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# Finite Element Analysis and Optimization of Single Cylinder Engine Crankshaft for Improving Fatigue Life

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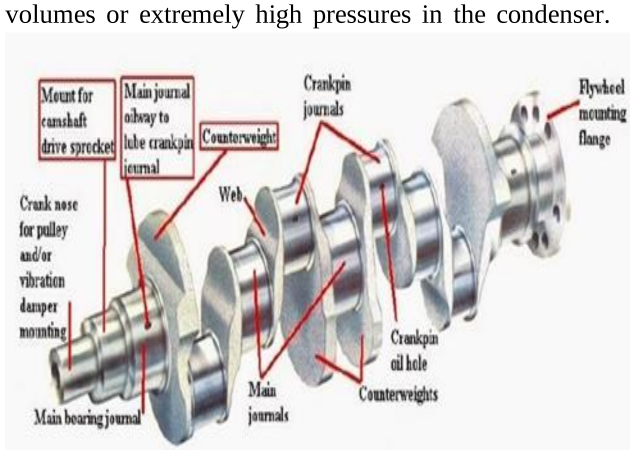
***Abstract*— Crankshaft is large volume production component with a complex geometry in the Internal Combustion (ICE) Engine. This converts the reciprocating displacement of the piston into a rotary motion of the crank. An attempt is made in this paper to study improve fatigue life of single cylinder engine crankshaft with geometry optimization. The modeling of the original and optimized crankshaft is created using SOLIDWORK Software and was imported to ANSYS software for analysis.**

**Geometry optimization resulted in 15% stress reduction of and life is optimized 62.55% crankshaft which was achieved by changing crankpin fillet radius and 25.88% stress reduction of and life is optimized 70.63% of crankpin diameter change. Then the results Von-misses stress, shear stress and life of crankshaft is done using ANSYS software results. From result of geometry optimization parameter like changing crankpin fillet radius and crankpin diameter are changes in model of crankshaft to improvement in fatigue life.**

**Keywords: - Crankshaft, Fatigue, Finite Element Analysis (FEA), Optimization**

## INTRODUCTION

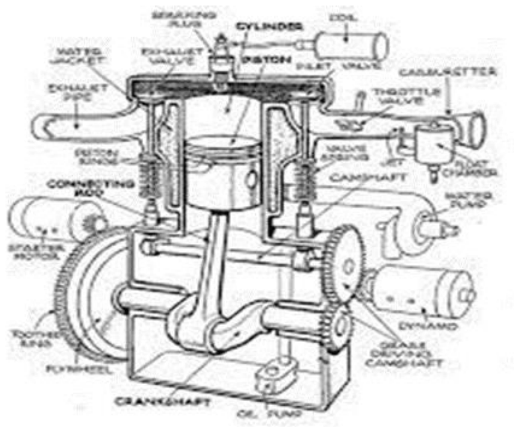
Crankshaft is one of the most important moving parts in internal combustion engine and it is a large component with a complex geometry in the engine. In general, it converts reciprocating motion of the piston is linear and is converted into rotary motion and vice versa with a four-link mechanism[40].The most common application of a crankshaft is in an automobile engine. However, there are many other applications of a crankshaft which range from small one cylinder lawnmower engines to very large multi cylinder marine crankshafts and everything in between[28].A crankshaft consists of cylinders as bearings, plates as the crank webs and crankpin. 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. It must be strong enough to take the downward force of the power stroke without excessive bending, so the reliability and life of the internal combustion engine depend on the strength of the crankshaft largely. Section geometry changes in the crankshaft cause stress concentration at fillet areas where bearings are connected to the webs of the crank. In addition, these component experiences both bending and torsional load during its life service. Therefore, areas of filleted portion are locations that experience the most critical stresses during the service life of the crankshaft[3].The typeof crankshaft depends on number of crankpins. Evaporator and large suction volumes or extremely high pressures in the condenser.




Crankshaft Nomenclatures

1.1.1 Single Cylinder Engines

A single-cylinder engine, with 4-strokes sometimes called a thumper, is a piston engine with one cylinder. This engine is often used for motorcycles, motor scooters, go-karts, all-terrain vehicles, radio-controlled vehicles, portable tools and garden machinery (such as lawnmowers, cultivators, and string trimmers).




## PROBLEM STATEMENT

Crankshaft is one of the critically loaded components in engine. Fatigue is the primary cause of failure of crankshafts due to the cyclic loading and presence of stress concentrations at the fillet areas caused by the bending and torsional [3].It exists when cyclic stresses/deformations occur in an area on a component. The fillet regions in crankshafts have been identified as the highest stressed or critical location of a crankshaft and are often the sight of fatigue crack initiation. Therefore due to this, this paper was proposed to analyze the stresses acting on the crank shaft and to improve fatigue life using geometry optimization like increase crankpin fillet radius, increasing crankpin diameter will improve life of crankshaft.

## OBJECTIVE

1. Finite Element Analysis and Optimization of Single Cylinder Engine Crankshaft for Improving Fatigue Life.
2. To model single cylinder engine crank shaft using SOLID WORK software with different fillet radius and crankpin diameter.
3. Analysis of single cylinder engine crank shaft using ANSYS 16 software with differentfillet radius and crankpin diameter.
4. Optimizing the geometry for reducing the stress, maximize fatigue life of single cylinder engine crankshaft using ANSYS software.
5. To evaluate the von-misses stress and shear stress and life at different fillet radius and diameter of crankpin using analytical and ANSYS solution.
6. To identify critical portion where stress acting are maximum then reduce maximum stressto reduce rate of failure using geometry change.

## MODELING AND FEM ANALYSIS

The finite element method is numerical analysis technique for obtaining approximate solutions toa wide variety of engineering problems. Finite element modeling of any solid component consists of geometry generation, applying material properties, meshing the component, defining the boundary constraints, and applying the proper load type. These steps will lead to the stresses and displacements in the component. In this study, this component is analyzed using SOLID WORK software for 3D modeling and ANSYS 16.0 software work bench for analysis were performed for both parameters like different fillet radius and different crankpin diameter of crankshafts.

## RESEARCH METHODOLOGY AND METHOD DESCRIPTION

Material:- Generally, crankshafts materials should be readily shaped, machined and heat-treated, and have adequate strength, toughness, hardness, and high fatigue strength. The crankshaft material used in this study is forged steel (AISI 1045) steel which is mediumcarbon steel and the type of engine is Honda engine.

a. 0.3-0.4: Lead screws, Gears, Worms, Spindles, Shafts, and Machine parts.
b. 0.4-0.5: Crankshafts, Gears, Axles, Mandrels, Tool shanks, and Heat-treated machine parts.

## CONDITIONS

- Crankshaft is assumed to a beam with two or more supports[37].
- Force is acting on the center of crankpin or at dead center[32].
- Assume that the distance (b) between the bearing 1 and 2 is equal to twice the piston diameter (D) [37]. Due to Piston force will act at the middle of the crankpin, and it will be balanced by the reactions.
- The crankpin is subjected to various forces and analysed in two positions which is at the position of maximum bending (when the crank is at dead center and twisting) [32].

## METHOD

- Bending stress
- Shear stress due to torsional moment on the shaft

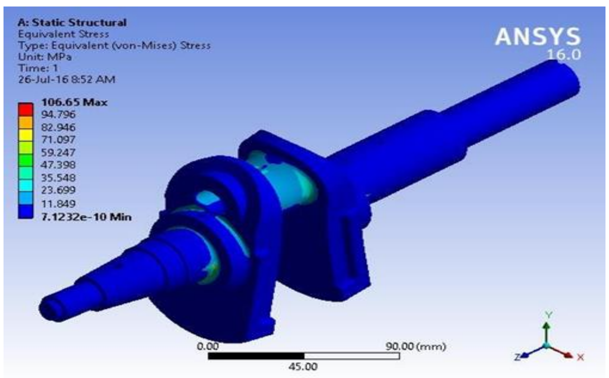
The crankpin is subjected to various forces but generally needs to be analysed in two positions. Firstly, failure may occur at the position of maximum bending (when the crank is at dead center).In such a condition the failure is due to bending and the pressure in the cylinder is maximum. Second the crank may fail due to twisting, so the crankpin needs to be checked for shear at the position of maximum twisting. The failure of a crankpin is likely to cause serious engine destruction. In the design of the crankshafts, it is assumed that the crankshaft is a beam with two or more supports. The crankpin is designed by considering two crank positions, i.e. when the crank is at dead center (or when the crankpin is subjected to maximum bending moment) and when the crank is at an angle at which the twisting moment is maximum

## RESULTS AND DISCUSSION

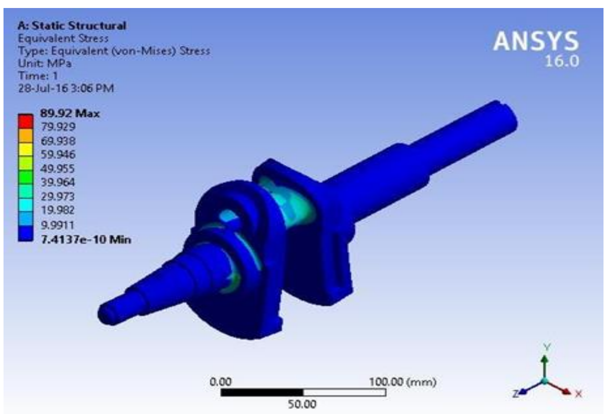
In this present work, the single cylinder engine crankshaft model was created by Solid worksoftware. Then, the model created by solid work was imported to ANSYS software for analysis.

Results in terms of fillet radius

Stress at different fillet radius

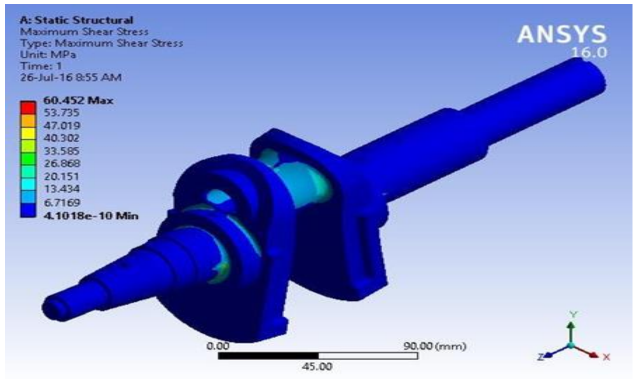



Von mises stress at 3 mm fillet radius

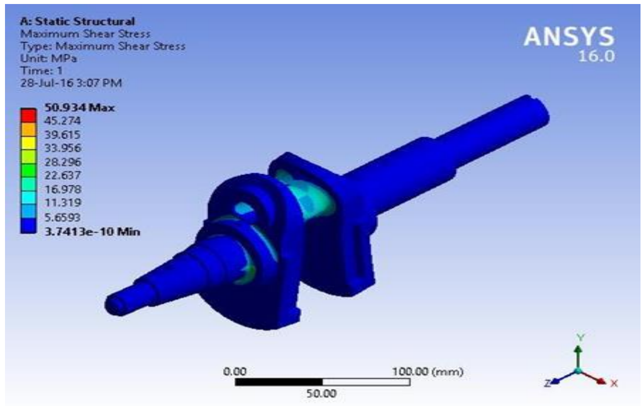



Von mises stress at 4.5 mm fillet radius

Shear stress at different fillet radius

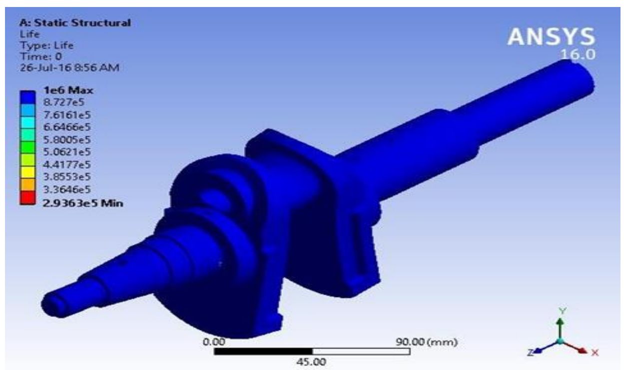



Shear stress at 3 mm fillet radius

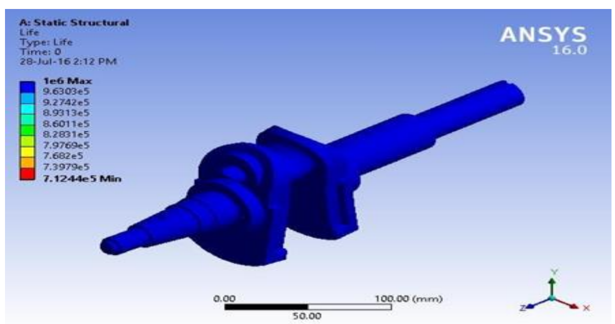



Shear stress at 4.5 mm fillet radius

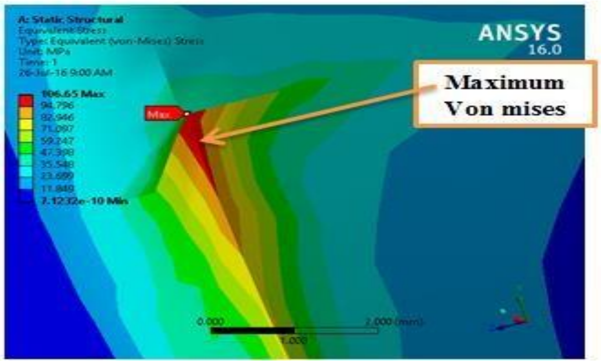
Life at different fillet radius



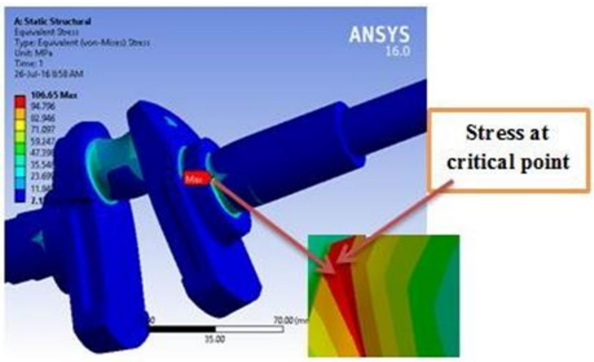

Life at 3 mm fillet radius




Life at 4.5 mm fillet radius



Maximum von mises stress of original cranksahaft




FE Model showing stress at the Critical fillet Crankshaft

## DISCUSSIONS

This paper focuses on the single cylinder engine crankshaft for improving fatigue life. Single cylinder engine crankshaft model in ANSYS predicts that the maximum value of the equivalent alternating stress decreases, and fatigue life increases.

| Alternating Stress (MPa) | Cycles |
|---|---|
| 3999 | 10 |
| 2827 | 20 |
| 1896 | 50 |
| 1413 | 100 |
| 1069 | 200 |
| 441 | 2000 |
| 262 | 10000 |
| 214 | 20000 |
| 138 | 1.e+005 |
| 114 | 2.e+005 |
| 86.2 | 1.e+006 |

Alternating stress vs. cycle

## CONCLUSION

In this paper, the crankshaft model was created by SOLIDWORK software. Then, the model created by SOLIDWORK was imported to ANSYS software. The analysis of the crank shaft willbe done using geometry optimization like different crankpin fillet radius and crankpin diameter. Finite element analysis using ANSYS and Analytical methods are done. The maximum stress appears at the fillet areas between the crankshaft journal and crank web. The edge of main journal is maximum stress area in the crankshaft. The FE model of the crankshaft geometry is meshed with tetrahedral elements. Mesh refinement are done on the crank pin fillet and journal fillet, so that fine mesh is obtained on fillet areas, which are generally critical locations on crankshaft. The failure in the crankshaft initiated at the fillet region of the journal, and fatigue is the dominant mechanism of failure. The comparison results of all different crankpin fillet radius and crankpin diameter will show the effect of stresses on crankshaft and this will help to select optimized one. Geometry optimization resulted in 15% stress reduction of and life is optimized 62.55% crankshaft which was achieved by changing crankpin fillet radius and 25.88% stress reduction ofand life is optimized 70.63% of crankpin diameter change. As the stress of the crankshaft is decreased this will increase fatigue life of the crankshaft. The crankpin fillet radius and crankpin diameter increases then Von misses stress and shear stresses are decreases as well as number of cycles to failure in increases. Analytical stress and FEA results showed close agreement and Fatigue life of modified crankshaft is improved rather than original and the optimized one can bereplaced the original one.

## RECOMMENDATION

From the result found from analytical and ANSYS result, the best way of analyzing fatigue life isin ANSYS result. In this paper better fatigue life of crankshaft is done due to geometry size optimization. We can see that as the stress decreases the life of the crankshaft increase. In this manner there are some recommendations given for the crankshaft. Predicting and preventive maintenance will help to decrease the crack initiation and crack propagation and minimize the cost of maintenance of crankshaft change due to damage. Additionally, by using better strength material property the fatigue life of the crankshaft will be improved.

## SCOPE FOR FUTURE WORK

By considering the aspects presented in this study more work can also be done in the same area. The considerations for future work are as follows:

- In Future parametric optimization can be done by changing other parameters (changing the main bearing radius, type of material etc.)

- According to FE analysis, blue locations shown in Figure have low stresses during servicelife and have the potential for material removal and weight reduction.
- Crankshaft has to be dynamically balanced; optimization process fulfills by changing the dimensions, geometry and removing or adding material in the crank web.

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REFERENCES

[1] Ashwani Kumar Singh, et al., "FEA of the crankshafts Design by using Ansys workbench For nickel chrome steel and structural steel, International Journal of Scientific & Engineering Research, Volume 5, Issue 4, 1249 ISSN 2229-5518".

[2] Amitpal Singh Punewale, et al., "Analysis & Optimization of Torsional Vibrations in a Four-Stroke Single Cylinder Diesel Engine Crankshaft, International Journal of Engineering and Technical Research (IJETR), Volume-3, Issue-4.

[3] Alex.K.D, et al., "Modeling the crankshaft by CATIA and dynamic analysis".

[4] Ashvanee garg, et al, "Performance Evaluation of Crankshaft from the Thermal Aspects: A Simulation Technique".

[5] Bhumesh J, et al., "Finite Element Analysis of Single Cylinder Engine Crank Shaft", International Journal of Advances in Engineering & Technology", vol. 6.

[6] Burrell, N. K., "Controlled Shot Peening of Automotive Components," SAE Technical Paper No. 850365, Society of Automotive Engineers, Warrendale, PA, USA.

[7] C.M. Balamurugan, et al., "Computer Aided Modeling and Optimization of Crankshaft", International Journal of Scientific & Engineering Research‟, ISSN 2229-5518, Issue 8, vol.2.

[8] Calculation of Crankshafts for I.C. Engines M53.

[9] Dinesh N. Bhut "Design and Analysis of Shaft with Groove as Discontinuity under Different Loading Conditions".

[10] F.S. Silva, "Analysis of vehicle crankshaft failure, Engineering Failure Analysis 10".

[11] Farzin H. Montazersadgh et al., "Modification of crankshaft for improvement in fatigue life."

[12] Fatigue Performance Comparison and Optimization of Forged Steel and Ductile Cast Iron Crankshafts, Ali Fatemi, Executive Summary.

[13] Gu Yingkui, et al., "Strength Analysis of Diesel Engine Crankshaft Based on PRO/E and ANSYS," Third International Conference on Measuring Technology and Mechatronics Auomation.

[14] H. Bayrakceken et al., "Failures of single cylinder petrol engines crank shafts", Engineering Failure Analysis, Vol. No. – 14, Page No- 725–730.

[15] Henry, et al., "Crankshaft Durability Predictionl, SAE Technical Paper No. 920087".

[16] Infante V et al., "Failure of Crankshaft of Aerongine: A Contribution for an Accident Investigation", Engineering Failure Analysis.

[17] Jimenez Espadafor F, et al., "Analysis of Diesel Generator Crankshaft Failure",Engineering Failure Analysis, Vol. 16, pp. 2333-2341.

[18] Jaimin Brahmbhatt, et al., "Design and Analysis of Crankshaft for Single Cylinder 4-Stroke Diesel Engine", International Journal of Advanced Engineering Research and Studies, IJAERS.

[19] Jian Meng, et al., "Finite Element Analysis of 4-Cylinder Diesel Crankshaft,"I.J.Image, Graphics and Signal Processing, 5, 22-29.

[20] Ktari A et al., "Fatigue Fracture Expertise of Train Engine Crankshafts", Engineering Failure Analysis, Vol. 18, pp. 1085-1093.

[21] Ms.Shweta Ambadas Naik ,‟Failure Analysis of crankshaft by finite element method".

[22] M. Zoroufi and A. Fatemi, "A Literature Review on Durability Evaluation of Crankshafts Including Comparisons of Competing Manufacturing Processes and Cost Analysis", 26th Forging Industry.

[23] Momin Muhammad Zia Muhammad Idris, "Crankshaft Strength Analysis Using Finite Element Method," International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 3, Issue 1

[24] Mr. Suraj K. Kolhe, "Diesel Engine Crankshaft High Cycle Fatigue Life Estimation and Improvement through FEA".

[25] Mr. Anant B. et al., "comparative analysis of crankshaft in single cylinder petrol engine crankshaft by numerical and analytical method".

[26] Nallicheri, et al.,"Material Alternatives for the Automotive Crankshaft; A Competitive Assessment Based on Manufacturing Economics," SAE Technical Paper No. 910139, Society of Automotive Engineers, Warrendale, PA, USA.

[27] Osman Asi, "Failure analysis of a crankshaft made from ductile cast iron Engineering Failure Analysis, Vol. No. – 13.

[28] Peterson's Stress Concentration Factors, Third Edition. Walter D. Pilkey and Deborah F. Pilkey.

[29] Park, H, Ko, et al., "Fatigue Life Analysis of Crankshaft at Various Surface Treatments," SAE Technical Paper No. 2001-01-3374, Society of Automotive Engineers, Warrendale, PA, USA.

[30] R.M. Metkar, et al., "A fatigue analysis and life estimation of crankshaft" - a review, International Journal of Mechanical and Materials Engineering (IJMME), Vol.6, No.3.

[31] Rinkle Garg, et al., "Finite Element Analysis and Optimization of Crankshaft Design "International Journal of Engineering and Management Research, Vol.-2, Issue-6, ISSN No.: 2250-0758.

[32] Rahul Kumar et al, "Conventional Design and Static Stress Analysis of IC Engine Component (Crank Pin) Using the Finite Element Method".

[33] RS Khurmi, JK Gupta , "A Textbook of Machine Design". Fourteenth Edition, Eurasia Publishing House, India.

[34] Shigley's, "Mechanical Engineering Design", Eighth Edition, The McGraw–Hill Companies.

[35] "Stress Analysis and Optimization of Crankshafts Subject to Dynamic Loading", Farzin Montazersadgh and Ali Fatemi, Final Project Report.

[36] S.Vigneshwaran T.M.Vigneshwaran,"Failure Analysis and Optimization Crankshaft in Diesel Locomotive".

[37] Theory and Design of Automotive Engines [AU51].

[38] Uchida, S., et al., "The Development of the DCI Crankshaft for the Nissan 60°-V6 Engine," SAE Technical Paper No. 841220, Society of Automotive Engineers, Warrendale, PA, USA.

[39] V.Vijayakumar, et al., "Design and Contact Analysis of Crankshaft Using Abaqus", International journal of research in aeronautical and mechanical engineering ISSN (ONLINE): 2321-3051.

[40] Xiao-lei Xu, et al., "Truck Petrol Engine Crankshaft Failure Analysis", Journal of Failure Analysis and Prevention. Vol. No. – 11.Domanski, P.A., Didion, D.A., Doyle, J.P. (1994), ―Evaluation of suction-line/liquid-line heat exchange in the refrigeration cycle‖, International Journal of Refrigeration,17, pp. 487–493.