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Study & Analysis of the Dynamic Behaviour for Crank Shaft by using Finite Element Method

Muvva V Narayana Murthy¹, KVS Prasad²

P.G. Student, Department of Mechanical Engineering, Gonna Institute of Information Technology & Sciences, Visakhapatnam, India¹

Assistant Professor, Department of Mechanical Engineering, Gonna Institute of Information Technology & Sciences, Visakhapatnam, India²

ABSTRACT: Crankshaft is an important mechanical part able to perform a conversion between reciprocating motion to a rotational motion. Crankshaft is distinguished as one of the main and the large volume production components with a complex geometry within the combustion (I.C) Engine. Basically 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 and the designing of the crankshaft is carried out using CATIA-V5 Software. Secondly simulation i.e. Finite element analysis (FEA) technique is performed to get the variation of stress level at critical locations, points of the crank shaft using the HYPERMESH and ANSYS software with the applied boundary conditions. In this work study and analysis of dynamic behaviour 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, HYPERMESH.

I. INTRODUCTION

Considering the Engineering processes and techniques Crankshaft plays a major role in power transmission sources. And it was the main basic and Fundamental component with a complex geometry in the engine, with produces a mechanism of reciprocating displacement of the piston to rotary motion with a four link mechanism. Basic features of crankshaft are as follows; bearing journals, throw, crank pin journal, crank gear, counterweights, and a power take-off (PTO).

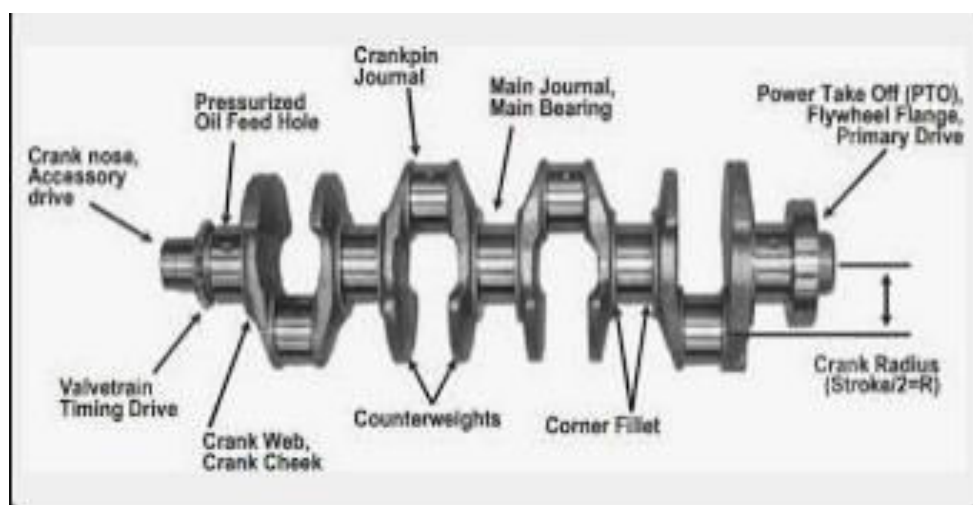


Fig. 1.1 Typical Crankshaft with main journals that support the crankshaft in the engine block.

A crankpin is a mechanical feature in an engine which is used to connect the crankshaft to the connecting rod for each cylinder. Geometry was cylindrical with a good precision ground surface.

The measurement from the centre of the crank pin journal to the centre of the crankshaft is termed as throw, which determines of the stroke of the engine.

Whereas we can observe result in smaller and lighter engines with higher power output and better fuel efficiency. This case study was conducted on a four cylinder four stroke cycle engine.

Figure 1.1 presents typical and detailed crankshaft with a feature i.e journals which actually act as supporters to the crankshaft. In the engine cylinder the piston, crankshaft, and the connecting rod constitute a four bar slider-crank mechanism. In which the displacement turns the sliding motion into a rotary which is commonly termed as slider mechanism. As the rotational output from the flywheel is more practical and reserved which is applicable as input power to other devices. Basically, the linear displacement of an engine isn't smooth, simple because the displacement is caused by the combustion of gas within the combustion chamber in higher levels.

The Major reason or concept of using the crankshaft is to reduce the sudden impact and shock on the other body when the input powers are directed without the crankshaft. This may reduce the fatigue criterion and increases the life of the engine cylinder and the reduced impact on other body as input power. Compressors, pumps, and generators are the few devices which experiences the input power.

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

In Higher Usages Crankshaft are subjected to enormous amounts of stress and it can be overviewed as a potentially equivalent to several amounts of force in the combustion chamber. This force which is actually applied to top of the piston and since the connecting rod connects the piston to the crank shaft, this force are transmitted equivalently to the crank shaft. The immensity of the force depends on many factors which is rod dimensions, weight of the connecting rod, piston, piston rings, pin, and crank radius. Mainly the Torsional and the bending applied on the crankshaft were due to combustion and the inertia forces which are experiencing are crankshaft.

The Crankshaft experiences failures within the engine as operating sources, mechanical sources, and repairing sources. And most importantly fatigue is the most common failure criterion because of repeated bending and torsional loads on the crankshaft body. Even with a soft and a tenured 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 simulated by a necessity for a comparative study, Analysis and research of crankshaft made from aluminium and its alloys which are a number of the mostly used materials to manufacture the crankshafts. It has been wish to develop an optimized geometry, material, and manufacturing procedure, Which leads to the major reduce of fuel efficiency. The theme of study of multi cylinder engines that specifies for implementing different styles of engines.

III. MATERIALS AND MANUFACTURING PROCESSES

The major material preparing of crankshaft in industry point of view was forged steel, forged iron and aluminium. Comparing the above materials with the performance point of view with relevance cyclic, static and impact loading are of great interest to the automotive industry. Zoroufi and fatemi are the responsible people who conducted the comprehensive comparison of producing processes with reference to mechanical properties, design and manufacturing aspects, and finished cost for crankshafts.

The process of shaping of metal by plastic deformation is known as forging. Cold forging is carried out at lower temperatures. As Forging takes place at higher temperatures due to easy of making shapes of required. Cold forgings near ambient temperatures, like bending, cold drawing, cold heading, coining, and extrusion to provide metal components to shut tolerances and net shape. In warm forging the metal is heated up to 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



Density	7.85e-009 tonne mm ⁻³
Isotropic Secant Coefficient of Thermal Expansion	1.2e-005 C ⁻¹
Specific Heat Constant Pressure	4.34e+008 mJ tonne ⁻¹ C ⁻¹
Isotropic Thermal Conductivity	6.05e-002 W mm ⁻¹ C ⁻¹
Isotropic Resistivity	1.7e-004 ohm mm

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

IV. MODELING AND ANALYSIS

In this study is to identify the best design based on stress values and fatigue life of three different cad models are used. All cad models are shown in below figure. The Early computer aided drawing system uses geometry construction and editing techniques to create the base model. These techniques created the models of wire frame and surfaces that could be edited by a geometric editing, Later parametric modeling systems were introduced, which will used to build relationships between geometric entities. These techniques based on constraints and parametric expressions defined by the user to build the base models. These approaches built a more intelligent model, but sometimes user face an error from carrying out a modification due to constraints Parametric systems also relied heavily on bodies created from swept sketches, loft bodies and did not have a wide variety of construction and editing techniques.

Modeling of the Crankshaft is done using CATIA. CATIA is one of the powerful modeling software package which 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. And CATIA constitute a user friendly environment. In this paper 3-D solid crankshaft is considered for the analysis

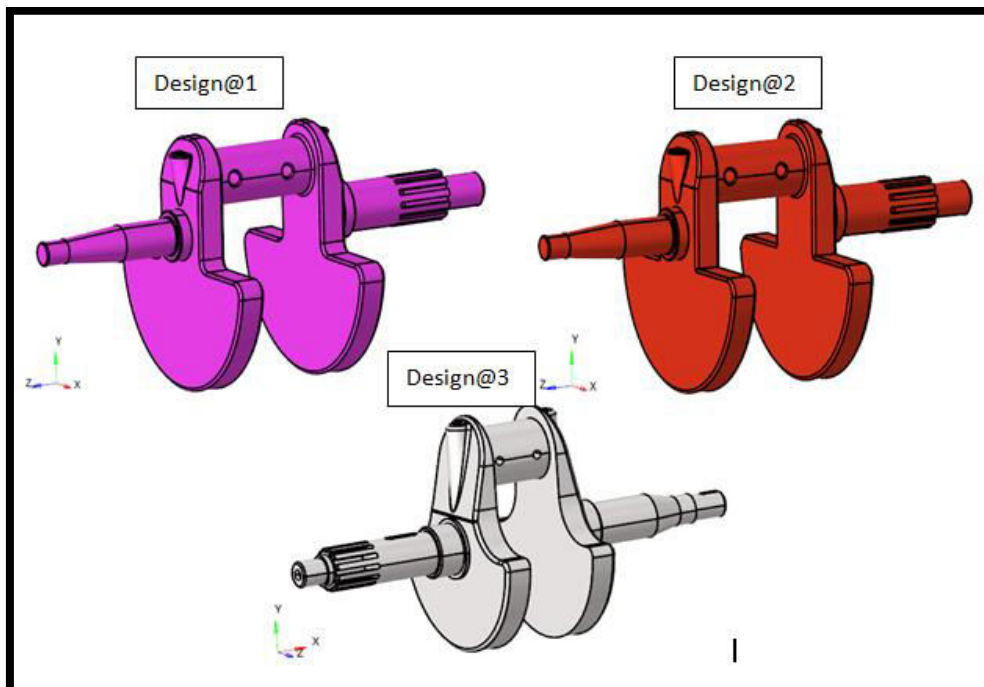


Fig2.Shows Design@1,Design@2and Design@3

The procedure carried out in CATIA to model the solid bar as follows; In order to generate the 2D Sketch which is the profile of the web; profile is projected using “project 3D element” option in catia and wish to convert the projected 3d element to the development element then tr “rotate” option is employed to rotate the projected profile from the centre of axis and fillet according to the finish in Catia Software and convert this cat part to IGES(Initial Graphic Exchange

Specification) format which need to upload in Hypermesh which can be easily uploaded in Hypermesh software without any internal errors. The CATIA part file can also be saved as STEP file.

The method of FEA depends on decomposition or diving the component into a finite number of sub-domains (elements) for which the systematic approximate solution is constructed by applying the variational or weighted residual methods. This is one of the general method carried out in each part on simulation bases. it reduces the 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 define the values of the field variables at specific points, referred to as nodes. The finite element method is a kind of a numerical procedure that can be used to obtain solutions to a large class of engineering problems involving stress analysis, electro-magnetism, heat transfer, and fluid flow.

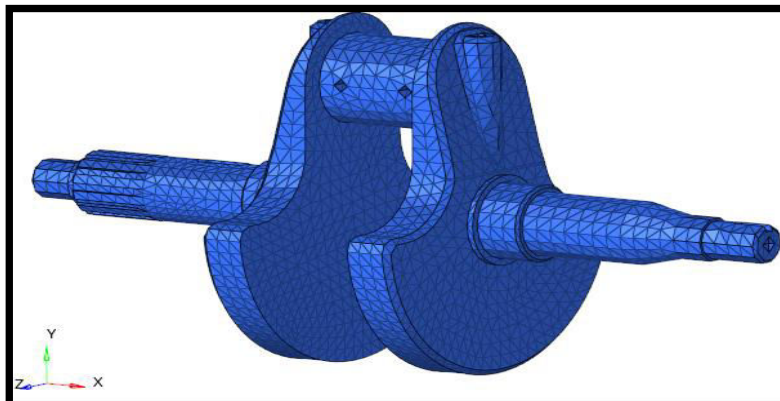


Fig. 3 Meshing of crank shaft

Analysis systems which commonly called “ANSYS” it is a finite element analysis software package it is a numerical method of deconstructing a complex system into very small pieces (of user Defined design size) called elements. The software internally creates the equation according to the behaviour of the elements after deconstruction. Workbench environment in ANSYS is an intuitive up-front finite element analysis tool that is used in conjunction with CAD systems and/or Design Model. it was mainly chosen software to solve the complex problems in structural, thermal, and electromagnetic analyses. The ANSYS and the workbench mainly focuses on the existing geometry, element disintegrating, with the applied loads as per the requirement solving the problems and finally viewing the results.

V. LOADING AND BOUNDARY CONDITION

In an engine of the commercial vehicle the crankshaft acts as the bearing which termed as the “main bearing” These bearings are housed in the main bearing bores of the engine block and considered as the simply supported. The Cylindrical shaft and the crank pin are considering for the creating of boundary conditions of journal bearings of the crankshaft. The boundary conditions are given with respect to the newly created polar co-ordinate system. These Boundary Condition option which constrains all degrees of freedom except in radial direction (theta constraint) Using ANSYS. The degree of freedom is arrested Since the rotational motion of tea solid model is constrained.



Fig. 4 Simply supported at bearing location



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

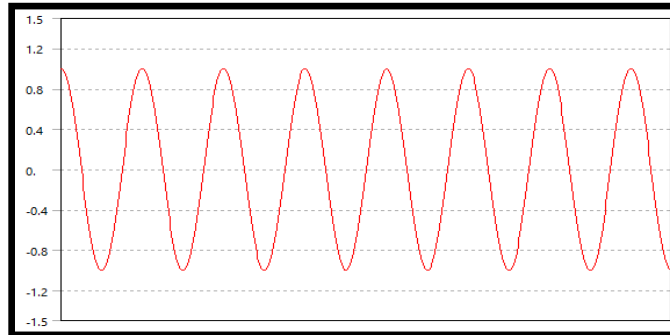


Fig. 5 Constant amplitude of fully reversed loading given to the crank shaft.

VI. RESULTS AND DISCUSSION

By comparing the natural frequencies of first mode shape of three designs it was found that the 97.716 Hz, 96.395, 96.759 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, Design@3

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

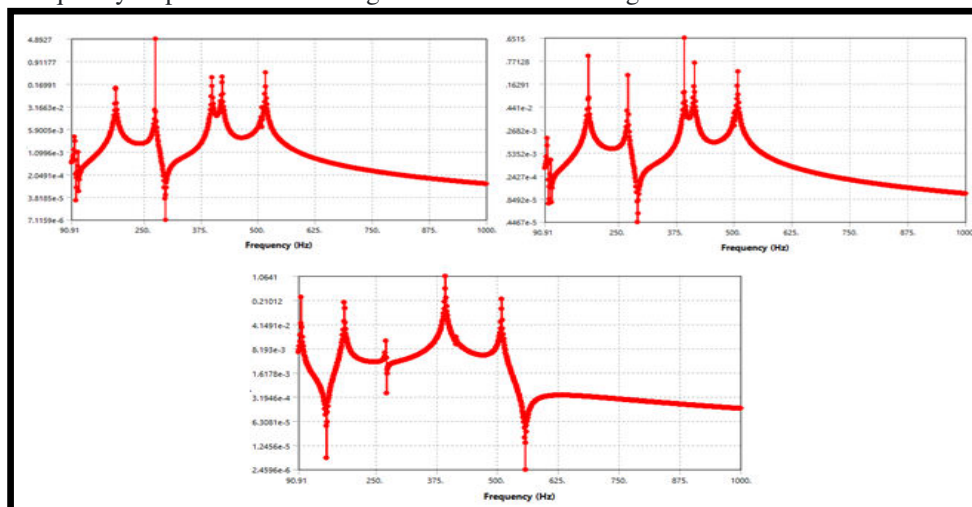
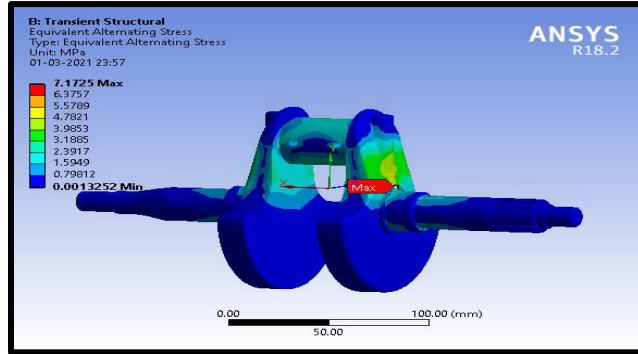
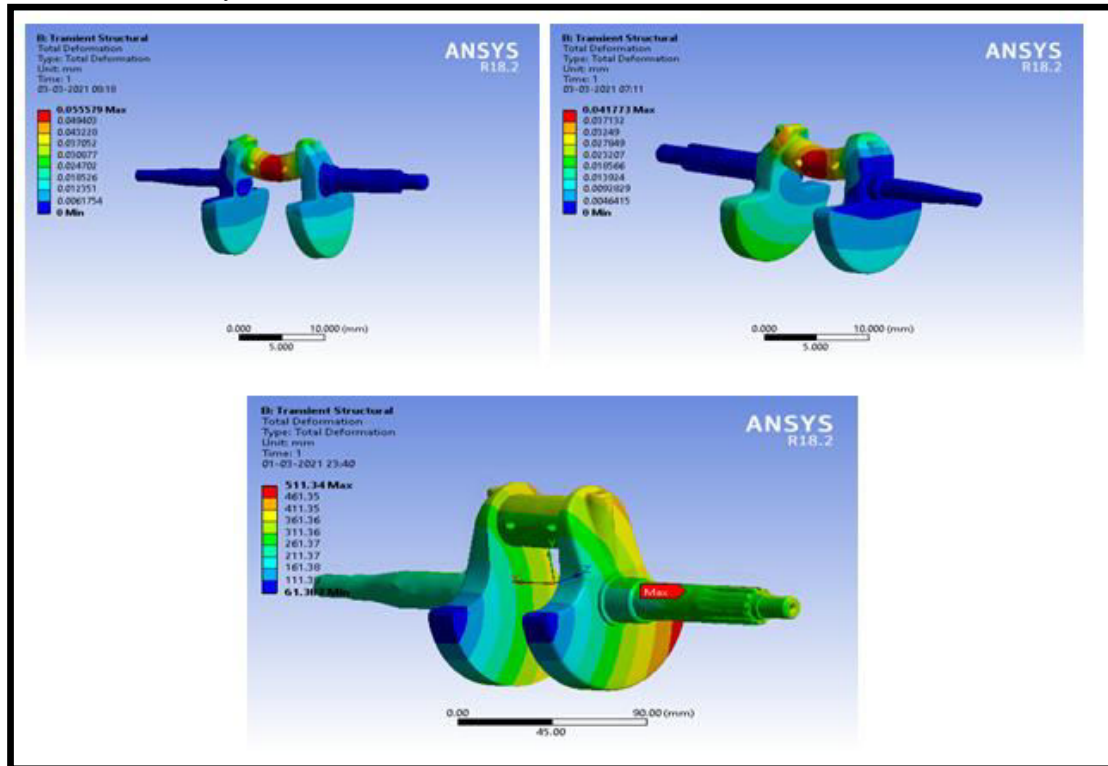


fig6 Harmonic analysis response of Design@1 ,Design@2, Design@3

Maximum Stress Values Due to Harmonic Loads



Total Deformation Due to Cyclic loads

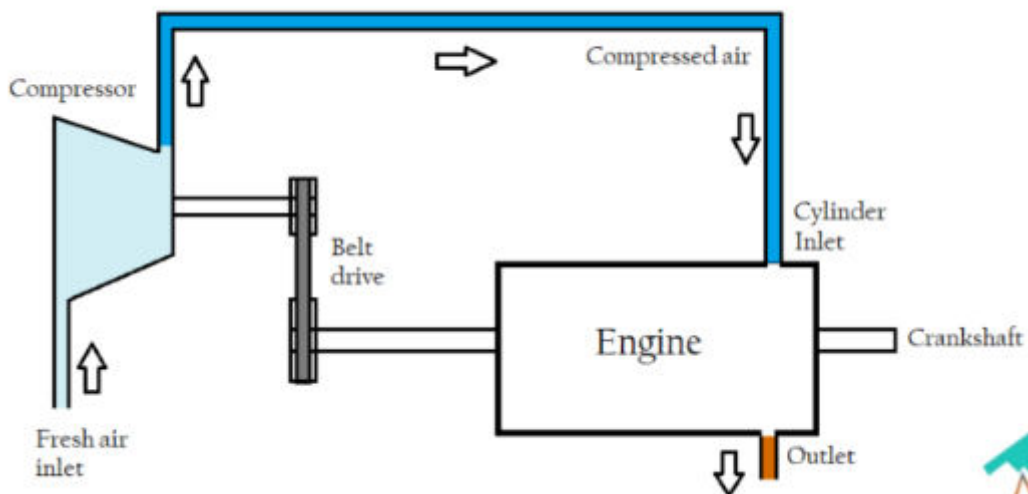


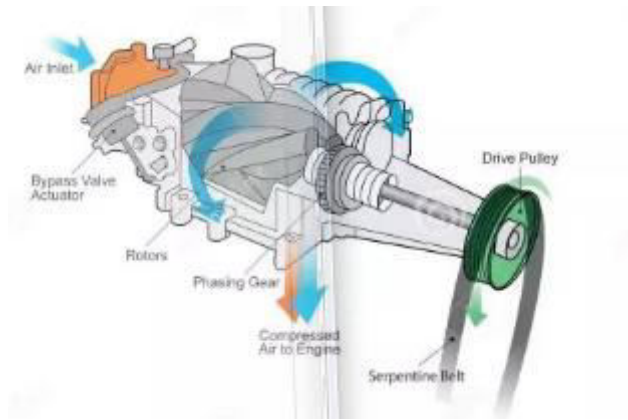
VII. CONCLUSION

As a result from the above performed analysis 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 way but 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. As it was clearly stated the deformation rate of Design@3 is comparatively less when the models experienced with cyclic loads. 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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