MODAL ANALYSIS OF CONNECTING ROD WITH DIFFERENT MATERIALS USING ANSYS

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Abstract: In an automobile engine, the connecting rod is one of the most crucial components. Between the piston and the crankshaft, the connecting rod serves as a link. Its main job is to transfer the push and pull from the piston pin to the crank pin, transforming the piston's reciprocating motion into the crank's rotating motion.

Internal engine connecting rods are typically made of steel and aluminium alloys (for light weight and high impact load absorption) or titanium (for higher performance engines at a higher cost) or composite materials. Composite materials are made up of two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics that are distinct from the individual components. Within the finished construction, the constituent components stay separate and distinct. For a variety of reasons, the new material may be preferred: Materials that are stronger, lighter, or less expensive than standard materials are common examples.

This research investigates the finite element analysis of connecting rods used in single-cylinder four-stroke petrol engines. Connecting rods made of various materials, such as medium carbon steels, aluminium alloys, and magnesium alloys, are subjected to modal analysis. The connecting rod is modelled in SOLIDWORKS and compared using the commercially available FEM programme ANSYS Software. By securing the piston end and applying load to the connecting rod's crank end, a modal analysis was performed. Total deformation for the given loading conditions is the output parameter in Modal analysis.

Keywords: CONNECTING ROD, PISTON, COMPOSITE, MODAL ANALYSIS, SOLIDWORKS, ANSYS, FEM.

1.INTRODUCTION:

1.1 CONNECTING ROD:

Between the piston and the crankshaft lies the connecting rod, which serves as a link. Its main job is to transfer the push and pull from the piston pin to the crankpin, converting the piston's reciprocating motion into the crank's rotary motion. In internal combustion engines, the connecting rod usually takes the shape depicted in Fig.1. A long shank, a little end, and a large end make up the structure. The shank can be rectangular, circular, tubular, I-section, or H-section in cross-section. Low-speed engines are often built with a circular shape, while high-speed engines are built with an I-section.

The ratio of l / r, where r is the radius of the crank, determines the length of the connecting rod (l). It should be noticed that as the length decreases, the ratio l / r decreases. This increases the angularity of the connecting rod, increasing the side thrust of the piston on the cylinder liner, and therefore increasing liner wear. The greater the length of the connecting rod, the greater the l / r ratio. This reduces the angularity of the connecting rod, reducing side thrust and the cylinder's wear as a result. The longer connecting rod, on the other hand, raises the engine's total height. As a result, a compromise is reached, and the l/r ratio is often maintained at 4 to 5.

The small end of the connecting rod is commonly shaped like an eye and fitted with a phosphor bronze bush. It has a piston pin that connects it to the piston.

The connecting rod's big end is frequently split (in two pieces) so that it may be readily placed on the crankpin bearing shells. Two cap bolts secure the split cap to the large end. The huge end bearing shells are made of steel, brass, or bronze with a thin coating of white metal or Babbitt metal (approximately 0.75 mm).

Connecting rods are often made using a drop forging process and should have sufficient strength, stiffness, and weight. Connecting rods are often made of mild carbon steels (containing 0.35 to 0.45 percent carbon) or alloy steels (chrome-nickel or chrome- molybdenum steels). When appropriately heat treated, carbon steel with 0.35 percent carbon has an ultimate tensile strength of around 650 MPa, and carbon steel with 0.45 percent carbon has an ultimate tensile strength of about 750 MPa. The alloy steels, which have an ultimate tensile strength of roughly 1050 MPa, are employed in the connecting rods of aircraft engines and vehicle engines.

Fig.2 Two-Wheeler Connecting Rod

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1.2 Types of Connecting Rod:

Following are the types of connecting rod, used in various types in engines:

1. Plain type rod
2. Fork and blade rod
3. Master and slave rod
4. Billet conrods
5. Cast rods
6. Forged rods
7. Powered metal conrods

1.3 Connecting Rod Errors:

A connecting rod is often subjected to large and repetitive forces during each rotation of the crankshaft. These created forces are proportional to the speed of the engine (RPM). While the connecting rod is continuously working in the crankshaft, it may damage or break. Following are the faults of a connecting rod:

1. Fatigue
2. Hydro lock
3. Over revving
4. Pin failure

1.3.1 Fatigue

Fatigue often occurs because the compression and stretch of the rod happen most of the time during the process. Eventually, this causes to wear of the rod till it gets breaks. Lack of oil and the presence of dirt in the engine can exacerbate this problem. This is the most common type of defect and often occurs in older engines as well. If the engine is rebuilt, you may also experience fatigue in adding a new engine. Well, this happens when cheap parts or wrong parts are used.

1.3.2 Hydro lock

Hydro lock occurs when water enters the piston chamber causing deformation of the connecting rod. This may occur when vehicles pass through a flooded road. A little drop of water in the cylinder can produce knocking or tapping in the engine. That can be easily corrected. But, if there is too much water in the cylinder, the spark is all over the place for a period of time, causing the cylinder rod to tilt or break.

1.3.3 Over Raving

Over raving is another type of fault of the connecting rod. That occurs in new and high-performance engines. If the tachometer displays a red colour, it indicates that the position of the connecting rod is in danger. This is because of forces working on the con rod rise dramatically at higher revolutions.

1.3.4 Pin Failure

Sometimes the piston pin is also damaged and results in catastrophic engine failure. This occurs when the connecting rod moves into the engine block or when the crankshaft is bent. In some engines, it can cause heavy power loss. The engine stops immediately when the pin breaks due to this problem. There is a possibility that the engine has survived, otherwise, a total breakdown may occur.

1.4 Forces Acting on the Connecting Rod:
The various forces acting on the connecting rod are as follows:

1. Force on the piston due to gas pressure and inertia of the reciprocating parts,
2. Force due to inertia of the connecting rod or inertia bending forces,
3. Force due to friction of the piston rings and of the piston, and
4. Force due to friction of the piston pin bearing and the crankpin bearing.

2.LITERATURE REVIEW:

- **Ramakrishna and Venkat [1]** had carried out a study of connecting rod of petrol engine of LML freedom. The work focused on optimization of the material in which current 4340 alloy steel connecting rods are replaced by AlSiC 9 results in a 61.65 % reduction in weight.
- **Bin Zheng, Yongqi Lou and Ruixiang Liu [2]** had carried out a study in which the material utilized for connecting rod in small commercial vehicle is 40Cr. It was analysis that maximum compression condition increases and factor of safety of connecting rod increases by 59%.
- **K. Sudershan Kumar et al. [3]** "Modelling and Analysis of Two Wheeler Connecting Rod," In this paper connecting rod material is replaced by Aluminium coated with Boron carbide. A model is design by using PRO-E software and analysis is done on ANSYS software.
- **G. M. Sayeed Ahmed [4]** worked on "Design Fabrication and Analysis of a Connecting Rod with Aluminium Alloys and Carbon Fibre" he replaced a forged steel connecting rod with Aluminium alloy and Carbon fibre. The Connecting Rod is modelled on Pro/E. Connecting rod of materials aluminium6061, aluminium 7075, aluminium 2014 and carbon fibre 280 GSM are used and analysis is done.
- **G. Naga MalleshwaraRao et al. [5]** "Design Optimization and Analysis of a Connecting Rod using ANSYS" The aim of this work is to find opportunities for weight reduction by analyzing various material like Genetic Steel, Aluminium, Titanium and Cast Iron.
- **A. Prem Kumar [6]** had carried out a study in which the present material Al 6061 is replaced by Al 6061 + SiC. When compared with present material, Al 6061 + SiC have lower deformation and also sustain a low Von misses strain. Thus result in high hardness.

3.CALCULATIONS:

DESIGN FOR PRESSURE CALCULATION

Consider 150cc Engine

Specifications

Engine type	=	air cooled 4-stroke
Bore x Stroke (mm)	=	57 x 58.6
Displacement	=	149.5 CC
Maximum Power	=	13.8 bhp @ 8500 rpm
Maximum Torque	=	13.4 Nm @ 6000 rpm
Compression Ratio	=	9.35:1
Density of Petrol (C_8H_{18})	=	737.22 kg/m³
	=	737.22×10^9 kg/mm³
Auto ignition temp.	=	288.85°K
Mass	=	Density x Volume
	=	$737.22 \times 10^9 \times 149.5 \times 10^3$
	=	0.110214 kg
Molecular weight of petrol	=	114.228 g/mole
	=	0.11423 kg/mole

from gas equation,

PV = m x R x T

Where,

P = Gas Pressure, Mpa
V = Volume
m = mass, kg
T = Temperature, °k
R = Specific gas constant = R/M
= 8.3144/0.114225
= 72.788 Nm/kg K

P = m x R x T/V
= 0.110214 x 72.788 x (288.85/149.5)
= 15.49 Mpa ≈ **16 Mpa**

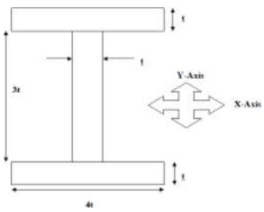
∴Calculation is done for max pressure of 16 Mpa.

Calculating Load Acting on Connecting Rod by Gases:

$F_1 = (\pi/4) \times (\text{bore})^2 \times \text{Gas Pressure (P)}$

$F_1 = 39.552 \times 10^3$ N

Calculation for Buckling Load



W_B = Load acting of connecting rod (F) x F.O.S

$W_B = 37663$ N

$I_{xx} = 34.91\, t_4$

$I_{yy} = 10.91\, t_4$

Area of section (A) = $11\, t^2$

Height of Section (H) = 5t

Width of Section (B) = 4t

Therefore, by using Rankine's Formula

$W_B = (\sigma_c \times A)/(1 + \alpha(L/K_{XX})^2)$

By solving the Rankine's Formula,
we get the value of 't' as 3.2 mm

Design of Small End

$F_g = d_1$ (inner dia.) x L_1 x P_{bp} (d_1 = 17.94 mm)
$L_1 = 1.5 \times d_1 = 26.94$ mm
Outer Diameter (d_2) = $d_1 + 2t_b + 2t_m$ = 31.94 mm

Design of Big End

$F_g = D_3$ (inner dia.) x L_2 x P_{bp}

- D_3 = 23.88 mm
- $L_1 = 1 \times D_3$

Outer Diameter (d_4) = $D_3 + 2t_b + 2t_m + 2b_d$
= 47.72 mm

Connecting Rod Dimensions:

S. No.	Parameters (mm)
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

4.MATERIALS AND THEIR PROPERTIES

We were able to finalise the resources we believe would be appropriate for the work based on our literature review. We've chosen three distinct materials, all of which are alloys. The many advantages that alloys have over metals are the basis for choosing them.

Materials:

- Medium Carbon Steel(**42CrMo4**)
- Aluminum Alloy(**AA 7075-T6**)
- Magnesium Alloy

Properties:

Base Material	**42CrMo4**	**AA 7075-T6**	**Magnesium Alloy**
Density value	**7.8 g/cm^3**	**2.81 g/cm^3**	**1.8 g/cm^3**
Young's modulus value	210Gpa	71.1Gpa	42Gpa
Tensile strength value	1000-1200 Mpa	572 Mpa	285 Mpa
Elongation at break value	10%	11%	2-10%
Poisson's ratio value	0.30	**0.33**	0.33
Melting temperature value	477°c	477°c	360°c
Thermal conductivity value	45 W/(m.k)	130-150 W/(m.k)	156 W/(m.k)
Linear thermal expansion coefficient value	-	2.36X10^{-5} (K^{-1})	2.66X10^{-6} (C^{-1})
Specific heat capacity value	473 J/(kg. k)	714.8 J/(kg. k)	0.9025J/(g. k)

5.1 Designing of Connecting Rod

The dimensions of the Connecting Rod are entered into the modelling software SOLIDWORKS. The geometry of the Connecting Rod is developed in SOLIDWORKS and exported in IGES format to the analysis software. The figure of the designed Connecting Rod is below.

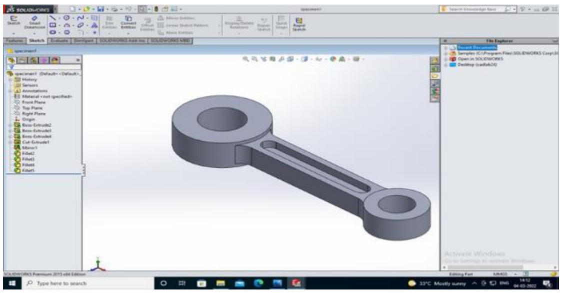


Fig. Connecting Rod Developed in SOLIDWORKS.

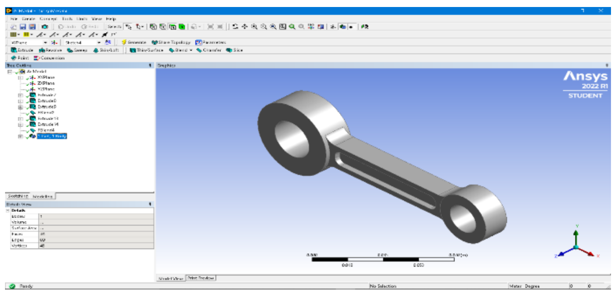
5.2 Analysis of Connecting Rod

Modal analysis

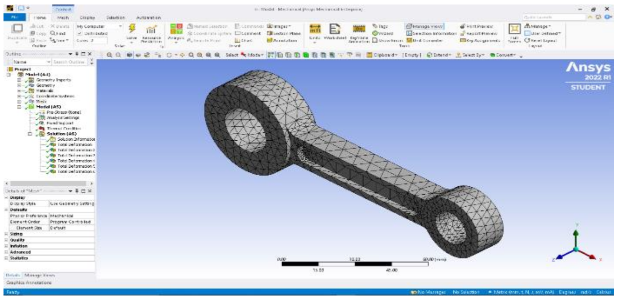
- The study of the dynamic dynamics of systems in the frequency domain is known as modal analysis. Modal analysis only calculates the system's natural frequencies.
- Modal analysis is the most basic, because all it provides are the geometry's "Resonance frequencies."
- At this point, it has nothing to do with loading and everything to do with geometry.
- Only the shape of your model and how it is limited influence the resonance frequencies.
- A vibrating system or external force causes another system to vibrate with higher amplitude at specified frequencies, which is known as resonance in physics.
- The system's resonant frequencies, also known as resonance frequencies, are the frequencies at which the response amplitude reaches a relative maximum.

5.2.1 Following is the procedure followed for Modal analysis in Ansys:

Step-1:-The assembled part files from SolidWorks is first to be imported through the IGES format.



Step-2:- The imported model is given the proper connections for the meshing process.
Step-3:- Once the connections are done, the part has to be meshed.
Step-4:- The mesh that has been selected is fine mesh with a relevance of 1 and adaptive curvature.
Step-5:- The type of mesh may be varied depending on accuracy and computer's processing power.



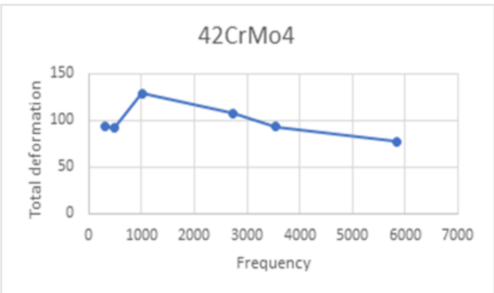
Step-6:- Analysis settings are set for modal analysis of six nodes and the required solutions are added.
Step-7:- The solution is evaluated for all the six nodes and the natural frequency are obtained.
Step-8:- The natural frequencies of the three materials are compared to find out which one is better.

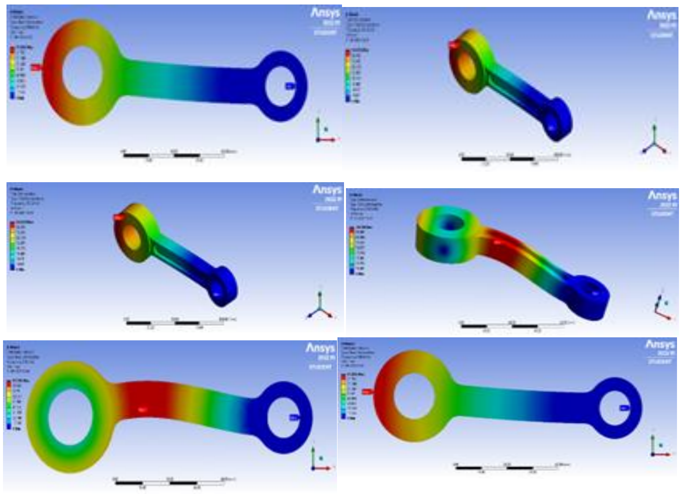
6. RESULTS:

6.1 Medium Carbon Steel:(42CrMo4)

Modes	Frequency (Hz)	Total Deformation (mm)
1	313.52	94.326
2	499.42	91.926
3	1057.9	129.27
4	2863.6	107.88
5	3732	93.536
6	6135.1	77.213

Graph (Frequency Vs Total Deformation)

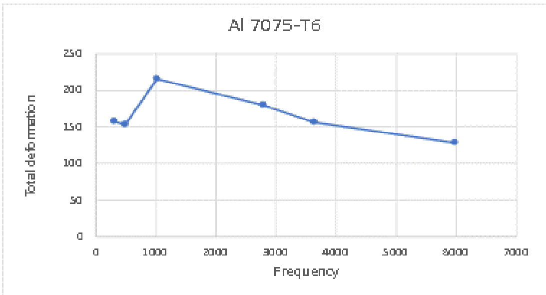




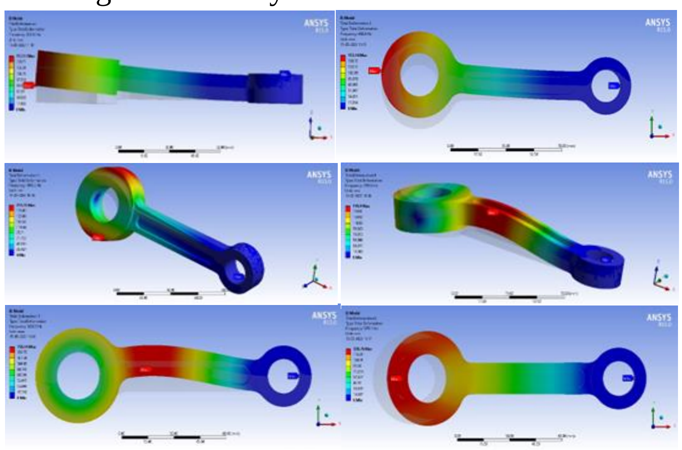
6.2 Aluminium Alloy:(AA 7075-T6)

Modes	Frequency (Hz)	Total Deformation (mm)
1	305.52	157.17
2	486.4	153.14
3	1012.2	215.35
4	2789.5	179.9
5	3630.5	156.14
6	5978.1	128.76

Graph (Frequency Vs Total Deformation)

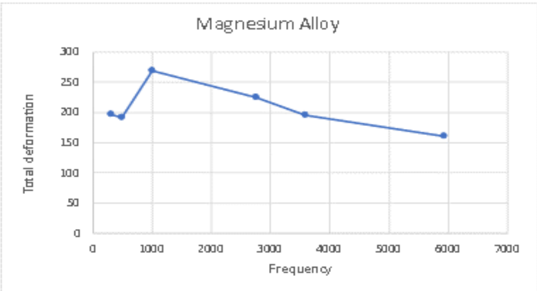


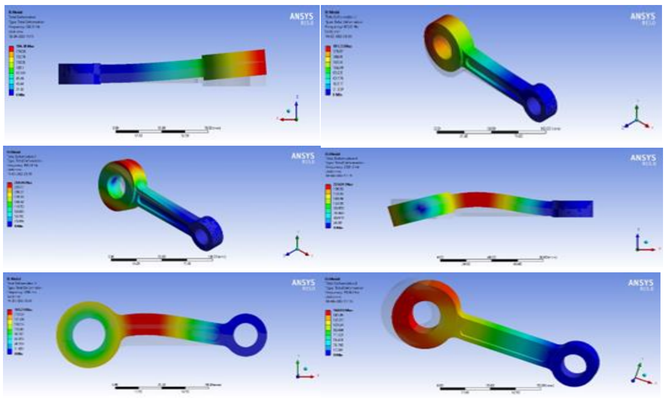
6.3 Magnesium Alloy



Modes	Frequency (Hz)	Total Deformation (mm)
1	302.51	196.38
2	481.52	191.33
3	995.43	269.06
4	2761.8	224.91
5	3592	195.23
6	5920.2	160.93

Graph (Frequency Vs Total Deformation)





6.4 Interpretation of Modal Analysis

We can determine the material to use based on the Mode shapes and Natural Frequencies obtained from the Modal Analysis of the Connecting Rod. The following is a summary of the findings.

• With the exception of medium carbon steels, the Aluminium Alloy has the highest Natural Frequency in Mode 1 and all other modes.

• When compared to the other alloys in the study, the Magnesium Alloy has the lowest density.

• The Aluminium Alloy AA 7075-T6 has the strongest strength of any alloy in comparison, except medium carbon steels.

• Magnesium Alloy's Natural Frequencies are quite similar to those of Aluminium.

• For all six modes, the mode forms of all four materials are quite similar, with minor differences.

• The resonant frequency of the material with the highest Poisson ratio appears to be the highest.

• For the resonant frequency, the Total Deformation is maximum for Magnesium Alloy and minimum for Aluminium Alloy AA 7075-T6.

7.CONCLUSIONS:

The results of the analyses show that the natural frequency of Medium Carbon Steel(42CrMo4) is the highest in the modal analysis. As a result, 42CrMo4 is frequently employed in the manufacture of connecting rod. However, the inherent frequencies of Aluminium Alloy and Magnesium Alloy are quite close to those of Medium Carbon Steels, making it safe to use as a connecting rod material. Magnesium Alloy is the lightest of all the alloys, which aids in the rod's weight reduction. Furthermore, Magnesium Alloy may be easily created using the Die Casting method, which is more cost-effective than Sand Casting for high-volume production.

Magnesium Alloy, on the other hand, cannot be used as a connecting rod for high-load engines due to its fracturing nature.

As a result, we believe that Aluminum and Magnesium are the finest materials for low-load range applications. The device's lower weight not only improves its efficiency but also makes it more robust.

8.Future Scope and Development

Comparison can be done between medium carbon steels and aluminium alloys with increased weight of the connecting rod when analysis is being done with aluminium alloy because the density difference between these two materials is huge. So by increasing the aluminium metal weight in connecting rod a better results can be obtained.

Additional adjustments to the design of the connecting rod can be made, such as choosing a section other than the I-section. Choosing different materials for the connecting rod allows for further study. It is possible to do a weight-loss analysis as well as a cost-benefit analysis. By adding or subtracting material from the connecting rod, the maximum stress concentration at the fillet of the crank and piston end may be lowered. Chamfering the sharp edges of connecting rods also helps to reduce stress and boost the connecting rod's strength. A dynamic study of the connecting rod can be performed, and additional failure variables can be evaluated.

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