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Static structural analysis of crankshaft for single cylinder camless engine

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Abstract

The crankshaft is a complex component, and as such, the influence of its geometric parameters on stresses seen under service loads is not well understood. The objectives of this work is to investigate the effects of a wide range of geometric parameters on stresses in crankshafts, to find correlation between results and to formulate simple methods of predicting peak stress levels: It is intended to achieve this by use of fatigue method. Analyses are carried out in 2D and 3D, making use of symmetry as far as possible. Variations in stresses are plotted over a wide range for each of the parameters. The analysis methods give accurate results for stress analysis of crankshafts and offer several advantages over traditional experimental techniques; they are ideally suited to parametric analyses, can be carried out relatively quickly, results are repeatable because boundary conditions can be exactly defined, and the cost of analysis is significantly reduced.The analysis is carried out in ANSYS for crankshaft along for single cylinder camless engine.

Key words : crankshaft, static, structural, analysis, camless, ANSYS

1. Introduction

The crankshaft is an integral part of the internal combustion engine, yet there is still much debate regarding the distribution of stresses within it. In particular, the influence of geometric parameters on the stresses within these complex components is not well understood. The investigation reported in this paper deals with crankshafts of high speed spark ignited petrol engines, commonly used in two wheelers and can be used in four wheelers by altering the designs. Such engines are built to fulfill four fundamental requirements; reliability, durability, ease of maintenance and economy of operation.

In the process of converting the linear reciprocating motion of the pistons into a rotational output, the crankshaft undergoes both bending and torsion. As these forces are transmitted through the crankshaft, it becomes highly stressed, particularly so at the crankpin/web and the journal/web intersections of the cranked shaft. As a consequence, fillet radii are used in these areas to reduce the stresses, but if the shaft is not carefully designed, these stresses can still reach unacceptably high levels with regard to material strength and fatigue life. Classification societies (discussed further in Chapter 2) exist to ensure that crankshafts are designed to exceed minimum standards.

2. FAILURE OF A CRANKSHAFT

The crankshaft is the central part of the engine

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and its failure would render the engine useless until costly repairs could be made or a replacement engine could be installed. The failure of a crankshaft can damage other engine components including the connecting rods or even the engine block itself. Therefore, when the failure of a crankshaft does occur it often results in replacing the engine or even scrapping the equipment the engine was used in. Considering the ramifications of a crankshaft failure, a crankshaft must be designed to last the lifetime of an engine.

The engine of a typical gasoline powered automobile has an engine speed that varies from 500 to 6,500 rpm and while traveling at highway speeds may be 2,500 r.p.m.It can easily be shown that a crankshaft has a desired life of many millions or even billions of cycles. For example if the life of an automobile is 200000 K.M and has an average speed of 75 K.M/hr and engine speed of 2,500 rpm, the engine, and crankshaft, would need to have a life of at 360 million cycles.

The gas and inertial loads in an engine create a multiaxial loading condition on a crankshaft as was shown by Jensen [1970][1]. In the study strain gages were mounted to a crankshaft from a V-8 engine and installed back in the engine. By running the engine and acquiring data, he was able to show that there was bending and torsion on the crankshaft. The study by Jensen and subsequent studies show that the torsion is small compared to the bending stress, therefore, the torsion is often neglected.

The fillets in crankshafts have been identified as the highest stressed, or critical, location of a crankshaft and are often the sight of fatigue crack initiation as was shown in the previously mentioned study by Jensen and other studies, including this one. The presence of a fillet or notch in a crankshaft is virtually unavoidable. Any change of diameter results in a stress concentration. While sharp corners can be avoided with the use of fillets, other measures are often necessary in order to increase the fatigue performance of crankshafts.

Silva [2][2003] classified the failure of crankshafts into three categories: operating sources, mechanical sources, and repairing sources. Operating sources include things such as misuse of an engine and a lack of lubrication. Mechanical sources of failure can include misalignment or vibration of the crankshaft due to balance issues. Repairing sources are those that are caused by repair to an engine or finishing of a crankshaft, such as improper grinding, incorrect bearings, or misalignment.

A cast iron crankshaft, which is typically ductile cast iron, has more ductility and therefore higher fatigue resistance than ordinary gray iron. The cast iron crankshaft could also be made from austempered ductile iron or ADI, which is a higher strength iron and has been shown to have longer fatigue life than ordinary ductile cast iron [Chatterley and Murrell, 1998][3].

Case hardening, or hardening on the surface of the material, is often done to increase the hardness in the main journals and crank-pins of the crankshaft, resulting in better wear. Not only does the surface hardening improve wear resistance, it also can induce compressive residual stresses, which results in increased fatigue performance of the crankshaft [Grum, 2003].

Ion nitriding is also used and has been shown to increase the fatigue strength of crankshafts [Park et al., 2001; Pichard et al, 1993][4].Bayrakçeken et al. [2006][5] investigated the failure of a small one-cylinder diesel engine used in agricultural applications. The analysis was performed on two crankshafts made of AISI 4140 steel, one of which was case hardened. Asi [6][2006] investigated the failure of a diesel crankshaft made of ductile cast iron. The crankshaft was taken from a 6 cylinder 115 HP engine. The failure of the crankshaft resulted in "catastrophic failure of the engine" after only 400 hours of service.

Fatigue testing typically requires destructive testing of both specimens and components in order to characterize the fatigue performance of a material or compare two materials. Damir et al. [7][2007], however, describe a process for nondestructive comparisons of fatigue behavior using modal analysis. Spiteri et al. [2007][8] experimentally and analytically investigated the fatigue performance of a ductile cast iron crankshaft subjected to bending loads. In a study by Park et al.[4] [2001] the effect of surface modifications was studied on microalloyed CrMo crankshafts.

Chatterley and Murrell[3][1998] compared the fatigue performance of several materials for use in a four-cylinder turbo charged diesel engine. The materials tested in the study were nitrided 1% CrMo, fillet rolled ductile iron (Su = 700MPa), and fillet rolled austempered ductile iron (ADI). Constant amplitude bending fatigue tests were conducted on the crankshafts to 107 cycles or failure, whichever occurred first. The study by Pichard et al.[4] [1993] explored the possibility of replacing forged steel or cast iron with a mirco alloyed steel in order to eliminate the need for additional heat treatments.

3. FAILURE OF A CRANKSHAFT

4. CONCLUSION

Comparative study needs to be applied for the selection of material and manufacturing process so as to have cost effectiveness and shape with fewer defects respectively.. In the crankshaft, the crack grows faster on the free surface while the central part of the crack front becomes straighter. Fatigue is the dominant mechanism of failure of the crankshaft. Residual imbalances along the length of the crankshafts are crucial to performance. Utilizing crankcase deflection analysis to improve crankshaft design and engine performance. Dynamic stress and strain analysis must be conducted due to the nature of the loading applied to the component such as crankshaft. Accurate stresses are critical input to fatigue analysis and optimization of the crankshaft.

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