

Study of Dynamic and Fatigue Analysis of Crank Shaft by Using Finite Element Method

Atul Kumar¹, Yalamanchili Suresh²

Department of Mechanical Engineering, Gonna Institute of Information and Technology and Sciences, Visakhapatnam, India ¹

Department of Mechanical Engineering, Gonna Institute of Information and Technology and Sciences, Visakhapatnam, India ²

ABSTRACT: Crankshaft is one of the main and the large volume production components with a complex geometry within the combustion (I.C) Engine. This converts the reciprocating displacement of the piston into a movement of the crank. During this paper thesis study the Fourier analysis and fatigue analysis on a crankshaft from a 4-stroke I.C Engine. The modelling of the crankshaft is formed using CATIA-V5 Software. Finite element analysis (FEA) technique is performed to get the variation of stress at critical locations of the crank shaft using the HYPERMESH and ANSYS software and applying the boundary conditions. In this work study and analysis of dynamic characteristics of Crank Shaft with the help of Finite element Method. Based on the obtained results with help of shape optimization improving the dynamic & fatigue characteristic behaviour.

KEYWORDS: Crankshaft, FEA analysis, CATIA, ANSYS.

I. INTRODUCTION

Crank shaft is the main Fundamental component with a complex geometry in the engine, which converts or turns the reciprocating displacement of the piston to a rotary motion with a four link mechanism.. Features of a crankshaft include the crank pin journal, throw, bearing journals, counterweights, crank gear, and a power take-off (PTO). A crank pin journal is a precision ground surface that provides a rotating pivot point to attach the connecting rod to the crankshaft. The throw is the measurement from the center of the crank pin journal to the center of the crankshaft, which is used to determine the stroke of an engine. The throw is equal to one-half the stroke. These improvements result in smaller and lighter engines with higher power output and better fuel efficiency. This study was conducted on a four cylinder four stroke cycle engine.

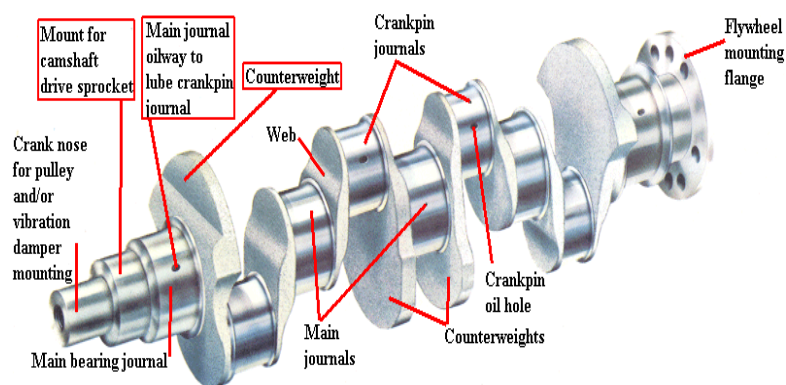


Fig. 1.1 Typical Crankshaft with main journals that support the crankshaft in the engine block.

Figure 1.1 presents a typical and detailed crankshaft with journals which actually act as supporters for the crankshaft. The crankshaft, piston, and connecting rod constitute a four bar slider-crank mechanism, which turns the sliding motion of the piston (i.e. slider mechanism) to a motion. Since the rotational output is more practical and applicable for input to other devices, the concept design of an engine is that the output would be rotation. Additionally, the linear displacement of an engine isn't smooth, because the displacement is caused by the combustion of gas within the

combustion chamber. Therefore, the displacement has sudden shocks and using this input for one more device may cause damage to it. The reason of using crankshaft is to alter these sudden displacements to a smooth rotary output, which acts as input to several devices like compressors, pumps, and generators.

Paper is organized as follows. Section II describes related info about crankshaft, section III lists out various materials and manufacturing processes for crankshafts whereas section IV presents the experimental results and section V presents conclusion.

II. RELATED INFORMATION

Crank shaft experiences large forces from gas combustion. This force which is applied to top of the piston and since the connecting rod connects the piston to the crank shaft, this force are transmitted to the crank shaft. The magnitude of the force depends on many factors which contains crank radius, rod dimensions, and weight of the connecting rod, piston, piston rings, and pin. Combustion force and inertia force experiencing on the crankshaft cause two types of loading on the crankshaft structure i.e. torsional and bending loads.

There are many sources of failure within the engine. They could be distinguished as operating sources, mechanical sources, and repairing sources. one in every of the foremost common crankshaft failures is fatigue at the fillet areas because of bending load caused by the combustion. Even with a soft case as the journal bearing contact surface, during a crankshaft freed from internal flaws one would still expect a bending or torsional fatigue crack to initiate at the radius, pin surface or at the surface of an oil hole.

This study was motivated by a necessity for a comparative study of research of crankshaft made from aluminium and its alloys which are a number of the mostly used materials to manufacture the crankshafts. it had been desired to develop an optimized geometry, material, and manufacturing procedure, which can reduce the burden for fuel efficiency. However, the view of study for multi-cylinder engines, the specified procedures used may be modified and implemented for crankshafts from other styles of engines.

III. MATERIALS AND MANUFACTURING PROCESSES

The major crankshaft material competitors currently employed in industry are forged steel, forged iron and aluminium. Comparing the performance of those materials with relevance cyclic, static and impact loading are of great interest to the automotive industry. Zoroufi and fatemi conducted the comprehensive comparison of producing processes with reference to mechanical properties, design and manufacturing aspects, and finished cost for crankshafts. This section deals with forging and casting processes because the two competing manufacturing processes in crankshaft production industry. Influencing parameters in both processes are detailed. Finally, the solid steel and also the forged iron products are compared in terms of fabric properties and manufacturing processes.

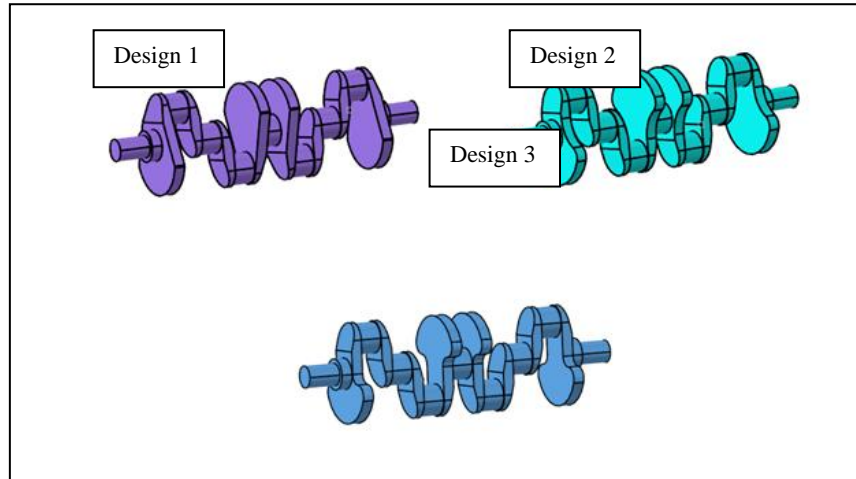
Forging is that the term for shaping metal by plastic deformation. Cold forging is completed at low temperatures, while conventional hot forging is finished at high temperatures, which makes metal easier to shape. Cold forgings are various forging processes carried out near ambient temperatures, like bending, cold drawing, cold heading, coining, and extrusion to provide metal components to shut tolerances and net shape. Warm forging could be a modification of the cold forging process where the work piece is heated to a temperature significantly below the everyday hot forging temperature, ranges from 500° C to 750° C Compared with cold forging, warm forging which has potential advantages of reduced tooling loads, reduced press loads, increased steel ductility, elimination of must anneal before forging, and favourable as-forged properties which will eliminate heat treatment. The utilization of the lower temperatures in cold and warm forging processes provides the benefits of reducing and even substantially eliminating

IV. MODELING AND ANALYSIS

In this study three different cad models are used to identify the best design based on stress values and fatigue life. All cad models are shown in below figure. The Early CAD system uses geometry construction and editing techniques to create the model. These techniques created the models of wire frame and surfaces that could be edited by a geometric editing, however, these systems had no capabilities to understand the relations between the geometry. Later parametric modeling systems were introduced, which could be used to build relationships between geometric entities. These techniques relied on constraints and parametric expressions defined by the user to build the model. These approaches built a more intelligent model, but could become restrictive; the constraints would sometimes stop a user from carrying out a modification, which had not been originally foreseen. Parametric systems also relied heavily on bodies created from swept sketches, and did not have a wide variety of construction and editing techniques.

Modeling of the Crankshaft is done using CATIA. CATIA is powerful modeling software package which is one of the most effective parametric modeling and surface feature based modeling software. Solid modeling is done in CATIA

which has a rich set of features to create and modify the designs. In this paper 3-D solid crankshaft is considered for the analysis.



The procedure followed in CATIA for modeling of the solid bar is, first getting the 2-D sketch which is the profile of the web, then the web profile is projected by using “project 3D element” option and then tr “rotate” option is used to rotate the projected profile. Care should be taken to convert the projected profile into construction lines. After modeling the crankshaft, it is saved as CATIA file and IGES file format for meshing purpose. IGES means Initial Graphic Exchange Specification; this file can be easily imported to any software package. The CATIA part file can also be saved as STEP file.

The basis of FEA relies on the decomposition of the domain into a finite number of sub-domains (elements) for which the systematic approximate solution is constructed by applying the variational or weighted residual methods. In effect, FEA reduces problem to that of a finite number of unknowns by dividing the domain into elements and by expressing the unknown field variable in terms of the assumed approximating functions within each element. These functions (also called interpolation functions) are defined in terms of the values of the field variables at specific points, referred to as nodes. The finite element method is a numerical procedure that can be used to obtain solutions to a large class of engineering problems involving stress analysis, heat transfer, electro-magnetism, and fluid flow

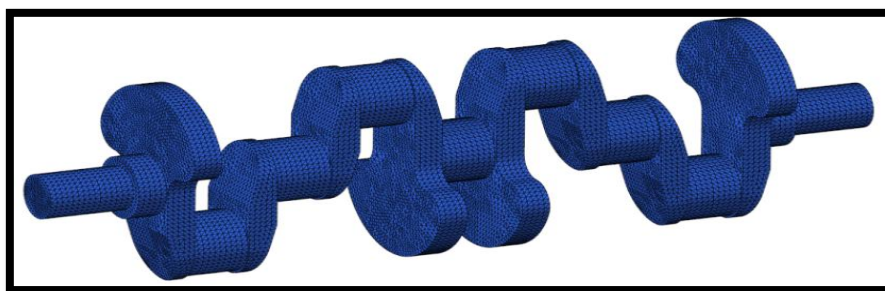


Fig. 3 Meshing of crank shaft

For analysing we have use the C45-Steel material . Material properties are listed in below table

Part	Material	Young’s Modulus (E)	Poisons Ratio	Density (Tonn/mm3)
Crankshaft	C45-Steel	210GPa	0.3	7.8e-9

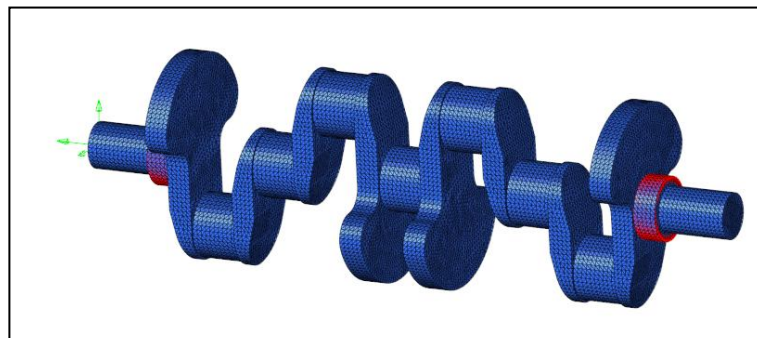
*Note: 1. Material temperature used for analysis is room temperature 23 C

ANSYS is general-purpose Finite Element Analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user designed size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a

comprehensive explanation of how the system acts as a whole. The ANSYS Workbench environment is an intuitive up-front finite element analysis tool that is used in conjunction with CAD systems and/or Design Model. ANSYS Workbench is a software environment for performing structural, thermal, and electromagnetic analyses. The Workbench focuses on attaching existing geometry, setting up the finite element model, solving, and reviewing results.

V. LOADING AND BOUNDARY CONDITION

In commercial vehicle engine, the Crankshaft revolves in the bearing called the “main” bearing. These bearings are housed in the main bearing bores of the engine block. The bearing locations are considered as simply supported. As the shaft and crankpins are cylindrical in shape, a new polar co-ordinate system is created for the purpose of creating boundary conditions for journal bearing. The boundary conditions are given with respect to the newly created polar co-ordinate system. These boundary conditions are given in ANSYS using Boundary Condition option which constrains all degrees of freedom except in radial direction (theta constraint). The rotations are constrained as the solid model does not have the rotational degrees of freedom.



In this study to observe the dynamic response of the crankshaft in first step we are performed the modal analysis up to first 10 natural frequencies followed by the frequency response analysis why because crankshaft is meant for rotating component and Cyclic loads needs to assign with crankshaft.

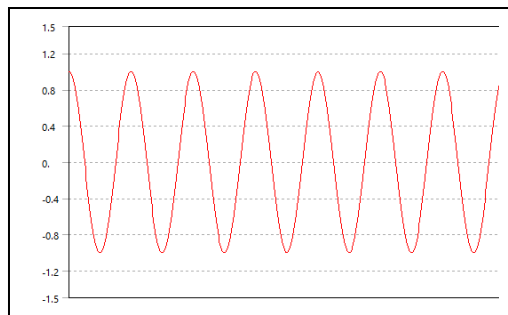


Fig. 5 Constant amplitude of fully reversed loading given to the crank shaft.

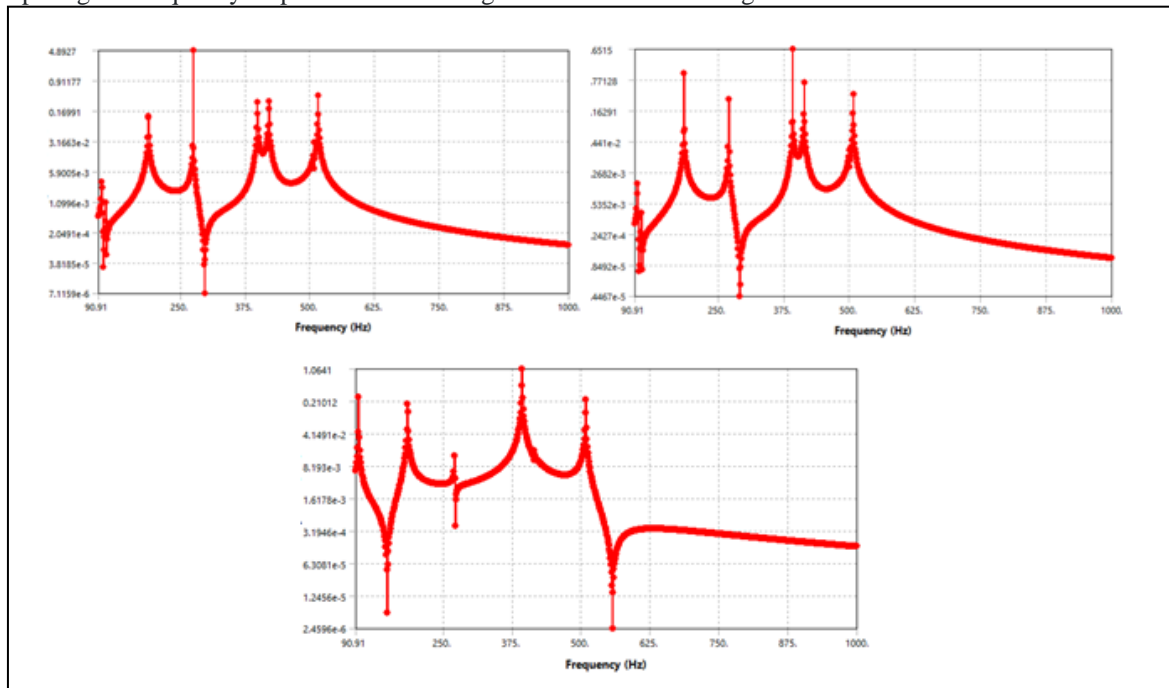
V. RESULTS AND DISCUSSION

Comparing the natural frequencies of first mode shape of three designs it was found that the 97.7 Hz, 96.3, 96.7 Hz Modal analysis of three different design crankshafts are shown in below figure.

Mode	Frequency [Hz]	Mode	Frequency [Hz]	Mode	Frequency [Hz]
1.	97.716	1.	96.395	1.	96.759
2.	105.76	2.	104.33	2.	104.73
3.	187.85	3.	185.31	3.	186.01
4.	204.86	4.	202.09	4.	202.85
5.	235.45	5.	232.27	5.	233.15
6.	274.73	6.	271.01	6.	272.04
7.	398.8	7.	393.41	7.	394.89
8.	420.88	8.	415.19	8.	416.76
9.	507.92	9.	501.05	9.	502.94
10.	516.12	10.	509.14	10.	511.06

Table 1 Modal analysis of Design@1, Design@2, and Design@3

Comparing the frequency response of three designs is shown in below figure.



Comparing the stress values due to cyclic loading of three designs are shown in below table.

Model	Stress (MPa)
Design @ 1	431
Design @ 2	393
Design @ 3	347

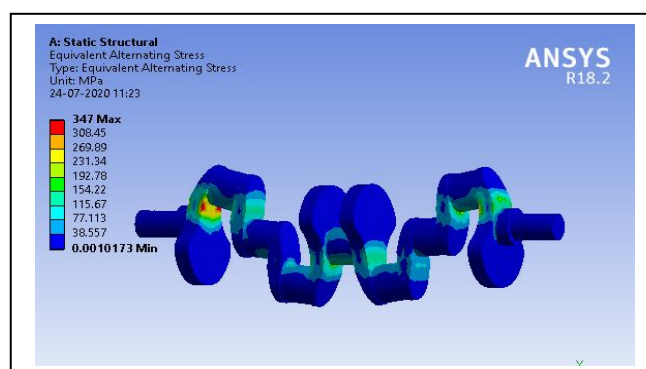


Fig. 6 Vonmises's stress value due to cyclic loading of Design@3

Comparing the fatigue life sensitivity values due to cyclic loading of three designs are shown in below figure

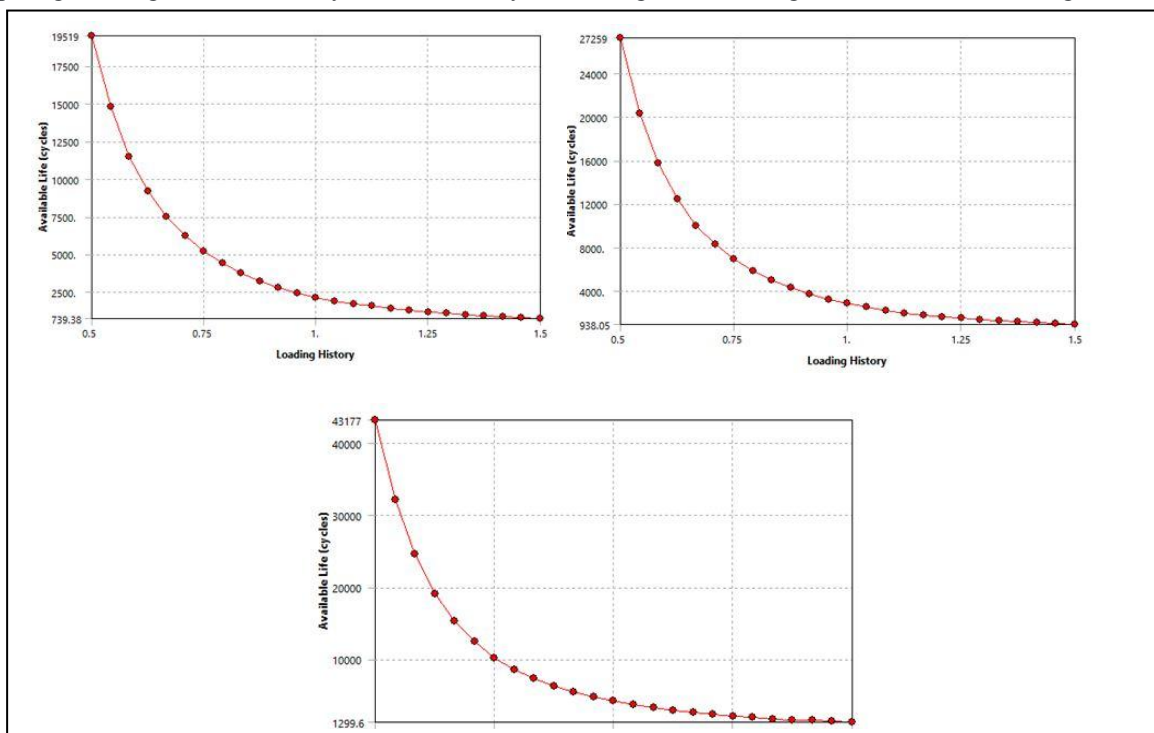


Fig. 6 Fatigue life sensitivity graphs due to cyclic loading of Design@1,2,3

V. CONCLUSION

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. The value of von-mises stresses that comes out from the analysis is far less than material yield stress so our all three design is safe. While comparing the all three designs, design 3 has more fatigue life than other designs. Fatigue sensitivity chart is given which shows how the fatigue results change as a function of the loading at the critical location on the model. We wanted to see the sensitivity of the models life if the load changed from 50% of the current load up to 150% of the current load. It is observed from the figure that when the load is increased up to 150%, the life decreases to 1299e6 cycles for design @3, and it with stand up to 43177e6 cycles without any failure indication. Even though we did finite element analysis for life estimation its approximation study for accurate and realistic its best practice to do experimental validation that is further more scope available in this study.

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