Modeling and Performance Analysis of Connecting Rod and Piston with Alternate Material

1*Mr.A.Karthikayan2*Sadasivam.K 3*Naveenkumar.K,S

1*Assistant Professor, 2&3*Student

Department of Mechanical Engineering,

Shree Venkateshwara Hi-Tech Engineering College, Gobi.

***Abstract* -** The connecting rod is the intermediate member between the piston and the Crankshaft. Its primary function is to transmit the push and pull from the piston pin to the crank pin, thus converting the reciprocating motion of the piston into rotary motion of the crank. This project describes designing and Analysis of connecting rod and piston. Currently existing connecting rod is manufactured by using steel Alloy. In this drawing is drafted from the calculations.

A parametric model of Connecting rod is modeled using SOLIDWORKS 2013 software and to that model, analysis is carried out by using ANSYS 13.0 Software. Finite element analysis of connecting rod is done by considering the materials, viz... Titanium Alloy. The best combination of parameters like Von misses Stress and strain, Deformation for two wheeler piston were done in ANSYS software. Steel alloy has more factor of safety, reduce the weight, increase the stiffness and reduce the stress and stiffer than other material like carbon steel. With Fatigue analysis we can determine the lifetime of the connecting rod. In this project, the main emphasis is placed on the study of thermal behaviour of piston, ANSYS on Cast iron and Aluminium alloy piston surfaces.

I. INTRODUCTION

1.1 The Internal Combustion Engine

The internal combustion engine converts chemical energy into useful mechanical energy by burning fuel. Chemical energy is released when the fuel-air mixture is ignited in the combustion chamber. The gas produced in this reaction rapidly expands forcing the piston down the cylinder on the power stroke. The piston reciprocates inside the cylinder; an exhaust and intake port open and closes during various stages of the cycle. The movement of the piston up or down the cylinder makes up one stroke of the four stroke cycle. The linear motion is then converted to rotary motion by the crankshaft. The crankshaft is shaped to balance the pistons which are fired in a particular order to reduce engine vibration (typically for a 4-cylinder engine, 1-2-4-3 or 1-3-4-2). The flywheel then helps smooth out the linear movement of the pistons.

1.2 Parts of Internal Combustion Engine

The basic components for a combustion cycle in a four stroke engine are as follows

- Cylinder

- Piston

- Valves

- Crank & Crank Shaft

- Flywheel

1.2.1 CYLINDER

A cylinder is the central working part of a reciprocating engine or pump, the space in which a piston travels. Multiple cylinders are commonly arranged side by side in a bank, or engine block, which is typically cast from aluminium or cast iron before receiving precision machine work. Cylinders may be sleeved (lined with a harder metal) or sleeveless. A sleeveless engine may also be referred to as a "parent-bore engine".

A cylinder's displacement, or swept volume, can be calculated by multiplying its cross-sectional area (the square of
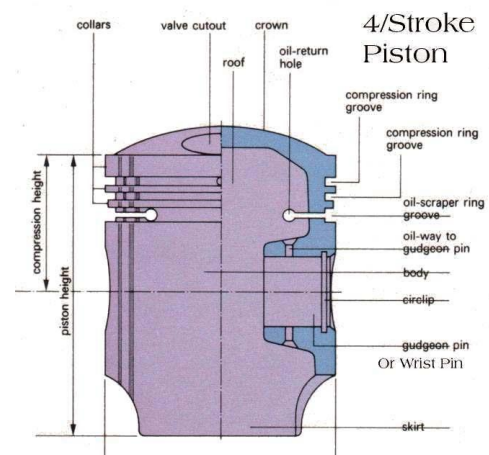
.The engine displacement can be calculated by multiplying the swept volume of one cylinder by the number of cylinders.

$$(\text{Cylinder Volume}) = \pi \cdot \left(\frac{\text{bore}}{2}\right)^2 \cdot \text{Strokes}$$

(Engine Displacement) = (Cylinder Volume) . (Number of Cylinders)

1.2.2 PISTON

In general, a piston is a lubricated sliding shaft that fits tightly inside the opening of a cylinder. Its purpose is to change the volume enclosed by the cylinder, to exert a force on a fluid inside the cylinder, to cover and uncover ports, or some combination of these. Piston in I.C. engines play an important role in transferring the energy generated on combustion chamber to connecting rod and thereby to crank shaft. The various parts of the piston are shown in the figure given below

. During running of the engine forces are induced on the piston. They are as follows:

Special Issue - 2017

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
ETDM - 2017 Conference Proceedings

1.2.2.1 NORMAL FORCE

This force is concentrated on piston by pressure of explosion by gas and air. We assume that this force is equal in every point of piston surface area; therefore, this force will act directly up on piston rod.

II. LITERATURE REVIEW

2.1 Literature Review For Static Structural Analysis Of Connecting Rod

REF.NO.1: Asadi, (2010) developed detailed load analysis under service loading conditions was performed for connecting rod and The conclusions can be drawn from this study as follows the maximum pressure stress was obtained between pin end and rod linkage and the maximum tensile stress was obtained in lower half of pin end.

REF.NO.2: H.B.Ramani has do Analysis of Connecting Rod under Different Loading Condition Using ANSYS Software. In spite of the great power of FEA, the disadvantages of computer solutions must be kept in mind when using this and similar methods, they do not necessarily reveal how the stresses are influenced by important problem variables such as materials properties and geometrical features, and errors in input data can produce wildly incorrect results that may be overlooked by the analyst.

REF.NO.3: Pravardhan S. Shenoy and Ali Fatemi (2005) carried out the dynamic load analysis and optimization of connecting rod. The main objective of this study was to explore weight and cost reduction opportunities for a production forged steel connecting rod. Typically, an optimum solution is the minimum or maximum possible value the objective function could achieve under a defined set of constraints. The weight of the connecting rod has little influence on the cost of the final component. Change in the material, resulting in a significant reduction in machining cost, was the key factor in cost reduction.

REF.NO.4: Shahrukh shamim studied finite element analysis of connecting rod used in single cylinder four stroke petrol engines. Static stress analysis is conducted on connecting rod made up of two different materials viz. E-glass/Epoxy and Aluminium composite reinforced with Carbon nano tubes. Modelling and comparative analysis of connecting rod is carried out in commercially used FEM software ANSYS 14.0.

Conclusion From Literature Review of Connecting Rod

From REF.NO.4, We have identified the following problems: Von-Mises Stress and Equivalent Strain acting in the big end and small end of connecting rod plays an important role in maintaining it from breaking / damaging. In this regards, we start our project work to find out a solution to the above listed problem.

2.2 Literature Review For Static Thermal Analysis Of Piston

REF.NO.1: The finite element analysis is performed using CAD software to investigate and analyze thermal stress distribution at the real engine condition during combustion process. Piston skirt may appear deformation usually causes crack on the upper end of the piston head reduce the

REF.NO.2: Finite element analysis is used to analyze stresses in a piston of an internal combustion engine. The stresses due to combustion gas load only are considered so as to reduce the weight and hence to increase the power output of engine.

REF.NO.3: The materials with high thermal conductivity is considered better than the material type of low thermal conductivity.

REF.NO.4: Abdullah Cahit Karaoglanli, Kazuhiro Ogawa,Ahmet Türk and Ismail Ozdemir, - Thermal Shock and Cycling Behavior of Thermal Barrier Coatings (TBCs) Used in Gas Turbines has presented Gas turbine engines work as a power generating facility and are used in aviation industry to provide thrust by converting combustion products into kinetic energy. Basic concerns regarding the improvements in modern gas turbine engines are higher efficiency and performance. Increase in power and efficiency of gas turbine engines can be achieved through increase in turbine inlet temperatures.

Conclusion From Literature Review of Piston

From REF.NO.4, We have identified the following problems: Temperature distribution and heat flux (Heat per unit area) plays an important role in maintaining piston from weak / damage. In this regards, we start our project work to find out a solution to the above listed problem.

III. INTRODUCTION TO ENGINEERING DESIGN

3.1 Engineering Design

Engineering design is the creative process of identifying needs and then devising a solution to fill those needs. This solution may be a product, a technique, a structure, a project, a method, or many other things depending on the problem. The general procedure for completing a good engineering design can be called the Engineering Method of Creative Problem Solving.

3.2 GENERAL STEPS INVOLED IN ENGINEERING DESIGN

a) Identifying the problem.
b) Gathering needed information.
c) Searching for creative solutions.
d) Overcoming obstacles to creative thinking.
e) Moving from ideas to preliminary designs (including modelling).
f) Evaluating and selecting a preferred solution.
g) Preparing reports, plans, and specifications.

(Project Planning)

h) Implementing the design. (Project Implementation)

1V. INTRODUCTION TO SOLIDWORKS

SolidWorks is a solid modelling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes.

SolidWorks is a solid modeller, and utilizes a parametric feature-based approach to create models and assemblies. The software is written on Parasolid-kernel.

user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.

Features refer to the building blocks of the part.

Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines.

V. INTRODUCTION TO ANSYS

ANSYS is an engineering simulation software provider founded by software engineer John Swanson. It develops general-purpose finite element analysis and computational fluid dynamics software. While ANSYS has developed a range of computer-aided engineering (CAE) products, it is perhaps best known for its ANSYS Mechanical and ANSYS Multiphysics products.

V1.MODELLING COMMANDS USED IN SOLID WORKS

6.1 Sketch

This command is used to create the new sketch like circle, line, rectangle, ellipse, etc,.The Solid Works window selects the sketch icon and select the plane or surface want to sketch.

6.2 Circle

This command is used to create the circle. Create circle by picking the center point and a point on the circle from Right Toolchest. Pick the origin for the circle's center - pick a point on the circle's edge- click the middle mouse button – ok

.

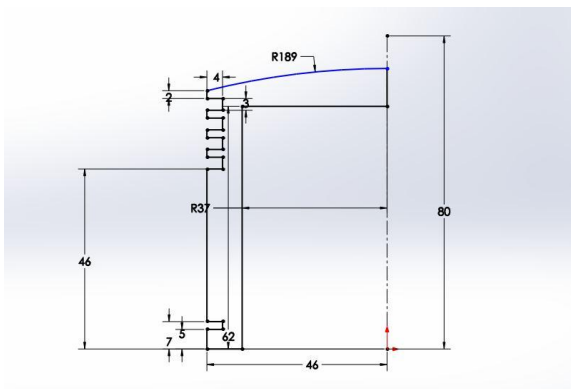### 6.3 Modeling of Piston in Soldidworks

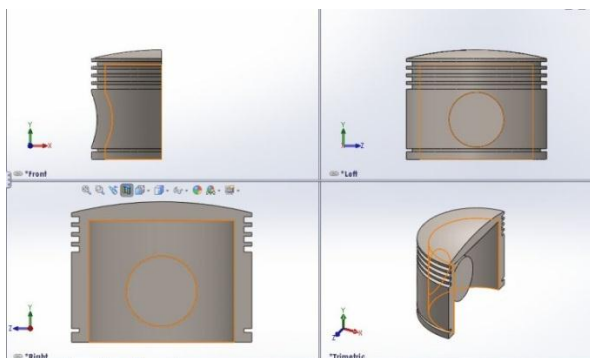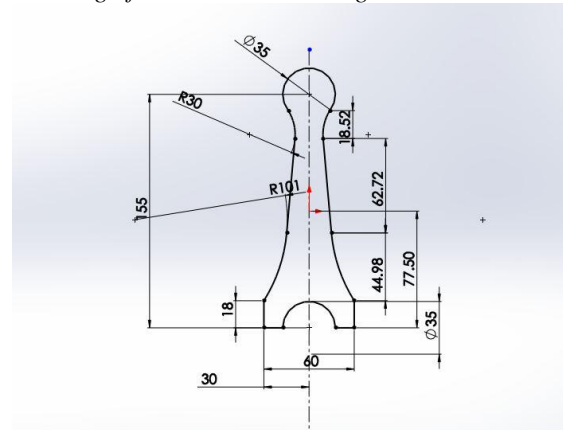

Figure 6.1 Modeling Stage 1 of Piston

Figure 6.2 Modeling Stage 2 of Piston

Modeling of Piston In Connecting Rod

Figure 6.3 Modeling Stage 1 of Connecting Rod

The beginning sketch is done with the help of line, Semi-cicle, Circle and Arc commands. The above sketch is for the piston base surface.

With the help of Extrude cut feature, small eye has been created at top portion of the connecting rod shown in the above figure.

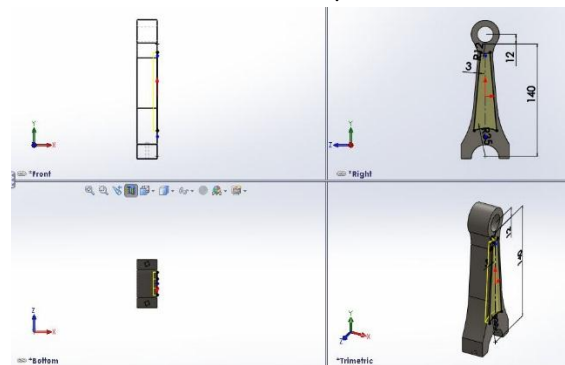T-section has been created and cut materials from that portions, following figure shown it clearly

.

Figure No.6.4 Modeling Stage 2 of Connecting Rod

Bottom piece of the connecting rod in big eye portion is created and as shown in following figure.

V11.THERMAL ANALYSIS PROCEDURE FOR PISTON

The 3D model of the axial flow propeller fan is converted as IGES format through the SOLID WORKS software. The IGES (International Graphic Exchange Specification) format is suitable to import in the ANSYS Workbench for analyzing.

7.1 Importing Geometry

- Open the ANSYS Workbench
- Create a new project on STEADY-STATE THERMAL
- Create new geometry
- File → import external geometry file → generate

7.2 Meshing

1. Open Mesh
2. Defaults → physical preference → Mechanical
3. Advanced → relevance centre → fine
4. 8Advanced → element size → default
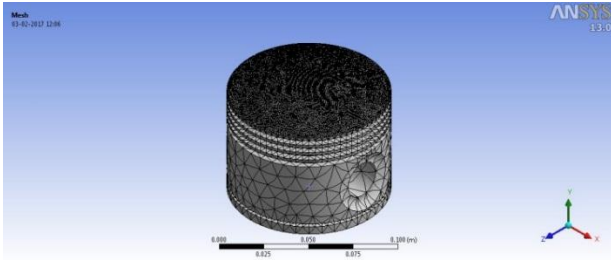5. Right click the mesh in the tree view → generate mesh

Special Issue - 2017

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
ETDM - 2017 Conference Proceedings

Figure 7.1 Piston after Meshing

7.3 Input Condition Setup
1. Click on top of Piston head and apply temperature input as 150^0C
2. Click on Convention → Select Geometry as Body (Entire Piston Body) → Film Coefficient as "Stagnant air in Simplified Case".

Then type "22^0C (ramped)" as Ambient Temperature & Click Apply

.4 Output Condition Setup
1. Click on Thermal → Temperature → Click on Apply
2. Click on Thermal → Total Heat Flux → Click on Apply
3. Click on Generate to get results.

Repeat the same steps to analyze for Piston with Aluminium Alloy AL4032.

V111.STATIC STRUCTURAL ANALYSIS ON CONNECTING ROD

The 3D model of the axial flow propeller fan is converted as IGES format through the SOLID WORKS software. The IGES (International Graphic Exchange Specification) format is suitable to import in the ANSYS Workbench for analyzing.

8.1 Importing Geometry
1. Open the ANSYS Workbench
2. Create a new project on STATIC STRUCTURAL.
3. Create new geometry
4. File → import external geometry file → generate

8.2 Meshing
1. Open Mesh
2. Defaults → physical preference → Mechanical
3. Advanced → relevance centre → fine
4. Advanced → element size → default
5. Right click the mesh in the tree view → generate mesh
6. Defaults → physical preference → Mechanical
7. Advanced → relevance centre → fine
8. Advanced → element size → default
9. Right click the mesh in the tree view → generate mesh

Figure 8.1 Connecting Rod after Meshing

8.3 Input Condition Setup
1. Right click on Static structural in tree view and select Force
2. Select geometry as "Small eye interior potion"
3. Type Value as 1.5e5 N (150KN) and click on Apply.
4. Right click on Static structural in tree view and select Fixed Support
5. Select geometry as "Big eye interior potion"
6. Click on Apply.

8.4 Output Condition Setup
1. Right click on Solution → Deformation → Click on Apply
2. Right click on Solution → Von-mises stress → Click on Apply
3. Right click on Solution → Equivalent Strain → Click on Apply
4. Click on Generate to get results.

Repeat the same steps to analyze for Connecting rod with Titanium Ti-6 Al-4v

1X.MATERIAL PROPERTIES

9.1 42CRMO$_4$ ALLOY STEEL
Material Properties of 42CrMo$_4$ Steel Alloy
42CrMo4 alloy steel is common chromium-molybdenum steel alloy of carbon (0.38% - 0.45%), manganese (0.60% - 0.90%), silicon (0.40% max), phosphorus (0.035% max), sulphur (0.035% max), chromium (0.90% - 1.2%), molybdenum (0.15% - 0.30%) that usually used after quenched and tempered, with high intensity, high hardenability.42CrMo4 round steel has better performance than 34CrMo4 steel due to carbon and chromium content is higher

Material Properties of 42CrMo$_4$ Steel Alloy

DESCRIPTION	VALUE
Density (Kg/m3)	7830
Young's modulus (GPA)	200
Poison Ratio	0.3
Bulk Modulus (GPA)	140
Shear Modulus (GPA)	80

9.2 TI-6AL-4V TITANIUM ALLOY
Ti-6Al-4V is an alpha-beta titanium alloy featuring high strength, low weight ratio and good corrosion resistance. It is one of the most commonly used titanium alloys and is applied in a wide range of applications where low density and good corrosion

Special Issue - 2017

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
ETDM - 2017 Conference Proceedings

resistance is necessary such as e.g. aerospace industry and biomechanical applications.

Chemical Composition of TI-6AL-4V Titanium Alloy

	V	AL	Fe	O	C	N	H	Y	Ti
Min	3.5	5.5	--	--	--	--	--	--	--
Max	4.5	6.75	.3	.2	.08	.05	.015	.005	Balance

Material Properties of TI-6AL-4V Titanium Alloy

DESCRIPTION	VALUE
Density (Kg/m3)	4429-4512
Young's modulus (GPA)	110-119
Poison Ratio	0.31-0.37
Bulk Modulus (GPA)	96.8-153
Shear Modulus (GPA)	40-45

9.3 Cast Iron

Material Properties of Cast Iron, Grey

DESCRIPTION	VALUE
Density (Kg/m3)	6800-7800
Young's modulus (GPA)	99.97
Poison Ratio	0.21-0.26
Bulk Modulus (GPA)	58-107
Shear Modulus (GPA)	41.37
Temperature (ºC)	21
Thermal Conductivity (W/mK)	47-80

X. RESULTS AND DISCUSSION

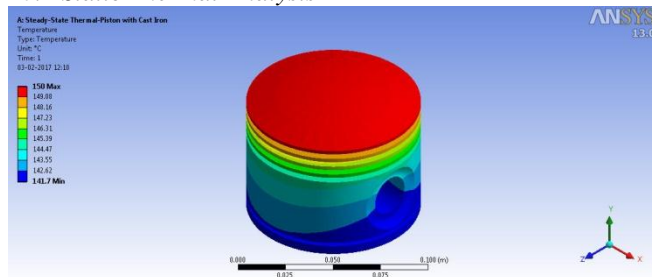*10.1 Static Thermal Analysis*

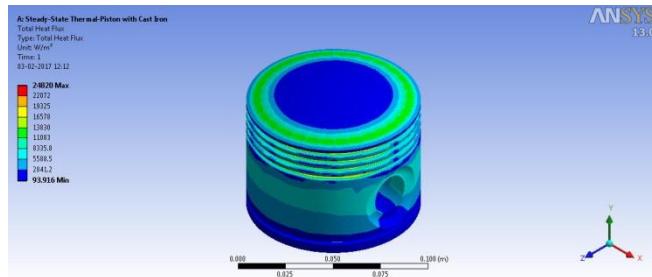

Figure 10.1 Temperature distribution of Piston with Cast Iron

Figure 10.2 Total Heat Flux of Piston with Cast Iron

Tabulation for Piston with Cast Iron

CAST IRON	MIN	MAX
Temperature (ºC)	141.7	150
Heat Flux (W/m)	93.916	24820

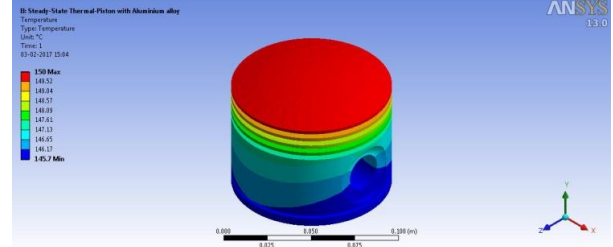*10.1.2 Result For Piston With Aluminium Alloy   AL4032*

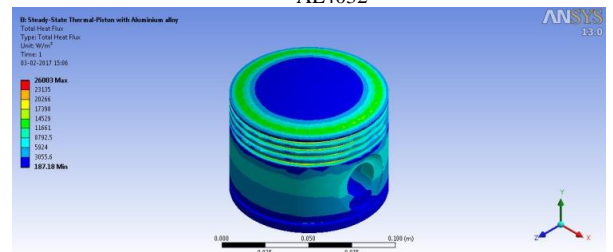Figure 10.3` Temperature distribution of Piston with Aluminium Alloy AL4032

Figure 10.4 Total Heat Flux of Piston with Aluminium Alloy AL4032

Tabulation for Piston with Aluminium Alloy   AL4032

AL4032	MIN	MAX
Temperature (ºC)	145.7	150
Heat Flux (W/m)	187.18	26003

10.2 Static Structural Analysis
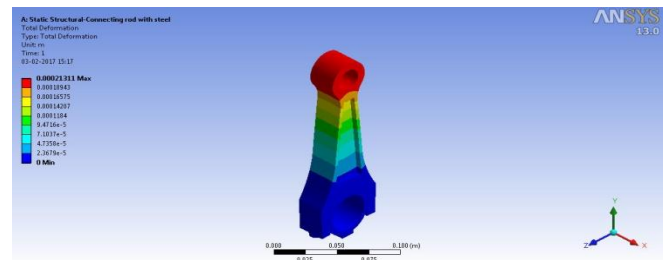
10.2.1 Result For Connecting Rod With Steel Alloy 42CRMO4

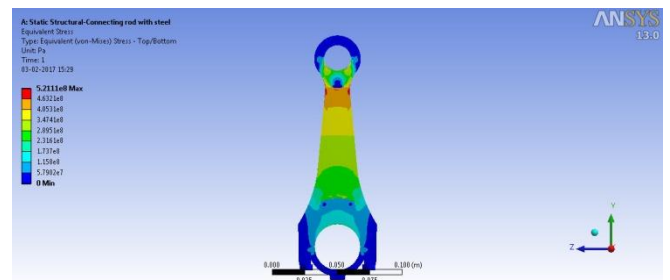Figure 10.5 Deformation of Connecting Rod with Steel Alloy 42CrMo4

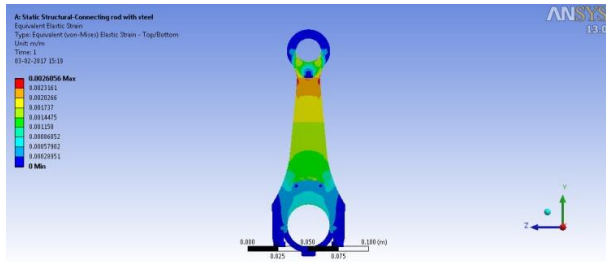Figure 10.6 Von-Mises Stress of Connecting Rod with Steel Alloy 42CrMo4

Special Issue - 2017

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
ETDM - 2017 Conference Proceedings

Figure 10.7 Equivalent Strain of Connecting Rod with Steel Alloy 42CrMo$_4$

Tabulation for Connecting Rod with Steel Alloy 42CrMo$_4$

42CRMO$_4$	MIN	MAX
Deformation (m)	0	0.00021311
Von-Mises Stress (MPa)	0	521.11
Equivalent Strain (m/m)	0	0.0026056

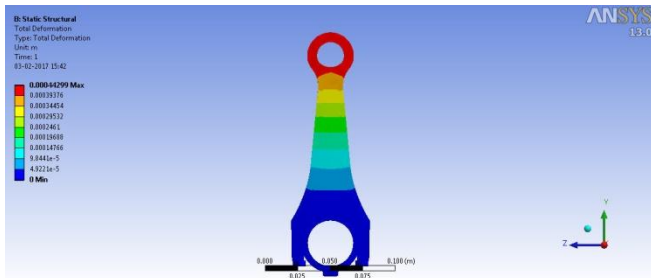*10.2.2 RESULT FOR CONNECTING ROD WITH TITANIUM TI-6AL-4V ALLOY*

Figure 10.8 Deformation of Connecting Rod with Titanium TI-6 AL-4V
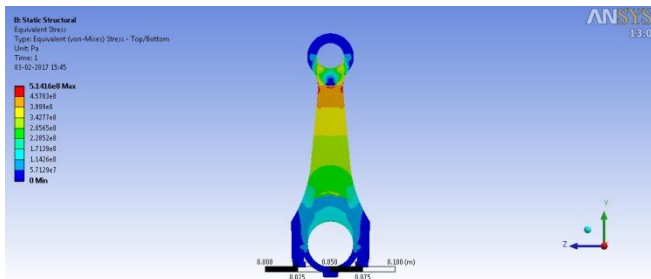

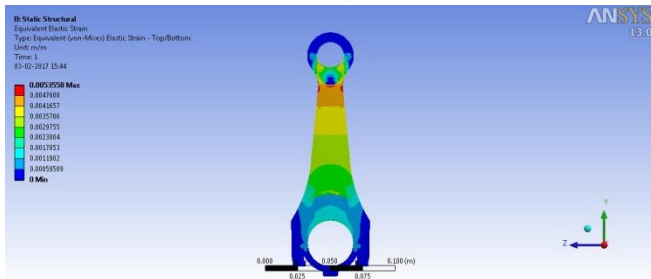Figure 10.9 Von-Mises Stress of Connecting Rod with TitaniumTI- 6 AL-4V

Figure 10.10 Equivalent Strain of Connecting Rod with Titanium

Tabulation for Connecting Rod with Titanium TI-6 AL-4V

TI-6 AL-4V	MIN	MAX
Deformation (m)	0	0.00044299
Von-Mises Stress (MPa)	0	514.16
Equivalent Strain (m/m)	0	0.0053558

X1.CONCLUSION

For Connecting rod, the conclusion of this analysis that the connecting rod can be designed and optimized under a load range comprising compressive load as one extreme load and tensile load. Furthermore, the existing connecting rod can be replaced by optimization with a new connecting rod made of lighter in weight. For Piston analysis, the minimum temperature at the piston with Cast Iron is 141.7^{0}C but in case of Aluminium Alloy minimum temperature is 145.7^{0}C, from this we can say that cast iron have low temperature gradient tha aluminium alloy. And also, Cast iron have less Heat flux (Heat occupied per unit area) compared to Aluminium alloy.So Cast iron will be best among Aluminium alloy.

REFERENCE

[1] Afzal, A. and A. Fatemi, 2004. "A comparative study of fatigue behavior and life predictions of forged steel and PM connecting rods". SAE Technical Paper

[2] A.Atish Gawale, A. Shaikh and Vinay Patil, "Nonlinear Static Finite Element Analysis and Optimization of connecting rod World Journal of Science and Technology, Vol. 2(4), pp .01-04, 2012.

[3] R. Bhagat, Y. M. Jibhakate, Thermal Analysis and Optimization of I.C. Engine Piston Using Finite Element Method, International Journal of Modern Engineering Research (IJMER), Vol.2, Issue.4, pp.2919-2921, 2012.

[4] R.S.Khurmi,J.K.Gupta, A Text Book of Machine Design, S.Chand & Co., pp. 1132-1144, 2004.