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Modelling and Analysis of a Crankshaft in a Single Cylinder Four Stroke Petrol Engine

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ABSTRACT

Crankshaft is one of the critical components for the effective and precise working of the internal combustion engine. In this project a FEA simulation is conducted on a crankshaft from single cylinder 4-sroke petrol engine. A three-dimension model of petrol engine crankshaft is created using Solid works software. Finite element analysis (FEA) is performed to obtain the variation of stress magnitude at critical location of crankshaft. The load applied to the FE model in Solid works simulation boundary conditions are applied according to the engine mounting conditions. The analysis is done for finding critical location in crankshaft. The maximum stress is predicted by simulation, with this value the fatigue life of crankshaft can be predicted by using S-N curve for C40 steel which is existing. Stress variation over the engine cycle and the effect of torsion and bending load in the analysis are investigated. Fatigue life can be increased by better surface finish (or) by some heat treatment (or) otherwise material change. Since the crankshaft material can only be forged and so heat treatment and surface finish won't give much advantage. It is proposing for a new material change, still it forging which is C60 steel. The fatigue life of crankshaft increased considerably by change the material C60 steel.

KEY WORDS: Fatigue life, Crankshaft, C40 steel, C60 steel, Solid works, and ANSYS.

1. INTRODUCTION

Crankshaft is a large component with a complex geometry in the engine, which converts the reciprocating displacement of the piston to a rotary motion with a four link mechanism. The crankshaft consists of three parts are crank pin, crank web, shaft. The big end the connecting rod is connecting to the crank pin. The crank web connects the crank pin to the shaft portion. The shaft portion rotates in the main bearings and transmits power to the outside source through the belt drive, gear drive or chain drive. Since the crankshaft experiences a large number of load cycles during its service life, fatigue performance and durability of this component has to be considered in the design process. Design developments have always been an important issue in the crankshaft production industry, in order to manufacture a less expensive component with the minimum weight possible and proper fatigue strength and other functional requirements. These improvements result in lighter and smaller engines with better fuel efficiency and higher power output. In designing a crankshaft for an engine, the following points should be taken into consideration:

- It should have enormous strength to withstand the high pressure.
- It should form effective oil sealing in the cylinder.
- It should provide sufficient bearing area to prevent undue wear.
- It should have high speed rotational without noise.
- It should reduce the torsional vibrations.
- It should have high fatigue strength.

Engine Specifications: The engine used for this work is a single cylinder four stroke air cooled type Hero Bajaj M80 80CCpetrolengine.Bajaj had upgraded its popular scooter M80 into a "Major" among the rural areas and the ancillary class even in urban cities, by adding a new and bold headlight and removing side panels. This time Bajaj also replaced the existing 2-stroke engine by all new 4-stroke engine making the- M80 Major 4S.

3d Model Generation of Crankshaft: Exact crankshaft of M80 has been procured and dimensions data has been extracted and the 3D model has been generated in Solid works as shown in figure 1.

The geometry has been cleaned up for the easy of meshing and so the areas.

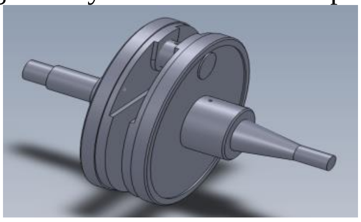

Figure.1. 3D modeling of crankshaft using Solid works

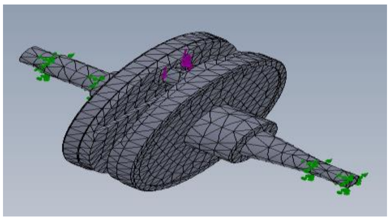

Figure.2. Meshed part of the designed crankshaft

Meshing in Solid works: The prepared 3D model of the crankshaft has been cleaned up for the fatigue simulation. The area which will have higher stress concentration are been considered appropriately. The threaded portions are replaced with their core diameter equivalent cylinder. The crankpin has been modeled with its lubricated holes. Lower order tetrahedral elements have been used for meshing the crankshaft.

Prediction of Pressure Acting on Crankshaft (PIN): The crankshaft will fed the exerted force from the piston when the gas is been fired. So the gas pressure acting on the pressure will be directly applied on the crankshaft through connecting rod. When considering the engine cycle the crankshaft will exert on more force on power stroke rather than the other intake (or) exhaust stroke. For fatigue life prediction, the gas pressure exerted while the power stroke is only been considered.

Calculation of pressure force acting on the crankpin: The following information is related to a carburetor engine: Bore B=80 mm, Stroke S=80 mm, Ratio of crank radius to CR length, λ=0.285, Mass of the piston group m_p=0.48 kg, Mass of CR assembly m_c=0.68kg, Inertia force of balanced weights 2Pcw=1000 N, Engine speed in idling Nid_{max}=6000 rpm. Table 1 gives maximum and minimum, of forces Fi and FR in column 2 and 3 acceleration of crank angle (column 1) at 5600 rpm

Table1. Maximum and minimum forces acting on crankshaft

ϴ	Tangential force Ft (N)	Radial force F_R (N)	$F_R + K_{Rcr}$	Rcp	$F_R + K_{Rcr} + Kre = R$
0°	0	-12103	-19283	19283	-28637
30°	-6025	-7660	-14840	16016	-24194
370°	+3387	+14897	+7417	8427	-1637
450⁰	+6322	-1864	-9044	11034	-18398

Solution:

$Rcp=\sqrt{(F_t^2+(F_R+K_{Rcr})^2)}$

$K_R = K_{Rcr}+K_{Rc}$

$K_{Rcr}= -m_{crc}R_{\omega}$

$R_c = -0.725 \times 0.72 \times 0.04 \times (\frac{2\prod X\, 5600}{60})^2 = -7180N,$

$K_{Rc}= - m_c R_{\omega}^2 = -0.68 \times 0.04 \times (\frac{2\prod X\, 5600}{60})^2 = -9354$ N

K_R = - (7180+935 = -16534 N

Using the above relations and values given in the column (2) and (3) of the tables in terms of values of terms in column (4) and (5) can be calculated.

Centrifugal force of counter weights 2Pcw =10000 N, acts opposite to the K_R.

Support the reactions at main journals $R_{\sum}$ due to the combined effect of radial forces F_R, K_R and $2P_{cw}$ in the crank plane is.

$R_{\sum} = 0.5 (F_R + K_R+2Pcw)$

Reactions F_t` at main journals to the tangential force Ft in the plane perpendicular to the crank plane and is

F_t`=0.5 F_t

Total force at the (reaction) at main journals

$R_{mj}=\sqrt{[(F_t`)^2+(R_{\sum})^2]}$

For single span crank shaft, the torque at the output of the main journals at AA, is

$T_{mj}= F_t x R$

The computed value of the above are in the Table 2,

Table.2. Computational validated value of forces

ϴ	F_T (N)	F_R (N)	$R_{\sum}$	F_t	R_{MJ}
0°	0	-12103	-9318.5	0	0
30°	-6025	-7660	-7097.0	-3012.5	241
370°	+3387	+14897	4181.5	1693.5	135.4
450°	+6322	-1864	-4199.0	3161	252.9

For Material C40 Carbon steel

σ_x=600 Mpa,σ_y=350 Mpa,

τ_y=210 Mpa, σ_{en}=270MPa,

$\sigma_{en\ axial}$=190MPa, τ_{en}=160MPa

Unit pressure on crank pin and main journal

$$P_b=\frac{Rc.p.max}{dc.p \times lc.p}= \frac{19283}{55\times40} = 8.77MPa$$

$D_{c.p.}$= 55, $l_{c.p.}$= 40

The pressure between the specified limits of 7MPa to 20MPa

So pressure acting on the crank pin has the significant impact on the maximum stress of the crankshaft than the pressure acting on the main journal.

Hence the pressure load of 8.77MPa is applied on the crank pin to predict maximum stress while performing FEA.

The mentioned pressure will be applied to the crankpin throughout its circumference which is equivalent to 9318.7 N.

C40 Steel Properties: Single cylinder M80 crankshaft made up of C40 steel. The material property of C40 has been listed below

Table.3. Chemical composition of C40steel

C ≤	Si ≤	Mn ≤	P ≤	S ≤	Other
0.37-0.44	0.40	0.50-0.80	0.045	0.045	Cr+Ni+Mo ≤ 0.63

The C40 material has only 0.50-0.80 % of magnesium. Still the grain structure ofC40 steel, if refined the fatigue strength will be much higher. The possible heat treatment solution may improve its fatigue life in somewhat small manner. But refining its grain structure by adding a constituent will improve its fatigue strength in a significant way.

Stress Vs number of cycle curve of the corresponding material which is C40 is used to find out the maximum life cycle of the modeled crankshaft.

Stress Contour for the Gas Pressure: The predicted maximum stress is 225.4Mpa which we can be neglect this peak load the maximum stress is only 157.3Mpa, So with this stress we can able to find the fatigue by referring its S-N curve.

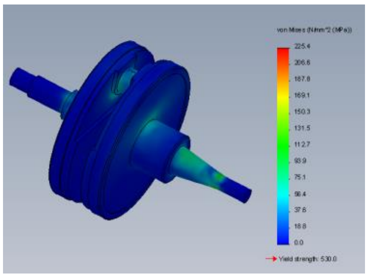

Figure.3.Stress variation on the modeled crankshaft

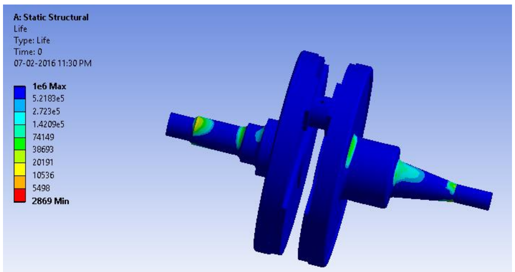

Figure.4. Life cycle estimation of a C40 steel crankshaft.

Life Cycle Estimation of C40 Steel: Diagram is estimated that the major area of crankshaft having 1e^6 cycles of life, which can be considered as infinite life. The least magnitude predicted in the simulation which is 2900 cycles is due to the modeling error. The result can be considered from the elements which are closer to the peak can be taken as worst life, which is 13693 cycles. Also the heat generated in the combustion chamber will also make the connecting rod, piston, as well as crankshaft to be heated up. Thus it reduces the residual stresses exerted in the crankshaft. So we can assume a factor of 1.2 will be a maximum life which is 20% more increase.

C60 Steel Properties: The C60 steel has 0.60-0.90 % of magnesium which is higher than the C40 steel. It is one of reason for the high fatigue strength in C60 steel.

For the same geometry shown in crankshaft the C60 steel is having the higher value of carbon content and magnesium content than the C40 steel which refining the grain structure. Hence increases fatigue strength.

Table4. Chemical properties of C60 steel

C ≤	Si ≤	Mn ≤	P ≤	S ≤	Other
0.57-0.65	**0.40**	**0.60-0.90**	**0.045**	**0.045**	**Cr+Ni+Mo ≤ 0.63**

Life Cycle Estimation Of C60 Steel: It is estimated that the major area of crankshaft having 2e^6 cycles of life, which can be considered as infinite life. Heat generated in the combustion chamber will also make the connecting rod, piston, as well as crankshaft to be heated up, it reduces the residual stresses exerted in the crankshaft.

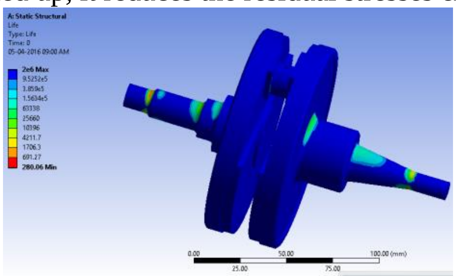

Figure.5.Life cycle estimation of the C60 steel crankshaft

2. CONCLUSION

The present studied about the crankshaft is carried out and also failure diagnosis for the crankshaft. The crankshaft failure occurs due to decrease in the fatigue strength. Crankshaft was modeled using Solid works software. The calculated maximum load is the key to find out the maximum stress of the crankshaft by using finite element analysis. From the analysis the maximum stresses and its locations are highlighted. The maximum life cycle for the C40 steel is $1e^6$ cycles. The life cycle of the C60 steel is predicted by as $2e^6$ cycles. From this analysis significant increase in life cycle of the crankshaft is achieved.

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