Modeling and Analysis of the Crankshaft Using Ansys Software

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ABSTRACT:

Crankshaft is large volume production component with a complex geometry in the Internal Combustion (I.C) Engine. This converts the reciprocating displacement of the piston in to a rotary motion of the crank. An attempt is made in this paper to study the Static analysis on a crankshaft from a single cylinder 4-stroke I.C Engine. The modelling of the crankshaft is created using CATIA-V5 Software. Finite element analysis (FEA) is performed to obtain the variation of stress at critical locations of the crank shaft using the ANSYS software and applying the boundary conditions. Then the results are drawn Von-misses stress induced in the crankshaft is 15.83Mpa and shear stress is induced in the crankshaft is 8.271Mpa. The Theoretical results are obtained von-misses stress is 19.6Mpa, shear stress is 9.28Mpa. The validation of model is compared with the Theoretical and FEA results of Von-misses stress and shear stress are within the limits. Further it can be extended for the different materials and dynamic analysis, optimization of crank shaft.

Keywords: *Crankshaft, finite element analysis (FEA), ANSYS Software, Static Analysis;*

I. INTRODUCTION:

Crank shaft is a large component with a complex geometry in the I.C engine, which converts the reciprocating displacement of the piston to a rotary motion with a four bar link mechanism. Crankshaft consisting of shaft parts, two journal bearings and one crankpin bearing. The Shaft parts which revolve in the main bearings, the crank pins to which the big end of the connecting rod are connected, the crank arms or webs which connect the crank pins and shaft parts. In addition, the linear displacement of an engine is not smooth; as the displacement is caused by the combustion chamber therefore the displacement has sudden shocks. 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. The magnitude of the forces depends on many factors which consist of crank radius, connecting rod dimensions, weight of the connecting rod, piston, piston rings, and pin.

Combustion and inertia forces acting on the crankshaft. 1. Torsional load 2. Bending load. 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 largely.

The crank pin is like a built in beam with a distributed load along its length that varies with crank positions. Each web is like a cantilever beam subjected to bending and twisting. 1. Bending moment which causes tensile and compressive stresses. 2. Twisting moment causes shear stress.

There are many sources of failure in the engine one of the most common crankshaft failure is fatigue at the fillet areas due to the bending load causes by the combustion. The moment of combustion the load from the piston is transmitted to the crankpin, causing a large bending moment on the entire geometry of the crankshaft. At the root of the fillet areas stress concentrations exist and these high stress range locations are the points where cyclic loads could cause fatigue crank initiation leading to fracture.

II. LITERATURE REVIEW:

Rinkle garg and Sunil Baghl. [1] have been analyzed crankshaft model and crank throw were created by Pro/E Software and then imported to ANSYS software. The result shows that the improvement in the strength of the crankshaft as the maximum limits of stress, total deformation, and the strain is reduced. The weight of the crankshaft is reduced .There by, reduces the inertia force. As the weight of the crankshaft is decreased this will decrease the cost of the crankshaft and increase the I.C engine performance.

C.M. Balamurugan et al [2] has been studied the Computer aided Modelling and Optimization of crankshaft and compare the fatigue performance of two competing manufacturing technologies for automotive crankshafts, namely forged steel and ductile cast iron. The Three dimensional model of crankshaft were created by solid edge software and then imported to Ansys software. The optimisation process included geometry changes compatible with the current engine, fillet rolling and results in increased fatigue strength and reduced cost of the crankshaft, without changing connecting rod and engine block.

Gu Yingkui, Zhou Zhibo. [3] have been discussed a three-Dimensional model of a diesel engine crankshaft were established by using PRO/E software and analytical ANSYS Software tool, it shows that the high stress region mainly concentrates in the knuckles of the crank arm & the main journal and the crank arm & connecting rod journal ,which is the area most easily broken.

Abhishekchoubey, and Jamin Brahmbhatt.[4] have been analyzed crankshaft model and 3-dimentional model of the crankshaft were created by SOLID WORKS Software and imported to ANSYS software. The crankshaft maximum deformation appears at the centre of crankpin neck surface. The maximum stress appears at the fillets between the crankshaft journals and crank cheeks and near the central point journal. The edge of main journal is high stress area.

R. J. Deshbhratar, and Y.R Suple.[5] have been analyzed 4- cylinder crankshaft and model of the crankshaft were created by Pro/E Software and then imported to ANSYS software The maximum deformation appears at the centre of crankshaft surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks, and near the central point. The edge of main journal is high stress area. The crankshaft deformation was mainly bending deformation under the lower frequency. And the maximum deformation was located at the link between main bearing journal and crankpin and crank cheeks. So this area prones to appear the bending fatigue crack.

III. OBJECTIVE:

An attempt in this paper, the crankshaft is modelled by using CATIA-V5 software, and static analysis is done by using ANSYS Workbench software. To evaluate the von-misses stress and shear stress.

IV. MATHEMATICAL MODEL FOR CRANKSHAFT:

Configuration of the Engine to which the crankshaft belongs, Fazin H. Montazersadgh and Ali Fatemi [6].

Crank pin radius	22.6
Shaft Diameter	34.925
Thickness of the Crank web	21.336
Bore diameter	53.73
Length of the crank pin	43.6
Maximum pressure	35bar

Force on the piston:

Bore diameter (D) =53.73mm, F_Q= Area of the bore ×Max. Combustion pressure

$$= \frac{\pi}{4} \times D^2 \times P_{max} = 7.93KN$$

In order to find the Thrust Force acting on the connecting rod (F_Q), and the angle of inclination of the connecting rod with the line of stroke (i.e. angle Ø).

$$\sin\phi = \frac{\sin\theta}{L/R} = \frac{\sin 35^0}{4}$$

Which implies $\emptyset = 8.24^0$

We know that thrust Force in the connecting rod, $F_Q = F_P/\cos\emptyset$

From we have

Thrust on the connecting rod, F_Q =8.01KN

Thrust on the crankshaft can be split into tangential component and radial component.

1. Tangential force on the crankshaft,

$$F_T = F_Q \sin(\theta + \emptyset) = 5.48KN$$

2 .Radial force on the crankshaft,

$$F_R = F_Q \cos(\theta + \emptyset) = 5.83KN$$

Reactions at bearings (1&2) due to tangential force is given by

$$H_{T1} = H_{T2} = F_T/2$$

Similarly, reactions at bearings (1&2) due to radial force is given by
$H_{R1} = H_{R2} = F_R/2$

4.1 Design of crankpin:
Let d= diameter of crankpin in mm
We know that bending moment at the centre of the crankshaft
$M_C = H_{R1} \times b_2 = 156.62$KN-mm
Twisting moment on the crankpin
$(T_C) = 61.94$KN-mm
From this we have equivalent twisting moment
$T_e = \sqrt{Mc^2 + Tc^2} = 168.42$KN-mm

Von-misses stress induced in the crankpin
$M_{ev} = \sqrt{(Kb + Mc)2 + \frac{3}{4}(Kt \times Tc)2}$
$= 177.860$KN-mm
$M_{ev} = \frac{\pi}{32} \times d^3c \times \sigma v$
$\sigma_v = 19.6$N/mm²
Shear stress:
$\tau_e = \frac{\pi}{16} d^3c \times \tau$
$\tau = 9.28$N/mm²

V. MODELING AND MESHING OF THE CRANKSHAFT:

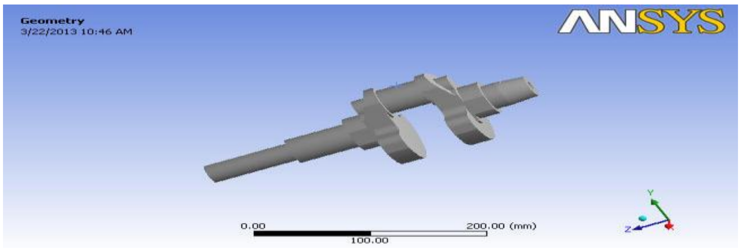

Figure :- 5.1. Model of the crankshaft

Mesh Statics:
Type of Element : Tetrahedrons
Number of nodes : 4873
Number of Elements: 2490

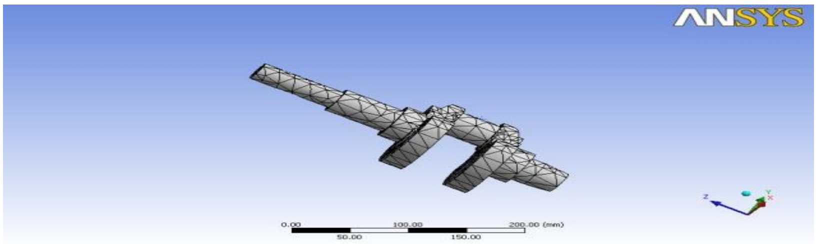

Figure :- 5.2 Meshed model of the crankshaft

VI. ANALYSIS:

Introduction to FEA:

The basis of FEA relies on the decomposition of the domain into a finite number of sub-domains (elements) for which the systematic approximate solution is constructed by applying the variational or weighted residual methods. In effect, FEA reduces problem to that of a finite number of unknowns by dividing the domain into elements and by expressing the unknown field variable in terms of the assumed approximating functions within each element. These functions (also called interpolation functions) are defined in terms of the values of the field variables at specific points, referred to as nodes. The finite element method is a numerical procedure that can be used to obtain solutions to a large class of engineering problems involving stress analysis, heat transfer, electro-magnetism, and fluid flow.

Introduction to ANSYS Software:

ANSYS is general-purpose Finite Element Analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user designed size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole.

The ANSYS Workbench environment is an intuitive up-front finite element analysis tool that is used in conjunction with CAD systems and/or Design Model. ANSYS Workbench is a software environment for performing structural, thermal, and electromagnetic analyses. The Workbench focuses on attaching existing geometry, setting up the finite element model, solving, and reviewing results.

Static Analysis:

Used to determine displacements, Stresses, Strain, Deformation etc. under static loading conditions in both linear and nonlinear static analysis. Nonlinearities include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep.

Apply Material for crankshaft (cast iron).

Material Type: cast iron
Young modulus: 1.78e+005Mpa
Poisson's ratio: 0.3
Density: 7.197e-006kg/mm³

VII. RESULTS AND DISCUSSION:

Analysis of crankshaft-cast Iron

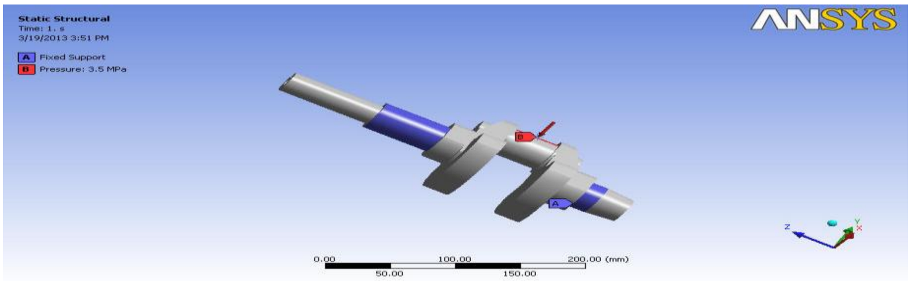

Figure:- 7.1 Apply Boundary conditioon the crankshaft

The two ends of the crankshaft is To be fixed, the load 3.5 Mpa is applied on the top of the crankpin surface.

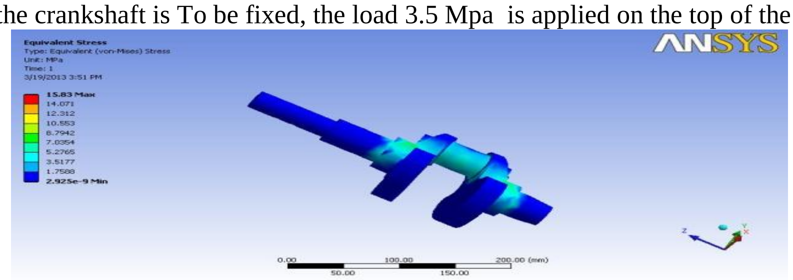

Figure:- 7.2 crankshaft voin-misses stress

The maximum stress induced in the crankshaft is 15.83 Mpa at the crankpin neck surface. Minimum stress 2.925e-9 Mpa.

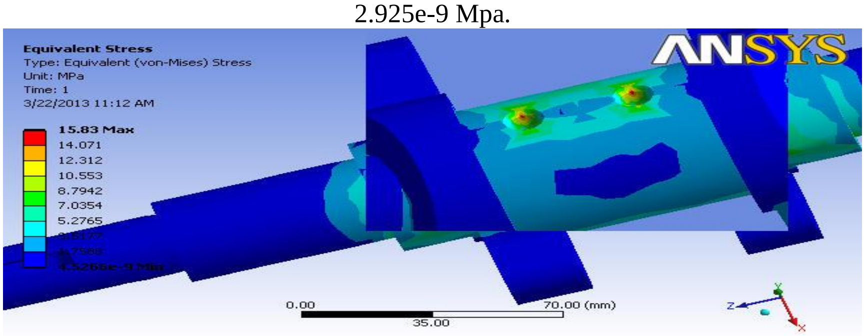

Figure:- 7.3 Maximum stress induced in the crankpin area

Maximum stress induced in the Crankshaft is 15.83Mpa at the fillet areas.

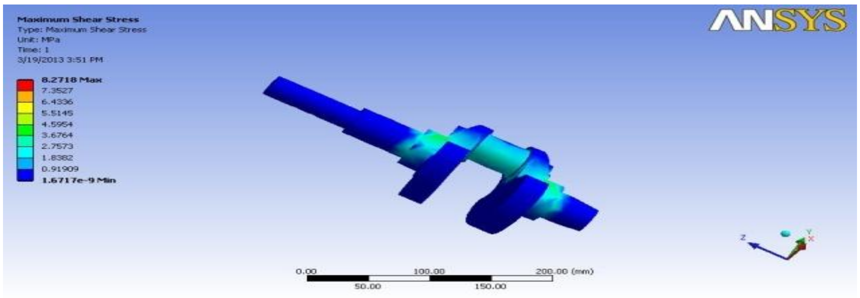

Figure:-7.4 crankshaft shear stress

The Maximum shear stress induced in the crankshaft is 8.2718Mpa, Minimum stress induced is1.6717e-91Mpa.

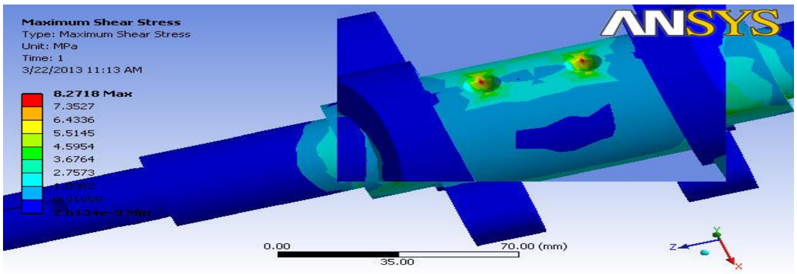

Figure:- 7.5 Maximum shear stress in the crankshaft.

The Maximum shear stress is 8.271Mpa at the crankpin area.

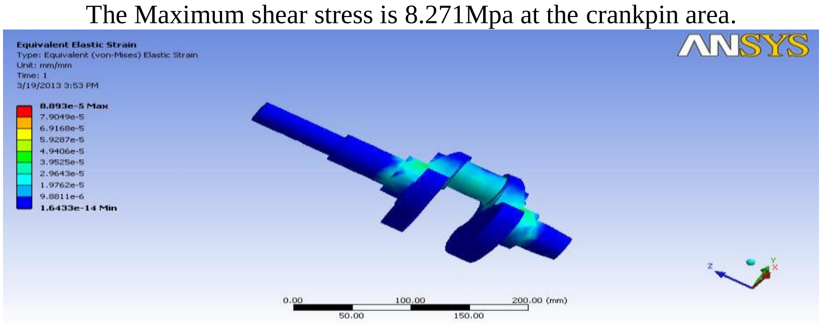

Figure:- 7.6 crankshaft(cast Iron) elastic strain Maximum Strain in the crankshaft is 8.893e-5.

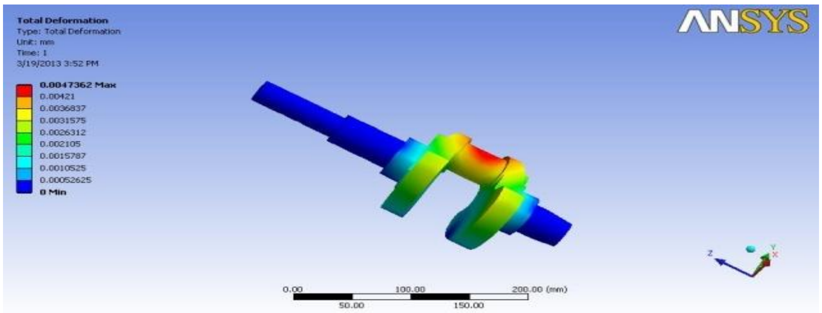

Figure:- 7.7 crankshaft total deformation

VIII. CONCLUSION:-

Validated Results:-

S.No	Type of stress	Theoretical	ANSYS results
1	Von-misses stress(N/mm²)	19.6	15.83
2	Shear stresses (N/mm²)	9.28	8.271

- The maximum deformation appears at the centre of the crankpin neck surface.
- The maximum stress appears at the fillet areas between the crankshaft journal and crank cheeks and near the central point journal.
- The value of von-misses stresses that comes out from the analysis is far less than material yield stress so our design is safe.

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