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Design and Analysis of an Improved Exhaust Manifold were Based on the Findings of an Existing Exhaust Manifold's Analysis

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Abstract*— The head section of the engine houses the exhaust manifold arrangement. At the opposite end, it is connected to the catalytic converter. At pressure ranging from 100 to 500 kPa, the exhaust gases that are transferred from the cylinder at temperatures of roughly 800°C comes out. The exhaust manifold framework is subjected to heavy loads in addition to elevated temperatures, which can cause thermo mechanical failure. adjusting an exhaust manifold's structure based upon thermal strains and deflections shown over various conditions of operation at various temperatures. The exhaust in this study has been connected with the 3 different cylinders for the analysis, the design's of both the exhaust manifold is been made on the SOLID WORKS 2019 and the analysis of the design's done using the analysis software ANSYS. Basically 2 main analyses have been performed (Thermal Analysis and Structural analysis) dependent on time and temperatures. All the cylinders provided 2 seconds for the results and total analysis time provided for the analysis is 6 seconds. The analysis assesses how much time required for a cylinder' s temperature to reach 0 C to 500℃. The major finding of the comparation shows the improved exhaust manifold has better combustion, the overheat of the cylinder has been lowered down, higher temperature has been attained and the whole cylinder has been covered that resulted in greater combustion and lower unburn fuel mixture. It is clearly portrayed in the analysis results the heat is evenly distributed in the entire improved exhaust manifold compared to the already established exhaust manifold the heat only distributed into only the manifold head only which results in early triggering of the temperature sensor of the vehicle, but the improved exhaust manifold has even distribution of temperature which does not trigger the sensor early and have better combustion with the better vehicles results.

***Keywords*— Thermo Mechanical, Catalytic Converter, Exhaust,Thermal Analysis and Structural analysis**

I. INTRODUCTION

An effective diesel engine entered the scene around the 1920s. Due to their reduced reliance on flammable, unstable fuel, diesel engines quickly became extremely popular[1].Following the Second World War, saw numerous changes within the economy, among people, the trend towards urbanisation, and the increasing reliance on private vehicles due to the closure of certain significant transit networks. Within the United States, the number of vehicles and trucks increased substantially. Air pollution caused harm to both humans and the environment as a result of the rapid increase in engine-powered vehicles. A non-renewable form of energy being petroleum fuel. The cost of petroleum has increased as the reserves of petroleum have progressively depleted. However, there is a significant annual increase in the number of automobiles, which has rekindled interest in alternative energy sources. Because of its renewable origin, superior ignition quality, equivalent energy content, and higher point of ignition, biodiesel has become a viable alternative to gasoline and diesel. The term "biodiesel" describes a diesel fuel made from animal or vegetable fats that has a lengthy chain of ester. Fatty acid compounds are created by reacting lipids using an alcohol.

A. Pollutants and Emission caused by the Vehicles

The primary causes of exhaust pollutants include nitrogen disassociation, non-stoichiometric burning, and contaminants found in petrol and diesel. Unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), along with particulate matter (PM) being the principal exhaust contaminants

Hydrocarbons (HC)- The exhaust via a petrol engine contains almost 6000 parts per million of hydrocarbon molecules. Within a variety of 1 to 1.5% of the gasoline, there are hydrocarbons. A limited number of out-of-equilibrium molecules make up the hydrocarbon. It results from the thermal breaking of massive fuel atoms that occur during the combustion event. The shape of the chamber of combustion and engine operating conditions have an impact on the HC element spectrum. Irritators and odorants are caused by hydrocarbon contaminants that are released into the atmosphere.

Carbon Monoxide (CO)- CO is a deadly gas, yet it also has no colour or smell to it by nature. CO is produced whenever an engine has a rich air/fuel mixture. Another explanation is that a small amount of fuel fails to ignite and a few carbon atoms stay as carbon monoxide since the engine lacks sufficient oxygen to fully transform all of the carbon molecules into carbon dioxide. Typically, a petrol engine's emissions produce 0.2% to 5% CO. Poor mixing, isolated rich patches, and incomplete combustion among the causes of carbon monoxide pollution. 3.

Nitrogen Oxide (NOx)- Nitrogen oxide levels can reach up to 2000 ppm when an engine's exhaust pollutants are released into the atmosphere. The different types of NOx, including NO and a minor amount of nitrogen oxide, are further separated. Typically, NOx is the main contributor of petrochemical smog. Additionally, the atmosphere's reaction with nitrogen oxide has an impact on the ozone layer's depletion[16]. A small amount of nitrogen is already present in gasoline mixes, and NOx are additionally released by atmospheric nitrogen that is already present. The operating temperature of ignition and the position of the spark plug inside the combustion chamber both affect how much NOx is produced.

Particulates- Diesel engines generate solid carbon particulates in their exhaust throughout the combustion process because of the rich air-fuel particles that exists inside the cylinder. This is an unwelcome odour pollution that is visible as smoke coming from the exhaust port.

B. Engine Manifolds

An internal combustion engine's intake and exhaust fluids are exchanged through the application of an intricate tubular construction known as an engine manifold. Typically, engine manifolds contain one entrance on one end and multiple openings on the opposite side, causing the single tubing to split into multiple branching tubes. Every resultant tube experiences a similar quantity of flow as the outcome of the input fluids being discharged equally across the network of branched tubing's. An internal combustion engine's input along with exhaust valves are connected to engine manifolds, which are used to route fluid into the exterior of the engine, accordingly.

Intake Manifold- complex network of pipes containing one input side and multiple output endpoints is called an intake manifold. The inlet manifold is another name for this manifold. Like the name implies, the fluid is delivered into the combustion chamber via a valve called an inlet using an inlet manifold. Air and a fuel-air combination are the fluids that drive diesel and gasoline (Petrol) engines, respectively.

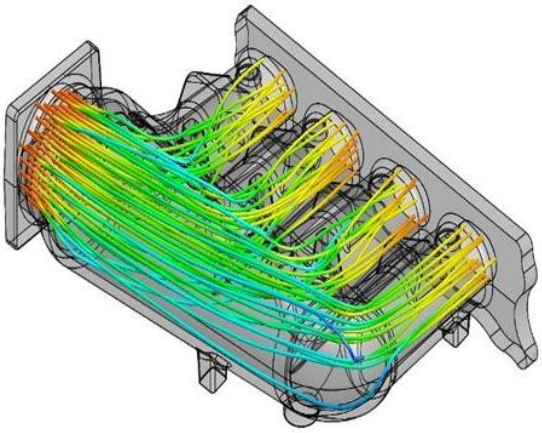


Fig.1 Construction of Inlet Manifold-

Exhaust Manifold- With numerous input ports and one exit opening, the exhaust manifold has a complicated tube structure. They are employed to drain the engine's exhaust fumes through the exhaust and outlet valves. It enables the vehicle's muffler to receive the burnt fumes via the engine that contain carbon as well as additional chemical pollutants. Exhaust Manifold Within a multi-cylinder engine, the exhaust fumes via each cylinder must be properly emitted without creating back pressure. Every of the cylinders block is joined to the exhaust manifold's intake holes. Each aperture collects exhaust gases, that are then expelled via one exhaust tube that is attached to the vehicle's muffler.

II LITERATURE SURVEY

The emission regulation regions and their effect on maritime transport have been examined in the research by ***Cullinane et al*** . The Marine Environmental Protection Committee (MEPC) established a limit upon the amount of sulphur allowed within ship fuel during April 2008. Under the list of items for controlling SOx and NOx emissions, various legislative and regulatory actions were required. [1].

Following the ***Hansen et al*** investigation, a study was conducted to compare the emissions of catalyst-equipped versus non-catalysed petrol automobiles while travelling on a highway. The journey speed for the various roadways affected the speed variation. The emissions rates were lowest when the speed was constant rather than varying in relation to a specified average trip velocity. The exhaust contaminants were measured using accurate constant volume collection and gas analyser equipment. At the slowest speeds, emissions for non-catalysed cars rose with divergence by 25%. Lower speeds exhibited the smallest variances in lowest exhaust emissions. On the contrary, the biggest variability in exhaust emissions occurred at the slowest speeds. Exhaust emissions within the catalyst fleet vehicles ranged from 0.3 to 0.05 gramme per km, and carbon monoxide emissions were extremely low at slower speeds with higher variation [2].

Johnston et al.'s research included methods that was trustworthy for specific methods of analysing the amount of fuel consumption and concurrent effects of transportation adjustments. The study was conducted over 2.25 km throughout morning peak. The 20 different car kinds with various specifications were picked for testing. The car's idle time, fuel usage readings, and the number of stops were all noted. During cycles of 140 seconds within non-transit zones as opposed to cycles of 90 seconds, that were substantially more prevalent the car used 35% more gasoline. On the contrary, the test cars had to remain within their lane under the conditions of a transit lane runs. In contrast to runs within non-transit paths, fuel consumption was greater during transit lane drives by 24%, and stops remained almost three times more often [3].

The specifics of exhaust pollutants along with fuel consumption driving high-performance diesel cars when idling was examined in the research by ***Khan et al***.75 automobiles were chosen so that the variances in exhaust pollutants could be studied. On the foundation of mechanical fuel injection (MFI) as well as electronic fuel injection (EFI), the cars were divided into two categories. Vehicles equipped with electronic fuel injection released 4636 g/h of carbon dioxide every hour when idling, 20 g/h of carbon monoxide, 6 g/h of hydrocarbon emissions, 86 g/h of nitrogen oxides, and 1 g/h of particulate matter. When the impact of air conditioning is taken into account, the amount of carbon dioxides, nitrogen oxides, particulates, hydrocarbons, and fuel consumed under idling conditions was increased by up to 25%. Vehicles with manual fuel injection averaged fuel consumption rates of 0.46 gal every hour, while those with electronic fuel injection averaged 0.47 gal every hour. When stationary vehicle rpm climbed from 600 to 1100, emission pollutants like carbon dioxide as well as oxides of nitrogen rose by up to 165% as well as 225%, accordingly, while particulate matter with fuel consumption rose by up to 76% and 170% [4].

According to ***Parida et al.'s*** research, the quick increase increasing vehicle density increased gasoline consumption, the frequency of signals for traffic, and fuel waste. The evaluations were conducted on a few particular cycles, particular days during the month, and several kinds of traffic signals within Delhi that contributed significantly to fuel waste. Additionally, it was shown that 98% or greater of drivers weren't turning off their engines at intersections with traffic signals. In Delhi, there were over upwards of 600 signal crossings where idle operation of vehicles resulted in the daily waste of 0.37 million kg of compressed natural gas with 0.13 million litres of petrol. The overall financial loss due to fuel waste ranged from Rs. 27.25 million per day through Rs. 9944.5 million per year [5].

III. METHODOLOGY

The research work solely dependent on the design using the software of Solid works 2023 of already established exhaust manifold and the design of improved exhaust manifold made on the results of the analysis of already established exhaust manifold and afterwards the analysis of the improved exhaust manifold also been done for getting the improved results. The analysis has been completed by using the ANSYS software.

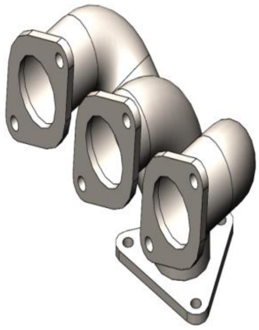


Fig 2

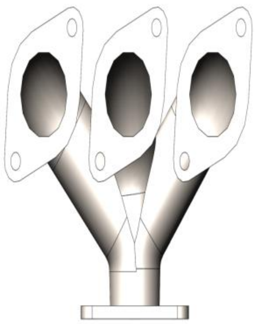


fig.3

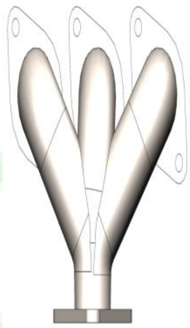


Fig. 4

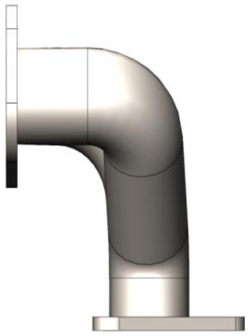


Fig. 5

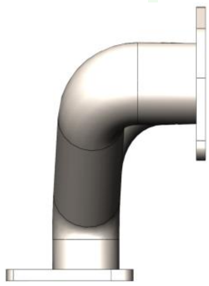


Fig.6

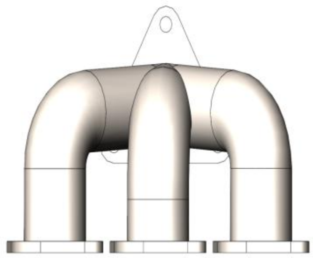


fig.7

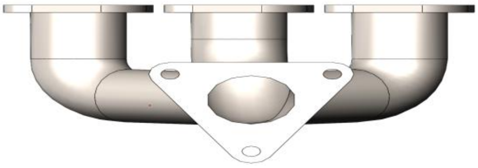


Fig. 8 Above are all the view derived from the design of the already established exhaust manifold.

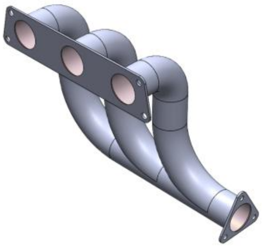


Fig.9

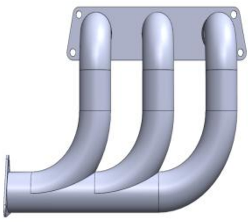


Fig 10

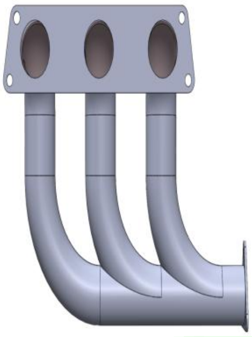


Fig.11

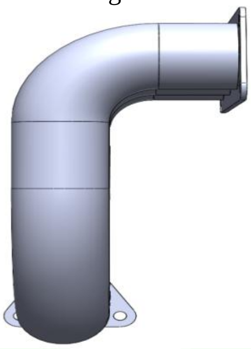


Fig. 12

Fig 13

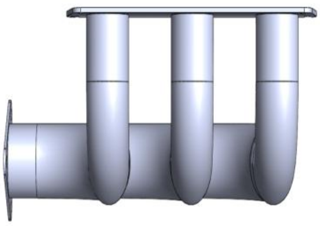


Fig. 14

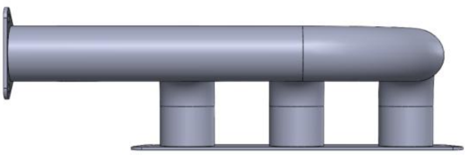


Fig. 15

Above are all the view derived from the design of the Improved exhaust manifold which has been improved respectively on the analysis results of the already established exhaust manifold. To prove the suggested exhaust manifold excellency a analysis has been done on the already established exhaust manifold and improved exhaust manifold utilizing ANSYS software which will be portrays in the results. For both the analysis these are the major points which are being kept in the consideration for the analysis and for the result-

1. Types of analysis
   a. Thermal Analysis (Transient)
   b. Structural Analysis (Temperature dependent
2. For the results 3 Cylinder have been chosen for the study.
3. The analysis assesses how much time it is needed for the temperature to reach from 0℃ to 500℃.
4. All the analysis has been settled for the time of 6 seconds to run for the findings. For every cylinder 2 seconds have been provided to attain the findings

IV.RESULT ANALYSIS

Analysis of Already Established Exhaust Manifold

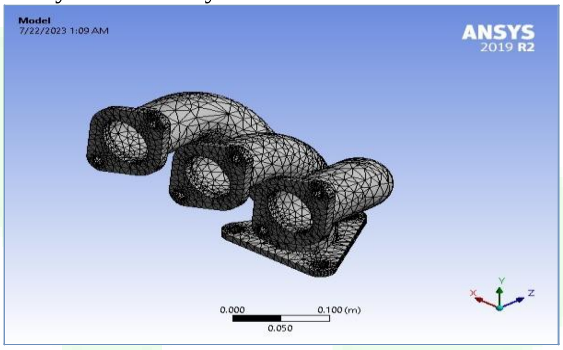


TABLE 1

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

TABLE 2
Model (A4, B4) > Geometry

Object Name	Geometry
State	Fully Defined
	Definition
Source	exhaust manifold.IGS
Type	Iges
Length Unit	Millimeters
Element Control	Program Controlled
Display Style	Body Color
	Bounding Box
Length X	0.35208 m

Length Y	0.23925 m
Length Z	0.21501 m
	Properties
Volume	2.2034e-004 m³
Mass	1.7297 kg
Scale Factor Value	1.
	Statistics
Bodies	1
Active Bodies	1
Nodes	54354
Elements	26629
Mesh Metric	None
	Update Options
Assign Default Material	No
	Basic Geometry Options
Solid Bodies	Yes
Surface Bodies	Yes

Object Name	Global Coordinate System
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. m
Origin Y	0. m
Origin Z	0. m
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

Line Bodies	No
Parameters	Independent
Parameter Key	ANS;DS
Attributes	No
Named Selections	No
Material Properties	No
	Advanced Geometry Options
Use Associativity	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes

Object Name	Initial Temperature
State	Fully Defined
Definition	
Initial Temperature	Uniform Temperature
Initial Temperature Value	22. °C

Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Clean Bodies On Import	No
Stitch Surfaces On Import	Program Tolerance
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

The table portrays the various settings for the analysis of already established exhaust manifold. In this setting the files sources for the analysis, geometry condition for the analysis, various boundary conditions that are required for the analysis are stated above.

Coordinate Systems TABLE 3
Model (A4, B4) > Coordinate Systems > Coordinate System

Transient Thermal (A5) TABLE 4
Model (A4, B4) > Analysis

Object Name	Transient Thermal (A5)
State	Solved
Definition	
Physics Type	Thermal
Analysis Type	Transient
Solver Target	Mechanical APDL
Options	
Generate Input Only	No

TABLE 5 Model (A4, B4) > Transient Thermal (A5) > Initial Condition

TABLE 6 Model (A4, B4) > Transient Thermal (A5) > Analysis Settings

Object Name	Analysis Settings
State	Fully Defined

	Step Controls
Number Of Steps	1.
Current Step Number	1.
Step End Time	6. s
Auto Time Stepping	On
Define By	Time
Initial Time Step	0.1 s
Minimum Time Step	0.1 s
Maximum Time Step	0.1 s
Time Integration	On
	Solver Controls
Solver Type	Program Controlled
	Radiosity Controls
Radiosity Solver	Program Controlled
Flux Convergence	1.e-004
Maximum Iteration	1000.
Solver Tolerance	0.1 W/m²
Over Relaxation	0.1
Hemicube Resolution	10.
	Nonlinear Controls
Heat Convergence	Program Controlled
Temperature Convergence	Program Controlled
Line Search	Program Controlled
Nonlinear Formulation	Program Controlled
	Output Controls
Calculate Thermal Flux	Yes
Contact Data	Yes
Nodal Forces	No
Contact Miscellaneous	No
General Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
	Analysis Data Management
Solver Files Directory	C:\Users\TARUN SAATYAKI\AppData\Local\Temp\WB_LAPTOP-OTMTSSL5_TARUN SAATYAKI_7716_2\unsaved_project_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	mks

Steps	Time [s]	Temperature [°C]
1	0.	22.
	1.	300.
	2.	500.
	6.	22.

The above table shows the boundary and default settings for the thermal analysis dependent on the transient thermal temperature analysis

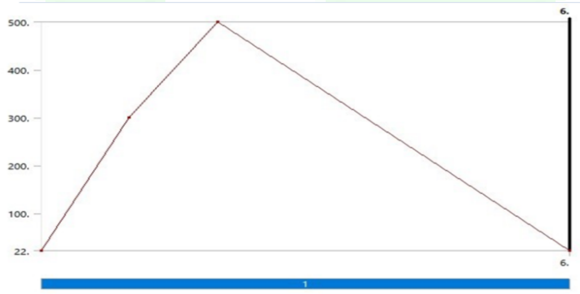


Fig. 16 Model (A4, B4) > Transient Thermal (A5) > Temperature
Model (A4, B4) > Transient Thermal (A5) > Temperature

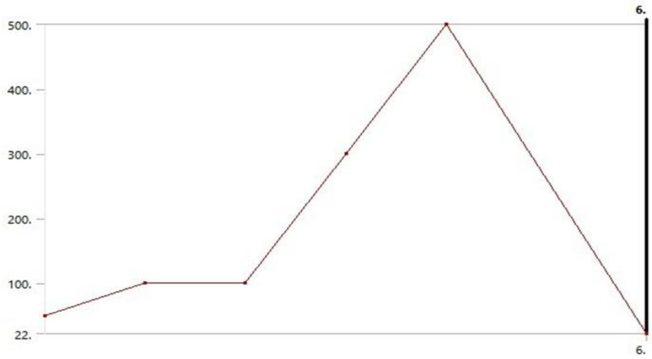


Fig. 16 Model (A4, B4) > Transient Thermal (A5) > Temperature 2

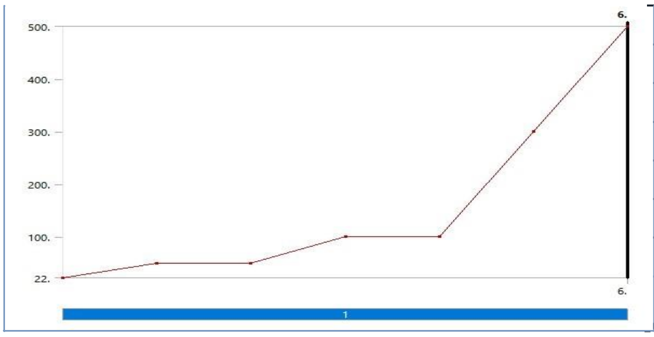


Fig 17 Model (A4, B4) > Transient Thermal (A5) >Temperature 3

TABLE 7
Model (A4, B4) > Transient Thermal (A5) > Temperature3

The above table and figure portray the range of the temperature to reach from 0℃ to 500℃ with respect to the time range for the third cylinder.

TABLE 8
Model (A4, B4) > Transient Thermal (A5) > Convection

Temperature [°C]	Convection Coefficient [W/m²·°C]
21.	5.

Solution (A6) TABLE 9
Model (A4, B4) > Transient Thermal (A5) > Solution

Object Name	Solution (A6)
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	1 m 58 s
MAPDL Memory Used	438. MB
MAPDL Result File Size	332.06 MB
Post Processing	
Beam Section Results	No

TABLE 10
Model (A4, B4) > Transient Thermal (A5) > Solution (A6) > Solution Information

Object Name	Solution Information
State	Solved
Solution Information	
Solution Output	Solver Output
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 11
Model (A4, B4) > Transient Thermal (A5) > Solution (A6) > Solution Information > Result Charts

Object Name	Temperature - Global Maximum	Temperature - Global Minimum
State	Solved	
Scope		
Scoping Method	Global Maximum	Global Minimum
Definition		
Type	Temperature	
Suppressed	No	
Results		
Minimum	55. °C	2.0613 °C
Maximum	502.18 °C	21.999 °C

The below figures portray the ranges of the minimum and maximum temperature ranges of the exhaust manifold attained at the head of the exhaust manifold input coming form cylinder. The temperature has been attained with the respect to the time required to get attain the max temperature of 500℃. In first figure the time provided 6 seconds and it totally portrayed in the figure range of temperature as the temperature reached 500℃ 2-3 times in the analysis.

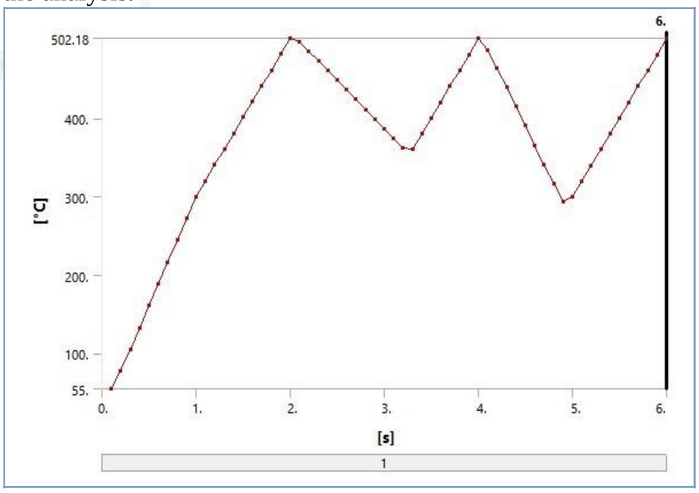
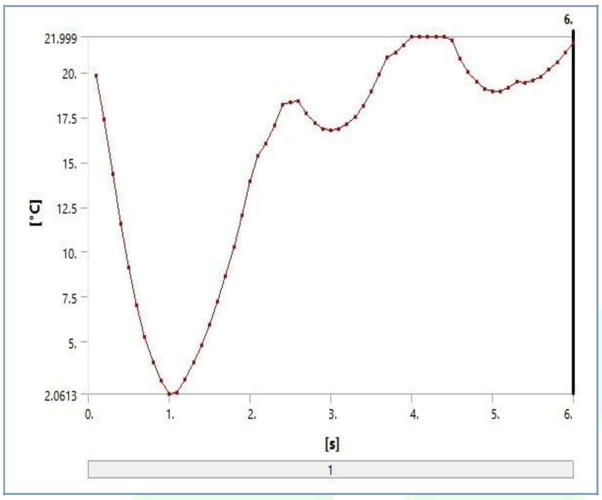


Fig 19. Model (A4, B4) > Transient Thermal (A5) > Solution (A6) > Solution Information > Temperature – Global Maximum

Fig 20. Model (A4, B4) > Transient Thermal (A5) > Solution (A6) > Solution Information > Temperature – Global Minimum



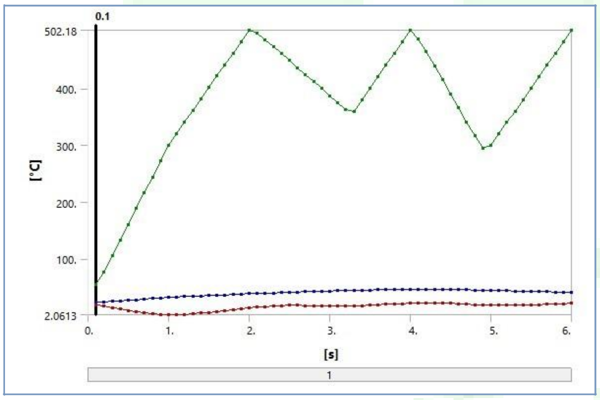


Fig 21 Model (A4, B4) > Transient Thermal (A5) > Solution (A6) > Temperat

V.CONCLUSIONS

The Study provided better understanding of the working of exhaust manifold on various boundary conditins and various temperatures with the to the defined time.

The study concludes with the result findings of test analysis of both the designs in which it totally shows the temperature convergence of the exhaust manifold, as we can see in the analysis result in which the already established exhaust manifold temperature distribution only

Transferring onto the manifold input heat which results in higher exhaust fumes, and higher temperature in exhaust sensor as well. The vibration and noise of the manifold also increases because of uneven temperature distribution onto the manifold.

The result of the improved exhaust manifold has the better temperature distribution and the temperature distributes on entire manifold component and as we know area is directly proportional to the temperature as the temperature distributes to the entire manifold the heat dissipates very easily as well, this results in better fuel combustion, area coverage of the manifold is higher, lower unburn fuel mixture directly results polluted exhaust gases.

This shows that more complicated parameter investigations and goals might be feasible while still accurately capturing temperature performance within a reasonable range, without progressively increasing simulation duration and complexity for each added parameter.system. future scope Analysis of noise reduction on the ideal exhaust system will be the next task. The best repetition must be chosen after performing parametric optimisation on all dimension's parameters. For the right engine, an experimental investigation of the exhaust is required. Cross-validation of the conceptual simulation outcomes with the experimental findings must be done. To make this easier, a perfect exhaust design that has been theoretically obtained must be created with the ability to physically monitor the flow characteristics.

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