

(An ISO 3297: 2007 Certified Organization) Vol. 4, Issue 11, November 2015

# Comparison of Fatigue Analysis of Four Cylinder Crank Shaft with Two Different Materials

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**ABSTRACT**: A crankshaft is a fundamental feature in a vehicle's engine. It is the system that converts linear energy into rotational energy. The crankshaft works to change piston motion with the help of connecting rods on the pistons, which enable the vehicle's engine to run. In fact, a crankshaft is the critical part of any engine assembly and it can last long if maintained properly. This paper deals with the material composition, operating conditions and failure of the crankshafts. In this regard, a model of the crankshaft has been prepared using NX CAD 8.5 and with help of NX Nastran, we were able to analyse stress distribution and deformation.

KEYWORDS: Crank shaft, Modeling, Analysis, NX CAD, NX Nastran

## I INTRODUCTION

Crank shaft 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 crank shaft 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 four cylinder four stroke cycle engine.

## **II** FUNCTION OF CRANKSHAFT IN ENGINES

The crank shaft, connecting rod, and piston constitute a four bar slider-crank mechanism, which converts the sliding motion of the piston (slider in the mechanism) to a rotary motion. Since the rotation output is more practical and applicable for input to other devices, the concept design of an engine is that the output would be rotation. In addition, the linear displacement of an engine is not smooth, as the displacement is caused by the combustion of gas in the combustion chamber. Therefore, the displacement has sudden shocks and using this input for another device may cause damage to it. The concept of using crankshaft is to change these sudden displacements to a smooth rotary output, which is the input to many devices such as generators, pumps, and compressors. It should also be mentioned that the use of a flywheel helps in smoothing the shocks. Figure below shows exploded view of a crankshaft.

#### **III OPERATING CONDITIONS & FAILURE OF CRANKSHAFTS**

Crankshaft is one of the largest components in the internal combustion engine that has a complex geometry consisting of cylinders as bearings and plates as the crank webs. Geometry section changes in the crank shaft cause stress



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concentration at fillet areas where bearings are connected to the crank webs. In addition, this component experiences both torsional and bending load during its service life. Therefore, fillet areas are locations that experience the most critical stresses during the service life of the crankshaft. As a result, these locations are main sections of fatigue failure of the component. The size of a crankshaft depends on the number of cylinders and horsepower output of the engine. The size of the crankshaft could range from 3.2 kg for a single cylinder engine with the output power of 12 hp, to 300 tons for a fourteen cylinder diesel engine with the output power of 108,920 hp.



Fig.1 Exploded view of a crankshaft

In an internal combustion engine, two load sources apply force on the crankshaft. The load applied by combustion in the combustion chamber to the piston is transmitted to the crankpin bearing by a four bar slider-crank mechanism. This is the main source of loading in the engine. The other load source is due to dynamic nature of the mechanism.

Since the engine operates at high speeds, the centrifugal forces are present at different rotating components such as connecting rods. These load sources apply both torsional and bending load on the crankshaft.

Silva (2003) classifies the cause of journal bearing failure or damage (jagged journals) to three possible sources;

- (a) operating sources such as oil absence on carter, defective lubrication of journals, high operating oil temperature, improper use of the engine (over-revving);
- (b) mechanical sources such as misalignments of the crankshaft on the assembling, improper journal bearings (wrong size), no control on the clearance size between journals and bearings, crankshaft vibration;
- (c) repairing sources such as misalignments of the journals (due to improper grinding), misalignments of the crankshaft (due to improper alignment of the crankshaft), high stress concentrations (due to improper grinding at the radius on both sides of the journals), high surface roughness (due to improper grinding, origination of wearing), improper welding or nitruration, straightening operation, defective grinding



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#### NX CAD Crankshaft Model



Fig.2 3D model of four cylinder crankshaft designed using NX CAD  $8.0\,$ 

#### **IV MATERIAL PROPERTIES**

Table.1 Aluminum 6061 (Material composition)

Chemical Name	Composition %	Material Properties	Values
Copper (Cu)	3.9	Density	2.794e-6 kg/mm3
Magnesium	0.15-0.68	Youngs	73119000kPa
(Mg)		Modulus	
Manganese(Mn)	0.75 max	Poissons	0.33
		Ration	
Silicon(Si)	1.5	Yield	393700kPa
		Strength	
Iron(Fe)	0.7	Fatigue	1008000mN/mm
		strength	
		coefficient	
Zinc(Zn)	0.25max	Fatigue	-0.114
		Strength	
		Exponent	
Titanium(Ti)	0.25 max	Ductility	0.418
		coefficient	
Chromium	0.1max	Ductility	-0.87
		Exponent	

Table.2 Aluminum 2014 (Material composition)

Chemical Name	Composition	Material	Values
		Properties	
Copper (Cu)	0.25 max	Density	2.67e-6 kg/mm3
Magnesium	0.2 to 0.45	Youngs	7000000kPa
(Mg)		Modulus	
Manganese(Mn)	0.35 max	Poissons	0.33
		Ration	
Silicon(Si)	6.5to 7.5	Yield	229000kPa
		Strength	
Iron(Fe)	0.6	Fatigue	594000mN/mm
		strength	



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		coefficient	
Zinc(Zn)	0.35	Fatigue	0.124
		Strength	
		Exponent	
Titanium(Ti)	0.25	Ductility	0.027
		coefficient	
Others	0.05max	Ductility	-0.53
		Exponent	

Table.1 Material composition for Al 6061 Table.2 Material composition for Al 2014

#### V EXPERIMENTAL RESULTS

## Vonmises Stress Results Deformation Results





Fig.5 Fig.6 Fig.3 Stress distribution for Al 6061, Fig.4 Displacement variation for Al 6061, Fig. 5 Stress distribution for Al 2014, Fig. 6 Displacement variation for Al 2014



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VI. RESULTS

<u>For Al6061 material</u> Max. Deformation=5.658e-3mm; Von Mises stress= 58.73 Mpa

For Al2014 material Max. Deformation=5.572e-3mm Von Mises stress= 64.73 MPa

#### **VII.** CONCLUSION

From the results, we observe that there is significant improvement in stress and displacement values for second material when compared with first one. Hence, it is advisable to replace them for load durability and to have a longer life.

#### VIII. ACKNOWLEDGEMENT

I am indeed grateful to my guide, Mr. K. S. Raghuram, Assoc. Professor (Ph.D) for his guidance and willingness to share his valuable knowledge. I also thank my friends Sai Kishore for his support throughout the project.

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