

STATIC ANALYSIS OF COMPOSITE CRANKSHAFT OF SINGLE CYLINDER PETROL ENGINE USING ANSYS SOFTWARE

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Abstract: This paper deals with the static analysis of a composite crankshaft of a single cylinder 4-stroke petrol Engine. For a reference crankshaft of Royal Enfield Bullet 350 CC is considered; which is made from medium carbon steel. Carbon fiber/Epoxy is used as an alternative material for medium carbon steel. In this paper crankshaft is modeled by using CATIA-V5 software. Structural analysis has been done by using ANSYS workbench 18.2. Proper boundary conditions applied to evaluate the von-mises stress, von-mises strain and total deformation. The FEA results obtained are von-mises stress induced in the crankshaft is 268.66 and 204.99 Mpa respectively for medium carbon steel and carbon fiber/epoxy. The theoretical results obtained are von-mises stress 273.51 N/mm² Mpa and von-mises strain 0.0014. The validation of crankshaft is compared with the theoretical and FEA results of von-misses stress and strain are in the limits.

Index Terms- Crankshaft, Structural analysis, Finite element analysis (FEA).

I. INTRODUCTION

Crankshaft is a mechanical part used in IC engine to convert the reciprocating motion of piston into rotating motion. The crankshaft is one of the largest components in the IC engine and has a complex geometry comprising of cylinders as bearings and plates as the crank webs. Crankshaft experiences large forces from gas combustion. This power is connected to the highest point of the cylinder and since the connecting rod interfaces the cylinder to the crankshaft, the power will be transmitted to the crankshaft. The greatness of the power relies on upon numerous elements which comprise of crank range, connecting rod dimensions, and mass of the connecting rod, piston, piston rings and pin. Ignition and inertia powers following up on the crankshaft cause two sorts of stacking on the crankshaft structure; tensional load and bending load.

The concept of using crankshaft is to change these sudden displacements to as smooth rotary output, which is the input to many devices such as generators, pumps and compressors. It should also be stated that the use of a flywheel helps in smoothing the shocks. Crankshaft experiences large forces from gas combustion. This force is applied to the top of the piston and since the connecting rod connects the piston to the crank shaft; the force will be transmitted to the crankshaft.



Fig-1 Royal Enfield Bullet 350 cc Crankshaft

1.1 Forces Acting On Crankshaft

A major source of forces imposed on a crankshaft is piston acceleration. The magnitude of the forces depends on many factors which consist of crank radius, connecting rod dimensions and weight of the connecting rod, piston, piston rings and pin. Combustion and inertia forces also act on the crankshaft.

Two main load acting on crankshaft are-

- a. Bending load

b. Torsional load

Bending moment causes tensile and compressive stresses and twisting moment causes shear stress. Crankshaft must be strong enough to take the downward force of the power stroke without excessive bending; so the reliability and life of the internal combustion engine depend on the strength of the crankshaft.

II. LITERATURE REVIEW

Farzin H. Montazersadgh et al [1], have done a dynamic simulation on a crankshaft from a single cylinder four stroke engine. Finite element analysis was performed to obtain the variation of stress magnitude at critical locations. They concluded that crankshaft analysis could be simplified to applying only bending load which located at crankpin area. Critical locations on the crankshaft geometry were also located on the fillet areas because of high stress gradients in these locations.

Surekha S. Shelke et al [2], have done Static analysis on crankshaft of a single cylinder 4-stroke petrol Engine. Analytically they have calculated the gas force, moment on pin, torque obtained at maximum power of given engine, equivalent bending Moment, equivalent twisting moment, von misses stress and strain. Then compared both analytical and FEA results for validation.

M Senthil Kumar et al [3], have analyzed crankpin failure in a Single cylinder engine by using ANSYS software. In study it was observed that the crankpin wears at the centre oil and caused failure. In crankpin highly stressed regions are the contact region with the web and centre of crank pin where hole is provided. The absence of oil and improper lubrication increases the wear at contact area rapidly.

K. Thriveni et al [4], have analyzed crankshaft. They found that the value of von-misses stresses that comes out from the analysis is far less than material yield stress so the design is safe.

JaiminBrahmbhatt et al [5], have done FEA analysis on Crankshaft. They found the maximum deformation at the centre of crankpin neck surface and the maximum stress at the fillets between the crankshaft journal and crank cheeks and near the central point Journal.

S.Sivaprabhu, T.Ramu et al [6], in this study a dynamic simulation was done on crankshaft of forged steel, metal matrix composite, E glass epoxy, Kevlar 29 and carbon epoxy composite, from similar single cylinder four stroke engines. Finite element analysis was done to obtain the total deformation, equivalent strain, and equivalent stress at critical locations. The dynamic analysis was done analytically and was verified by simulations in ANSYS. They compared total deformation, equivalent strain, equivalent stress and weight for different material mentioned above.

III. ANALYTICAL CALCULATIONS

Technical Specification of Royal Enfield Bullet 350

Table-1: Technical Specification of Royal Enfield Bullet 350 Engine

Type	Single Cylinder, 4 stroke
Displacement	346cc
Bore x stroke	70mm x 90mm
Compression Ratio	8.5 : 1
Maximum Power	19.8 bhp @ 5250 rpm

Dimensions of crankshaft are as below:

Table-2 Engine Dimensions

Symbol	Parameter	Value
d	Piston Diameter	70mm
l_c	Length of crankpin	74.76mm
d_c	Diameter of crankpin	35mm
L	Stroke	90mm
d_s	Shaft diameter	22mm
T	Thickness of the crank web	29mm
R	Shaft center to web center	37.5mm

- **Pressure Calculations:**

Density of petrol (C_8H_{18})

$$\rho = 750 \text{ kg/m}^3 = 750 \times 10^{-9} \text{ kg/mm}^3$$

- **Operating Temperature:**

$$T = 20 \text{ }^\circ\text{C}$$

$$= 20 + 273.15$$

$$= 293.15 \text{ }^\circ\text{K}$$

- **Mass of displacement :**

$$m = \rho \times V$$

Where,

$$\rho = \text{Density}$$

$$V = \text{Volume}$$

$$m = 750 \times 10^{-9} \times 346 \times 10^3$$

$$m = 0.2595 \text{ Kg}$$

- **Molecular mass of petrol :**

$$M = 114.228 \times 10^{-3} \text{ kg / mole}$$

- **Gas constant for petrol :**

$$R = 72.7868 \times 10^3 \text{ J / kg / mol K}$$

$$As, PV = mRT$$

$$P \times 346 \times 10^3 = 0.2595 \times 72.7868 \times 10^3 \times 293.15$$

$$P = 16.003 \text{ MPa} = 16.003 \text{ N/mm}^2$$

- **Design Calculations:**

$$F_p = \text{Pressure (P)} \times \text{Cross Section Area of Piston (A)}$$

$$F_p = 16.003 \times \pi/4 \times d^2$$

$$F_p = 61587.0993 \text{ N}$$

- **Moment on Crankpin:**

By the given dimensions of the crankpin,

$$\text{Diameter of the crankpin (dc)} = 35 \text{ mm}$$

$$\text{Length of the crankpin (lc)} = 74.76 \text{ mm}$$

$$M_{\max} = (F_p/2) \times (lc/2)$$

$$M_{\max} = (61586.7614 / 2) \times (35/2)$$

$$M_{\max} = 1151056.569 \text{ N.mm}$$

- **Section Modulus of Crankpin:**

$$Z = \left(\frac{\pi}{32}\right) \times d_c^3$$

$$Z = 4209.2433 \text{ mm}^2$$

- **Torque Obtained At Maximum Power of Given Engine:**

$$P = (2\pi NT/60)$$

$$14.76 \times 10^3 = (2 \times \pi \times 5250 \times T)/60$$

$$T = 26.8472 \text{ N.m}$$

$$T = 26847.2 \text{ N.mm}$$

- **Von Mises Stress**

$$\text{Torque (T)} = 26847.2 \text{ N.mm}$$

$$\text{Bending Moment (M}_{\max}) = 1151056.569 \text{ N.mm}$$

Assumptions:

$$\text{Combined shock \& fatigue factor for bending (k}_b) = 1$$

$$\text{Combined shock \& fatigue factor for torsion (k}_t) = 1$$

- **Equivalent bending moment:**

$$M_{eq} = \sqrt{(K_b \times M_{\max})^2 + \frac{3}{4}(K_t \times T^2)}$$

$$M_{eq} = \sqrt{(1 \times 1151056.569)^2 + \frac{3}{4}(1 \times 26847.2)^2}$$

$$M_{eq} = 1151.291 \times 10^3 \text{ N.mm}$$

Thus,

$$\sigma_{von} = \frac{M_{eq}}{Z}$$

$$\sigma_{von} = \frac{1151.291 \times 10^3}{4209.2433}$$

$$\sigma_{von} = 273.51 \text{ MPa}$$

$$\text{Analytical Equivalent Stress } (\sigma_{von}) = 273.51 \text{ N/mm}^2$$

- **Equivalent twisting moment:**

$$T_{eq} = \sqrt{(M_{\max}^2 + T^2)}$$

$$= \sqrt{(1151056.569^2 + 26847.2^2)}$$

$$= 1151.37 \times 10^3 \text{ N.mm}$$

Now,

$$T_{eq} = \frac{\pi \times d_c^3 \times \tau}{16}$$

$$1305.306 \times 10^3 = \frac{\pi \times 35^3 \times \tau}{16}$$

$$\tau = \frac{1305.2995 \times 10^3 \times 16}{\pi \times 35^3}$$

$$\tau = 137.76 \text{ N/mm}^2$$

- **Strain for medium carbon steel:**

$$\varepsilon = \frac{\sigma_{von}}{E}$$

$$\varepsilon = \frac{273.51}{200000}$$

$$\varepsilon = 0.0014$$

From analytical calculations it is found that,

Analytical Equivalent Stress (σ_{von}) = 273.51 N/mm²

Analytical Equivalent Strain (ε) = 0.0014

IV. FEA ANALYSIS

4.1 3D Modelling of Crankshaft:

Dimensions of the Royal Enfield Bullet 350cc crankshaft carried out by using instrument like vernier caliper and micrometer. And then Crankshaft modeled with the help of CATIA-V5 Software.

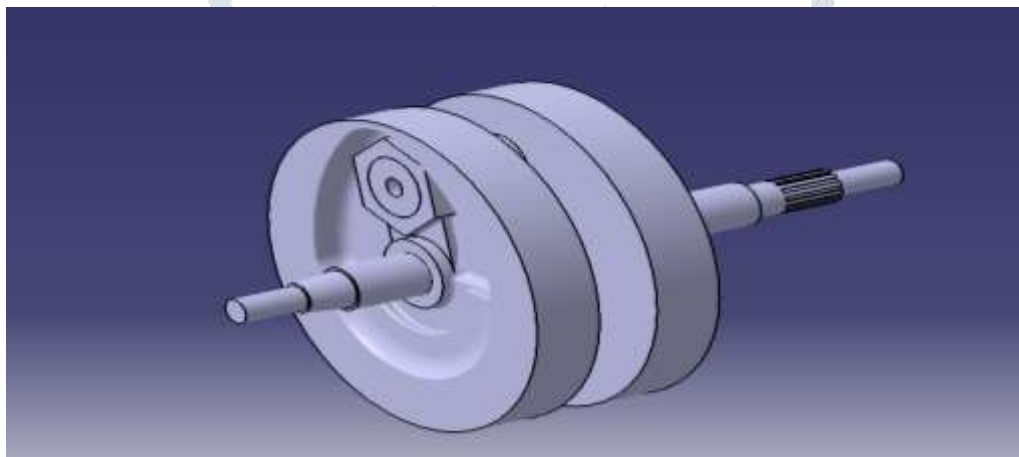


Fig-2 Assembly of Crankshaft

4.2 Input CAD Model in ANSYS Software:

After 3D modeling next step is analysis. From the ANSYS software “.igs” file of crankshaft imported for static analysis.

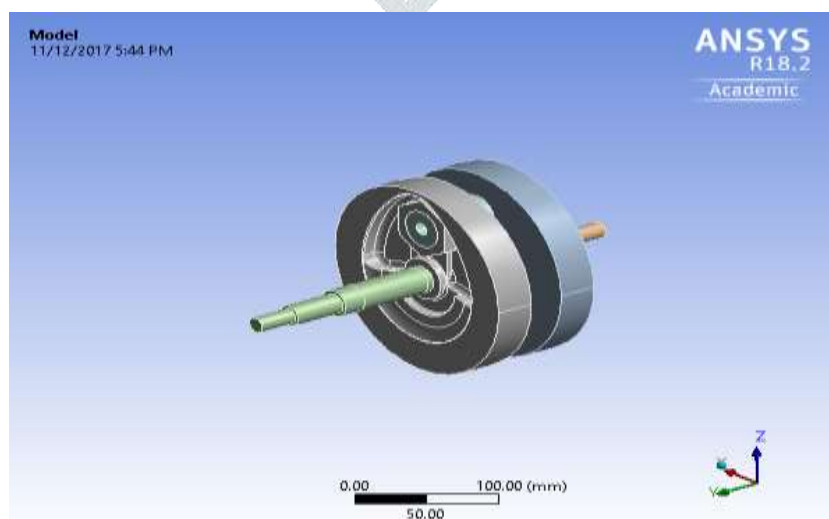


Fig-3 Model in ANSYS Workbench

4.3 Meshing:

Here we have selected tetrahedral mesh. Tetrahedral meshing methodology is utilized for the cross section of the strong district geometry. Meshing delivers fantastic cross section for boundary representation of solid auxiliary model.

Element Type-Tetrahedrons
 Nodes-18608
 Elements-10732



Fig-4 Meshing

4.4 Define Material Properties:

Properties of Medium Carbon Steel:
 Density = 7845 Kg/m³
 Poisson's ratio = 0.285
 Young's Modulus = 200 x 10³ Mpa
 Yield tensile strength =520 MPa

Properties of Outline Row 5: Medium Carbon steel			
	A	B	C
1	Property	Value	Unit
2	Density	7845	kg m ⁻³
3	Isotropic Elasticity		
4	Derive from	Young's ...	
5	Young's Modulus	2E+05	MPa
6	Poisson's Ratio	0.285	
7	Bulk Modulus	1.5504E+11	Pa
8	Shear Modulus	7.7821E+10	Pa

Fig-5 Default Material Properties (Medium Carbon Steel)

4.5 Application of boundary conditions and load:

The shaft of the crankshaft is fixed form both side which is showed in green color in all the dof and load of 61587 N generated due to maximum gas pressure is applied at the crankpin in vertical direction (-ve Z-component).

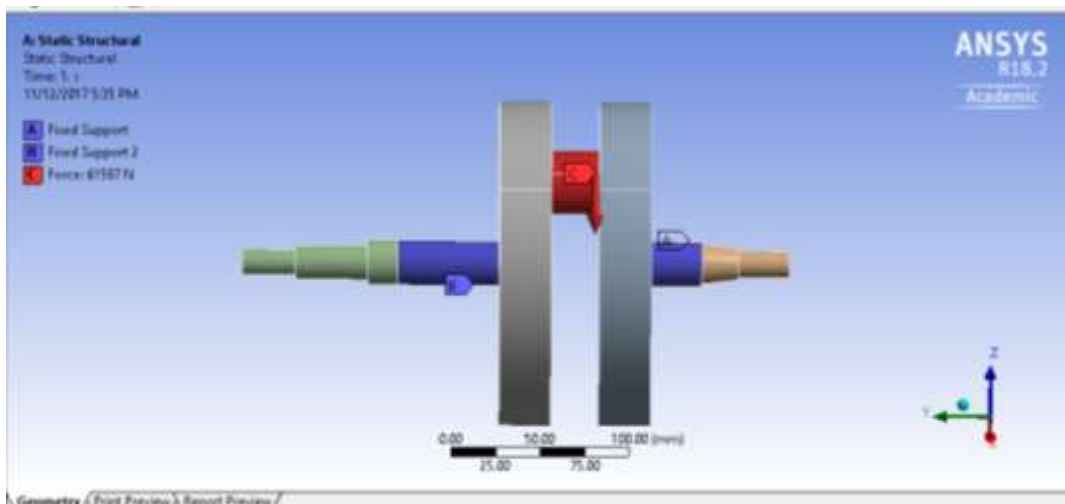


Fig-6 Apply Boundary Condition and Load

4.6 Meshing Solution:

Problem is solved for linear static behavior. The crankshaft is checked for von mises stress, von-mises strain and total deformation

4.7 Results:

As result we get the minimum and maximum values for which we solved our problem. It shows areas with maximum and minimum stress, strain and deformation.

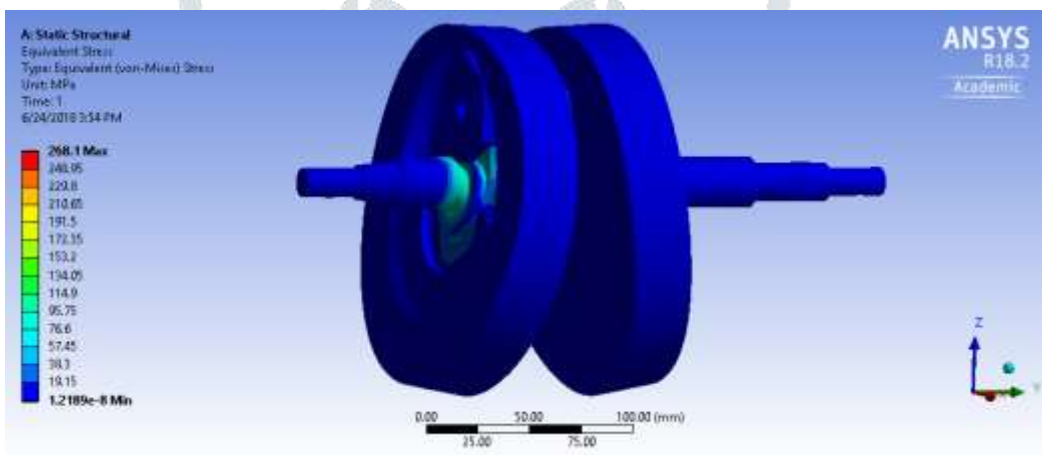


Fig-7 Equivalent (von mises) Stress

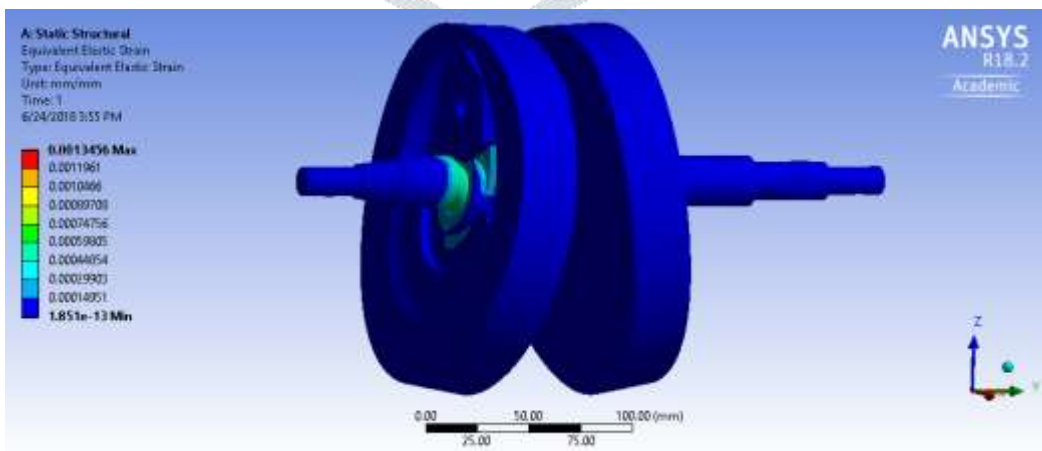


Fig-8 Equivalent (von mises) Strain

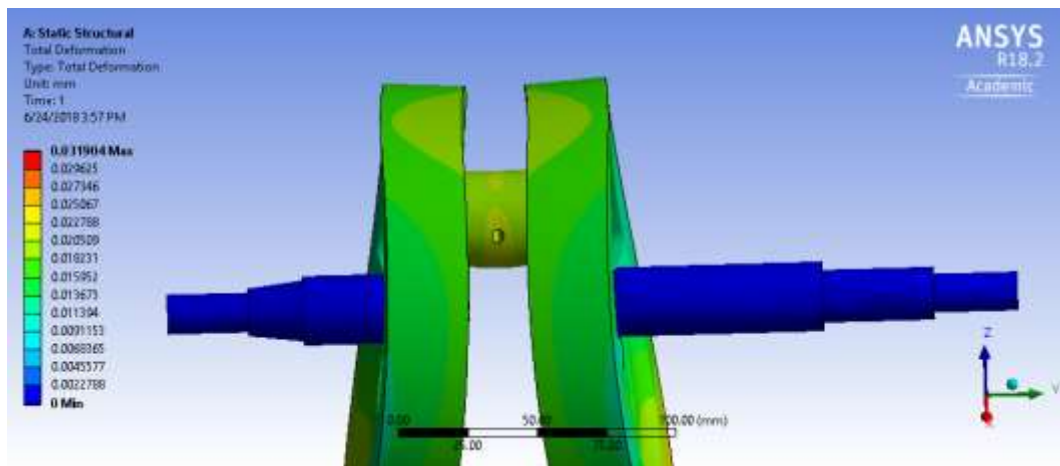


Fig-9 Total Deformation

4.8 Changed material Properties for Composite Material (Carbon-Epoxy):

As replacing material we are using Carbon-Epoxy material. So properties of Carbon-Epoxy updated for the same model to do analysis.

Properties of Carbon-Epoxy:

Density = 1600 Kg/m³

Poisson's ratio = 0.3

Young's Modulus = 2.1e+005 Mpa

Properties of Outline Row 3: Carbon-Epoxy Project				
	A	B	C	D E
1	Property	Value	Unit	
2	Material Field Variables	Table		
3	Density	1600	kg m ⁻³	
4	Isotropic Elasticity			
5	Derive from	Young's Modulu...		
6	Young's Modulus	2.1E+05	MPa	
7	Poisson's Ratio	0.3		
8	Bulk Modulus	1.75E+11	Pa	
9	Shear Modulus	8.0769E+10	Pa	

Fig-10 Default Material Properties (Carbon-Epoxy)

4.9 Result:

After changing the material update the workbench which will automatically apply the same boundary condition and solve for the results.

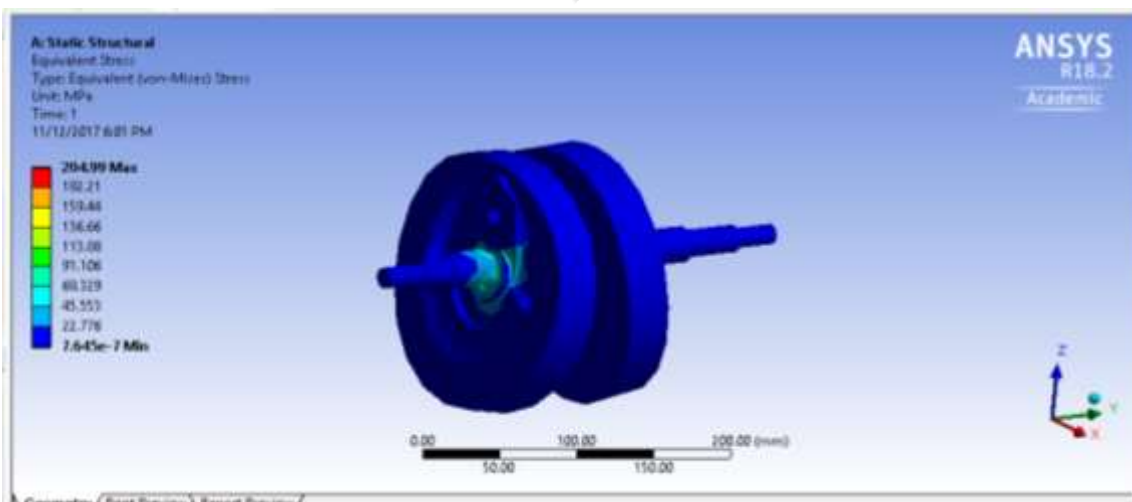


Fig-11 Equivalent (von mises) Stress

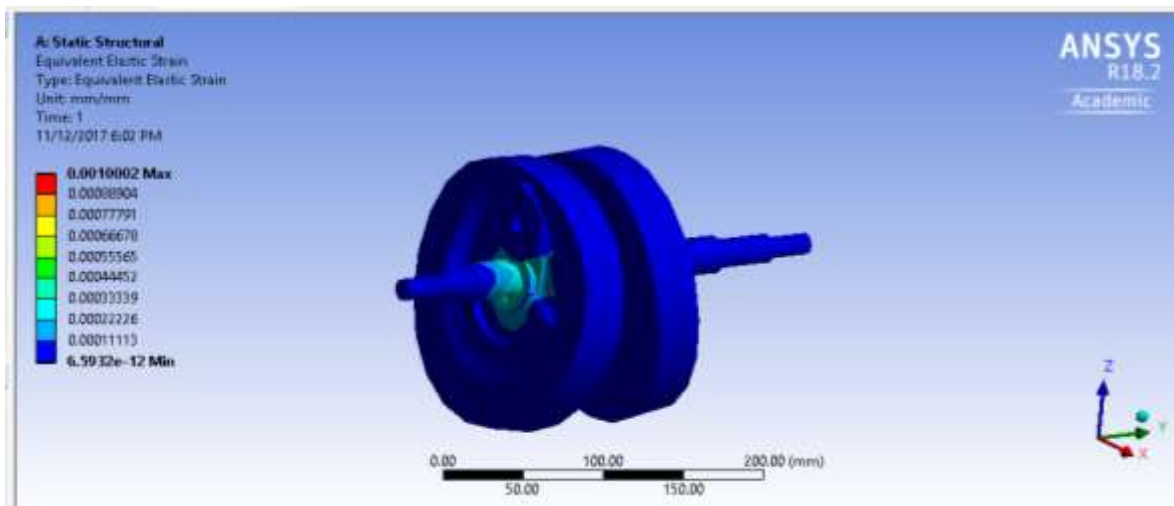


Fig-12 Equivalent (von mises) Strain

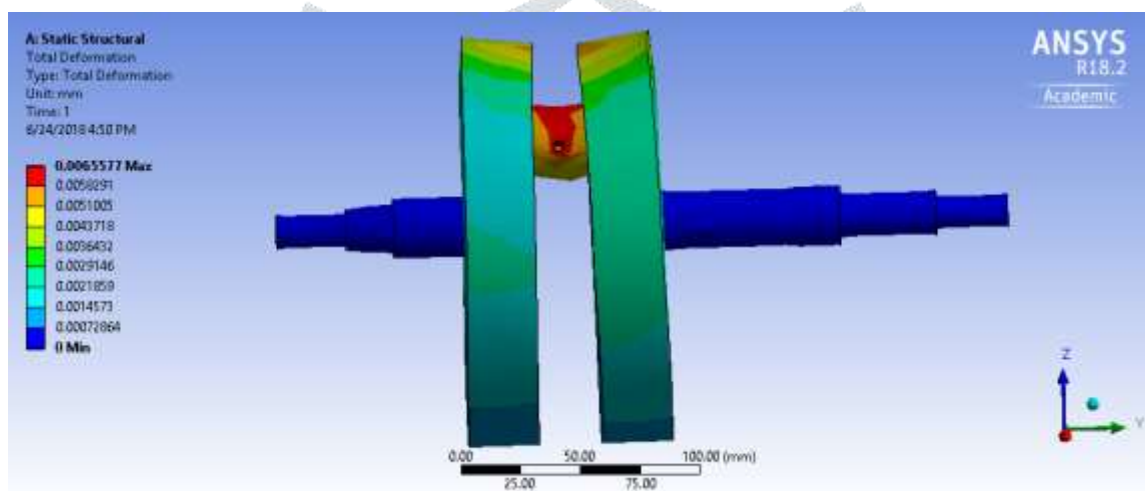


Fig-13 Total Deformation

V. RESULTS AND DISCUSSION

Table No-3 FEA Results

Properties	Medium Carbon Steel	Carbon-Epoxy
Total Deformation (mm)	0.0319	0.0065
Equivalent [von mises] Stress (Mpa)	268.66	204.99
Equivalent [von mises] Strain	0.00134	0.0010
Weight (Kg)	10.4	2.18

Table No-4 Difference between Analytical and FEA Results

Parameter	Analytical	FEA (Medium Carbon Steel)	FEA (Carbon-Epoxy)
Von mises stress (N/mm ²)	273.51	268.66	204.99
Von mises strain	0.0014	0.00134	0.0010

A difference of the von mises stress is observed between the analytical and FEA result which is acceptable as variation tolerance is set due to meshing technique and solution algorithm.

VI. CONCLUSION

Analysis results from testing the crankshaft under load are listed in the table. The maximum deformation occurs at the centre of the crankpin neck surface. The results such as total deformation, equivalent elastic strain and equivalent stress for each material are determined. Comparing the optimized materials and the conventional material, Carbon-Epoxy composite has the low values of total deformation, stress and strain. And also weight of the crank shaft is reduced by 79.03%. The value of von-mises stress of FEA analysis for carbon fiber/epoxy crankshaft is less than the material yield stress so this design is safe.

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