CFD Analysis of Exhaust Manifold Using Solid works and Ansys Workbench

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Abstract- *Exhaust manifold plays an important role in the exhaust system, the manifold delivers the waste toxic gases to a safe distance and it is used to reduce the sound pollution and air pollution. Exhaust manifold suffers with lot of thermal stress, due to this blow holes occurs in the surface of the exhaust manifold and also more noise is developed. The waste toxic gases from the multiple cyinders are collected into a single pipe by the exhaust manifold. The waste toxic gases can damage the material of the manifold. In this study, to prevent the damage nickel chrome molybdenum alloy is used a material for exhaust manifold to perform analysis. The existing results of stainless steel made exhaust pipe results are compared with exhaust pipe made of alloy. Initially the flow characteristics of exhaust manifold due to exhaust flow is analyzed with the parameters like pressure, velocity and temperature. The obtained pressure is used as an input to study the structural characteristics of exhaust manifold made of stainless steel and SAE-4340. The obtained results are compared to calibrate the improved performance of alloy made exhaust pipe.*

I. INTRODUCTION

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. A vehicle's exhaust manifold plays the leading role in a car or truck's exhaust system. It connects to each exhaust port on the engine's cylinder head, and it funnels the hot exhaust down into one simple exhaust pipe. With the help of the exhaust manifold gaskets, it also prevents the toxic exhaust fumes from sneaking into the vehicle and harming the occupants. Needless to say, it's pretty important to have your exhaust manifold in good working order. The average V-shaped engine has two exhaust manifolds attached to it. One is for cylinder bank one, and the other is for cylinder bank two. The vast majority of inline engines have just one exhaust manifold. Rotary engines? They usually have just one exhaust manifold, though the turbocharged models have "down pipes" on the hot side of the turbo as well. Naturally there are exceptions to all of these rules, but in the real world, these exceptions are fairly rare. When it comes to the construction of exhaust manifolds, they are either going to be cast iron, or welded tubular steel. Exhaust manifold is a part of IC engines, its role is to collect and carry the exhaust gases away from the cylinder head and send it to the exhaust system, with a minimum of back pressure. The exhaust manifold plays an important role in the performance of an engine system. Particularly, the efficiencies of emission and fuel consumption are closely related to the performance of exhaust manifold. Exhaust Manifolds are affected by thermal stresses and deformations due the temperature distribution, heat accumulation or dissipation and other related thermal characteristics. The exhaust manifold is able to influence the gas exchange process in several aspects, like the piston work during the exhaust stroke, the short-circuit of fresh charge from the intake into the exhaust and even the filling of the cylinder. In this sense, the most influential boundary condition imposed by the manifold is the pressure at the valve and especially the instantaneous pressure evolution. The mean backpressure is determined mainly by the singular elements, such as the turbine, the catalytic converter and the silencer. Special interest must be given to the back pressure parameter. Back pressure is an undesired effect because as the back pressure increases so does the amount of residuals left in the head. The increase in weight of residuals will decrease the volume of the fresh charge, in turn increasing the temperature at the beginning of compression as well. Several experiments show how the increase in back pressure influences the thermal efficiency for different induction manifold pressures. Proper analysis of the flue gases of various fuels in exhaust manifold is a difficult exercise however use of finite element method and computational fluid dynamics has shown promise.

II. LITERATURE REVIEW

1. Marupilla Akhil Teja*, KatariAyyappa, Sunny Katam and Panga Anusha

"Analysis of Exhaust Manifold using Computational Fluid Dynamics"

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. Flow through an exhaust manifold is dependent on the time since crank angle positions vary with respect to time. Unsteady state simulation can predict how an intake manifold work under real conditions. The boundary conditions are no longer constant but vary with time. The main objectives that to be studied in this work is:

- To prepare the cad model in the CATIA software by using the actual parametric dimensions.
- To prepare finite element model in the Computer aided analysis software by specifying the approximate element size for meshing.
- To find and calculate the actual theoretical values for the input boundary conditions.
- To study the flow patterns generated due to the flow of the exhaust gases from the manifold.
- To study the velocity and pressure distribution in ports at maximum flow rate.
- To study the static pressure drop, total pressure drop, and energy loss in the flow pattern generated in the exhaust manifold.

2. Gopaal, MMM Kumara Varma, Dr L Suresh Kumar

"Exhaust Manifold Design – FEA Approach"

The Exhaust manifold in the engines is an important component which has a considerable effect on the performance of the I.C engine. The exhaust manifold operates under high temperature and pressure conditions. Their design usually has to be performed by trial and error through many experiments and analyses. Therefore, an automated design optimization would reduce technical, schedule, and cost risks for new engine developments. This paper deals with the various factors that are to be considered in the design of the exhaust manifold. It tries to explain the effect of various factors during the Finite Element Analysis.

3. Kanupriya Bajpai, Akash Chandrakar, Akshay Agrawal, Shiena Shekhar

"CFD Analysis of Exhaust Manifold of SI Engine and Comparison of Back Pressure using Alternative Fuels"

Exhaust manifold is one of the most critical components of an IC Engine. The functioning of exhaust manifold is complex and is dependent on many parameters viz. back pressure, exhaust velocity, scavenging etc. In the present work, the performance of a four-stroke four cylinder gasoline engine exhaust manifold have been analysed 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. The LPG fuel gives minimum back pressure, temperature and velocity being approximately in the same range for all three fuels viz. gasoline, alcohol and LPG. Thus, LPG can be considered as a suitable alternative for gasoline in terms of minimum back flow in manifold.

4. Saravanan J, Valarmathi T N, Rajdeep Nathc, Prasanth Kumar

"Experimental Analysis of Exhaust Manifold with Ceramic Coating for Reduction of Heat Dissipation"

Exhaust manifold plays an important role in the exhaust system, the manifold delivers the waste toxic gases to a safe distance and it is used to reduce the sound pollution and air pollution. Exhaust manifold suffers with lot of thermal stress, due to this blow holes occurs in the surface of the exhaust manifold and also more noise is developed. The waste toxic gases from the multiple cylinders are collected into a single pipe by the exhaust manifold. The waste toxic gases can damage the material of the manifold. In this study, to prevent the damage zirconia powder has been coated in the inner surface and alumina (60%) combined with titania (40%) has been used for coating the outer surface of the exhaust manifold. After coating experiments have been performed using a multiple-cylinder four stroke stationary petrol engine. The test results of hardness, emission, corrosion and temperature of the coated and uncoated manifolds have been compared. The result shows that the performance is improved and also emission is reduced in the coated exhaust manifold.

5. Mr. Sachin g. Chaudhari, mr. Parag n. Borse, Mr. Raghunath y. Patil

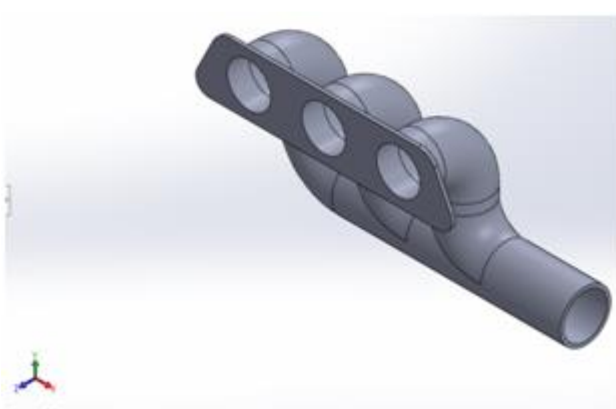
"Experimental and CFD Analysis of Exhaust Manifold to Improve Performance of IC Engine"

Exhaust manifold collect 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 paper, 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 has been collected and discussed.

III. INTRODUCTION TO SOLIDWORKS

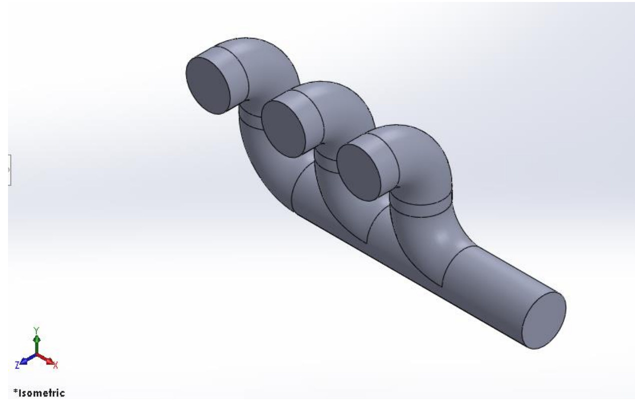
SolidWorks (stylized as SOLIDWORKS), is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) software program that runs on Microsoft Windows. The SolidWorks is produced by the DASSAULT SYSTÈMES— a subsidiary of Dassault Systems, S. A. based in Velizy, France— since 1997.

SolidWorks is currently used by over 2 million engineers and designers at more than 165,000 companies worldwide. In 2011–12, the fiscal revenue for SolidWorks was reported $483 million.



The created bend tube is distributed over the surface of base tube with the help of linear pattern tool

The fixture to connect with engine is created using extrude and fillet tool

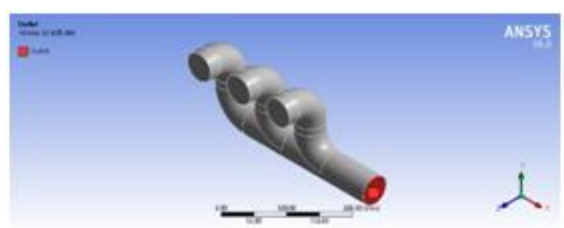


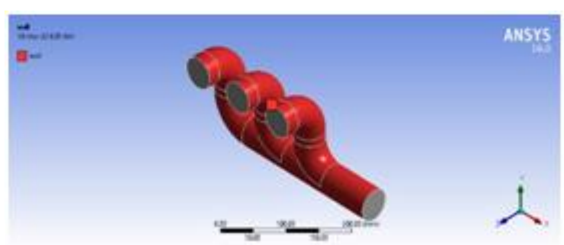
The 3D model of flow geometry profile to study the flow characteristics

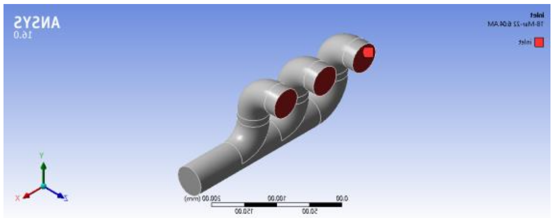
IV. ANSYS WORKBENCH

ANSYS Workbench combines the strength of our core simulation tools with the tools necessary to manage your projects. You will work with your ANSYS Workbench project on the main project workspace, called the Projecttab. The project is driven by a schematic workflow, represented visually on a flowchart like diagram called the Project Schematic. To build an analysis, you add building blocks called systems to the Project Schematic; each system is a block of one or more components called cells, which represent the sequential steps necessary for the specific type of analysis. Once you have added your systems, you can link them together to share and/or transfer data between systems. From the cells in the Project Schematic, you can work with various ANSYS applications and analysis tasks

ANALYZING PROCEDURE







INLET IS ASSIGNED TO INITIATE THE FLOW

OUTLET IS ASSIGNED TO EXHAUST THE FLOW

THE WALLS ARE ASSIGNED TO DEFINE THE EXTERIOR DOMAIN IN WHICH FLUIDS ARE ALLOWED TO FLOW

EQUATIONS USED

Energy equations

In physics, **mass–energy equivalence** is a concept formulated by Albert Einstein that explains the relationship between mass and energy. It states every mass has an energy equivalent and vice versa—expressed using the formula

$$E = mc^2$$

Viscous laminar equation

The Standard, RNG, and Realizable k- ϵ Models This section presents the standard, RNG, and realizable k- ϵ models. All three models have similar forms, with transport equations for k and ϵ. The major differences in the models are as follows:

The method of calculating turbulent viscosity. The turbulent Prandtl numbers governing the turbulent diffusion of k and ϵ

The generation and destruction terms in the ϵ equation. The transport equations, methods of calculating turbulent viscosity, and model constants are presented separately for each model. The features that are essentially common to all models follow, including turbulent production, generation due to buoyancy, accounting for the effects of compressibility, and modeling heat and mass transfer.

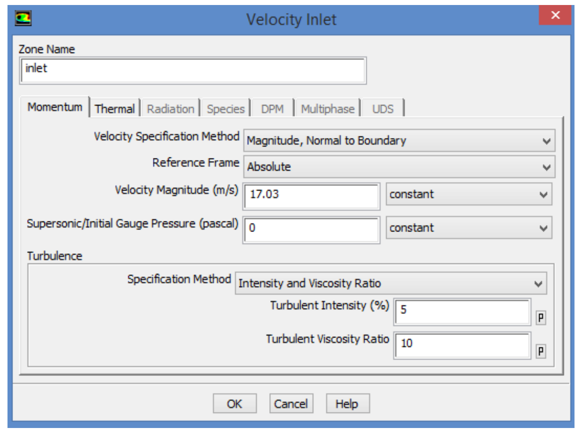
Fluid medium used

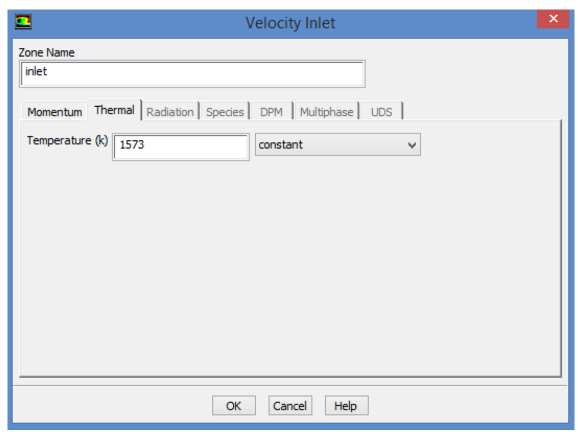
Air

Boundary conditions

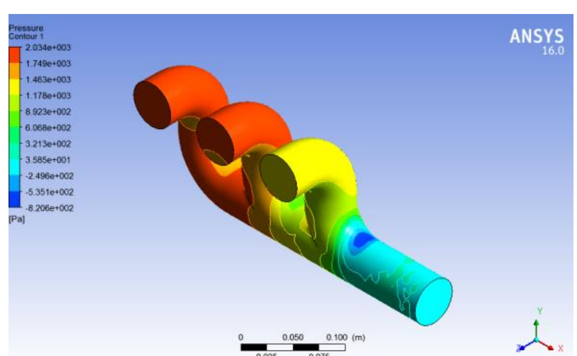
Inlet

Type: Velocity inlet (17.03m/s)
Temperature of fluid (1573 k)
Outlet
Type: Pressure outlet
No of iterations used: 100

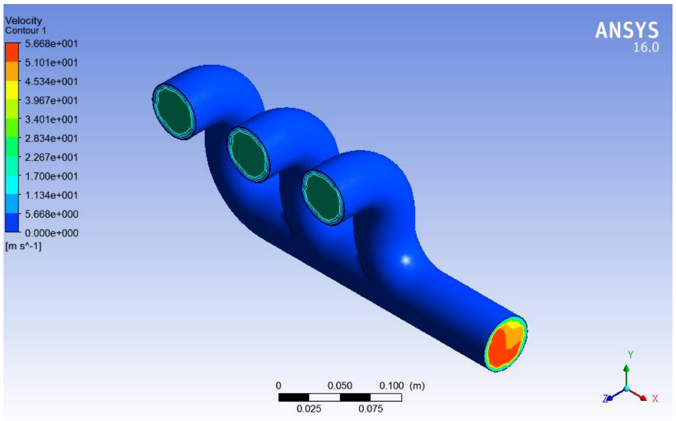




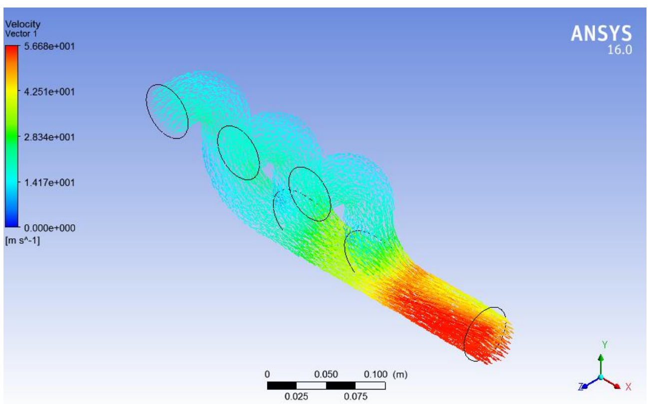
V. RESULTS OF FLOW ANALYSIS



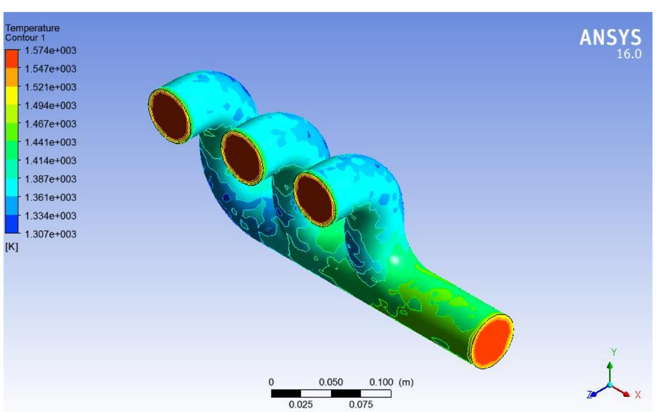
PRESSURE DISTRIBUTION EXPERIENCED DURING THE FLOW OF EXHAUST



VELOCITY DISTRIBUTION EXPERIENCED DURING THE FLOW OF EXHAUST



VELOCITY DISTRIBUTION IN THE FORM OF VECTOR

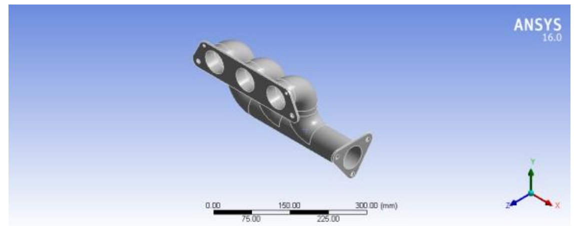


TEMPERATURE DISTRIBUTION EXPERIENCED DURING THE FLOW OF EXHAUST

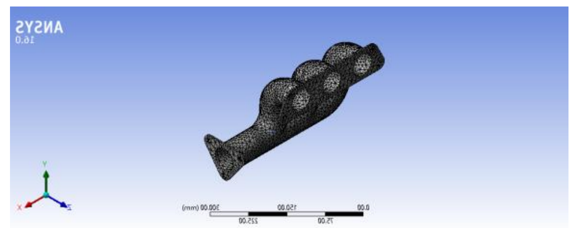
VI. STRUCTURAL ANALYSIS

The structural analysis is a mathematical algorithm process by which the response of a structure to specified loads and actions is determined. This response is measured by determining the internal forces or stress resultants and displacements or deformations throughout the structure. The structural analysis is based on engineering mechanics, mechanics of solids, laboratory research, model and prototype testing, experience and engineering judgment..

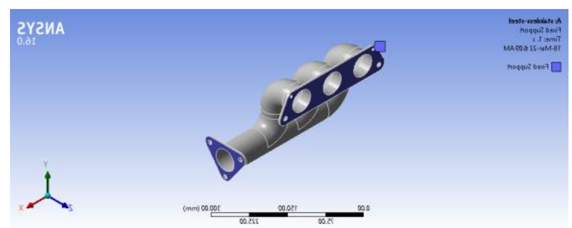
VII. ANALYSING PROCEDURE



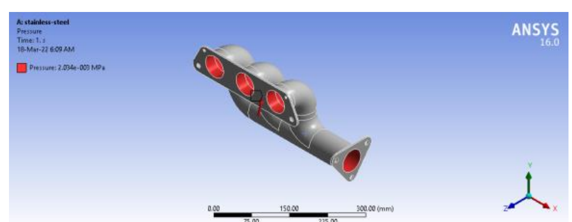
EXHAUST MANIFOLD IMPORTED IN ANSYS WORKBENCH



MESHED MODEL



FIXED SUPPORT



INPUT PRESSURE EXPERIENCED DURING THE FLOW OF EXHAUST

VIII. STAINLESS STEEL

The steel is an alloy of iron and carbon with a maximum carbon content of 2.1%. **Stainless steels are a group of steels that are resistant to corrosion through the addition of alloying elements**.

The term stainless steel is used to describe a family of about 200 alloys of steel with remarkable heat and corrosion resistance properties. The carbon percentage can range from 0.03% to 1.2%.

Its distinguishing characteristic is the high amount of chromium. Stainless steel contains a minimum of 10.5% of chromium that improves its corrosion resistance and strength. The chromium in the alloy creates a passive layer on oxidation when exposed to air. This layer acts as a shield against further corrosion essentially making the alloy rustproof. This mechanism allows for retaining a spotless appearance for long periods under normal working conditions.

Stainless steel has been used with phenomenal success in various industries for over 70 years. More applications are being discovered with every passing year as its advantages become more widely identified.

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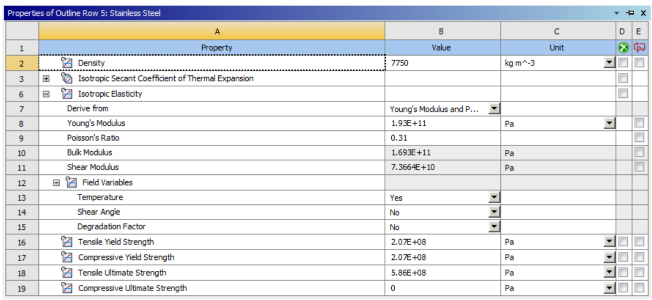
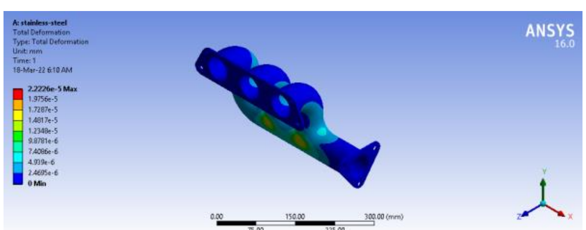


Properties of Outline Row 5: Stainless Steel

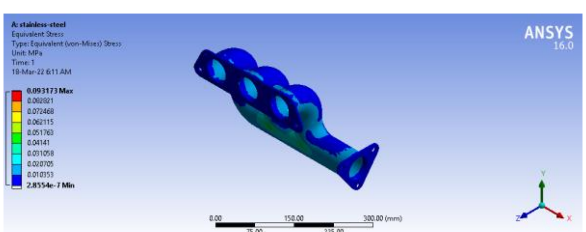
	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7750	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
7	Derive from	Young's Modulus and P...			
8	Young's Modulus	1.93E+11	Pa		
9	Poisson's Ratio	0.31			
10	Bulk Modulus	1.693E+11	Pa		
11	Shear Modulus	7.3664E+10	Pa		
12	Field Variables				
13	Temperature	Yes			
14	Shear Angle	No			
15	Degradation Factor	No			
16	Tensile Yield Strength	2.07E+08	Pa		
17	Compressive Yield Strength	2.07E+08	Pa		
18	Tensile Ultimate Strength	5.86E+08	Pa		
19	Compressive Ultimate Strength	0	Pa		

Properties of stainless steel assigned in ansys library

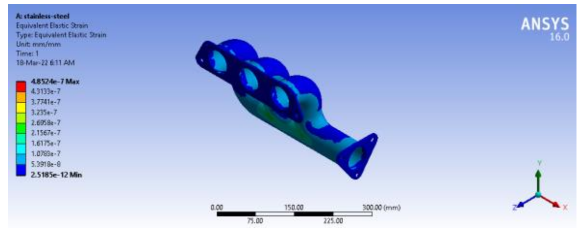
IX. RESULTS OF STAINLESS STEEL



Total deformation



Stress distribution



Strain distribution

X. SAE 4340

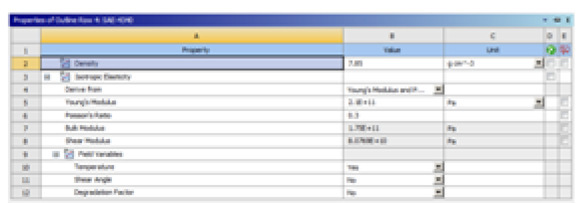
Alloy steels are designated by AISI four-digit numbers. They comprise different kinds of steels having composition exceeding the limitations of B, C, Mn, Mo, Ni, Si, Cr, and Va set for carbon steels.

AISI 4340 alloy steel is a heat treatable and low alloy steel containing chromium, nickel and molybdenum. It has high toughness and strength in the heat treated condition.

Chemical Composition

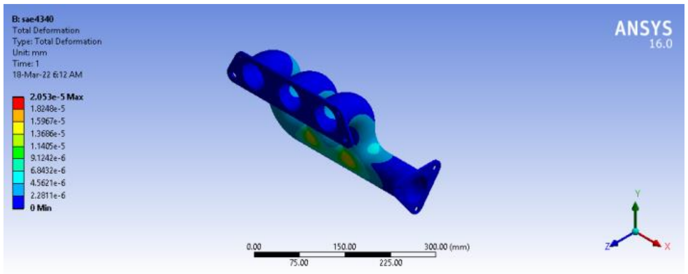
The following table shows the chemical composition of AISI 4340 alloy steel.

Element	Content (%)
Iron, Fe	95.195 - 96.33
Nickel, Ni	1.65 - 2.00
Chromium, Cr	0.700 - 0.900
Manganese, Mn	0.600 - 0.800
Carbon, C	0.370 - 0.430
Molybdenum, Mo	0.200 - 0.300
Silicon, Si	0.150 - 0.300
Sulfur, S	0.0400
Phosphorous, P	0.0350

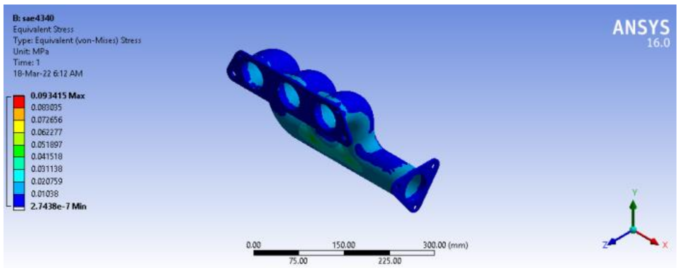


Properties of SAE 4340 assigned in ansys library

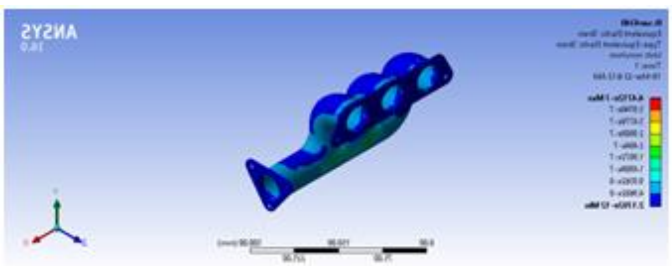
XI. RESULTS OF SAE 4340



Total deformation



Stress distribution



Strain distribution

XII. TABULATED RESULTS

Materials	Total deformation (mm)		Stress distribution		Strain distribution		Weight (KG)
	Min	Max	Min	Max	Min	Max	
Stainless steel	0	2.22 e-5	2.85 e-7	0.09	2.51e -12	4.85e -7	4.15
SAE 4340	0	2.05 e-5	2.74 e-7	0.09	2.17e -12	4.47e -7	4.21

XIII. CONCLUSION

Brief study about exhaust manifold types working is done in this project. Exhaust manifold is modelled by using solidworks 2016 software using different commands and tools. Model is converted into IGES (initial graphics exchange specification) file, and transferred to ANSYS 16 Workbench software for analysis. Computational fluid dynamic analysis is performed on exhaust manifold to study its flow characteristics such as pressure, velocity and temperature. Inlet temperature is taken as 1573 K, obtained temperature, pressure and velocity are noted and tabulated.

The aim of this thesis was to improve the life of exhaust manifolds in order to allow for higher exhaust gas temperatures in heavy-duty engines, which is an important step in complying with coming emission legislations. To select the most suitable material for the application, the effects of the environment on the fatigue life is an important factor in order to understand the influence of real service conditions on the component life. The use of SAE 4340 increased high-temperature oxidation and fatigue resistance in exhaust gas temperatures, thereby reducing the corrosion level when compared with stainless steel.

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