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Static structural and thermal analysis of single-cylinder engine

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ABSTRACT

Structural analysis is the process of studying the effects of loads on physical structure and their components. Single Stroke engine consists of a piston, a connecting rod, a crankshaft and one cylinder. This paper contains static structural analysis of a Single Stroke Engine and its components i.e., Piston, crankshaft and connecting rod. Single Stroke engine is mostly used in motorcycles, motor scooters, go-karts, all-terrain vehicles, radio-controlled vehicles, portable tools and garden machinery (such as lawnmowers, cultivators, and string trimmers). Single Cylinder engines are simpler and more compact when compared to multi cylinder engines. Effects of loads and different boundary conditions are observed on the single stroke engine using ANSYS software. Ansys Mechanical APDL suite is used for static structural analysis. The material used in this analysis for the Single Stroke Engine is a Structural steel. The aim of this paper is to determine the total deformation, Equivalent stress, Equivalent strain on the single stroke engine and its components. Modelling and assembly of parts is done on CATIA V5R21.

Keywords: *Structural Analysis, Finite Element Analysis, Meshing.*

1. INTRODUCTION

First commercial Internal combustion Single Stroke Engine was patented by Étienne Lenoir, a Belgian inventor in 1959. This single stroke engine replaced the large and heavy steam engines used in locomotives. This engine ran on coal gas and air mixture by the ignition {jumping sparks} by Ruhmkorff coil. However, this engine required a powerful water-cooling system. Later Nicolaus August Otto, a German engineer started the construction of a replica of the Lenoir engine. He proposed that instead of using gas, it would work better if fueled with ethyl alcohol. Later Gottlieb Daimler and Wilhelm Maybach patented an improved single cylinder engine in 1883. This engine generated 1HP and was relatively small and used petrol as fuel. Nowadays single stroke engines can be found with diesel variation also. A single stroke engine only uses one stroke piston to rotate the output shaft continuously to complete a cycle. This engine consists of a combustion cavity. The piston is moved reciprocally between the combustion chambers using the process of fuel combustion. This piston is connected to the crankshaft by a connecting rod. When the piston is moved, the crankshaft starts to rotate. This rotating crankshaft then transmits this power to the wheels and thus the vehicle is moved. Most powerful single stroke engine currently in use is VITPILEN701. There is great airflow around all sides of the cylinder so air-cooling is more effective for this engine. This also reduces the overall weight of the vehicle. Single Stroke engine is mostly used in motorcycles, motor scooters, go-karts, all-terrain vehicles, radio-controlled vehicles, portable tools and garden machinery (such as lawnmowers, cultivators, and string trimmers). Single Cylinder engines are simpler and more compact when compared to multi cylinder engines.

2. COMPONENTS

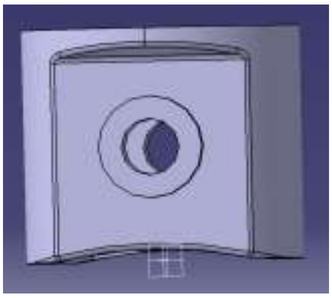


Fig.1: Piston


Fig.2: Connecting rod

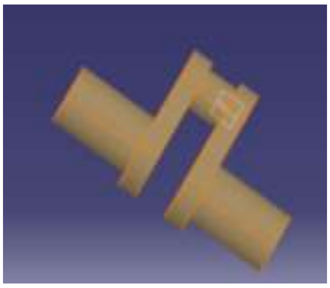


Fig.3:Crankshaft

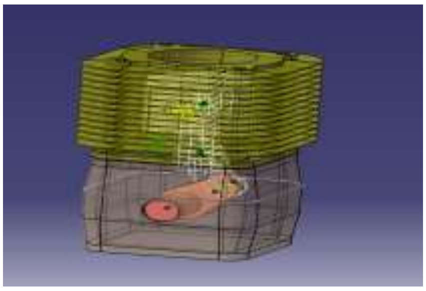


Fig.4: Assembly of Single Cylinder Engine

3. METHODOLOGY

Initiative of paper is to design components and assembly of Single Cylinder Engine. While designing static structural and thermal steady state analysis of Single cylinder engine was carried out by taking material properties into account. Each component is considered to be made of structural steel. Different meshing models like Fine, Medium and coarse carried out along with combinations, results are shown.

Table no.1: Material properties of Structural steel

Young's modulus (GPa)	210
Poisson's ratio	0.3
Yield Strength (MPa)	433
UTS (MPa)	460

3.1 Analysis of Piston

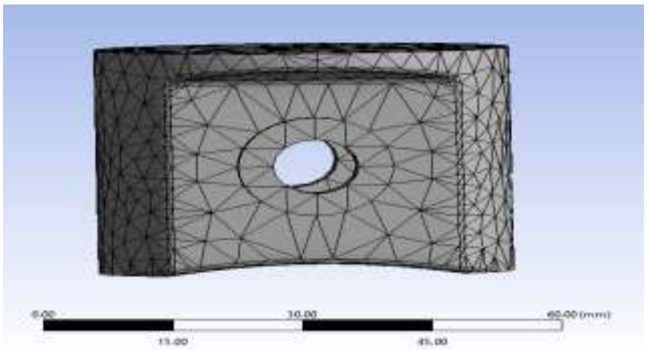


Fig.5: Tetrahedron meshing of piston

Number of nodes	7417
Number of elements	3797

Boundary conditions:

1.Pressure applied over piston is 500000 Pa

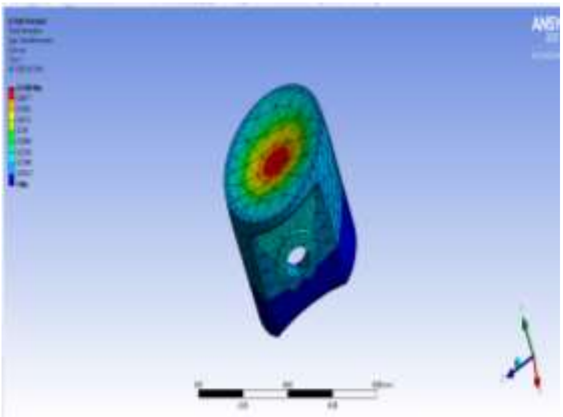


Fig.6:Total Deformation

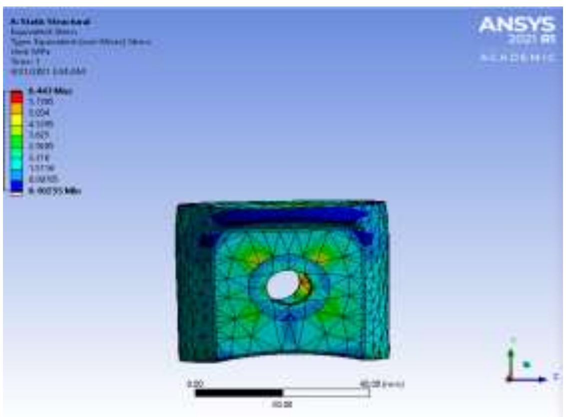


Fig.7:Equivalent stress

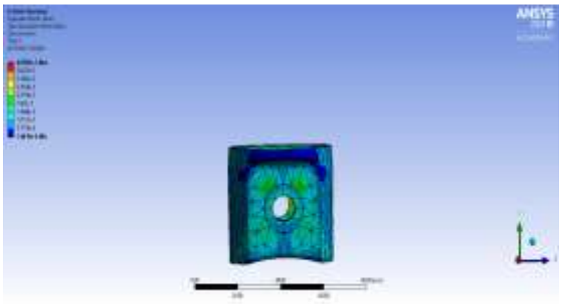


Fig.8: Equivalent Elastic Strain

Table no 2: Results of Structural analysis of Piston:

Parameter	Total Deformation(m)	Equivalent Stress(pa)	Equivalent Elastic Strain(m/m)
Minimum	0	0.10255	1.4039e-6
Maximum	0.001692	6.443	4.058e-5
Average	0.00075221	2.9205	1.882e-5

3.2 Analysis of crankshaft

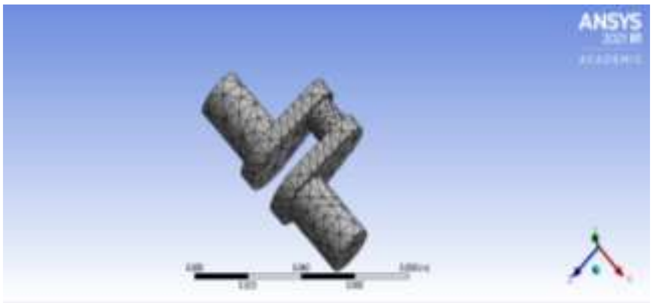


Fig.9: Tetrahedron meshing of Crankshaft

No. of Nodes	2734
No. of Elements	1449

Boundary conditions:
1.Rotational Velocity:100 rad/sec
2.Force:10000N

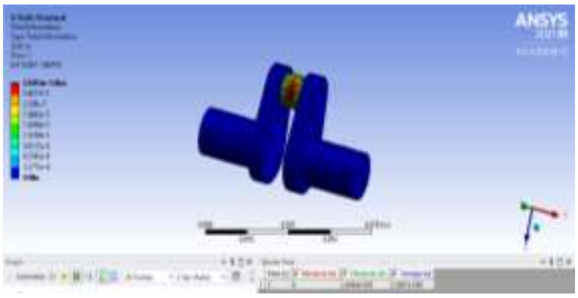


Fig.10:Total Deformation of Crankshaft

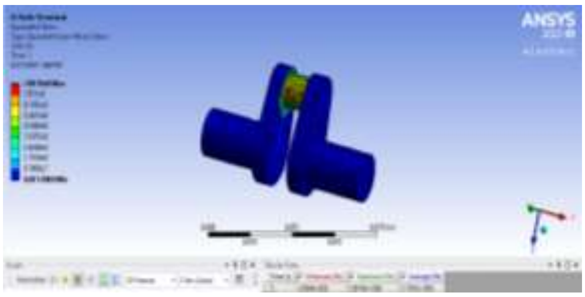


Fig.11:Equivalent Stress of Crankshaft

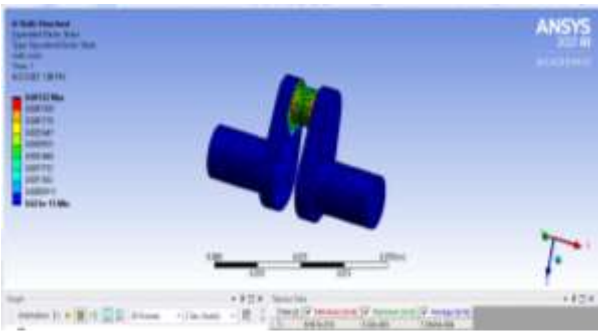


Fig.12:Equivalent Elastic Strain of Crankshaft

Table no.3: Result of Structural analysis of Crankshaft

	Total deformation(m)	Equivalent Stress(pa)	Equivalent Elastic Strain(m/m)
Maximum	2.9494e-5	7.8919e+8	5.32e-3
Minimum	0	1.3084e-3	9.921e-15
Average	3.2907e-6	1.1787e+8	7.5545e-4

3.3 Analysis of connecting rod

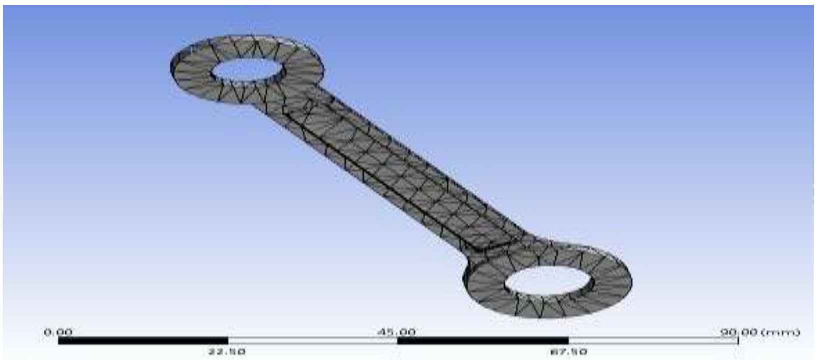


Fig.13: Tetrahedron meshing of Connecting Rod

No. of Nodes	6305
No. of Elements	3587

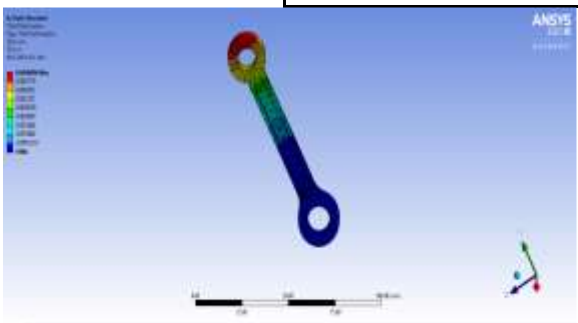


Fig.14:Total Deformation of Connecting Rod

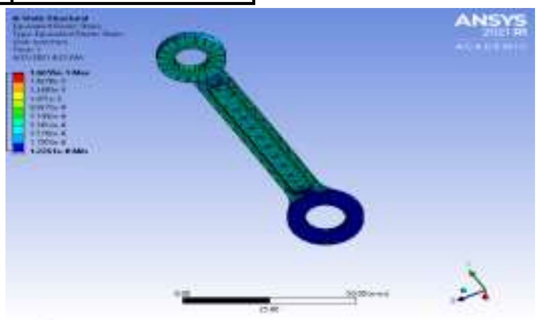


Fig.15:Equivalent Stress of Connecting Rod

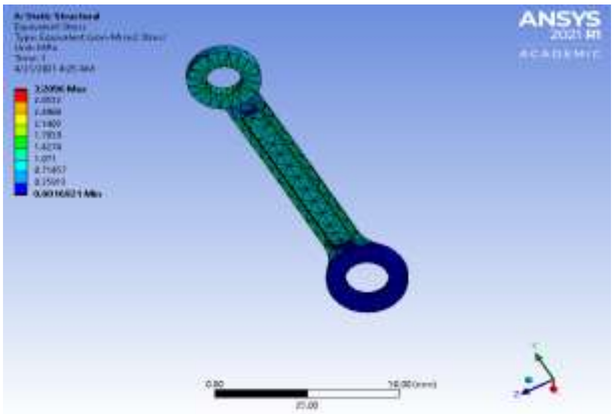


Fig.16: Equivalent Elastic Strain of connecting rod

Table no.3: Result of Structural analysis of connecting Rod

Parameter	Total deformation(m)	Equivalent Stress(pa)	Equivalent Elastic Strain(m/m)
Maximum	0.0041774	3.2096	1.6059e-5
Minimum	0	0.001692	1.2261e-8
Average	0.0020887	1.4274	7.1442e-6

3.4 Analysis of assembly

1. Static Structural analysis with Coarse meshing

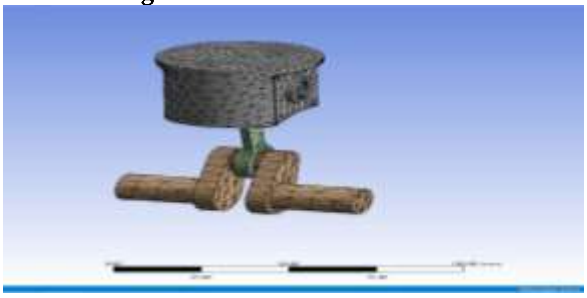


Fig.17:Coarse meshing of Assembly

No. of Nodes	45318
No. of Elements	25390

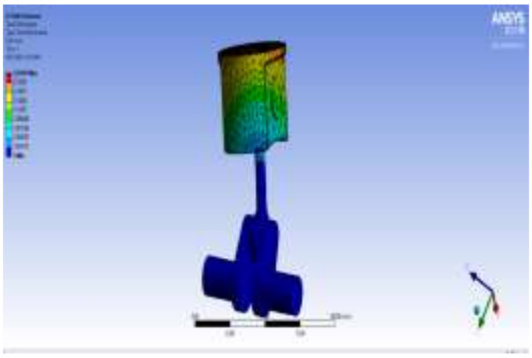


Fig18:Total Deformation of Assembly

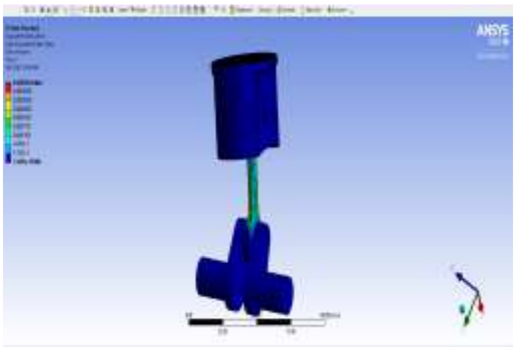


Fig19:Equivalent Stress of Assembly

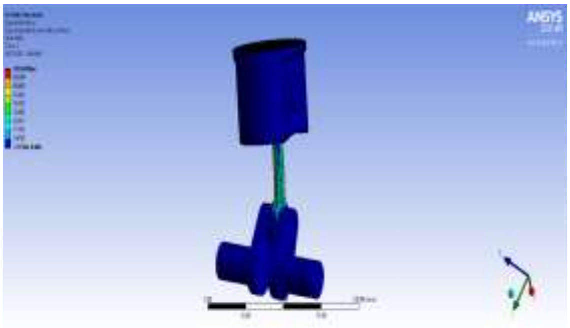


Fig20: Equivalent Elastic Strain of Assembly

2. Static Structural analysis with Fine meshing

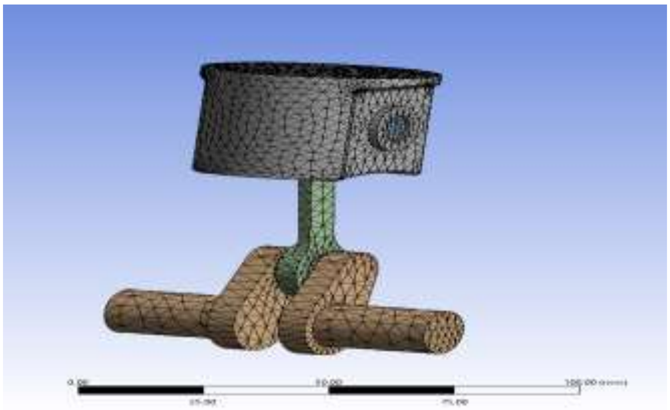


Fig. 21:Fine Meshing of Assembly

No. of Nodes	45318
No. of Elements	25390

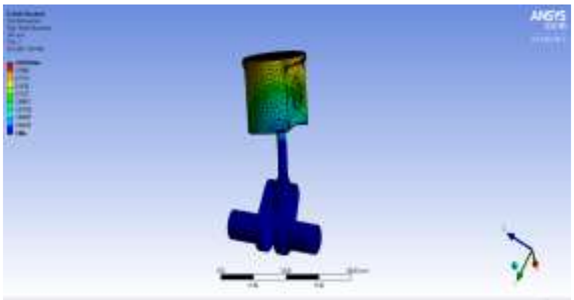


Fig.22:Total Deformation of Assembly

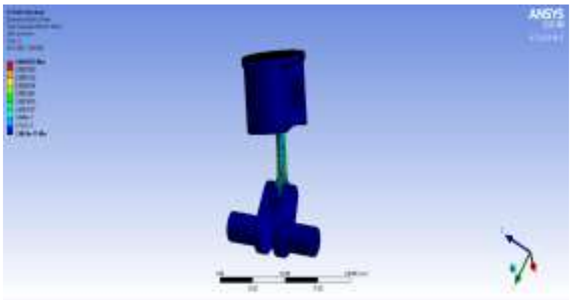


Fig23:Equivalent Stress of Assembly

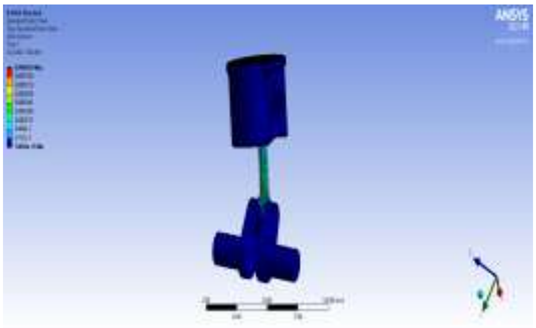


Fig 24:Equivalent Elastic Strain of Assembly

3. Static Structural analysis with Medium meshing

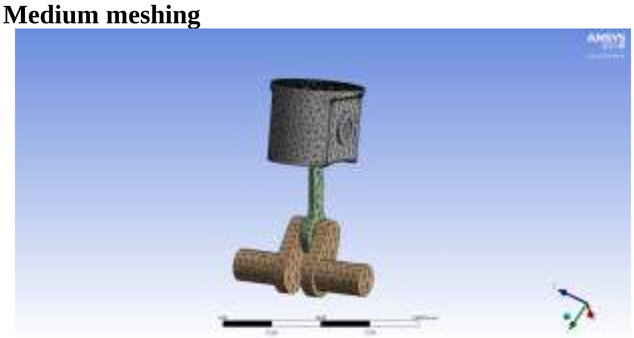


Fig.25:Medium meshing of Assembly

No. of Nodes	21588
No. of Elements	11402

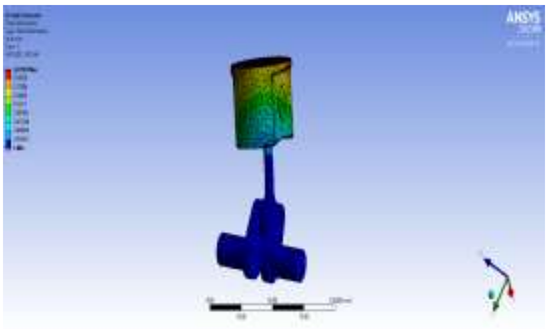


Fig.26:Total Deformation of Assembly

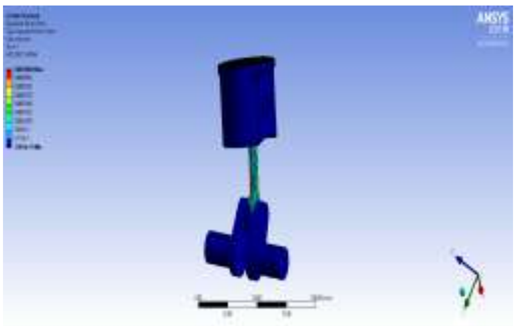


Fig.27:Equivalent Stress of Assembly

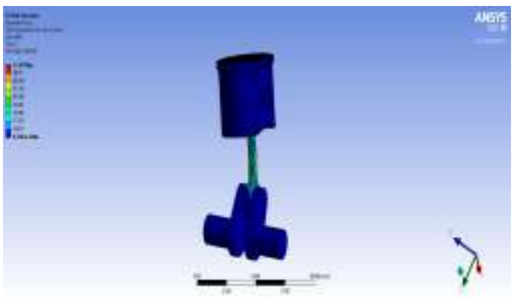


Fig.28:Equivalent Elastic Strain of Assembly

Table No.4: Result of all three meshing:

Type Of Meshing	Total Deformation(m)	Equivalent Strain(m/m)	Equivalent Stress(pa)
coarse	0.2169	0.000397	78.03
fine	0.22052	0.00042	84.02
Medium	0.21981	0.000388	77.591

4. THERMAL ANALYSIS OF ASSEMBLY

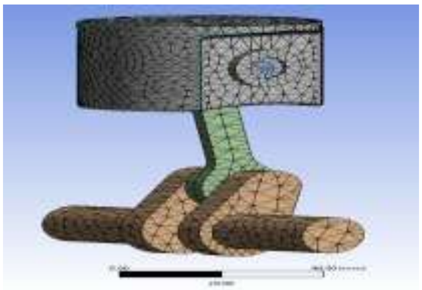


Fig 29: Tetrahedron meshing of thermal model

Boundary Conditions
Initial Temperature 660

Radiation 22 deg C

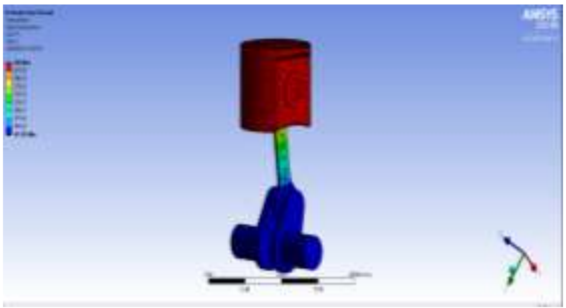


Fig.30:Final Temperature of Assembly

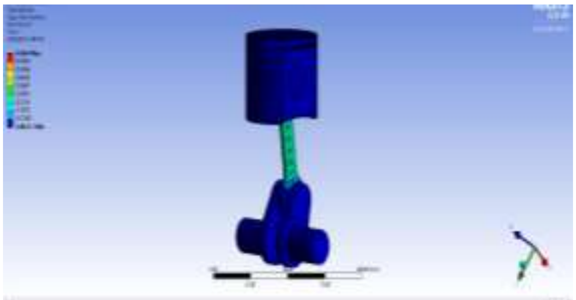
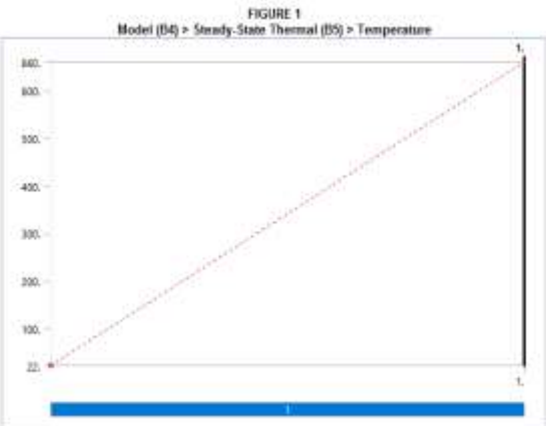
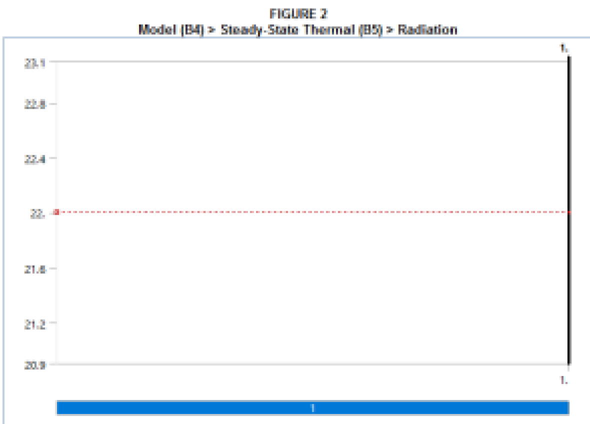


Fig.31:Total Heat Flux of Assembly

Table No.5:Result of Thermal Analysis

Parameter	Maximum	Minimum
Final temperature	660 deg C	0.69641
Total flux	417.85 W/mm^2	2.6827e-5 W/mm^2





5. RESULT AND DISCUSSION

Here we obtain discrete and analysis of components in static and steady state thermal parameters.
It is observed from the result table of all parameters of every component and assembly that the Equivalent Stress and Equivalent Strain and total deformation differ according to mesh size.

According to the result table no.4 Tetrahedron Fine meshing gives minimum deformation, Equivalent stress and Equivalent Elastic strain compared to Coarse and Medium Meshing.

After doing thermal analysis we obtained final temperature and total flux respectively.

6. CONCLUSION

Above observation gives an idea about the design and analysis of a single stroke cylinder engine, hence the FEA of assembly is done and is proved as safe since none of the deformation exceeds the given safety values. It has explained various parameters of analysis using ANSYS workbench software, This result will help in better optimization of the engine design

7. REFERENCES

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