A Review: Design and Failure Analysis of 4- Stroke Single Cylinder Diesel Engine Crankshaft

Ankurkumar D. Pandya [1]
PG Scholar, CAD/CAM
V.V.P Engineering Collage
Rajkot, India

Prof. D. D. Kundaliya[2]
Asst. Prof. V.V.P Engineering College
Rajkot, India

Abstract— **The crankshaft is an important component of an I.C. engine. This convert reciprocating displacement of the piston in to a rotary motion of the crankshaft. The objective of this study is to review design and failure analysis of 4-stroke single cylinder diesel engine crankshaft. The modeling of the crankshaft is created by using CREO & Pro-E software and Finite element analysis (FEA) is performed to obtain the variation of the stress at critical location of the crankshaft using ANSYS software. The analysis of crankshaft is based on according to the engine condition, boundary condition and design specification of crankshaft including crank pin or journal. This analysis is done for finding critical location in crankshaft. The validation of the model is compared with the theoretical and FEA results of stresses are within the limits. Further it can be extended for the different materials, design modification and the analysis of single cylinder diesel engine crankshaft.**

Keywords— ***single cylinder, 4-stroke diesel engine,Crankshaft, failure analysis, Literature review, crankpin, design calculation.***

I. INTRODUCTION

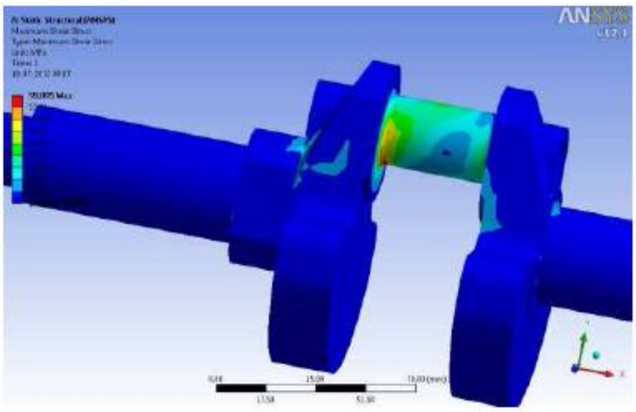
Crankshaft is a large component with a complex geometry in the engine, which converts the reciprocating displacement of the piston to a rotary motion with a four link mechanism. Al-Jazari was the first engineer to invent the Crankshaft, which is considered the single most important invention after the wheel. This system is used to transform linear motion into rotating motion, and visa versa, and is central to the modern machinery such as internal combustion engines used today. Since the crankshaft experiences a large number of load cycles during its service life, fatigue performance and durability of the 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.

The crankshaft must be strong enough to take the downward force during power stroke without excessive bending. So the reliability and life of internal combustion engine depend on the strength of the crankshaft largely. And as the engine runs, the power impulses hit the crankshaft in one place and then another. 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.

Crankshafts have altered very little in their basic design since the very first steam reciprocating engines were put into ships during the nineteenth century. What has changed is the material and level of design and engineering to ensure a crankshaft can cope with the high powers and speeds required by modern day marine diesel engines. Crankshafts are the very heart of the engine. They need to be rigid, with high torsional strength, be able to withstand forces and, without compromise, need to be compact.[8]

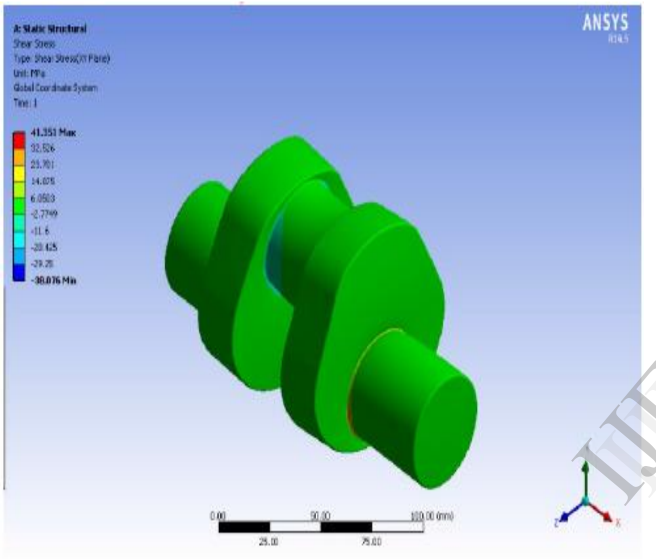
II. LITERATURE REVIEW: DESIGN AND ANALYSIS OF 4-STROKE SINGLE CYLINDER DIESEL ENGINE CRANKSHAFT

Jaimin Brahmbhatt have been analyzed crankshaft model was created by Solid works 2009 software. Then, the model created by Solid works was imported to ANSYS software. After that FEA Results Conformal matches with the theoretical calculation so they can say that FEA is a good tool to reduce time consuming theoretical Work. The maximum deformation appears at the center of crankpin neck surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks and near the central point Journal. The edge of main journal is high stress area. The Value of Von-Misses Stresses that comes out from the analysis is far less than material yield stress so their design is safe and they should go for optimization to reduce the material and cost. After Performing Static Analysis they performed Dynamic analysis of the crankshaft which results are more realistic whereas static analysis provides an overestimate results. Accurate stresses and deformation are critical input to fatigue analysis and optimization of the crankshaft. After Analysis Results, they can Say that Dynamic FEA is a good tool to reduce Costly experimental work.[1]



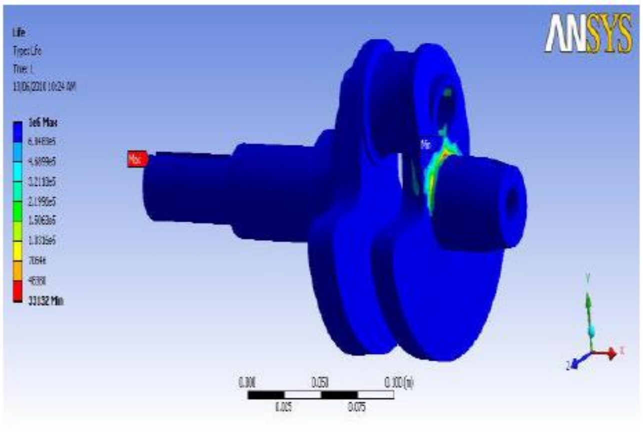
[Figure: Results of Analysis Maximum Deformation at a Phase Angle 355, maximum shear stress is generated at crankpin][1]

Amit solanki and jaydeepsinghdodiya have analyzed crankshaft model was created by Pro-E Software. Then, the model created by Pro-E was imported to ANSYS software. FEA Results Conformal matches with the theoretical calculation so they say that FEA is a good tool to reduce time consuming theoretical Work. The maximum deformation appears at the center of crankpin neck surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks and near the central point Journal. The edge of main journal is high stress area. The Value of Von-Misses Stresses that comes out from the analysis is far less than material yield stress so design is safe and goes for optimization to reduce the material and cost. After Performing Static Analysis they performed Dynamic analysis of the crankshaft which results are more realistic whereas static analysis provides an overestimate results. Accurate stresses and deformation are critical input to fatigue analysis and optimization of the crankshaft. After Analysis Results, they can Say that Dynamic FEA is a good tool to reduce Costly experimental work.[2]



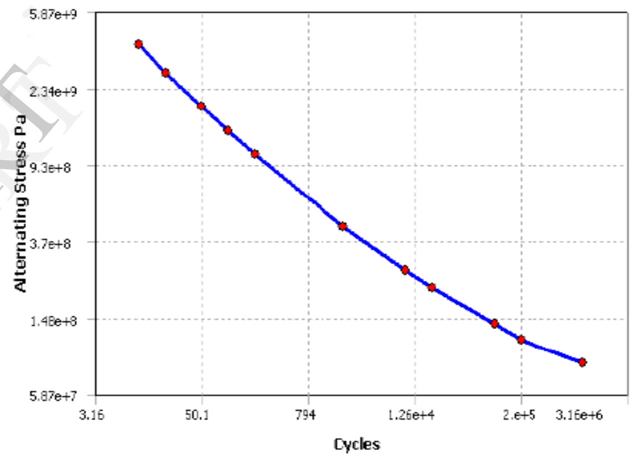
[Figure: Analysis and result after applying tangential force, fig describe The edge of main journal is high stress area][2]

Bhumesh J. Bagde and Laukik P. Raut have been analyzed the crankshaft model was created by Pro-E Wildfire 4.0 software. Then the model created by Pro-E Wildfire 4.0 was imported to ANSYS software. The analysis of the crankshaft is done using five different materials. Static Structural Analysis and fatigue analysis of crankshaft was performed on ANSYS software and the deformation and stresses were compared. Analysis has been performed on existing material of Crankshaft and four alternate materials also considered for crank shaft. Analysis describes the critical portion where stresses acting are maximum and the chances of crack formation are maximum. The stresses induced are minimum for SAE 1137 material of crank shaft as compare to other materials. The fatigue life of materials EN9 and SAE 1137 is better as compare to other materials. The time and efforts required for analysis using software is very less and accuracy is also good. So they say that FEA is a good tool to reduce time consuming theoretical work.[3]



Fatigue Analysis of crank shaft

The figure shows the probable life of the crank shaft. The red color portion shows that the life of the crank shaft is minimum at that region and the blue color portion shows that the fatigue life of the component is maximum at that region. The portion shown by the red color shows that the fatigue life of the component is minimum and it is the portion where the chances of crack formation are maximum.[3]



Alternating stress parameters of crank shaft

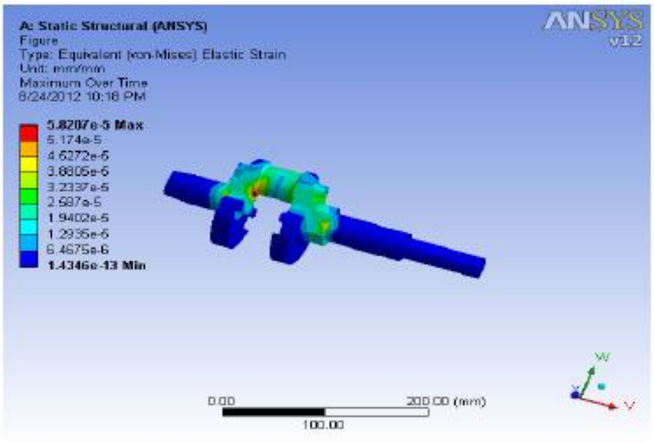
Figure shows the Alternating stress parameters of crank shaft : As the number of cycles per revolutions goes on increasing alternating stress increases proportionally as shown in graph. The maximum alternating stress is between 58.7 x 10^9 pa. to 23.4 x10^9 Pa. Maximum number of cycles is 3.16x10^6.[3]

Rinklegarg and Sunil Baghlhas been analyzed crankshaft model and crank throw were created by Pro/E Software and then imported to ANSYS. Finite Element analysis of the single cylinder cast iron crankshaft has been done using FEA tool ANSYS Workbench. From the results obtained from FE analysis, many discussions have been made. The results obtained are well in agreement with the similar available existing results. The model is well safe and under permissible limit of stresses.

1. Results describe the improvement in the strength of the crankshaft as the maximum limits of stresses, total deformation and strain is reduced.

2. The weight of the crankshaft is also reduced by 3934g. Thereby, reduces the inertia force.

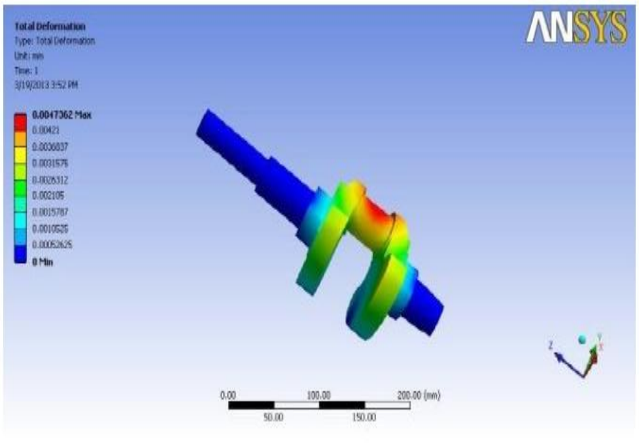
3. As the weight of the crankshaft is decreased and decrease the cost of the crankshaft and increase the engine performance. [4]



[Figure shows the Equivalent Strain of Modified Design][4]

K. Thriveni and Dr.B.JayaChandraiah have been analyzed crankshaft model and crank were created by CATIA-V5 software and finite element analysis performed by ANSYS. There are generally two categories for the vibrations the free frequency vibrations and frequency vibrations, free vibrations occur when the system is under the action of oscillating systems and their inherent forces external forces there are controversial. In free-frequency case there is no boundary conditions are applied in the crankshaft. In natural free-frequency the crankshaft should not be vibrating but some period of time vibrations are occurred because self weight of the crankshaft. The frequency occurred in 7th node. This frequency is known as resonance frequency. In free-frequency case the resonance frequency is 1150.967Hz at 7th mode. When the engine running at the high speed the driving frequency is merely 100Hz. As the lowest natural frequency is far higher than driving frequency, possibility of resonance is rare. In frequency case the minimum frequency occurred at 1st mode is 890.735Hz, the maximum frequency occurred at 10th node is 5539.023Hz. [5]

K. Thriveni and Dr.B.Jaya Chandraiah has been analyzed crankshaft model and crank was created by CATIA-V5 software and finite element analysis is performed by ANSYS software. The result show that the maximum deformation appears at the centre of the crankpin neck surface. The maximum stress appears at the fillet areas between the crankshaft journal and crank cheeks and near the central point journal. The value of von-misses stresses that comes out from the analysis is far less than material yield stress so our design is safe.[6]



[Figure shows that The maximum deformation appears at the centre of the crankpin neck surface. The maximum stress appears at the fillet areas between the crankshaft journal and crank cheeks and near the central point journal.][6]

Mr. B. varun created crankshaft model by SOLIDWORKS 2009 software. Then the model created by solid works was analyzed SOLIDWORKS simulation software. They focused on the optimization possibilities in the crankshaft. A crankshaft made from AISI 1035 steel was selected utilize the form flexibility of the forging process and the cost benefit using steel. According to output of the simulations the goals defined by the optimization are realizable, without encountering fatigue problems. Additional reduction in bearing diameter or larger inner diameter would lead to be loss in durability, which can cause in crankshaft to operate under the safety limit, even at lower limit.[7]

V.Vijayakumar and T.Gopalkrishnan created the crankshaft model by ABAQUS software. They conformal match the FEA Results with the theoretical calculations. They can say that FEA is a good tool to reduce time consuming theoretical Work. The maximum deformation appears at the center of crankpin neck surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks and near the central point Journal. The edge of main journal is high stress area. the value of Von-Misses stresses that comes out from the analysis is far less than material yield stress so design is safe and go for optimization to reduce the material and cost.[9]

III. DESIGN CALCULATION FOR CRANKSHAFT

The configuration of the diesel engine for crankshaft is tabulated in table - 1 belongs, V.Vijayakumar and T.Gopalkrishnan [9].

TABLE 1 SPECIFICATION OF ENGINE

1	Capacity	Cc
2	Number of cylinders	1
3	Bore stroke	Mm
4	Compression Ratio	
5	Maximum Power	hp
6	Maximum Torque	Nm
7	Maximum Gas Pressure	bar

A . Design of the crankshaft when the crank is at an angle of maximum twisting moment

(1)Force on piston

F=Area of the bore × Max. Combustion pressure

(2)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).

$$\sin \emptyset = \frac{\sin\theta}{\frac{L}{R}}$$

(3)Thrust in the connecting rod

$$\tan \theta = \frac{F_p}{\cos \emptyset}$$

Thrust on the crank shaft can be split into Tangential component and the radial component.

a. Tangential force on the crank shaft,

b. FT = FQ sin (ϴ+ Ø)

c. Radial force on the crank shaft,

d. FR = F cos (ϴ+ Ø)

(4) Reactions at bearings due to tangential force is given by

HT1 = HT2 =

(5)Similarly, reactions at bearings due to radial force is given by,

HR1 = HR2 =

B . Design Of Crankpin

(1)Let dc = diameter of crankpin in mm
We know that the bending moment at the centre of the crankpin

$$M_c = H_{R1} \times b_2$$

From this we have the equivalent twisting moment

$$T_e = \sqrt{M_c^2 + T_c^2}$$

(2) We know that equivalent twisting moment

$$T_e = \frac{\pi}{16}(d_c^3) \times \tau$$

(3) Design of crank pin against fatigue loading According to distortion energy theory
The von Mises stress induced in the crank-pin is,

$$T_e = \sqrt{(K_b \times K_c) + \frac{1}{2}(K_t \times T_c)}$$

(4) Here, Kb = combined shock and fatigue factor for bending
Kt = combined shock and fatigue factor for torsion

$$T_e = \frac{\pi}{32} \times d_c^3 \times 6\vartheta$$

Results:
From above calculation, we have found the diameter of the crankpin, length of the crank pin, diameter of the shaft, web thickness (both right and left hand) and web width.

C . Design Calculations:

(1) IP= Indicated power in KW

IP = $P(i) \times L \times A \times n \times K$

Pi=Indicated mean effective pressure
L=Stroke length
D=Bore diameter
K= No. of cylinders
n = N/2 for 4-stroke
N=Speed in rpm

(2) IP = P(i) x L x A x n x K / 60000

At the TDC of the piston, the volume will be reduced by the compression. At this moment, the maximum pressure inside the cylinder will be

Max. Pressure = B.M.E.P × Compression ratio

Now, this value of B.M.E.P acts on the piston head, and the whole force is transmitted to the crankpin through the connecting rod. This force is the most critical in the design of the crankshaft and the design in done on the basis of the above mentioned force. To find the force exerted on the crankpin by the piston:

Piston force, F (KN) = cylinder bore area (mm^2)

Considering the crankpin as a simply supported beam, we will see that

R1 + R2 = F and R1 = R2
Therefore, R1 = R2 = F÷2

Piston force will act at the middle of the crankpin, and it will be balanced by the reactions from the bearings at either side of the crankpin. Let the reactions be R1 and R2.

(3) Maximum bending moment (M) on the crank pin is given by
Where, b is the distance from the centre of the bearing to the centre of connecting rod
From the above equation, we get that

Where,
d = diameter of the crankpin = max. Bending stress of the material of the crankshaft with suitable factor of safety equating the values of M in the above equations, we can get the value of the crankpin
Length of crankpin

$$(L_e) = F \times D \div P$$

Where, P = maximum permissible stress on the bearing.

IV CONCLUSION:

Crankshaft experiences a large number of load cycles during its service life, fatigue performance and durability of the component has to be considered in the design process. The maximum deformation appears at the center of crankpin neck surface. The maximum stress appears at the fillets between the crankshaft journal and crank cheeks and near the central point Journal. The edge of main journal is high stress area. FEA Results Conformal matches with the theoretical calculation so FEA is a good tool to reduce time consuming theoretical Work and also reduce costly experimental work.

REFERENCES

[1]. Jaimin Brahmbhatt, Prof. Abhishek choubey, "Design and Analysis of Crankshaft for Single Cylinder 4-Stroke Diesel Engine", International Journal of Advanced Engineering Research and Studies, IJAERS/ Vol.I / Issue IV/July-Sept., 2012/88-90 E-ISSN2249–8974.

[2]. Amit Solanki, Jaydeepsinh Dodiya, "Design and Stress Analysis of Crankshaft for Single Cylinder 4-Stroke Diesel Engine" INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET),Vol.2 Issue V, May 2014, Page 320, ISSN: 2321-9653.

[3]. Bhumesh J. Bagde, Laukik P. Raut, “Finite Element Structural and Fatigue Analysis of Single Cylinder Engine Crankshaft” International Journal of Engineering Research & Technology (IJERT),Vol. 2, Issue 7, July 2013, ISSN: 2278-0181.

[4]. Rinkle Garg, Sunil Baghla, "Finite Element Analysis and Optimization of Crankshaft Design" International Journal of Engineering and Management Research, Vol.-2, Issue-6, December 2012, Pages: 26-31, ISSN No.: 2250-0758.

[5]. K. Thriveni, Dr. B.Jaya Chandraiah, "Modal Analysis of A Single Cylinder 4-Stroke Engine Crankshaft", International Journal of Scientific and Research Publications, Volume 3, Issue 12, December 2013, ISSN 2250-3153.

[6]. K. Thriveni1 Dr.B.Jaya Chandraiah, "Modeling and Analysis of the Crankshaft Using Ansys Software", International Journal of Computational Engineering Research, Vol. 03, Issue 5, page84-89.

[7]. Mr. B. varun, "stress analysis and optimization of crankshafts subject to static loading" international journal of engineering and computer science, volume 3 issue 5 may, 2014 page no. 5579-5587, ISSN: 2319-7242.

[8]. www.cslglobal.com, issue 2, November 2011.

[9]. V.Vijayakumar and T.Gopalkrishnan, "design and contact analysis of crankshaft using abaqus" international journal of research in aeronautical and mechanical engineering, vol.2 issue.3, march 2014. Page: 57-63, ISSN (online): 2321-3051.