

Fluent Analysis of Exhaust Manifold with Different Flow Rates

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ABSTRACT

Exhaust manifold is one of the most critical components of an IC Engine. The designing of exhaust manifold is a complex procedure and is dependent on many parameters viz. back pressure, exhaust velocity, mechanical efficiency etc. Preference for any of this parameter varies as per designers needs. Usually fuel economy, emissions and power requirement are three different streams or thought regarding exhaust manifold design. In any multi-cylinder IC engine, an exhaust manifold (also known as a header) collects the exhaust gases from multiple cylinders into one pipe. This header is connected to these cylinders through bends. It is attached downstream of the engine and is major part in multi-cylinder engines where there are multiple exhaust streams that have to be collected into a single pipe. Exhaust gases comes out of this Header as a single stream of hot exhaust gases through single outlet. This work comprehensively analyzes eight different models of exhaust manifold and concludes the best possible design for least emissions and complete combustion of fuel to ensure least pollution. The main objective of this investigation is to design an exhaust manifold by using CATIA V5 R20 software and also find out pressures and velocities at various mass flow rates in the exhaust manifolds with Long Bend Side Exit (LBSE), Long Bend Middle Exit (LBME) and Reducer and find out the performance of the exhaust manifold with various modifications in its design or adding a component for the exhaust manifold to increase its effectiveness. In the current analysis mass flow rates considered in the exhaust manifold are 2 kg/s, 4 kg/s, 6 kg/s, 8 kg/s, 10 kg/s, 12 kg/s in all the various modification ns in the exhaust manifolds.

Key words: Manifold, IC Engine, LBME, LBSE.

1. INTRODUCTION

1.1 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.

1.2 Types of turbo manifolds:

1.21 Log manifold:

The log type manifold is the most economical manifold on the market. They are almost bullet proof when it comes to reliability and they are the most compact manifolds available. Most manifolds you find on factory turbocharged cars are log type manifolds.



Fig.1.1 A typical diagram of exhaust manifold

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This is understandable when you manufacturer is all about reliability. When it comes to performance, a log manifold will leave you wanting. This hurts the turbo's performance and hurts the motors performance as well being that a log manifolds common plenum is so close to the other cylinders, it causes a lot of back flow of exhaust.

2. Literature Survey

Analyzed the performance of the manifolds with a tapered longitudinal section. [1]

In their research paper they had applied a multi-disciplinary optimization approach for the exhaust system, exhaust manifold and catalytic converter, in highly integrated concurrent engineering software framework. [2]

In their research they had employed numerical simulations (CFD methods) for estimating the flow loss coefficient in manifolds. [3]

In their research paper they have developed a multi-objective optimization method for the exhaust manifold by using Divided Range Multi objective Genetic Algorithm. [4]

In their research paper they used GT-Power, 1-dimensional software, for estimating the engine performance of a single cylinder IC engine. [5]

Designing Exhaust Manifolds Using Integral Engineering Solutions| focused on the development of a reliable approach to predict failure of exhaust manifolds and on the removal of structural weaknesses through the optimization of design. [6]

In their paper they had performed CFD analysis to estimate the performance of the exhaust manifold while placing the catalytic converter near to it (Close-Coupled Catalytic Converter). [7]

In this research paper he conducted CFD simulations on manifold of direct injection diesel engine. They had used the RANS (Reynolds Averaged Navier Stokes) solver approach with RNG k-ε turbulence model for the simulations. The flow inlet for the manifolds was modeled using _pressure-inlet.[8]

In his research paper they had applied CFD methods to identify the optimum exhaust manifold for a 4-stroke 4-cylinder SI engine.[9]

In this paper they had developed an exhaust system heat transfer model that included the steady state and transient heat conduction as well as convection and radiation.[10]

3.1. GEOMETRIC MODELLING

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Assault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Assault Systems product lifecycle management software suite.

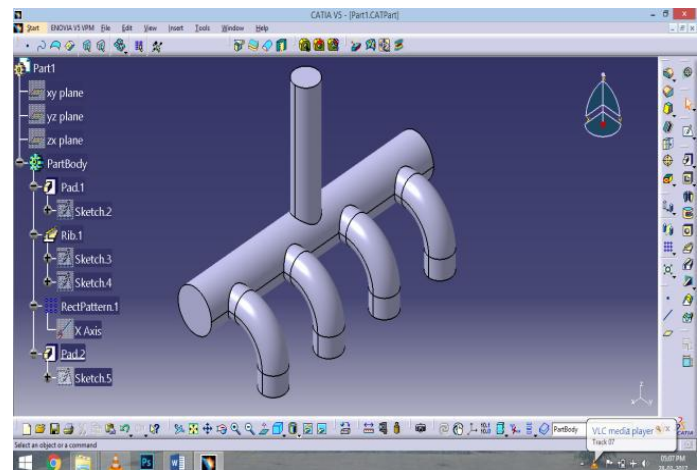


Fig no.3.1 Long Bend Centre Exit

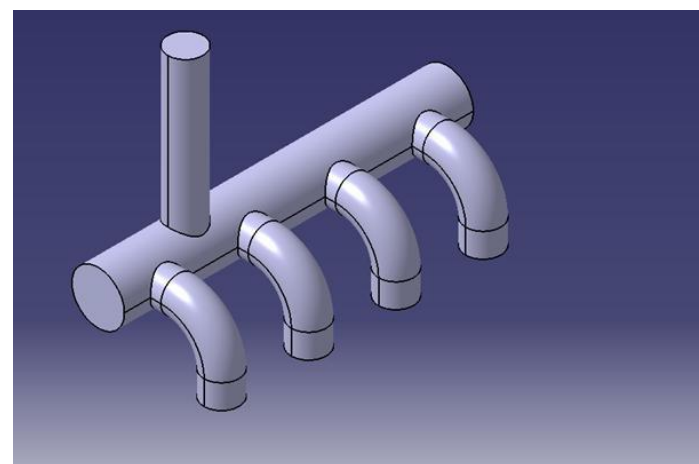


Fig no. 3.2 Long Bend Side Exit

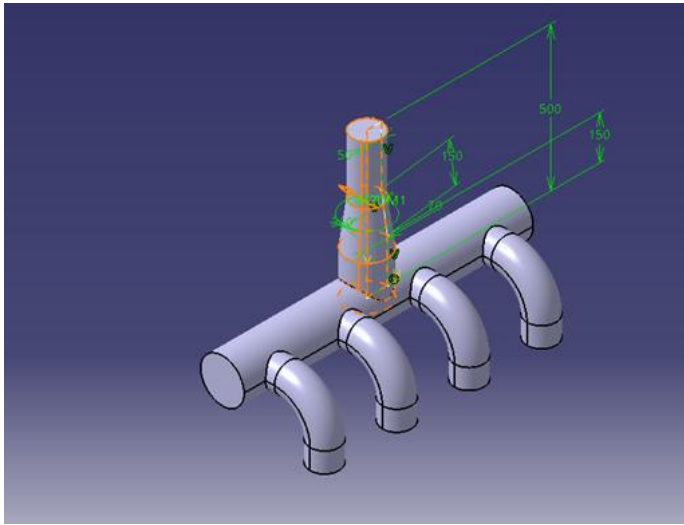


Fig 3.3 Long Bend Centre Exit with Reducer (LBCER)

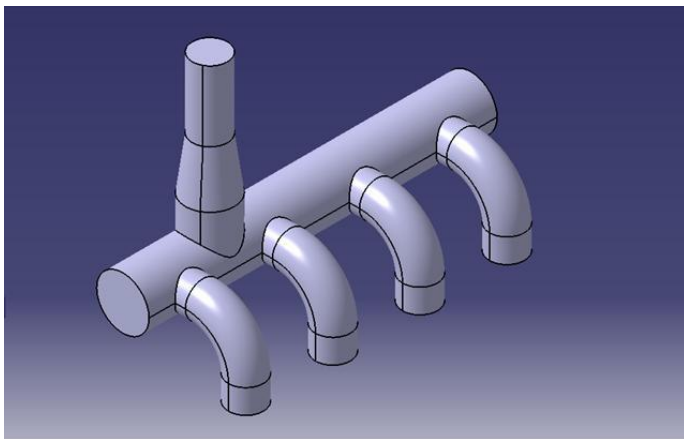


Fig 3.4 Long bend side exist with reducer

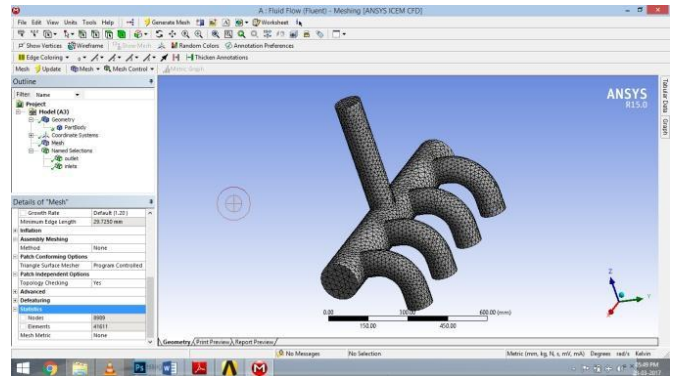


Fig 4.1 Coarse mesh of exhaust manifold

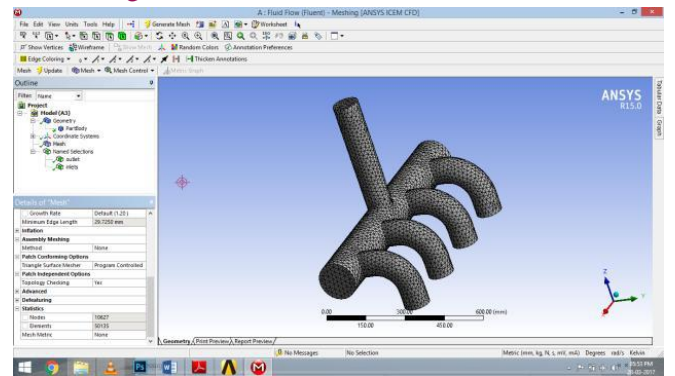


Fig 4.2 Fine meshed exhaust manifold

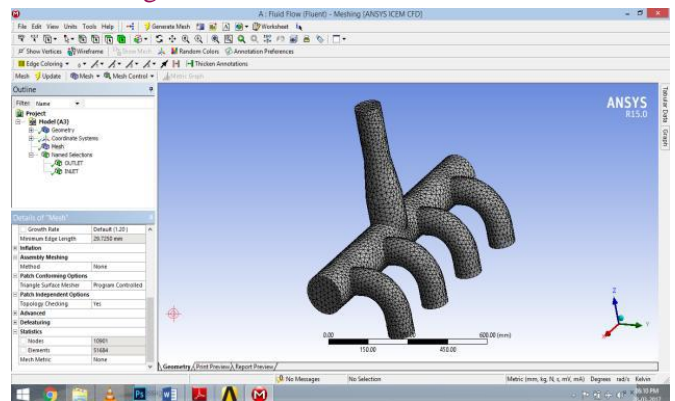


Fig 4.3 Meshed model of exhaust manifold

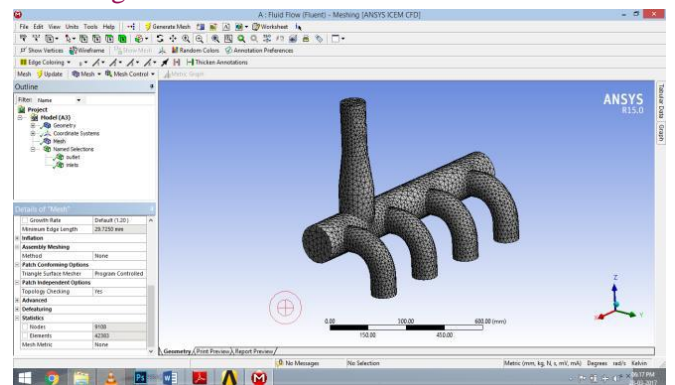


Fig 4.4 Meshed model of side exist

4. Steps involved in analysis using ANSYS

The ANSYS program has many finite element analysis capabilities, ranging from a simple, linear, static analysis to a complex, nonlinear, transient dynamic analysis. A typical ANSYS analysis consists of the following steps:

- Build the model using key points, lines, areas and volume commands.
- Giving material properties.
- Choosing proper element.
- Meshing the model to discretise it into elements.
- Applying the given loads.
- Applying the boundary conditions.
- Running the solution phase.

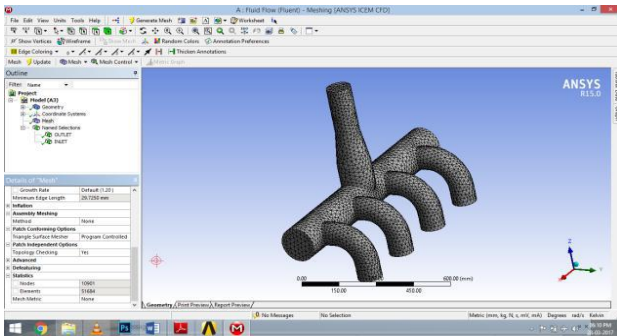


Fig 4.5 Meshed model of Centre exist

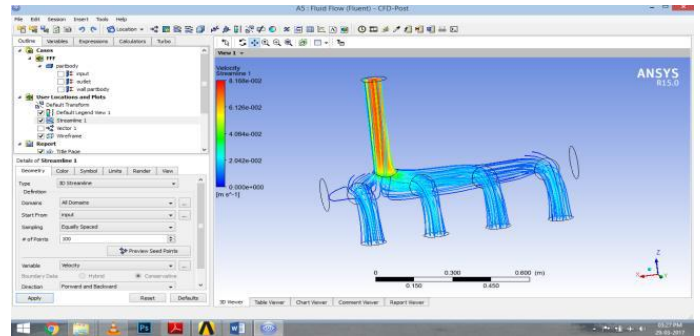


Fig 5.2 Streamlines of Velocity in Exhaust Manifold

5. RESULTS AND DISCUSSIONS

The main objective of this investigation is to find out pressures and velocities at various mass flow rates in the exhaust manifolds with Long Bend Side Exit (LBSE), Long Bend Middle Exit (LBME) and Reducer and find out the performance of the exhaust manifold with various modifications in its design or adding a component for the exhaust manifold to increase its effectiveness.

In the current analysis mass flow rates considered in the exhaust manifold are 2 kg/s, 4 kg/s, 6 kg/s, 8 kg/s, 10 kg/s, 12 kg/s in all the various modifications in the exhaust manifolds.

Case-1: Pressure and Velocity Variations in Exhaust Manifold with LBSE

The exhaust manifold with LBSE is considered for this analysis at different mass flow rates in turbulent region. In this analysis five mass flow rates are considered and analysed. The mass flow rates were considered randomly and entire analysis depends on the mass flow rate considered.

Mass Flow Rate: 2 kg/s

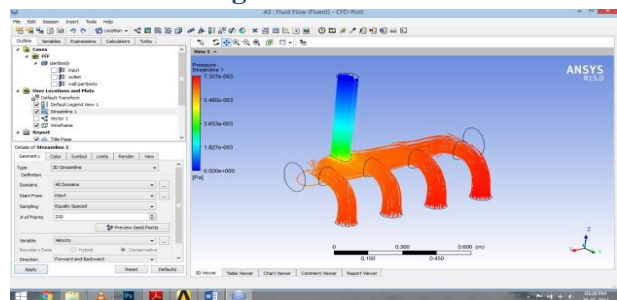


Fig 5.1 Streamlines of Pressure Drop in Exhaust Manifold

Here in this case the fluid which is flowing in the Exhaust Manifold is shown in the above figures. As we know that the pressure drop increases with increase in Reynolds number as both of them are directly proportional to each other. Here mass flow rate of the fluid flowing is taken as 2kg/s. Depending on the mass flow rate the Reynolds number and pressure also changes. The minimum and maximum pressure drop and velocities in the exhaust manifold listed below. Here in this case also change in pressure of the liquid is clearly shown in the form of both vectors and streamlines the liquid moves in the exhaust manifold. Greater pressures may damage the manifold as greater vibrations were created which in turn decreases the performance of the manifold.

Table 5.1 pressure and velocity at 2Kg/Sec

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	7.307e-003	0.00e+00	8.168e-0.002	0.00e+00

Mass Flow Rate: 4 Kg/S

Table 5.2 pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	2.126e-0.002	-3.675e-0.005	1.536e-0.001	0.00e+00

5.3 Mass Flow Rate: 6 Kg/S

Table 5.3

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	4.099e-002	-1.216e-004	2.187e-001	0.00e+00

Mass Flow Rate: 8Kg/s

Table 5.4 Pressure and velocity drop calculations

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	6.583e-002	-5.737e-004	2.781e-001	0.00e+00

Mass Flow Rate:10 Kg/s

Table 5.5 pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	9.584e-002	-506e-003	3.367e-001	0.00e+00

Mass Flow Rate:12 Kg/s

Table 5.6 pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	1.306 e-001	-1.321e-002	4.026e-001	0.00e+00

Case-2: Pressure and Velocity Variations in Exhaust Manifold with LBCE

The exhaust manifold with LBCE is considered for this analysis at different mass flow rates in turbulent region. In this analysis five mass flow rates are considered and analyzed. The mass flow rates were considered randomly and entire analysis depends on the mass flow rate considered.

Mass Flow Rate: 2Kg/s

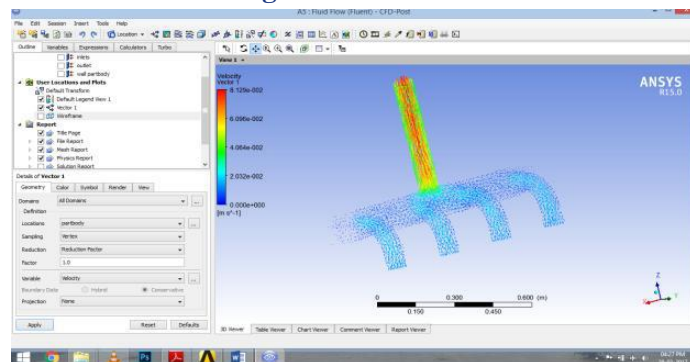


Fig.5.5 Velocity drop in stream lines

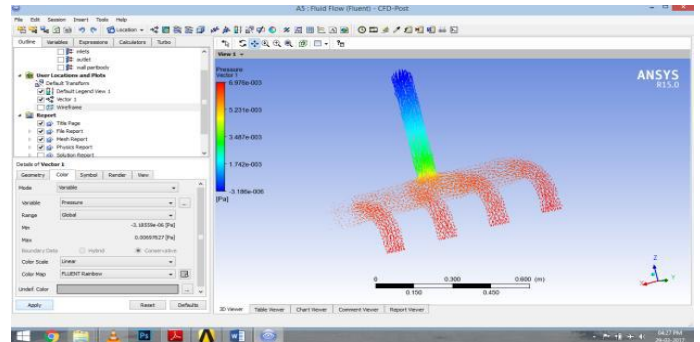


Fig 5.6 pressure drop in streamlines

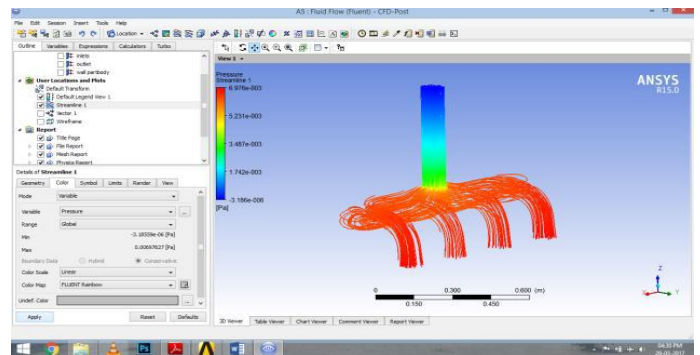


Fig 5.7 pressure drop in streamlines

Table 5.7 Pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	6.976e03	-3.18e05	8.129e002	0.00e+000

Mass Flow Rate:4Kg/s

Table 5.8 Pressure and velocity drops

S.No	Pressure Drop		Velocity	
	Max	Min	Maximum	Minimum
1	2.032e-002	-4.066e-005	1.520e-001	0.00e+000

Mass Flow Rate:6Kg/s

Table 5.9 Pressure and velocity drops

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	-1.095e-004	3.926e-002	2.185e-001	0.000e+00

Mass Flow Rate: 8Kg/s

Table 5.10 pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	6.322e-002	1.244e-003	2.805e-001	0.00e+000

Mass Flow Rate:10 Kg/s

Table 5.11 Pressure and velocity drops

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	9.205e-002	-7.623e-003	3.396e-001	0.000e+000

Mass Flow Rate: 12 Kg/s

Table 5.12 Pressure and velocity drops

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	1.257e-001	-1.690e-002	4.034e-001	0.000e+000

Case-3: Pressure and Velocity Variations in Exhaust Manifold with Reducer

The exhaust manifold with reducer is considered for this analysis at different mass flow rates in turbulent region. In this analysis five mass flow rates are considered and analysed. The mass flow rates were considered randomly and entire analysis depends on the mass flow rate considered.

Mass Flow Rate: 2 Kg/s

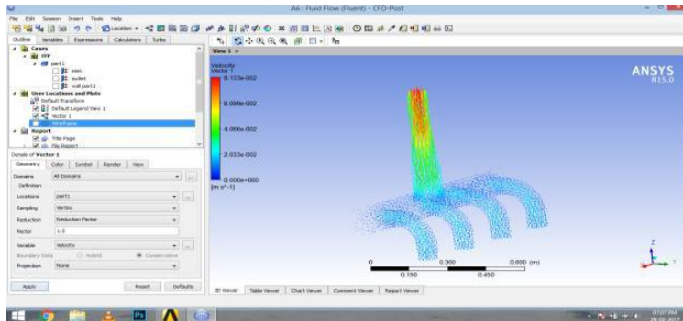


Fig.5.11 Velocity drop in stream lines

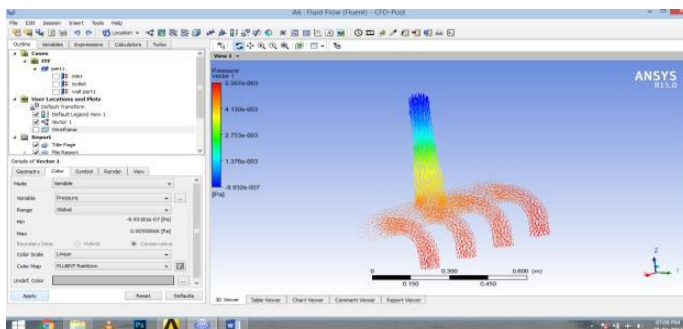


Fig.5.12 Pressure drop in streamlines

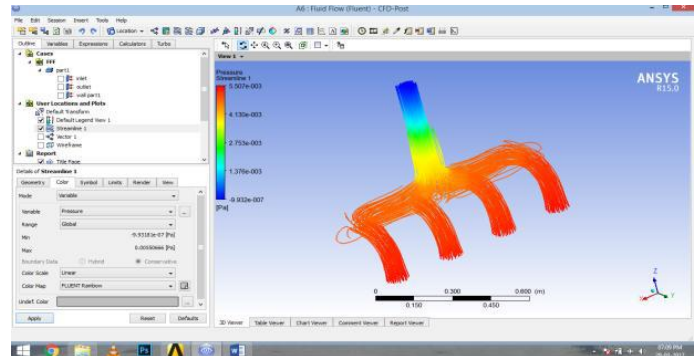


Fig.5.13 Velocity drop in streamlines

Table 5.13 Pressure and velocity drops

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	5.507e-003	-9.932e-007	8.133e-002	0.000e+000

Mass Flow Rate:4 Kg/s

Table 5.14

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	1.606e-002	0.000e+000	1.497e-001	0.000e+000

Mass Flow Rate: 6 kg/s

Table 5.15 Pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	3.063e-002	0.000e+000	2.123e-001	0.000e+000

Mass Flow Rate:8 kg/s

Table 5.16 Pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	4.951e-002	0.000e+000	2.709e-001	0.000e+000

Mass Flow Rate:10 kg/s

Fig.5.17 Pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	7.180e-002	0.000e+000	3.273e-001	0.000e+000

Mass Flow Rate: 12 kg/s

Fig.5.18 Pressure and velocity drop

S.No	Pressure Drop		Velocity	
	Max	Min	Max	Min
1	9.768e-002	0.000e+000	3.823e-001	0.000e+000

6. CONCLUSION

In this thesis the investigation is to find out pressures and velocities at various mass flow rates in the exhaust manifolds with Long Bend Side Exit (LBSE), Long Bend Middle Exit (LBME) and Reducer and find out the performance of the exhaust manifold with various modifications in its design or adding a component for the exhaust manifold to increase its effectiveness.

In the current analysis mass flow rates considered in the exhaust manifold are 2 kg/s, 4 kg/s, 6 kg/s, 8 kg/s, 10 kg/s, 12 kg/s in all the various modifications in the exhaust manifolds.

From the above investigations it is found that Long Bend Middle Exit (LBME) with Reducer is giving the better performance.

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