of various models on the basis of fluid flow. A multi-cylinder Maruti - Suzuki Wagon-R engine with maximum speed of 1500 rpm is taken for the analysis. The load and performance test is conducted. From the experiment back pressure and exhaust temperatures are measured. The mass flow rate and velocities are calculated. Flow through the exhaust manifold is analyzed using commercially available software with mass flow rate and pressure as boundary conditions.

D. Vivekananda Navadagi and Siddaveersangama D

They analyzed the flow of exhaust gas from two different modified exhaust manifold with the help of Computational fluid dynamics. To achieve the optimal geometry for the low back pressure they have analyzed two different exhaust manifold, base geometry exhaust manifold and the modified geometry exhaust manifold. In the base model of the exhaust manifold the outlet is at side of the first inlet where as in the modified model of the exhaust manifold the outlet is at the centre of the exhaust manifold. Analysis has been done for the two different exhaust manifolds. The results were compared for the two models and it is found that the modified model gives low back pressure in comparison with other base model which ensures the improvement in the efficiency of the engine. The flow distribution in the exhaust manifold channels would be highly dependent on the header shape and the flow rate.

E. Jafar M Hassan

Had analyzed the performance of the manifolds with a tapered longitudinal section. The length of the manifold for this study was 127 cm while the manifold diameter was 10.16 cm. Authors had used the numerical simulations (CFD) for this research work. The flow conditions corresponding to Re = 10x104, 15x104 and 20x104 were considered. The results were analyzed in terms of uniformity coefficient. Based on their CFD simulation results, they had concluded that the tapered header configuration provides better flow distribution as compared to the header with circular cross-section.

III. MAINFOLD

In automotive engineering, an exhaust manifold collects the exhaust gases from multiple cylinders into one pipe. The word manifold comes from the Old English word manigfeald (from the Anglo-Saxon manig [many] and feald [fold]) and refers to the folding together of multiple inputs and outputs (in contrast, an inlet or intake manifold supplies air to the cylinders). Exhaust manifolds are generally simple cast iron or stainless steel units which collect engine exhaust gas from multiple cylinders and deliver it to the exhaust pipe.

The most common types of aftermarket headers are made of mild steel or stainless steel tubing for the primary tubes along with flat flanges and possibly a larger diameter collector made of a similar material as the primaries. They may be coated with a ceramic-type finish (sometimes both inside and outside), or painted with a heat-resistant finish, or bare. Chrome plated headers are available but these tend to blue after use. Polished stainless steel will also colour (usually a yellow tint), but less than chrome in most cases. Another form of modification used is to insulate a standard or aftermarket manifold. This decreases the amount of heat given off into the engine bay, therefore reducing the intake manifold temperature.

A. Back Pressure

Engine exhaust back pressure is defined as the exhaust gas pressure that is produced by the engine to overcome the hydraulic resistance of the exhaust system in order to discharge the gases into the atmosphere. The exhaust back pressure is the gauge pressure in the exhaust system at the outlet of the exhaust turbine in turbocharged engines or the pressure at the outlet of the exhaust manifold in naturally aspirated engines.

The word back may suggest a pressure that is exerted on a fluid against its direction of flow indeed, but there are two reasons to object. First, pressure is a scalar quantity, not a vector quantity, and has no direction. Second, the flow of gas is driven by pressure gradient with the only possible direction of flow being that from a higher to a lower pressure.

B. Effects of Increased Back Pressure

– At increased back pressure levels, the engine has to compress the exhaust gases to a higher pressure which involves additional mechanical work and/or less energy extracted by the exhaust turbine which can affect intake manifold boost pressure. This can lead to an increase in fuel consumption, PM and CO emissions and exhaust temperature. The increased exhaust temperature can result in overheating of exhaust valves and the turbine. An increase in NOx emissions is also possible due to the increase in engine load.
– Increased backpressure may affect the performance of the turbocharger, causing changes in the air-to-fuel ratio-usually enrichment—which may be a source of emissions and engine performance problems. The magnitude of the effect depends on the type of the charge air systems. Increased exhaust pressure may also prevent some exhaust gases from leaving the cylinder (especially in naturally aspirated engines), creating an internal exhaust gas recirculation (EGR) responsible for some NOx reduction. Slight NOx reductions reported with some DPF system, usually limited to 2-3% percent, are possibly explained by this effect.
– Excessive exhaust pressures can increase the likelihood of failure of turbocharger seals, resulting in oil leakage into the exhaust system. In systems with catalytic DPFs or other catalysts, such oil leak can also result in the catalyst deactivation by phosphorus and/or other catalyst poisons present in the oil.
– All engines have a maximum allowable engine back pressure specified by the engine manufacturer. Operating the engine at excessive back pressure might invalidate the engine warranty.
– It is generally accepted by automotive engineers that for every inch of Hg of back pressure (that's Mercury - inches of Hg is a unit for measuring pressure) approximately 1-2 HP is lost depending on the displacement and efficiency of the engine, the combustion chamber design etc.

C. Exhaust Velocity

– Exhaust system is designed to evacuate gases from the combustion chamber quickly and efficiently. Exhaust gases are not produced in a smooth stream; exhaust gases originate in pulses. A 4-cylinder motor will have 4 distinct pulses per complete engine cycle a 6 cylinder has 6 pulses and so on. More the pulses produced, the more continuous the exhaust flow. Back pressure can be loosely defined as the resistance to positive flow - in this case, the resistance to positive flow of the exhaust stream.
– It is a general misconception that wider exhaust gives helps in better scavenging. But actually main factor behind good scavenging is exhaust velocity. The astute exhaust designer knows that flow capacity must be balanced with velocity. The faster an exhaust pulse moves, the better it can scavenge out all of the spent gasses during valve overlap.The guiding principle of exhaust pulse scavenging is that a fast moving pulse creates a low-pressure area behind it. This low-pressure area acts as a vacuum and draws along the air behind it. A similar example would be a vehicle travelling at a high rate of speed on a dusty road.
– There is a low pressure area immediately behind the moving vehicle - dust particles get sucked into this low pressure area causing it to collect on the back of the vehicle. Exhaustive work has taken place already in this field. Scheeringa et al studied analysis of Liquid cooled exhaust manifold using CFD. He to improve the fundamental understandings of manifold operation obtained detailed information of flow property distributions and heat transfer. He to investigate the parametric effects of operating conditions and geometry on the performance of manifolds performed a number of computations.

D. Objectives

– This work focuses upon study of pressure distribution and velocity distribution inside an exhaust manifold of different geometries and to conclude best possible geometry from emissions point of view.
– We have flaunted with symmetric and asymmetric designs and have flocked concepts of having either long or short bends (inlet for exhaust manifold).These calculations were carried out at loading condition i.e. 2kg.

E. Factors to be considered during the Design and Development of Exhaust Manifold

1) Runner Length: This is arguably one of the most important factors. First would be to make sure that the runners are as equal length as possible. The idea being that the exhaust pulses will be spaced out evenly and arriving at the turbine wheel on the turbo at their own time in the firing order. If they arrive sooner or later, they may interfere with the exhaust pulses from the next firing cylinder. Next, a longer runner manifold will have better flow up top, while a shorter manifold can yield a faster spool, with also less transient lag.
2) Runner Volume: Runner volume needs to be considered when building a turbo manifold. While a larger runner diameter does facilitate lower exhaust backpressure for better flow on the top-end, it does cause a lower exhaust velocity. A lower exhaust velocity will cause longer spool times, and less transient response out of the turbo. Collectors: A collector's job is to tie all of the cylinder's pipes together in one common place and send them into a single exit pipe. A collector is generally a conglomeration of pipes all merged together, allowing for a smooth transition from the primaries or secondary into the rest of the exhaust. When properly constructed, a good collector will take the low pressure waves created earlier and send them back up the primaries, thus quickening the entire evacuation process. There are two scenarios in which exiting exhaust gases will encounter once they move past the valve: low-pressure or high-pressure. Low-pressure situations within the exhaust pipes help promote better flow by allowing for increased velocity through the exhaust ports while high-pressure situations do the opposite.
3) Back Pressure: Back pressure can be produced at two places, i.e., when the exhaust valve opens and cam overlap taking place. Pressure measurements at the exhaust valve during the start of the exhaust stroke at bottom dead centre (BDC) to cam overlap at the end of the exhaust stroke/beginning of the intake stroke at top dead centre (TDC). Notice the positive (backpressure) spike at the far left as the exhaust valve just opens at BDC. The exhaust gases must now push against this POSITIVE (back) pressure before it can leave the combustion chamber.

– The pressure tracing is upwards and positive. Energy must be used up in order to overcome the initial positive (back) pressure in the exhaust system before the exhaust gas is pushed out of the combustion chamber. Further we must be able to overcome the positive backpressure. It well known that, the exhaust gas begins to travel faster and creates a NEGATIVE pressure the pressure tracing is downward or has a negative value. When it is with a more negative pressure, then it means that, there is creation of more suction or a vacuum in the system. The system is literally sucking or pulling out exhaust gas from the combustion chamber or cylinder.
– This sucking or "SCAVENGING" affect not only helps to remove more exhaust gas from the cylinder. It also helps to suck more intake air and fuel mixture. Faster the exhaust gas travel more will be the vacuum creation. However, it is necessary to have much as negative pressure creation before cam overlaps.

IV. Designing & Modeling Of Exhaust Manifold

Large numbers of design and analysis software are available in the market for designing and analysis of parts. Some of those are:

– PTC creo
– Solid works
– CATIA
– ANSYS
– Hypermesh
– Inventor

From above software's for my convenience i had chosen CATIA and ANSYS for design and analysis of exhaust manifold

A. Introduction to CATIA:

CATIA started as an in-house development in 1977 by French aircraft manufacturer Avions Marcel Dassault, at that time customer of the CADAM software to develop Dassault's Mirage fighter jet. It was later adopted in the aerospace, automotive, shipbuilding, and other industries.Computer Aided Three dimensional Interactive Application (CATIA) is well known software for 3-d designing and modeling for complex shapes.

Commonly referred to as 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development (CAX), including conceptualization, design (CAD), engineering (CAE) and manufacturing (CAM). CATIA facilitates collaborative engineering across disciplines around its 3DEXPERIENCE platform, including surfacing & shape design, electrical, fluid and electronic systems design, mechanical engineering and systems engineering.

1) CATIA V5 Workbenches:

CATIA V5 serves the basic design tasks by providing different workbenches. A workbench is defined as a specified environment consisting of a set of tools that allows the user to perform specific design tasks. The basic workbenches in CATIA V5 are Part Design, Wireframe and Surface Design, Assembly Design, Drafting CATIA facilitates the design of electronic, electrical, and distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing.

2) Part Design Workbench:

The Part design workbench is a parametric and feature-based environment in which you can create solid models. The basic requirement for creating a solid model in this workbench is a sketch. The sketch for the features is drawn in the Sketcher workbench that can be invoked within the Part Design workbench. You can draw the sketch using the tools in this workbench. While drawing a sketch, some constraints are automatically applied to it. You can also apply additional constraints and dimensions manually. After drawing the sketch, exit the Sketcher workbench and convert it into a feature. The tools in the Part Design workbench can be used to convert the sketch into a sketch-based feature. This workbench also provides other tools to apply the placed features, such as fillets, chamfers, and so on. These features are called the dress-up features. You can also assign materials to the model in this workbench.

3) Wireframe and Surface Design Workbench:

The Wireframe and Surface Design workbench is also a parametric and feature-based environment, and is used to create wireframe or surface models. The tools in this workbench are similar to those in the Part Design workbench with the only difference that the tools in this environment are used to create basic and advanced surfaces.

4) Assembly Design Workbench:

The Assembly Design workbench is used to assemble the components using the assembly constraints available in this workbench. There are two types of assembly design approaches:

- Bottom-up
- Top-down
- In the bottom-up approach of the assembly design, the components are assembled together to maintain their design intent.
- In the top-down approach, components are created inside the assembly in the Assembly Design workbench. You can also assemble an existing assembly to the current assembly.
- The Space Analysis toolbar provides the Clash analysis tool that helps in detecting clash, clearance, and contact between components and sub-assemblies.

5) Drafting Workbench:

The Drafting workbench is used for the documentation of the parts or assemblies created earlier in the form of drawing views and their detailing. There are two types of drafting techniques:

- Generative drafting
- Interactive drafting

The generative drafting technique is used to automatically generate the drawing views of the parts and assemblies. The parametric dimensions added to the component in the Part Design workbench during its creation can be generated and displayed automatically in the drawing views. The generative drafting is bidirectional associative in nature. You can also generate the Bill of Material (BOM) and balloons in the drawing views.

In interactive drafting, you need to create the drawing views by sketching them using the normal sketching tools and then adding the dimensions.

6) Generative Sheet Metal Design Workbench:

The Generative Sheet metal Design workbench is used for the designing the sheet metal components. Generally, the solid models of the sheet metal components are created to generate the flat pattern of the sheet, study the design of the dies and punches, study the process plan for designing, and the tools needed for manufacturing the sheet metal components.

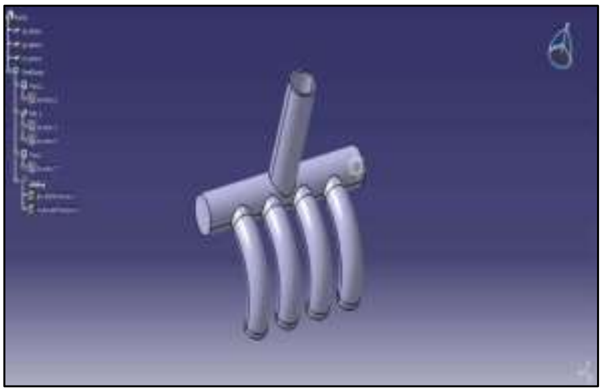

Fig. 3: Geometry Model

B. Scope of Application

Commonly referred to as a 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development (CAx), including conceptualization, design (CAD), engineering (CAE) and manufacturing (CAM). CATIA facilitates collaborative engineering across disciplines around its 3DEXPERIENCE platform, including surfacing & shape design, electrical, fluid and electronic systems design, mechanical engineering and systems engineering.

CATIA facilitates the design of electronic, electrical, and distributed systems such as fluid and HVAC systems, all the way to the production of documentation for manufacturing

1) Mechanical Engineering

CATIA enables the creation of 3D parts, from 3D sketches, sheet metal, composites, and moulded, forged or tooling parts up to the definition of mechanical assemblies. The software provides advanced technologies for mechanical surfacing & BIW. It provides tools to complete product definition, including functional tolerances as well as kinematics definition. CATIA provides a wide range of applications for tooling design, for both generic tooling and mould & die.

2) Design

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches.

3) Systems Engineering

The CATIA Systems Engineering solution delivers a unique open and extensible systems engineering development platform that fully integrates the cross-discipline modeling, simulation, verification and business process support needed for developing complex 'cyber-physical' products. It enables organizations to evaluate requests for changes or develop new products or system variants utilizing a unified performance based systems engineering approach. The solution addresses the Model Based Systems Engineering (MBSE) needs of users developing today's smart products and systems and comprises the following elements:

- Requirements Engineering, Systems Architecture Modeling, Systems Behaviour Modeling &
- Simulation, Configuration Management & Lifecycle Traceability, Automotive Embedded

- Systems Development (AUTOSAR Builder) and Industrial Automation Systems
- Development (Control Build).

CATIA uses the open Modelica language in both CATIA Dynamic Behaviour Modeling and Dymola, to quickly and easily model and simulate the behaviour of complex systems that span multiple engineering disciplines. CATIA & Dymola are further extended by through the availability of a number of industry and domain specific Modelica libraries that enable user to model and simulate a wide range of complex systems – ranging from automotive vehicle dynamics through to aircraft flight dynamics.

4) Electrical Systems

CATIA v5 offers a solution to facilitate the design and manufacturing of electrical systems spanning the complete process from conceptual design through to manufacturing. Capabilities include requirements capture, electrical schematic definition, interactive 3D routing of both wire harnesses and industrial cable solutions through to the production of detailed manufacturing documents including form boards.

5) Fluid Systems

CATIA offers a solution to facilitate the design and manufacturing of routed systems including tubing, piping, Heating, Ventilating & Air Conditioning (HVAC). Capabilities include requirements capture, 2D diagrams for defining hydraulic, pneumatic and HVAC systems, as well as Piping and Instrumentation Diagram (P&ID). Powerful capabilities are provided that enables these 2D diagrams to be used to drive the interactive 3D routing and placing of system components, in the context of the digital mockup of the complete product or process plant, through to the delivery of manufacturing information including reports and piping isometric drawings.

C. Improvement in Exhaust Manifold Design

The design of exhaust manifolds has been developed for many years. As engines have been improved so have exhaust manifolds. Early exhaust manifolds were much less efficient than today’s exhaust manifolds. Designs that did not contribute to a smooth flow were very typical in early times. The back pressure built up was much greater; this increased the work done by the particular piston at the exhaust stroke. Large amounts of residual gases remain in the compression chamber and, as a consequence, the temperature increases. Sometimes when working hard the manifold glows red-hot, forcing the use of asbestos, a highly heat-resistant fibrous silicate mineral, to protect paintwork. Nowadays, exhaust manifold designs have been transformed completely.

In order to improve earlier configurations, designers and researchers have come up with different designs with respect to various parameters that affect the exhaust manifold. Lot of work on effect of various parameters on the analysis, design, and performance of exhaust manifold has been reported

Traditional manifold optimization has been based on tests on exhaust manifold. This trial & error method can be effective but is very expensive and time consuming. Beside this method cannot provide any information about the actual flow structure inside the manifold. This vital information can be obtained using 3D CFD analysis.

V. DESIGNED MODELS OF EXHAUST MANIFOLD LONG BEND CENTER EXIT WITH REDUCER

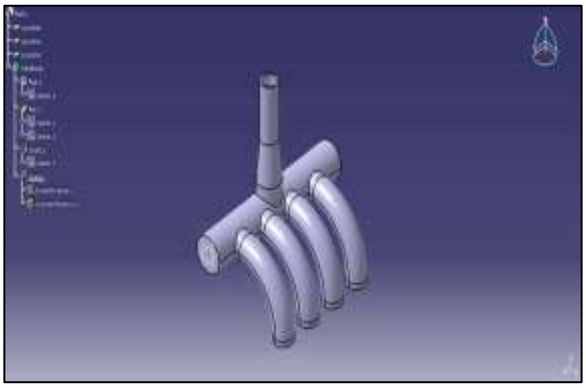

Fig. 4: Geometry

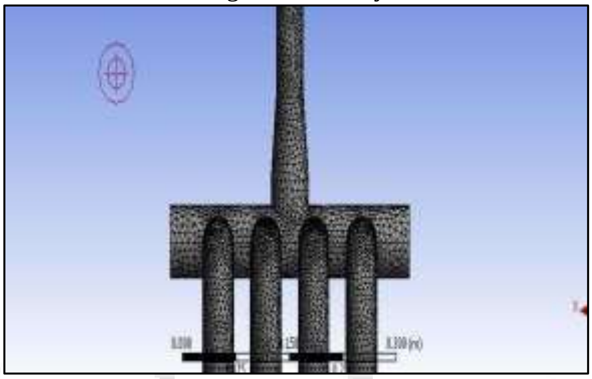

Fig. 5: Meshing

A. Long Bend Center Exit

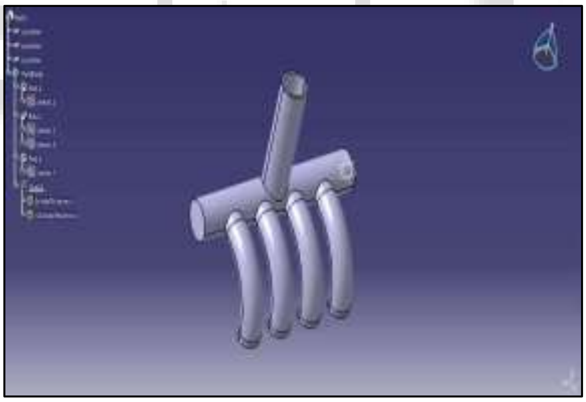

Fig. 6: Geometry of Long Bend Centre Exit

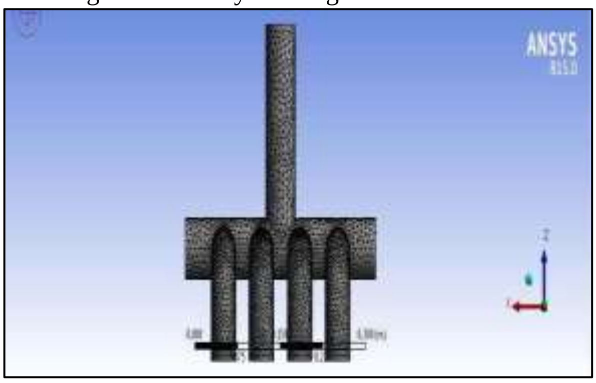

Fig. 7: Meshing

B. Long Bend Side Exit

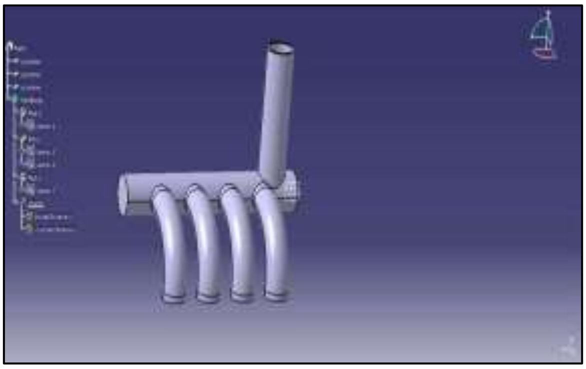

Fig. 8: Geometry of Long Bend Side Exit

C. Long Bend Side Exit with Reducer

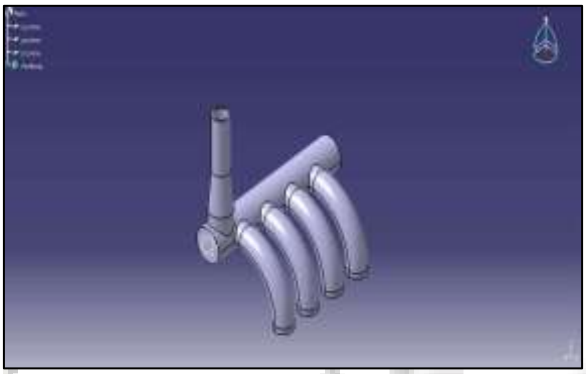

Fig. 9: Geometry of Long bend side exit with reducer

D. Short Bend Center Exit

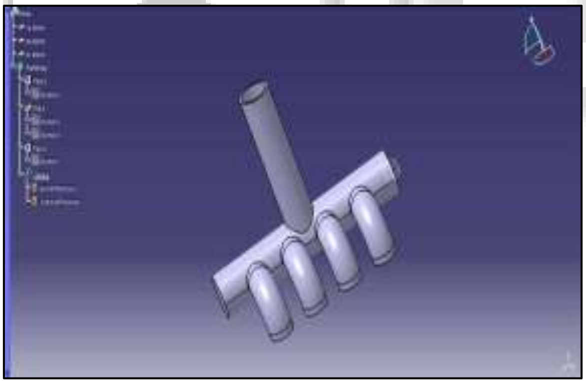

Fig. 10: Short Bend Centre Exit Geometry

E. Short Bend Center Exit with Reducer

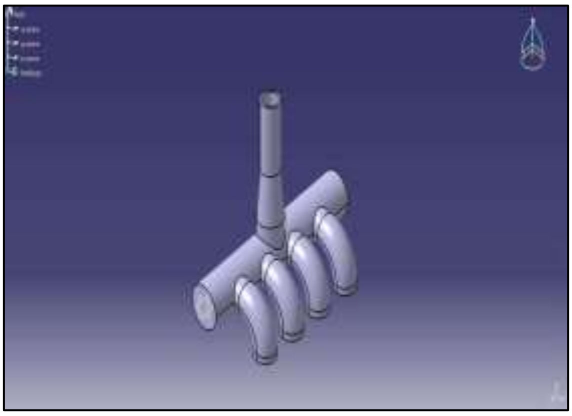

Fig. 11: Short Bend Centre Exit with Reducer

F. Short Bend Side Exit

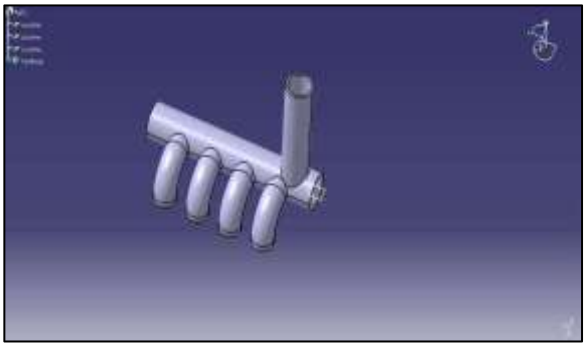

Fig. 12: Geometry of Short bend Side Exit

G. Short Bend Side Exit with Reducer

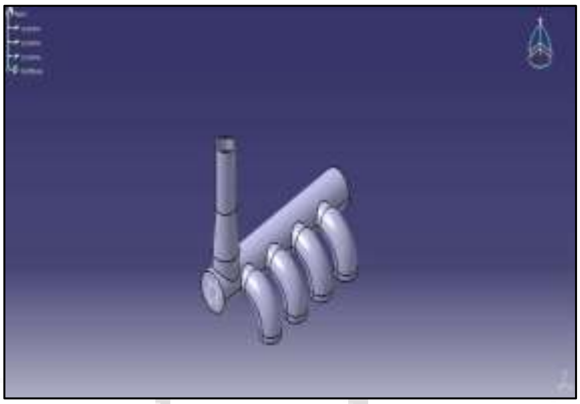

Fig. 13: Geometry of Short Bend Side Exit with Reducer

VI. INTRODUCTION TO FLUID FLOW (FLUENT)

ANSYS Fluent fluid flow systems in ANSYS Workbench to set up and solve a three-dimensional turbulent fluid-flow and heat-transfer problem in a mixing elbow. It is designed to introduce you to the ANSYS Workbench tool set using a simple geometry. Guided by the steps that follow, you will create the elbow geometry and the corresponding computational mesh using the geometry and meshing tools within ANSYS Workbench. You will use ANSYS Fluent to set up and solve the CFD problem, then visualize the results in both ANSYS Fluent and in the CFD-Post post processing tool. Some capabilities of ANSYS Workbench (for example, duplicating fluid flow systems, connecting systems, and comparing multiple data sets) are also examined in this tutorial.

A. Steps Involved in the Ansys Fluid Flow

Launch ANSYS Workbench .Create a fluent fluid flow analysis system in ANSYS Workbench .import the geometry to ANSYS Create the computational mesh for the geometry using ANSYS MeshingSet up the CFD simulation in ANSYS Fluent, which includes:

- Setting material properties and boundary conditions for a turbulent forced-convection problem.
- Initiating the calculation with residual plotting.
- Calculating a solution using the pressure-based solver.
- Examining the flow and temperature fields using ANSYS Fluent and CFD-Post.
- Create a copy of the original fluent fluid flow analysis system in ANSYS Workbench.

– Change the geometry in ANSYS Design Modeler, using the duplicated system.
– Regenerate the computational mesh.
– Recalculate a solution in ANSYS Fluent.
– Compare the results of the two calculations in CFD-Post.

B. Material Fluid Properties

Exhaust gas will be considered as an incompressible fluid operating at 230- 280°c. The material properties under these conditions are

Material	Air + Gasoline
Density (kg/m3)	1.0685
Viscosity (Pa-s)	3.0927 x 10- 5
Specific heat (J/kg-K)	1056.6434
Thermal conductivity	0.0250

Table 1: Fluid Properties

VII. RESULT & CONCLUSION

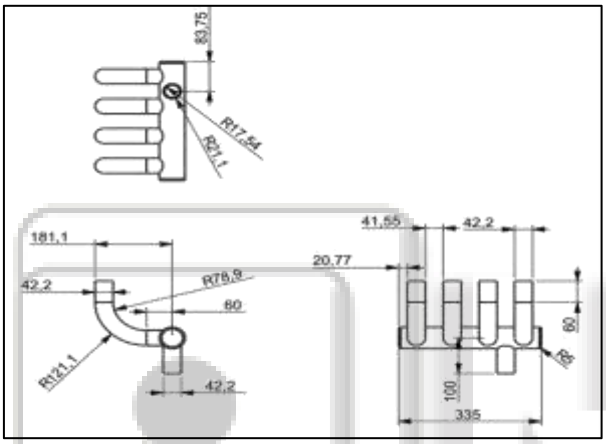

Fig. 14: 2d Drawing

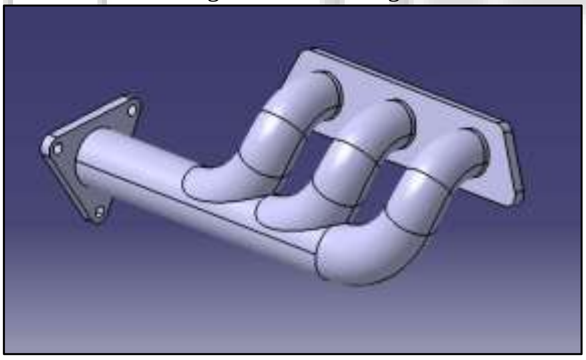
Fig. 15: 3d Drawing

A. Long Bend Center Exit

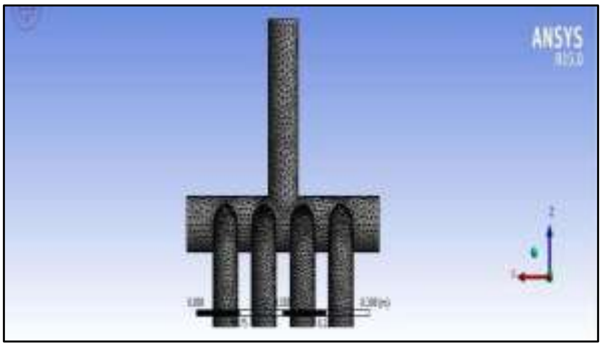

Fig. 16: Meshing of Long Bend Centre Exit

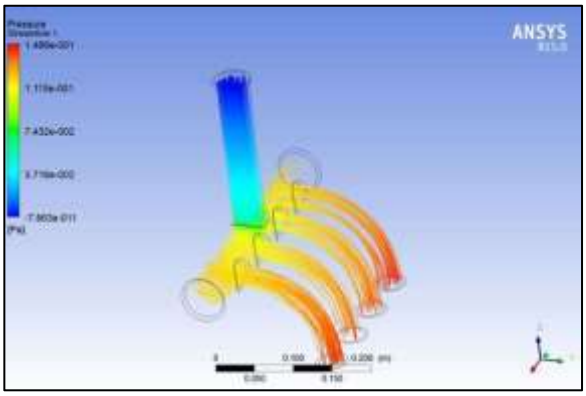

Fig. 17: Pressure

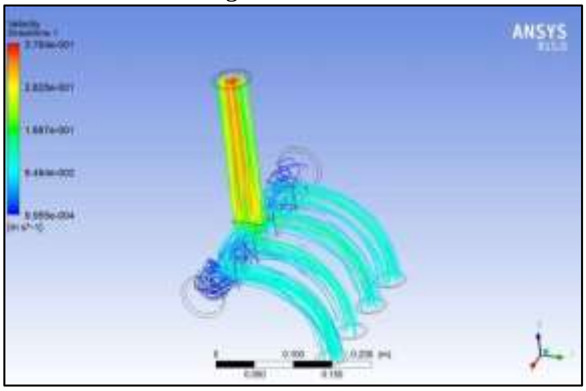

Fig. 18: Velocity

B. Long Bend Center Exit with Reducer

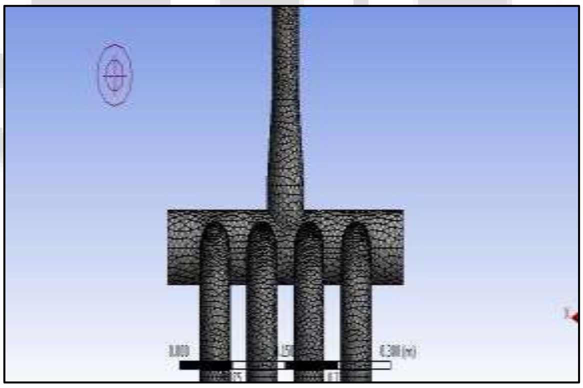
Fig. 19: Meshing of Long Bend Centre with Reducer

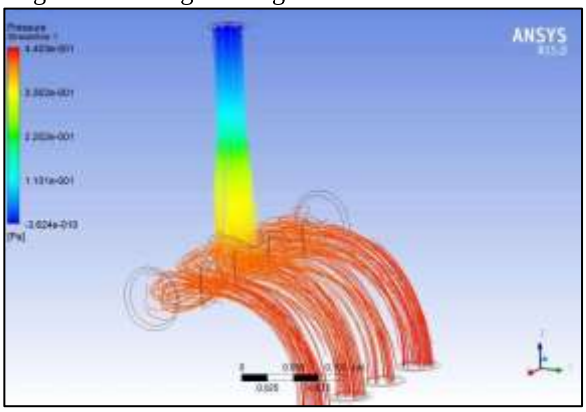

Fig. 20: Pressure

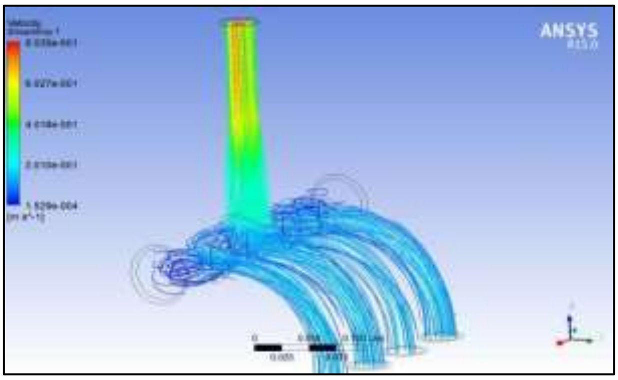

Fig. 21: Velocity

C. *Long Bend Side Exit*

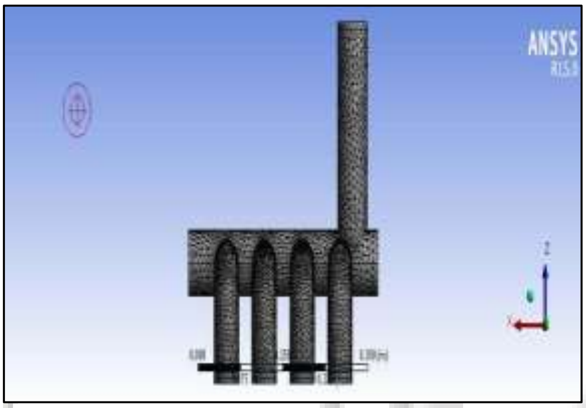

Fig. 22: Meshing of Long Bend Side exit

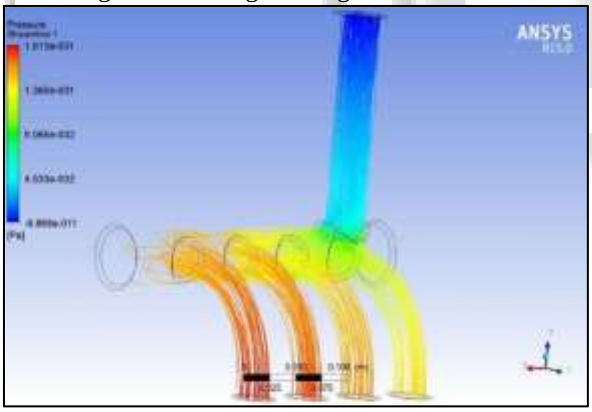

Fig. 23: Pressure

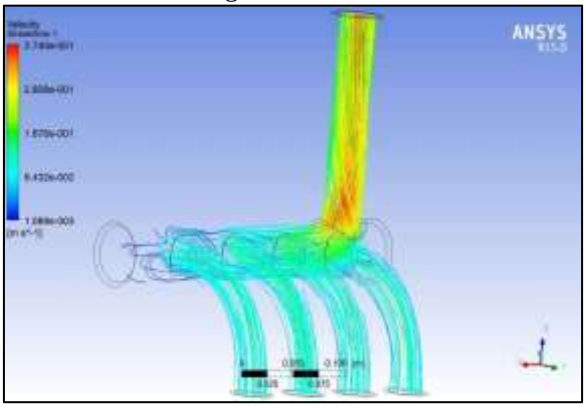

Fig. 24: Velocity

D. *Long Bend Side Exit with Reducer*

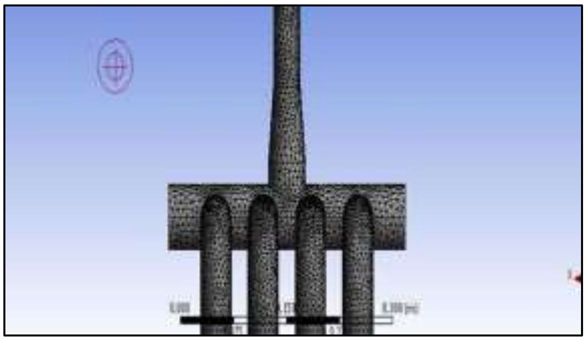

Fig. 25: Meshing of Long Bend Side Exit with Reducer

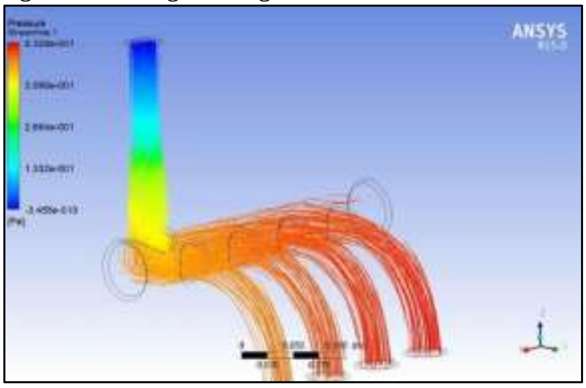

Fig. 26: Pressure

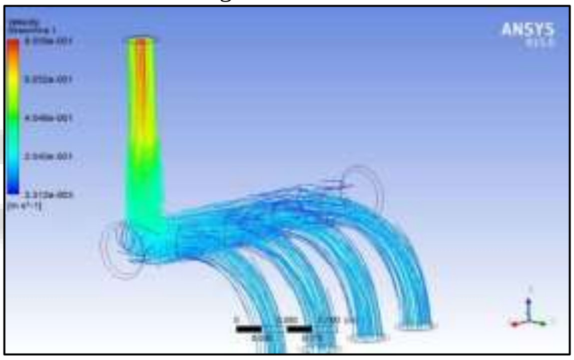

Fig. 27: Velocity

	2KG	4KG	6KG	8KG	10KG	12KG
SBCE	940	976	1002	1036	1079	1111
SBSE	1020	1071	1098	1113	1132	1172
LBCE	850	863	894	923	984	1012
LBSE	973	1005	1039	1076	1099	1125
SBCER	984	1012	1047	1077	1114	1154
SBSER	1180	1214	1222	1222	1272	1303
SBSER	1037	1080	1112	1112	1187	1201
LBSER	1138	1174	1219	1219	1276	1271

Table 2: Backpressure for Different Models inPascal

	2KG	4KG	6KG	8KG	10KG	12KG
SBCE	17.03	18.1	18.7	19.52	21.45	23.01
SBSE	18.1	18.6	19.1	20.2	21.6	23.5
LBCE	20.2	21.33	22.07	23.52	23.98	24.77
LBSE	18.71	18.92	19.23	20.12	22.21	23.65
SBCER	17.7	17.79	18.23	19.86	21.1	23.89

SBSER	16.8	17.12	18.6	19.9	21.76	23.92
SBSER	17.3	18.67	19.54	21.96	23.65	24.71
LBSER	17.9	18.01	19.1	20.65	21.86	23.98

Table 3: Exhaust Velocity for Different Models in Meter per Second (m/s)

E. Short Bend Centre Exit

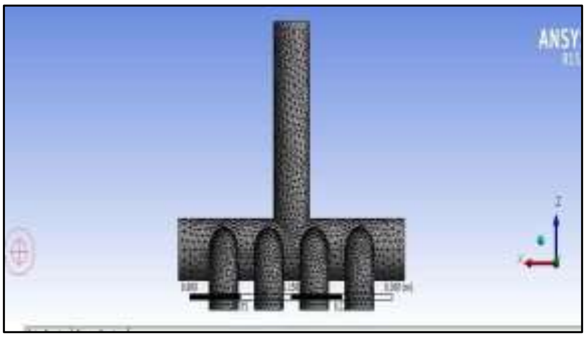

Fig. 28: Meshing Short Bend Centre Exit

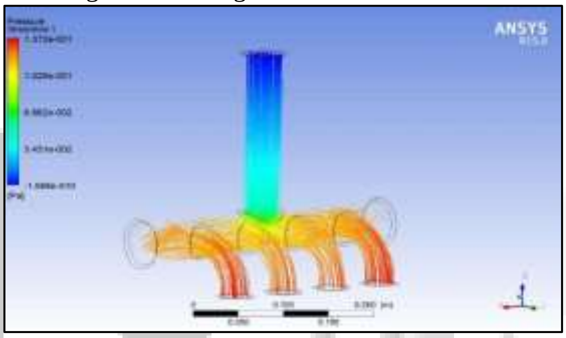

Fig. 29: Pressure

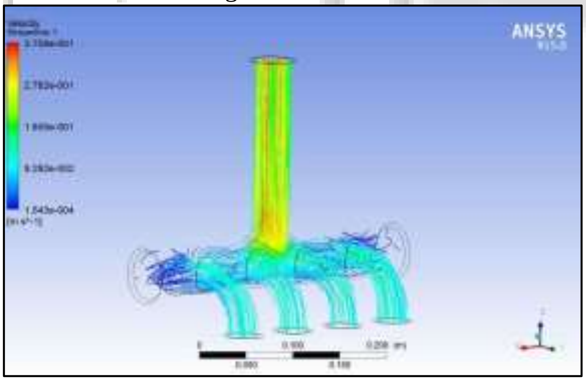

Fig. 30: Velocity

F. Short Bend Center Exit With Reducer

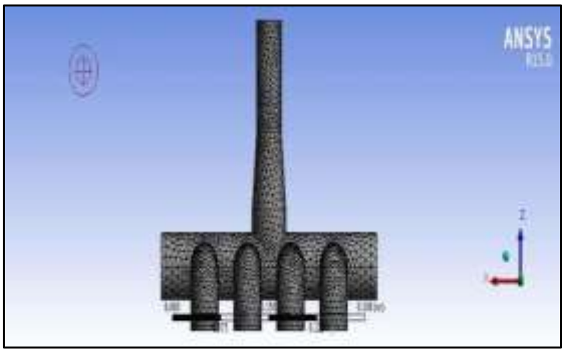

Fig. 31: Meshing of Short Bend with Reducer

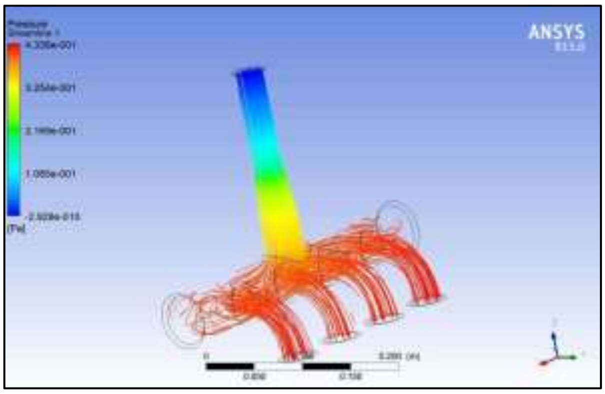

Fig. 32: Pressure

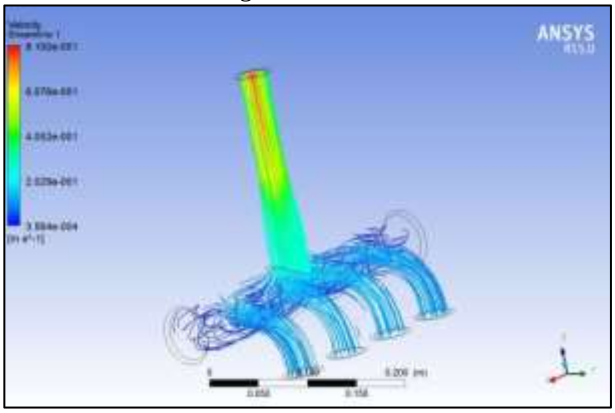

Fig. 33: Velocity

G. Short Bend Side Exit

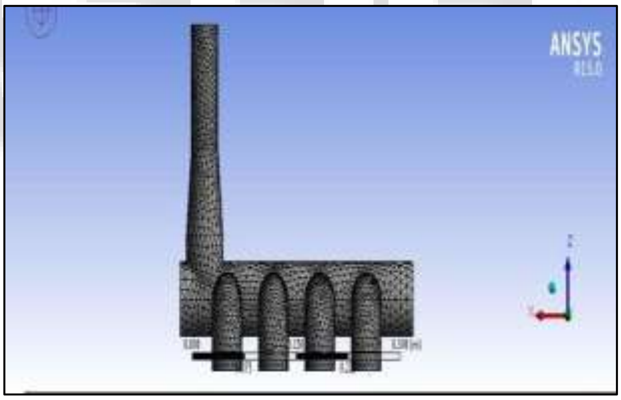

Fig. 34: Meshing of Short Bend Side Exit

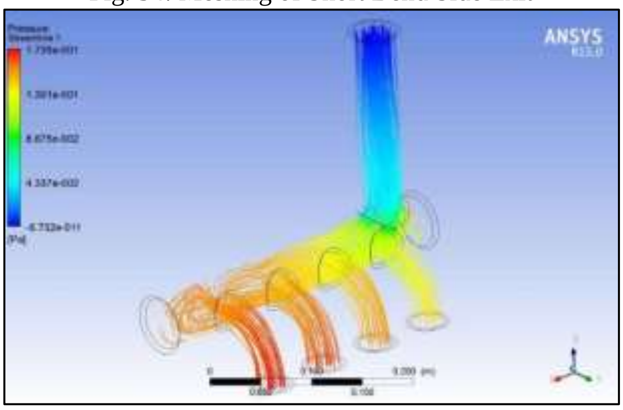

Fig. 35: Pressure

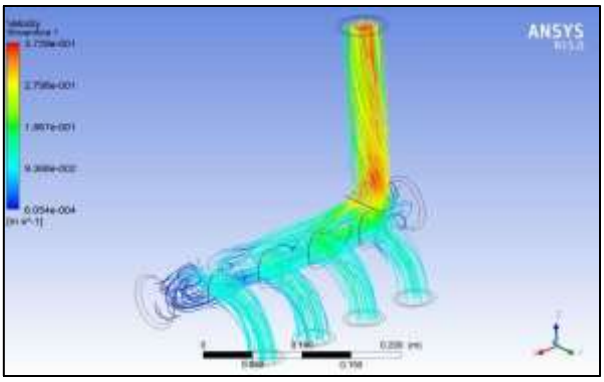

Fig. 36: Velocity

H. Short Bend Side Exit with Reducer

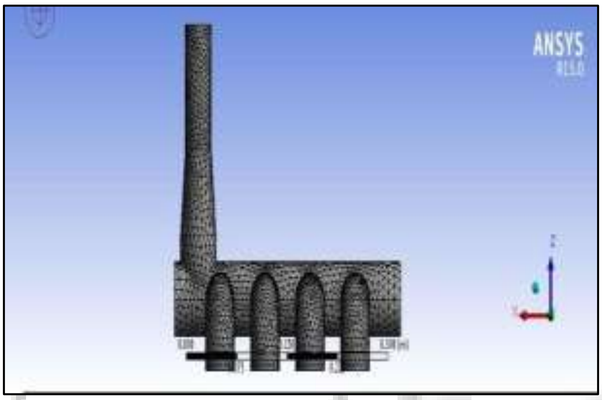

Fig. 37: Meshing of Short bend side With Reducer

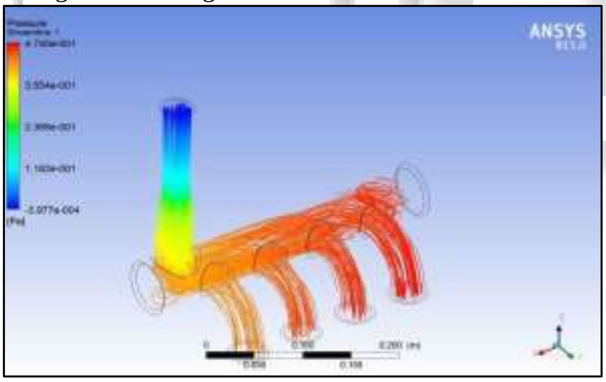

Fig. 38: Pressure

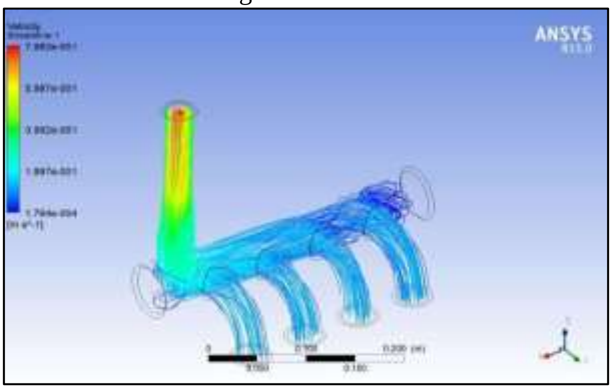

Fig. 39: Velocity

VIII. CONCLUSION

Present research work is devoted to the evaluation of different models of exhaust manifold for the purpose of reducing exhaust emissions from a four cylinder SI engine. For this purpose, a set of eight alternatives was chosen, and modeled with the help of CATIA V5modeling software. In next stage, CFD of different models were carried out on the basis of k-ε model, which finally yield the values of back pressures, and exhaust velocities at different loading conditions. After that performance score was calculated for both the parameters, and as the last step of project overall performance score for different types was calculated. Following are the conclusions drawn during different during conduction of CFD, and ranking procedures in the project work. It has been presented that the research methodology depending on three-dimensional model of airflow in the outlet systems with the application of standard numeric methods. The model may be the basis for performing changes in geometry of outlet system concerning minimizing the flow losses and shaping the field of velocity. The model enables of calculations of outlet system of internal combustion engines on the stage of its construction.

- Forces exerted by gas particles in the manifold effect the values of back pressure and exit velocity, due to which overall performance score on the basis of these two parameters changes.
- Short bend models show better performance, as compared with long bend models.
- Due to increased length, differences in overall performance score in long bend models are greater than that of short bend models. And
- Out of available set of alternatives, long bend center exit (LBCE) model of manifold is the best one because it has scored rank first for overall performance score.

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