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DESIGN AND ANALYSIS OF FLANGE IN STAINLESS STEEL EXHAUST MANIFOLD

ENGINE MANIFOLD ANALYSIS

B.Dhanasakkaravarthi[1], K.Balasubramanian[2], V.Vinod Kumar[3],
S.Santhosh Kumar[4],V.Sharun[5]

[1 &2]Associate Professor Department of Mechanical Engineering,
[3,4&5] Assistant professor Department Of Mechanical Engineering Panimalar Institute Of Technology, Poonamllee, Tamilnadu, Chennai-123

Abstract —*The concept that is used today for their manifolds is based on welding the pipes into place in the flange. When pipes are welded into flanges due to this several negative effects occur. The welding process is expensive due to high technology welding roots and time consumption. The pipe and flange are exposed to large thermal stresses that are applied when welding. These stresses weaken the materials. Welding defects can occur when welding, some of the defects can take shape as small pieces of material, weld spatter, that can get loose and end up destroying the catalytic converter. Other defects can occur in the welding seam and they must be repaired manually. The task with this project is to find an alternative solution concept for the connection of pipes into flanges in manifolds. Thus overcoming the present defects caused by the welded flange.*

Keywords*-Analysis of Engine Exhaust manifold, weld flange, thermal stress*

I. INTRODUCTION

Exhaust manifolds are generally simple cast iron or stainless steel units which collect engine exhaust 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 extractors in Australian English, and simply as "tubular manifolds" in UK English. These consist of individual exhaust head pipes for each cylinder, which then usually converge into one tube called a collector. Headers that do not have collectors are called zombie headers, and are used exclusively on race cars. The manifold is essentially divided into three components

- The flange.
- The primary pipes.
- The collector

1.1 Manifold

The manifold can be classified into two different types that are

- Welded manifold
- casted manifold

The most common types of aftermarket headers are made of either ceramic or stainless steel. Ceramic headers are lighter in weight than stainless steel, however, under extreme temperatures, they can crack - something stainless steel is not prone to. Another form of modification used is to insulate a standard or aftermarket manifold. This decreases the amount of heat given off into the engine bay, therefore reducing the intake manifold temperature. There a few types of thermal insulation but three are particularly common

Cast Manifold

Welded Manifold

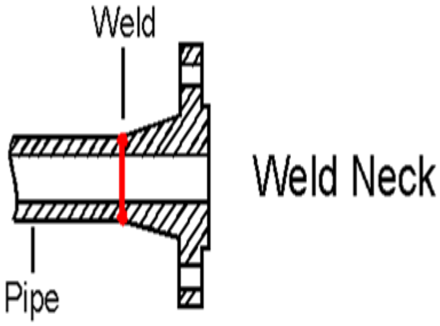
Fig 1. Engine manifold types

1.2 Flange

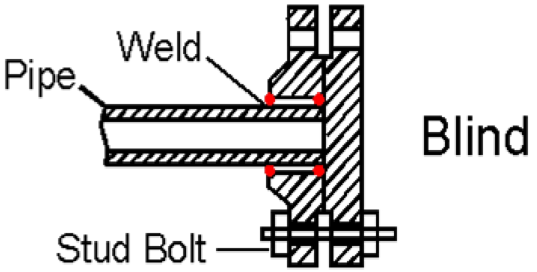
A. Types of Flange

a. Weld Neck Flange

This flange is circumferentially welded into the system at its neck which means that the integrity of the butt welded area can be easily examined by radiography. The bores of both pipe and flange match, which reduces turbulence and erosion inside the pipeline. The weld neck is therefore favored in critical applications



Weld neck flange



Blind flange

Fig.2 Weld neck and blind flange

b. Blind flange

This flange is used to blank off pipelines, valves and pumps; it can also be used as an inspection cover. It is sometimes referred to as a blanking flange.

c. Socket Weld Flange

This flange is counter bored to accept the pipe before being fillet welded. The bore of the pipe and flange are both the same therefore giving good flow characteristics.

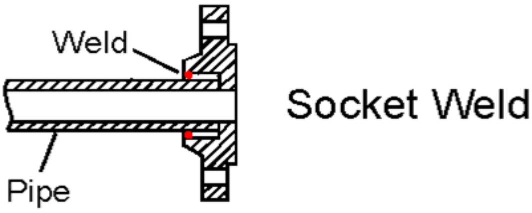


Fig.3 Socket Weld Flange

d. Lap Joint Flange

These flanges are always used with either a stub end or taft which is butt welded to the pipe with the flange loose behind it. This means the stub end or taft always makes the face. The lap joint is favored in low pressure applications because it is easily assembled and aligned. To reduce cost these flanges can be supplied without a hub and/or in treated, coated carbon steel.

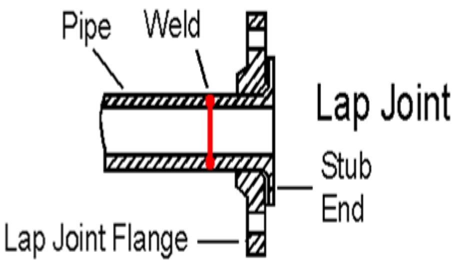


Fig.4 Lap Joint Flange

II. PROBLEM IDENFICATION

2.1 Failure modes of exhaust manifolds

Failures of exhaust manifolds are mainly caused by the extreme temperature amplitudes/gradients the part has to withstand. A secondary cause for failures is the dynamic excitation of the exhaust subsystem, especially if not negligible masses of attached parts like turbocharger or close-coupled-catalyst are driven into resonance. Typical structural failure modes are manifold cracking and leakage. Those are related to the design and boundary conditions if a proper material choice was done initially. Understanding the root cause of a failure is the most challenging part on the way to a solution.

2.2 Understanding failures

TMF cracking – An initial thermal loading of exhaust manifolds can cause the material to exceed the yield stress in large areas of the exhaust manifold. Cyclic temperature loading causes a few areas to exhibit local cyclic plastic straining of the material, which may cause a crack initiation. Depending on the location of the high loaded areas, individual design parameters need to be considered in order to find a target-oriented optimization strategy. It becomes obvious that a detailed knowledge of the system behavior is needed, in order to interpret results correctly.

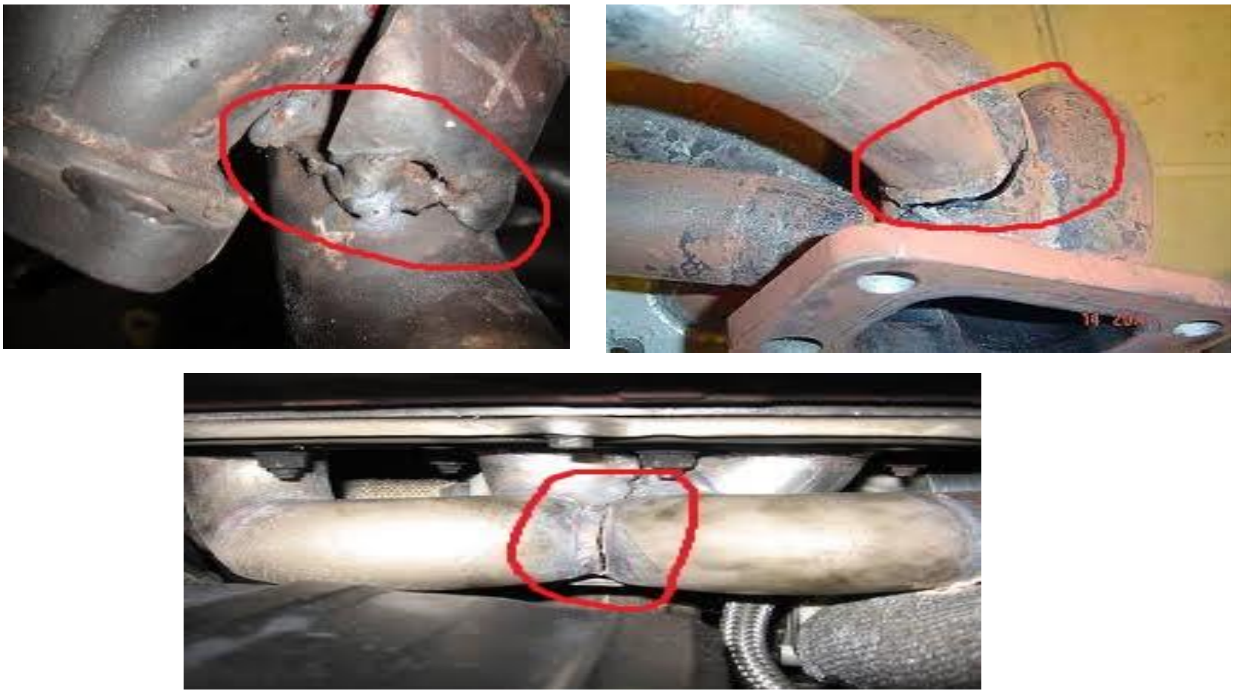


Fig.5 Weld crack failures in Engine Manifold

a. Crater crack

Crater cracks occur when a crater is not filled before the arc is broken. This causes the outer edges of the crater to cool more quickly than the crater, which creates sufficient stresses to form a crack. Longitudinal, transverse and/or multiple radial cracks may form.

b. Hat crack

Hat cracks get their name from the shape of the cross-section of the weld, because the weld flares out at the face of the weld. The crack starts at the fusion line and extends up through the weld. They are usually caused by too much voltage or not enough speed.

c. Longitudinal crack

Longitudinal cracks run along the length of a weld bead. They are usually caused by high shrinkage stresses, especially on final passes, or by a hot cracking mechanism. Root cracks start at the root and extent part way into the weld. They are the most common type of longitudinal crack because of the small size of the first weld bead.

d. Transverse crack

A gap or break in the surface of a weld perpendicular to the weld axis that may be completely within the weld metal or may extend from the weld metal into the base metal. Excess hydrogen, an excessively strong weld metal, and high levels of residual stress result in transverse cracks.

III. LITERATURE REVIEW

A. Exhaust System Manifold Development paper was published in **2012** SAE Technical Paper.Author, Lakshmikanth Meda, Yan Shu, Martin Romzek.This paper describes the simulation and experimental work recently carried out during a typical exhaust manifold system development utilizing fabricated stainless steel manifolds.. This paper describes all the analytical steps, procedure and tools such as CFD is used in the development of a manifold system. The CFD tool utilizing conjugate heat transfer is used to calculate temperature distribution on the manifold. The manifold system is subjected to high temperatures and engine pulsations. The simulation results are also compared with the measured experimental thermal data.

B. Coupled Analysis of Thermal Flow and Thermal Stress of an Engine Exhaust Manifold paper was published in 2004 SAE Technical Paper Author, Qin Yin Fan , Masayuki Kuba, Junichi Nakanishi .Using the temperature distribution of solid structures obtained by a CFD analysis, thermal-stress analyses can be conducted.. This is the simplest and most direct approach. Flow and temperature field is solved using CFD software and resulting film coefficient between solid and fluid and the ambient temperature is interpolated to the corresponding mesh of the solid surfaces generated for thermal-stress analysis. After that, the temperature distribution within the solid is calculated and the thermal-stress analysis is carried out.

IV. DESIGN OF FLANGE

4.1 Whole flange

The classic whole flange is not possible to redesign in many ways. It simply consists of a stamped metal plate with holes for pipes and screws. The thickness of the flange material is possible to change; otherwise this stamped flange looks almost the same in different manifolds.

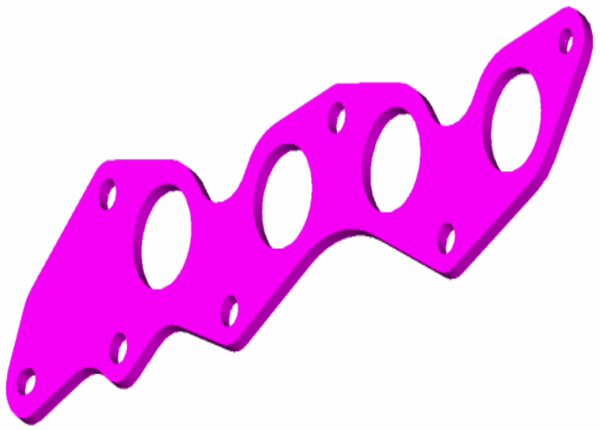


Fig.6 Whole Flange

4.2 Divided Flange

The divided flange can be made in several different designs. The major benefit with this solution is that the flange can be mounted after the pipes have been end shaped. .Four types of divided flanges have been constructed. A divided flange does not support the pipes properly when it is mounted on an engine because of the weakness in the middle of the flange. To prevent this tendency a flange with different levels which slide together could solve the problem. If the screw only penetrates one part of the dived flange and this makes it weak in between the rows of screws. To make a stronger flange each screw must penetrate both parts of the flange.

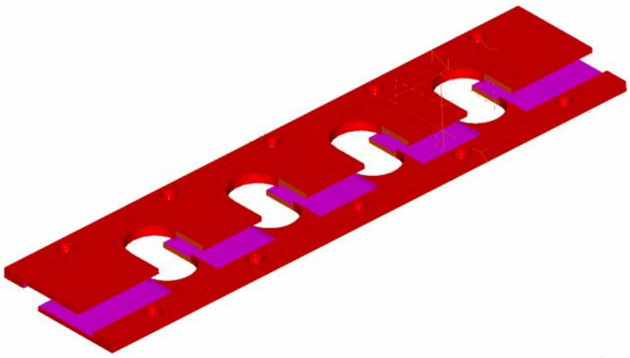


Fig.7 Divided Flange

4.3 Selection of flange Design

The flange design employed is of the divided flange type. We employ the simple divided flange. The divided flange is comprises of two separate pieces, the upper flange and the lower flange. The two pieces are machined to fit perfectly with each other and holes are provided to allow the seating of the pipes. The fit has to be perfect to prevent leakage of exhaust fumes.

The casts begin as slabs of metal of dimensions slightly larger than the required dimension. The upper piece is machined to support a step, and also milled with the provisions to house the pipe. The lower flange is machined to fit in the step of the upper flange. The two pieces of the flange are designed as shown below.

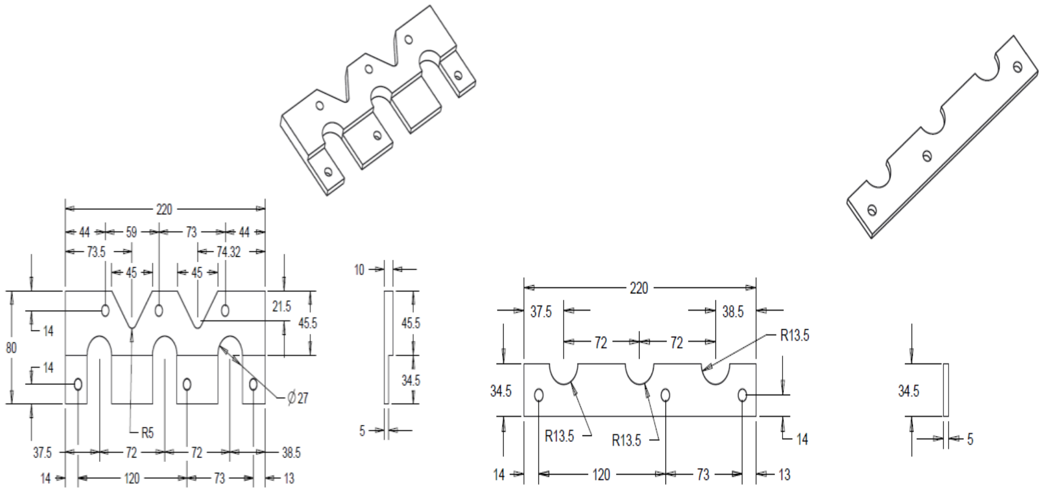
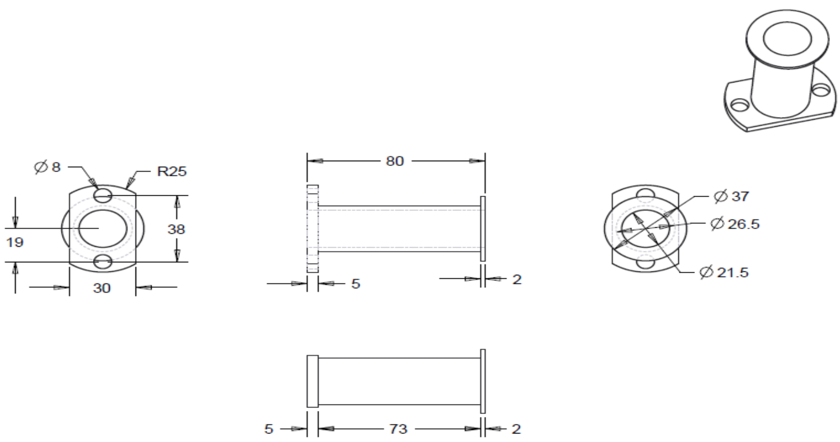


Fig.8 Upper and lower Flanges

V. DESIGN OF PIPE

5.1 Design of pipe

Design of flange is very important because the hot air from the exhaust is carried to the manifold by the help of the pipe. So while designing the pipe it should be clear that no leakage occurs in the pipe. There were some criteria on which the design was made. They are it should be easy to manufacture and it should have good sealing area. The pipe has larger diameter than the hole in the flange. The pipe is squeezed into the hole and stays in the hole only because of the tension between the pipe and the flange. The end of the pipe is inserted in to the exhaust chamber the pipe also contain some sealing area, this sealing area is between the flange and the engine. The presence of such sealing area prevents the leakage of the exhaust gas.

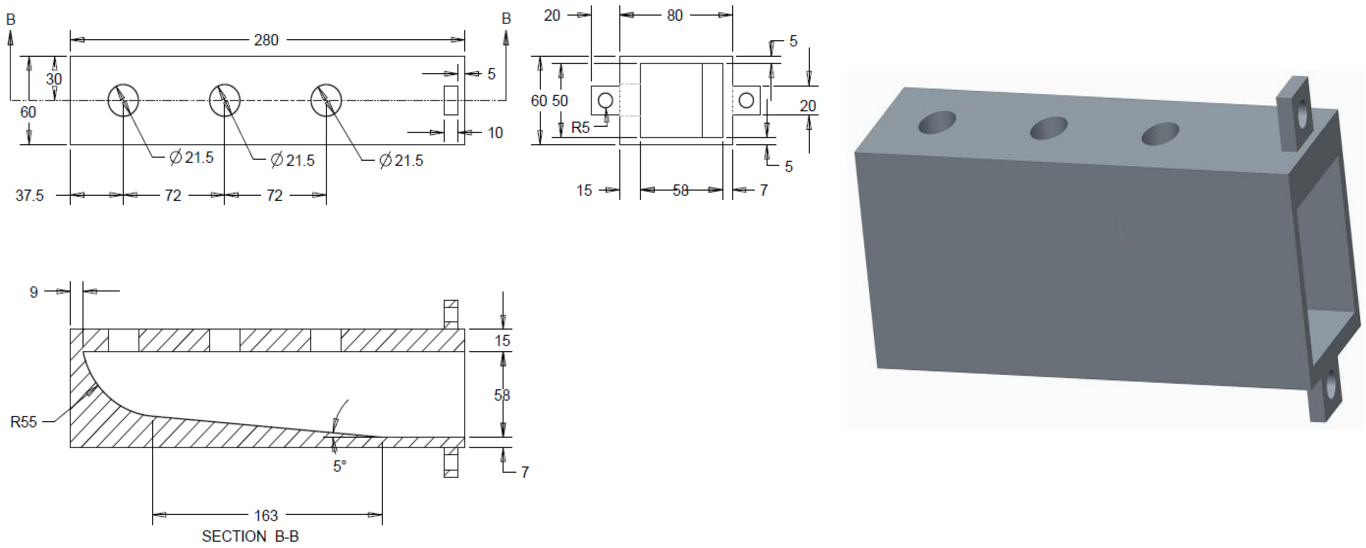


All dimensions are in mm

Fig.9 Upper and lower Flanges

5.2 Design of collector

The collector is the part of the manifold into which fumes from the engine flow from the pipes. The job of the collector is to combine all the exhaust gasses from all the cylinders of the engine and lead it into one single exhaust pipe. The manifold must have a definite geometry to facilitate the proper flow of exhaust gasses and to prevent back flow. The collector is produced by casting. One side of the collector is drilled with holes so as to connect the pipes and also provided with provisions for bolting the pipes to the collector.



All dimensions are in mm

Fig.10 Collector Design

5.3 Assembly

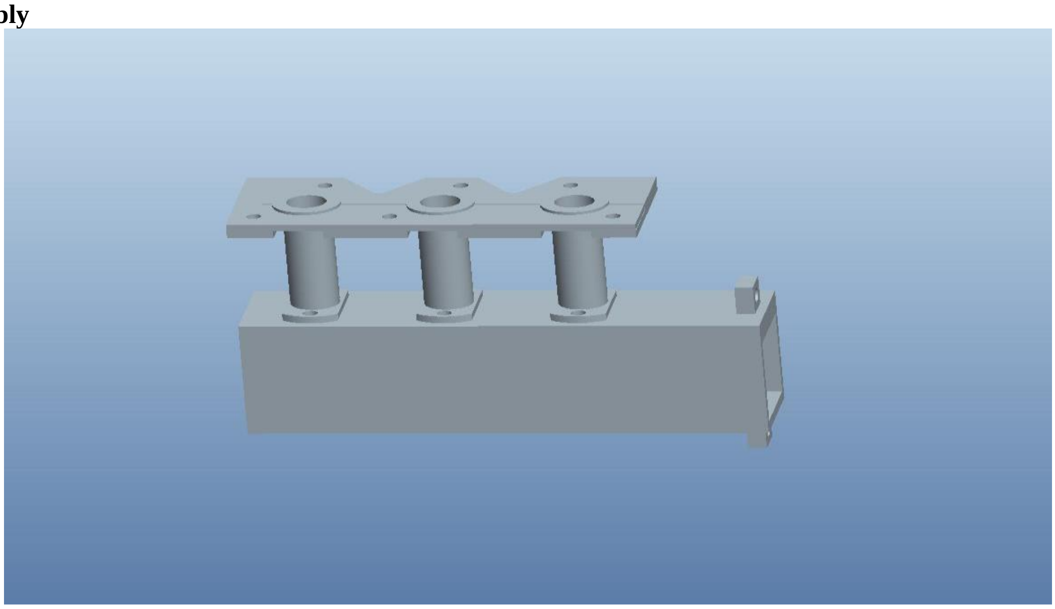


Fig.11Assembled view of pipe with Collector Design

VI. ANALYSIS

6.1 Material selection

A. Cast Iron

Cast iron (C3.4, Si1.8, Mn 0.5) was usually used to make engine parts because of its durability level, at one period of time Cast iron was the main basic building block of the automotive industry. Over the period of years cast iron was substituted for other material like aluminium with the basic idea of reducing the weight of a vehicle.

- Cast iron generally means grey cast iron, but classify a big faction of ferrous alloys, which coagulate with a eutectic. Iron makes up nearly 95 per cent where as the key alloying agents are carbon and silicon.
- The quantity of carbon in cast iron is anywhere between 2.1 per cent to 4 per cent cast irons also generally comprise of appreciable quantities of silicon, generally anywhere between 1-3 per cent.
- Due to its low melting point, good fluidity, castability, exceptional machinability and ware resistance, cast irons have gone on to become a vital engineering substance with a broad range of applications.

B. Mild Steel

Mild Steel is the material selected to manufacture the frame. Mild Steel is one of the most common of all metals and one of the least expensive steels used. It is to be found in almost every product created from metal. Some the main reasons for choosing mild steel are listed below:

- Having less than 2 % carbon it will magnetize well and being relatively inexpensive can be used in most projects requiring a lot of steel.
- However when it comes to load bearing, its structural strength is not usually sufficient to be used in structural beams and girders.
- Most everyday items made of steel have some milder steel content. At worst a coat of oil or grease will help seal it from exposure, and help prevent rusting

C. Steel

Steel frames are often built using various types of steel alloys (17% Cr & 0.5% C) including chromyl. They are strong, easy to work, and relatively inexpensive, but denser (heavier) than many other structural materials. Steel tubing in traditional standard diameters is often less rigid than oversized tubing in other materials (due more to diameter than material); this flex allows for some shock absorption giving the rider a slightly less jarring ride compared to other more rigid tubing such as oversized aluminum.

D. Properties

a. Corrosion Resistance

Excellent in a wide range of atmospheric environments and many corrosive media. Subject to pitting and crevice corrosion in warm chloride environments, and to stress corrosion cracking above about 60°C. Considered resistant to potable water with up to about 200mg/L chlorides at ambient temperatures, reducing to about 150mg/L at 60°C.

b. Heat Resistance

Good oxidation resistance in intermittent service to 870°C and in continuous service to 925°C. Continuous use of 304 in the 425-860°C range is not recommended if subsequent aqueous corrosion resistance is important. Grade 304L is more resistant to carbide precipitation and can be heated into the above temperature range.

E. Results

a. Thermal stress analysis

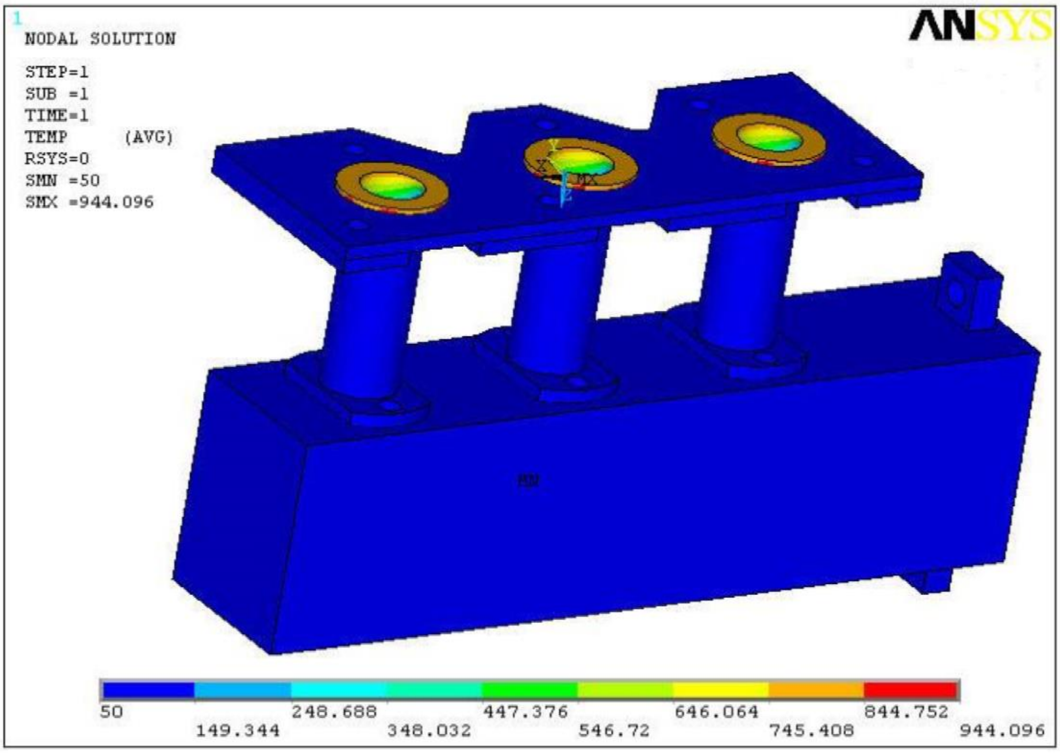


Fig.12 Thermal stress results

b. CFD Analysis

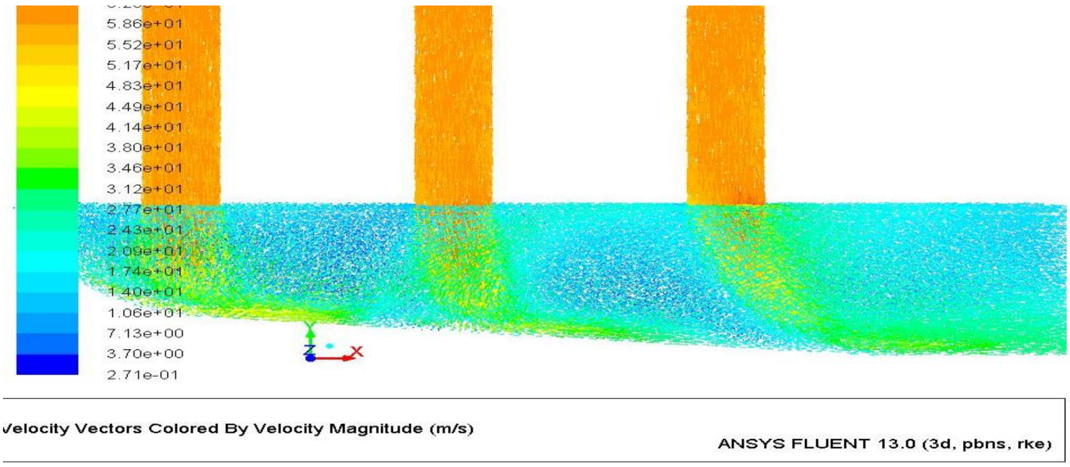


Fig.12 CFD results

VII. CONCLUSION

Thus through the course of the report and the presentations and experiments conducted we hope to have been able to convey the ideology across. The application of the custom exhaust or even supplication of some of the basic ideologies adapted in the project has scope in the automotive field. The design of the manifold will help reduce service costs, ease of replacement and provide better performance. This has also ensured minimization of damage caused to the catalytic converter by welded manifold. Various analysis were carried out and the result clear proves that the designed manifold is safer and better and can used as replacement for existing manifold

REFERENCES

[1] Design of a new SI engine intake manifold with variable length plenum Original Research Article Energy Conversion and Management,Volume 51, Issue 11,November 2010, Pages 2239-2244 M.A. Ceviz, M. Akın.

[2] Fault diagnosis for internal combustion engines using intake manifold pressure and artificial neural networkExpert Systems with Applications, Volume 37, Issue 2,March 2010, Pages 949-958 Jian-Da W u, Cheng-Kai Huang, Yo-Wei Chang, Yao-Jung Shiao.

[3] A comparison of water–diesel emulsion and timed injection of water into the intake manifold of a diesel engine for simultaneous control of NO and smoke emissions Energy Conversion and Management, Volume 52, Issue 2, February 2011, Pages 849-857 K.A. Subramanian.

[4] Automotive Air Intake Manifold Application using Nylon 6,6 Composite Material -SAE Paper #: 1999-01-3011Paper : 1999-01-3011-Technical paper.

[5] Wyatt, D. D. "Analysis of Errors Introduced By Several Methods of Weighting Non-Uniform Duct Flow" NACA-TN-3400, 1955

[6] Margary R, Nino E, Vafidis C. The effect of intake duct length on the in-cylinder air motion in a motored diesel engine. SAE Paper No:900057; 1990

[7] Shaw CT, Lee DJ, Richardson SH, Pierson S. Modeling the effect of plenum-runner interface geometry on the flow through a n inlet system. SAE Paper No: 2000-01-0569;2000.

[8] Automotive Air Intake Manifold Application using Nylon 6,6 Composite Material -S AE Paper #: 1999-01-3011Paper # 1999-01-3011-Technical paper

[9] Young MB. Cyclic dispersion in the homogeneous-charge spar kignition engine. A Literature Survey. SAE Paper No: 810020;1981.

[10] Lancaster DR, Krieger RB, Lienesch JH. Measurement and analysis of engine pressure data. SAE Paper No: 750026; 1975

[11] Atul A. Patil, "Experimental Verification And CFD Analysis Of Single Cylinder Four Strokes C.I. Engine Exhaust System", Pratibha: International Journal Of Science, Spirituality, Business And Technology (IJSSBT),Vol. 3, No. 1,Dec 2014

[12] Mohd Sajid Ahmed, "Design And Analysis Of A Multi-Cylinder Four Stroke SI Engine Exhaust Manifold Using CFD Technique", Volume: 02 Issue: 09 | Dec-2015

[13] John D. Anderson, Jr., "Computational fluid dynamics-The basic with applications", McGraw -Hill international l Editions 1995.

