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Thermal Analysis of Exhaust Manifold Coating with High Temperature Resistant Materials

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Abstract: In IC engines exhaust system plays an important role in delivering the waste gases to a safe distance and also it helps in reducing the sound pollution and air pollution ,these exhaust systems ,mainly exhaust manifolds suffer a lot of thermal stress the life of the manifold is much effected due to the exposer with hot flue gases ,sometimes due to emissive heating these manifolds will get blow holes and produce a lot of noise , zirconia based materials exhibits low thermal conductivity, high hardness, and stable fracture toughness compared to other evaluated materials. One material that can be applicable in diesel exhaust application is mullite, which showed similar performance to zirconia based materials.

In this study we design a exhaust manifold with different coatings on it and we test it with Finite Element Methodology, but due to design limitations and some messing problem the work is carried forward by assuming complete body with coating material both temperature distribution and thermal stress concentrations are calculated using Finite Element Methodology. For modelling Catia V5 R20 is used and for Finite Element Methodology Ansys 15.0 is used.

1. INTRODUCTION

An internal combustion engine (**ICE**) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high-temperature and high-pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades, or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical. The first commercially successful internal combustion engine was created by Étienne Lenoir around 1859 and the first modern internal combustion engine was created in 1864 by Siegfried Marcus.

The term internal combustion engine usually refers to an engine in which combustion is intermittent, such as the more familiar stroke and two-stroke piston engines, along with variants, such as the six-stroke piston engine and the Wankel rotary engine. A second class of internal combustion engines use continuous combustion: gas turbines, jet engines and most rocket engines, each of which are internal combustion engines on the same principle as previously described. Firearms are also a form of internal combustion engine.

Internal combustion engines are quite different from external combustion engines, such as steam or Sterling engines, in which the energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized or even liquid sodium, heated in a boiler. ICEs are usually powered by energy-dense fuels such as gasoline or diesel, liquids derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for vehicles such as cars, aircraft, and boats.

1.1 Exhaust Materials

Usually, header systems are fabricated from welded-up collections of cuts from pre-formed "U" bends and straight segments of tubing in the chosen material. There are several reasons for that, but the most persuasive is the fact that, in order to achieve the design single configuration, there is not usually ample grip-space between bends to form the pipes from a piece of tube. In some cases, where the bends are not too closely spaced, the pipes can be bent up in one piece using a mandrel bender which will retain the circular cross section of the tube throughout the bend and transition. The typical exhaust tube bender commonly found in automotive exhaust shops is not suitable for that duty since those benders distort the cross-section of the bends terribly and shrink the cross-sectional area.

Tubing bend radii (the radius of the plan-view centerline of the bend) are expressed in terms of multiples of the tubing diameter. For example, a "1.5-D bend" in 2-inch diameter tubing would have a bend radius of 3 inches. One fabricator described some specialized machinery he had devised for making high-quality exhaust tubing from sheet. The first machine rolls the sheets into straight tube sections of the required diameter. The second machine completes the straight section of tube with a continuous welded seam using a semiautomatic inert-gas-shielded process. A third machine does what had been thought to be impossible: bending 0.50-mm wall inconel tubes into less-than-1-D radius sections while retaining accurate cross-sectional geometry.

There are several materials commonly used in competition header and exhaust systems, depending on the requirements and operating temperatures.

For the most demanding applications, Inconel tubing is commonly used. Although the name "Inconel" is a registered trademark of Special Metals Corp., the term has become something of a generic reference to a family of austenitic nickel-chromium-based superalloys which have good strength at extreme temperatures and are resistant to oxidization and corrosion. Because of the excellent high-temperature properties, Inconel can offer increased reliability in header systems, and in certain applications, it is the only material which will do. The high-temperature strength properties can enable weight-reducing designs, since, for a given reliability requirement, Inconel allows the use of much thinner-wall tubing than could be used with other materials. The catch, as usual, is that Inconel tubing is quite expensive.

Certain Inconel alloys retain very high strength at elevated temperatures. One of the favorites for header applications is Inconel-625, a solid-solution alloy containing 58% Nickel, 22% Chromium, 9% Molybdenum, 5% Iron, 3.5% Niobium, 1% Cobalt. It has good weldability using inert-gas-shielded-arc processes, and good formability in the annealed condition, and has a lower thermal expansion rate than the stainless alloys commonly used in exhaust systems. Weldability and formability are both important because of the somewhat limited availability of Inconel tubing sizes, which often makes it necessary to form tubing sections from sheet. The yield strength of this alloy at 650 °C (1200°F) is 345 MPa (50 ksi), while at 870°C (1600°F) it is a remarkable 276 MPa (40 ksi). As with many metals, the high-temperature strength diminishes as the amount of time the parts are exposed to extreme temperatures increases.

1.2 NASCAR Cup

The required Cup engine configuration (90° V8 with a two-plane crankshaft) provides an interesting challenge for exhaust system designers. Because of the firing order of this engine configuration, the exhaust pulses on each bank of the engine are unevenly-spaced. In the words of the technical director of one prominent team: "The exhaust system design in Cup is an interesting tradeoff between minimizing flow losses while at the same time trying to optimize whatever tuning you can do with a non-equally-spaced system, which isn't a lot."

With the GM cylinder-numbering system (1-3-5-7 on the left) and firing order {18436572; the 4-7 swap is not allowed in Cup}), the exhaust pulse spacing on the left side (expressed in terms of degrees of crankshaft rotation) is 270°-180°-90°-180° while the spacing on the right side is 90°-180°-270°-180°. This uneven pulse spacing gravely impedes the achievement of a well-tuned exhaust system such as can be achieved with evenly-spaced pulses and a 4-into-1 collector.

That tuning difficulty led (more than a decade ago) to the re-introduction of the 4-into-2-into-1 (so-called "Tri-Y") configuration, which has been around since at least the 1960's. In the "Tri-Y", cylinders on each bank are paired so as to provide the maximum separation between pulses. Using the above numbering scheme, the primaries of cylinders 1 & 5 and 3 & 7 would be merged into slightly larger secondary pipes, which after the appropriate length, would be merged into the larger collector. On the right side, adjacent primaries are paired (2 & 4, 6 & 8). That provides a 450°-270° separation between pulses in each secondary.

2. CATIA

CATIA also known as Computer Aided Three-dimensional Interactive Application and it is software suit that developed by the French company call Dassult Systems.

CATIA is a process-centric computer-aided design/computer-assisted manufacturing/computer-aided engineering (CAD/CAM/CAE) system that fully uses next generation object technologies and leading edge industry standards. CATIA is integrated with Dassult Systems Product Lifecycle Management

(PLM) solutions. It allows the users to simulate their industrial design processes from initial concept to product design, analysis, assembly and also maintenance. In this software, it includes mechanical, and shape design, styling, product synthesis, equipment and systems engineering, NC manufacturing, analysis and simulation, and industrial plant design. It is very user friendly software because CATIA Knowledge ware allows broad communities of user to easily capture and share know-how, rules, and other intellectual property assets.

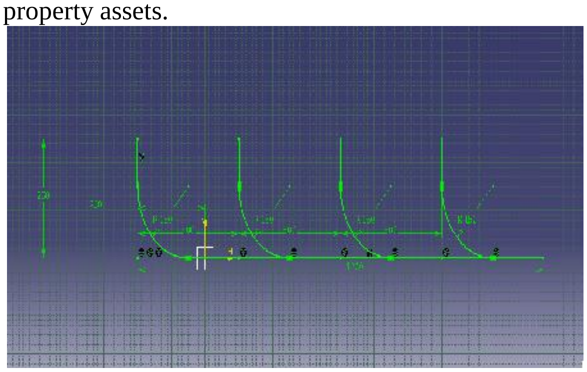

Figure.1 2D design with dimensions

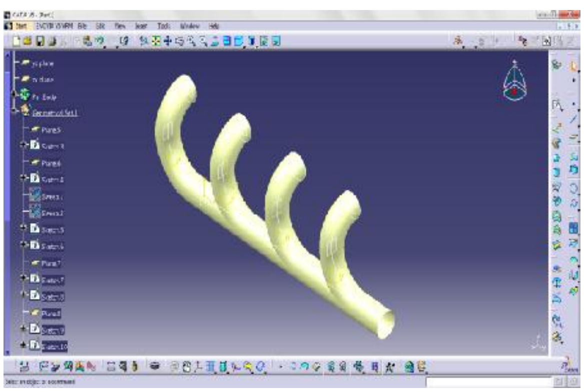

Figure.2 3D representation of swiped model

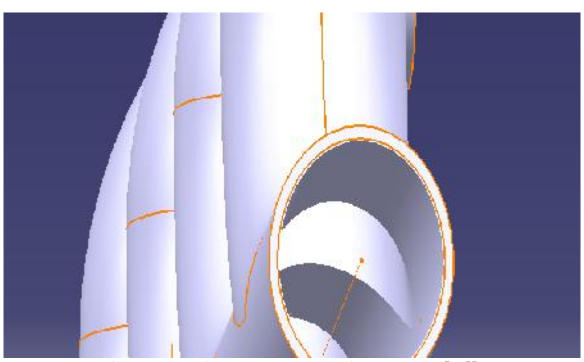

Figure.3 Picture representing outer shell

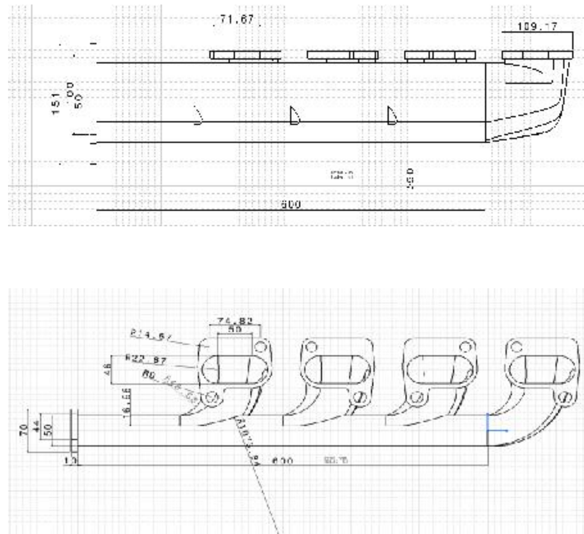

Figure.4 Draft of design

2.1 ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

2.2 Thermal Analysis Of Exhaust Manifold Made Of Cast Iron Coated With Silicon Nitride:

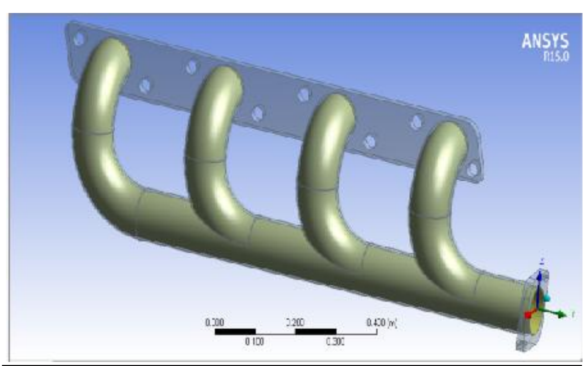

Figure.5 Input Model Of Exhaust Manifold

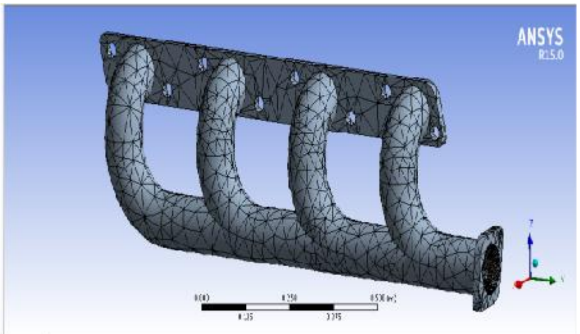

Figure.6 Meshed Model Of Exhaust Manifold

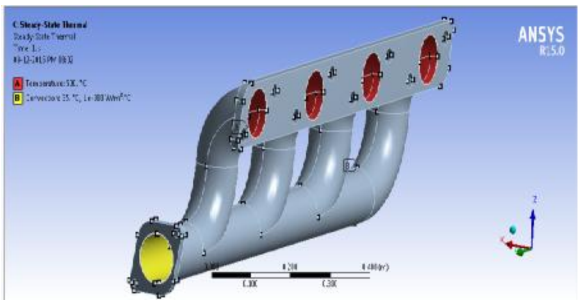

Figure.7 Boundary Conditions

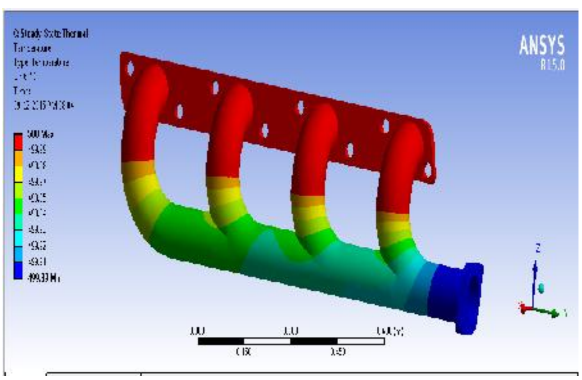

Figure.8 Counterplots Of Temperature Distribution

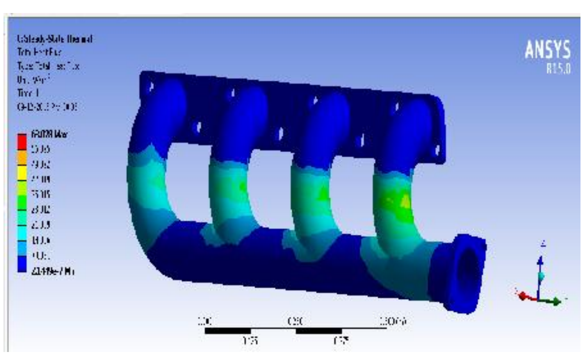

Figure.9 Ounterplots Of Total Heat Flux

3. Thermal Analysis Of Exhaust Manifold Made Of Cast Iron Coated With Zinc Oxide

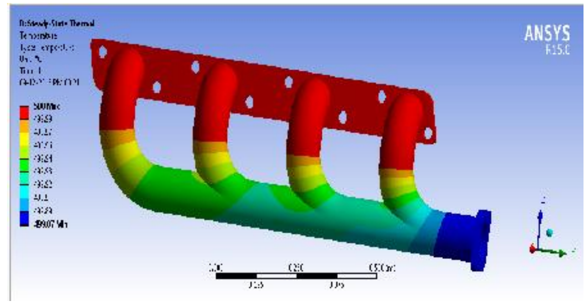

Figure.10 Counterplots Of Temperature Distribution

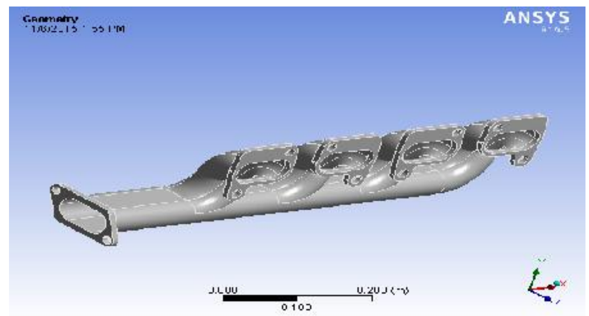

Figure.11 Thermal Analysis Of Exhaust Manifold Using Zinc Oxide

3.1 CFD ANALYSIS OF EXHAUST MANIFOLD

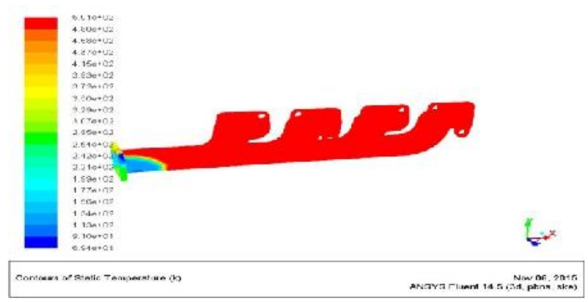

Figure.12 Temperature

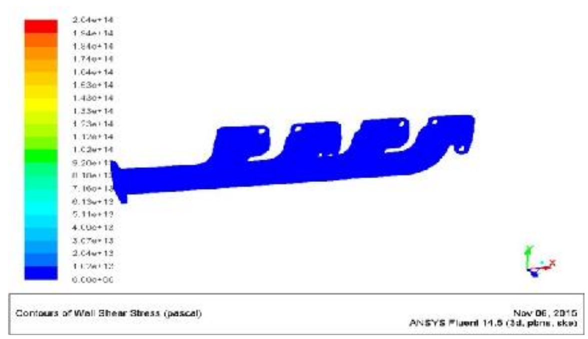

Figure.13 Wall Flux

4. RESULT

4.1 Comparison Result Table for model 1

thermal analysis	temperature maximum		heat flux		directional heat flux	
	min	max	min	max	min	max
model coated with silicon nitride	499.89	500	2.14E-07	63.028	-47.554	44.709
model coated with zinc oxide	499.87	500	6.29E-09	48.569	-33.55	33.437

4.2 Comparison Result Table model 2

4.2.1 Thermal Analysis

	temperature		heat flux	
	min	max	min	max
cast iron	421.84	500.2	2.10e-13	11.916
silicon nitride	499.99	500	1.01e-09	12.991
zinc oxide	499.98	500	3.31e-10	13.13

4.2.2 CFD ANALYSIS Of Model 2

	temperature		pressure		density	kinetic energy		velocity magnitude	shear stress
	min	max	min	max		min	max		
cfd	6.94e-01	5.01e-02	-7.65e+16	2.95e+16	1.07e+16	2.43e-08	3.18e+15	1.58e+07	2.04e+14

CONCLUSION

In this study we design an exhaust manifold with different high temperature resistant materials and we test it with Finite Element Methodology, both temperature distribution and thermal stress concentrations are calculated using Finite Element Methodology.

Here after design we have imported it into the Ansys and first Thermal analysis is done on it using the materials-cast iron, silicon nitride, zinc oxide. By using these materials the results are obtained and when they are compared with each other we can conclude that cast iron has the best ability to dissipate heat but it will get effected by the heat very soon, even though silicon nitride and zinc oxide are poor conductors, we should consider there insulation property's as when manifold gets heated up it will act as a heat source to the cylinder head on which it is mounted. More over these materials won't chip in course of time so clogging of exhaust system is also avoided, which also prevents back pressure conditions.

Now even CFD analysis is done to the best output material here and the results obtained are plotted in a tubular form. As per the results obtained totally we can conclude that the exhaust manifold with and zinc oxide are the best suited materials with better life.

We can also reduce the cost of the manifold if we use these materials as coatings on the manifold

REFERENCE

- The scientific design of exhaust and intake systems by Philip Hubert Smith, John Cruickshank Morrison, R. Bentley, 1971
- The Design and Tuning of Competition Engines by Philip Hubert Smith, BENTLEY ROBERT Incorporated, 1977
- Automobile Engines - In Theory, Design, Construction, Operation, Testing and Maintenance by A.W. Judge
- Silicon Nitride (Si3N4) Properties and Applications

http://www.azom.com/properties.aspx?ArticleID=53

- Zinc Oxide (ZnO2) Properties and Applications

http://www.azonano.com/article.aspx?ArticleID=3348