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Research Paper

RESIDUAL STRESS ANALYSIS OF NITRIDE STEEL CRANKSHAFT FOR MULTICYLINDER ENGINE

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Crankshaft is a most critical component in Multi cylinder Engine. The residual stresses induced by the fillet rolling process of ductile cast iron crankshaft. The stress concentration near the fillet of the crankshaft section under bending without concentrations of residual stresses are investigated by a two-dimensional elastic finite element analysis. Effective Residual stress intensity factor ranges are approximately estimated and compared to an assumed threshold stress intensity factor range which determine cracks can continue to propagate for a given crack length. The conventional material such as ductile cast-iron is replaced by Nitride steel for minimizing the residual stress of Multi cylinder crankshaft. The results indicate that the four-bubble failure criterion only determines the crack initiation life for small cracks initiated on the surfaces of fillets. The four-bubble failure criterion does not indicate whether a fatigue crack initiated on the fillet surface can propagate through or arrest in the compressive residual stress zone induced by the rolling process. The remodelled crank shaft shows that the residual stress is less when compared with conventional crankshaft.

Keywords: Engine, Crankshaft, Residual stress, Nitrite steel, Analysis

INTRODUCTION

The crankshaft in an internal combustion engine converts the linear motion of the piston into a rotary motion. This rotary motion is used to drive the automobile or other device that means by the crankshaft. A crankshaft has a very wide range of applications from small one cylinder lawnmower engines to very large multi cylinder marine engines. Crankshaft is a component that is intended to last the lifetime of the engine and/or vehicle. Being a high speed, rotating component, its service life contains many millions, or even billions of cycles of repetitive loading. 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.

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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. Fatigue crack growth analysis of a diesel engine forged steel crankshaft was investigated by Guagliano *et al.* (1993) and Guagliano *et al.* (1994). They experimentally showed that with geometry like the crankshaft, the crack grows faster on the free surface while the central part of the crack front becomes straighter. Based on this observation, two methods were compared; the first considers a three dimensional model with a crack modeled over its profile from the internal depth to the external surface. In order to determine the stress intensity factors concerning modes I and II a very fine mesh near the crack tip is required which involves a large number of nodes and elements, and a large computational time. The second approach uses two dimensional models with a straight crack front and with the depth of the real crack, offering simpler models and less computational time. Osman Asi (2006) performed failure analysis of a diesel engine crankshaft used in a truck, which is made from ductile cast iron. At present nitriding for increasing fatigue strength of structural metallic materials more widely is used (Prakash *et al.*, 1998; Zoroufi, 2005; Shenoy, 2006; Farzin *et al.*, 2007; Jonathan Williams *et al.*, 2007; and Xiaorong Zhou, 2009) which it results in negative effect (for example, nitriding of high strength bearing steel SUJ2 resulted in decrease of fatigue strength. The results of experimental data on the influence of nitriding on fatigue strength will be considered below Low cycle fatigue.

Nitride Steel

Nitriding is a process of case hardening a special alloy steel (nitralloy) in an atmosphere of ammonia or in contact with nitrogenous material at a temperature below the transformation range. The surface hardness is produced by the absorption of nitrogen without quenching. Single stage nitriding is being done at 500-510 ºC with 30% dissociation of ammonia. Ammonia dissociates according to the following reaction 2NH3 ↔ 3H2 + N2 ↓ Nitriding steel are hardened and tempered at 560-650 ºC to minimize distortion and to have a uniform high surface hardness. Hence the process is very ideal for components having complex shapes/ critical section to control distortion.

Area Affected due to residual stresses in Crank shaft.

1. Gudgeon pin.
2. Connecting rod.
3. Crank shaft.
4. Engine block.
5. Cylinder.
6. Piston.

STRUCTURAL ANALYSIS OF CRANKSHAFT

ANSYS is a general-purpose finite-element modelling package for numerically solving a wide variety of mechanical problems. These problems include static/Dynamic; structural analysis (both linear and nonlinear), heat transfer, and fluid Problems, as well as acoustic and electromagnetic problems may be analyzed with finite element methods. Structural analysis is probably the most common application of the finite element method. The term structural implies crank shaft residual stress and fatigue analysis. The crankshaft bears the constraints of main journals and longitudinal thrust bearing. Because of the effect of load, crankshaft main journals appear bend deformation between the lower main-bearing half and upper main-bearing half. And the longitudinal thrust bearing can prevent effectively the crankshaft axial movement and ensure the piston and connecting rod assembly normally works. Five surface radial symmetry constrains were exerted on the five main journals surface respectively, axial displacement constrains were exerted on the two end face of crankshaft. Then the modal analysis was carried out using the ANSYS software. In this experimental work crank shaft model was created by PRO-E modelling and Imported to ANSYS software. The figure represents the bending stress and twisting moment is influenced in crank pin and then spread the crank web surface, however the yield point of von misses is less than forged steel crankshaft. So it is best suitable for manufacturing crankshaft for multi cylinder IC Engine.

Stress Analysis of Existing Crankshaft (Ductile Cast Iron)

Figure 1: X-Component of Stress

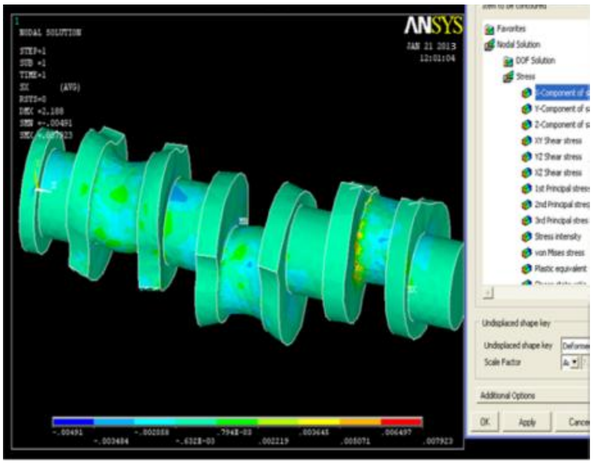


Figure 2: Y-Component of Stress

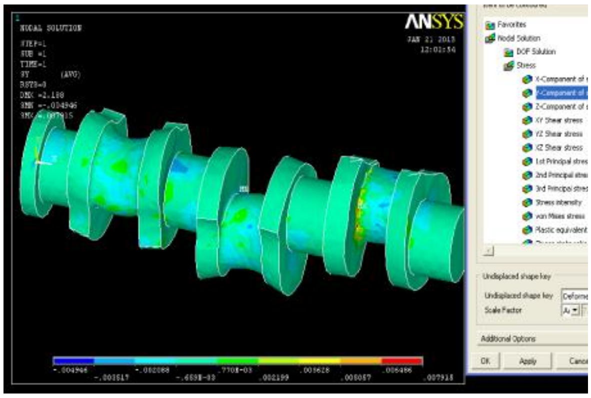
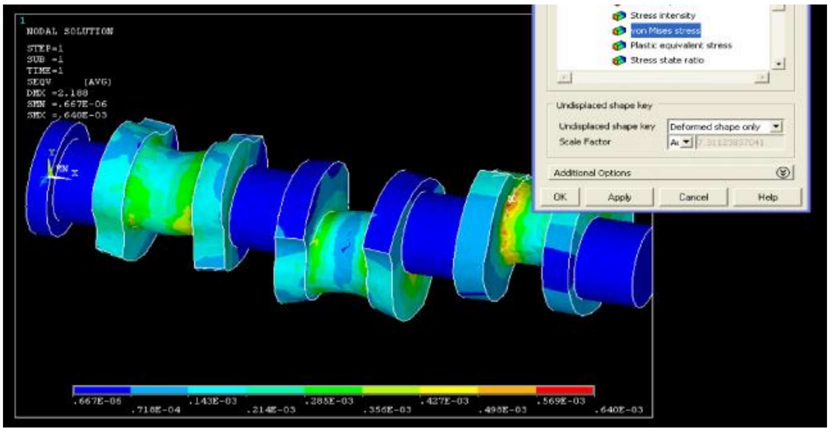


Figure 3: Z-Component of Stress and Von-Mises Stress



Stress Analysis in the Redesign Crankshaft (Using Nitride Steel)

Figure 4: X-Component Stress

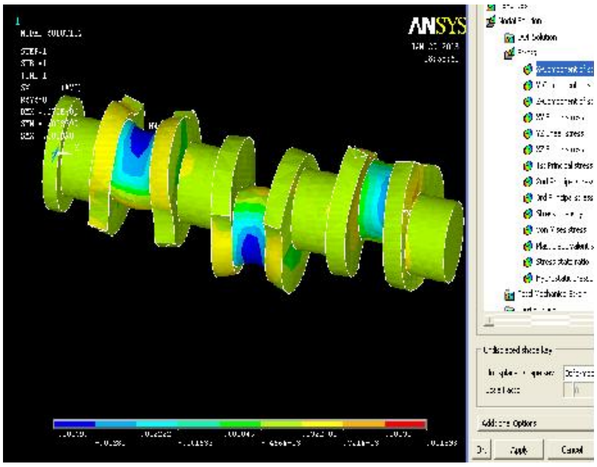


Figure 6: Z-Component Stress and Von Mises Stress

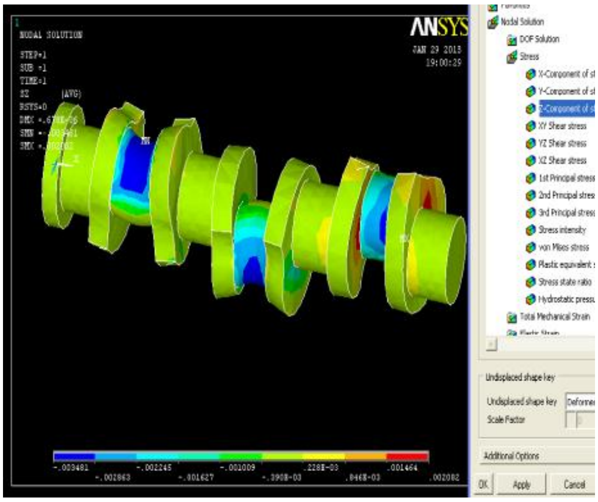
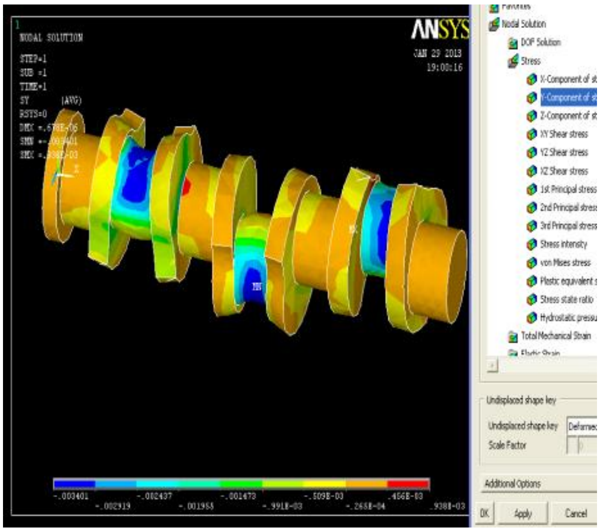


Table 1: Comparison Between Crankshaft Stresses

Stresses in Direction	Before Modeling the Crankshaft	After Modeling the Crankshaft
X-component	0.0079230	0.001898
Y-component	0.007915	0.938E-03
Z-component	0.00805	0.002080
Von Mises Stress	0.640E-03	0.640E-03

Figure 5: Y-Component Stress



CONCLUSION

In the conventional crankshaft the residual stress is maximum at the crank pin journal area and the possibility of occurrence of crack is high. This residual stress is minimized by changing material as nitride steel and forming the fillet between the edges of crank pin journal .The remodelled crank shaft shows that the residual stress is less when compared with conventional crankshaft. Thus the remodelled design can be adopted in manufacturing of crank shaft and may avoid the crack being produced in crankshaft journal.

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