EXHAUST MANIFOLD OPTIMIZATION OF AN INTERNAL COMBUSTION ENGINE BY USING THERMAL ANALYSIS

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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. In any multi-cylinder IC engine, an exhaust manifold (also known as a header) collects the exhaust gases from multiple cylinders into one pipe.

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. 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.

Key words: Finite element analysis, exhaust manifold, CFD analysis, thermal analysis.

1. 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 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. For many engines, there are aftermarket tubular exhaust manifolds known as headers in US English, as extractor manifolds in British and Australian English, and simply as "tubular manifolds" in UK English.[citation needed] These consist of individual exhaust headpipes for each cylinder, which then usually converge into one tube called a collector. Headers that do not have collectors are called zoomie headers.

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 color (usually a yellow tint), but less than chrome in most cases. Exhaust wrap is wrapped completely around the manifold. Although this is cheap and fairly simple, it can lead to premature degradation of the manifold.

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

Diagram of an exhaust manifold from a Kia Rio. 1. manifold, 2. gasket, 3. nut; 4. heat shield; 5. heat shield bolt

EXHAUST SCAVENGING

When an engine starts its exhaust stroke, the piston moves up the cylinder bore, decreasing the total chamber volume. When the exhaust valve opens, the high pressure exhaust gas escapes into the exhaust manifold or header, creating an 'exhaust pulse' comprising three main parts:

The high-pressure head is created by the large pressure difference between the exhaust in the combustion chamber and the atmospheric pressure outside of the exhaust system As the exhaust gases equalize between the combustion chamber and the atmosphere, the difference in pressure decreases and the exhaust velocity decreases. This forms the medium-pressure body component of the exhaust pulse The remaining exhaust gas forms the low-pressure tail component. This tail component may initially match ambient atmospheric pressure, but the momentum of the high and medium-pressure components reduces the pressure in the combustion chamber to a lower-than-atmospheric level.

This relatively low pressure helps to extract all the combustion products from the cylinder and induct the intake charge during the overlap period when both intake and exhaust valves are partially open. The effect is known as 'scavenging'. Length, cross-sectional area, and shaping of the exhaust ports and pipeworks influences the degree of scavenging effect, and the engine speed range over which scavenging occurs.

2. LITERATURE REVIEW

Balaji Net al [1]The majority of the research work 1. Cfd analysis of exhaust manifold of multi-cylinder si engine to Determine optimal geometry for reducing emissions

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. 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.

KEYWORDS: Multi-Cylinder SI Engine, Exhaust Manifold, Back Pressure, Exhaust Velocity, LBCE, LBSE, LBSER,LBCER, SBCE, SBSE, SBCER, SBSER

2. A LITERATURE REVIEW ON EXHAUST MANIFOLD DESIGN.

Abstract

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.

3. METHODOLOGY AND PROBLEM DESCRIPTION

For exhaust manifold the mass flow rate of flue gasses was evaluated keeping speed constant at

1500rpm.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.

4. 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.

4.1. INTRODUCTION TO CREO

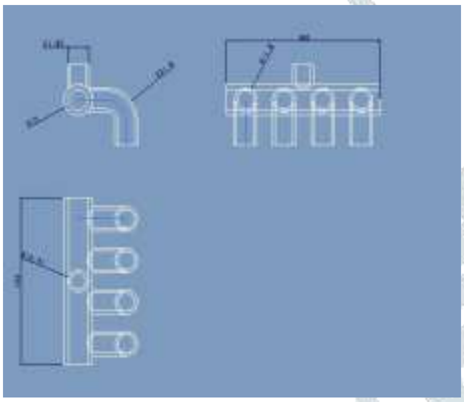
CREO is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated CREO CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and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

Different modules in CREO

Part design, Assembly, Drawing& Sheet metal.

3D MODEL

2D MODEL



4.2. 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.

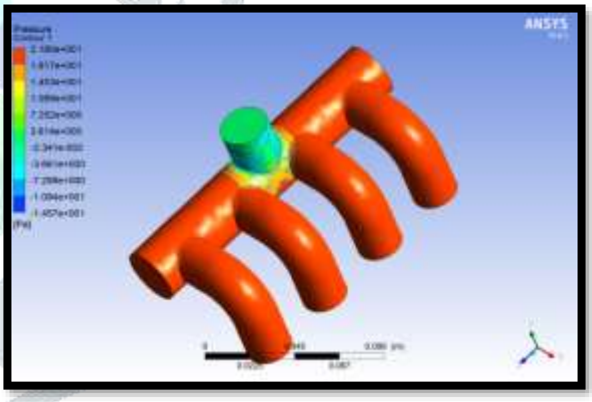
4.3 INTRODUCTION TO CFD

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

5. RESULTS AND DISCUSSIONS:

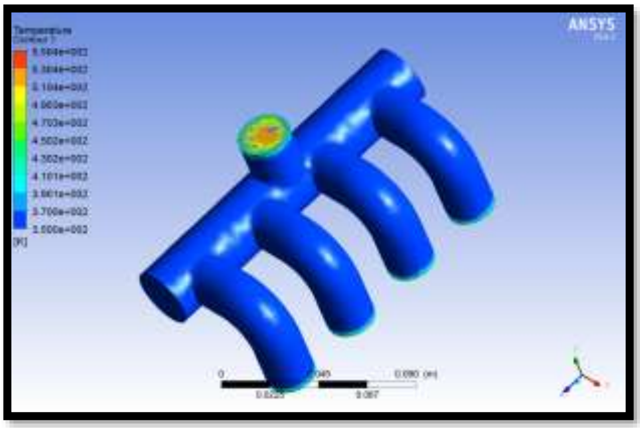
AT LOAD -12KG

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.

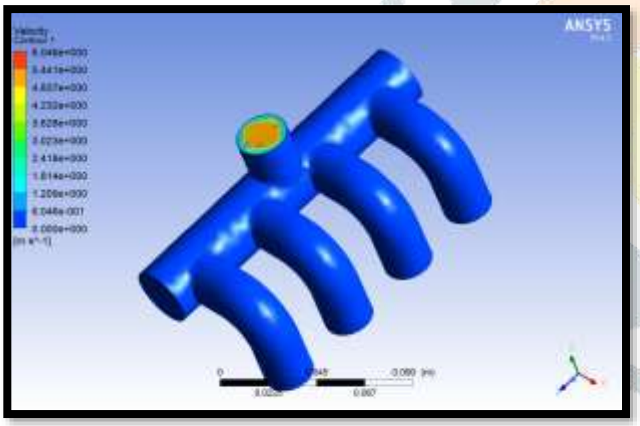
STATIC TEMPERATURE



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

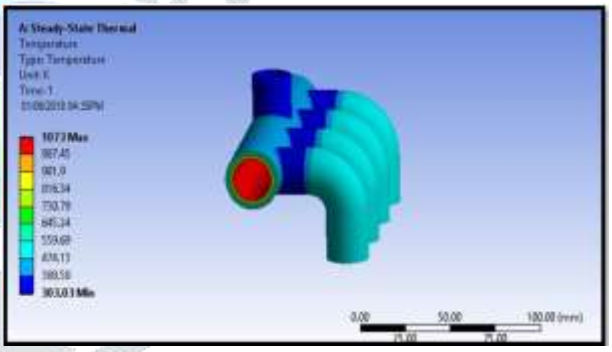
Mass Flow Rate	(kg/s)
inlet	0.0025440005
interior-____msbr	0.003119438
outlet	-0.0025481251
wall-____msbr	0
Net	-4.1245949e-06

Heat transfer rate

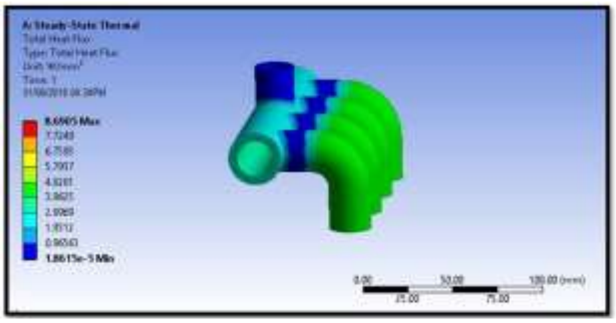
Total Heat Transfer Rate	(w)
inlet	676.146
outlet	-539.75635
wall-____msbr	-139.05457
Net	-2.664917

MATERIAL-ZINC OXIDE

TEMPERATURE



HEAT FLUX



RESULTS AND DISCUSSIONS

Cfd result table

Load (KG)	Pressure (N/mm^2)	Temperature (K)	Velocity (m/s)	Mass flow Rate(Kg/sec)	Heat Transfer 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 RESULTS TABLE

MATERIAL	TEMPERATURE(k)		HEAT FLUX(w/mm^2)
	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

7. CONCLUSION

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.

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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