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Structural Static Analysis of Crankshaft

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Abstract: ***Crankshaft is one of the vital components for the effective and precise working of Internal Combustion engine with the complex geometry; which converts the reciprocating displacement of the piston to a rotary motion. In this paper an attempt is made to study the Static structural analysis on crankshaft from single cylinder 4-stroke I.C Engine. The 3-Dimensional Modeling of crankshaft is done using Catia V5R20 software and Finite element Analysis is performed by using ANSYS Software by applying boundary conditions as the sides fixed and pressure spectrum is applied in the middle of crankpin. Bending moment causes the tensile and compressive stresses; Twisting moment causes Shear stresses. Thus, Analysis was conducted on the crankshaft with three different materials cast iron, High carbon steel and Alloy steel (42CrMn) to obtain variation of stress magnitude at critical locations. Analysis results are compared with Theoretical results of von-misses and shear stress which are in the limits to validate the model.***

Keywords: Alloy Steel (42CrMn), Ansys16.0, Cast Iron, Crankshaft, High Carbon Steel

1. Introduction

Crankshaft is one of the vital components for the effective and precise working of Internal Combustion engine with the complex geometry; which converts the reciprocating displacement of the piston to a rotary motion. The crankshaft consists of three parts i.e. crank pin, crank web and shaft. The big end of the connecting rod is attached to the crank pin; the crank web connects the crank pin to the shaft portion which is rotated by the main bearings and transmits power to the outside source through the belt drive, gear drive or chain drive. Crankshaft experiences a large number of cyclic loads during its service life so the reliability and life of I.C engine depend on the strength of the crankshaft mostly. As the Engine runs, the power impulses hit the crankshaft in middle so it must be strong enough to withstand the downward force without excessive bending. One of the most common crankshaft failures is fatigue at the fillet areas due to bending load caused by the large forces from gas combustion .Crankshaft cause two types of loading during combustion and inertia forces those are bending load and torsion load. Crankshaft deformation mainly was bending deformation under lower frequency and greatest deformation identified at the link between main bearing journal, crankpin and crank cheeks. Crank web acts like a Cantilever beam which is subjected to Bending and Twisting moments. Bending moment roots to tensile and Compressive Stresses; twisting moment roots to shear Stress.

Gu Yingkui [1] discusses about a 3D model of a diesel engine crankshaft which was developed by using PRO/E software and Using ANSYS software. This paper states that the high stress region mainly concentrates in the knuckles of the crank arm & the main journal and the crank arm & connecting rod journal so the area tends to break easily. Jian Meng [2] discusses about the crankshaft model developed by Pro/ENGINEER software and analysed using Ansys software. The crankshaft deformation was mainly bending deformation occurs under the lower frequency and the maximum deformation was observed at the link between main bearing journal, crankpin. K.Thriveni and Dr.B.Jayachandraiah [3] states about the modelled crankshaft using Catia-V5 and performed analysis in ANSYS resulting that maximum deformation occurs at the centre of crankpin neck surface and maximum stress appears at fillet areas of crankshaft. K.Sandhya [4] discusses about the developed crankshaft model in solid works and analysed in ANSYS software, static analysis is conducted on crankshaft with 3 different materials in different orientations and analytical results are validated with theoretical results. Jamin Brahmbhatt [5] discusses about the crankshaft from a single cylinder 4 stroke diesel engine created in solid works software and analysis done in Ansys software. Von-misses stress, vibration modal and frequency relationship is explained by harmonic analysis to show accurate stresses and deformation.Pawan Kumar Singh[6]discusses about crankshaft developed in CAD software and analyzed in ANSYS. Results are compared with theoretical ANSYS results thus design is safe for the condition of the value of von-misses stresses that comes out from the analysis is far less than material yield stress.

2. Objective

Crank shafts used in I.C Engines are made of Cast Iron and High Carbon offers the advantage of high strength, but there are failure cases like maximum deformation at crankpin neck surface and maximum stresses at fillet areas between the crankshaft journal and crank cheeks near central point journal. The objective of the work is add material 42CrMn (Alloy Steel) for Crankshaft which 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. Then approved model is compared with the theoretical and FEA results for Von-misses stress and shear stress for three materials.

3. Design Methodology

1) Studying the Failure causes of Crankshaft.
2) Selection of three different materials.
3) Preparation of 3D model using CATIAV5 software.
4) Analysing the crankshaft using ANSYS software.
5) Comparing the Analytical results with Theoretical results to validate the model.

4. Design Calculations for Crankshaft

Configuration of the Engine to which the crankshaft belongs, K.Thriveni, Dr.B.JayaChandraiah [3] is tabulated below:

Table 4.1: Specifications of Engine

Crank pin radius	17.62mm
Shaft diameter	34.92mm
Thickness of Crank web	21.34mm
Bore diameter	53.73mm
Length of Crank pin	43.69mm
Maximum Pressure	35bar

4.1 Design of Crank shaft when crank is at the angle of Maximum twisting moment force on the piston:

Bore diameter (D) =53.73mm,
Force of piston: F_p=Area of Bore×Maximum combustion Pressure

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

To find the Thrust force acting on the connecting rod (F_Q), we should find the angle of inclination of the connecting rod with the line of stroke (∅).

Angle of inclination, $\sin \emptyset = \frac{\sin \theta}{\frac{l}{r}} = \frac{\sin 35°}{4}$

Which implies, $\emptyset = 8.24°$

From that we have, Thrust force in the connecting Rod, $F_Q = \frac{F_P}{\cos \emptyset} = \frac{7.93}{\cos 8.24°} = 8.01KN$

Now the Thrust Force is divided into Tangential and Radial Components.

1) Tangential force on crankshaft, $F_T = F_Q(\sin(\theta + \emptyset)) = 8.01(\sin(35 + 8.24°)) = 5.48KN$
2) Radial Force on Crankshaft, $F_R = F_Q(\cos(\theta + \emptyset)) = 8.01(\cos(35 + 8.24°)) = 5.83KN$

Reactions at bearings due to tangential force is given by, $H_{T_1} = H_{T_2} = \frac{F_T}{2} = 2.74KN$

Similarly, Reaction at bearings due to Radial Force, $H_{R_1} = H_{R_2} = \frac{F_R}{2} = 2.91KN$

4.1.1 Design of crankpin

Let diameter of crankpin in mm, d=35.24mm

We know that Bending Moment of Crankshaft at the centre of the crankshaft,

$M_C = H_{R_1} \times b = 125.8$KN-mm

Twisting Moment of Crankshaft, $T_C = H_{T_1} \times R = 48.2$KN-mm

From this we have, Equivalent Bending Moment, $M_{ev} = \sqrt{(K_b + M_c)^2 + \frac{3}{4}(K_t + T_c)^2} = 135KN$

Von-Misses Stresses induced in the crank pin, $\sigma_v = \frac{M_{ev} \times 32}{\pi \times d^3} = 32.58MPa$

Equivalent Twisting Moment, $T_{ev} = \sqrt{{M_c}^2 + {T_c}^2}$

Shear Stress: $\tau = \frac{T_{ev} \times 16}{\pi \times d^3} = 15.71MPa$

5. Design and Analysis of Crankshaft

5.1 The design of crankshaft is done using CATIAV5R20

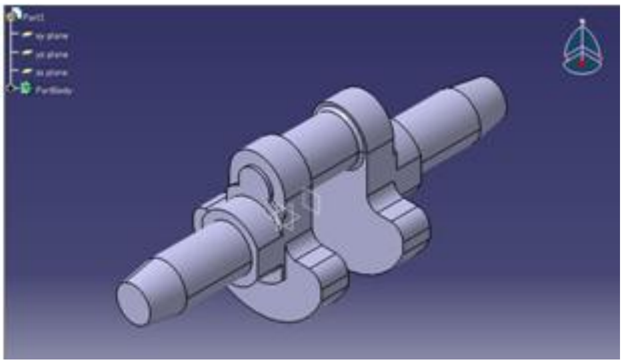

Figure 5.1 Crank shaft modeled using CATIA V5

Meshing Statics

The modelled crankshaft in CATIAV5R20 .igs file is imported into ANSYS software and the model is meshed.
Mesh Element: Tetrahedron
Mesh Type: Area
Edge length: 2.5mm

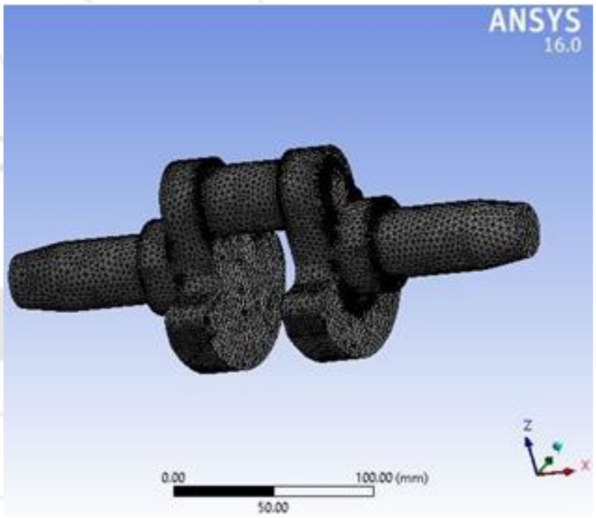

Figure 5.2 Meshed Model of the Crankshaft

Boundary Condition: Two sides of the shaft are fixed, and the Pressure is applied on the centre of the Crankpin.

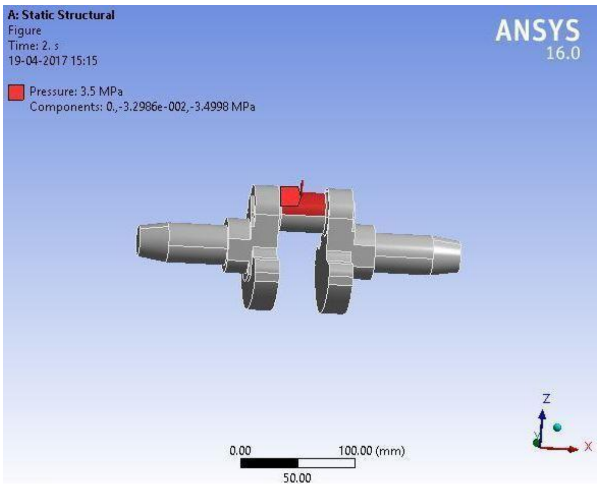

Figure 5.3 Pressure applied on the Crankshaft

5.2 Analysis of Crankshaft

Structural Static Analysis: A static analysis is used to calculate the effects of steady loading conditions ignoring the effects of inertia and damping. In static analysis loading and response conditions doesn't vary with time. The input loading conditions that can be given in a static analysis are moment, applied force and pressure and the output can by displacement, forces in a structure, stress and strain. If the values obtained in static analysis crosses the allowable values it will result in the failure of structure.

Materials Used For Crankshaft:
- Cast Iron
- High Carbon Steel
- Alloy Steel(42CrMn)

Table 5.1: Properties of the Materials

Material Name	Young modulus	Poisson ratio	Density	Yield Stress
Cast iron	178000 N/mm^2	0.3	7.197e-006 Kg/mm^3	130MPa
High Carbon Steel	200000 N/mm^2	0.295	7.872e-006 kg/mm^3	415MPa
Alloy Steel (42CrMn)	210000 N/mm^2	0.3	7.9e-006 kg/mm^3	930MPa

6. Results

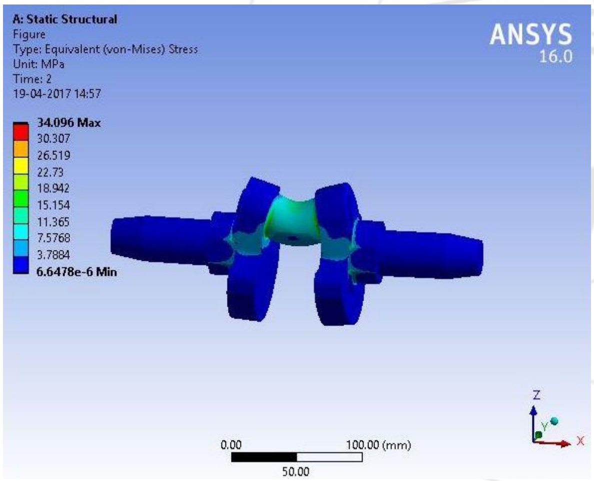

Figure 6.1 Cast Iron Von-Misses Stress

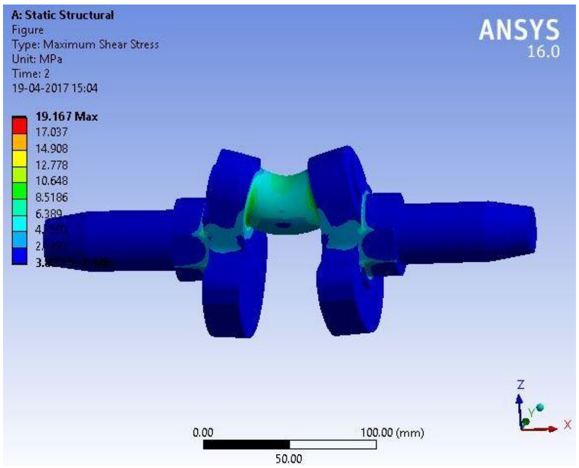

Figure 6.2: Cast Iron Shear stress

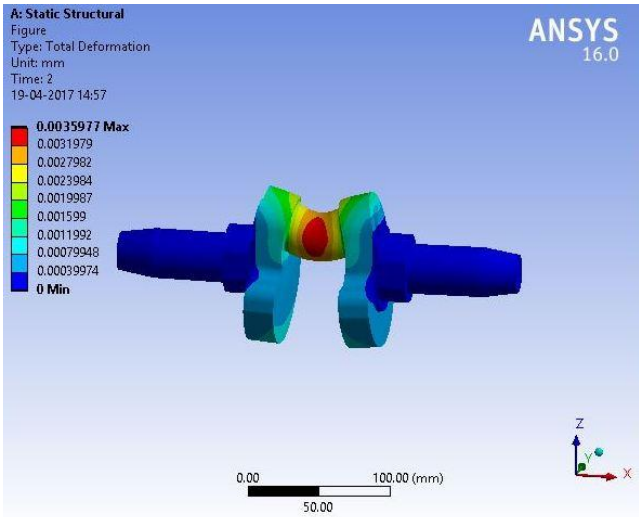

Figure 6.3: Cast Iron Total Deformations

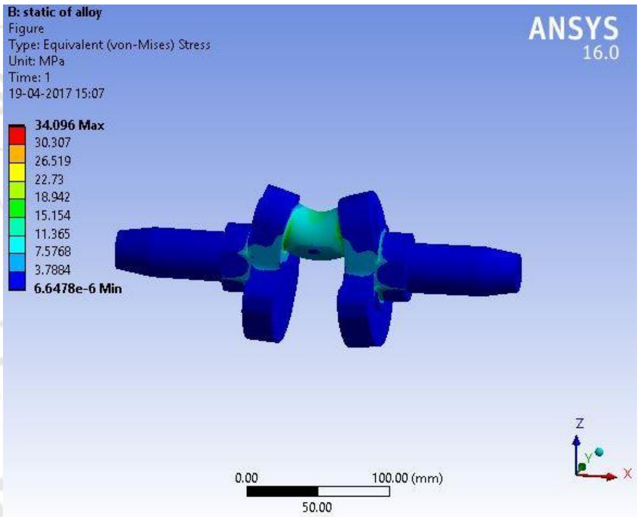

Figure 6.4 High Carbon Steel Von-misses Stress

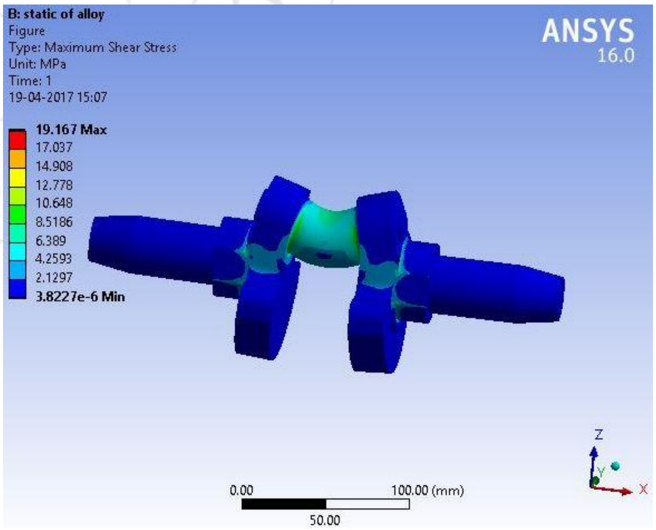

Figure 6.5 High Carbon Steel Shear Stress

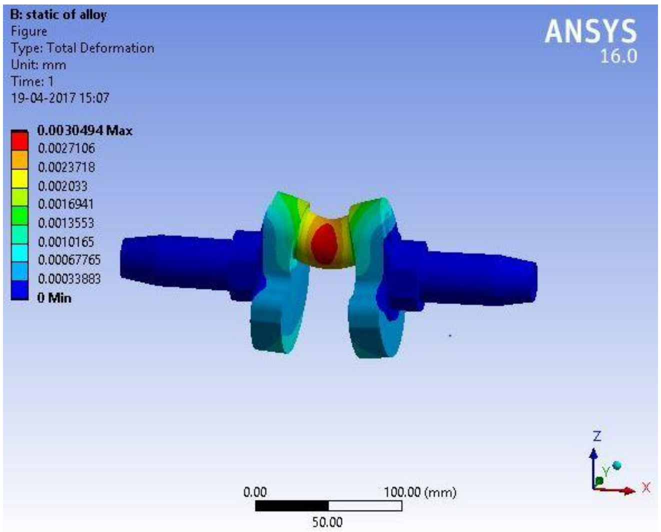

Figure 6.6: High Carbon Steel Total Deformation

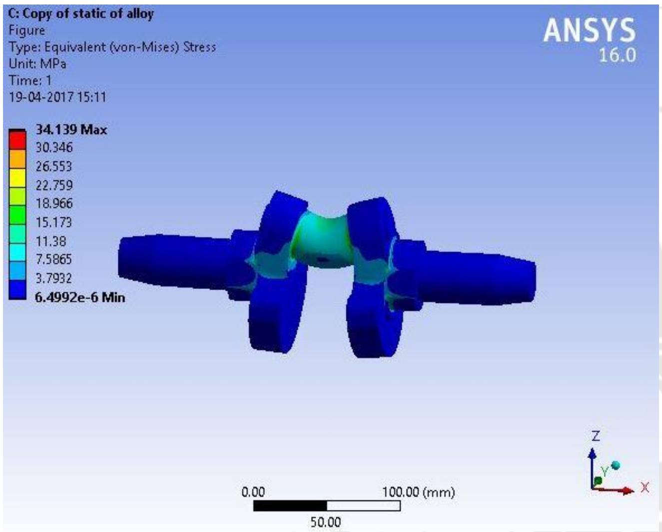

Figure 6.7: Alloy Steel (42CrMn) Von-Misses Stress

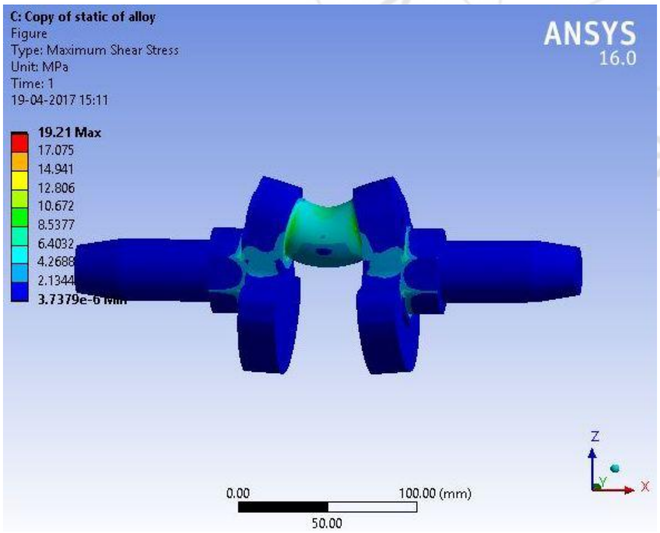

Figure 6.8: Alloy Steel (42CrMn) Shear Stress

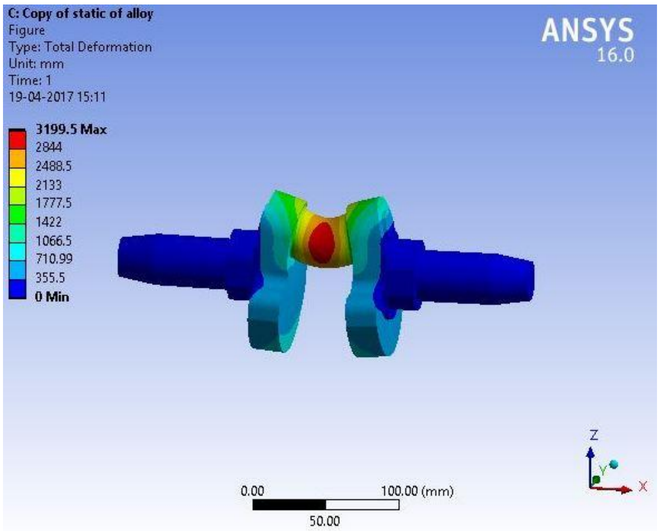

Figure 6.9 Alloy Steel (42CrMn) Total Deformation

Table 6.1: Results of the Structural Analysis for three materials

Material	Equivalent Stress (MPa)	Shear Stress (MPa)	Total Deformation(mm)
Cast Iron	34.09	19.16	0.0035
High Carbon Steel	34.09	19.16	0.0030
Alloy Steel (42CrMn)	34.13	19.21	0.0031

7. Conclusion

Table 7.1 Comparison between the Theoretical and ANSYS results

S.No	Type of Stress	Theoretical Results	Ansys Results
1	Von-Misses stress (MPa)	32.58MPa	34.13MPa
2	Shear Stress (MPa)	15.71MPa	19.21MPa

From the above results, Alloy steel (42CrMn) shows encouraging values of Von-Misses Stresses and Shear stresses compared to other two materials with the little variation. From the results it is concluded that the crankshaft design is within the limits since the Value of Von-Misses Stresses that comes out from the analysis is far less than material yield stress. The Maximum deformation appears at the center of the crankpin neck surface.

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