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Static Structural Finite Element Analysis Of Crankshaft Using Structural Steel And Aluminium Alloy: ANSYS Workbench

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Abstract: The crankshaft is one of the essential components of an internal combustion engine, in which the reciprocating motion of the piston is converted into rotary motion through the connecting rod. The current work consists of two types of analysis. In the first part of the study, strength analysis on a single cylinder four stroke diesel engine crankshafts. The best combination of parameters like Von Mises stress, deformation and weight reduction for crankshaft is carried out. In the second part of the study, two materials namely structural steel and aluminium alloy are selected for analysis and comparison of these two materials properties such as Von-Mises stress, strain and total deformation were determined and results were compared. Crankshaft needs to be checked carefully to ensure that the design is fully optimized for that optimization of the crankshaft is studied and changing the geometry and shape of the existing crankshaft. In the present work CAD model of the crankshaft has been designed in the AUTOCAD 2016 software and then finite element analysis (FEA) has been carried out by using ANSYS 15.0 workbench software. Static analysis of crankshaft is done to find the maximum stress and deformation point.

***Index Terms* - Structural Steel, Crankshaft, ANSYS, Finite Element Analysis.**

I. INTRODUCTION

Crankshafts play a vital role as control and operational components in internal combustion engines (IC engine) because crankshafts can modify the reciprocating motion of the IC engine pistons into rotational motion [2]. These are designed to heavy loads into the engine train. They can be lead to bend the system in torsional stress cycle [4]. The main bearing components are base by the engine block [2]. The connecting rods are joint to the off-centred main bearing. A crank throw designed by two full main bearings of joints and one crankpin, which is shown in Figure 1.

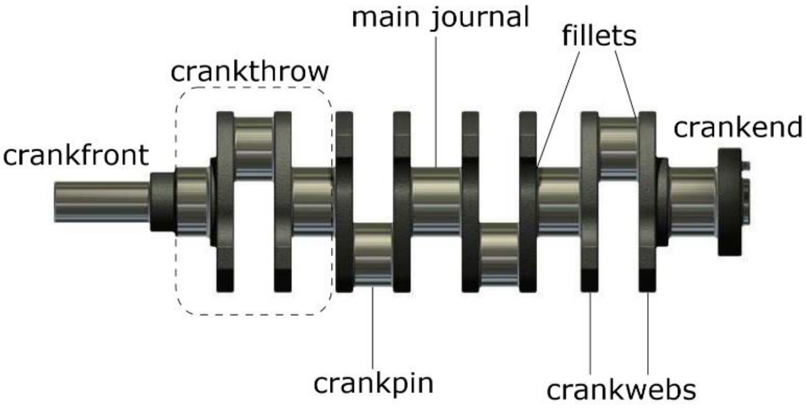


Figure 1.1: Schematic drawing of a four-cylinder crankshaft

The crankshaft is vital, and a considerable apparatus part is having complex and superior geometry in the block of the engine, which transforms the reciprocating displacement of the IC piston to a rotating cyclic motion with a proper four-link system mechanism [4]. The paper needs to depict the better efficient fuel economical with lighter weight in high efficiency in output [4]. This study is based on a single cylinder with a four-stroke engine cycle [2]. Two different designed crankshafts from the same engines were considered in this proposed research. The finite element analysis (FEA) was used in four various static steps for each designed crankshaft. Stresses from the mechanical breakdown describe dynamic loading to the designed crankshafts. In the past study was done on the forged steel designed crankshaft to specify the weight optimization and the cost of manufacture [12].

II. CRANKSHAFT DESIGN FAILURE

The frequency and inter-area tie-line power should be near to the scheduled values for large scale power systems. The crankshaft is mainly designed as a component of an engine which converts the reciprocating motion of the piston into rotational motion [8]. The central rotating part of an engine is crankshaft, which is mainly designed from ductile iron [5]. The crankshaft consists of many features like crankpin journal, throw, bearing journals, counterweights, crank gear, and the power take-off (PTO). The rotating pivot point of the crankpin journal usually attaches the connecting rod to the crankshaft [19].

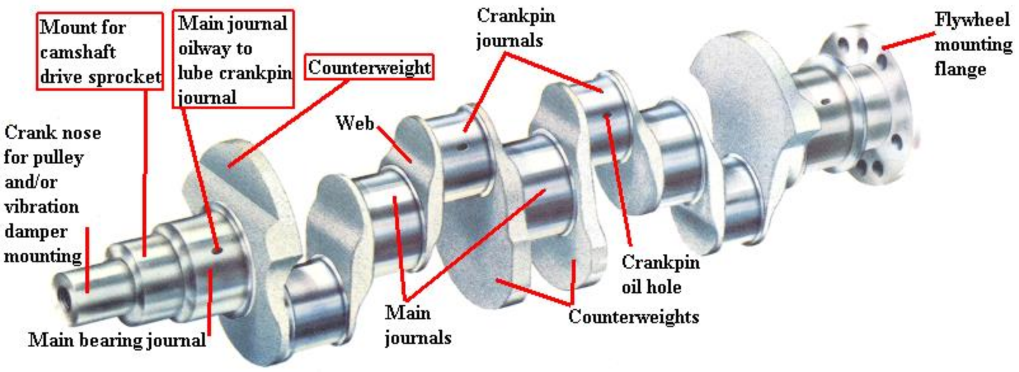


Figure 1.2: Crankshaft Design

Figure 1.8: Failure of Crankshaft

The three major sources like operating sources, mechanical sources and repairing sources are mainly responsible for the failure in the engine [35]. Fatigue is the most common failure in the crankshaft mainly occurs at fillet areas due to the bending loads triggered by the combustion effect. A twisting or torsional crack should be expected at pin surface, radius or oil whole surface of the crankshaft. Significant stress experiences at crankshaft fillet in its service life due to its geometry and engine system [37].

III. FINITE ELEMENT ANALYSIS

The finite element method is one of the most common numerical method used to find out the solution related to engineering and mathematical physics problems. The solution analysis mainly includes issues like stress analysis, electromagnetic and heat transfer. The finite element analysis can be used as a physical problem solver method in the field of loadings, complicated geometrics and material properties. In this numerical analysis method, the domain is segregated into smaller units or elements called finite elements. Hand calculation is the only method used in finite element analysis and structural development analysis.

Material Properties:

Table 5.1 Material properties of structural steel

Material Selected	Structural Steel
Density (kg/m^3)	7850
Young’s Modulus (pa)	2e11
Yield strength (pa)	2.5e8
Poisson Ratio	0.3
Behaviour	Isotropic

Table 5.2 Material properties of Aluminum Alloy

Material Selected	Aluminium Alloy
Density (kg/m^3)	2770
Young’s Modulus(pa)	7.11e10
Yield strength (pa)	2.8e8
Poisson Ratio	0.33
Behaviour	Isotropic

IV. STATIC STRUCTURAL ANALYSIS

A static analysis includes static equivalent loads like steady inertia loads and time-varying loads used for the calculation of loading effects by ignoring the inertia and damping effects of the loads. The high stress leads to crack formation, which is the leading cause for the failure of the crankshaft in a single cylinder engine. The stress value can be minimized by doing modification in the design with reduced weight, which leads to the lighter crankshaft. This stress minimization leads to the reduction of inertial and centrifugal forces.

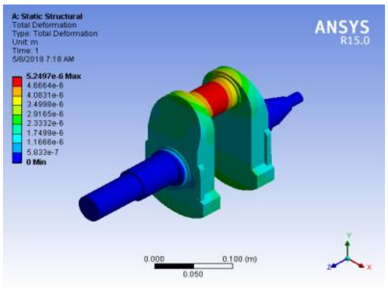
Comparison of static structural FEA results for un-optimized crank by varying material:

Sl.No	**Parameters**	**Existing Values**	**FEA results for Structural Steel**	**FEA results for Aluminium Alloy**
1	**Total deformation (m)**	8.75e-3	5.24e-6	1.48e-5
2	**Directional deformation (m)**	4.78e-3	2.66e-7	8.45e-7
3	**Von-misses strain (m/m)**	2.56e-4	2.6e-4	7.54e-4
4	**Von-misses stress(pa)**	6.55e7	5.338e7	5.35e7
5	**Shear stress (pa)**	1.863e	1.707e7	1.68e7

6	**Safety factor**	4.7496	1.6148	1.5456

V. ANSYS VALIDATION RESULTS

1.5.1 Static structural FEA results of varying Parameters for Structural Steel:



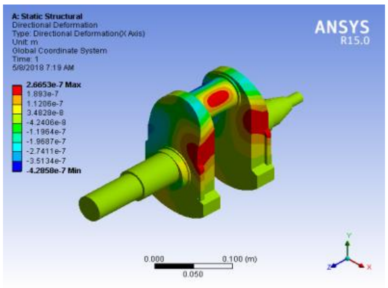
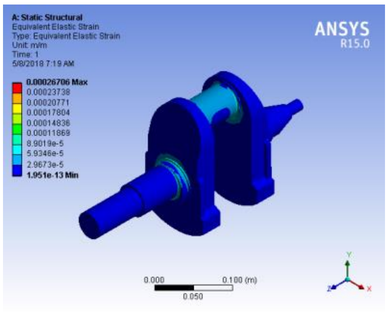


Figure 6.5: total deformation of crank

Figure 6.6: Directional Deformation



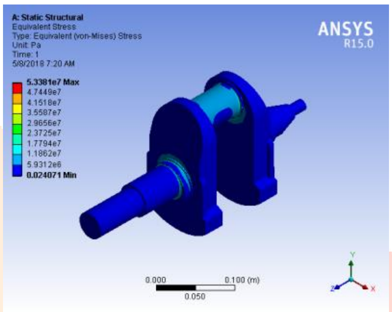
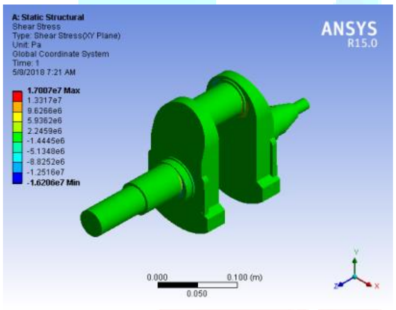


Figure 6.7: Equivalent Strain

Figure 6.8: Von-Misses Stress



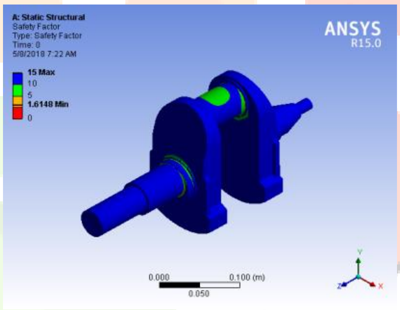
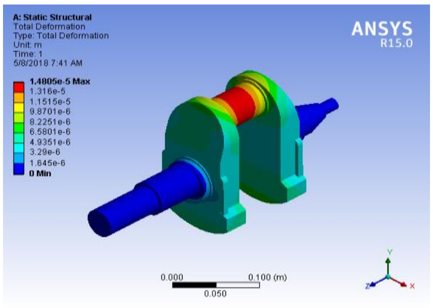


Figure 6.9: Shear Stress

Figure 6.10: Safety Factor

1.5.2 Static structural FEA results of varying Parameters for Aluminium Alloy:



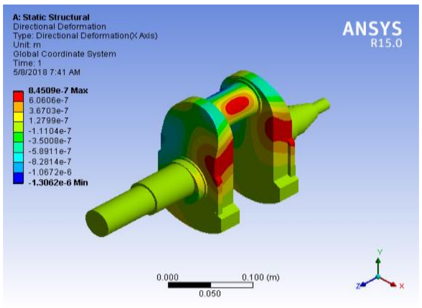


Figure 6.11: Total Deformation

Figure 6.12: Directional Deformation

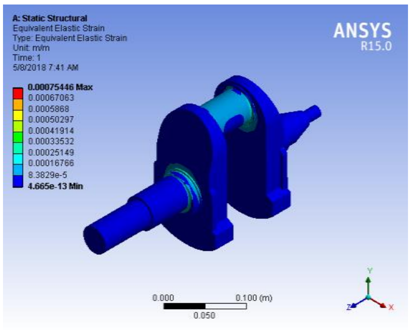


Figure 6.13: Elastic strain

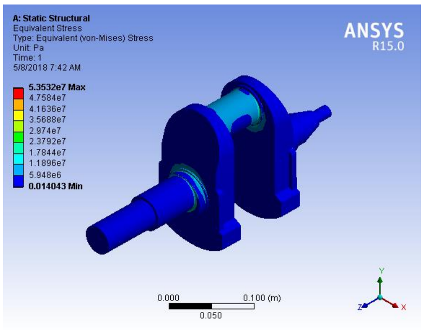


Figure 6.14: Von-Misses Stress

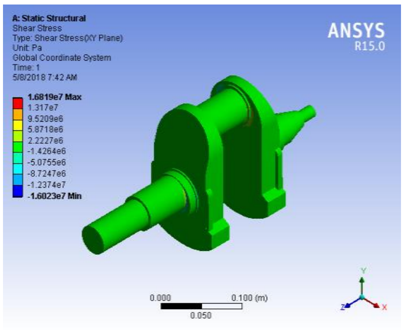


Figure 6.15: Shear Stress

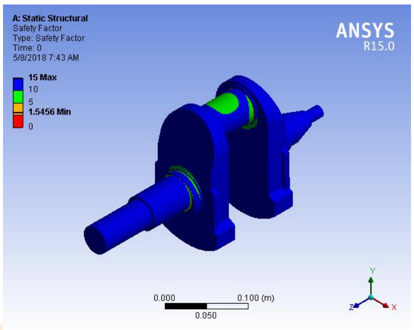


Figure 6.16: Factor of Safety

VI. CONCLUSION

The results obtained from the Finite element analysis (FEA) shows that the critical location of the crankshaft geometry discovered in the fillet region. The crankshaft failure may instigate at the crank pin and therefore in future scope, the fatigue phenomena regarded as the main reason for failure. The failure of the crankshaft can be studied by vibrational calculation. Thus from the above study, it has been concluded that the finite element method is the essential tool for designing and optimization of the crankshaft.

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