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Optimization through CAE Practices for Forged Crankshaft of a Two - Wheeler to Effect Mass Reduction

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Abstract: ***The main objective of this study was to investigate mass and cost reduction for forged crankshaft of two wheeler. Every stroke of the engine subjected to its adjacent components to cyclic loading that pulls and pushes the components like piston, connecting rod and crankshaft. The crankshaft, in turn, is connected to the transmission system and is a critical component from the design perspective. The design of the crankshaft can be done in a justifiable manner if an attempt is made to identify the effects of the operating loads on the component in the form of the type of stress induced with its peak value and the location of these stresses over the component. This study consists of two major sections, Finite Element Analysis and Optimization for mass reduction. In this dissertation work, 3-D finite element analysis is planned to be carried out by virtue of static stress analysis of crankshaft. Alternatives for Design would be suggested while attempting to modify the geometry of the Crankshaft by changing the different parameter. The load was applied to FE model in Hypermesh, and boundary conditions were applied according to engine mounting conditions. The no. of cycles of failure can be predicted using MSC Fatigue software.***

Keywords: Crankshaft, FEA, Mass, Static & Fatigue analysis etc.

1. 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. 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.

2. Objective

1) To optimize the Mass and manufacturing cost of the original crankshaft, while maintaining or improving its structural integrity/ performance.
2) To develop an optimized geometry which will reduce the Mass of the original component for fuel efficiency.

3. General Description of the FEM

In engineering problems there are some basic unknowns. If they are found, the behavior of the entire structure can be predicted. The basic unknowns or the Field variables which are encountered in the engineering problems are displacements in solid mechanics, velocities in fluid mechanics, and electric and magnetic potentials in electrical engineering and temperatures in heat flow problems. In a continuum, these unknowns are infinite. The finite element procedure reduces such unknowns to a finite number by dividing the solution region into small parts called elements and by expressing the unknown field variables in terms of assumed approximating functions (Interpolating functions/Shape functions) within each element. The approximating functions are defined in terms of field variables of specified points called nodes or nodal points. Thus in the finite element analysis the unknowns are the field variables of the nodal points. Once these are found the field variables at any point can be found by using interpolation functions.

4. Finite Element Model

Fig.1 shows the 3-Dimensional model in catia environment. As the crankshaft is of a single cylinder four stroke petrol engines used for two wheelers, it doesn't have a flywheel attached to it, a vibration damper and oil holes, making the modeling even simpler. The dimensions of crankshaft are listed in Table 1.

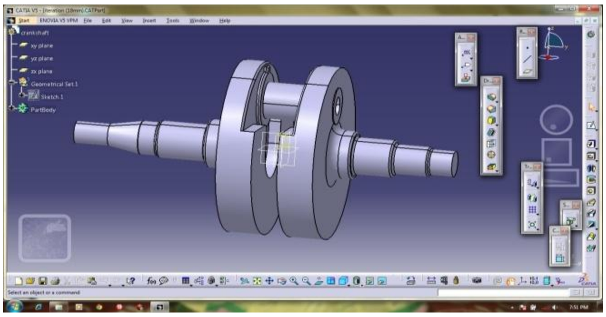

Figure 1: Modeling of modified crankshaft

Table 1: Dimensions of Crankshaft

Parameter (mm)	Original	Modified
Crankpin Outer Diameter	20	20
Crankpin Inner Diameter	0	10
Crankpin Length	49	49
Web Thickness	21	18
Length	191	191

The procedure of using FEM usually consists of following steps. (a) Meshing (b) Material (c) Determining and imposing loads and boundary conditions; (d) Result analysis

A. Meshing

Greater the fineness of the mesh better the accuracy of the results. The mesh size is 2. The Fig.2 shows the meshed model in hypermesh consisting of 146003 nodes and 89663 elements.

B. Material

The material used for crankshaft is 42Cr4Mo4.The material properties are listed in Table 2.

Table 2: The Material Properties

Density	7830kg m^-3
Elongation	11
Tensile strength	1000-1200MPa
Yield strength	600MPa
Young's modulus	200000

C. Loading and 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, this constraint is defined as afixed semicircular surface as wide as ball bearing width and same constraint for other side of the crankshaft. Gas Force F is calculated using maximum cylinder pressure and bore diameter of engine cylinder which is 12KN and distribution of load over the connecting rod bearing is uniform on 120 degree of contact area.

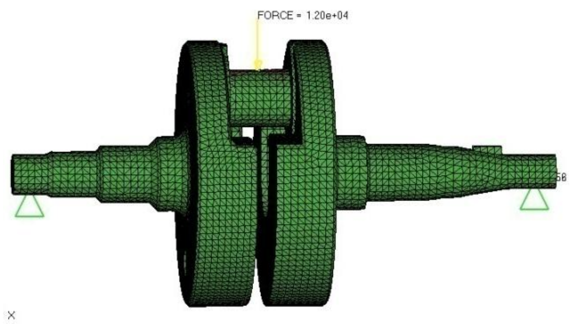

Figure 2: Meshing, loading and boundary conditions.

D. FEA Result and Discussions

Design Modification has been done by changing the parameters like crank web thickness and crank pin diameter of the crankshaft, other parameters are constraints. Based on the finite element analysis performed for the number of Iteration of a crankshaft. The result obtained by FEA are tabulated in following table 3.

Crankshaft	Web Thickness (mm)	Crankpin Diameter (mm)	Maximum Deformation (mm)	Maximum Von-Mises stress (MPa)	Minimum Fatigue life (No. of cycle)	Mass (Kg)
Original	**21**	**0**	**0.18**	**592**	**2.1×10^{10}**	**2.224**
Iteration I	20	8	0.21	599	9.69×10^{9}	2.1
Iteration II	19	9	0.2	605	7.7×10^{9}	2
III Modified Crankshaft	**18**	**10**	**0.21**	**564**	**1.7×10^{9}**	**1.944**
Iteration IV	17	11	0.22	647	1.53×10^{9}	1.879
Iteration V	16	12	0.27	771	1.51×10^{5}	1.86

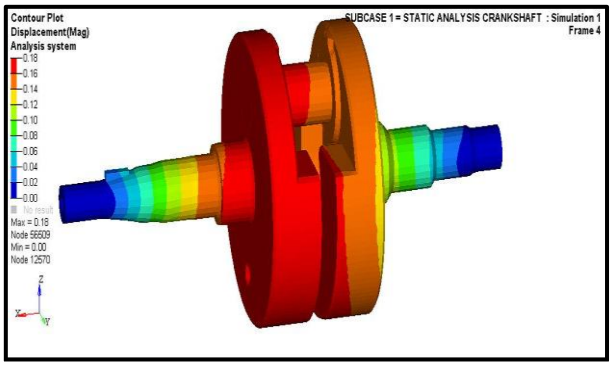

Figure 3: Total Deformation of Original Crankshaft is 0.18

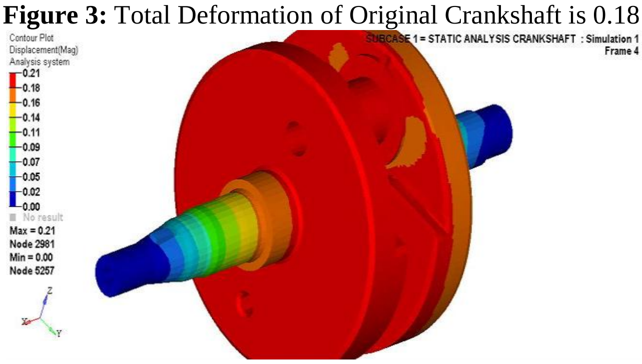

Figure 4: Total Deformation of Modified crankshaft is 0.21

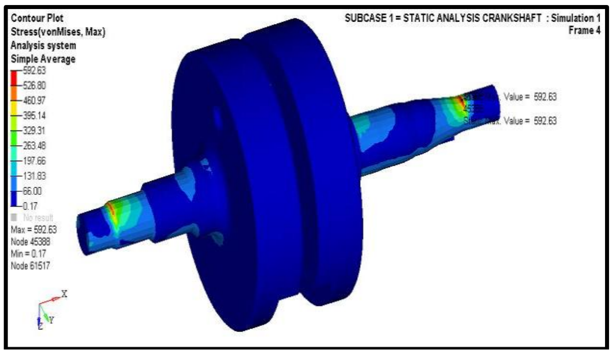

Figure 5: Maximum stress 592.63MPa induced in original crankshaft

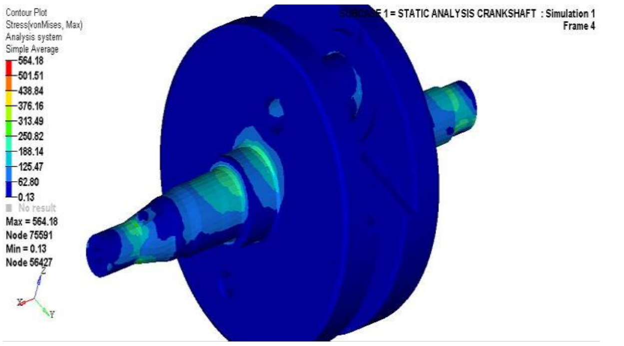

Figure 6: Maximum stress 564.18MPa induced in Modified crankshaft

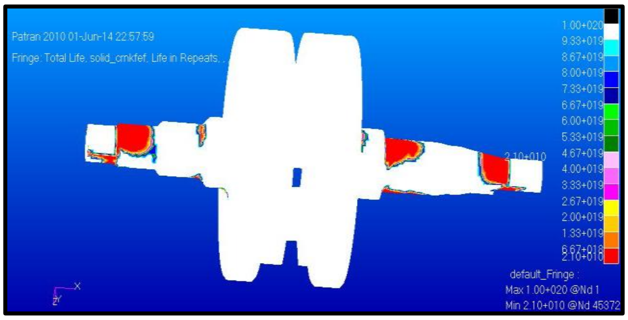

Figure 7: Minimum fatigue life of original Crankshaft is2.1×10^{10}

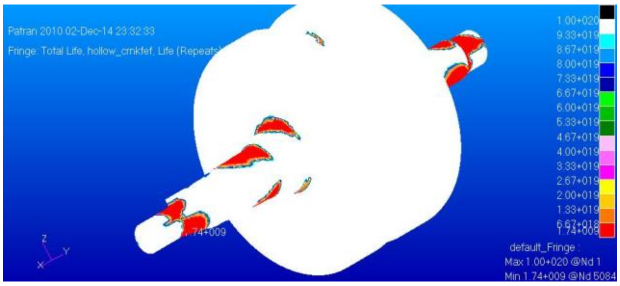

Figure 8: Minimum fatigue life of modified Crankshaft is 1.7×10^{9}

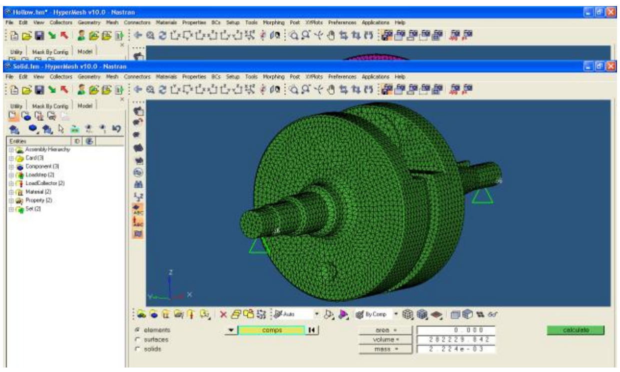

Figure 9: Mass of Original Crankshaft is 2.224 Kg

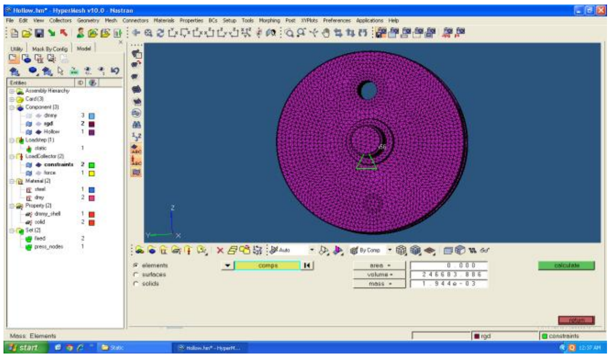

Figure 10: Mass of Modified Crankshaft is 1.944 Kg.

5. Experimentation for Validation

Experimentation has done for original crankshaft on universal testing machine. comparison of results as below in table 4.

S.N.	*Parameter*	*Mathematical*	*FEA*	*Experimental*
1	Maximum stress (MPa)	515	592.6	576
2	Deformation (mm)	0.15	0.18	0.21

6. Conclusion

The Experimental results were compared with FEA and the results show good agreement with test results. The value of von-misses stresses that comes out from the analysis is less than material yield stress i.e. 600 MPa so our design is safe. It can be observed from table no.3 As mass of crankshaft is reduced the fatigue life is also reduced but since 10^{6} is considered to be safe fatigue life for crankshaft. The modified crankshaft at Iteration III is safe from fatigue life point of view. Geometry optimization resulted in 13% mass reduction of forged crankshaft which was achieved by changing crankpin and crank web dimensions. As the mass of the crankshaft is decreased this will decrease the cost of the crankshaft.

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