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Manifold Optimization of an Internal Combustion Engine by using Thermal Analysis

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Abstract: In this thesis, 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.

Keywords: Exhaust Manifold, IC Engine, CFD Modeling for Exhaust Manifold.

I. INTRODUCTION

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 manifold (from the Anglo-Saxon mani [many] and fold [fold]) and refers to the folding together of multiple inputs and outputs (in contrast, an inlet or intake manifold supplies air to the cylinders).

The goal of performance exhaust headers is mainly to decrease flow resistance (back pressure), and to increase the volumetric efficiency of an engine, resulting in a gain in power output. The processes occurring can be explained by the gas laws, specifically the ideal gas law and the combined gas law, A ceramic mixture is bonded to the manifold via thermal spraying to give a tough ceramic coating with very good thermal insulation.

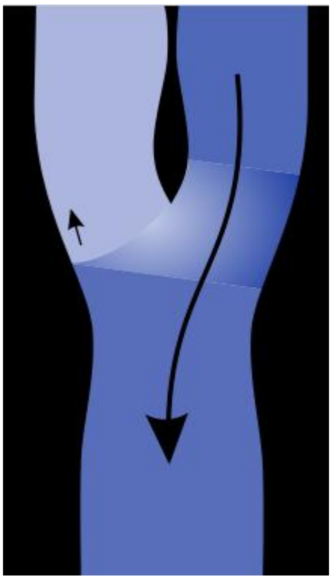

Fig. 1 exhausts scavenging

This is often used on performance production cars and track-only racers. Exhaust wrap is wrapped completely around the manifold. Although this is cheap and fairly simple, it can lead to premature degradation of the manifold.

A.WHY A CROSS PLANE V8 NEEDS AN H OR X EXHAUST PIPE

Cross plane v8 have a left and right bank each containing 4 cylinders. When the engine is running, pistons are firing according to the engine firing order. If a bank has two consecutive piston firings it will create a high pressure area in the exhaust pipe, because two exhaust pulses are moving through close in time. As the two pulses move in exhaust pipe they should encounter either an X or H pipe.

II. LITERATURE REVIEW

CFD analysis of exhaust manifold of multi-cylinder SI engine determine optimal geometry for reducing emissions

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. 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.

A literature review on exhaust manifold design

Exhaust manifolds collects the exhaust gases from the engine cylinders and discharge to the atmosphere

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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.

III. METHODOLOGY AND PROBLEM DESCRIPTION

For exhaust manifold the mass flow rate of flue gasses was evaluated keeping speed constant at1500rpm.These calculations were carried out at different loading condition i.e. 2kg, 6kg, 12kg, 14kg, 16kg and 18 kg. Pressure and velocity contours were obtained exhaust manifold at six above mentioned loading conditions. modelling were prepared using Pro engineer and analysis was carried out using Ansys workbench 15.0.The results were categorized into groups and comprehensive game matrix was prepared to render a peculiar performance score to each of these loads& materials to finally conclude upon the best load and material.

IV.INTRODUCTION TO CAD/CAE

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

A.INTRODUCTION TO PRO-ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Different modules in pro/engineer

Part design, Assembly, Drawing& Sheet metal

B.INTRODUCTION TO FINITE ELEMENT METHOD:

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

V. RESULTS AND DISCUSSIONS

A.MODELS OF MANIFOLD

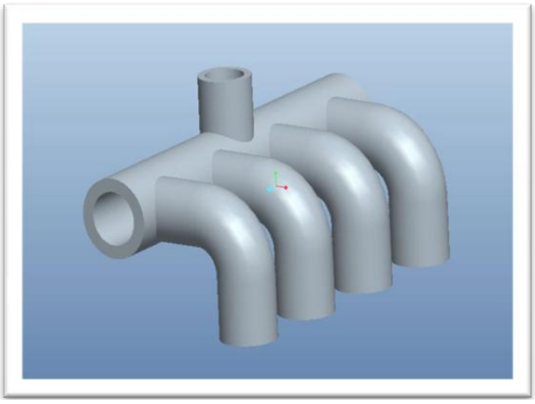


Fig.2 3D model of exhaust manifold

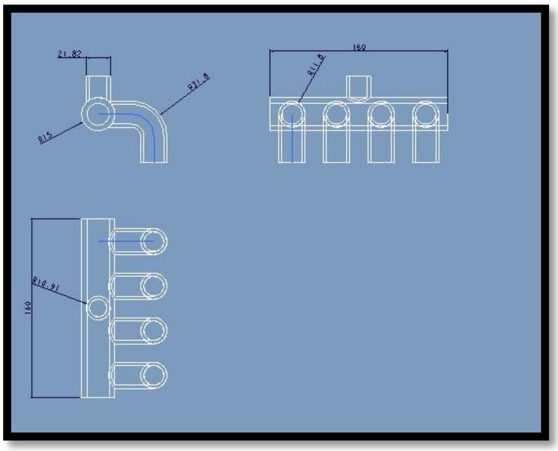
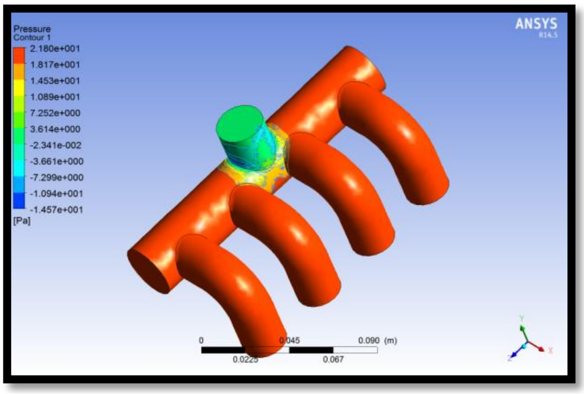


Fig. 3 2D model of exhaust manifold

B. CFD ANALYSIS OF EXHAUST MANIFOLD

LOAD AT 12 KG STATIC PRESSURE



According to the above contour plot, the maximum static pressure at inlet of the manifold because the applying the boundary conditions at inlet of manifold and minimum static pressure at outlet of the manifold.

According to the above contour plot, the maximum pressure is 2.180e+001Pa and minimum static pressure is -1.457e+001Pa.

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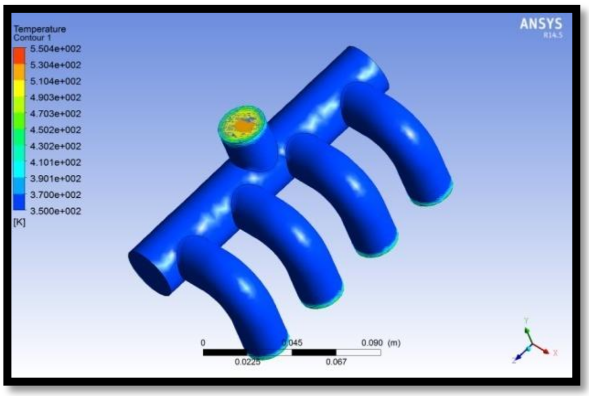
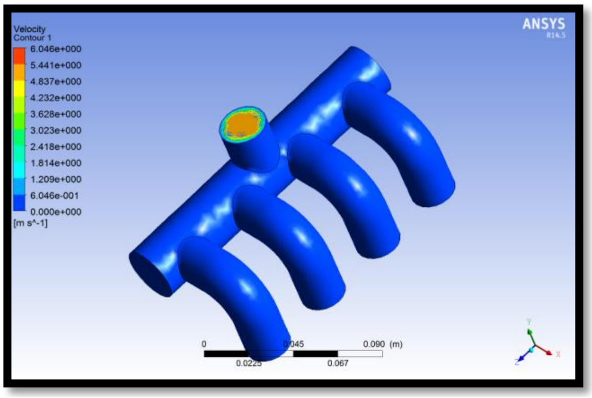
STATIC TEMPERATURE



According to the above contour plot, the maximum temperature at inlet and outlet of the boundaries, because the applying the boundary conditions at inlet of the manifold and minimum temperature at inside the manifold.
According to the above contour plot, the maximum temperature is 5.504e+002K and minimum temperature is 3.5e+002K.

VELOCITY



According to the above contour plot, the maximum velocity magnitude of the at inlet and outlet of the boundaries, because the applying the boundary conditions at inlet of the manifold and minimum velocity magnitude at inside the manifold.
According to the above contour plot, the maximum velocity is 6.046e+000m/s and minimum velocity is 6.046e-001m/s.

MASS FLOW RATE

Mass Flow Rate	(kg/s)
inlet	0.0025440005
interior-____msbr	0.003119438
outlet	-0.0025481251
wall-____msbr	0
Net	-4.1245949e-06

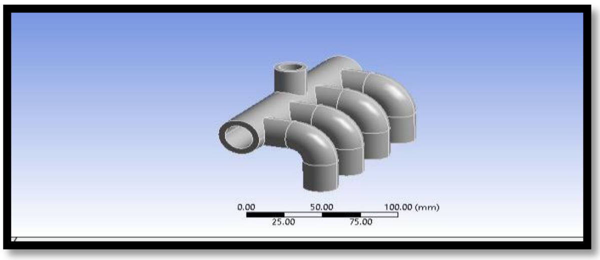
HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
inlet	676.146
outlet	-539.75635
wall-____msbr	-139.05457
Net	-2.664917

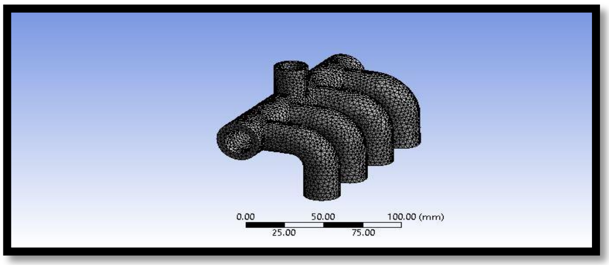
THERMAL ANALYSIS OF EXHAUST MANIFOLD

Materials:
Used Materials cast iron, zinc oxide, stainless steel, & silicon nitride material for manifold

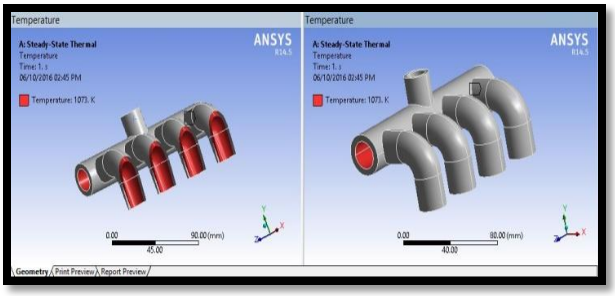
Imported model



Meshed model

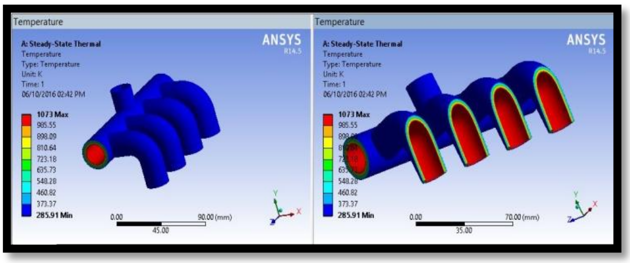


BOUNDARY CONDITIONS



Material: zinc oxide

Temperature



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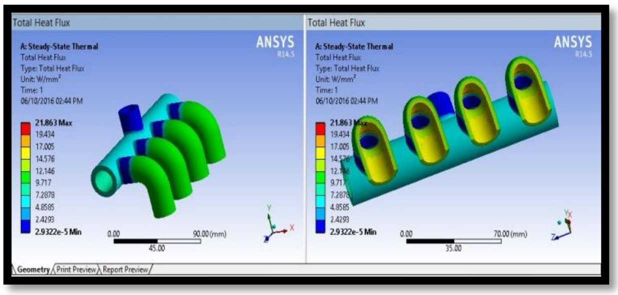
Heat flux



V. RESULTS AND DISCUSSIONS

CFD ANALYSIS RESULT TABLE

Table 1:cfd analysis results at different load conditions

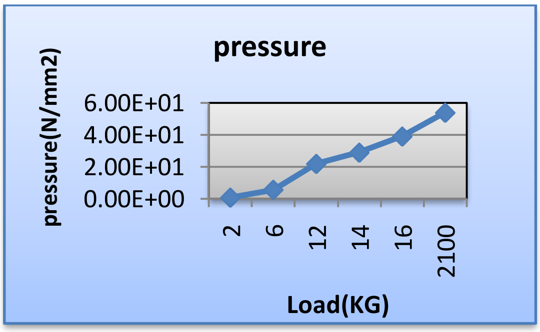
Load (KG)	Pressure (N/mm²)	Temperature (K)	Velocity (m/s)	Mass flow Rate (Kg/sec)	Heat Trans -fer Rate (w)
2	7.390e-01	5.50e+02	1.02	2.26e-07	0.1788
6	5.64	5.506e+02	3.01	7.8254e-07	0.9055
12	2.18e+01	5.504e+02	6.04	4.124e-06	2.664
14	2.885e+01	5.503e+02	7.01	1.87e-06	1.8945
16	3.891e+01	5.503e+02	8.11	2.369e-06	0.404
18	5.376e+01	5.503e+02	9.55	2.0400e-06	1.5016

THERMAL ANALYSIS RESULT TABLE

Table 2: thermal analysis results with different materials

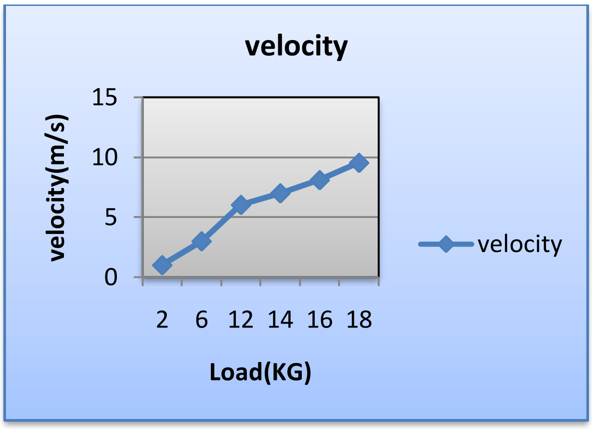
MATERIAL	TEMPERATURE(k)		HEAT FLUX(w/mm²)
	min	max	
Cast iron	285.91	1073	16.61
Stainless steel	297.32	1073	5.9139
Silicon nitride	303.03	1073	10.42
Zinc oxide	303.03	1073	8.670

GRAPHS



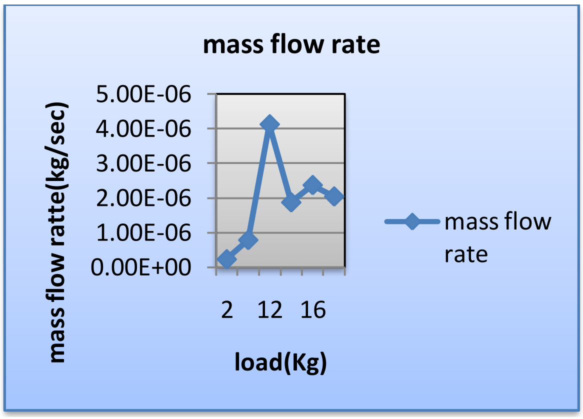
Variation of maximum pressure for various loads

A plot between maximum pressure and loads by FEA approach is shown in above fig. From the plot the variation of maximum static pressure is observed. Maximum static pressure increases with increases loads



Variation of maximum heat transfer coefficient for various loads

A plot between maximum velocity and loads by FEA approach is shown in above fig. From the plot the variation of maximum static velocity is observed. Maximum velocity increases with increases loads.



Variation of maximum mass flow rate for various velocities

A plot between maximum mass flow rate and loads by FEA approach is shown in above fig. From the plot the variation of maximum mass flow rate is observed. Maximum mass flow rate increases at load 12Kg.

VI. CONCLUSION

In this thesis, an exhaust manifold modeled 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.
By observing the CFD analysis the pressure increases the increasing the load conditions and mass flow rate, heat transfer rate increased at 12kg.

By observing the thermal analysis results the heat flux more for cast iron than steel, zinc oxide& silicon nitride. We consider the weight of the material less for zinc oxide so we concluded the zinc oxide material is the better material for exhaust manifold.

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