Design and Numerical evaluation of crankshaft of diesel engine for total deformation and strain

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Abstract. The crankshaft is an engine component that converts the linear (reciprocating) motion of the piston into rotary motion. Features of a crankshaft include the crankpin journal, throw, bearing journals, counterweights, crank gear, and a power take-off (PTO). Crankshafts are machined through a sequence of automated operations that remove material using lathes and milling machines. Other off-the-line processes include inspection, test, and repair. High-count cylinder engines involve higher inertias, overlapping combustion events and torsional vibrations of the flexible crankshaft which strongly complicate the diagnostics. The equivalent inertias and stiffnesses of the system were calculated from drawings, modelling of the crankshaft with a CAD (computer-aided design) software and finite element method. Crankshaft is internal cylinder pressure (or torque) estimation is an important engine parameter with significant implications for diagnostic and control applications in internal combustion (IC) engines. Many speed-based diagnostics methods employ models of the engine dynamics. In a dynamic model of a small four-cylinder diesel engine with the assumption of a rigid crankshaft is employed to estimate individual cylinder power production.

1. Introduction
The crankshaft is an engine component that converts the linear (reciprocating) motion of the piston into rotary motion. Features of a crankshaft include the crankpin journal, throw, bearing journals, counterweights, crank gear, and a power take-off (PTO). [1] Crankshafts are machined through a sequence of automated operations that remove material using lathes and milling machines. Other off-the-line processes include inspection, test, and repair. [2] High-count cylinder engines involve higher inertias, overlapping combustion events and torsional vibrations of the flexible crankshaft which strongly complicate the diagnostics. The equivalent inertias and stiffnesses of the system were calculated from drawings, modelling of the crankshaft with a CAD (computer-aided design) software and finite element method. [3] Crankshaft is internal cylinder pressure (or torque) estimation is an important engine parameter with significant implications for diagnostic and control applications in internal combustion (IC) engines. Many speed-based diagnostics methods employ models of the engine dynamics. In dynamic model of a small four-cylinder diesel engine with the assumption of a rigid crankshaft is employed to estimate individual cylinder power production. In the signature analysis of crankshaft speed fluctuations is utilised for detection of misfiring cylinders. In dynamic engine models with flexible crankshafts are used to construct high-gain non-linear observers for indicated pressure or torque. The estimated indicated pressure or torque can be directly used for cylinder health diagnostics as well as controls. The additional advantage due to the presented characteristics of the crankshaft oscillations are improved capability in handling engine-to-engine variations and decreased memory/storage requirements. An inherent advantage that is not investigated in this paper is the potential for performing diagnostics on faults that are not related to cylinder health. [4] Crankshafts of motor vehicles generally run at high rotation, between 700 and 8000 rpm, depending on the engine type. Diesel engines of vehicles usually run below 4000 rpm. However at this rotation range, significant imbalances can arise from the engine operation. The common root causes of crankshaft failures are due to fatigue phenomenon. Most of damages take place on the main journals and crankpins close to the web fillets and lubricating holes where are present high stress levels being therefore critical zones. Poor design, deficient assembly or inadequate engine operation, shaft misalignments, wrong geometry of fillets on crankpin-webs and main journals, inadequate lubricating holes geometry, as well as abnormal vibrations and resonant frequencies generally are the most probable causes of damage in engines.
2. Design of crankshaft

The crankshaft is designed in solid works software with version 2016. The dimension of the crankshaft is shown in figure 1 and figure 2. The crankshaft is designed for three cylinder engine. Figure 3 shows the solid model of the final crankshaft design.

Figure 1: side view of Crankshaft

Figure 2: top view of Crankshaft

Figure 3: top view of Crankshaft
3. **Ansys Analysis**

The model is analysed through Ansys analysis software with version Ansys 14. For the analysis we used structural material properties because most of the either cast iron or structural steel is used as a fabrication material. Figure 4 shows the meshed model of the crankshaft.

![Figure 4: mesh model of Crankshaft](image)

For analysis Bounding Box with dimensions (XxYxZ) 0.543 m x 0.135 m x 0.16 m is considered and mass of the component taken for analysis is 16.371 kg and the volume of the component is 2.0855e-003 m³. The crankshaft model is meshed with 37953 nodes and 21740 elements. The mechanical properties of structural steel which is considered for the total deformation and strain analysis are Density with value 7850 kg m⁻³, Coefficient of Thermal Expansion with value 1.2e-005 C⁻¹, Specific Heat with value 434 J kg⁻¹ C⁻¹, Thermal Conductivity with value 60.5 W m⁻¹ C⁻¹, Resistivity with value 1.7e-007 ohm m, Compressive Yield Strength with value 2.5e+008 pa, Tensile Yield Strength with value 2.5e+008 pa, Tensile Ultimate Strength with value 4.6e+008 pa, Young's Modulus with value 2.0e+011 pa, Poisson's Ratio with value 0.3, Bulk Modulus with value 1.6667e+011 Pa and Shear Modulus with value 7.6923e+010 Pa.

![Figure 5: Equivalent strain analysis of Crankshaft](image)

From the Figure 5 which shows Equivalent strain analysis of Crankshaft, the maximum Equivalent Elastic Strain is 2.4973e-005 m/m and the Minimum Equivalent Elastic Strain is 3.1335e-008 m/m. From the Figure 6 which shows maximum principal elastic strain of Crankshaft, the maximum principal elastic strain is 1.9219e-005 m/m and the Minimum principal elastic strain is 6.0353e-009 m/m.
Figure 6: maximum principal elastic strain analysis of Crankshaft

From the Figure 7 which shows Total Deformation of Crankshaft, the maximum Total Deformation is 37.539 m and the Minimum Total Deformation is 5.1243e-002m.

Figure 7: Total deformation analysis of Crankshaft

4. Conclusion
The crankshaft is designed in solid works software with version 2016. The dimension of the crankshaft is shown in figure 1 and figure 2. The crankshaft is designed for three cylinder engine. Figure 3 shows the solid model of the final crankshaft design. The model is analysed through Ansys analysis software with version Ansys 14. For the analysis we used structural material properties because most of the either cast iron or structural steel is used as a fabrication material. Figure 4 shows the meshed model of the crankshaft. maximum Equivalent Elastic Strain is 2.4973e-005 m/m and the Minimum Equivalent Elastic Strain is 3.1335e-008 m/m. maximum principal elastic strain is 1.9219e-005 m/m and the Minimum principal elastic strain is 6.0353e-009 m/m. maximum Total Deformation is 37.539 m and the Minimum Total Deformation is 5.1243e-002m.

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