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"An Overview and Thermal Analysis of Vehicle Exhaust Gasket"

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ABSTRACT
The Exhaust system is an integral part of the vehicle. To remove the waste gases from the vehicle it came in existence. The performance of engine is mainly affected by exhaust manifold and gasket used because they directly affect the engine stability and control. Generation of back pressure and thermal load restrict to achieve desirable requirement. The protection of the exhaust system from internal and external factors it is necessary to optimize the design of exhaust manifold and gasket because development of crack is more in these two parts.A gasket is designed in this project. For 3D modeling of gasket Creo 4.0 is usedand with the help of ANSYS 17.1the analysis has performed.
Keywords: Design, Thermal analysis, Gasket, Creo, ANSYS Analysis.

I. INTRODUCTION

The failure of exhaust gasket baffling the engineer for long. The frequently occurring the stress cause the fatigue cracking and plastic deformation of gasket. The Exhaust System is the execration system of vehicle. There are 8 important parts of the exhaust system, they are:

1. Exhaust Manifold
2. Catalytic Converter
3. Resonator
4. Muffler
5. Pipes (Intermediate& Tail Pipe)
6. Gasket
7. Flexible Coupling
8. Oxygen Sensor

Since Exhaust parts is subjected to high temperature generated by vehicle engine, due to this thermal load.
To accomplish the required performance as per our convenience, reduction of fatigue failure, wear, thermal stress, cracking in the parts should be avoided. Therefore, proper designing and thermal analysis of vehicle should be done to avoid any future failure for safety purpose.The temperature is decreases form Exhaust manifold to end part of exhaust system i.e., exhaust tip. The high temperature occurs in exhaust manifold which is connected with catalytic converter. The Gasket acts like as seal which connect the exhaust manifold to cylinder head. Thefunction of gasket is to prevent leakage between two mating surfaces under compressed condition and to possess anti-vibration& noise reduction properties.

The main causes of failure of gasket are:

1. Fatigue& Wear
2. Improper Installation
3. Material Composition Incompatibility
4. Excessive Load& Pressure
5. Improper Design.

The failure of gasket causes following issues:

1. Poor Fuel Economy.
2. Excessively Noise generation.
3. Acceleration power decreases.
4. Strange smell produces.
5. Leakage of hazard Gases.

Thermal and mechanical deficiencies of gasket can be reduced by adequate designing and selection of suitable materials.In operating conditions, the gasket subjected to pressure and temperature, so it become crucial to test it in appropriate pressure and temperature range before adopting in exhaust system.
The selection of gasket material in such a way that it should possesses high tensile strength, durability, and withstand cracking &fatigue failure under normal operating conditions.

II. LITERATURE REVIEW

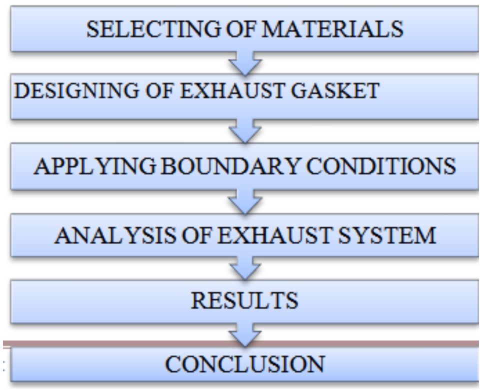
- K. Nanthagopal[1], B. Ashok[1]*, R. Thundil Karuppa Raj[1], Harshit Sabloke[1], Amit Agrawal [2](2016) have given an overview of "Design Considerations and Overview of an Engine

Exhaust Manifold Gasket"they have explicate the failure of gasket under thermal-mechanical influences and improper sealing & joint. The stress and pressure distribution areobtained to achieve mechanically efficient and durable gasket. They have concluded that the star type gasket endows constrain motion to eliminate wear and vibration. Inconel type of alloy is used to provide corrosion and temperature resistant properties. They have focused on design failure and suggested that MLS (Multi-Layer Steel) gasket offers high recovery, durability and compressibility.[1]

- Gopaal[#1], MMM Kumara Varma[*2], Dr L Suresh Kumar[#3](2014) have made the great effort to achieve the optimal design engine by influencing the exhaust manifold design. Thermal, Structural analysis, Dynamic analysis, Modal analysis couple field analysis and Harmonic response analysis have performed to check the structure at several frequencies and to determine the stress in the structure. They have investigated the criteria for the selection of material within the design limit.[2].
- Fabio Bruzzone, Cristiana Delprete and Carlo Rosso (2020) have focused on single beaded metal gasket and its influence due to compressive load. They have simulated the modal by forming and compression process. Experiments have performed and load-displacement curve has drawn with or without forming process. With the result obtain they have concluded that clamping force increases evenly with thickness of gasket.[3].
- Noshirwaan Aibada, M. Ramachandran, Krishna Kumar Gupta, P. P. Raichurkar (2017) have researched on the Gasket materials, their characteristic and applications. They have classified gasket into four categories and briefly discussed to each material falling into these categories. They have concluded that selection of gasket material should depend on the operating temperature and pressure range of otherwise wrong selection may lead to significant damage to the surfaces.[4]

III. METHODOLOGY

The Steps to be performed for this experiment is as follows:



IV. SELECTION OF MATERIALS

Selecting of gasket material depend on the operating conditions, system requirement, cost and gasket properties. The gasket is mainly classified as:

1. Metal
2. Non-metal
3. Hybrid
4. Polymer

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SR NO.	METAL	NON-METAL	POLYMER	HYBRID
1	Stainless Steel	Graphite	PTFE	Stainless steel/Graphite
2	Rhenium	Silicone	Silicone-rubber	Diamond/Rhenium
3	Gold	Non-asbestos	EPDM	Stainless steel/Rubber
4	Copper	Graphite	Pyrophyllite	Graphite/Teflon
5	Inconel	Boron nitride	Fluoroelastomer	HDPE/Polyaniline
6	Aluminium	Potassium Titanate	Polyethylene	Rubber/Asbestos
7	Monel	Nitrile-butadiene	Polypropylene	Glass filled PTFE
8	Titanium	Vermiculite + Steatite	Chloroprene	Stainless steel/Asbestos

Table 1

For the exhaust gasket we need to have a high-quality surface sealing, high-temperature and high-pressure resisting material, SinceAll Metallic and Hybrid gaskets fill these requirements, hence they are best to fit for this application. Gold and Rhenium are malleable&stable material but costlier than others that's whyits gasket used only for specific applications. The most common used material for the exhaustgasket is as follows:

1. Steel
2. Copper
3. Inconel
4. Monel
5. Aluminium
6. Titanium….etc.

These materials came into variable grades and can be single or multi-layered. Out of these materials steel and copper is ideal material for exhaust gasket due to easily available and less cost than others. These materials can't be used in its purest form due to higher elasticity. Therefore, their composites forms are used.

PROPERTIES OF EXHAUST GASKET MATERIAL:

				Temperature Range (Min-Max)	Pressure Range (Min-Max)	
S. No.	Material	Density (Kg/m^3)	Thermal Conductivity (W/m-K)	Melting Point (°C)	Compressive Strength (Mpa)	Linear Temperature Expansion Coefficient {- α - {10-6 m/(m °C)}
1	Stainless Steel	7750	15.1	1375-1530	170-310	10.8-12.5
2	Steel	8030	16.27	1540	250	10-17.5
2	Graphite	2260	600-5000	3600	31-345	4.0-8.0
3	Copper	8978	387.6	1085	45-330	17-18
5	Inconel	8170	15	1290-1350	965-1035	11.5-12.6
6	Aluminium	2710	220	655	30-280	21-24
7	Monel	8360-8840	21.8	1300-1350	172-345	13.5

Table 2

V. DESIGNING OF EXHAUST GASKET

The design needed where failure starts. Failure is because of higher stress concentrationdue to temperature and pressure. The stress is not removed completely from body but can be reduce by following methodologies:

1. Strengthening the hole size by reinforcement.
2. Use of functionally graded material
3. Optimization of shape

The mitigation of stress by optimization of shape is not found always feasible due to design constraint, example – bolt and rivet holes etc. but it can be minimized to some extent.

Here, three factors are taken into consideration during design. They are:

1. Shape of Gasket
2. Cross Section of Gasket
3. Thickness of Gasket

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On the basis of system on which gasket is installed, these factors can be fluctuated. Here 3 models are designed with the help of Creo 4.0 software. The thickness and all the dimensions are kept same. The gasket hole cut shape is different in all models i.e. star, circle and oval. Bolt is tightened in this area responsible for stress concentration due to sudden change in shape.

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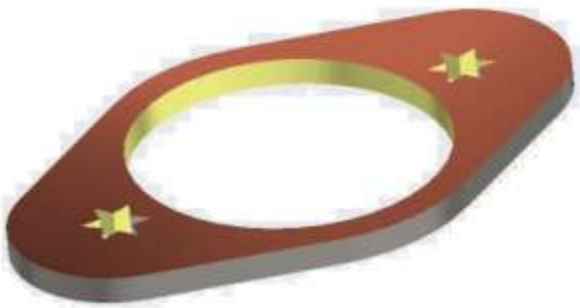

Fig 1: Model 1-Star Design

Fig 2: Model 2-Circle Design

Fig 3: Model 3-Oval Design

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VI. ANALYSIS OF EXHAUST GASKET

The transientstate thermal analysis and structural analysis has performed on 3 gaskets to calculate stress and deformation. 2 materials have been selected i.e., copper alloy and stainless steel to perform experiment.

TRANSIENT THERMAL ANALYSIS: The analysis of temperature & fluxes on the system with respect totime is called transient thermal analysis. Temperature changes over time period due to environment and external factors.

STRESS CONCENTRATION DUE TO TEMPERATURE:

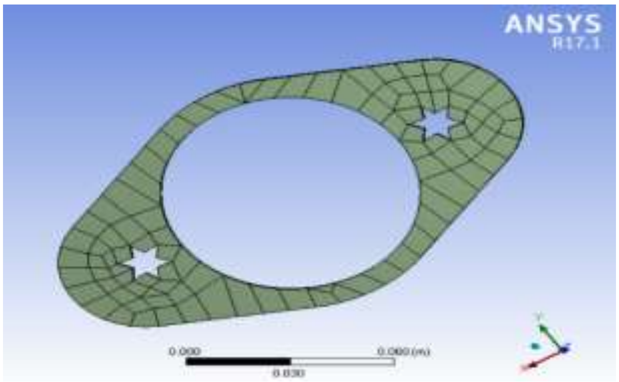

Fig 4. Meshed Exhaust Gasket

Ansys 17.1 is used for simulation. 3 Boundary Conditions are applied, which are:

1. Temperature at upper face (500℃ & 700℃ respectively).
2. Fixed the Bolt tightened area
3. Pressure on the upper face (200 MPa).

The steps to be perform for analysis is as follows:

1. Selecting the Material
2. Meshing The Object
3. Apply Boundary Conditions
4. Solve

A. Effect of Temperature

The material gets expand and contract due to change in temperature may result in thermal stress developmentbecause of restriction of freely movement of body. If temperature increase the stress generation also increases,

Meshing is a set of multiple elements having node. The purpose of meshing is to represent larger body into small discrete cells to perform Finite Element Analysis using mathematical formula for accurate results.

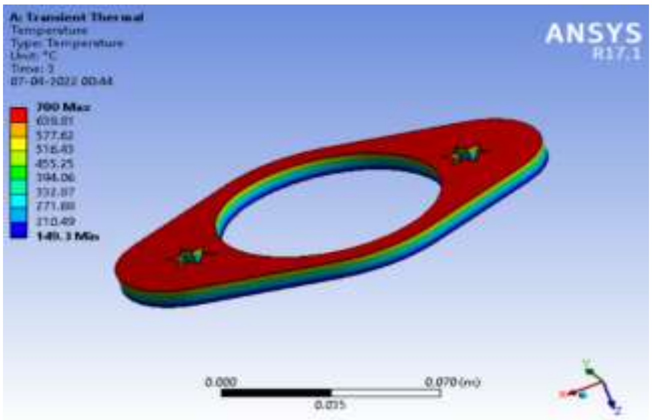

Fig 5. Temperature Effect on Stainless Steel

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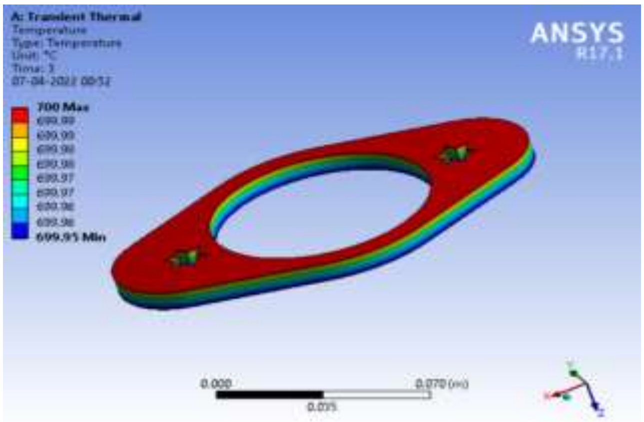

Fig 6. Temperature Effect on Copper Alloy

B. Effect of Total Deformation

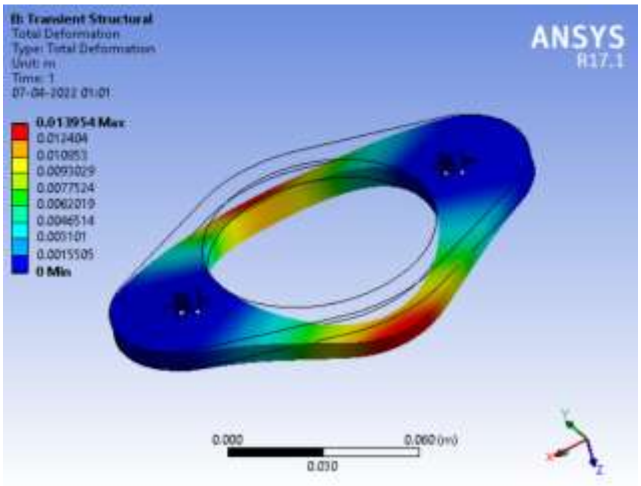

Fig 7. Deformation Effect on Stainless Steel

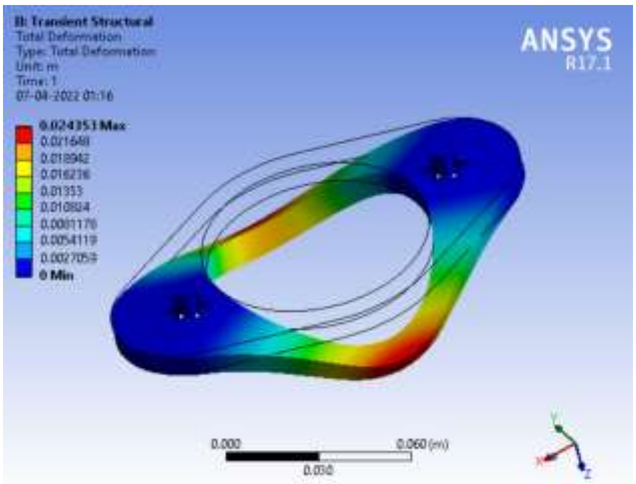

Fig 8. Deformation Effect on Copper Alloy

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C. Effect of Stress

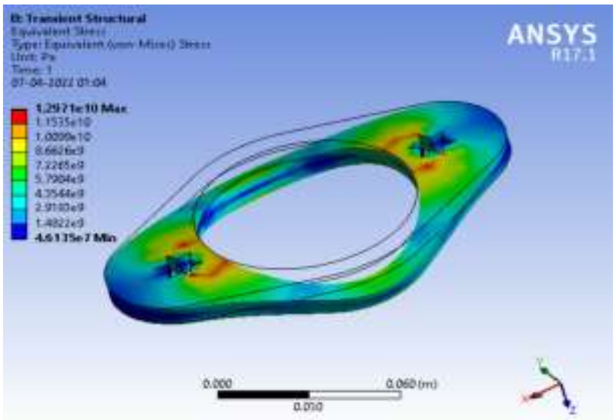

Fig 9. Stress Effect on Stainless Steel

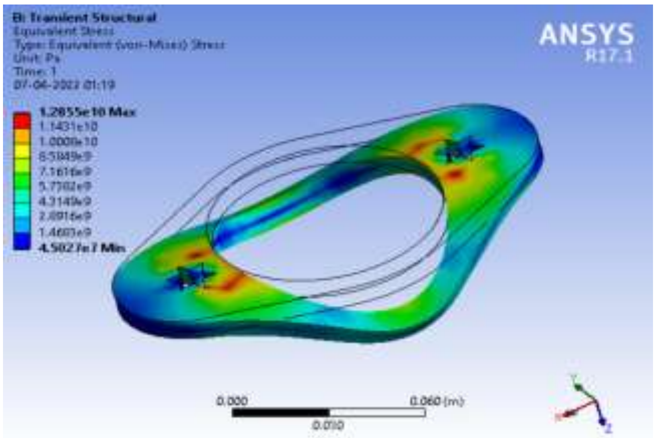

Fig10. Stress Effect on Copper Alloy

VII. RESULTS:

The result obtained is briefly discussed are as follows:

Temperature Analysis of Exhaust Gasket					
Initial Temperature - 22°C, Pressure - 200 Mpa			Material		
			Stainless Steel		
			Temperature(°C)	Stress(Pa)	Deformation(mm)
SR. NO.	MODEL	Max. Temp.	Minimum (In 3 Seconds)	Minimum-Maximum	Minimum-Maximum
1	**Model 1**	500°C	111.75	4.61e7-1.29e10	13.95
	Thickness = 8mm Hole Shape - Star	700°C	149.3	4.61e7-1.29e10	13.95
2	**Model 2**	500°C	109.86	1.06e8-1.48e10	13.3
	Thickness = 8mm Hole Shape - Circle	700°C	146.62	1.06e8-1.48e10	13.3
3	**Model 3**	500°C	110.79	9.73e7-1.52e10	14.81
	Thickness = 8mm Hole Shape - Oval	700°C	147.93	9.73e7-1.52e10	14.81

Table 3

Temperature Analysis of Exhaust Gasket					
Initial Temperature - 22°C, Pressure - 200 Mpa			Material		
			Stainless Steel		
			Temperature(°C)	Stress(Pa)	Deformation(mm)
SR. NO.	MODEL	Max. Temp.	Minimum (In 3 Seconds)	Minimum-Maximum	Minimum-Maximum
1	Model 1	500°C	499.97	4.50e7-1.28e10	24.35
	Thickness = 8mm Hole Shape - Star	700°C	699.95	4.5e7-1.28e10	24.35
2	Model 2	500°C	499.97	1.04e8-1.39e10	23.19
	Thickness = 8mm Hole Shape - Circle	700°C	699.95	1.03e8-1.39e10	23.19
3	Model 3	500°C	499.97	5.09e7-1.561e10	25.87
	Thickness = 8mm Hole Shape - Oval	700°C	699.95	5.09e7-1.561e10	25.87

Table 4

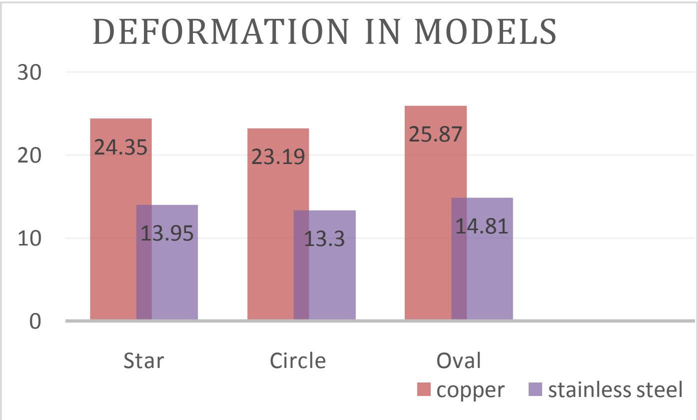

Chart 1

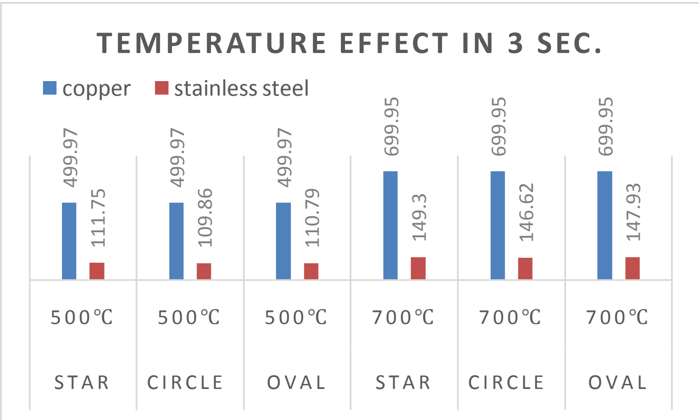

Chart 2

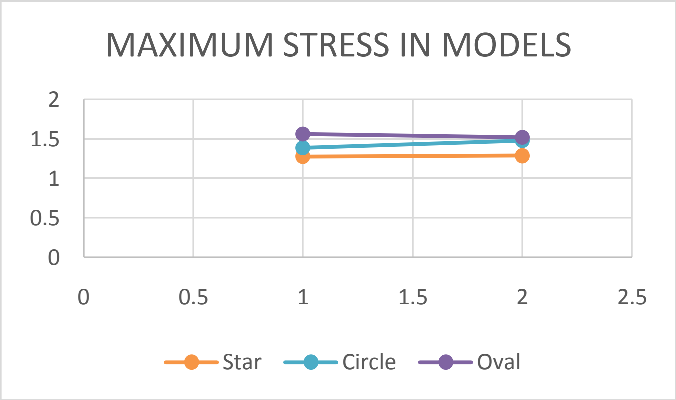

Chart 3

VIII. CONCLUSION

The Analysis is performed on exhaust gasket by using 2 materials i.e.,Copper Alloy and Stainless Steel, as result obtain, we can conclude the following points:

1. TheHeat transfer in copper is greater than steel
2. Copper deforms more than the steel because coefficient of expansion of copper is higher than steel.
3. The higher stress concentration nearly occurs in hole cuts region.
4. The stress is same for 500℃ and 700℃, thus no significant change of stress due to temperature for defined range.
5. The Stress concentration is higher in oval shape design and lower in Star shape model.
6. The temperature is higher in star shape model due to maximum surface area than other two models.

Thus, we can say that circle shape model is perfect because of low temperature region and low stress concentration.

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