Stress Analysis & Optimization of Crankshaft Under Dynamic Loading

Aditya G Wattamwar[1], Dr S P Palekar[2]
[1, 2] Dept of Mechanical Engineering
[1, 2] Sanjivani College of Engineering, Kopargoan

Abstract- *Many high performance crankshafts are formed by the forging process, in which a billet of suitable size is heated to the appropriate forging temperature, typically in the range of 1950 - 2250°F, and then successively pounded or pressed into the desired shape by squeezing the billet between pairs of dies under very high pressure. These die sets have the concave negative form of the desired external shape. Complex shapes and / or extreme deformations often require more than one set of dies to accomplish the shaping. Originally, two-plane V8 cranks are forged in a single plane, then the number two and four main journals were reheated and twisted 90° to move crankpins number two and three into a perpendicular plane.Crankshafts at the upper end of the motorsport spectrum are manufactured from billets of high-grade alloy steel. Billet crankshafts are fully machined from a round bar ("billet") of the selected material (Figure 05). This method of manufacture provides extreme flexibility of design and allows rapid alterations to a design in search of optimal performance characteristics.*

Keywords- Crankshafts, Performance of Crankshaft, Design of Crankshaft

I. INTRODUCTION

The crankshaft is an engine component that converts the linear (reciprocating) motion of the piston into rotary motion. The crankshaft is the main rotating component of an engine and is commonly made of ductile iron. Features of the crankshaft include the crankpin journal, throw, bearing journals, counterweights, crankgear, and a power take-off. A crankpin journal is a precision ground surface that provides a rotating pivot point to attach the connecting rod to the crankshaft. The throw is the measurement from the centre of the crankshaft to the centre of the crankpin journal, which is used to determine the stroke of an engine. The throw is equal to one-half the stroke. The longer the throw, the greater the stroke, or distance, a piston travels.

II. LITERATURE REVIEW

As our primary objective is to study the alternative material for crankshaft for cost reduction and modifying geometry if it does not meets yield/UTS limits and hence a literature survey is carried out to understand current trends in this field.

Witeka et al. [1]performed stress and failure analysis of the crankshaft of diesel engine. After visual examination, authors observed bench marks typical for fatigue failure. Additional observations of the crack initiation zone indicated that crack origin was not covered by material defects or corrosion products.

Halicioglu et al. [2]performed structural design and analysis of a servo crank press. The study presents design, construction and demonstration of a servo crank press system for metal forming operations. The research involves structural design and analysis with dynamic considerations of the servo crank press.

Fonte et al. [3]conducted failure mode analysis of two crankshafts of a single cylinder diesel engine. This paper reports an investigation carried out on two damaged crankshafts of single cylinder diesel engines used in agricultural services for several purposes. Recurrent damages of these crankshafts type had happened after approximately 100h in service.

Witek et al. [4]has performed the stress and modal analysis of a diesel engine. Visual examination of damaged part showed that the fatigue beach marks on the fracture. They also carried out additional investigation using the scanning electron microscope revealed the presence of micro-cracks in crack origin area.

Cevik et al. [5]achieved Optimum Crankshaft Design. In this study computer aided automated optimization methodologies are integrated into the design procedure to achieve the best possible design solution according to the objectives under consideration of the predefined constraints.

Montazersadgh et al. [6]did optimization of a Forged Steel Crankshaft Subject to Dynamic Loading, In this study a dynamic simulation was conducted on a forged steel crankshaft from a single cylinder four stroke engine.

Ukhande et al. [7]did Optimization of Crankshaft Torsional Rigidity for Fatigue There study aims to evaluate crankshaft torsion rigidity by analytical method and its Finite Element Analysis (FEA) correlation, evaluate twist angle using virtual testing and its correlation with test bench data and evaluate most critical geometric parameters of crankshaft (Crankpin diameter, Pin width, Throw, Web thickness and Web width) and their quantitative contribution in torsional rigidity.

Londhe et al. [8] did optimization of Crankshaft Torsional Vibration Damper for a 4-Cylinder 4-Stroke Engine. They concluded that, in multi-cylinder internal combustion engines torsional vibrations which increases vibratory torque is the major reason for the failures of crankshaft due to raised fillet stresses.

Meng et al. [9] performed the stress analysis and modal analysis of a 4-cylinder crankshaft is discussed using finite element method in this paper. Three-dimension models of 480 diesel engine crankshaft and crank throw were created using Pro/ENGINEER software The finite element analysis (FEM) software ANSYS was used to analyse the vibration modal and the distortion and stress status of the crank throw.

III. METHODOLOGY

In this project the stress distribution on the crankshaft will be evaluated by using FEA. The finite element analysis will be performed by using ANSYS software. The static analysis is carried out to calculate stresses and deflection for applied loading. The materials used in this project are forged steel and cast iron.

The methodology used for doing the analysis is as follows:

[1] Develop a 3D model using CREO 2.0/Catia software
[2] The 3D model is converted into step. file and imported into ANSYS to perform couple field analysis.
[3] The static and dynamic analysis will be performed on the crankshaft for forged steel and cast iron.
[4] Deflections and stresses will be plotted for the crankshaft in the ANSYS software from the above analysis.
[5] Develop the mathematical model for carrying out analytical study.
[6] Comparison of the results obtained from analytical & FEA approaches for validation purpose.

Table 01: Material Properties of Forged steel and Cast Iron

Material Property	Unit	Forged Steel	Cast Iron
Modulus of Elasticity	GPa	221	178
Poisson's Ratio	-	0.3	0.27
Mass Density	kg/m3	7833	7197

FE Analysis of Crankshaft

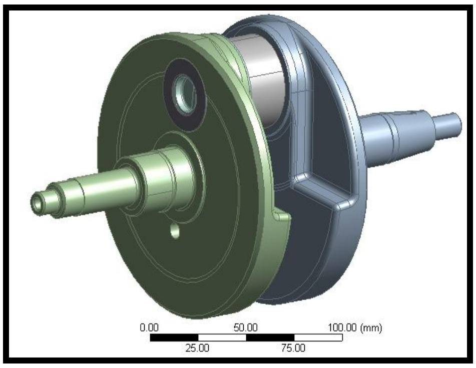
Tool Used:

In the present study Ansys 16.0 software is utilized for analyzing natural frequencies and static deflection.

3.1 Static Analysis:

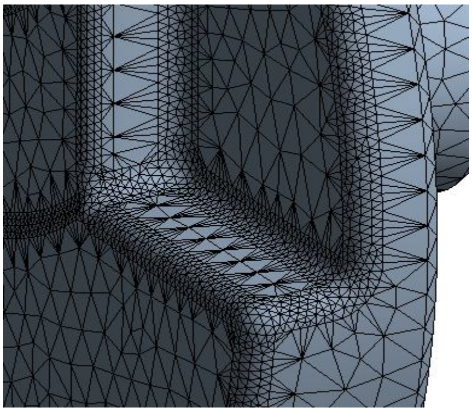
[A] Geometry Modeling:

CAD (Geometry) Modeling is the base of any project. CAD Modeling of any project is one of the most time consuming process.



[B] Meshing

Meshing involves division of the entire of model into small pieces called elements. It is convenient to select the free mesh because it has sharp curves, so that shape of the object will not alter. To mesh the plate the element type must be decided first. SOLID187 is used here for meshing plates.



Forged Steel: 1%-Chromium-molybdenum Steel

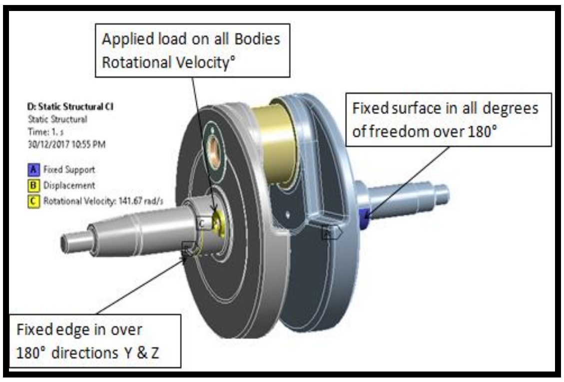
This forging steel isused for medium-to heavy-duty petrol- and diesel-engine crankshafts. The composition of this alloy is 0.4% carbon, 1.2% chromium, 0.3% molybdenum, and rest iron.

CI: Nodular Cast Irons.

These cast irons are also known as speroidal-graphite irons or ductile irons. These grey cast irons have 3 to 4% carbon and 1.8 to 2.8% silicon, and graph.

[C] SOLID187 Assumptions and Restrictions

The element must not have a zero volume. Elements may be numbered SOLID187 Geometry or may have node L below the I, J, K plane. An edge with a removed midside node implies that the displacement varies linearly, rather than parabolically, along that edge. See Quadratic Elements (Midside Nodes) in the Modeling and Meshing Guide for information about using midside nodes. When mixed formulation is used (KEYOPT (6) = 1 or 2), no midside nodes can be missed.



To achieve this structure about 0.02% residual cerium or 0.05% residual magnesium or even both is added to the melt due to which the sulphur is removed and many small spheroids in the as-cast material are formed.

III. CONCLUSIONS

In the present work the Static & Dynamic Analysis of crankshaft for forged steel & Cast Iron material has been performed by using FEA approach**.** Effect of rotational velocity has been observed for both materials. Natural Frequency for both the crankshafts has been calculated for avoiding resonance condition.

Based on the results of numerical investigations the following conclusions are formulated:

[1] Both the materials are meeting static analysis acceptance limit, since the stresses induced in them are less than material yield strength and ultimate tensile or compressive strength.
[2] Current material of crankshaft is forged steel having FOS safety is 3 and proposed material for cost and mass optimization is notched CI having factor of safety 3.3 which is 14% higher than that of steel.
[3] As compared to the forged steel there is 6% reduction in mass of the CI crankshaft which may be due to lower density of CI. At 8500RPM 1st natural frequency of both the materials is higher than force frequency which meets modal analysis acceptance criteria.

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