Stress Analysis in Crankshaft Through FEM

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Abstract— The crankshaft is the important part component of an engine. The main purpose of the crankshaft in automobile is to transform reciprocating linear motion to rotary motion. This thesis present the result of stress analysis done on a crankshaft of a single acting Four Stroke Diesel Engine using Solid Work, ANSYS and FEMAP Software. The three dimension model of crankshaft are develop in Solid work software and analysis in solid work first and after that import in ANSYS and FEMAP for stress analysis. The static analysis is done and is verified by simulation in finite element analysis software Solid work, ANSYS and FEMAP .A calculation method is used to validate the model. Finite element analysis is performed to obtain the variation of stress magnitude at critical locations.

***Keyword** : Diesel Engine,Crankshaft in Solidwork ANSYS and FEMAP,Finite Element Analysis,Stress Analysis.*

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I. INTRODUCTION

A **crankshaft** *crank*—is a mechanical part which is able to perform a conversion between the reciprocating motion and rotational motion. In Otto cycle engine or Internal Combustion Engine (IC Engine), a piston or series of it will reciprocate in a linear manner, for example, ups and downs.[1] The linear motion translated into rotational motion. The power generate from the movement of the piston is transmitted to the crankshaft w move the car. The Mechanical parts that translates all the piston linear motions is called Crankshaft.

Wiiard W. Pulkabek, (2004) said that in modern IC Engine, the crankshaft can rotate up to 20000 RPM. At the 20000 RPM forces are exceeds 3000 N push down the crankshaft due to which careful consideration of material and calculations is needed to create a crankshaft that can take not only directional forces but also rotational motion.[2] Crankshafts Materials should be readily shaped machined, Heat-treated and have enough strength, toughness, hardness and high fatigue strength.[3] The crankshaft are generally manufactured from steel either by forging or casting process. The bearing and connecting rod bearing liners are made of Tin, Babbitt and Lead alloy. The Forged crankshafts are more stronger than the cast crankshafts but it's more expensive. [4] Forged crankshafts made from SAE 1045 or similar type of steel. Forging makes it very dense and tough shaft with a grain running parallel to the principal stress direction. Many high performance crankshafts formed by the forging process. In forging Process a billet of suitable size is heated to the appropriate forging temperature typically in the range between 1950 to 2250°F. The Suitable size billet successively pressed into the desired shape by pairs of Die. In Die the billets are squeezing under very high pressures. These die sets have the concave negative form of the desired external shapes.[5] Crankshafts cast in steel generally modular ir on or malleable iron. The main advantage of the casting process is that crankshaft material & Machining costs are reduced because the crankshaft may be made close to the required shapes and size including counter-weights.[6] Cast crankshafts can handle loads from all directions because the metal grain structures is uniform and random throughout.

II. DESIGN CALCULATION FOR CRANKSHAFT

The specification of Single acting Four Stroke Petrol engine for crankshaft is TABULATED below:

Type	Single Cylinder Petrol Engine
No. of Cylinder	1
Boar/Stroke	400mm/600mm
Engine Speed	200 RPM
Mean Effective Pressure	0.5 N/mm^2
Maximum Combustion Pressure	2.5 N/mm^2
Compression Ratio	18:1

A. Design the crankshaft when the crank is at an angle of maximum bending Moments

The maximum gas pressure on the piston will transmit max. force on the crankpin in the plane of the crank due to which only bending of the shaft. The crankpin and ends of the crankshaft will be only subjected to bending moment. Thus, when the crank is at the dead center the bending moment on the shaft is Maximum and the Twisting moment is zero.

Let, D = Diameter of Piston or cylinder bore in mm,

p = Maximum intensity of pressure on piston in N/mm2

The Thrust in the connecting rod will be equal to Gas load on the Piston (F_p). We know that gas load on the piston,

$$F_p = \frac{\pi}{4} \times D^2 \times P$$

F_p = 314.159 KN

In order to find the Thrust connecting Rod (F_Q), find the angle of inclination Ø

Sin Ø = Sin 35^0/ 5 = 0.1147

Ø = 6.58

Thrust in connecting Rod $F_Q = F_p / \cos Ø$ = 316.08 KN

Thrust on Crankshaft can be split into Tangential Component & Radial Component.
Tangential Force on component $F_T = F_Q$ Sin (Ø+θ)
F_T = 316.08 sin (35 + 6.58) = 209.69 KN

Radial Force on Crankshaft $F_R = F_Q$ cos (Ø+θ)
F_R = 316.08 cos (35 + 6.58) = 236.36 KN

Distance between two bearings is given by
b = 2 D = 2 × 400 = 800 mm
$b_1 = b_2$ = b/2 = 800/2 = 400 mm

Reaction at bearing due to Radial Force

$H_{R1} = H_{R2} = \frac{F_R \times b_1}{b}$
= 236.36 × 400 / 800 = 118.18 KN

Reaction at bearing due to Tangential Force
$H_{T1} = H_{T2} = \frac{F_b \times b_2}{b}$
= 209.69 × 400/800 = 104.84 KN

B. Design of Crankpin

Bending Moment at the Centre of crankpin,
$M_C = H_{R1} \times b_2$ = 118.18 × 400 = 47272 KN-mm

Twisting Moment on crankpin,
$T_c = H_{T1} \times r$ = 104.84 ×300 = 31452 KN-mm

Equivalent Twisting moment
$T_E = \sqrt{M_C^2 + T_C^2} = \sqrt{(47272)^2} + \sqrt{(31452)^2}$
= 56779.13 KN-mm

We Know
$T_E = \frac{\pi}{16} \times \tau \times d_c^3$
= 56779.13 × 10^3 = 3.14/32 × $(d_c)^3$ × 35
d_c = 202.19 mm Say 205 mm

The length of the crankpin is given by

$l_c = \frac{F_p}{d_c \times P_b}$ = 155 mm

C. Design of left hand Crank web

The crank web is generally designed for eccentric loading. There will be two stresses acting on the crank web one is Direct Compressive Stress and the other is Bending Stress due to piston gas load (F_p).
Let, w= Width of crank web
t = Thickness of crank web

The width of crank web (w) is taken
w = 1.125 d_c + 12.7 mm
= 1.127 × 205 + 12.7 = 243.3 mm say 245 mm

Thickness of web t = 0.5 d_c to 0.9 d_c mm
Take 0.5 d_c = 0.5 × 205 = 102.5 mm

D. Design of right hand crank web:
The dimensions of the right hand Crank Web (i.e. thickness and width) are made equal to left hand crank web from the balancing point of view.

E. Design of crank pin against fatigue loading

According to distortion energy theory, the Von-Misses stress induced in the crank-pin is,
$M_{EV} = \sqrt{(Km \times Mc)}^2 + \frac{3}{4}\sqrt{(KT \times Tc)}^2$ = 102975.195 KN-mm

We Know $M_{EV} = \frac{\pi}{32} \times (d_c)^3 \times \sigma_v$
102975.195 × 10^3 = 3.14/32 × $(d_c)^3 \times \sigma_v$
σv = 121.81 N/mm^2 or 121.81 MPa

Result

Diameter of crank pin = 205mm

Length of crankpin = 155 mm

Width of crank web = 245 mm

Thickness of crank web = 102.5 mm

Diameter of shaft = 220 mm

III. DESIGN METHODOLOGY

A. Prodduse of Statics Analysis

First, we prepare a model of crankshaft in Solid work software and save as .IGES file format for Analysis of crankshaft in solid work software and Import .IGES model in ANSYS Workbench 16.0 & FEMAP for simulation analysis.

B. Applying Material for Crankshaft Material Details:

Material Type – Plane Carbon Steel
Poisson Ratio – 0.28
Yield Strength – 6.20422e+008 N/m^2

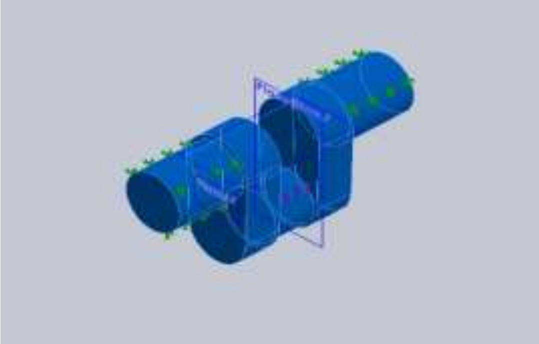


Fig. 3.1 Crankshaft in Solidwork

C. Result of Crankshaft in Solidwork

Number of nodes:- 636303

Number of elements:- 450127
Mesh Size – 7mm

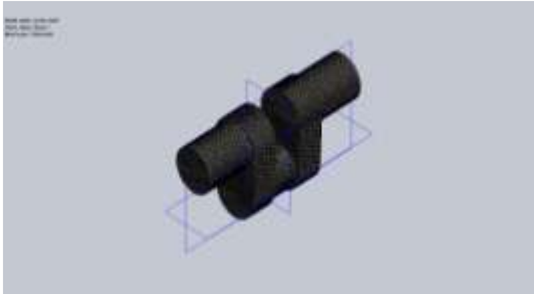


Fig. 3.2 Meshed Model of Crankshaft

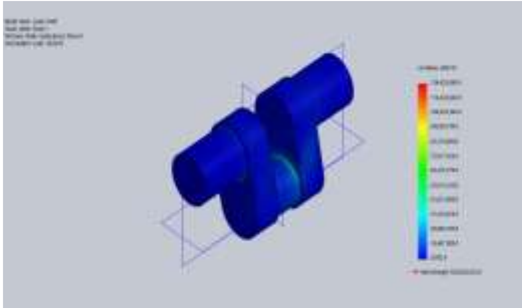


Fig. 3.6 Von-Misses Stress analysis in solidwork

D. Result of Crankshaft in ANSYS

Number of nodes:- 416552
Number of elements:- 244665
Mesh Size – 7mm

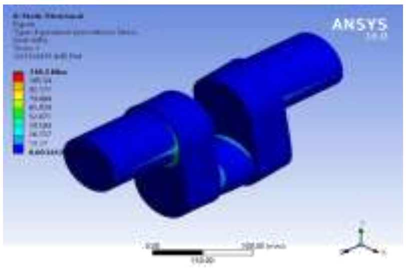
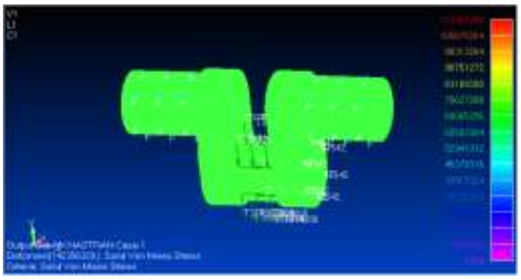


Fig. 3.6 Von-Misses Stress analysis in ANSYS

E. Result of Crankshaft in FEMAP

Number of nodes:- 332572
Number of elements:- 228948
Mesh Size – 7mm



IV. RESULT AND CONCULSION

In this paper, the crankshaft model was created by Solid work software. Then, the model created by Solid work was imported to ANSYS & FEMAP software.
Result table:-

Type of Stress	Theoretical Stress	FEA Analysis (Solid work)	FEA Analysis (ANSYS)	FEA Analysis (FEMAP)
Von Misses	121.81MPa	124.82 MPa	118.5 MPa	113.43 MPa

- Above Results Shows that FEA Results is different in different software of same Mesh size of 7 mm. In above Result ANSYS give the best result which is Conformal matches with the theoretical calculation so we can say that Finite Element analysis is a good tool to reduce time consuming theoretical Work.
- After Performing Static Analysis I Performed Dynamic Analysis of the crankshaft which provide more realistic result whereas static analysis provides an overestimate results.

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