# Design and Analysis of Exhaust Manifold Comparing Different Specifications

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***Abstract***

*The exhaust manifold in an internal combustion engine is a very vital component affecting the performance of an engine. The engine's volumetric efficiency is directly depended on its ability to push out the exhaust gases effectively to suck in more air for combustion. To effectively expel the exhaust gases, a good manifold is required and in cases of a turbocharged engine the manifold is even more important. The objective of this project is to analyze existing designs of exhaust manifold to establish a better understanding of the significance of various factors involved in its design process. The material and specifications are varied and results were compared in present paper.*

**Keywords —** *CFD, Turbo Charger, Main foil, Heat Flux, Fluid Velocity, Temperature.*

## I. INTRODUCTION

Exhaust manifold receives the exhaust gases comes out from chamber and passes to environment. The usually assembled with cylinder. Cast iron is material used for exhaust manifolds.

Factors to be considered during the design and development of exhaust manifold

### *A. 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.

### *B. 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.

### *C. 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 secondaries into the rest of the exhaust.

### *D. 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).

## II. LITERATURE REVIEW

**Dr. VVRLS Gangadharet al., 2017,** In this research, an existing model of an engine Exhaust Manifold is modeled in 3D modeling software. Thermal analysis is done for both models using different materials copper, Nickel, Stainless steel and manganese. Analysis is done in ANSYS.

By observing the thermal analysis results, the heat flux (i.e) heat transfer rate is more for Copper when compared with other materials. The heat transfer rate is slightly less for modified model than original model.

**Kanupriya Bajpai et al., 2017,** In the present work, the performance of a four-stroke four cylinder gasoline engine exhaust manifold have been analyzed using three different fuels - gasoline, alcohol, and LPG for the estimation of flow characteristics, thermal characteristics, and minimum back pressure. The manifold modelling is done in Creo2.0 followed by meshing and analysis in ANSYS.

**P Sylvester Selvanathan et al., 2017,** This papers aims to analyze the design of an exhaust manifold to establish the significance of various factors involved in designing an exhaust manifold by comparing various existing designs using Computational Fluid Dynamics.

The 3 different models are analyzed using CFD software to obtain the velocity vector, static pressure and turbulent kinetic energy along the manifold and the turbine housing. The simulation data was used to obtain the necessary results using CFD Post.

**Puneetha C G et al., 2015,** In this Study comprehensively analyzes four different models of exhaust muffler and concludes the best possible design for least pressure drop. Back pressure was obtained based on the flow field analysis and was also compared with all muffler design. Virtual simulation for back-pressure testing is performed by Computational Fluid Dynamic (CFD) analysis using Acusolve CFD. Finite Element (FE) model generation of the muffler structure is performed using Hyper Mesh as the preprocessor. The structural mesh is modeled using 2D shell elements, wherein the internal tubes with fine perforated holes are considered.

**Marupilla Akhil Teja et al., 2016,** Overall engine performance of an engine can be obtained from the proper design of engine exhaust systems. With regard to stringent emission legislation in the automotive sector, there is a need design and develop suitable combustion chambers, inlet, and outlet manifold. Exhaust manifold is one of the important components which affect the engine performance. Flow through an exhaust manifold is time dependent with respect to crank angle position. In the present research work, numerical study on four-cylinder petrol engine with two exhaust manifold running at constant speed of 2800 rpm was studied.

**Nikhil Kanawade and Prof. Omkar Siras, 2016,** Exhaust manifolds collects the exhaust gases from the engine cylinders and discharge to the atmosphere through the exhaust system. The engine efficiency, combustion characteristics would depend upon how the exhaust gases were removed from the cylinder. The design of an exhaust manifold for the internal combustion engine depends on many parameters such as exhaust back pressure, velocity of exhaust gases etc. In this literature review, the recent research on design of exhaust manifold, their performance evaluation using experimental methods as well as Numerical methods (CFD), various geometrical types of exhaust manifold and their impact on the performance had been collected and discussed.

**Sachin G. Chaudhari et al.,2007,** This paper is focused on reducing the backpressure in the exhaust manifold to increase the combustion efficiency using experimental analysis and CFD analysis. Exhaust manifolds collects the exhaust gases from the engine cylinders and discharge to the atmosphere through the exhaust system. The engine efficiency, combustion characteristics would depend upon how the exhaust gases were removed from the cylinder. The design of an exhaust manifold for the internal combustion engine depends on many parameters such as exhaust back pressure, velocity of exhaust gases etc.

**Mohd Sajid Ahmed et al., 2015,** The major work is to improve the design to lower the backpressure in the exhaust manifold which increases the performance of the engine. In the present work, analysis is carried out for different shape of exhaust manifolds using CFD software. To achieve the optimal geometry for the low backpressure and high exhaust velocity, five different models were designed and comprehensively analyzed with the help of velocity contours and pressure contours.

**Abhishek Srivastava and Shailendra Sinha, 2017,** The design of an exhaust manifold which is studied and experimented in the paper depends on pressure drop and volumetric flow rate. Various geometrical types of exhaust manifold had been studied using experimental methods as well as numerical methods (CFD). This paper reveals about severe heat cycles conditions, the exhaust manifold of an engine can have problems of crack and extensive plastic deformations, and the finite element method is being applied to predict thermal stress and deformations in manifold area.

**Mesut Durat et al., 2013,** In the study, three-dimensional transient CFD analysis has been performed for the whole exhaust pipe. The results of CFD analysis was in very good agreement with those of experimental data. Also, an optimal catalyst location was determined by the CFD analysis performed in transient regime. Heat transfer phenomena were also investigated analytically using different Nusselt number correlations given in the literature. Analytic results were compared with those of the experimental data. Each correlation gave reasonable results with different range of Reynolds number.

**V. Ashok Kumar et al., 2016,** In this research, an exhaust manifold modelled by PRO-E design software. The thesis will focus on CFD and thermal analysis with different loads (2, 6,12,14,16 and 18 kg). Thermal analysis done for the exhaust manifold by cast iron, stainless steel, silicon nitride& zinc oxide. In this thesis the CFD analysis to determine the heat transfer rate, mass flow rate, pressure drop and thermal analysis to determine the temperature distribution, heat flux with different materials. 3D modeled in parametric software Pro-Engineer and analysis done in ANSYS.

**Nikhil Kanawade and Omkar Siras, 2015,** The study was conducted using the CFD simulations and the experimental approach. The flow pattern inside the manifold was studied using the streamlines and the necessary optimization was performed. STAR CCM+ was used for performing the CFD simulations. The Realizable k-epsilon turbulence model with All

Y+ Wall Treatment was applied for the CFD simulations. An experimental study was conducted for the optimized geometry as part of the project validation. The optimized exhaust manifold provided ~26% less flow losses as compared to the base model.

## III. RESEARCH PROBLEM

Solid Works is used to model and analyze Industrial Turbo Manifold. Three materials are considered to analyse same model. Material considered are, Cast Iron (CI), Mild Steel (MS) and Stainless Steel (SS) material.

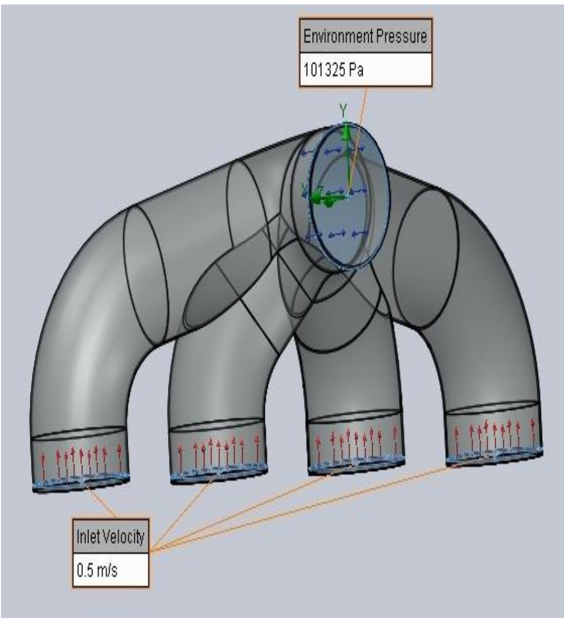



**Figure: Model and input parameters**

Geometrical specifications are also varied i.e. five models with three different materials are modelled and analysed to perform research.

**Table I Geometrical Specification**

| Geometrical Specifications | Diameter mm | Center Height mm |
|---|---|---|
| 70x125 | 70 | 125 |
| 70x150 | 70 | 150 |
| 70x175 | 70 | 175 |
| 70x200 | 70 | 200 |
| 70x225 | 70 | 225 |

## IV. OBJECTIVES

- To elaborate CAD application in the field of Exhaust manifold analysis.
- To perform FEM model simulation with CAD software.
- To find flow patterns from exhaust gases from the manifold.
- To study the velocity, pressure distribution, static pressure drop, total pressure drop, and energy loss.

## V. RESEARCH PROBLEM

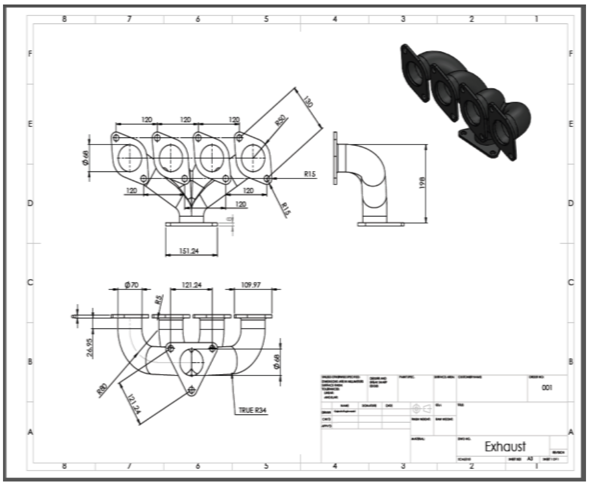



**Figure: Model Diagram Specifications**

## VI. ANALYSIS AND RESULTS

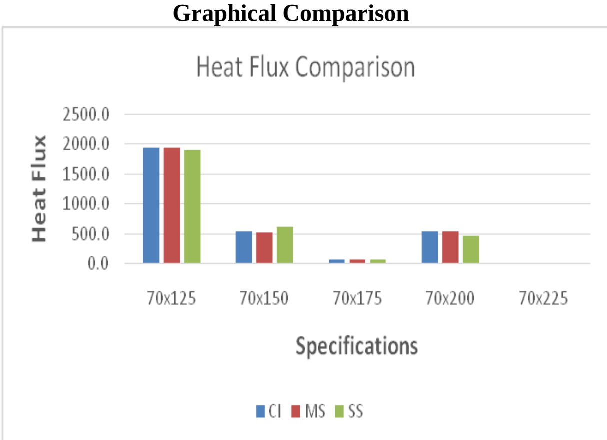
CAD model is prepared in the SolidWorks software by using the actual parametric dimensions. Flow pattern is studied with velocity and pressure distribution of exhaust gases. Static pressure drop, total pressure drop, and energy loss in the flow pattern generated in the exhaust manifold were also studied and compared.

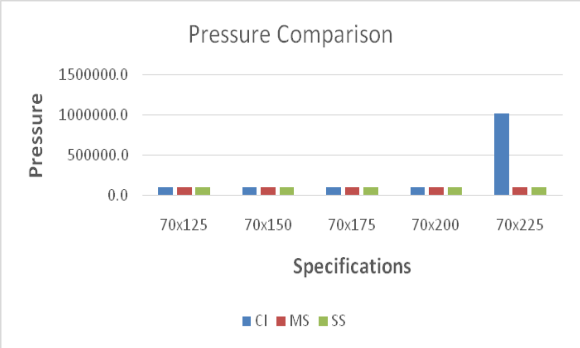
**Table II Results**

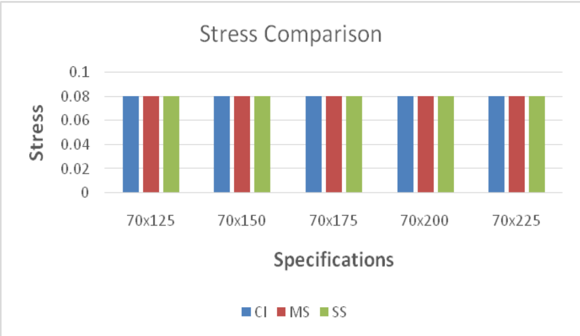
| Geometrical Specifications | CI | | | | MS | | | |
|---|---|---|---|---|---|---|---|---|
| | Heat Flux | Pressure | Stress | Velocity | Heat Flux | Pressure | Stress | Velocity |
| **70x125** | 1934.0 | 101326.9 | 0.08 | 2.48 | 1924.9 | 101326.9 | 0.08 | 2.48 |
| **70x150** | 521.9 | 101326.8 | 0.08 | 2.45 | 511.5 | 101326.8 | 0.08 | 2.45 |
| **70x175** | 47.6 | 101327.0 | 0.08 | 2.60 | 47.6 | 101327.0 | 0.08 | 2.60 |
| **70x200** | 537.5 | 101326.8 | 0.08 | 2.51 | 538.7 | 101326.8 | 0.08 | 2.50 |
| **70x225** | 0.0 | 1013270.0 | 0.08 | 2.27 | 0.0 | 101327.0 | 0.08 | 2.55 |

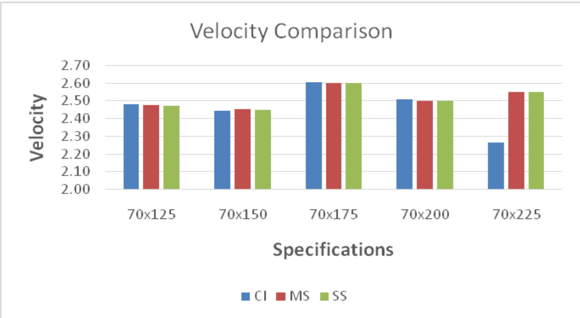
| Geometrical Specifications | SS | | | |
|---|---|---|---|---|
| | Heat Flux | Pressure | Stress | Velocity |
| **70x125** | 1891.9 | 101326.9 | 0.08 | 2.47 |
| **70x150** | 615.4 | 101326.8 | 0.08 | 2.45 |
| **70x175** | 48.0 | 101327.0 | 0.08 | 2.60 |
| **70x200** | 461.3 | 101326.8 | 0.08 | 2.50 |
| **70x225** | 0.0 | 101327.0 | 0.08 | 2.55 |

**Graphical Comparison**






## VII. COMPARISON INTERPRETATION

Desired heat flux is found with the manifold specification of 70x125 mm is maximum of all other cases modelled, designed and considered. Stresses and pressure are unchanged for all results. Velocity fluctuated by little value for all models analyzed and compared.

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