ANALYSIS AND OPTIMIZATION OF CRANK SHAFT FOR A SINGLE CYLINDER FOUR STROKE SI ENGINE

Raghuram Pradhan[1], Sukumar Puhan[2]
[1&,2](Professor, Mechanical Department, PACE Institute of Technology and Sciences, India)

ABSTRACT : ***The crankshaft, sometimes casually abbreviated to crank, is that part of an engine which translates reciprocating linear piston motion into rotation. It typically connects to a flywheel, to reduce the pulsation characteristic of the four stroke cycle, and sometimes a torsional or vibrational damper at the opposite end, to reduce the torsion vibrations often caused along the length of the crankshaft by the cylinders furthest from the output end acting on the torsional elasticity of the metal. The main objective of this project was to investigate weight and cost reduction opportunities for performing a detailed loading analysis. Therefore, this study consists of stress analysis in this project a module of the Crankshaft was designed in CATIA and analysis was conducted a forged steel crankshaft. The need of load history in the FEM analysis necessitates on crankshaft in ANSYS. Finite element analysis was performed to obtain the variation of stress magnitude at critical locations. The pressure volume diagram was used to calculate the load boundary condition in the model, and other inputs were taken from the engine specification chart. The analysis was done for different engine speeds and as a result, engine speed and critical region on the crankshafts were obtained. Stress variation over the engine cycle in the analysis was investigated.***

KEYWORDS – Crank shaft, Optimization, CATIA, FEA & ANSYS

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.

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.

I. METHODOLOGY

1.1. Software Used

CATIA: CATIAV5 R15 is an interactive Computer- Aided Design and Computer Aided Manufacturing system. The CAD functions automate the normal engineering, design and drafting capabilities found in today's manufacturing companies. The CAM functions provide NC programming for modern machine tools using the CatiaV5 R15 design model to describe the finished part. CatiaV5 R15 functions are divided into "applications" of common capabilities. These applications are supported by a prerequisite application called "CatiaV5 R15 Gateway".

FEA- Finite element analysis is a method of solving, usually approximately, certain problems in engineering and science. It is used mainly for problems for which no exact solution, expressible in some mathematical form, is available. As such, it is a numerical rather than an analytical method. Methods of this type are needed because analytical methods cannot cope with the real, complicated problems that are met with in engineering. For example, engineering strength of materials or the mathematical theory of elasticity can be used to calculate analytically the stresses and strains in a bent beam, but neither will be very successful in finding out what is happening in part of a car suspension system during cornering.

ANSYS- ANSYS is general-purpose finite element analysis (FEA) software package.Finite Element Analysis is a numerical method of deconstructing a complex systemnto very small pieces (of user-designated size) called elements. The software implements equations that govern the behavior of these elements and solves them all, creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

Structural and modal analysis

At first the 3D modeling is done and mesh is prepared. Using ANSYS the analysis is being done as per the following steps.

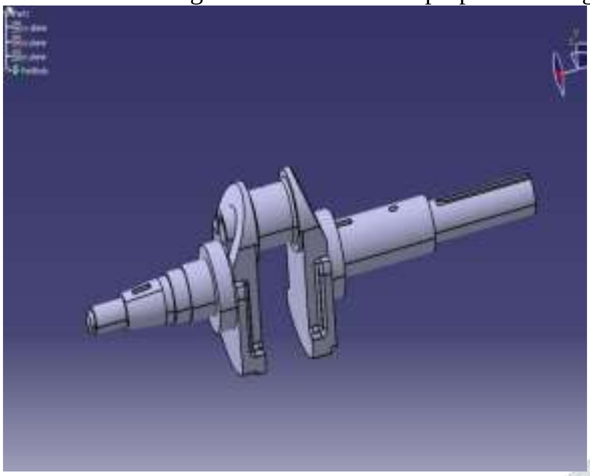

Fig-3.1 Import from 3D Model

Fig-3.2 Generating mesh

Fig- 3.3 Deformation of crankshaft

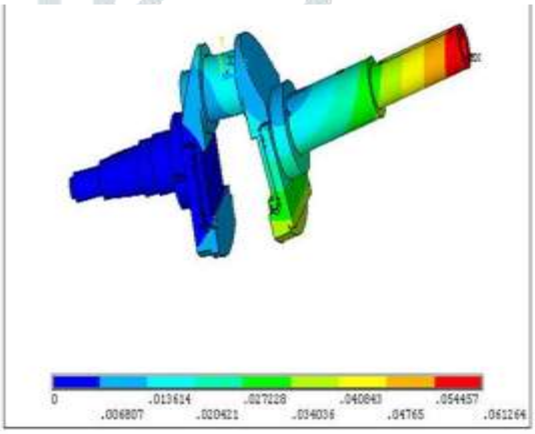

Fig- 3.4 Vector sum of displacement of crankshaft

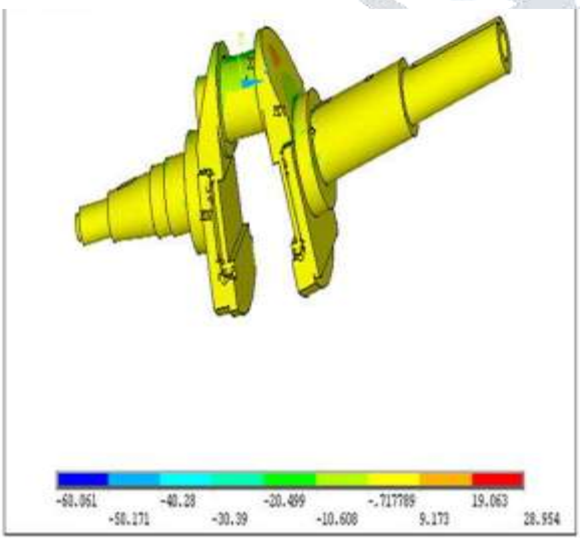

Fig- 3.4- X Direction stress of crankshaft

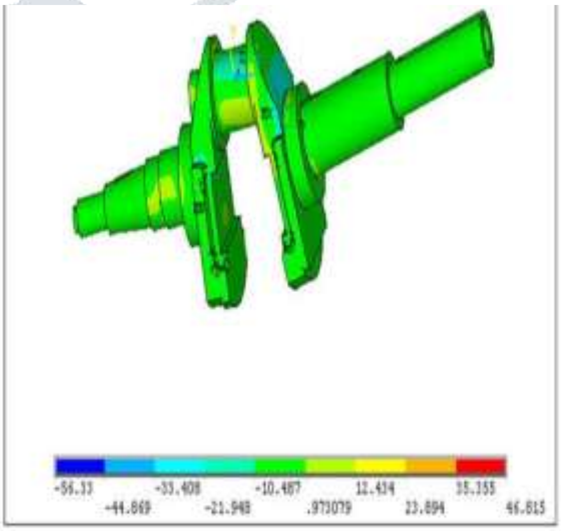

Fig- 3.5 Y Direction stress of crankshaft

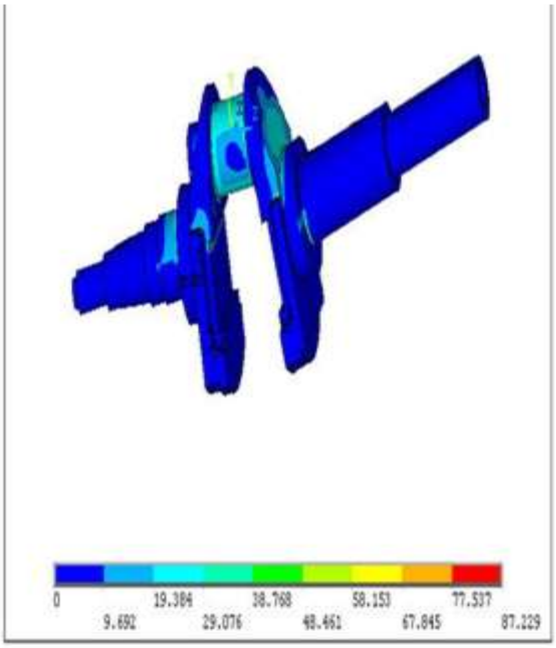

Fig-3.6 Von Mises stress of crankshaft

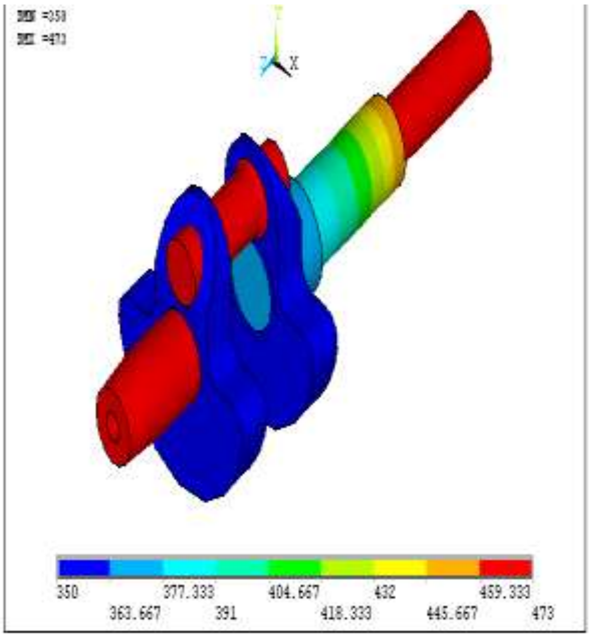

Fig-3.7 Nodal temperature vector sum of crankshaft

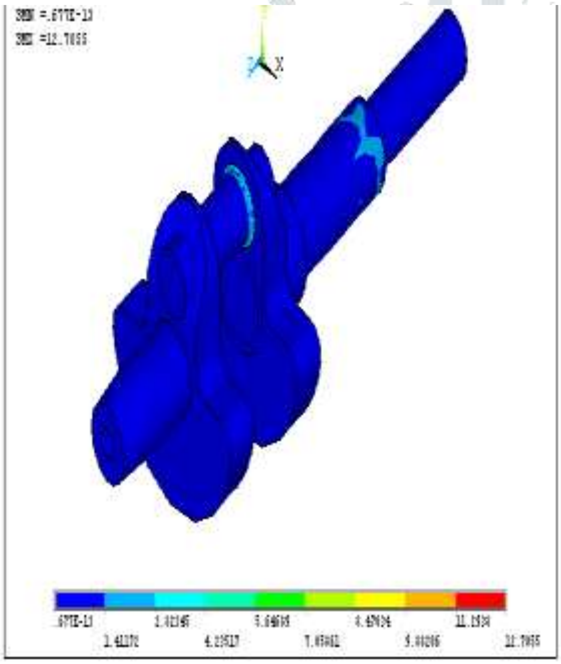

Fig- 3.8 Thermal gradient vector sum of crankshaft

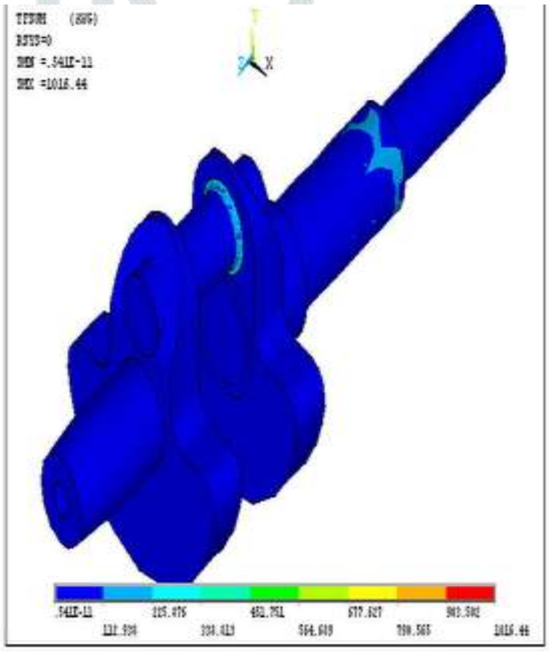

Fig- 3.9 Thermal flux vector sum of crankshaft

IV. CONCLUSION

A forged steel and a ductile cast iron crankshaft were chosen for this study, both of which belong to similar single cylinder four stroke air cooled gasoline engines. First, both crankshafts were digitized using a CMM machine. Load analysis was performed based on dynamic analysis of the slider crank mechanism consisting of the crankshaft, connecting rod, and piston assembly, superposition of stresses from unit load analysis in the FEA.

The following conclusions can be drawn from the analysis:

1. Dynamic loading analysis of the crankshaft results in more realistic stresses whereas static analysis provides overestimated results. Accurate stresses are critical input to fatigue analysis and optimization of the crankshaft.
2. There are two different load sources in an engine inertia and combustion. These two load source cause both bending and torsional load on the crankshaft. The maximum load occurs at the crank angle of 3550 for this specific engine. At this angle only bending load is applied to the crankshaft.
3. Considering torsional load in the overall dynamic loading conditions has no effect on Von Misses stress at the critically stressed location. The effect of torsion on the stress range is also relatively small at other locations undergoing torsional load. Therefore, the crankshaft analysis could be simplified to applying only bending load.
4. Superposition of FEM analysis results from two perpendicular loads is an efficient and simple method of achieving stresses for different loading conditions according to forces applied to the crankshaft from the dynamic analysis.

5. Experimental stress and FEA results showed close agreement, within 7% difference. These results indicate non-symmetric bending stresses on the crankpin bearing, whereas using analytical method predicts bending stresses to be symmetric at this location. The lack of symmetry is a geometry deformation effect, indicating the need for FEA modeling due to the relatively complex geometry of the crankshaft.

REFERENCES

1. Altan, T., Oh, S., and Gegel, H. L., 1983, *"Metal Forming Fundamentals and Applications,"* American Society for Metals, Metal Park, OH, USA.

2. Ando, S., Yamane, S., Doi, Y., Sakurai, H., and Meguro, H., 1992, *"Method for Forming Crankshaft,"* US Patent No. 5115663, United States Patent.

3. Baxter, W. J., 1993, "Detection of Fatigue Damage in Crankshafts with the Gel Electrode," *SAE Technical Paper No. 930409*, Society of Automotive Engineers, Warrendale, PA, USA.

4. Borges, A. C., Oliveira, L. C., and Neto, P. S., 2002, "Stress Distribution in a Crankshaft Crank Using a Geometrically Restricted Finite Element Model," *SAE Technical Paper No. 2002-01-2183*, Society of Automotive Engineers, Warrendale, PA, USA.

5. Burrell, N. K., 1985, "Controlled Shot Peening of Automotive Components," *SAE Technical Paper No. 850365*, Society of Automotive Engineers, Warrendale, PA, USA.

6. Chien, W. Y., Pan, J., Close, D., and Ho, S., 2005, "Fatigue Analysis of Crankshaft Sections Under Bending with Consideration of Residual Stresses," *International Journal of Fatigue*, Vol. 27, pp. 1-19.

7. Fergusen, C. R., 1986, "Internal Combustion Engines, Applied Thermodynamics," John Wiley and Sons, Inc., New York, NY, USA.