DYNAMIC ANALYSIS ON THE CROSS PLANE CRANKSHAFT USING ANSYS

Ravikumar N[1] | Balasubramani K[2] | Selvam V[3]

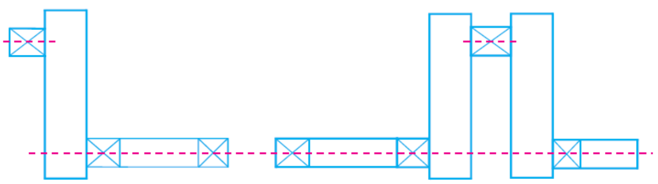
[1](Dept. of Mechanical Engg.,Asst. Professor, Kongunadu College of Engg and Tech., India, suryakumar08@gmail.com)
[2](Dept. of Mechanical Engg., Asst. Professor,Kongunadu College of Engg. and Tech. India,balasubramaninkl@gmail.com)
3(Dept. of Mechanical Engg. Asst. Professor,Kongunadu College of Engg., and Technology,India, svselvam5@gmail.com)

Abstract— *A flat plane Crankshaft has significant secondary in balance (like a 4 cylinder) which cause the engine to vibrate which can start shaking the car to pieces. A cross plane crankshaft has good balance and the vibrations are much smaller, which may give it an advantage in long distance sports car racing. Cross plane crank shaft is employed recently in Mercedes Benz, Yamaha..In this study, an attempt is made to do dynamic analysis on the cross plane crankshaft in Ansys to study its behavior under dynamic loading. The results from the dynamic analysis of the cross plane crankshaft are compared with the flat plane crankshaft. The knowledge about the cross plane crank shaft and its advantage and disadvantage over the normal flat plane crank shaft is the first step towards the of the cross plane shaft that could be achieved with the help of literatures related to the this topic. The modeling of the cross plane crank shaft will be done in Ansys. The time dependent load acting on the crank shaft is to be calculated from the concept of Dynamics which is very essential in carrying out the dynamic analysis in Ansys. From the results of the dynamic analysis, the strength and rigidity of the crank shaft is explained and compared with the flat plane crank shaft.*

Keywords— cross plane; dynamic analysis

1. 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. Since the crankshaft experiences a large number of load cycles during its service life, fatigue performance and durability of this 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. This study was conducted on a single cylinder four stroke cycle engine. Two different crankshafts from similar engines were studied in this research. The finite element analysis was performed in four static steps for each crankshaft. Stresses from these analyses were used for superposition with regards to dynamic load applied to the crankshaft. Further analysis was performed on the forged steel crankshaft in order to optimize the weight and manufacturing cost. Figure 1.1 shows a typical picture of a crankshaft and the nomenclature used to define its different parts.



(*a*) Side Crankshaft.

(*a*) Centre Crankshaft.

SERVICE LOADS AND FAILURES EXPERIENCED BY CRANKSHAFTS

Crankshaft experiences large forces from gas combustion. This force is applied to the top of the piston and since the connecting rod connects the piston to the crankshaft, the force will be transmitted to the crankshaft. The magnitude of the force depends on many factors which consists of crank radius, connecting rod dimensions, weight of the connecting rod, piston, piston rings, and pin. Combustion and inertia forces acting on the 3 crankshaft cause two types of loading on the crankshaft structure; torsional load and bending load. There are many sources of failure in the engine. They could be categorized as operating sources, mechanical sources, and repairing sources (Silva 2003). One of the most common crankshaft failures is fatigue at the fillet areas due to bending load caused by the combustion. Even with a soft case as journal bearing contact surface, in a crankshaft free of internal flaws one would still expect a bending or torsional fatigue crack to initiate at the pin surface, radius, or at the surface of an oil hole. Due to the crankshaft geometry and engine mechanism, the crankshaft fillet experiences a large stress range during its service life. Figure 1.4 shows a crankshaft in the engine block from side view. In this figure it can be seen that at the moment of combustion the load from the piston is transmitted to the crankpin, causing a large bending moment on the entire geometry of the crankshaft. At the root of the fillet areas stress concentrations exist and these high stress range locations are the points where cyclic loads could cause fatigue crack initiation, leading to fracture.

2. LITERATURE REVIEW

An extensive literature review on crankshafts was performed by Zoroufi and Fatemi (2005). Their study presents a literature survey focused on fatigue performance evaluation and comparisons of forged steel and ductile cast iron crankshafts. In their study, crankshaft specifications, operation conditions, and various failure sources are discussed. Their survey included a review of the effect of influential parameters such as residual stress on fatigue behavior and methods of inducing compressive residual stress in crankshafts. The common crankshaft material and manufacturing process technologies in use were compared with regards to their durability performance. This was followed by a discussion of durability assessment procedures used for crankshafts, as well as bench testing and experimental techniques. In their literature review, geometry optimization of crankshafts, cost analysis and potential cost saving opportunities are also briefly discussed.

MATERIALS AND MANUFACTURING PROCESSES

The major crankshaft material competitors currently used in industry are forged steel, and cast iron. Comparison of the performance of these materials with respect to static, cyclic, and impact loading are of great interest to the automotive industry. A comprehensive comparison of manufacturing processes with respect to mechanical properties, manufacturing aspects, and finished cost for crankshafts has been conducted by Zoroufi and Fatemi (2005)[1].

SHAPE COMPLEXITY IN FORGING

The main objective of forging process design is to ensure adequate flow of the metal in the dies so that the desired finish part geometry can be obtained without any external or internal defects. Metal flow is greatly influenced by part or die geometry. Often, several operations are needed to achieve gradual flow of the metal from an initially simple shape into the more complex shape of the final forging by Koike, T. and Matsui, T., 2001.[2]

HEAT TREATMENT

All hot forged parts receive a certain amount of heat treatment in the process of being forged and, thereafter, may be used without additional heat treatment. For maximum usefulness, however, many forgings are heat treated one or more times before being put into service. For instance, bearing sections and fillet areas on crankshafts are heat treated in order to improve fatigue and wear properties of the material at these certain locations. Usually forgings are heat treated before and after their machining. The purpose of the initial treatment is to secure uniform structure of the metal and contribute to ease of machining of the forged part. The final treatment makes it possible to use the finished forgings for the service intended. For example, forged tools must be hard and tough, consequently, they must receive final hardening and tempering treatments (http://www.sme.org/, 2007).

3. MODELING AND ANALYSIS

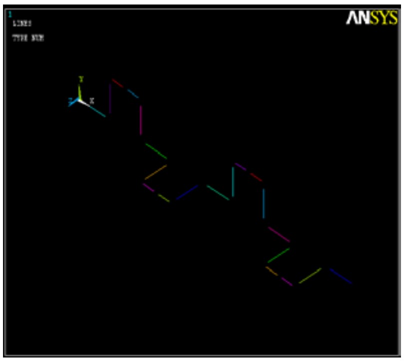
Both the flat and cross plane crankshaft is modeled in the Ansys as per the dimensions using the entities like key points, lines as shown in the figure below. The crankshaft experiences a complex loading due to the motion of the connecting rod, which transforms two sources of loading to the crankshaft. The main objective of this study was to analyze both the cross and flat plane crankshaft under dynamic loading which requires accurate magnitude of the loading on this component that consists of bending and torsion. The significance of torsion during a cycle is ignored which is one of the main assumption in the present study. So there is a need for obtaining the displacement during a loading cycle and this requires FEA over the entire engine cycle. The crankshaft is subjected by the both bending and the axial stress, so its just enough to create or treat the model as 2D instead of 3D. The finite element type “BEAM ELEMENT” is also available in which both bending and axial stress is easily plotted after the problem is solved dynamically. The whole crankshaft is meshed by the 2D ELASTIC BEAM ELEMENT. The dynamic analysis is carried out with the gas pressure acting on the crank pin of the crankshaft as a function of time for both the flat and cross plane shaft in order to find out its time dependent amplitude.

DEFINITION OF PROBLEM DOMAIN

The main objective of this chapter is to determine the magnitude and direction of the loads that act on the bearing between connecting rod and crankshaft, which is then used in the FEA over an entire cycle on both the flat and cross plane crankshaft in order to determine the displacement of the node at the point of load acting on the crankshaft.

TWO DIMENSIONAL MODEL:

(a)Flat Plane Model

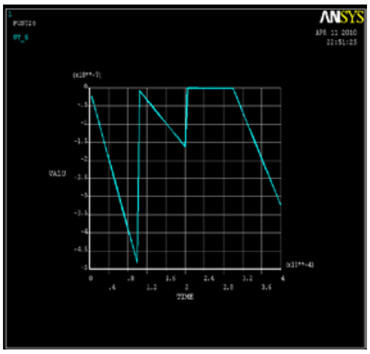


(b) Cross Plane Model

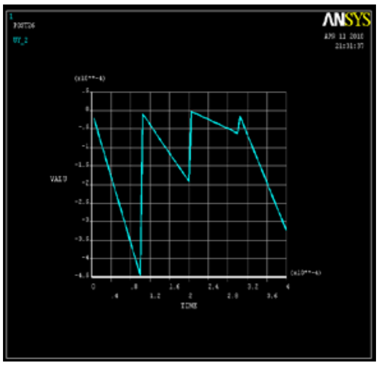
Fig 2 – 2D MODEL

4. RESULTS AND DISCUSSION

The displacement at the NODE 4 in the first cylinder crank pin surface for the cross and flat plane crankshaft is plotted against time and shown in figure 3.



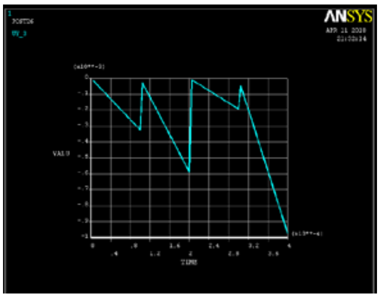
(a) Cross Plane Crankshaft



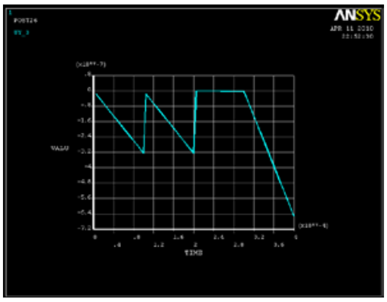
(b) Flat Plane Crankshaft

Figure 3

The displacement at the NODE 9 in the second cylinder crank pin surface for the cross and flat plane crank shaft is plotted against time and shown in figure 4.



(a) Cross Plane Crankshaft



(b) Flat Plane Crankshaft

Figure 4

5. CONCLUSION

During the time periods between 2e-4 to 3e-4 seconds, the displacement at the node numbers 4,9,14 on the cylinder 1,2,3 is constant but in the case of the flat plane the displacements never becomes constant. It indicates the vibration in the case of cross plane is less when it compared with the flat plane crankshaft.

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