# Finite element analysis of polymer based automotive connecting rod

[1]Raj kumar, [2]Nishant Saxsena, [1]Arvind Singh

[1]Department of Mechanical Engineering

[2]Assistant Professor & Head of Mechanical Department

Millennium Institute of Technology (MIT), Bhopal, M.P. (India)

---------------------------------------------------------------------***---------------------------------------------------------------------

**Abstract** - *The research has been done for finite element analysing the polymer based composite material connecting rod. The connecting rod of light weight engines undergoes in high stresses, which causes fatigue failure and buckling effects. Finally damages and break the connecting rods. To overcome with such effects, the conventional material for manufacturing the connecting rod for light weight internal combustion(IC) engines has been compared and replaced by carbon fiber reinforced polymer (PEEK, Polyetheretherketon) which contain 40% of carbon fibers. The connecting rod 'conrod' has been analyzed on light weight engine (HONDA CD110 motorbike) before performing the experiment on large scale engines. The 3-dimensional model made on CATIA V5R16 and analyzed on ANSYS17.0. Experiment performed by undertaking a load of 6500N axially on piston pin of connecting rod. The paper discusses the various parameters affecting the connecting rod and defines the better suitability of composite material over conventional material.*

***Key words***: *PEEK, ANSYS, CATIA, fatigue strength, alloy steel, composites, carbon fibers.*

## 1. IINTRODUCTION

The connecting rod plays an important role in the internal combustion engines. It transmits the power from piston to the crankshaft in fractions of seconds. The overall power and speed of engine depends on connecting rod, its dimensions, its materials and various factors, which effect or contribute in working of connecting rod. If we succeeded in designing efficient and light weight connecting rod, then we can achieve the maximum, almost 100% mechanical efficiency, without any losses. It all depends on the depth of research and innovation, a keen work is required to be done to achieve an ideal connecting rod. Only technology could not resolve and conclude the desired results.

Therefore, the most advance PEEK composite i.e. Victrex PEEK90HMF40 [1] containing 40% of carbon fibers, has been selected to replace the conventional ferrous material (AISI-8620 Alloy steel) [2] connecting rod. The following PEEK possesses high wear resistance capacity as well as high strength. The following material can also withstand at high amplitude of buckling and fatigue effects.

To perform accurate analysis, the exact replica of rod have been tried to recreate using CATIA V5R16. It also possesses the validation of rod's theoretical data by its practical data by means of calculations. The rod is subjected to axial load along the X-axis of the plane of rod, keeping degree of freedom constant along Y-axis. Generally, in light weight vehicles with the displacement of 100-300cc, the 3-4Mpa of pressure is generated by combustion of gases, which forces the piston down for reciprocating motion.

## 2. Literature survey

**Webster *et al.*** (1983)[3] performed three dimensional finite element analysis of a high-speed diesel engine connecting rod. For this analysis they used the maximum compressive load which was measured experimentally, and the maximum tensile load which is essentially the inertia load of the piston assembly mass. The load distributions on the piston pin end and crank end were determined experimentally. They modeled the connecting rod cap separately, and also modeled the bolt pretension using beam elements and multi point constraint equations.

**Folgar *et al.*** (1987)[4] developed a fiber FP/Metal matrix composite connecting rod with the aid of FEA, and loads obtained from kinematic analysis. Fatigue was not addressed at the design stage. However, prototypes were fatigue tested. The investigators identified design loads in terms of maximum engine speed, and loads at the crank and piston pin ends. They performed static tests in which the crank end and the piston pin end failed at different loads. Clearly, the two ends were designed to withstand different loads.

In a study reported by **Repgen** (1998)[5], based on fatigue tests carried out on identical components made of powder metal and C-70 steel (fracture splitting steel), he notes that the fatigue strength of the forged steel part is 21% higher than that of the powder metal component. He also notes that using the fracture splitting technology results in a 25% cost reduction over the conventional steel forging process. These factors suggest that a fracture splitting material would be the material of choice for steel forged connecting rods. He also mentions two other steels that are being tested, modified micro-alloyed steel and a modified Alloy Steel SAE-AISI 8620.

**Anil kumar** (2012) [6], He worked on the optimization in weight and reduce inertia force on the existing connecting rod, by changing some variables. The weight of the connecting rod was also reduced by 0.004 kg which was not significant but reduces the inertia forces. Fatigue strength plays the most significant role (design driving factor) in the optimization of this connecting rod. Optimization was performed to reduce weight of the existing connecting rod. This optimization can also be achieved by changing the current forged steel connecting rod into some other materials such as C-70 steel etc.

**B. Anusha** (2013) [7] made a comparative study on connecting rod of Hero Honda Splendor is done to determine von-misses stresses, strain, shear stress and total deformation for the given loading conditions using analysis software using ANSYS. Static analysis of two materials is carried out by ANSYS and the maximum von misses stress for cast iron is 91.593Mpa and the maximum stress for structural steel is 82.593Mpa.

**Rukhsar Parveen Mo. Yusuf at al.** (2015)[8]. Experiment performed on connecting rod to analyze the buckling effect on it with the use of PRO-E and ANSYS12 by considering anonymous connecting rod. The structural steel is selected by the scholar (by default, present in material library of ANASYS software), not able to provide the authentic material for analysis. As, structural steel is been used for constructions and conventional purposes, not for engine elements.

## 3. METHODOLOGY

The dimensional values of connecting rod of HONDA CD110 internal combustion 4-stroke engine [9] has been calculated theoretically and verified with the practical values to obtain true analysis.

The given below Table.1 describes the specifications of analyzed connecting rod engine.

| Specifications | Values |
|---|---|
| Displacement ($V_d$) | 109.19cc |
| Maximum Power (*P*) | 8.25bhp @7500rpm (6.15kW) |
| Maximum Torque (*T*) | 8.63Nm @5500rpm |
| Cooling system | Air cooled |
| Compression ratio (*r*) | 9.2:1 |
| Bore | 50mm |
| Stroke | 55.6mm |

The following Table.2 shows the properties of the AISI-8620 alloy steel and PEEL90HMF40 composite materials properties

| Properties | Alloy steel SAE-AISI 8620 | Polyether-etherketon (PEEK) |
|---|---|---|
| Density(g/cm3) | 7.87 | 1.45 |
| Poisson's ratio | 0.29 | 0.39 |
| Specific heat capacity (kg^-1 C^-1) | 434 | 2300 |
| Melting point (°C) | 1289 | 343 |
| Young's modulus (GPa) | 200 | 3.6 |
| Tensile Strength (Mpa) | 550 | 330 |
| Compressive strength (Mpa) | 1000 | 600 |
| Bulk modulus (GPa) | 166 | 5.4545 |
| Shear modulus (GPa) | 81.395 | 1.295 |

## 4. CALULATIONS

To design a connecting rod, the cross-sectional dimensions of rod are needed to be obtained. The force exerted on connecting rod along Y-axis of the plane of rod is found to be more than three time less as compared to X-axis plane of rod. So, buckling load is considered as major load acting on rod including inertia force and gas force.

Now, buckling load is also given by:

$$W_B = \frac{\sigma_c \; x \; A}{1 + \alpha\left[\frac{L}{K_{xx}}\right]^2} \tag{1}$$

**Power produced by Engine (P):**

$$P = 2N\pi T \tag{2}$$

From equation (2): P (kW) = 4.9676kW

**Engine Displacement ($V_d$):**

$$V_d = No.of\ cylinder\ x \frac{\pi}{4}\ x\ (Bore)^2\ x\ Stroke$$

$$V_d = 1\ x \frac{\pi}{4}\ x\ (5.00)^2\ x\ 5.56 = 109.17x10^{-3}\text{m}^3$$

**Brake Mean Effective Pressure (*bmep*):**

$$bmep = \frac{4\pi T}{V_d} = \frac{4x3.14x8.63}{109.17x10^{-6}} = 0.99\text{ Mpa}$$

**Length of connecting rod (L):**

For short rod: Minimum rod/stroke ratio = 1.60
and Maximum rod/stroke ratio= 1.80
Considering ratio: 1.70
Length of connecting rod (L)
= 1.7 x stroke = 1.7x 55.6
L = 94.52 ~ 95mm

**Load on piston ($F_L$):**

According to Buckling load ($W_B$):

Let, Maximum gas load ($P_g$) = 2.2 x $P_{mep}$ [*Let, Gas load ≈2.2 x gas pressure*]

Mean effective pressure ($P_{mep}$) = 1.35Mpa

The maximum force on piston ($F_L$) is equal to force on connecting rod ($F_C$) equal to due to gas pressure.

$$F_L = F_C = \frac{\pi D^2}{4} x\, P_g = 6500N \quad (3)$$

Buckling load, $W_B$= Max. gas load ($F_C$) *x* Factor of safety (F.O.S.) [*FOS =6*]

$W_B = 6500\, x\, 6$ = 39000N ~ 40,000N

**Dimensions of flange and web of AISI-8620 alloy steel connecting rod**

Compressive strength (σc) = 850N/mm2
Rankine constant (α) = 1/2500
Rankine Constant (α) = σc / π²xE
σc = Compressive strength
E = Young's modulus
From equation (1):

$$40{,}000 = \frac{850\, x\, 11t^2}{1 + \frac{1}{2500}\left[\frac{95}{1.78t}\right]^2}$$

$$40{,}000 = \frac{9350t^2}{1 + \frac{1}{2500}\left[\frac{95}{1.78t}\right]^2}$$

t = 2.5mm [For safe design]

The thickness of the flange and web of the section (t) = 2.5mm
Width of section (B) = 7mm [Design consideration]
Depth or the height of section (H) = 12.5 [Design consideration]
Distance between flange = 7.5mm [Design consideration]

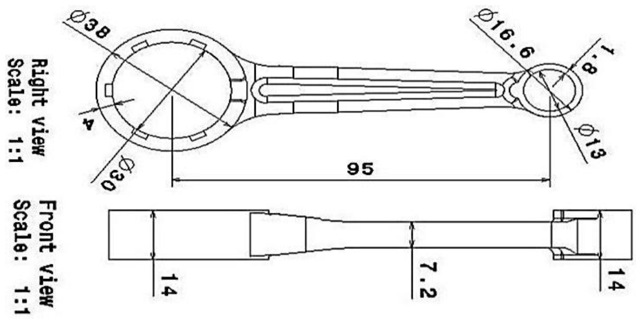



Fig. 1 Dimensions of AISI-8620Alloy steel connecting rod using CATIA V5R16

**Connecting rod flange and web dimensions for PEEK 90HMF40:**

From equation (1):

$$W_B = \frac{310\, x\, 11t^2}{1 + \frac{1}{750}\left[\frac{95}{K_{xx}}\right]^2}$$

$$40{,}000 = \frac{310\, x\, 11t^2}{1 + \frac{1}{750}\left[\frac{95}{1.78t}\right]^2}$$

$t^2 = 11.75$
t = 4mm
The thickness of the flange and web of the section (t) = 4mm
Width of section (B) = 14mm [*Design consideration*]
Depth or the height of section (H) = 16mm [*Design consideration*]
Distance between flange = 8mm

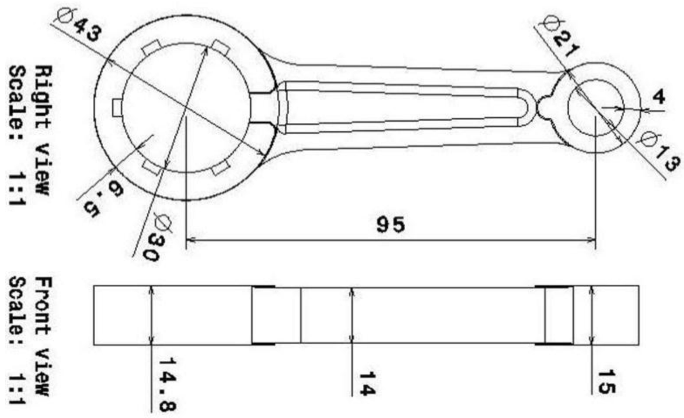
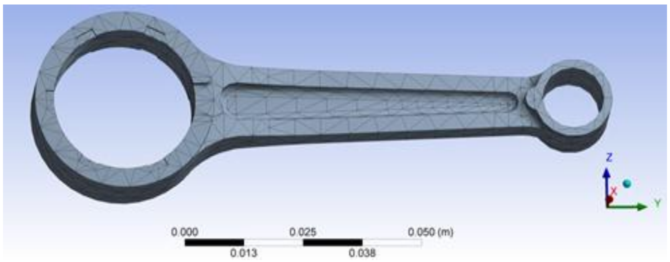



Fig.2. Dimensions of AISI-8620Alloy steel connecting rod using CATIA V5R16

**5. Results and analysis**

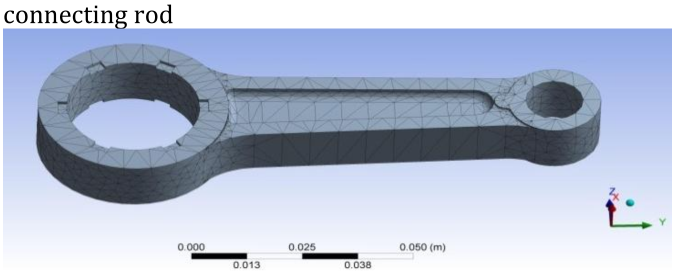
Fig.3: Mesh generation in Alloy Steel SAE-AISI 8620 connecting rod

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 03 |Mar -2017 www.irjet.net p-ISSN: 2395-0072



Nodes formed: 6676, Number of Elements: 3646, Mass: 0.10087 kg

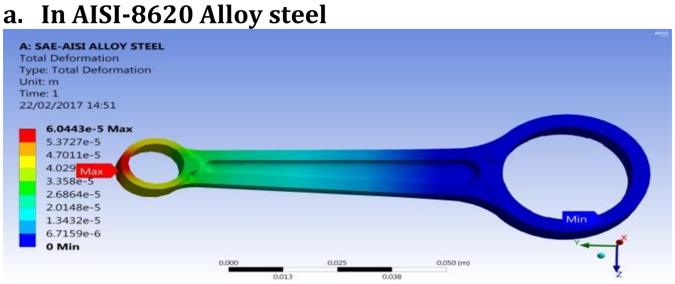
Fig.4: Mesh generation in PEEK90HMF40 composite connecting rod



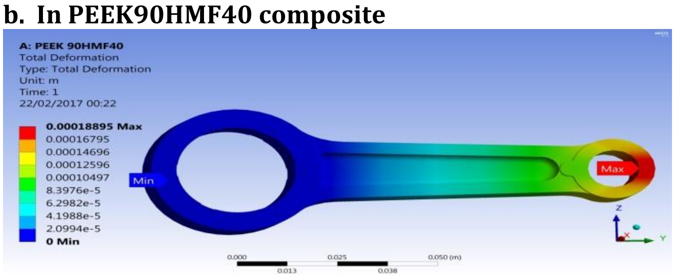
Nodes formed:15280, Number of Elements: 8913, Mass: 4.0073e-002 kg

### i. Total Deformation

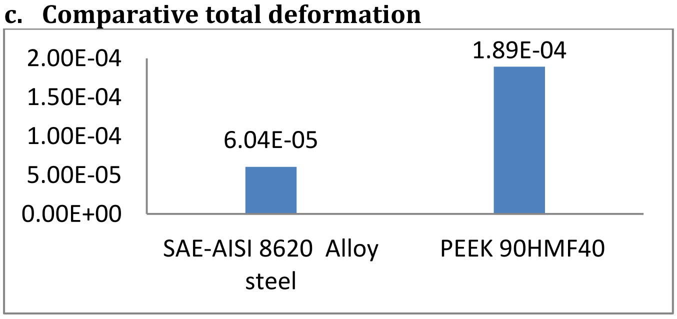
#### a. In AISI-8620 Alloy steel




#### b. In PEEK90HMF40 composite

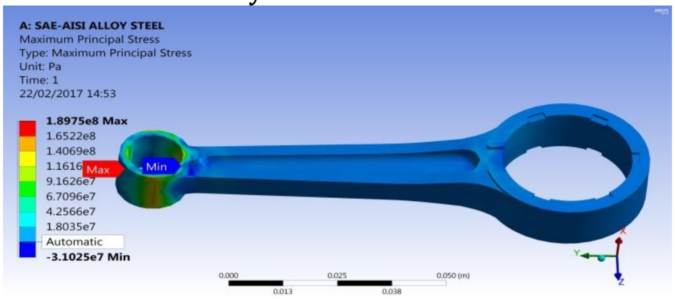



#### c. Comparative total deformation

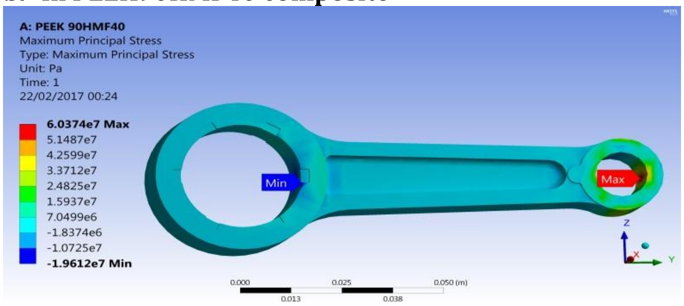



### ii. Maximum Principal Stress

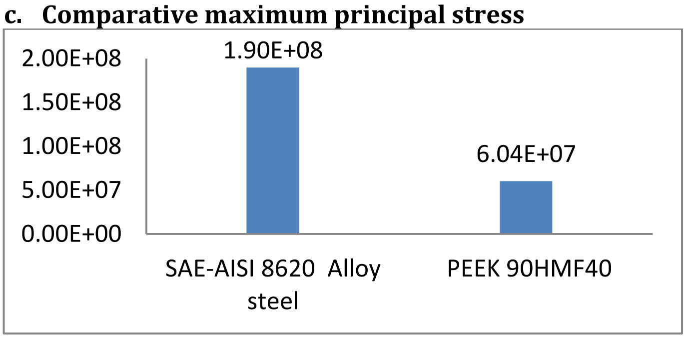
#### a. In AISI-8620 Alloy Steel




#### b. In PEEK90HMF40 composite

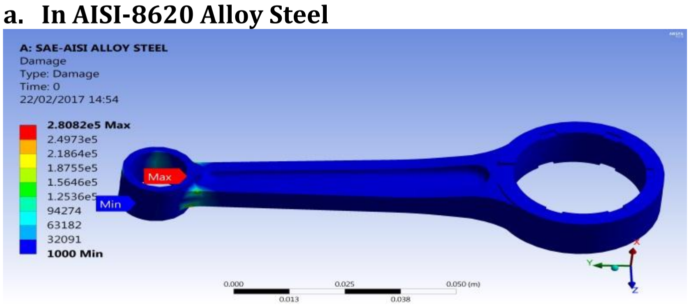



#### c. Comparative maximum principal stress



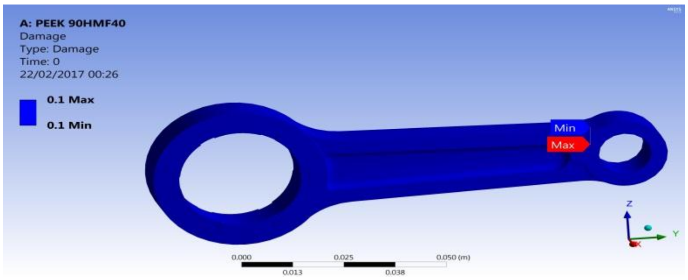

### iii. Fatigue damage

#### a. In AISI-8620 Alloy Steel

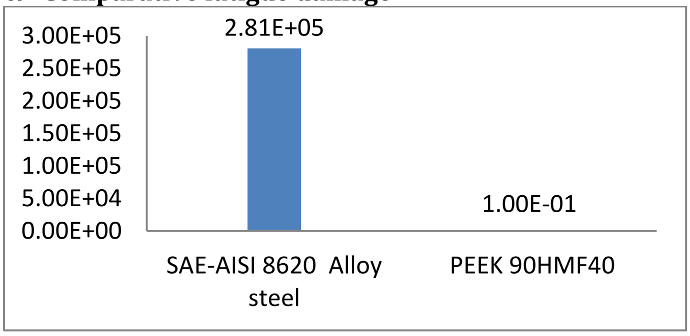



#### b. In PEEK90HMF40 composite

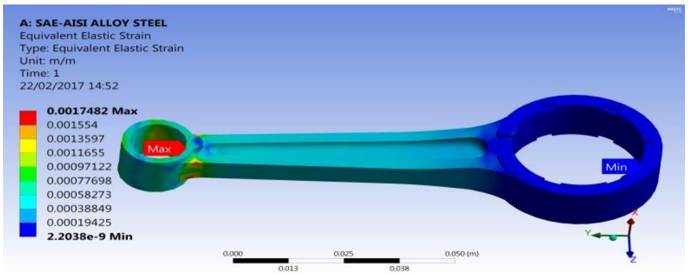



c. Comparative fatigue damage

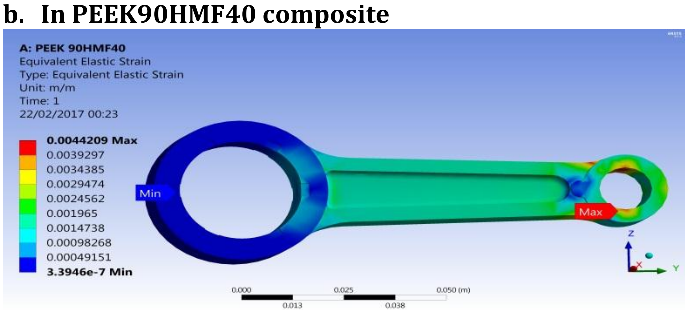



## iv. Equivalent strain

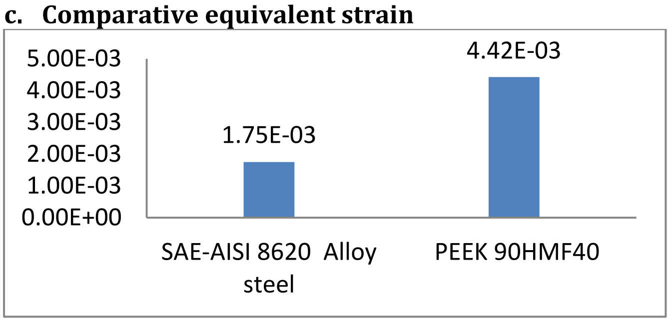
a. In AISI-8620 Alloy Steel




b. In PEEK90HMF40 composite

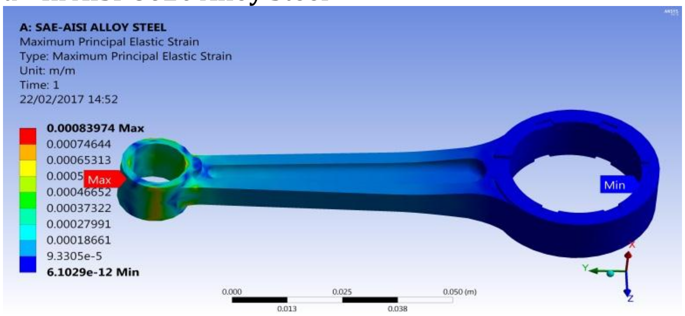



c. Comparative equivalent strain

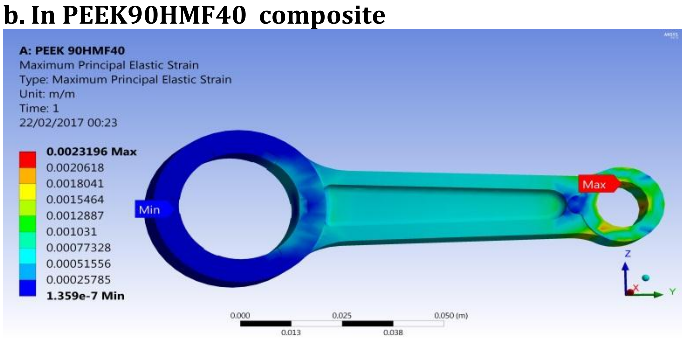



## V. Maximum Principal Strain

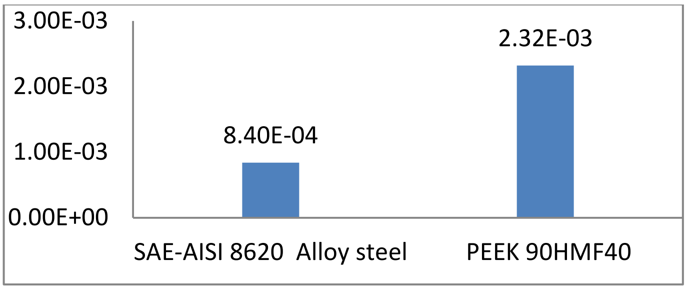
a. In AISI-8620 Alloy Steel




b. In PEEK90HMF40 composite




c. Comparative maximum principal strain




## 6. CONCLUSIONS

- The Fatigue damage in PEEK is 2x10$^5$ times less as compared with alloy steel.
- The mass of PEEK rod is found to be 60% less as compared to alloy steel. As the Inertia force is directly proportional to mass of element, so it will increase the efficiency of engine, increase in angular velocity of rod with decrease in mass.
- The coefficient of friction (μ) of PEEK lies between 0.05 -0.14, while the steel has 0.15-2.0 on steel with lubrication.
- As IC the engine can produce maximum load (10MPa), the above study reviles that the PEEK could easily bear the maximum load and is safe for designing.

## 7. FUTURE SCOPE OF STUDY

- It could be revolution in automobile industry, if the composite material replaced the existing metal rod , which will improve the overall performance of engine, frictional losses and weight reduction of engines.
- PEEK is made of eco-friendly engineering plastic with high scratch and wear resistance. The material will not dissolve into the engine oil nor contaminate the lubricant, thus providing superior performance and extending the life of the entire connecting rod set.
- Conventional connecting rod material could be replaced by Non-conventional material like PEEK and Carbon fiber etc. Currently, the following composite material are been used in the pneumatic pumps and engines components. But with some change in chemical properties, for enhancing its tensile strength then it could use in conventional automobiles.

## 8. REFERENCES

1. VICTREX PEEK90MHF40, victres high performance polymers, World Headquarters, Victrex plc, Hillhouse International, Thornton Cleveleys, Email: victrexplc@victrex.com.
2. AISI-8620 alloy steel from SAE-AISI 8620 (SNCM220, 1.6523, G86200) Ni-Cr-Mo Steel, http://www.makeitfrom.com/materialproperties/SAEAISI8620SNCM2201.
6523G86200NiCrMoSteel.
3. Webster, W. D., Coffell R., and Alfaro D., 1983, "A Three Dimensional Finite Element Analysis of a High Speed Diesel Engine Connecting Rod," SAE Technical Paper Series, Paper No. 831322.( http://papers.sae.org/831322/ )
4. Folgar, F., Wldrig, J. E., and Hunt, J. W., 1987, "Design, Fabrication and Performance of Fiber FP/Metal Matrix Composite Connecting Rods," SAE Technical Paper Series 1987, Paper No. 870406.( http://papers.sae.org/870406/ )
5. Repgen, B., 1998, "Optimized Connecting Rods to Enable Higher Engine Performanceand Cost Reduction," SAE Technical Paper Series, Paper No. 980882.
6. Anil kumar, 2012. Optimization of Connecting Rod Parameters using CAE Tools, International Journal of
7. Latest Trends in Engineering and Technology (IJLTET),Vol. 1 Issue 3 September 2012, ISSN: 2278-621X.
8. B. Anusha, 2013. Comparison of Materials For Two-Wheeler Connecting Rod Using Ansys, International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 9- Sep 2013.
9. Rukhsar Parveen Mo. Yusuf at al.(2015) 'Buckling analysis of connecting rod', IPASJ International Journal of Mechanical Engineering (IIJME), Volume 3, Issue 12, December 2015, Page no. 59-66.
10. HONDA CD110 specifications by https://www.honda2wheelersindia.com/cd110dream/

## BIOGRAPHY

Raj Kumar, Born in India, Graduated from Sagar Institute of Science and Technology (SIStec) in 2014, Bhopal, currently perusing M.Tech from Millennium Institute of Technology (MIT), Bhopal in Machine Design.