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DESIGN AND ANALYSIS OF 4-IN-LINE MULTI-CYLINDER PETROL ENGINE

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ABSTRACT

A **4-IN LINE** multi-cylinder engine is a reciprocating internal combustion engine with multiple cylinders. It can be either a 2-stroke or 4-stroke engine, and can be either PETROL or spark-ignition. The cylinders and the crankshaft which is driven by and co-ordinates the motion of the pistons can be configured in a wide variety of ways. Internal combustion (IC) Engine is a complex power generating machines and used widely in automotive industry. IC engine is not just a single component it is an assembly of various components. They are 1. Piston, 2. Connecting rod, 3. Crankshaft and 4. Cylinder head 5. Piston rings 6. Cam shaft. For the design of these components the original dimensions are taken from the 110cc engine. After the selection of dimensions, the components are designed in the CATIA V5 R21 software. After the required design is achieved, the design is imported to the Ansys workbench 2024 R2 software. Structural Analysis, Dynamic Analysis and Thermal Analysis are done on the Petrol Engine components. Structural Analysis is used to test whether Petrol Engine components. Withstands under working conditions are not. Thermal Analysis is done for knowing the life of the component. Dynamic analysis is done to explain the number of mode shapes for Petrol Engine. Analysis study is done for 3 materials Cast iron, Steel-440, and Aluminium-7075 Epoxy to compare the results.

INTRODUCTION

A multi-cylinder petrol engine is a type of engine that uses more than one cylinder to produce power. Each cylinder is a tube where fuel and air are burned to create energy. The engine has multiple cylinders (like 4, 6, or 8), which work together to make the engine smoother, more powerful, and efficient.

A multi-cylinder petrol engine is an engine with more than one cylinder, commonly found in vehicles like cars, bikes, and trucks. Each cylinder acts as a small power unit, where a mixture of petrol and air is burned to create energy. This energy comes from a process called combustion, where a spark plug ignites the mixture, causing an explosion. The explosion pushes a piston inside the cylinder, which moves up and down to turn the engine's crankshaft. In a multi-cylinder engine, all cylinders work together, firing at different times, to produce continuous power. This design makes the engine more powerful, smoother, and efficient compared to a single-cylinder engine. Multi-cylinder engines are ideal for vehicles that need higher speed, better performance, and the ability to carry heavier loads. They also reduce vibrations, making the driving experience more comfortable. This is why multi-cylinder petrol engines are widely used in modern transportation

LITERATURE SURVEY

P. Tejashree [2024]: The present analysis was conducted on one cylinder crank throw of a four-stroke cycle engine. However, as a result of the groundwork of study and thus the analysis square measure the same for multi-cylinder engines, the ways in which used could also be altered and implemented for crankshafts from differing types of engines. burden and price of the shaft. Opportunities for the reduction of the burden of the shaft were studied and a lightweight weight shaft is rumored during this paper.

B. Mounika and Madhuri R.P. [2023]: The Static structural analysis on the crankshaft done by using a single-cylinder 4-stroke engine. The 3-Dimensional Modelling of the crankshaft is done using Catia V5R20 software and Finite part Analysis is performed by exploitation ANSYS code by applying boundary conditions because the sides fastened and pressure spectrum is applied within the middle of the crankpin. Thus, an analysis was conducted on the shaft with 3 completely different materials forged iron, high steel and steel (42CrMn) to get the variation of stress magnitude at crucial locations. Analysis results area unit compared with Theoretical results of von misses and shear stress that area unit within the limits to validate the model.

Farzin H. Montazevsadgh and Ali Fatemi [2022]: This study explores weight and cost reduction opportunities for a forged steel crankshaft by analyzing loads through dynamic simulation of the slider-crank mechanism. A rational validation approach was adopted using ADAMS for engine modeling, while FEA was used to determine stress distribution across the crankshaft geometry throughout a full engine cycle.

S Suganthini Rekha [2021]: This work focuses on evaluating and comparing the load-bearing and fatigue performance of crankshafts manufactured using two different production materials: cast steel and Ti-6Al-4V reinforced with 12% Tic particles. Static structural analysis was carried out using ANSYS finite element software, with validation through theoretical calculations. Key performance parameters such as equivalent stress, strain, and total deformation were compared for both materials. The findings aim to support crankshaft optimization and engine design enhancement.

PL. S. Muthaiah This study analyzes and optimizes an exhaust manifold design to balance backpressure reduction and particulate matter filtration efficiency. Using Computational Fluid Dynamics (CFD), various configurations of conical geometry and mesh size were tested to find the best design that minimizes backpressure without compromising emissions standards.

Kulal et al. (2013) This work presents a detailed CFD-based analysis of eight different exhaust manifold designs for a multi-cylinder Maruti Suzuki Wagon-R engine. By simulating fluid flow and validating results with experimental data like backpressure and exhaust temperature, the study identifies the most fuel-efficient design. CFD proves to be an effective tool for optimizing engine components while minimizing testing costs.

Venkat Venkata Rajam et. al. (2013), This study focuses on the design optimization of a piston using CATIA and ANSYS, aiming for mass reduction while maintaining performance. A ceramic coating was applied to the crown, and material was removed from non-critical areas like barrel thickness and ring land width. Despite slight increases in von Mises stress and deflection, all results remained within safe design limits.

Manjunatha T. R. et. al. (2013), The analysis of both high and low-pressure stages during suction and compression strokes identified potential high-stress regions. Results showed that the stresses remained below allowable limits, confirming the design's safety.

Pai (1996), proposed a method to optimize the shape of a connecting rod under cyclic loading, considering both fatigue crack initiation and growth using fracture mechanics. Finite element analysis was used to compute stresses, which were then integrated into an optimization routine to maximize fatigue life while meeting design constraints.

Prof. N. P. Doshi, conducted an analysis of a connecting rod using both analytical and finite element methods, focusing on a rod used in a light commercial vehicle by Tata Motors. The study evaluated stress distribution under load, helping to assess the rod’s structural integrity using common materials like steel and aluminum.

PRAPOSED SYSTEM METHODOLOGY

Dimensions of Piston

PARAMETERS	
Ring land(h_2)	0.963 mm
Thickness of piston barrel at open end(t_1)	8.744 mm
Thickness of piston barrel at open end(t_2)	2.186 mm
Length of skirt (L_S)	40.2 mm
Piston pin diameter (d_O)	20.1 mm
Piston boss diameter (1.5 d_O)	30.15 mm

Cylinder Design Parameters

Design Parameters	Calculated Value
Diameter (D)	78mm
Length(L)	78mm
Break mean effective pressure (Bmep)	11.76 bar
Indication mean effective pressure (Imep)	13.85 bar
Pumping mean effective pressure (Pmep)	138.5 bar
Volume	1500cc
Indicated Power	141.176 HP
Friction Power	21.176 HP
Mechanical Efficiency (Assumed)	85%
Break Power	120HP

CAM Shaft Dimensions

Camshaft diameter	8mm
Journal diameter	50 mm Cam
Peak	21 mm
Total lift of cam	7.65mm

Specifications of Crank Shaft

S.no.	Parameters (mm)
1	Crank pin diameter (d_C) = 65
2	Crank pin length (l_C) = 65
3	Width of Crank web (W) = 75
4	Thickness of Crank web (t) = 46
5	Diameter of shaft under flywheel (d_S) = 50
6	Diameter of shaft at the juncture of the right-hand crank web (d_{S1}) = 55
7	The diameter of the journal at the bearing 2 (d_{S1}) = 55

Specifications of Connecting Rod

S. No	Parameters
1	Thickness of the connecting rod (t) = 3.2
2	Width of the section (B = 4t) = 12.8
3	Height of the section (H = 5t) = 16
4	Height at the big end = (1.1 to 1.125) H = 17.6
5	Height at the small end = 0.9H to 0.75H = 14.4
6	Inner diameter of the small end = 17.94
7	Outer diameter of the small end = 31.94
8	Inner diameter of the big end = 23.88
9	Outer diameter of the big end = 47.72

Types of Material

1. Steel-440
2. Cast Iron
3. Aluminium-7075 Epoxy

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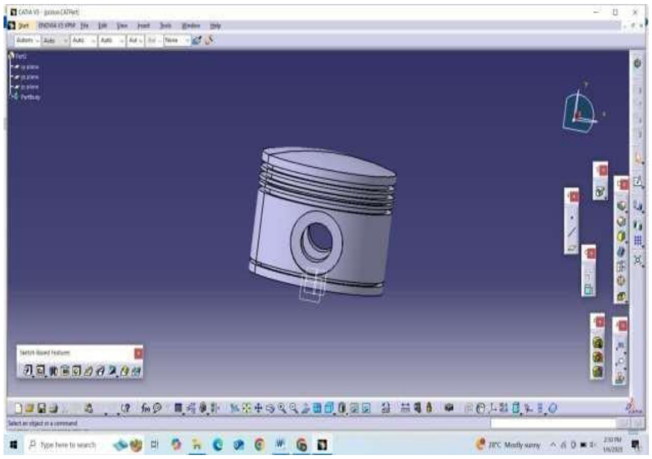
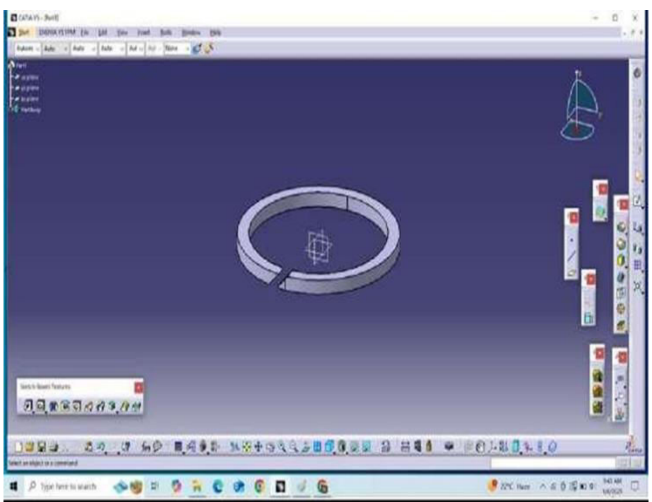
MODULING OF 4-IN LINE MULTI CYLINDER PETROL ENGINE



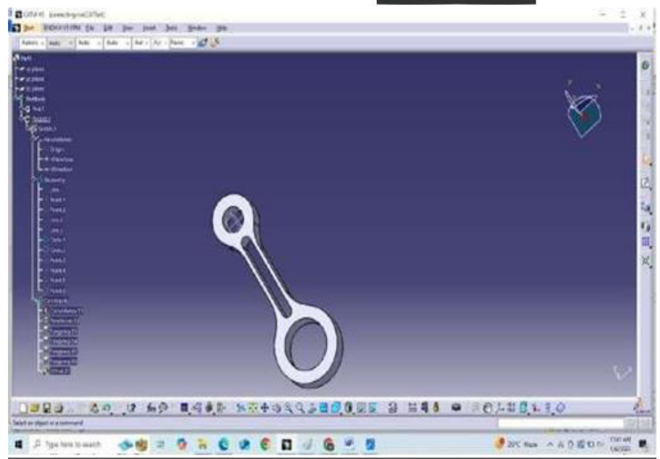
3D PISTON

A 3D model of a piston created using CATIA V5 software. It illustrates key features such as the piston crown, ring grooves, and gudgeon pin hole, typically used for design and analysis in internal combustion engines.



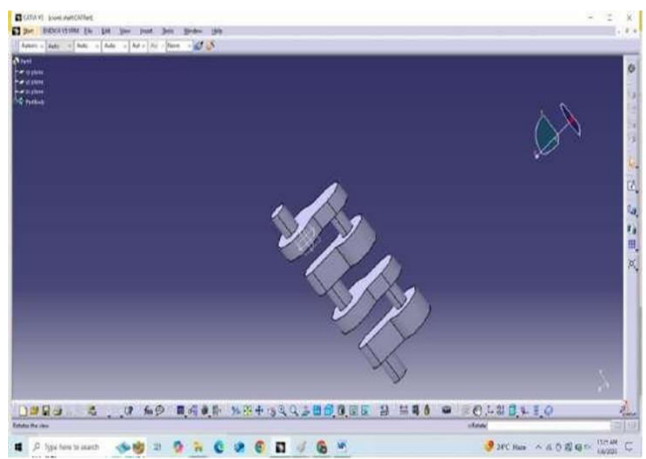
3D PISTON RING

3D CAD model of a piston ring created using CATIA V5. This component is essential for sealing the combustion chamber, controlling oil consumption, and transferring heat from the piston to the cylinder wall.



3D Connecting Rod

To draw the connecting rod diagram in CATIA V5, start by creating a sketch on a plane using basic shapes like circles and lines to define the profile. Then use pad (extrude) and pocket (cut) features to give it thickness and add internal cutouts, completing the 3D model.



3D CRANK SHAFT

To draw the crankshaft in CATIA V5, begin by sketching the side profile of the crank throws and main journals using lines and arcs. Use the pad, pocket, and mirror features to create the symmetrical crank geometry, then apply fillets for smooth transitions and finishing.

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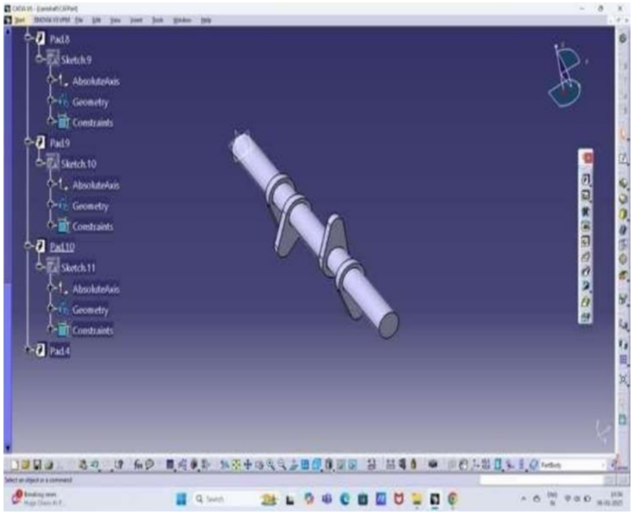
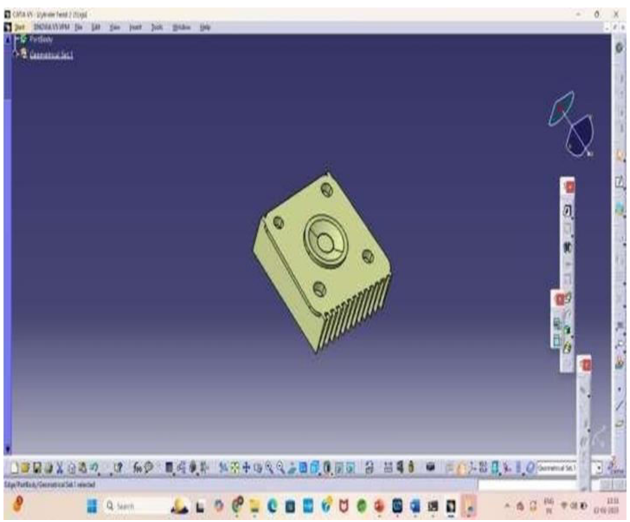


3D CAM Shaft

3D model in CATIA, create individual sketches for each feature (cylinders, flanges) on appropriate planes using the Sketcher workbench, then use the Pad tool to extrude them. Assemble and align each part using reference axes and constraints to form the complete shaft-like structure.



3D Cylinder Head

Heat sink-like component in CATIA, start by sketching a rectangle on the base plane and pad it to the desired height. Then use pocket features to create the central circular cut and side grooves, and add holes using the hole tool on the top face.

but can lead to knocking, so a balance must be found.

ANALYSIS OF 4-IN LINE MULTI CYLINDER PETROL ENGINE

ANSYS is a large-scale multipurpose finite element program developed and maintained by ANSYS Inc. to analyze a wide spectrum of problems encountered in engineering mechanics.

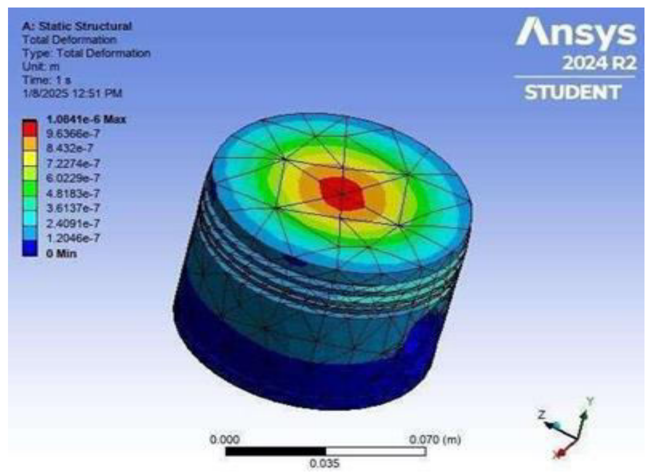
There are three types of analysis involved in:

1.Static Structural Analysis

2.Thermal Analysis

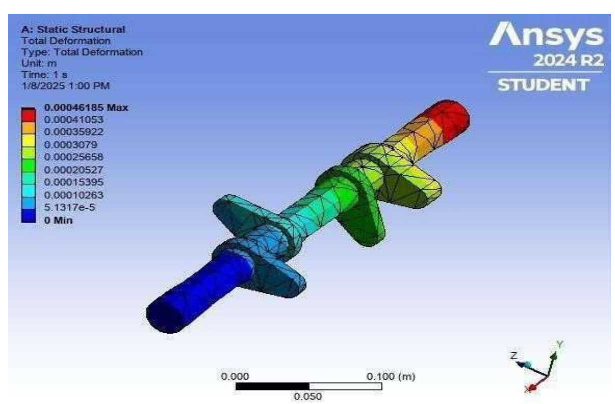
3.Dynamic Analysis

1.Static Structural Analysis



Aluminium-7075 Epoxy (PISTON) Total Deformation 0 m to1.0841e^{-006} m

A maximum deformation of 1.084e^{-6} m at the top center. The deformation gradually decreases outward, indicating good structural stability and uniform load distribution.



Steel-440(CAM SHAFT) Total Deformation 0m to 4.6185e^{-004} m.

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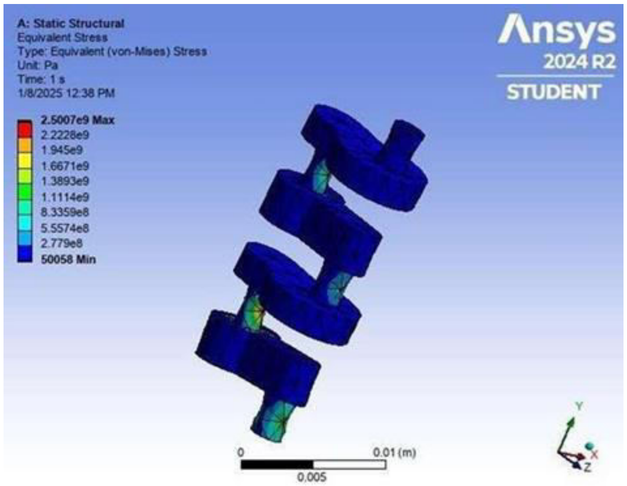
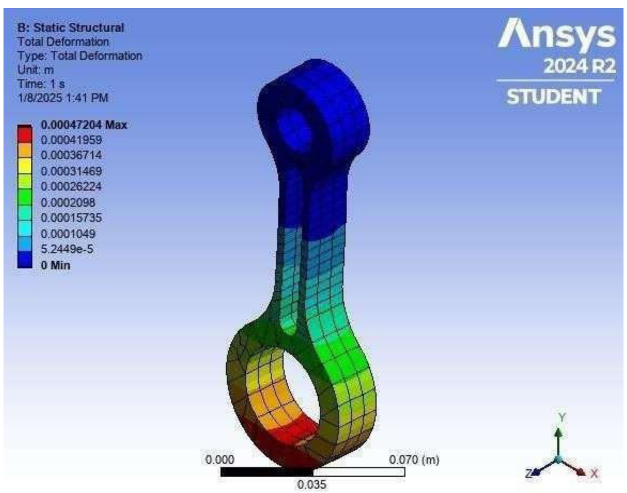


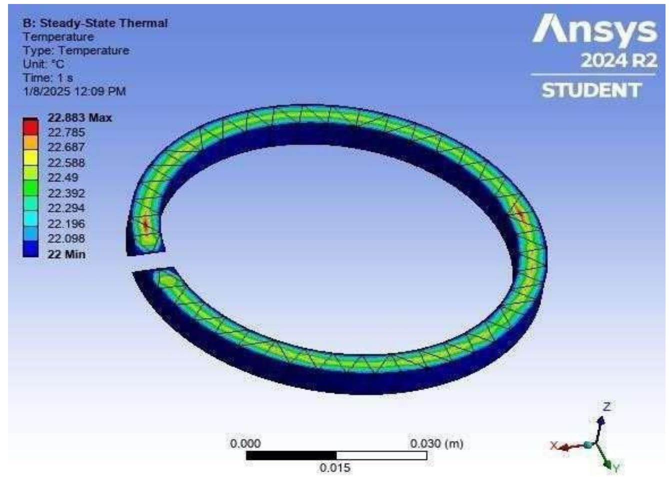
Cast Iron (CRANK SHAFT) Equivalent (von-Mises) Stress 50058 Pa to $2.5007e^{+009}$ Pa



Aluminium-7075 Epoxy (CONNECTING ROD) Total Deformation 0.m to $4.7204e^{-004}$ m

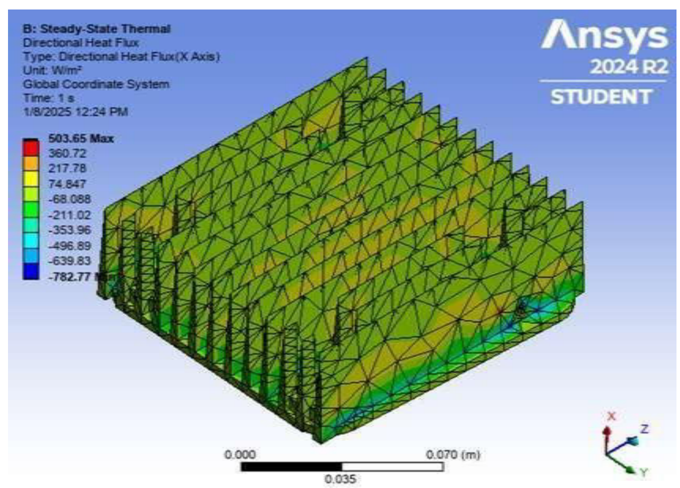
The maximum deformation is 0.00047204 m, shown in red at the bottom ring area. The blue region at the top shows minimal or zero deformation, likely where the rod is fixed. This analysis helps ensure the design can withstand operational forces without excessive bending.

2.Thermal Analysis



Aluminium-7075 Epoxy (PISTON RING) Temperature 22. °C to 22.883 °C

The temperature ranges from 22°C to 22.88°C, with slight gradients likely due to thermal boundary conditions. The analysis is in steady-state, meaning the temperature distribution does not change over time.



Aluminium-7075 Epoxy (CYLINDER HEAD) Directional Heat Flux -782.77 W/m² to 503.65 W/m²

This is a thermal simulation result from ANSYS 2024 R2 showing a steady-state temperature distribution. Cooler areas are shown in blue, while warmer zones are in red/yellow, mostly near the base.

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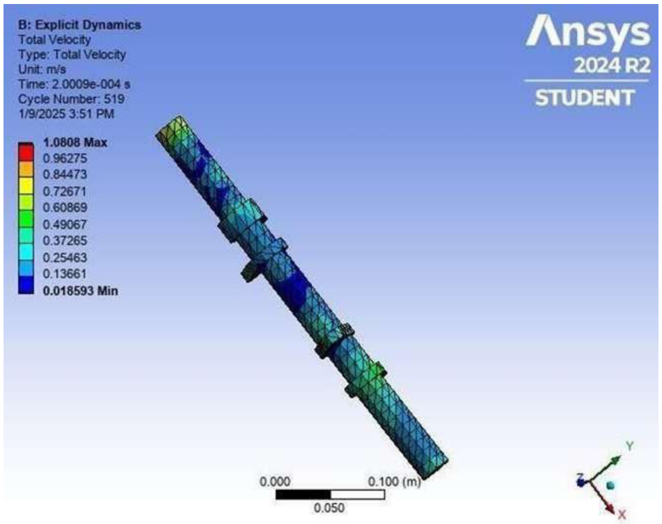
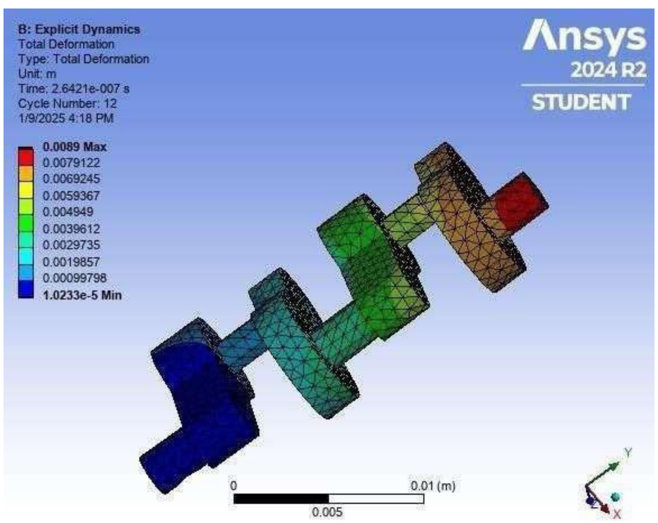
3.Dynamic Analysis



Aluminum -7075 Epoxy (CAM SHAFT) Total Velocity 1.8593e^{-002} m/s to 1.0808 m/s



Aluminium-7075 Epoxy (CRANK SHAFT) Total Deformation 1.0233e^{-005} m to8.9e^{-003} m

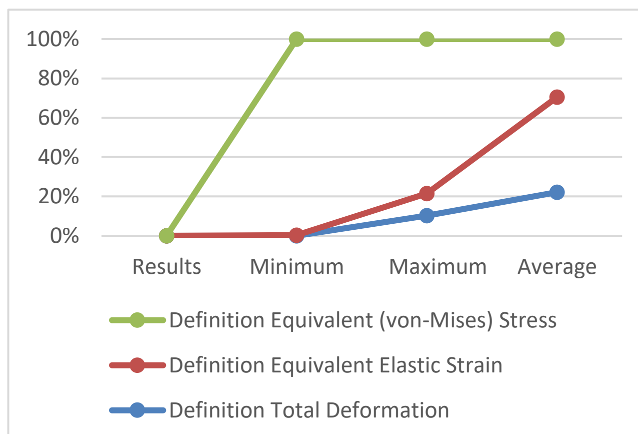
This explicit dynamic analysis shows total deformation of an Aluminum 7075-epoxy crankshaft under time-dependent loading. Maximum deformation (~0.0089 m) is observed at the outer ends, with minimal displacement near the center. This helps assess the crankshaft's behavior under dynamic conditions to ensure reliable engine performance.

RESULT

Static Structural

Table 1: Deformation, Strain, Stress values for Al-7075 Epoxy (Piston)

Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	4.8944e^{-007} m/m	2125.7 Pa
Maximum	1.0841e^{-006}m	1.2011e^{-005} m/m	8.3473e^{+005} Pa
Average	1.7878e^{-007} m	3.9049e^{-005} m/m	2.3854e^{+005} Pa



Graphical representation of Al-7075 Epoxy (Piston)

Table 2: Deformation, Strain, Stress values for Al-7075 epoxy (Crank Shaft)

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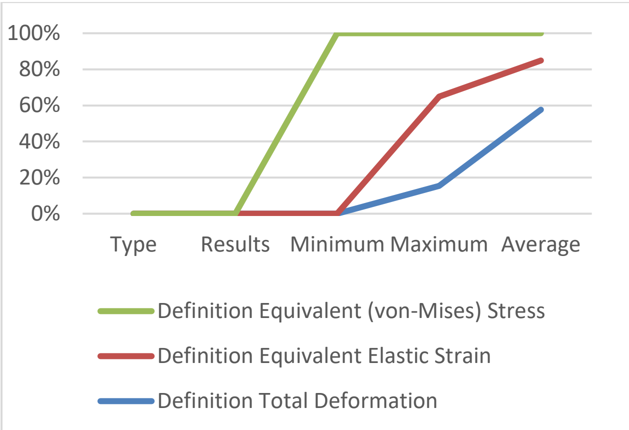
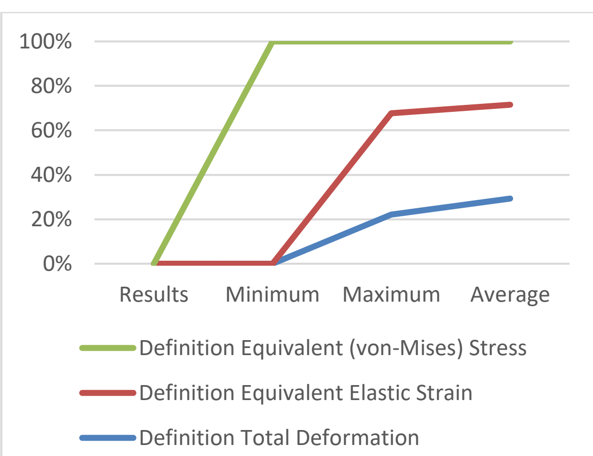


Graphical representation of Al-7075 Epoxy (Crank Shaft)

Table 3: Deformation, Strain, Stress values for Al-7075 Epoxy (connecting rod)

Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	$6.5124e^{-007}$ m/m	42732 Pa
Maximum	$4.7204e^{-004}$ m	$9.7485e^{-004}$ m/m	$6.9192e^{+007}$ Pa
Average	$1.4101e^{-004}$ m	$2.0313e^{-004}$ m/m	$1.37e^{+007}$ Pa



Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
Results			
Minimum	0. m	$7.2188e^{-012}$ m/m	0.40003 Pa
Maximum	$1.294e^{-003}$ m	$5.9329e^{-004}$ m/m	$4.1665e^{+007}$ Pa
Average	$5.22e^{-004}$ m	$5.2945e^{-005}$ m/m	$3.0442e^{+006}$ Pa

Graphical representation of Al-7075 Epoxy (Connecting Rod)

2.Thermal Analysis

Table 4: Temperature, Heat Flow of Al-7075 Epoxy (piston ring)

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	22. °C	2.3577 W/m²	$-1.0197e^{+005}$ W/m²
Maximum	22.883 °C	$1.0197e^{+005}$ W/m²	79744 W/m²
Average	22.099 °C	29876 W/m²	283.32 W/m²

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
Results			
Minimum	21.998 °C	$4.5323e^{-009}$ W/m²	-782.77 W/m²
Maximum	22.028 °C	2273.4 W/m²	503.65 W/m²
Average	22.002 °C	479.25 W/m²	-1.8852 W/m²

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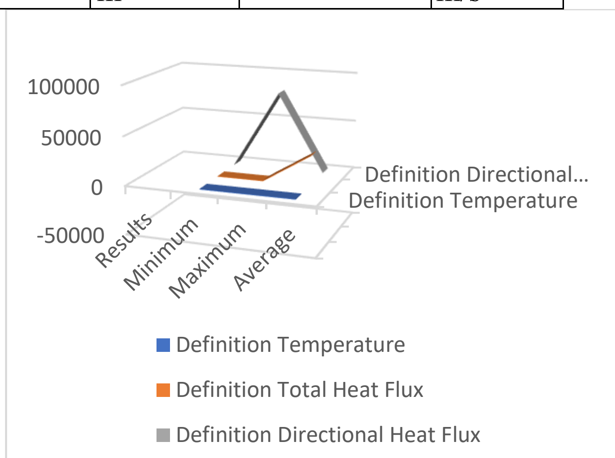
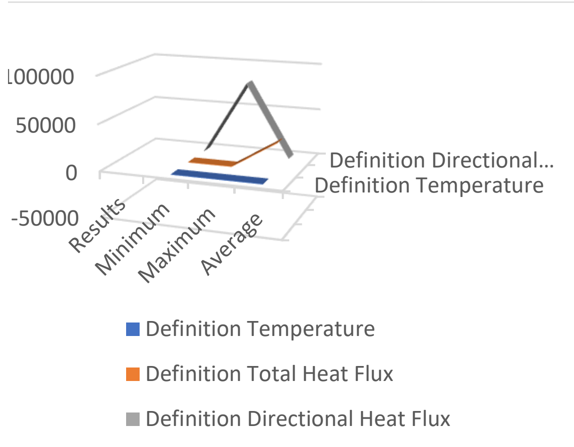
Definition			
Type	Total Deformation	Directional Deformation	Total Velocity
Results			
Minimum	$1.0233e^{-005}$ m	$-2.3046e^{-004}$ m	11.858 m/s
Maximum	$8.9e^{-003}$ m	$1.5999e^{-004}$ m	1477.5 m/s
Average	$3.6807e^{-003}$ m	$-2.1193e^{-005}$ m	362.94 m/s



Graphical representation of Al-7075 Epoxy (piston rings)

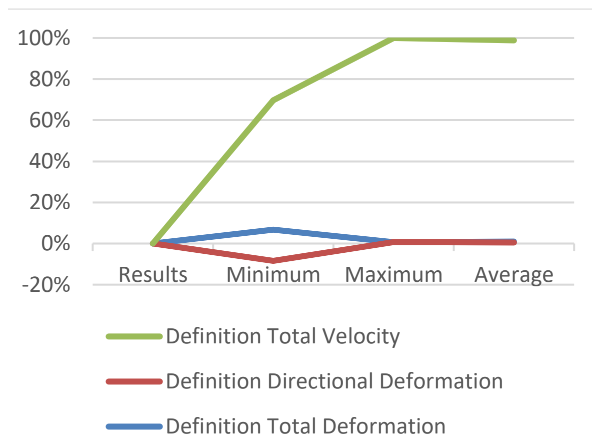
Table 5: Temperature, Heat Flow of Al-7075 Epoxy (Cylinder head)



Graphical representation of Al-7075 Epoxy (Cylinder Head)

.Dynamic Analysis

Table 6: Deformation, Directional Deformation, Velocity value of Al-7075 Epoxy (Crank shaft)



Graphical representation of Al-7075 Epoxy (Crank shaft)

CONCLUSION

It can be seen from the above result that, our objective to find out after the loads falling on the flywheel in the Multi Cylinder Petrol Engine the design has been successful. This is showing us that clearly each component in assembly is having minor displacement. Stress is at the fixing location (Minimum Stress which is acceptable). Three materials were employed to analyses the piston in this thesis: Cast iron, Steel- 440, and

Aluminium-7075 Epoxy. The piston and connecting rod, camshaft. Crankshaft, cylinder head model was constructed with the aid of the Catia V5 R20 tool, and it was analyzed with the assistance of Ansys Workbench. Each material in this thesis was examined using three separate boundary conditions: structural, thermal and dynamic analysis. Thermal analysis results make it simple to determine how a material observes temperature or how much heat it can transport per unit area Aluminium-7075 Epoxy material has a minimum factor of safety value of 1.5 at this load, and according to design constraints, any object should maintain a minimum factor of safety value above 1.5. This information comes from the results of structural analysis. Aluminium-7075 Epoxy material can withstand a maximum amount of pressure of 10Mpa on top of the piston.

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