Finite Element Analysis of Camshaft Performance in Internal Combustion Engines

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Abstract: **The camshaft is a crucial element in internal combustion engines, working alongside the crankshaft to convert its rotation into the necessary reciprocating motion for opening and closing engine valves. This action controls the fuel flow into the combustion chamber. Material selection and design significantly affect the camshaft's efficiency. Enhancing the engine's effectiveness involves a meticulous choice of camshaft materials, which can be analyzed through finite element analysis. This study aims to assess various commonly used materials in camshaft production. The primary focus is on evaluating the equivalent stress, strain, and total deformation across different materials across different materials. The appropriate material for the camshaft is identified after comparison.**

Keywords: Finite Element Analysis, Camshaft, IC engines, ANSYS

1. INTRODUCTION

The internal combustion engine constitutes a pivotal arrangement within automobiles, comprising various integral components, among which the camshaft holds significance. The camshaft consists of cylindrical rods featuring pear-shaped cams and is intricately linked to several other rotating elements within the engine. Engine efficiency and cost can be improved by proper arrangement of the camshafts [1].

The camshaft's functions in an engine are to control valve timings, the entry of the fuel and air mixture into the engine, and the exhaust. This control significantly impacts the engine's performance [2]. Every camshaft cylinder has lobes designed for both intake and exhaust valves. The amount to which these cam lobes open, when they move, and how quickly they do so are all determined by their design. The present investigation involved an examination of an inline-four engine. This engine employs eight-lobed cams to regulate valve movement through the conversion of rotary energy into reciprocating movement [3]. The camshaft's role is pivotal in determining the engine system's performance, significantly impacting the overall output of vehicle [4].

Camshafts commonly operate at varying speeds corresponding to the engine's speed changes. Modern vehicles have double overhead camshafts that are used to operate the exhaust valves and the intake valves. Engines typically are designed for single (inline 4 or 6-cylinder engines) and dual (V6 and V8) overhead camshafts. The flow of intake and exhaust gases has been improved by enabling valves through dual camshafts in the engine. Thus, this phenomenon of flow contributes to an overall boost in the engine's power.

The study encompassed stress analysis and failure analysis of the camshaft, highlighting the crucial role of this component within an engine. It aimed to establish correlations by investigating particular materials suitable for camshaft manufacturing, employing finite element analysis (FEA) to analyse results obtained from this study [5]. The camshaft was subjected to design, remodelling, and Finite Element Method (FEM) analysis to enhance its durability and suitability for various loading conditions [6]. Utilizing Ansys software, the study computed the deformation of the camshaft when subjected to diverse loading conditions for various materials [7].

Camshaft assemblies made from various materials have been analysed using various meshing settings in FEA in this research. SolidWorks and ANSYS were employed to generate camshaft drawings and perform the finite element analysis [8]. Regular engine servicing plays a crucial role in extending the lifespan of the camshaft. This is particularly important because over time, other rotating components fall loose, they might come into contact with the camshaft, potentially leading to breakage or cracking [9]. Valves opening and closing are controlled through the camshaft and its associated components. The pressure is applied on the valves or intermediary mechanisms by cam lobes through rotation, causing them to open. The cylinder's intake and exhaust valves have been controlled by converting the engine's rotary motion into the necessary reciprocating motion using the camshaft at an instant.

The development of a 3-D model of a camshaft used in a multi-cylinder engine is done using modelling software. This model is then imported into ANSYS software.

Three distinct materials: aluminum alloy 360, forged steel, and cast iron—are used to provide loads to the camshaft once element characteristics, meshing, and limitations have been assigned. The objective of material optimization is to investigate the possibility of replacing traditional materials with new composite alloys. Then, the displacement and stress caused by the applied loads are determined by performing static analysis. Subsequently, modal analysis is performed to ascertain frequency values considering the camshaft's geometric shape and material properties [10].

FEA methodologies, encompassing modal analysis and static structural analysis, were utilized for the computation of the fatigue characteristics of the camshaft. This project involved establishing a number of characteristics, including the safety factor, peak stress, total deformation, and natural frequency [11].

This study compares various materials for a camshaft based on their equivalent stress, strain, and total deformation. The manuscript is structured as: Section 2 elucidates the examination of the camshaft, Section 3 shows the findings and deliberations, and Section 4 presents the conclusions.

2. THE ANALYSIS OF THE CAMSHAFT

This section illustrates the performance of static structural analysis for various materials using ANSYS software.

For analysis of the camshaft, engine specifications and camshaft specifications are presented in tables 1 and 2, respectively.

Table 1: Engine specifications

Power	27.6KW at 5000 RPM
Torque	59Nm at 2500 RPM
Cylinder volume	796CC
Stroke	72mm
Bore	66.5mm
C.R (compression ratio)	9:2
Inlet valve opens	10° BTDC
Firing order	1-3-2

Table 2: Camshaft specifications.

Cam width	18mm
Camshaft diameter	28.6mm
Journal diameter	50mm
Cam height	41.3mm
Total lift of cam	7.65mm

Steps are used in static structural analysis as shown in Figure 1.

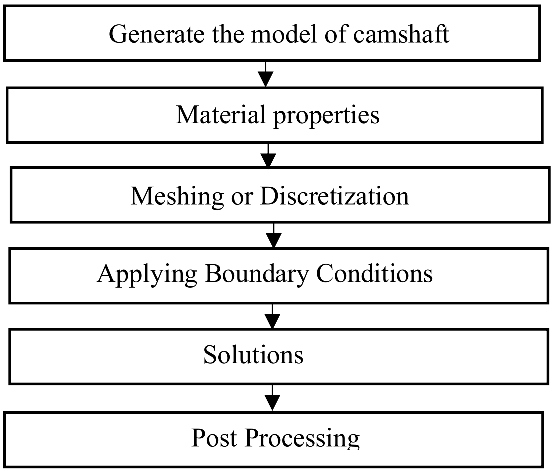
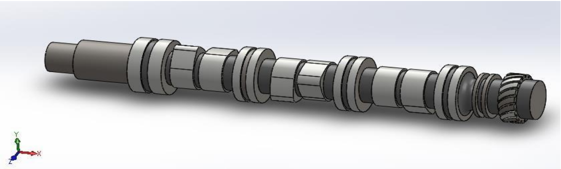


Figure 1: Steps in static structural analysis



A solid work is used to generate 3D model of camshaft as shown in the Figure 2.

Figure 2: A CAD model of camshaft

The different material properties are shown in the Table 3.

Table 3: Material properties

Material	Density (kg/m^3)	Poisson's ratio	Young modulus (Pa)
EN8D	7800	0.3	1.90 × 10^11
EN24	7840	0.295	2.07 × 10^11
SS (structural steel)	7850	0.3	2.10 × 10^11
Cast iron	7200	0.28	1.1 × 10^11

Meshing or discretization of camshaft is shown in the Figure 3.

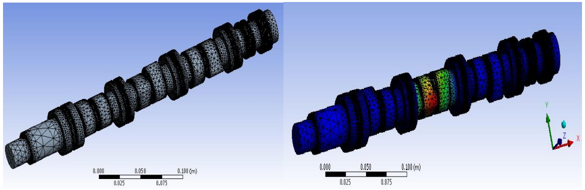


Figure 3: Meshing or discretization of cam shaft

Boundary conditions are applied for analysis of the camshaft as shown in the Figure 4

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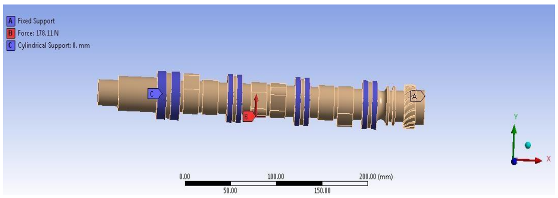

Figure 4: Boundary conditions

3. RESULTS AND DISCUSSIONS

This section describes the analysis of the equivalent stress, strain, and total deformation for various materials using ANSYS as shown in Table 4, aiming to compare and determine the best-suited material. In our focus on enhancing engine performance, the maximum stress values across the three materials appeared identical at 0.98 MPa, while cast iron showed a slightly offset value of 0.01 MPa. Evaluating materials solely based on stress proves challenging. Therefore, considering another parameter, strain becomes crucial. In the case of EN8D and EN24 materials, both exhibit the lowest strain values, accompanied by minimal deformation. However, despite EN24 having lower strain values, its significantly higher weight compared to EN8D may negatively impact the engine's overall performance. As such, a slight compromise regarding deformation could be considered to achieve optimal engine performance without compromising excessively on weight.

Table 4. Comparison of various materials

Materials	Equivalent stress (MPa)	Equivalent strain	Total deformation (mm)
EN8D	0 .980	5.02×10^{-6}	1.49×10^{-4}
EN24	0.98	4.04×10^{-6}	1.19×10^{-4}
SS (structural steel)	0.98	5.27×10^{-6}	1.66×10^{-4}
Cast iron	0.97	9.64×10^{-6}	2.80×10^{-4}

The results of the equivalent stress, strain, and total deformation of cam shaft from ANSYS are shown in the Figures 5, 6 and 7, respectively.

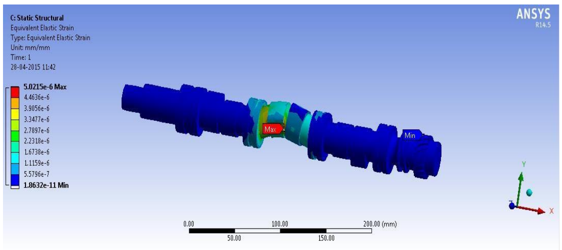

Figure 5: The equivalent stress of the cam shaft.

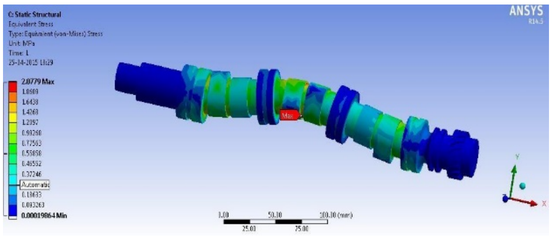

Figure 6: The equivalent strain of the cam shaft.

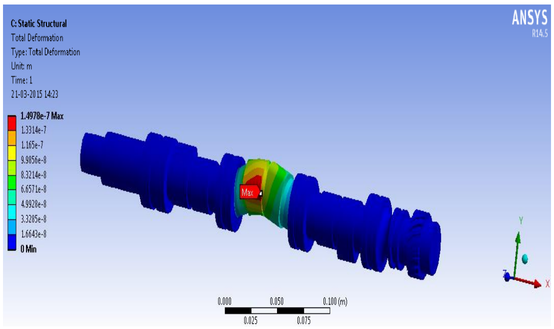

Figure 7: Total deformation of the cam shaft

4. CONCLUSIONS

An examination of different materials typically employed in camshaft production has been conducted via finite element analysis in this investigation. The primary focus is on evaluating the equivalent stress, strain, and total deformation across different materials across different materials. It is observed that EN8D is the most suitable material to achieve optimal engine performance without compromising excessively on weight.

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