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DESIGN AND ANALYSIS OF TWIN PISTONS MOUNTED WITH SINGLE CONNECTING ROD

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ABSTRACT

In the last ten years, the mechanical power output of car and bike engines are increased significantly. Currently, the improvement of fuel economy is the most important issue in automobile engine development. In this paper mainly concentrates on the connecting rod of the I.C engine. Connecting rod is the mediator between the piston and the crank. Its function is to transmit the thrust from the piston pin to crank pin, thus converting the reciprocating motion of the piston to rotary motion of the crank. Generally one piston mounted the single connecting rod and also connecting rod is manufactured using carbon steel and in recent days aluminium alloys are used for manufacture the connecting rods. In this work, twin pistons mounted with single connecting rod. Further, existing connecting rod material also replaced by Al360, Beryllium alloy and magnesium alloy. Modelling and analysis of twin pistons mounted with single connecting rod is performed by Creo and Ansys. FEA analysis was carried out by considering three materials Al360, beryllium alloy and magnesium alloy. In this paper a solid 3D model of Connecting rod was developed by using CREO software and stress and deformation analysis was carried out by using ANSYS 12.0 Software. By implementing this modification in an engine which improve the mileage, power output, reduce the fuel droplets, exhaust emissions, unburned gases, and reduces weight of the engine.

I. INTRODUCTION

An internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. An internal combustion engine is an engine that creates

Its energy by burning fuel inside itself. This paper mainly considered on various stresses acting on connecting rod during its operation. Now a days, engines require higher speed and power need of connecting rod with higher strength and stiffness, but must be lighter in weight and size. Materials used for manufacturing of connecting rod is either carbon steels or alloy steels.

Generally carbon steel is used for manufacturing of connecting rod and in recent days aluminium alloys are finding its application in connecting rod because they are lighter. This causes to increase the overall engine performance. In this paper the Alternative material is used for manufacturing of connecting rod like Al360, Beryllium alloy and magnesium alloy.

The concept model of connecting rod was developed by using Creo software and total deformation and stress results are taken for applying the materials like Al360, Beryllium alloy and magnesium alloy from the Analysis 12.0 software.

II. THEORITICAL DESIGN OF CONNECTING ROD

THEORITICAL DESIGN

A connecting rod is a machine member

Which is subjected to alternating direct Compressive and tensile forces. Since the compressive forces are much higher than the tensile forces therefore the cross section of the connecting rod is designed as a strut and the Rankine's formula is used.

A connecting rod subjected to an axial load W may buckle with X axis as neutral axis or Y axis as neutral axis. The connecting rod is considered like both ends hinged for bucking about X axis and both ends are fixed for buckling about Y axis. A connecting rod should be equally strong in buckling about other axes. In order to have a connecting rod equally strong in buckling about both the axes, the buckling loads must be equal.

$K^2xx = 4 K^2yy$ ………… (2.1)

$Ixx = 4 Iyy$…………….. (2.2)

This shows that the connecting rod is four times strong in buckling about Y axis than about X axis. If $Ixx > 4 Iyy$, then buckling will occur about y axis and if $Ixx < 4 Iyy$, buckling will occur about X axis. In actual practice Ixx is kept slightly less than 4 Iyy. It is usually taken between 3 and 3.5 and the connecting rod is designed for buckling about X axis. The design will always be satisfactory for buckling about Y axis.The most suitable section for the connecting rod is I section with the proportions as shown in Figure 2.1.

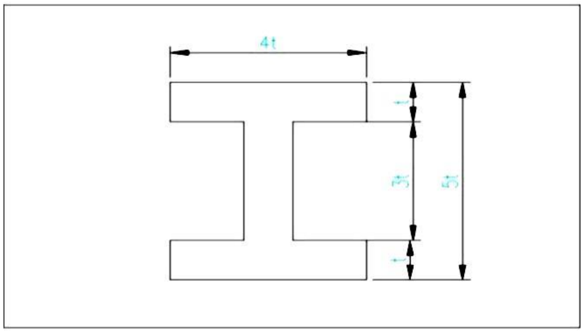


Fig. 2.1.Connecting rod cross section

Area of the section = $2 (4 \times t \times t) + (3 \times t \times t)$

…… (2.3)

Area of the section = $11t^2$ Moment of inertia about X axis

$Ixx = (4t \times (5t)^3 - 3t \times (3t)^3)/12$ .... (2.4)

$Ixx = 419 t \times t^3 /12$

Moment of inertia about Y axis

$Iyy = (2t \times (4t)^3 + 3 \times t \times t^3)/12$ ……... (2.5)

$Iyy = 131\ t \times t^3 / 12$

$Ixx/Iyy = (419 \times 12)/ (12 \times 131)$

$Ixx/Iyy = 3.2$ …………… (2.6)

Since the values of Ixx/Iyy lies between 3 and 3.5 therefore I section chosen is quite satisfactory.

FORCES ACTING ON THE CONNECTING ROD

A connecting rod is subjected to the following forces.

1. Force due to gas or steam pressure and inertia of reciprocating parts and
2. Inertia bending forces.

FORCE DUE TO GAS OR STEAM PRESSURE

It may be noted that in a horizontal engine reciprocating parts are accelerated from rest during the first half of the stroke. (When the piston moves from inner dead center to outer dead center). It is then retarded during the latter half of the stroke. The inertia force due to the acceleration of reciprocating parts opposes the force on the reciprocating parts helps the force on the piston.

Fp = force due to pressure+ inertia force

Inertia force per unit length at the crank pin= $m_1 \times w^2 \times r$

Where, m1= mass (Kg per unit length)

W= Buckling load on the piston and r= Radius of the connecting rod.

Inertia force per unit length at the gudgeon pin = 0 and,

Maximum bending stress due to inertia of the connecting rod, $F_{max} = M_{max} / Z$

Where, F_{max} = Maximum force of the connecting rod.

M_{max} = Maximum bending moment of the connecting rod.

Z = section modulus.

III. LITERATURE SURVEY

G.Sailaja and S. Irfan Sadaq (2012)

Carried out the static and modal analysis to determine the dynamic behavior of connecting rod by considering deformation, strain and stresses when made with Beryllium alloy using Ansys software. These parameters help in identifying a section of failure due to stresses induced.

Ambrish Tiwari et.al., (2014)

done the complete connecting rod Finite Element Analysis (FEA) methodology to explore weight and cost reduction opportunities for a production of forged steel connecting rod. They performed a fatigue study based on Stress Life (SxN) theory, considering the Modified Goodman diagram.

Nikhil U.Thakare et.al, (2015)

carried out the connecting rod is replaced by aluminium based composite material reinforced with silicon carbide and fly ash and it also describes the modeling and analysis of connecting rod. FEA analysis was carried out by considering two materials of connecting rod for 180cc engine and the software gives a view of stress distribution in the whole connecting rod which gives the information that which parts are to be hardened or given attention during manufacturing stage.

IV. MODELLING OF CONNECTING ROD

FEATURE BASED MODELING

Models are created in Creo by building features. These features have intelligence, in that they contain knowledge of their environment and adapt predictably to change.

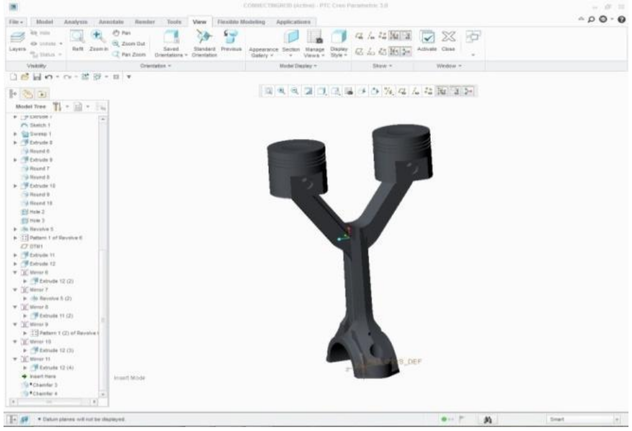


Fig. 4.1 Creo Modelling of New

Connecting Rod

COVER

Fig. 4.2 Cover for connecting rod

Volume = 2.1879024e+04 mm^3

Surface Area = 1.0710839e+04 mm^2

DISTANCE PIECE

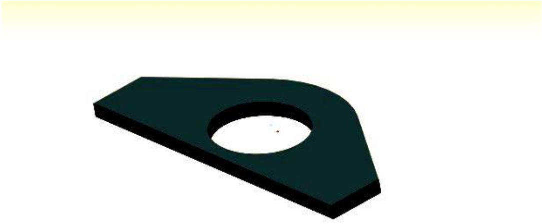


Fig. 4.3 Distance Piece Volume = 1.0222913e+03 mm^3 Surface Area = 1.0393000e+03 mm^2

M10 NUT

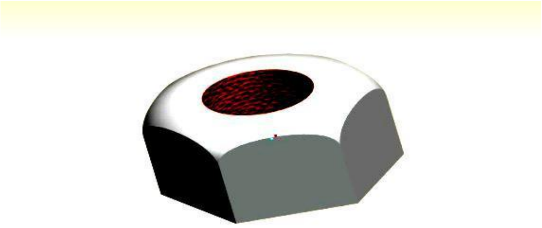


Fig. 4.4 M10 Nut

Volume = 2.7745789e+03 mm^3

Surface Area = 1.5837742e+03 mm^2

STUD

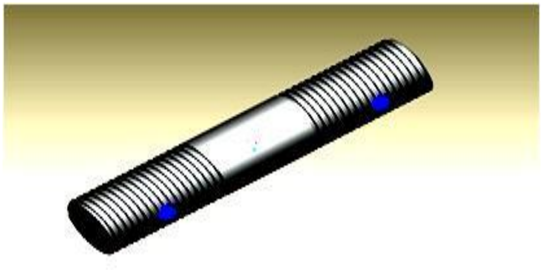


Fig.4.5 Stud

Volume = 3.5707203e+03 mm^3

Surface Area = 2.2682509e+03 mm^3

3D MODELLING IN CREO

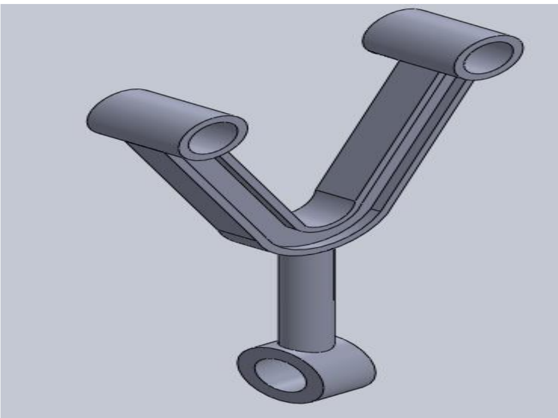


Fig. 4.3 Distance Piece

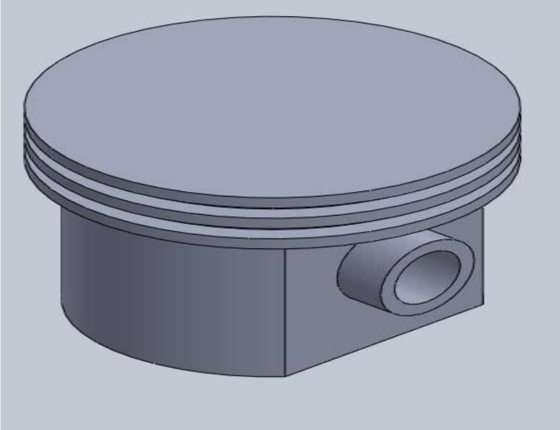


Fig. 4.7 Isometric View of the Piston

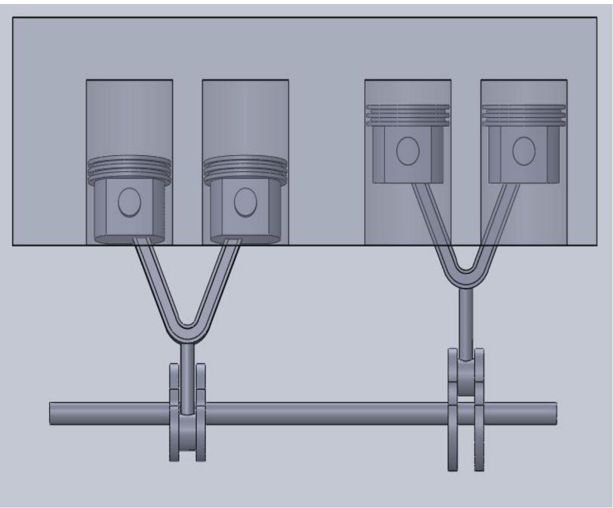


Fig. 4.8 Connecting Rod Assembly

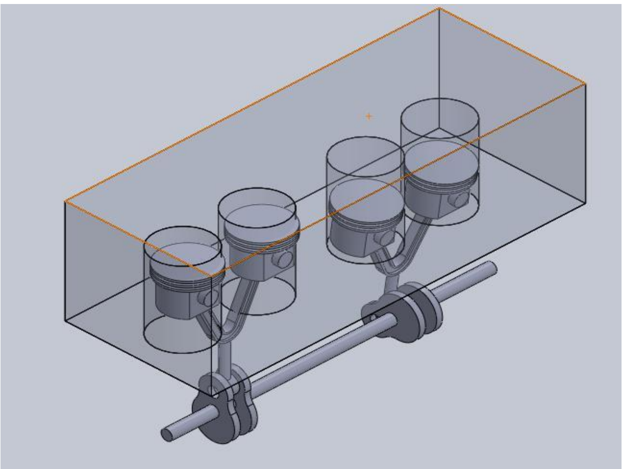


Fig. 4.9 Isometric view of Engine Assembly

BILL OF MATERIALS

Bill of materials (BOM) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture an end item (final product). It may be used for communication between manufacturing processes, or confined to a single plant.

The table 4.1 represents the Bill of materials of the concept model of the connecting rod.

Table.4.1 Bill of Materials

Sl.No	**DESCRIPTION**	**MATERIAL**	**QUANTITY**
1	Base Frame	Mild steel	4 No’s
2	Cylinder assembly	EN 18	2 No’s
3	Connecting Rod set	Forged steel	1
4	Piston assembly	Aluminium alloy	2 No’s
5	Crankshaft	Stainless steel	1

V. ANALYZING

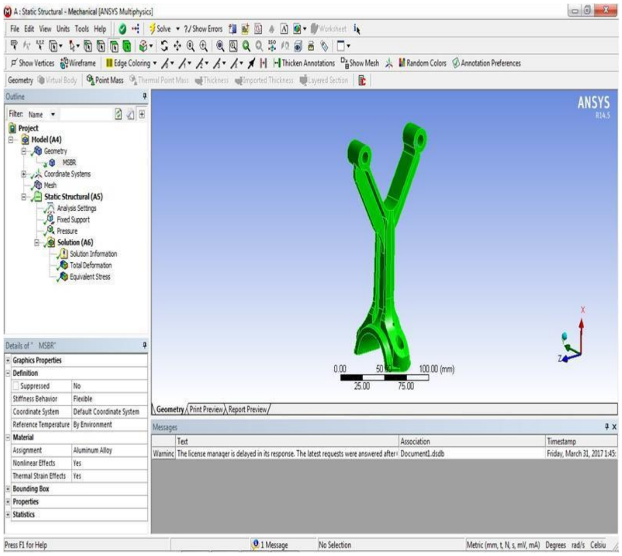
ANSYS Program is a general purpose program for almost any type of Finite Element analysis in any industry. General purpose also refers to the fact that the program can be suited in all disciplines of engineering.

The ANSYS program offers the following approaches to model generation:

1. Creating a solid model with ANSYS
2. Using direct generation
3. Importing a model created in a Computer-Aided Design (CAD) system.

STEPS INVOLVED IN MODEL GENERATION

1. Enter the pre-processor (PREP7) to initiate the model building session. Most often, model will build using solid modelling procedures.
2. Establish a working plane.
3. Generate basic geometric features using geometric primitives and Boolean operators.
4. Activate the appropriate coordinate system.
5. Generate other solid model features from the bottom up. That is, create key points, and then define lines, areas and volumes as needed.
6. Use more Boolean operators or number controls to join separate solid model regions together as appropriate.
7. Create tables of elements attributes (element types, real constants, material properties, and element coordinate systems).
8. Set element attributes pointers.
9. Set meshing controls to establish the desired mesh density if desired
10. Create nodes and elements by meshing the solid model.
11. After generated nodes and elements, add features such as surface to surface contact elements, coupled degrees of freedom, and constraint equations.
12. Save the model data to Job named.
13. Exit pre-processor.



Details of "MSBR"

Graphics Properties	
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Aluminum Alloy
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Statistics	

	Text	Association	Timestamp
Warninc	The license manager is delayed in its response. The latest requests were answered after	Document1.dsdb	Friday, March 31, 2017 1:45:

Fig. 5.1 IGS File Imported from Creo

SOLID98 ELEMENT DESCRIPTION

SOLID98 is a 10-node tetrahedral version of the 8-node solid5 element. The element has quadratic displacement behaviour and is well suited to model irregular meshes (such as produced from various CAD/CAM systems). SOLID 98 has large deflection and stress stiffening capabilities the element is defined by ten nodes with up to 6 degrees of freedom at each node. The loads acting in the component are given as input in structural analysis.

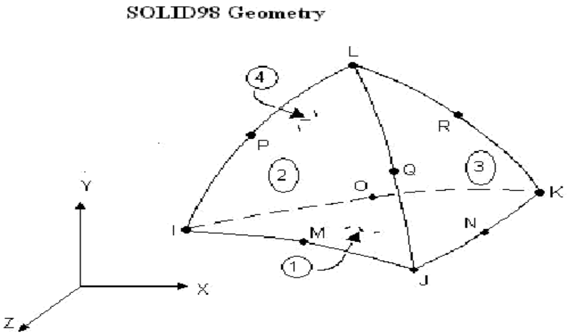
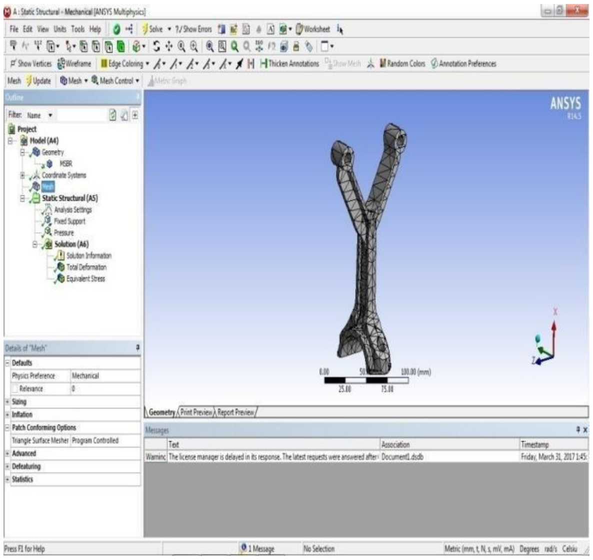


Fig. 5.2 Solid 98 element



Details of "Mesh"

Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Inflation	
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Advanced	
Defeaturing	
Statistics	

Messages

	Text	Association	Timestamp
Warninc	The license manager is delayed in its response. The latest requests were answered after	Document1.dsdb	Friday, March 31, 2017 1:45

Fig. 5.3 Meshing Model

VI. STRESS & TOTAL DEFORMATION ANALYSIS

ANSYS program is a general purpose program for almost any type of Finite Element Analysis virtually in any industry. ANSYS program has a comprehensive graphical user interface (GUI) that gives users easy, interactive access to program functions, commands, documentation and reference material.

The following shows the three stages involved for the analysis:

- Pre-processing
- Execution
- Post processing

This project mainly considered on various stresses acting on connecting rod during its operation. The stresses acting on connecting rod are axial and bending stresses. Because of high speed, the stress generated in connecting rod increases, if this stress exceeds the designed parameter failure of connecting rod takes place. In this project the alternative material is used for manufacturing of connecting rod like Al360, Beryllium alloy and magnesium alloy. The concept model of connecting rod was developed by using Creo software and total deformation and stress results are taken for applying the materials like Al360, Beryllium alloy and magnesium alloy from the Analysis 12.0 software.

The input pressure ranges provide to the connecting rod like 2000 bar and the temperature range like 400-450^0 c.

FAILURE ANALYSIS OF CONNECTING ROD

In normally the input pressure ranges of the I.C Engine connecting rod is to be 2000 Mpa. When increase the pressure up to 2500 Mpa then the fuel droplets are reduced in the I.C. Engine. So, the exhaust emissions are reduced. The above factors are based upon merit of this project and when increase the pressure the pressure ranges of the engine, the connecting rod material is affected and deformed. Basically, the material is not deformed when it does not cross the yield strength (or) working stress. So, when it reaches the yield strength of the particular material the materials are to be deformed. The yield strength of the Aluminium is 276×10^6 N/m^2, Magnesium is 130 $\times10^6$ N/m^2 and Beryllium is 240×10^6 N/m^2.

TABLE FOR ANALYSIS RESULTS

Table. 6.1 Total Deformation of Connecting Rod

Sl. No	**MATERIAL**	**DEFORMATION in mm**
1.	ALUMINIUM	0.3115
2.	MAGNESIUM	0.4922
3.	BERYLLIUM	1.68E-07

Table. 6.2 Stress of Connecting Rod

Sl.No	**MATERIAL**	**STRESS in Pascal**
1.	ALUMINIUM	94.87×10^6
2.	MAGNESIUM	94.96×10^6
3.	BERLIYUM	94.67×10^6

According to all the deformation results of the three materials (Table 6.1), aluminium having lesser deformation compared to the magnesium and also both aluminium and magnesium having greater deformation compared to the beryllium material. So, the final result is total deformation analysis of the connecting rod, the beryllium have the capability of the very less deformation. So, this one is the alternative material for using the connecting rod.

According to all the stress results (Table 6.2) of the three materials, aluminium having lesser stress induced (94.87×10^6 Pa) compared to the magnesium (94.96×10^6 Pa) and also both aluminium and magnesium having greater stress induced compared to the beryllium material(94.67×10^6 Pa). So, the final result is stress analysis of the connecting rod, the beryllium have the capability of the very less stress. So, this one is the alternative material for using the connecting rod.

ANALYSIS RESULTS OF MATERIALS

STRESS RESULTS

TOTAL DEFORMATION RESULTS

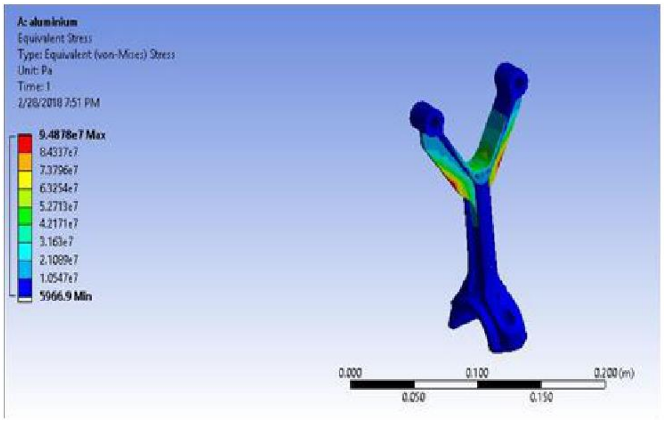


Fig.6.1 Stress of Aluminium (94.87 Mpa)

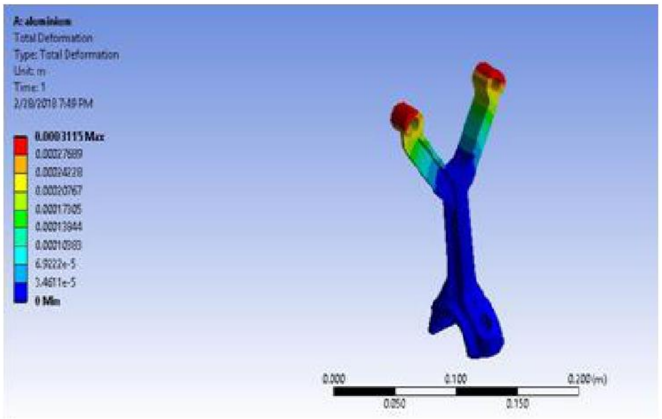


Fig.6.2 Total Deformation of Aluminium (0.31mm)

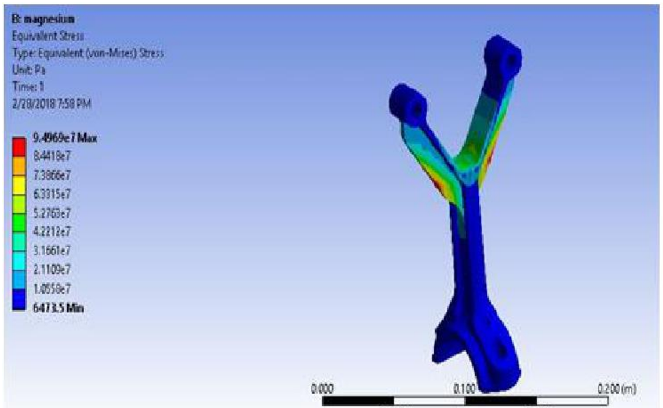


Fig.6.3 Stress of Magnesium (94.96 Mpa)

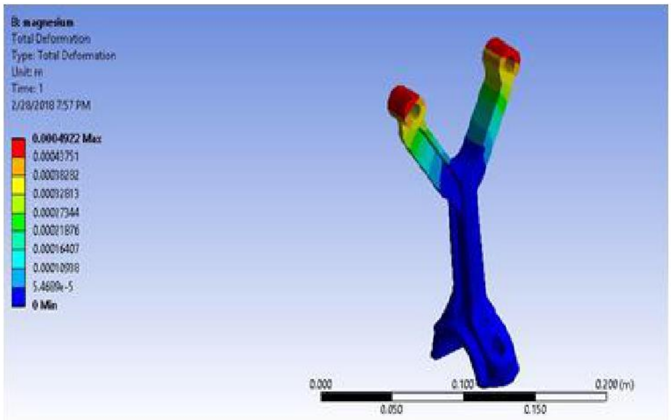


Fig.6.4 Total Deformation of Magnesium (0.49 mm)

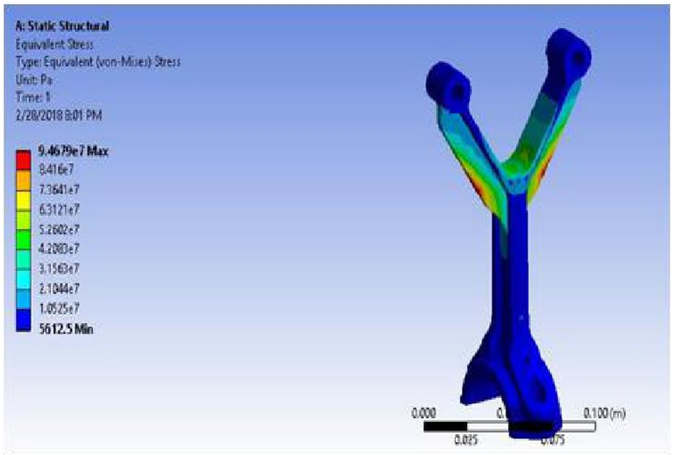


Fig.6.5 Stress of Beryllium (94.67 Mpa)

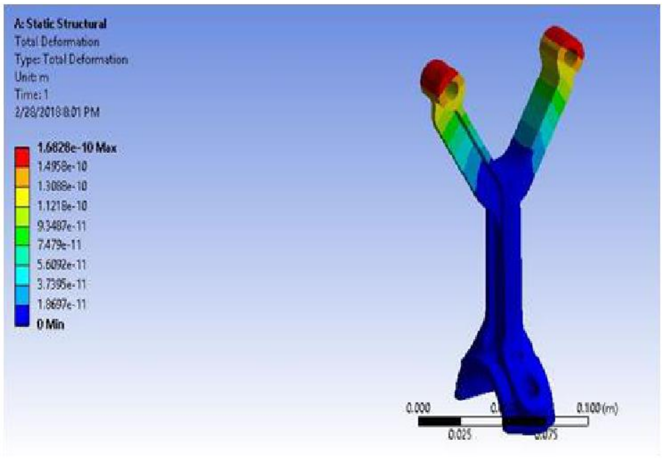


Fig.6.6 Total Deformation of Beryllium (1.6E-7 mm)

FAILURE ANALYSIS RESULTS

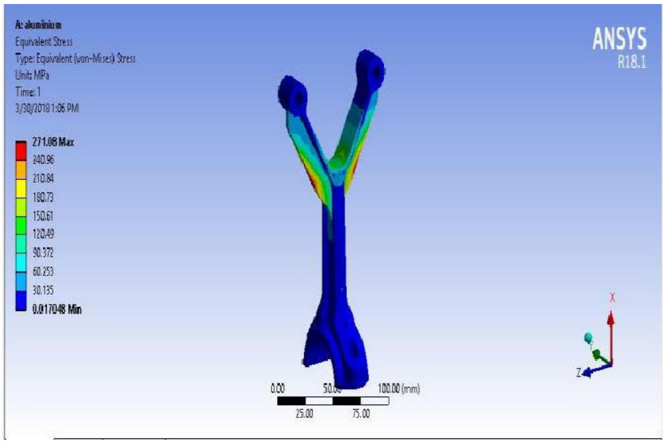


Fig.6.7 Stress of Aluminium (279 Mpa)

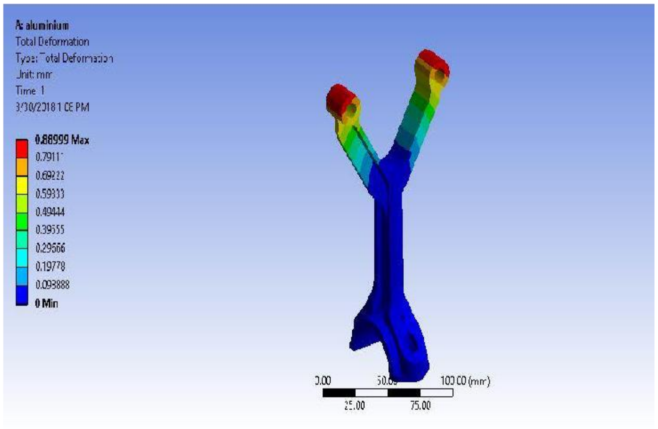


Fig.6.8 Total deformation of Aluminium (88 mm)

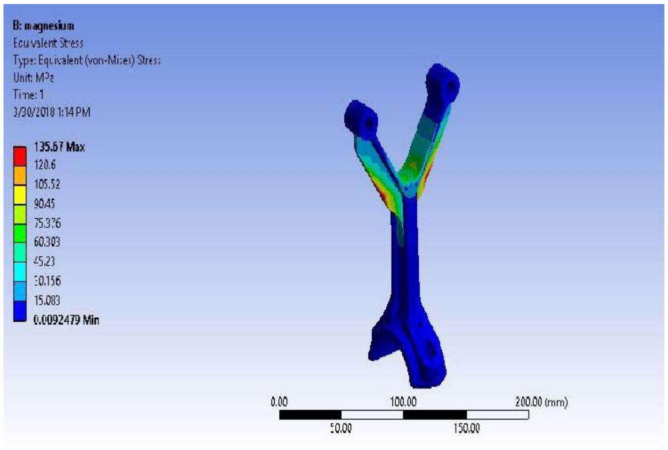


Fig.6.9 Stress of Magnesium (135.67 Mpa)

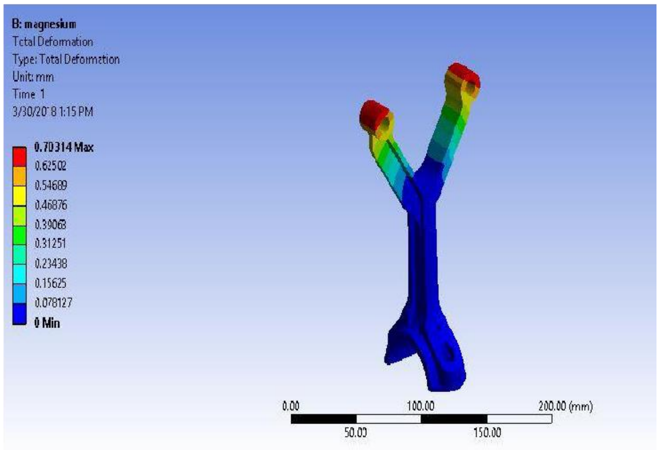


Fig.6.10 Total Deformation of Magnesium (70 mm)

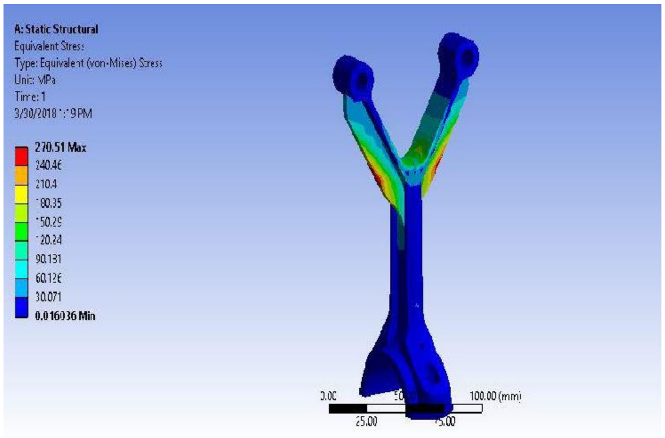


Fig.6.11 Stress of Beryllium (270 Mpa)

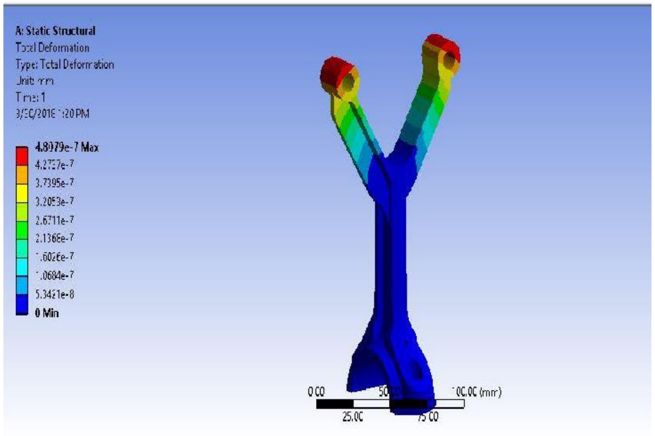


Fig.6.12 Total Deformation of Beryllium (480 mm)

VII. RESULTS & DISCUSSIONS

GRAPHICAL COMPARISONS OF DIFFERENT MATERIALS

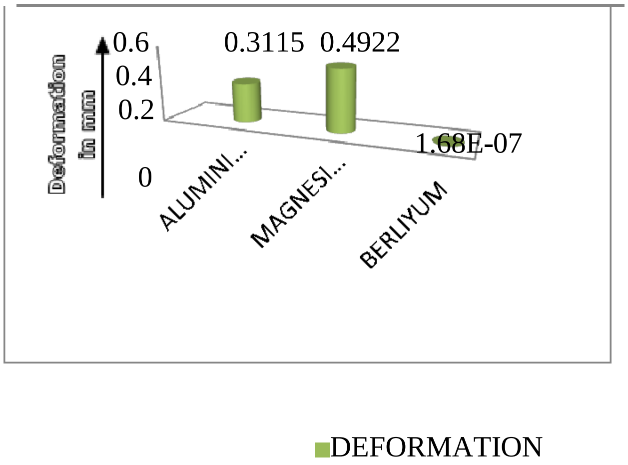


Fig. 7.1 Graphical Representation of

Deformation

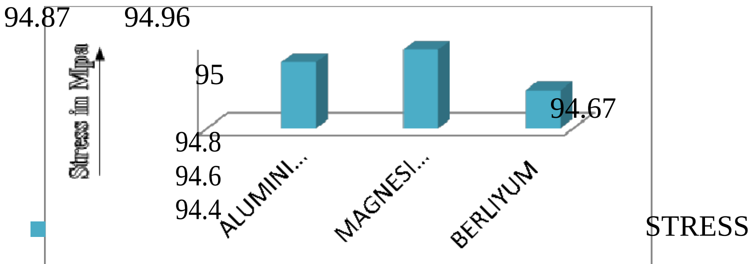


Fig. 7.2 Graphical Representation of

Stress

Generally one piston mounted the single connecting rod and also connecting rod is manufactured using carbon steel and recent days for aluminium alloy. Now days the Connecting rods are made up of aluminium silicon alloy, which expands enormously due to generation of heat in the piston. This will affect clearance volume and insufficient clearance can cause the piston size in the cylinder. To reduce the expansion and to analyze the various characteristics of Connecting rod like stress, deformation, density, and Young’s modules and poison’s ratio, the material of the connecting rod is modified and analyzed.

For example, take a six cylinder engine. The recent day models of the engines which have the six cylinders and each piston mounted with the cylinders. Similarly, each connecting rod mounted with each cylinder. This project represents the twin pistons mounted with the single connecting rod. For a same example, six cylinders IC Engine the first 2 cylinder pistons are mounted with the single connecting rod. The next 2 pistons mounted with the single connecting rod and same as the last 2 pistons mounted with the single connecting rod. So, totally the six connecting rods are reduced into three connecting rods. Due to this reason, the whole weight of the engine is to be reduced and also the connecting rod material is changed by beryllium material using this material provides low density, stress induced and low deformation occurred. The weight of the beryllium material is low. So, engine weight is reduced. Due to reduction of weight, the power output of the engine is to be increased that is speed output efficiency of the engines are increased. Due to, combination of the twin pistons with the single connecting rods the power output is to be increased. That is, the firing order is to be combined from 1-5-3-6-2-4 to (1-2)-(5-6)-(3-4). So, fuel droplets are reduced. For analysis of connecting rod model the ANSYS software is used. The structural analysis on the connecting rod is done by changing different materials under same loading conditions and same dimensions of the connecting rod. The theory of von- mises Theory is used for calculating the stress induced in the connecting rod when it is in heavy loaded conditions. For the current manufacturing condition, it was necessary to investigate finite element modelling techniques, optimization techniques, and developments in new materials, fatigue modelling, and material cost analysis for connecting rod which are made by large volume production.

Table.7.1 Result Comparisons

Sl. No	**MATERIAL**	**STRESS in Mpa**	**DEFORMATION in mm**
1.	ALUMINIUM	94.87	0.3115
2.	MAGNESIUM	94.96	0.4922
3.	BERLIYUM	94.67	1.68E-07

VIII. MERITS AND APPICATIONS

MERITS

1. The Number of connecting rods is reduced.
2. Reduces the weight of the both four cylinder and six cylinder engine.
3. Reduces the unburned gases inside the engine.
4. Reduces the fuel droplets in the engine.
5. Increases the power output of the engine.
6. Reduces the exhaust emissions.

APPLICATIONS

The following war air craft’s having the twin pistons with single connecting rod.

1. Beech craft Baron G58 Air craft
2. Piper Seminole PA-44 Air craft
3. Piper Seneca Air craft

IX. CONCLUSION

- This paper mainly concentrates on designed a twin piston mounted with single connecting rod. Modelling and developing the concept model of connecting rod using Creo software and analyze the connecting rod by using Ansys software.

- Analyzing the connecting rod by Ansys software for three different materials namely 1. Al360, 2. Magnesium alloy, 3. Beryllium alloy.

- Stress analysis and deformation analysis are carried out by using Ansys 12.0 software. From the analysis,

  Beryllium (stress-94.67×10^{5} and Deformation-$1.68E\times10^{-7}$) better than other materials. This beryllium is suitable for connecting rod manufacturing.

X. REFERENCES

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