FEA OF A CRANKSHAFT IN CRANK-PIN WEB FILLET REGION FOR IMPROVING FATIGUE LIFE

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ABSTRACT

A crankshaft is often designed with a fillet radius to improving fatigue life of crankshaft. The fatigue life of crankshaft is depend on the proper fillet radius. This fillet radius is changes than fatigue life is also changes of crankshaft. In most of the time fatigue failure is occur in crank-pin web fillet region. The crankshaft fillet rolling process is one of the commonly adopted methods in engineering to improve fatigue life of the crankshaft. A finite element analysis is implemented to approximate the stress distribution induced in the crankpin fillet region. The modelling of crankshaft is created by Creo-parametric. Finite element analysis is performed to obtain the variation of stress at critical locations and fatigue life of the crank shaft using the ANSYS software and applying the boundary conditions. Radius of fillet is changes in model of crankshaft to improvement in fatigue life. This work in doing for optimization of a crankshaft in crank-pin web fillet region with fatigue life as well as to study a relation between fillet radius/diameter of crankpin to fatigue life. .

KEYWORDS— Crankshaft failure, fatigue, Fatigue life estimation, Finite element analysis.

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. The function of the crankshaft is to convert the convert mechanical energy of the piston being driven back and forth by the pneumatic energy provided by pressure change as a result of the combustion reaction. Crankshafts are high volume production internal combustion engine components and their most commonly used is in an automobile engine. In an engine, the reciprocating motion of the piston is linear and is converted into rotary motion using through the crankshaft. There are many applications of a crankshaft which range from small one cylinder engines to very large multi-cylinder marine crankshafts [1].

Crankshafts in automotive engines can experience a significant number of service cyclic loads. Since fatigue cracks initiated near the fillet lead to one of the primary failure mechanisms of automotive crankshafts, fillet rolling processes have been used to improve the fatigue lives of crankshafts for many years. The fillet rolling process induces compressive residual stresses near the fillet surface. The compressive residual stresses lower the fatigue driving stresses near the fillet surface due to operating loads and consequently increase the fatigue lives of crankshafts.

As a crankshaft is subject to operating loads, the induced stresses at these high stress concentration areas could initiate fatigue cracks and lead to failure. A fillet rolling operation is one of the commonly used techniques to improve fatigue strength of a crankshaft because this rolling process introduces compressive residual stresses on the contact surface and sub-surface, which will prohibit fatigue cracks to initiate and continuously propagate. The invention regards to minimize stress in fillet region and increases fatigue life of crankshaft using rolling in fillet region of different radius and deep of rolling. The aim of invention is achieve static analysis through ANSYS stress value of crankshaft value to improve fatigue life of crank shaft [2].

LITERATURE REVIEW

A more amount of work has been done on crankshaft optimization and analysis in fillet of crankshaft using experimental as wee as numerical simulation methods and finite element analysis (FEA). But fewer researches have carried on the radius of fillet with FEA. The basic literature available is provided the Mahesh L. Raotole, D. B. Sadaphale, and J. R.Chaudhari presented the Prediction of Fatigue Life of Crank Shaft using S-N Approach [4]. Sanjay B, V M Nandedkar and Surender Kumar Kaundal explains finite element analysis approach for stress analysis of crankshaft under dynamic loading [5]. Paul Spiteria Simon Ho, Yung-Li Lee are explained assessment of bending fatigue limit for crankshaft sections with inclusion of residual stresses [6]. Rajesh M.Metkar, Vivek K.Sunnapwar published Evaluation of FEM based fracture mechanics technique to estimate life of an automotive forged steel crankshaft of a single cylinder diesel engine[7].

PROBLEM DEFINITION

Crankshaft is one of the critically loaded components in engine. Fatigue is a source of crankshaft failure. Although, traditionally, crankshaft damages are attributed to wear and lubrication sources, fatigue is responsible for a significant number of crankshaft failure.[8] Fatigue exists when cyclic stresses/deformations occur in an area on a component. The cyclic stresses/ deformations have mainly many origins, in that majorly fluctuating loads, torsion and bending on crank shaft. If number of cylinder are increases this parameter are more affected for the crankshaft fatigue failure. In Fig.1 fatigue failure occur in fillet region of crankshaft.

Fig. 1 Final failure on fillet of crankshaft

DESIGN CALCULATION

For the project work using paggio vehicle of engine model G 400 WG III. The technical specification of engine is in Table I.

TABLE I
The Technical Specification of Engine

Capacity	395 cc
Number of Cylinders	1
Bore × Stroke	86 x 68 mm
Compression Ratio	09:01
Maximum Power	8.1hp @ 3600 rpm
Maximum Torque	16.7 Nm @ 2200 rpm
Maximum gas pressure	25 bar
Fillet Radius	3.5

Force on the Piston Fp = Area of the bore x Max. Combustion pressure = $\pi \times D^2 \times P_{max}$ = 14.52 KN
In order to find the thrust in the connecting rod (FQ), We should first find out the angle of inclination of the Connecting rod with the line of stroke (i.e. angle Ø).
We know that

$$\text{Sin } Ø = (\text{Sin } \Theta/(L/R)) = \sin 35^0/4$$

Which implies Ø = 8.24°

We know that thrust in the connecting rod

$$FQ = FP/COS\Theta$$

From this we have,
Thrust on the connecting rod FQ= 14.67 KN
Thrust on the crank shaft can be split into Tangential Component and the radial component.

1) Tangential force on the crank shaft, FT= FQ sin

$$(\theta + Ø) = 10.05 \text{ KN}$$

2) Radial force on the crank shaft, $F_R = F_Q \cos(\theta + Ø)$ = 10.68 KN
Reactions at bearings (1 & 2) due to tangential force is given by,
$H_{T1} = H_{T2} = (F_T \times b_1)/b$ = 5.02KN (Since b1=b2=b/2)
Similarly, Reactions at bearings (1 & 2) due to radial force is given by,
$H_{R1} = H_{R2} = (F_R \times b_1)/b$ = 5.34KN (Since b1=b2=b/2)

FEA APPROCH

Finite element analysis of crankshaft is done by geometry generation using creo-Parametri software and analysis is using through the ANSYS 14.5 WORKBENCH software. Using proper type of loading and boundary condition are very important in finite element analysis.

A. Generation of Geometry of Crankshaft using Creo-Parametric

From the measuring all parameter of actual crankshaft of Paggio vehicle of engine model G 400 WG III to the drawing, the dimensions of crankshaft, solid model is generated using Creo-Parametric software. Fig.2 shows the solid model of the forged steel crankshaft from actual dimension. After completion of solid model save as this part as IGES for Exporting into ANSYS WORKBENCH Environment.
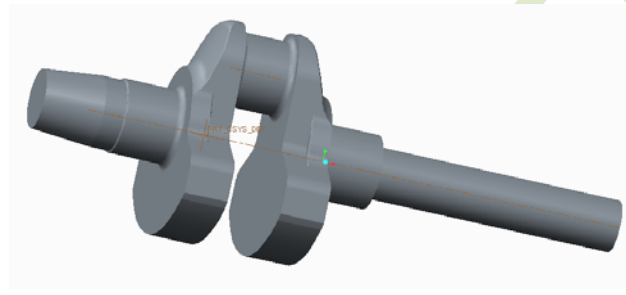

Fig.2 Generated Geometry of Crankshaft

B. Engineering Data

In the engineering data add the basic property of crankshaft.
Material Details
Material Type: - Forged Steel
Designation: - 42CrMo4
Yield strength (MPa):- 680
Ultimate tensile strength (MPa):- 850
Elongation (%):-13
Poisson ratio:-0.3

C. Mesh Generation

Import IGES format model in ANSYS WORKBENCH simulation module. Quadratic tetrahedral elements are used to mesh the crankshaft finite element geometry.
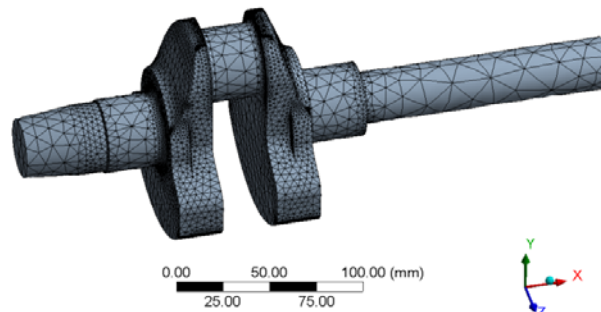

Fig.3 Meshed Model of Crankshaft

Tetrahedral elements are used for meshing the imported complex geometries to the ANSYS WORKBENCH software. In Fig.3 shows the meshed model of crankshaft of 17789 numbers of nodes and 9615 number of elements.

D. Boundary conditions

Boundary conditions are playing the important role in finite element analysis. The bearing support is fixed and applies tangential and radial force on crankshaft. Fig.4 shows the apply remote displacement for bearing support fixed and apply forces on crankpin.
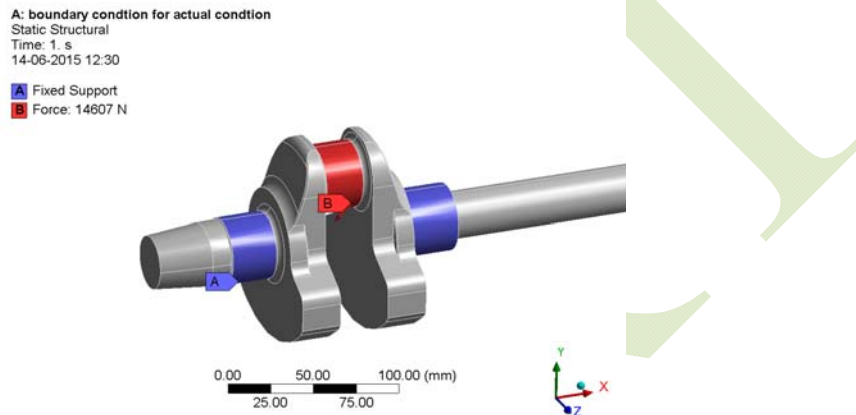

Fig.4 Boundary conditions for crankshaft

E. Von Misses Stress

After compilation boundary condition find out the critical point (maximum stress) on crankshaft to know the where crack is occurring. Fig.5 shows the von misses stress on the crankshaft. From figure maximum stress in on the fillet of crankshaft.
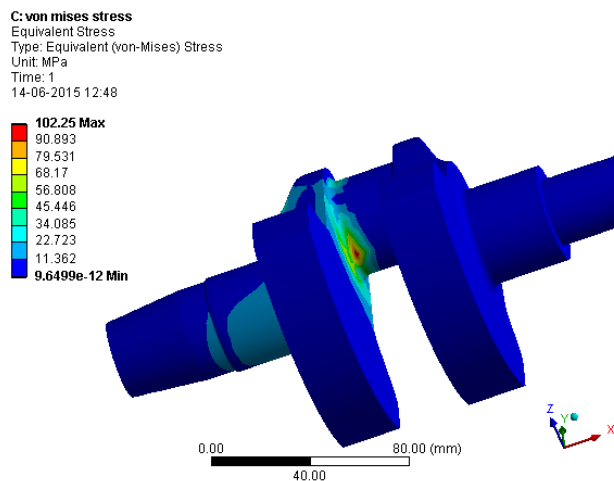

Fig.5 Von Misses Stress

F. Fatigue life

Using fatigue tool obtain fatigue life of crankshaft and obtain same for the various radius of fillet in crankpin region. Fig.6 shows the fatigue life of crankshaft. From the figure the minimum fatigue life is obtained on the maximum Von misses stress occur means the fatigue crack starts from that region. To comparing fatigue life of different fillet radius in crankpin following the same method to obtain fatigue life. In the geometry only changes the fillet radius and other boundary conditions are same.
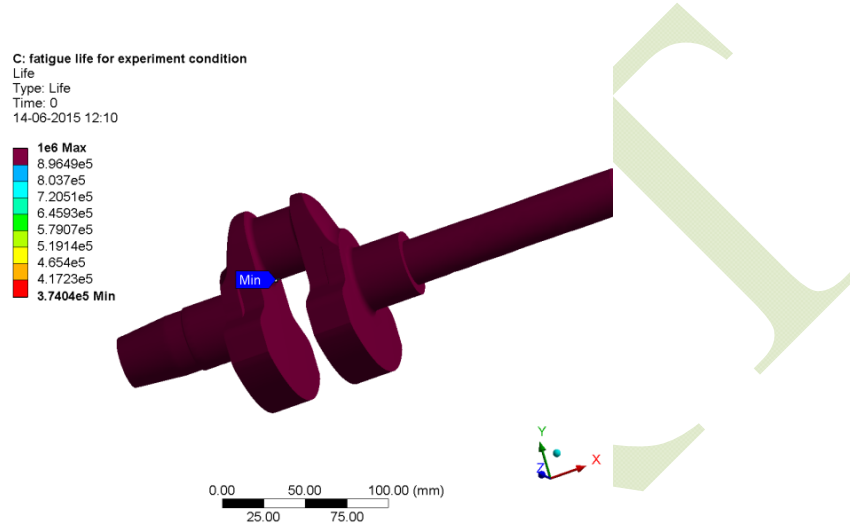

Fig.6 Fatigue life of crankshaft

RESULTS

The results are obtained using the FEA using ANSYS software for 3.5 fillet radius 3.7404×10^5 fatigue life of existing forged crankshaft. The crack start from the where the maximum von misses stress is formed. Therefore, fatigue life of forged steel crankshaft obtained for different fillet radius r to crank pin diameter d ratio and it is shown below. It is seen from the table, fatigue life of crankshaft increases with the increase in r/d ratio. Similarly, the calculation for r/d = 0.03, 0.06, 0.08 and 0.1 and software calculation results as given in the following Table3.

TABLE III
Number Of Cycles To Failure For Different r/d Ratio

Sr. No.	Fillet Radius	r/d Ratio	Number of Cycles to Failure
1	1.5	0.03	2.4951×100000
2	2.5	0.06	3.1685×100000
3	3.5	0.08	3.7404×100000
4	4	0.1	5.7842×100000
5	4.5	0.1125	8.1389×100000

To obtain above results only changes in the radius of fillet of crankpin all other parameters and boundary conditions are same. Results are obtained from the ANSYS WORKBENCH 14.5 using fatigue tool.

CONCLUSIONS

In this paper finite element analysis use to calculating number of cycles to failure of crankshaft. The maximum stress and deformation appears at the centre of crankpin fillet between the crankshaft journal and crank cheeks, and near the central point journal. The edge of main journal is maximum stress area in the crankshaft.

FEA analysis using ANSYS WORKBENCH FROM fatigue tool is very efficient and simple method for achieving fatigue at different loading condition according to force applied to the crankshaft. The use of numerical method such as Finite Element Method now a day's commonly used to gives detail information about various structure or components.

The r/d ratio is increases than Von misses stress are decreases as well as number of cycles to failure in increases.

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