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Research

Analysis of Variable Crankshaft Geometries for a 6 Cylinder IC Engine

QI KUN-PENG[1]*,HASSAN ALI[1],CHEN CHAO-FAN[1]

[1]College of Locomotive and Rolling stock Engineering, Dalian Jiaotong University, Dalian, (116028)

Abstract:Using FEM analysis software, the purpose of this research project was to examine several crankshaft shapes applicable to an internal combustion engine with six cylinders. The primary objectives of the study were to determine the maximum loading that could be placed on the piston and the crankshaft rotations that correspond to that loading, as well as to investigate the stress distribution and factor of safety for various crankshaft diameters. The model was created with the help of the software CATIA, and it was examined with the help of the software ANSYS FEM analysis. According to the findings, the gas pressure that was present during the power stroke was the factor that had the most significant impact on the crankshaft. This led to a downward bending of the crankpin in the area that included the lubrication holes. According to the findings, the geometry with a crankshaft diameter of 50 millimeters, crankpin diameter of 42 millimeters, and crank web thickness of 13.5 millimeters had the lowest stress values and the highest factor of safety of 1.92 when subjected to heavy loading circumstances.

Keywords: **:** Crankshaft, IC Engine, Ansys Simulation, Co-simulation, FEM Analysis

*Corresponding Author

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Introduction

The majority of vehicles, aircraft, and industrial equipment rely on power generated by internal combustion engines. A lot of weight is put on the design and material qualities of the parts that make up an internal combustion engine when determining how well those parts work. The crankshaft is a critical part of an internal combustion engine because it changes linear motion into rotation [1].

During engine operation, the crankshaft experiences a wide range of complex loading circumstances, such as combustion pressure, inertial forces, and thermal expansion. Because of this, crankshafts need to be constructed with robustness in mind, so that they can take a beating and keep on ticking. The geometry, material, and production method must all be carefully considered while designing a crankshaft [2].

Using finite element analysis (FEA) software to simulate the loading conditions and stress distribution in the crankshaft is one method for optimizing the design of a crankshaft. Because of its ability to simulate real-world stresses and deformations, FEA is invaluable for understanding how complicated parts will behave under different loads. Crankshaft design can benefit from FEA in many ways, such as the identification of stress concentration

locations, the mapping of stress distribution across the crankshaft, and the identification of stress-induced failure mechanisms[3].
The purpose of this research was to use finite element method (FEM) analytical software to examine the effects of different crankshaft shapes on a 6-cylinder internal combustion engine. Analysis of stress distribution and safety factor for various crankshaft diameters was performed, along with the determination of maximum piston loading and related crankshaft rotations. CATIA was used for the model's creation and ANSYS for the FEM analysis. To make sure the design would hold up under a variety of settings, the pressure loads were determined by considering 6 extreme working scenarios.
Picking the right crankshaft geometry is essential for the engine's efficiency and longevity. Crankshaft design needs to strike a good balance between a number of competing goals, such as durability, rigidity, weight, and price. Material qualities can greatly affect the engine's durability and performance, so careful consideration must be given when making a material choice.
The findings of this research have important implications for the development of internal combustion engine crankshafts. The results of this research can be applied to the development of more efficient and long-lasting crankshafts for internal combustion engines. As the need for more fuel-efficient and dependable internal combustion engines grows, the use of FEM analysis software as a tool for optimizing crankshaft design is likely to become more and more prevalent [4].
In conclusion, the results of this study highlight the value of employing FEM analysis tools when examining crankshafts with a range of geometries. Results from this research can be utilized to enhance the design of crankshafts for internal combustion engines, better guaranteeing their efficiency, longevity, and affordability. Inspiring additional research in this field and aiding in the continuous development of more efficient and dependable internal combustion engines is a primary goal of this study.

Research Methodology

The purpose of this research was to use finite element method (FEM) analysis software to compare the stress distribution and factor of safety between various variable crankshaft geometry for a 6-cylinder internal combustion (IC) engine. Analysis of stress distribution and safety factor for various crankshaft diameters was performed, alongwith the determination of maximum piston loading and related crankshaft rotations.
In order to begin this investigation, a 3D model of the crankshaft was created in CATIA. The prototype had a crankshaft cast from QT-500 nodular cast iron, a material frequently used for crankshafts due to its great strength and longevity. The model consisted of six cylinders. The maximum stresses and stress areas were examined with the help of ANSYS FEM analysis software, and the results were found to be consistent across all three shaft diameters (50mm, 55mm, and 60mm). The crankshaft was also modeled in three dimensions using CATIA software [5]. The crankshaft's geometry was figured out with the help of the model, which was then fed into a finite element analysis.

Fig1: CAD Model

QT-500 Nodular Cast Iron was offered as the material for the crankshaft. It is mostly made of iron and contains about 3.5% carbon along with other metals [6]. You can easily machine it because to its moderate strength and durability. It is not easilycorroded and can withstand extreme temperatures.

Table 1: QT: 500 Material properties

Material Code	QT500
Yield Strength （MPa）	320
Density （kg/m^3）	7600
Poisson's ratio	0.293
Young's modulus （MPa）	1.62E+05

Six extreme operating situations were used to determine the loading conditions, including maximum combustion pressure, maximum inertial forces, and maximum thermal expansion [6]. Maximum crankshaft rotations at which piston loading is greatest were found after pressure loads on the crankshaft were established.

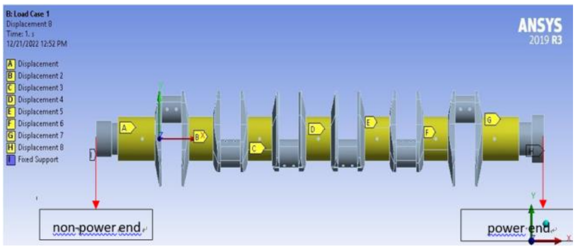


Fig2: Boundary conditions

The load is assumed to be uniformly distributed along the length of the crankpin, as shown in Figure 3, to facilitate modelloading in the software and simplify the analysis. Connecting rod load can be calculated with this simplified formula [7].

$$q_{x\theta} = \frac{9Q_c}{16LR}\cos\frac{3\theta}{2}$$

Where Qc is the total force applying on the crankshaft's connecting rod journal, R is the crankshaft's connecting rod's radius (19mm), Length of the bearing along the crankshaft axis L = 32 mm.

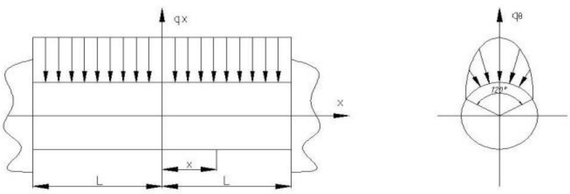


Fig3: Simplified loading distribution over crankpin

Maximum gas forces for each cylinder are listed in table 2 below, based on the ignition sequence stated above for the 6-cylinder diesel engine. The gas force in each cylinder is greatest at 7.5 degrees after top dead center (TDC), hence this is where we measure the results. From cylinder 1 to 6, the crankshaft must rotate at crucial angles of 7.5 degrees, 487.5 degrees, 247.5 degrees, 607.5 degrees, 155 degrees, and 367.5 degrees.

Table 2: Forces on crankshaft in critical working conditions

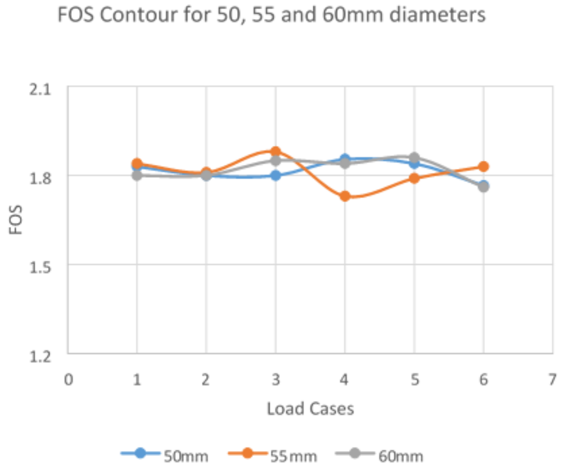
crank angle (⁰)	7.5	487.5	247.5	607.5	1550	367.5
Force on the first journal (N)	607509	-59563	-51626	-56500	-86342	-78816
Force on the second journal (N)	-51626	607509	-59563	-86342	-78816	-56500
Force on the third journal (N)	-59563	-51626	607509	-78816	-56500	-86342
Force on the fourth journal (N)	-86342	-56500	-78816	607509	-51626	-59563
Force on the fifth journal (N)	-56500	-78816	-86342	-59563	607509	-51626
Force on the sixth journal (N)	-78816	-86342	-56500	-51626	-59563	607509

The stress distribution and factor of safety for each variable geometry were examined once the FEM study was completed. Plotting the FOS findings for all the different geometries allowed us to pick the optimal layout.
For each crankshaft geometry, the stress distribution and safety factor were analyzed using ANSYS FEM analysis software. The finite element method is employed by the program to model the stress distribution and loading conditions of the crankshaft. Crankshaft design considerations, such as stress concentration regions, stress distribution over the component, and failuremechanisms, can be informed by the FEM analysis' findings.

Results

According to the findings, there is a load with a high pressure exerted on the crank pin in the area around the lubrication holes [9]. The gas pressure that is present during the power stroke has the most significant impact on the loaded part, which results in a bending of the crankpin in a downward direction. In addition to this kind of distortion, there is also an axial deformation that the thrust bearings help to support [8]. For the purpose of selecting the optimal design, the outcomes of the FOS analysis for all of the variable geometries were plotted against one another. The geometry with a 50 mm crankshaft diameter, 42 mm crankpin diameter, and 13.5 mm crank web thickness was found to have the lowest stress values and the highest FOS of any of the shaft geometries after being subjected to extreme loading conditions and put through all of the available shaft geometry tests.

Fig4: A study of the FOS between crankshafts with varying diameters



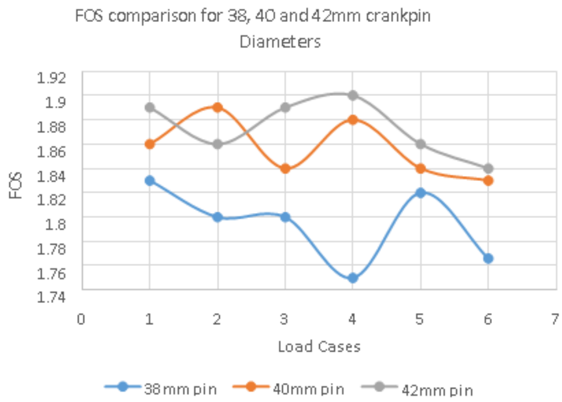


Fig5: FOS comparison for variable crankpin diameters

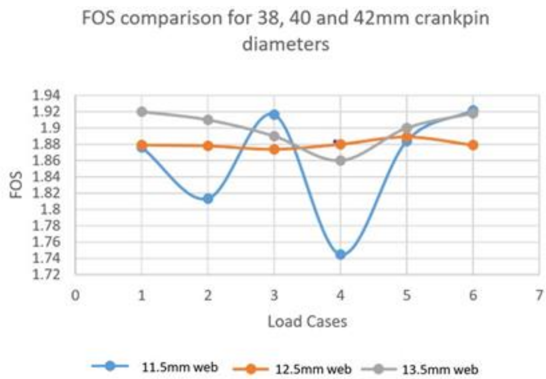


Fig6: FOS comparison for variable web thicknesses

Discussion

According to the findings of this research, the variable crankshaft shape that was chosen is the one that is best suited for theengine when it is subjected to intense loading circumstances. It was discovered that the maximum stress values were much lower than the material's yield strength; this finding provides evidence that the design can be put into operation without risk [10]. The fact that the highest factor of safety for the chosen geometry is 1.92 gives rise to the hypothesis that it possesses sufficient strength to sustain the loads that have been applied. According to the findings, gas pressure during the power stroke has the most significant impact on the loaded member, which leads to a downward bending of the crankpin in the region of the lubricating holes [11]. This finding suggests that gas pressure is the most important factor in this relationship.

Conclusion

In conclusion, this study demonstrated the importance of analyzing variable crankshaft geometries using FEM analysis software. The results indicated that the geometry with a 50mm crankshaft diameter, 42mm crankpin diameter, and 13.5mm crank web thickness had the minimum stress values and maximum factor of safety under extreme loading conditions. The findings of this study can be used to improve the design of crankshafts for internal.

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