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Design and Stress Analysis of Metal Matrix Composite Single Cylinder 4 Stroke Engine Crankshaft

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Abstract—generally the crankshaft analysis is done in the analysis software ANSYS by designing in the modelling software UNIGRAPHICX NX8 as per standards, discretization of the model in the meshing tool HYPERMESH and analysis is made by applying the boundary conditions derived from the engine specifications and conditions. Material used for the crankshaft is the metal matric composite aluminium silicate (Al-Sic). Similar boundary conditions are applied on both the crankshaft models and static analysis is done and both the results are concluded.
Keywords:- Cast iron, Aluminium silicate, ANSYS, UNIGRAPHICX, HYPERMESH, Static.

I. INTRODUCTION

Crankshaft is the core part of the automobiles for diesel and petrol which literally converts the reciprocating motion force to the linear motion and the mechanism is fulfilled, generally crankshafts are mounted below the piston which connected to the crankshaft through the connecting rod. Basically crankshafts are made by forging technique and casting technique. Materials used for the crankshaft are cast iron, aluminium, magnesium based alloys, titanium, and some of the crankshafts are coated with nickel chromium and etc. As crankshaft is completely a rotating part and pressure applied on the crankpin experiences lot of stress subjected to frequent failure and most of the cases crankshaft fails at the fillet radius of the crankpin so material used for the crankshaft should be strong enough to withstand the load. In this current research the crankshaft is made of metal matrix composites i.e. Al-Sic (aluminium silicate) and determines that Al-Sic is suitable for the crankshaft. Amit solanki and jaydeepsingh dodiya has conducted an analysis on crankshaft part model was created by Pro-E Software. Then, ANSYS software is used for analysis of the created model. Results from FEA concluded that experimental values are similar to theoretical calculation so they say that FEA is a good tool to decrease time consuming theoretical Work. The deformation appears at the centre of crankpin neck surface is maximum. The stress appears maximum at the fillets between the crankshaft journal and crank cheeks and near the central point Journal. The Value of Von-Misses Stresses obtained from the analysis is less than material yield stress so design is safe and optimized to reduce the material and cost. Static and Dynamic analysis of the crankshaft are done Dynamic analysis results are more realistic compared to static analysis. Accurate stresses and deformation are critical input to fatigue analysis and optimization of the crankshaft. After Analysis conclusion Dynamic FEA is a best tool to reduce experimental work.

II. DESIGN CALCULATION FOR CRANKSHAFT

The Specifications of the Engine for crankshaft are listed below

Table 1: Specifications of engine

Type	Single cylinder engine
No of cylinders	1
Capacity	996
Bore x Stroke	98 x 66 mm
Cooling System	Liquid cooled
Compression Ratio	11.5:1
Max Power	112 hp / 83.5 kW @ 8500 rpm
Max Torque	99 Nm / 73 ft. lbs @ 7000 rpm
Transmission	6 Speed

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A. Design of crankshaft numerical calculations

To find volume,

$$\text{displacement} = \frac{\pi}{4} \times \text{bore}^2 \times \text{stroke} \times \text{number of cylinders}$$

V=(.785)(98)^2*(66)(1)
V=497836.62mm

To find pressure,

Mean effective pressure=(Px60xn)/(Nxv)

P=20.12mpa

To find force,

Force =∏/4 xd²xP

F=15.17kN

B. Design of the crankshaft when the crank is at an angle of maximum twisting moment

We know that piston gas load, F_P =15.17KN

Assume that the distance between the bearings is equal to twice the piston diameter

$b = 2D = 2 \times 98 = 196$ mm

and $b_1 = b_2 = \frac{b}{2} = \frac{196}{2} = 98$ mm

In order to find the thrust in the connecting rod (F_Q), we should first find out the angle of inclination of the connecting rod with the line of stroke (*i.e.* angle φ). We know that

$$\sin\varphi = \frac{\sin\theta}{l/r} = \frac{\sin 35°}{5} = 0.1147$$

$\therefore \quad \varphi = \sin^{-1}(0.1161) = 6.58°$

We know that thrust in the connecting rod,

$$F_Q = \frac{F_P}{\cos\varphi} = \frac{15.17}{\cos 6.58°} = 15.27\text{KN}$$

Tangential force acting on the crankshaft,

$F_T = F_Q \sin(\theta + \varphi) = 15.27 \sin(35° + 6.58°) = 10.13$ kN

And radial force, $F_R = F_Q \cos(\theta + \varphi) = 15.27 \cos(35° + 6.58°)$ =11.42kN

Due to the tangential force (F_T), there will be two reactions at bearings 1 and 2, such that

$$H_{T1} = \frac{F_T \times b_1}{b} = \frac{10.1*98}{196} = 5.0 \text{ kN}$$

and

$$H_{T2} = \frac{F_T \times b_2}{b} = \frac{\square\square\square\square}{196} = 5.0 \text{ kN}$$

Volume 4 Issue IV, April 2016
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Due to the radial force (F_R), there will be two reactions at bearings 1 and 2, such that

$$H_{R1} = \frac{F_R \times b_1}{b} = \frac{11.42*98}{196} = 5.71 \text{ kN}$$

$$H_{R2} = \frac{F_R \times b_2}{b} = \frac{11.42*98}{196} = 5.71 \text{ kN}$$

C. Design of crankpin

We know that the bending moment at the centre of the crankpin,

$$M_C = H_{R1} \times b_2 = 5.71 \times 98 = 559.58 \text{ kN-mm}$$

and twisting moment on the crankpin,

$$T_C = H_{T1} \times r = 5.01 \times 33 = 165.33 \text{ kN-mm}$$

According to distortion energy theory the von misses stress induced in the crank pin is

$$M_{ev} = \sqrt{(\text{Kb x Mc})^2 + \frac{3}{4}(\text{Kt x Tc})^2} = 1139.58 \text{kN-mm}$$

Here, Kb = combined shock and fatigue factor for bending (Take Kb=2)
Kt = combined shock and fatigue factor for torsion (Take K t =1.5)

$$M_{ev} = \frac{\pi}{32} \text{ x } (d_c)^3 \text{ x } 6_v$$

Therefore von-misses stress=375.347N/mm2

III. DESIGN METHODOLOGY

A. Initially part modelling of the crankshaft is made in UNIGRAPHICX NX8 tool and save the file in .IGES for analysis of crankshaft in ANSYS by importing.

B. Material application for crankshaft details

Material type: - Aluminium silicate (Al-Sic)
Poisson ratio: - 0.29
Yield strength:-500Mpa

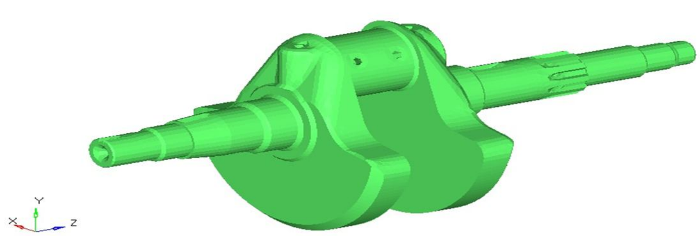

Fig 3.1 Crankshaft Model

Volume 4 Issue IV, April 2016
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C. Meshing of crankshaft:

Type of element: - Tetrahedron10.
Number of Nodes:-17338.
Number of Elements:-74045

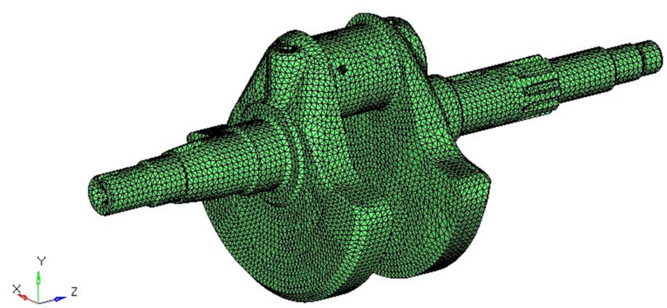

Fig 3.2 Meshed model of crankshaft

D. Boundary conditions for analysis:

Boundary conditions play an important role in the part of analysis. Here we have taken the displacements for fixed bearing supports.

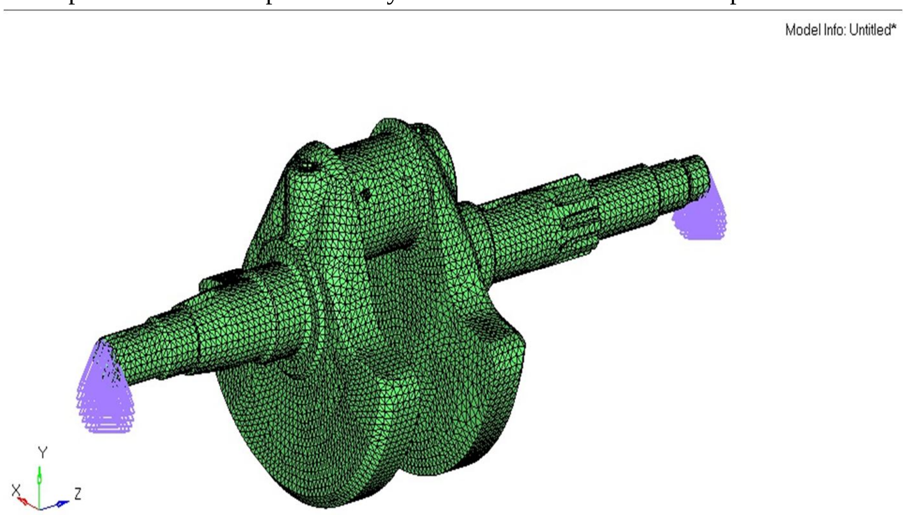

Fig 3.3 Fixed supports boundary conditions

E. Type of analysis

Static structural analysis

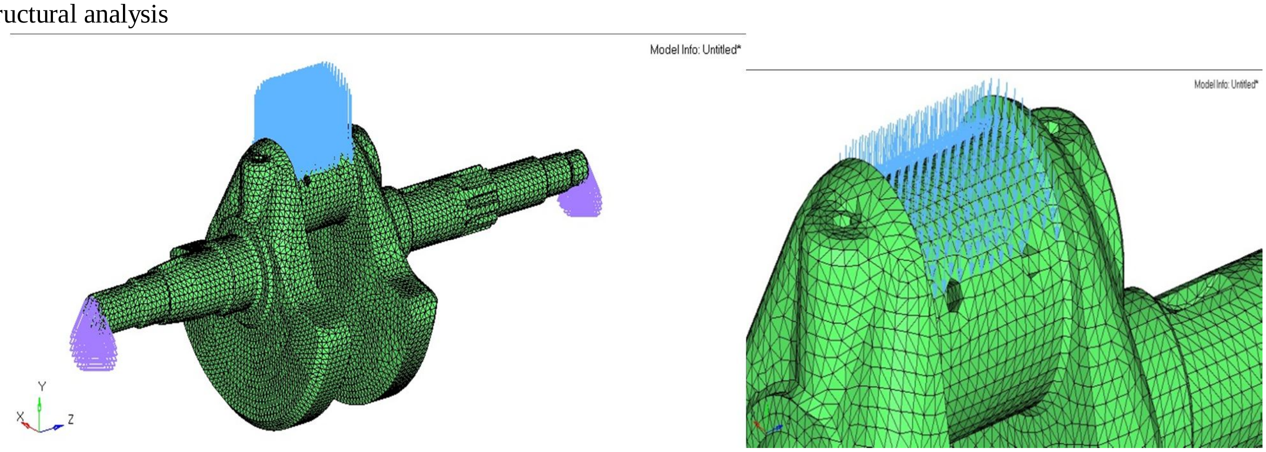

Fig 3.4 Applying of tangential force

F. Analysis run and results

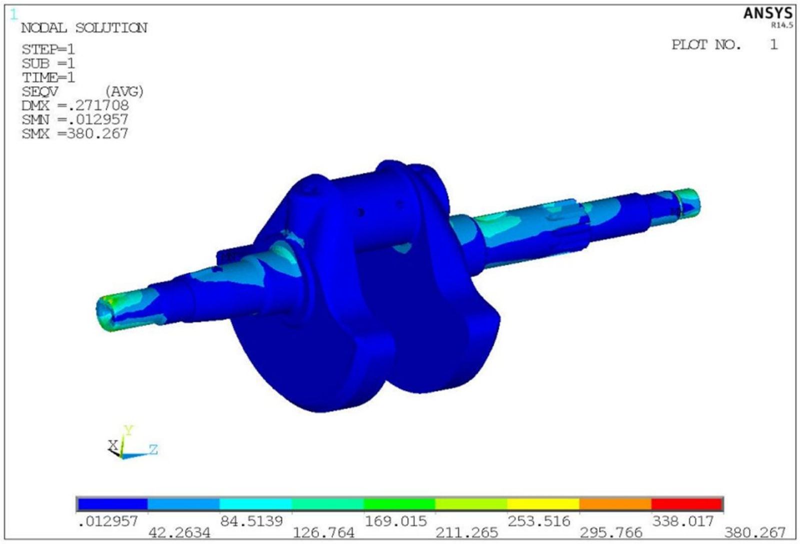

Fig 3.5 Von-Misses stress analysis

IV. RESULTS AND DISCUSSIONS

In this paper the model of crankshaft is created in UG NX8 and imported to ansys for analysis

Results table: 02

Type of stress	Theoretical	FEA Analysis
Von-Misses stress, N/mm^2	375.347	380.267

A. Above Results Shows that FEA Results that theoretical value matches with the experimental FEA value so FEA tool is the best tool to reduce the time and cost. According to the analysis the maximum deformation appears at the centre of crankpin. So the damage occurs more at the fillet radius. The edge of main journal is high stress area.

B. The Value of material yield stress is more compared to von-misses stress obtained von-Misses Stresses so our design is safe and we should go for optimization to reduce the material and cost.

C. Finally analysis results that FEA can be used to analyse instead of the theoretical work.

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