Maximum Utilization of Present Crank Shaft by Using FEA Method

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Abstract

The project, 'Fine Element Analysis of MK15 Engine Crankshaft involves modeling and analysis of crankshaft.The crankshaft analyzed in this project is of MK15 Engine, a product of Greaves Limited. The present MK15 engine has an output of 2HP at 3000 rpm.This Engine is simulated to obtain 3Hp at 3600 rpm, by modifying induction and exhaust system, with other engine hardware components remaining same. Therefore it is necessary to validate the hardware components like crankshaft, connecting rod, piston, etc to withstand additional load. In this project crankshaft is analyzed for linear static loads and various stress plots are obtained. The natural frequency of the component is also determined using modal analysis. Finite Element modeling and analysis of the component is done using the finite element analysis package "ANSYS".

Keywords: *FEA, MK15 Engine, Crankshaft*

1. Introduction

An engine is a device which transforms the chemical energy of a fuel into sensible, or "thermal", energy and uses this sensible energy to perform useful work. In the internal combustion engine both processes can be considered to take place within the cylinder. Crankshaft is one of the critical part of the Internal Combustion Engine which converts the reciprocating motion of the connecting rod to rotary motion.
The crankshaft is subjected to both tensional and bending stresses, which may be greatly increased by resonance. Hence it is very difficult to calculate the stress developed in the crankshaft during the operating conditions. Hence finite element technique can be used for the stress of crankshaft. The basic idea in the finite element method is to find the solution of a complicated problem by replacing it by a simpler one. By this method, we will be able to find approximate solution rather than the exact solution. The existing mathematical tools will not be sufficient tools will not be sufficient to find the exact solution. Thus in the absence of any other convent method to find even the approximate solution of a given problem, we have to prefer finite element method. In the finite element method, the solution region is considered as built up of many small inter connected sub regions called finite element. In each element, a convenient approximate solution is assumed and the conditions of overall equilibrium of the structure are derived. The satisfaction of these conditions will yield an approximate solution for the displacement and stresses.

Crankshafts are usually made of open-hearth steel, Alloy steel, cast steel, cast iron, etc. Nowadays spheroidal graphite iron (S.G Iron) is also used for manufacturing crankshafts.

Table 1. Specification of Mk 15 Engine

Type	4-Stock Side valve single cylinder
Bore	62.5 mm
Stock	50 mm
Displacement	153 cc
Length of connecting rod	101 mm
Fuel	Petrol start kerosene run
Max. out put	2Hp at 3000 r.p.m (Present Model) 3600r.p.m (Proposed model)
Continues output speed	3000 r.p.m (Present Model) 3600r.p.m (Proposed model)
Cooling System	Forced Air Cooling
Dry Weight	18 Kgs
Compression Ratio	4.5:1
Starting System	Recoil Starter
Peak Pressure	14 bar (Present Model) 21 bar(Proposed model)

2. Materials and Methods

The Crankshaft of MK 15 engine is made from spheroidal graphite Iron (S.G. Iron) of grade 700/2

Table 2. Materials Properties

SI.NO	PROPERTIES	VALUE
1	Young s Modulus	1.724×105 N/mm2
2	Density	6.976×10-6 Kg/mm2
3	Poisons Ratio	0.3
4	Yield Strength	400 N/mm2
5	Tensile Strength	700 N/mm2
6	Hardness	225 – 300BHN

2.2. Pure bending analysis

Bending load will be maximum during the combustion stroke. Combusting will take place when the piston is at the top dead center. During the time of combustion of the fuel the pressure created in the cylinder will be maximum. This peak pressure will be transmitted to the crankshaft through connecting rod. In the top dead center position there will not be any torsion in the crankshaft.

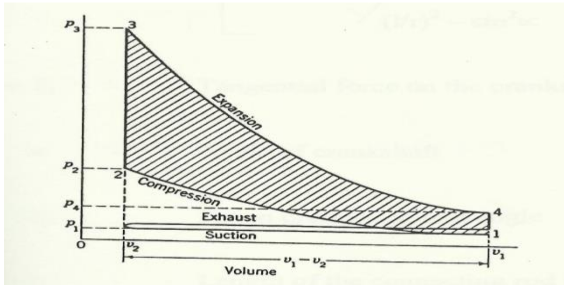


Fig 3.2 PV diagram for 4-Stroke engine

Figure1. 3HP engine the peak pressure is 21 bard

Maximum load = P x A

P = Peak pressure in N/m2

A = Cross sectional area of Bore in a m2

P = 20x 105 N/m2

A = 3.066x 10-3 m2

Maximum load = 6438.6N

Let Max Load = 6440N

2.3. Torsional analysis

The tangential force acting on the crankshaft can be calculated using the formula:

$$Ft = Fp \quad \sin\propto = 1 + \frac{\cos\propto}{\sqrt{(\frac{l}{r})^2 - b\sin^2\propto}} \quad \ldots (3.1)$$

Where Ft - Tangential force on the crankshaft.

∝ - Angle of crankshaft

Fp - Piston pressure at that angle

I - Length of the connecting rod in mm

r - Radius crankshaft in mm

For constant volume combustion engine the crank angle which corresponds to the largest value of 'Ft' is from 250 to 350

Length of the connecting rod 1 = 101mm

Radius of the crankshaft r = 25mm

Let the cranks angle ∝ = 300

And considering Fp as peak load in worst conditions

Fp = 6440N

Ft = 6440N

$$\sin 30 = 1 + \frac{\cos 30}{\sqrt{(\frac{101}{25})^2 - b\sin^2 30}}$$

Ft = 3916N

Let Ft = 4000N

2.4. Modal analysis

Continuous output speed = 3600 r.p.m

Frequency f = 3600/60Hz

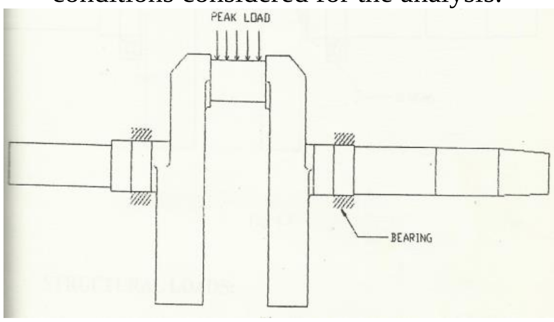
F = 60 Hz

2.5. Finite – Element Method

The finite – element method is a powerful computer based method analysis that is finding wide acceptance for the realistic modeling of many engineering problems. In finite – element analysis a continuum solid or fluid is considered to be built up of numerous tiny connected elements. Since the elements can be arranged in virtually any fashion, they can be used to model very complex shapes. Thus it is no longer necessary to find an analytical solution that treats a close "idealized" modal and guess at how the deviation from the model affects the prototype. As the finite element method has developed, it has replaced a great deal of expensive preliminary cut – and try development with quicker and cheaper computer modeling.

2.5. Boundary Condition

Structural loads and restraints on degree of freedom (D.O.F) were the two boundary conditions considered for the analysis.



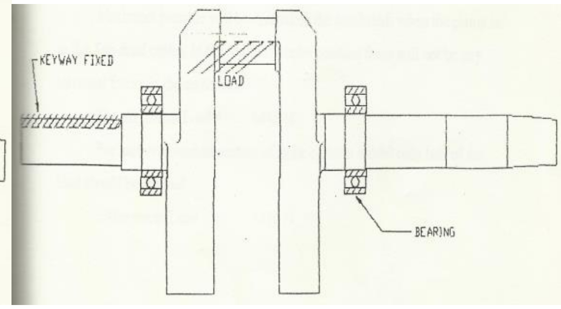


Figure2. Pure Bending Analysis **Figure 3. Torsional Analysis**

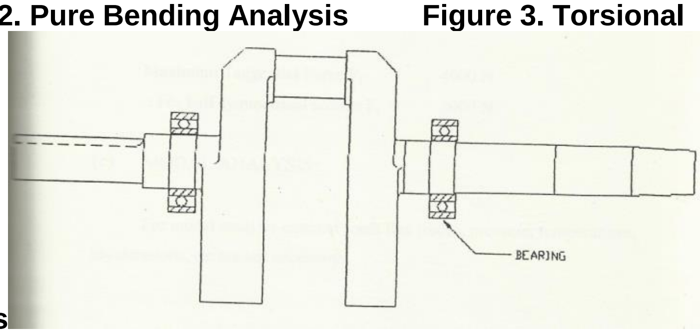


Figure 4. Modal Analysis

3. Results And Discussion

STUDY III

3.1. Bending Analysis:

Case study one is find out the bending stress (Von-Mises stress theory) using method of linear static analysis applying bending load condition and also find out the resultant displacement Maximum pressure will be exerted on the crankshaft when the piston is in the Top Dead Centre position there will not be any torsional forces in the crankshaft.

Maximum Load= 6440 N,For half symmetrical section of finite element model only half of the load should be applied.

Maximum Load= 3220 N

Figure 5. Bending Analysis

The stress plot for static bending load shows various stress values acting on the elements of the crankshaft. The maximum stress 80.364 N/mm2 is acting on crankpin. Because the load is directly acting on the crankpin.

In resultant displacement plot the value of maximum displacement is 0.011123mm.

STUDY III

3.2. Torsional Analysis:

In this Case study find out the bending stress (Von-Mises stress theory) using method of linear static analysis applying torsional load condition and also find out the resultant displacement Maximum Tangential force and Half Symmetrical values are 4000 N and 2000N respectively.

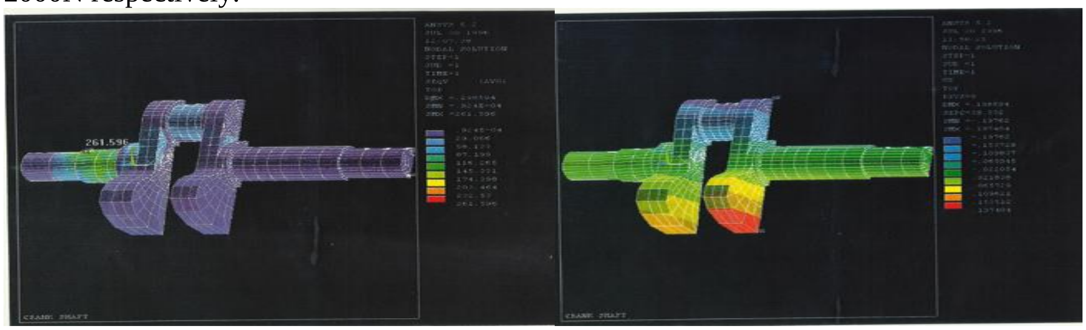


Figure 6. Torsional Analysis for Tangential force

The stress plot fir tangential load shows a maximum stress of 261.596 N/mm2 which is acting on the key way of the output shaft. In the Z axis displacemen5t plot the value of displacement varies from -0.19762mm to +0.197404mm.

Table 3. Design Check with Allowable Stress

Analysis No	Load Condition	Allowable Stress N/mm2	Stress Obtained N/mm2	Factor of Safety	Design Check
1	Bending Load (Peak Load)	400	80.634	4.96	OK
2	Torsional Load (Very Worst Condition)	400	261.596	1.53	OK

The design check is done by comparing the obtained stress for static loads with the allowable stress that is the yield strength of the material of the crankshaft and found that the crankshaft will withstand the additional load while upgrading the power of the MK15 Engine.

STUDY III

3.3. Modal Analysis

In this Case study find out the deformed shape using method of Modal frequencies applying load and frequency condition and also change the time. For modal analysis external loads like forced, pressure, temperatures, accelerations, etc are not necessary.

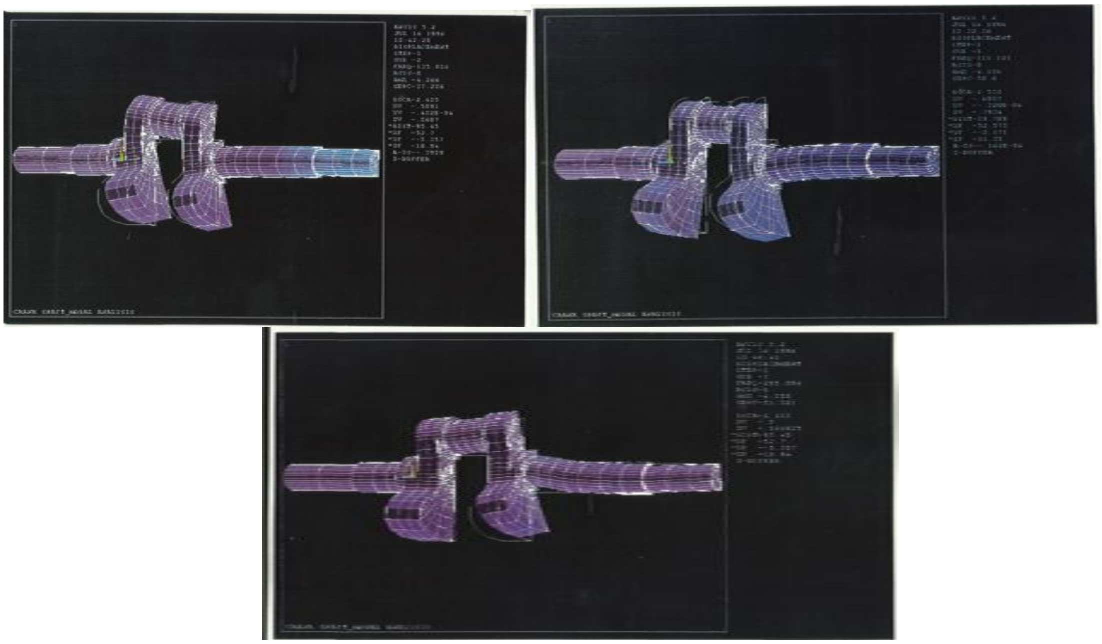


Figure 7. Modal Analysis

From the result file of modal analysis the least natural frequency of the crankshaft is found to be 111.12 Hz. Hence the natural frequency won't match with the running frequency of 60 Hz. Therefore failure won't occur due to resonance.

4. Conclusion

The modeling and analysis of the crankshaft is carried out successfully and various stress plots and natural frequencies are studied and the results are discussed. The design check for the resulting stress values for static load conditions has been done in comparison with the yield strength of the material of the component and found to be safe design. The natural frequency of the component is also found out and checked with the running frequency and found to be safe:

In future evaluation of MK15 engine crankshaft can be done for: Strength of the component under varying load. Prediction of fatigue life. The result of this project will help the Research and Development Department of Greaves Limited, for upgrading the power of MK15 Engine.

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