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Design, Analysis & Balancing of 5 Cylinder Engine Crankshaft

Yogesh S. Khaladkar[1], Lalit H. Dorik[2], Gaurav M. Mahajan[3], Anil V. Fajage[4]

[1,2,3,4] B.E. Student, Dept. of Mech. Engg. Dr.D.Y. Patil Institute of Engg. & Tech. Ambi, University of Pune, India.

Abstract: *The crankshaft is a backbone of internal combustion engine. So the design & analysis is major aspects to get high power transmission & efficiency. The selection of material is an important parameter while designing any mechanical component. The material should be high strength & capacity to absorb the shocks as well as fatigue. The material also have less wear tendency. The crankshaft should be high torque transmitting capacity. So to achieve these objectives high carbon steel are used for design & analysis purpose. This paper gives the idea about analysis as well as proper balancing of weights by using these three materials. The modelling is done by using solid work software & then analysis by using ANSYS software with Finite Element Analysis (FEA) method. The 5 cylinder engine gives the power stroke at 144 degree angle. By addition of counterweights & modified design these odd cylinders are balanced properly. The Finite Element Analysis Method is used to determine stress, strains & deflection at most stressed point which results into failure of shaft. Results obtained from analysis are used during weight optimization. The Shaft is analyzed using static analysis. For absorbing vibrations proper damping material is used to achieve the requirement of safe design. The optimization results into reduction of weight as well as cost.*

Keywords: *ANSYS, Crankshaft,Damping, Finite Element Analysis, Optimization.*

I. Introduction

1.1) Design:

Mechanical design includes weight optimizationas well as optimum size, shape, etc. against failureunder the application of operational loads. A good design should also minimize the cost of material and cost of production. Failures that are commonly associated with mechanical components which are broadly classified as:

(a) Failure by breaking of brittle materials and fatigue failure of ductile materials.
(b) Failure by yielding of ductile materials, subjected to non-repetitive loads.
(c) Failure by elastic deformation. The last two modes cause change of shape or size of the component rendering it useless and, therefore, refer to functional or operational failure.

Most of the design problems refer to one of these two types of failures. Designing, thus, involves estimation of stresses and deformations of the components at different critical points of a component for the specified loads and boundary conditions, so as to satisfy operational constraints.

1.2) Finite Element method:

In FEM, actual component is replaced by a simplified model, identified by a finite number of elements connected at common points called nodes, with an assumed behavior or response of each element to the set of applied loads, and evaluating the unknown field variable (displacement, temperature) at thesefinite number of points. The crankshaft is the most important moving part of internal combustion engine. It converts reciprocating motion into rotary motion. Since the crankshaft experiences a large number of load cycles during its working. The performance, durability, torque transmitting capacity, stress, strains, service life, fatigue failure and durability of this component has to be considered in the design process. It must be strong enough to take the downward force of the power stroked without excessive bending. So the reliability and life of internal combustion engine depend on the strength of the crankshaft largely. The torsional vibration appears when a power impulse hits a crankpin toward the front of the engine and the power stroke ends. If not controlled, it can break the crankshaft. Strength calculation of crankshaft becomes a key factor to ensure the life of engine. This study is about 5 cylinder engine crankshaft. The modelling of crankshaft is done by using solid work software. The Finite Element Method is used to calculate stresses & deflection of crankshaft by using ANSYS software. The main aim is to increase efficiency & balancing of crankshaft by weight optimization. Thus the reduction in weight results into material reduction. So the cost will be lower than the conventional engine. The 5 cylinder engine gives more efficiency than 4 cylinder engine. The material for crankshaft is Cast Iron. Other alternate materials on which analysis has been done are, Forged steel, high carbon steel.

II. Literature Review

V. Vijaykumar [1] presented a paper on analysis of crankshaft using finite element analysis method with ABAQUS software. The material specifications are reviewed. Paper gives idea about dynamic load acting on crankshaft during operation. To find critical stresses and maximum load for crankpin is calculated by analyzing the results obtained from ABAQUS.

Solanki et al.[2] gives the idea about the design of crankshaft depends upon dynamic loading and optimization can lead to shaft diameter to fulfil the requirement of automobile.

V. Mallikarjuna Reddy[3] this gives the invention about the problem occurs in 6 cylinder diesel engine. The model is made by using unigraphics and analyzed by using ANSYS.

III. Design Calculations for Crankshaft

The specification of diesel engine for Safari Dicor are tabulated as follows.

No. of cylinders	5
Bore(D)	85mm
Stroke	96mm
Displacement	2179cc
Compression Ratio	17.2:1
Max. Power	104.4KW @4000rpm
Max. Torque	320Nm @ 1700-2700rpm
Max. Gas Pressure	25bar

3.1) Deign of crankshaft:

When the crank is at an angle of Maximum bending moment. At this position of the crank, the maximum gas pressure on the piston will transmit maximum force on the crankpin in the plane of the crank causing only bending of the shaft.

Let 'D' be the bore diameter in mm,

P= Pressure intensity in N/mm^2

F_p= Gas load on piston in N.

Force on piston F_p= Area of bore× Max. Combustion pressure

$= \pi/4*D^2*25*10^5$

=14.18KN.

In order to find thrust in connecting rod, we should find out angle of inclination of connecting rod with line of stroke (i.e. angle φ)

$\sin\varphi = \sin\theta/(l/r)$

$= \sin\theta/n = (\sin 35)/4$

$\varphi = 8.24^0$.

Thrust in connecting rod $F_{CR} = F_p / \cos\varphi$

=14.32KN.

Thus, thrust in C.R. is in tangential as well as radial direction which are as follows,

a)Tangential force on crankshaft, $F_T = F_{CR} \sin(\theta + \varphi)$

=9.81KN.

b) Radial force on crankshaft, $F_R = F_{CR} \cos(\theta + \varphi)$

=10.43KN.

Now, the reactions at bearings due to tangential force are:

$H_{T1} = H_{T2} = F_T/2 = 4.9KN$

Similarly, reactions due to radial force are:

$H_{R1} = H_{R2} = F_R/2 = 5.21KN$.

3.2) Design of crankpin:-

Let d_c be the diameter of crankpin. The bending moment at center of crankpin is given by

$M_C = H_{R1}*b$

=5.21*86=448.06Nm.

Twisting moment on crankpin is T_c=170.68Nm

The equivalent twisting moment

$T_e = (M_c^2 + T_c^2)^{1/2}$

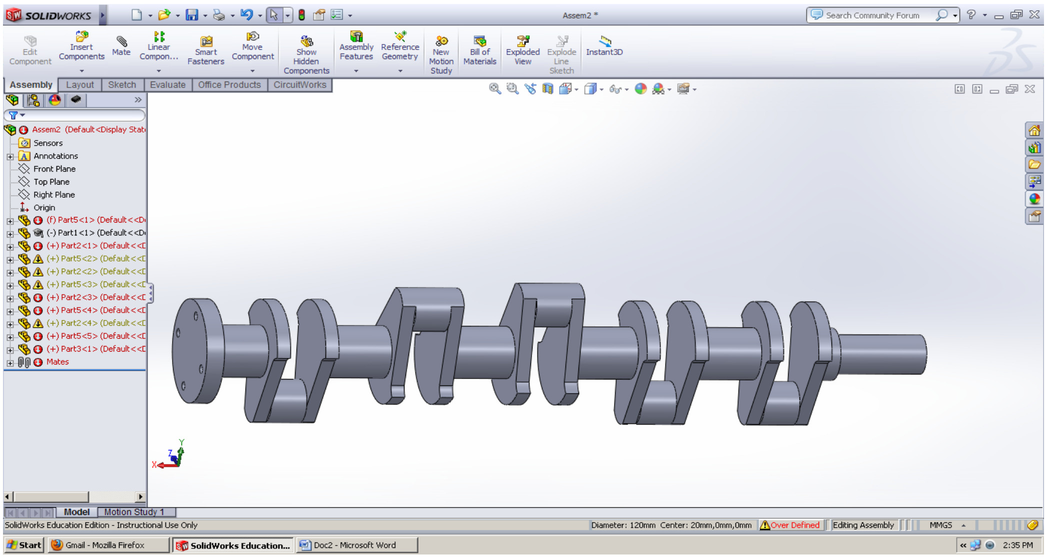
=479.46Nm

Also equivalent twisting moment

Te=(π/4*d_c^3*Prem. Shear stress)
Permissible shear stress=35N/mm^2
From above equation
479.46= π/4*d_c^3*35
d_c =45mm.
Diameter of crankpin=45mm.
C) Von mises stresses $M_{ev}=((K_b*M_c)+(0.5*K_t*T_c))^{1/2}$
M_{ev}=914.22N/mm^2.

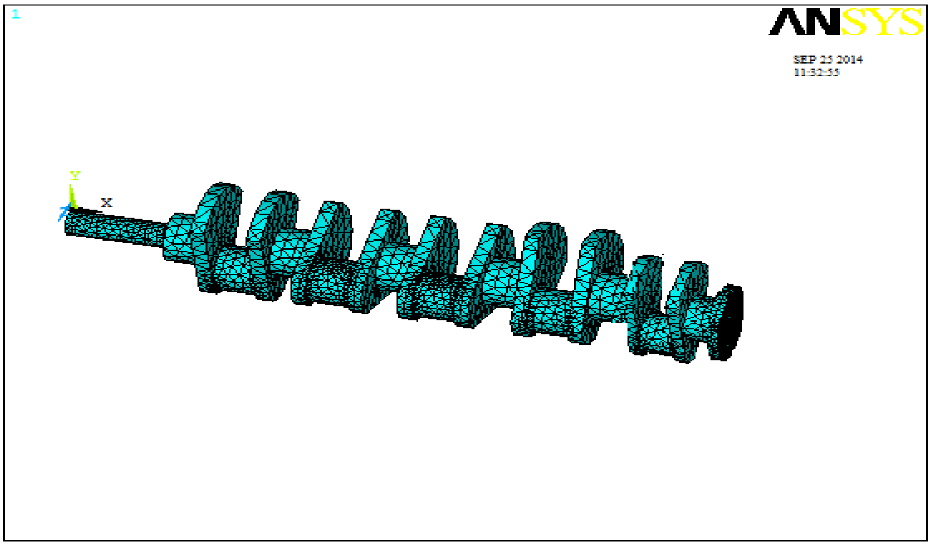
IV. Modelling Of Crankshaft

The software used for modelling is Solidwork. The solidwork includes following parameters:-
1.Part Design
2. Assembly Design
3. Drafting
4.Sketch
5.3D modelling.



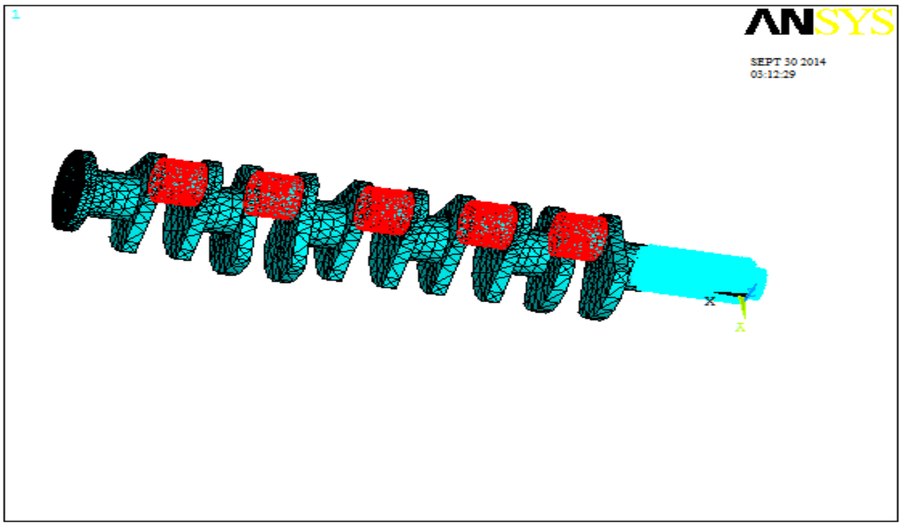
V. Meshing of crankshaft

The Meshing (Discretization) is the first step of Finite Element Method. In this step the component or part is divided into number of small parts. To analysis each element of the component meshing is done using mesh tool in ANSYS.



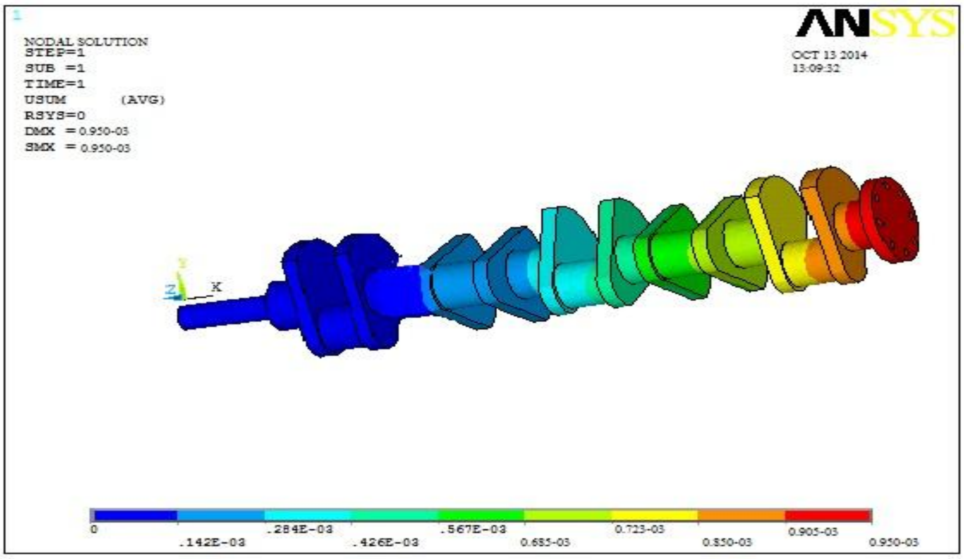
VI. Loading & Boundary Conditions

Crankshaft is a constraint with a ball bearing from one side and with a journal on the other side. The ball bearing is press fit to the crankshaft and does not allow the crankshaft to have any motion other than rotation about its main axis. Since only 180 degrees of the bearing surfaces facing the load direction constraint the motion of the crankshaft.



VII. Static Structural Analysis

After applying the boundary conditions & force the next step is that to perform static analysis of crankshaft. In this we are concern with deflection of crankshaft & stresses produced in crankshaft. The total deformation is shown in figure. The deformation is not same throught the length. It depends upon the load & boundary conditions. The red colour portion shows the maximum deformation while blue colour shows the minimum deformation. The maximum displacement is 5mm.



VIII. Results

By applying forces & boundary conditions, deformation of shaft generates stresses.

Sr.No.	Type Of Stresses	Theoretical	FEA Analysis
1	Von-Misses Stresses	914.22	950.0
2	Shear Stresses	110.25	120.7

IX. Conclusion

In this paper the crankshaft model is made by using solidworks and then analyzed by using ANSYS. The conclusions are made from the results are as maximum stresses occurs at the centre of crankpin. The maximum stress occurs at fillet between crank journal and crank cheeks. The edge of the crankshaft offers high stress. The practical results are matches to theoretical results, so Finite Element Analysis(FEA) is best method for analysis of permissible stresses. As there are 5 cylinders having efficiency equal to 6 cylinder, so our design gives the weight optimization as well as low cost. The materials used are appropriate having high capacity to absorb shocks and vibration with proper balancing.

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