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Research Paper on Static Structural Analysis and Simulation to Obtain Stress Magnitude at Critical Location of Crankshaft in Internal Combustion Engine

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***Abstract* - This research focuses on conducting a static structural analysis and simulation to assess stress levels at critical points on a crankshaft within an internal combustion engine. As a vital engine component, the crankshaft endures significant mechanical stresses generated by piston forces during operation. Finite element analysis (FEA) was employed to simulate the crankshaft's response to static loads. The crankshaft model was initially developed in Pro/ENGINEER and then imported into ANSYS software for detailed simulation. The primary goal was to map the stress distribution across the crankshaft and identify areas susceptible to potential failure.**

The analysis indicated that stress concentrations are particularly high at certain critical locations, making them vulnerable to fatigue failure under prolonged cyclic loading. A comparison between forged steel and cast iron crankshafts revealed that the forged steel variant exhibited lower strain, suggesting superior performance and greater durability under static loading conditions. This study concludes that the forged steel crankshaft not only withstands the imposed stresses effectively but is also well-suited for mass production, which could result in cost savings. The insights gained from this research contribute to the refinement of crankshaft design, ultimately improving the efficiency and reliability of internal combustion engines.

***Key Words*- Crankshaft, Static Structural Analysis, Finite Element Analysis (FEA) , Stress Distribution ,Internal Combustion Engine Forged Steel**

I. 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. This study was conducted on a single cylinder four stroke cycle engine. Two different crankshafts from similar engines were studied in this research. The finite element analysis was performed in four static steps for each crankshaft. Stresses from these analyses were used for superposition with regards to static load applied to the crankshaft. Further analysis was performed on the forged steel crankshaft in order to optimize the weight and manufacturing cost. Figure 1.1 shows a typical picture of a crankshaft and the nomenclature used to define its different parts.

2. FORMULATION OF PROBLEM

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. Rotation output of an engine is a practical and applicable input to other devices since the linear displacement of an engine is not a smooth output as the displacement is caused by the combustion of gas in the combustion chamber. A crankshaft changes these sudden displacements to a smooth rotary output which is the input to many devices such as generators, pumps, compressors.

2.1 STRESSES IN CRANKSHAFT:

The crankpin is like a built in beam with a distributed load along its length that varies with crank position. Each web like a cantilever beam subjected to bending & twisting. Journals would be principally subjected to twisting.

1. Bending causes tensile and compressive stresses.
2. Twisting causes shear stress.
3. Due to shrinkage of the web onto the journals,

compressive stresses are set up in journals & tensile hoop stresses in the webs.

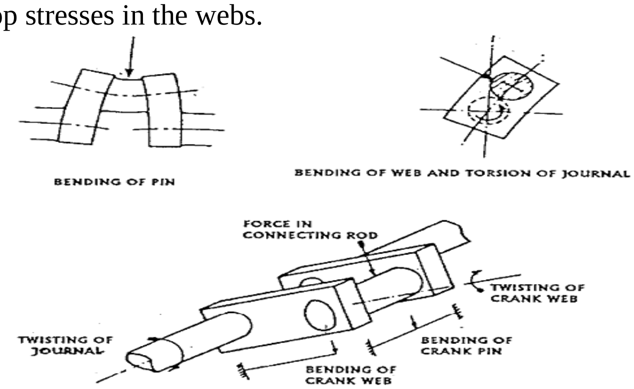


Figure 1. Stresses in Crankshaft

Table 4.1.2: MANUFACTURING PROCESSES AND IT GRADE PRODUCED

SR. NO	MANUFACTURING PROCESSES	IT GRADE PRODUCED	SR. NO	MANUFACTURING PROCESSES	IT GRADE PRODUCED
1	Lapping	4 and 5	6	Reaming	6 to 10
2	Honing	4 and 5	7	Turning	7 to 13
3	Cylindrical Grinding	5 to 7	8	Boring	8 to 13
4	Surface Grinding	5 to 8	9	Milling	9 to 13
5	Broaching	5 to 8	10	drilling	10 to 13

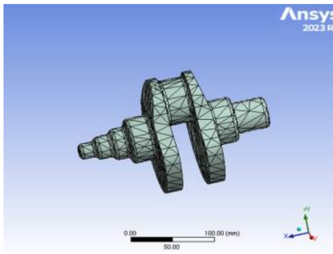
3. ANALYSIS AND COMPARASION OF FORGED STEEL AND CAST IRON CRANKSHAFT (FEM)

. This chapter discusses geometry generation used for finite element analysis, describes the accuracy of the model and explains the simplifications that were made to obtain an efficient FE model. Mesh generation and its convergence are discussed. Using proper boundary conditions and type of loading are important since they strongly affect the results of the finite element analysis. Identifying appropriate boundary conditions and loading situation are also discussed. Finite element models of two components were analysed; the cast iron crankshaft and the forged steel crankshaft. Since these two crankshafts are from similar engines, the same boundary conditions and loading were used for both. This facilitates proper comparison of this component made from two different manufacturing processes. The results of finite element analysis from these two crankshafts are discussed in this chapter. Above mentioned FE models were used for dynamic analysis considering the boundary conditions according to the mounting of the crankshafts in the engine.

In order to evaluate the FEA results, a component test was conducted with strain

gages. FEA boundary conditions were changed according to the test setup. Strain gages were mounted on the forged steel crankshaft and results from FE analysis and experimental data were compared in order to show the accuracy of the FE model. Finally, results from dynamic FE analysis, which consist of stress history at different locations, were used as the input to the optimization process discussed in Chapter 5.

TETRAHEDRON MEASHING



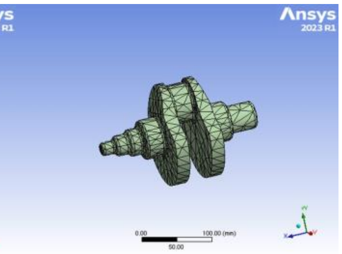
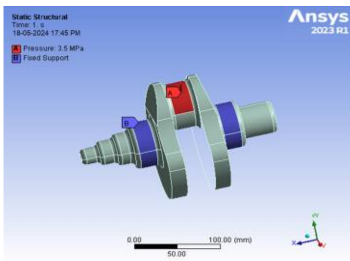


Fig. FORGED STEEL *Fig. CAST IRON*

LOAD AND BOUNDRY CONDITION



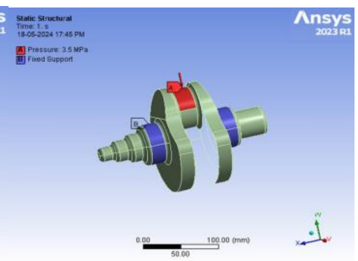
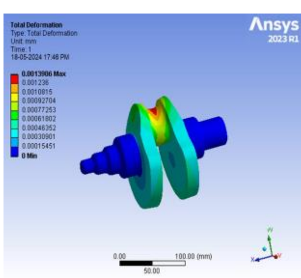


Fig. FORGED STEEL *Fig. CAST IRON*

DEFORMATION



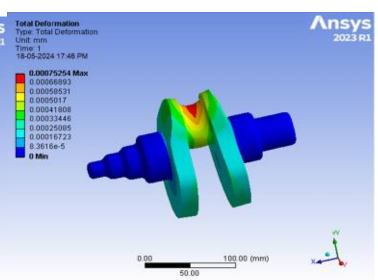


Fig. FORGED STEEL *Fig. CAST IRON*

5.SIMULATION

A simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with; usually, this is impossible, too expensive or impractical to do in the system it represents. The operation of the model can be studied, and hence, properties concerning the behavior of the actual system or its subsystem can be inferred. In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time.

Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance. For instance, simulation can be used to answer questions like: What is the best design for a new telecommunications network? What are the associated resource requirements? How will a telecommunication network perform when the traffic load increases by 50%? How will a new routing algorithm affect its performance? Which network protocol optimizes network performance? What will be the impact of a link failure?

The steps involved in developing a simulation model, designing a simulation experiment, and performing simulation analysis are:

Step 1. Identify the problem.
Step 2. Formulate the problem.
Step 3. Collect and process real system data.
Step 4. Formulate and develop a model.
Step 5. Validate the model.
Step 6. Document model for future use.
Step 7. Select appropriate experimental design.
Step 8. Establish experimental conditions for runs.
Step 9. Perform simulation runs.
Step 10. Interpret and present results.

4. CONCLUSION:

Based on the results and analysis, the following conclusions can be made:In this project, the crankshaft model was initially created using Pro/ENGINEER software, after which the model was imported into ANSYS for further analysis.The analysis results, which include the stresses and deflections experienced by the crankshaft under static load, are detailed in the table. The strain observed in the forged steel crankshaft is lower than that of the cast iron crankshaft. Given that the forged steel crankshaft successfully withstands the static load, it is deemed structurally sound. Consequently, the forged steel crankshaft is suitable for the forging process, and mass production can lead to cost reductions

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