FEA of a Lab-Scale IC Engine Connecting Rod

Daramy Vandi Von Kallon
Department of Mechanical Engineering Technology
University of Johannesburg
Johannesburg, South Africa
dkallon@uj.ac.za

Bai Kamara
Department of Mechanical Engineering Technology
University of Johannesburg
Johannesburg, South Africa.
baikamara78@gmail.com

Abstract

Torsional vibration is a special form of vibrations that usually describes torsional deformation motion of rotating shafts that transmit torque to other components. The crankshaft of an Internal Combustion (IC) engine is connected to the engine cylinder piston via the connecting rods. Connecting rods are highly dynamically loaded components used for thrust transmission in combustion engines. This paper investigates the effect of torsional vibration of the IC Engine connecting rod. Simulations were carried out using Autodesk inventor using the Raleigh model.

Keywords: Torsional vibration, crankshaft, IC engine, connecting rod and simulation.

I. Introduction

Rotating shafts may experience different kinds of deformations resulting to induced vibrations from radial loads, axial loads, and torque loads. Torsional vibration arising from torque loads may induce torsional deformation motion of rotating shafts in an internal combustion (IC) engine. The causes of torsional vibration in connecting rods are in themselves caused by the crankshaft torsional vibrations arising from elastic deformations of the crankshaft body and the periodic effect of torque on the crankshaft. Hence the IC Engine Connecting Rod torsional vibration can be considered an elastic torsional deformation caused by the periodic excitation torques on the crankshaft during engine operations. Several problems associated with torsional vibration includes crankshaft failure, flywheel bolt failure, bearing bush pitting, increasing knock noises of timing gear, decreasing engine power and sometimes damage to the connecting rod. Optimization in the automotive industry is an essential tool as this reduces components production cost and time with a stronger and lighter connecting rod being produced. The connecting rod design component and weight would significantly influence the performance of the car and the manufacturer credibility. A change in the structural design of the connecting rod and material used would also significantly impact on the engine's weigh and performance (Shaari *et* al, 2010).

II. Literature on the ~~Subject~~ Connecting Rod Design

The crankshaft is one of the most important components of internal combustion engine. The crankshaft transfers the loads from the connecting rods to the gearbox via the flywheel. In diesel engines the large torsional moment at low rotational speed causes high stress as observed in assembly of crankshaft, piston and connecting rods. The high stress amplitude common with bad design or production defects can cause decrease in the fatigue life of engine components such as connecting rods and crankshafts. The results of failure analysis of the piston engines crankshafts were described in several research. An interesting fracture study of boxer engine crankshaft was described by (Kailas at al, 2016). According the authors the catastrophic failure of the crankshaft observed was caused by poor design of the steel support shells and bedplate bridges. The failure investigations of the crankshaft of diesel engines were performed by (Mirehei et al, 2008). A crankshaft contains two or more centrally located coaxial cylindrical ("main") journals and one or more offset cylindrical crankpin ("rod") journals. The two-plane V8 crankshaft pictured in Figure 1 has five main journals and four rod journals, each spaced 90° from its neighbours. The crankshaft main journals rotate in a set of supporting bearings ("main bearings"), causing the offset rod journals to rotate in a circular path around the main journal centres, the diameter of which is twice the offset of the rod journals. The diameter of that path is the engine "stroke": the distance the piston moves up and down in its cylinder. The big ends of the connecting rods ("conrods") contain bearings ("rod bearings") which ride on the (offset) rod journals. Torsional vibration (TV) to some degrees is experienced because of the reciprocating nature from reciprocating machinery. Limited research work on the relationship between torsional vibration and block or linear vibrations have been carried out. Generally, torsional vibration effect in recent piston slap studies has been ignored. During an engine operation, the crankshaft rotates with a torsional vibration, the piston inertial forces, connecting rod, and crankshaft all fluctuate, this will affect the dynamics of the piston on both the reciprocating and the secondary orientations. It has been observed by many researchers that both the combustion and piston slap noise are because of the overlapped frequency and time domain. According to More and Sadaphale (2016) the composite connecting rods manufactured from aluminium has more weight with low stiffness as compared to the aluminium alloy. A massive connecting rod increases the engine gross weight and this will consume more fuel. Recent studies showed that the aluminium alloy material ALFASIC composed of a similar mechanical property to aluminium connecting rod but has less weight and a higher stiffness. With the application of ALFASIC connecting rod in the automotive sector, this would result in the engine gross weight reduction and an increased durability with a better improvement in the engine traction parameter and performance. Shenoy and Fatemi (2005) carried out an optimization study on forged steel connecting rod with a consideration for weight improvement and a reduced production cost. The optimization was performed under a cyclic load comprising two extreme loads, a dynamic tensile load and static comprehensive load. The weight reduction was achieved using an iterative procedure. Mirehei et al. (2008) carried out a study estimating the lifespan and the fatigue on the connecting rod of a universal tractor (U650) with the application of ANSYS software, Figure 1. The stress rate, the stress concentration and the hotspots experienced by the connecting rod was investigated. It was agreed that the components life prediction can be consequently obtained.

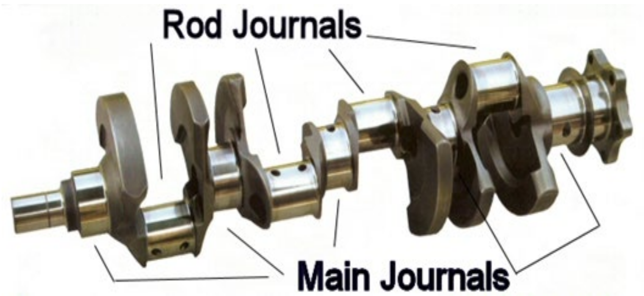

Figure 1. Crankshaft (Mirehei et al, 2008).

III. IC Engine Connecting Rod Design

The connecting rod is the most essential component of the IC engine. It serves as a link between the piston and the crankshaft which converts the piston reciprocating motion to the crankshaft rotary motion. The IC Engine connecting rods are dynamically loaded components used for force transmission. The efficient design and use of these rods can therefore prolong the life of an IC engine. The modelling of the connecting rod via simulations runs back to early in 1983 by notable designers such as Webster and his team. The need for modelling of IC engine connecting rod is because they impact production time, the strength, weight, and cost of production. The design excellence and the weight of the connecting rod significantly influence vehicle performance, Figure 2. A connecting rod is subjected to millions of cyclic loadings and hence the durability in designing the component is of paramount importance. In the designing process it would be necessary to investigate finite element modelling techniques, optimization techniques and new techniques to reduce the weight at the same time increase the strength of the connecting rod itself. Shenoy (2004) explored the weight and cost reduction opportunities for a production forged steel connecting rod. The connecting rod in an automobile engine is a critical component that produces high volume. It links the rotating crankshaft with the reciprocating piston, trust from the piston is directly transmitted to the crankshaft through the connecting rod. Connecting rods are designed and manufactured using various available materials, in most cases cast iron is used for connecting rods manufacture within the automobile industry, considering the density of the cast iron, this can lead to an increase mass making the connecting rod more heavier which can negatively impact on the engine performance efficiency. This challenge in the automotive sector requires an alternatively a less dense material for the connecting rod design. Recently, the use of aluminium for the manufacture of connecting rods has replaced the use of carbon steel as the aluminium is less dense compared to the carbon stell. More recent studies have shown that aluminium alloy (ALFASIC) is less dense than aluminium and it is more suitable for use in the manufacture of connecting rods. Aluminium alloy (ALFASIC) has replaced aluminium for connecting rods manufacture in the automotive industry.

Figure 2: Connection rod (Mirehei et al, 2008).

3.1 Design Model

Figure 3 is the design of connecting rod using an Autodesk inventor.

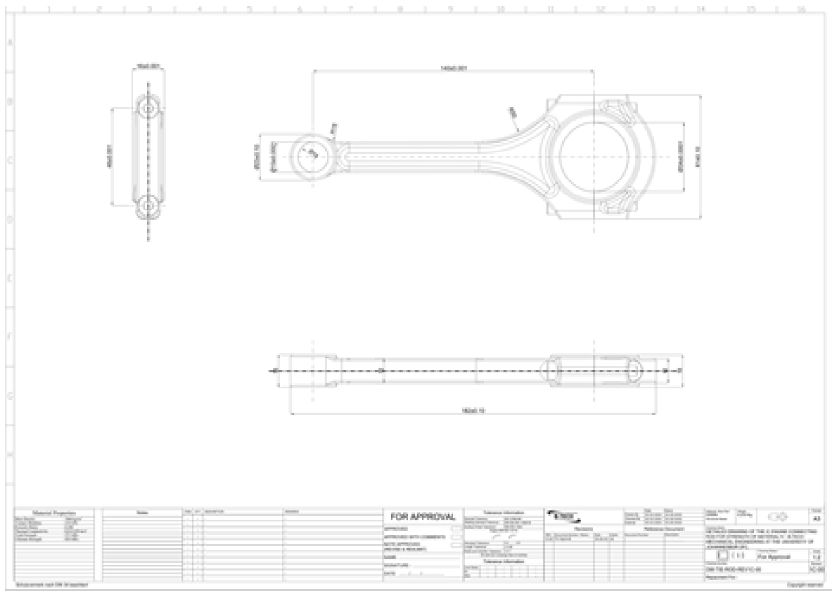

Figure 3: Design of connection rod.

During the operations of an internal Combustion (IC) Engine, the engine components will experience multiple vibrations. One main component that would experience more vibrations is the connecting rod that connects the crankshaft to the cylinder piston. The mechanical design of these components can seriously impact the performance of the internal combustion (IC) engine. Table 1 shows the dimensions used for the design of the connecting rod and the load for testing. These values are taken to be similar to those found on Race Engine \magazine and compared to lab scale connecting rods at the Department of Mechanical and Industrial Engineering Technology at the University of Johannesburg. The detailed model drawing is shown in Figure 3. From the load in Table 1 the expected stresses in the rod was determined.

Table 1: Connecting rod dimensions and loading for detailed design

Sr. no.	Parameters	Value
1.	Connecting rod length	140 mm
2.	Big end outer diameter	61 mm
3.	Big end inner diameter	34 mm
4.	Small end outer diameter	23 mm
5.	Small end inner diameter	14 mm
6.	Force	50 N

Stress on the rod is given as:

$$\text{Stress } (\sigma) = \frac{Force\ (F)}{Area\ (A)} \quad (1)$$

Stress at the big end of the rod is:

$$\sigma_{BigEnd} = \frac{50}{\frac{\pi(0.061^2 - 0.034^2)}{4}}$$

$$\sigma_{BigEnd} = 0.0694Mpa$$

Stress at the small end of the rod

$$\sigma_{SmallEnd} = \frac{50}{\frac{\pi(0.023^2 - 0.014^2)}{4}}$$

$$\sigma_{SmallEnd} = 0.1912MPa$$

IV. Simulation and Testing of Model

Table 2: Parts Properties

Part Name	Piston Rod Eye. Par
Mass	0.0233kg
Volume	29810.112mm^3
Weight	2278.685mN

Table 3: Material Properties

Material Name	Steel – Structural: 1.0545 S355N
Mass Density	7800.000 kgm^{-3}
Young's Modulus	210000.003MPa
Poisson's Ratio	0.280
Thermal expansion Coefficient	0.0000/C
Thermal Conductivity	0.014KW/m-C
Yield Strength	275.000MPa
Ultimate Strength	450.000MPa

Table 4: Load set and Constrain Information

Load Set Name	Load 1
Load Type	Force
Number of load Element(s)	1
Load Value	500000.00 mN
Load set Name	Load 2
Load Type	Force
Number of load Element(s)	1
Load Value	50000.00 mN
Number of constrain faces	7

Table 5: Displacement results

Type	Extent	Value	X	Y	Z
Resultant Displacement	Minimum	0.00e – 000	-7.20mm	142.11mm	-8.00mm
	Maximum	1.20e – 0.05mm	0.00mm	16.98mm	8.00mm

Table 1 shows the part properties for the piston rod, with the materials chosen to be light but strong. Structural steel is chosen for this application, Table 3, with good strength and thermal properties. The model was prepared for simulation , Table 4, from which displacements values along each axis was determined, Table 5.

V. Discussion

The calculation result shows that the small area experiences more stress than the bigger area subjected to the same force. The small area of the connecting rod experiences a stress of 0.1912 MPa, whereas the bigger area is 0.0694 MPa. The two materials selected for simulation testing using auto desk inventor were structural steel S335N and S235N. The FEA conducted using these materials shows that they are more suitable for fabrication of the Crankshaft and Connecting Rod of an IC engine since they can withstand torsional vibrations.

VI. Conclusions

From the auto Desk inventor simulation results obtain it can be concluded that the use of structural steel in the design and manufacturing of crankshaft and connecting rod of an IC engine would endure the torsional vibration effect in the IC engine.

References

Sun et al (2018). Research on torsional vibration reduction of crankshaft in off-road diesel engine by simulation and experiment © *JVE INTERNATIONAL LTD. JOURNAL OF VIBROENGINEERING*. VOL. 20, ISSUE 1. ISSN 1392-8716 345 2785.

Witeka et al (2017). Failure investigation of the crankshaft of diesel engine. *2nd International Conference on Structural Integrity, ICSI 2017,* Funchal, Madeira, Portugal.

Jack Kane. 'RACE ENGINE TECHNOLOGY MAGAZINE' http://www.epieng.com/piston_engine_technology/crankshaft_design_issues.htm,

J. Yao, Y. Xiang, S. Qian, S. Wang, and S. Wu, "Noise source identification of diesel engine based on variational mode decomposition and robust independent component analysis," Applied Acoustics, vol. 116, pp. 184–194, 2017.

C. Servière, J.-L. Lacoume, and M. El Badaoui, "Separation of combustion noise and piston-slap in diesel engine-part II: separation of combustion noise and piston-slap using blind source separation methods," Mechanical Systems and Signal Processing, vol. 19, no. 6, pp. 1218–1229, 2005.

Kailas S. More, Devendra B. Sadaphale. May 2016. Design and Analysis of Connecting Rod for high-speed Application in I.C Engine. *International Journal of Engineering Research & Technology (IJERT)*. ISSN: 2278-0181. Vol. 5 Issue 05

M.S. Shaari, M.M. Rahman, M.M. Noor, K. Kadirgama and A.K. Amirruddin. National Conference in Mechanical Engineering Research and Postgraduate Studies (2nd NCMER 2010) 3-4 December 2010, Faculty of Mechanical Engineering, UMP Pekan, Kuantan, Pahang, Malaysia; pp. 155-166. ISBN: 978-967-0120-04-1.

Shenoy, P.S and Fatemi, A. 2005. Connecting rod optimization for weight and cost reduction, *SAE Technical Paper,* Paper No. 2005-01-0987.

Mirehei, A., Zadeh, H.M., Jafari, A. and Omid. M. 2008. Fatigue analysis of connecting rod of universal tractor through finite element method (ANSYS). *Journal of Agricultural Technology*. 4(2): pp 21-27.

Biographies

Dr Daramy Vandi Von Kallon is a Sierra Leonean holder of a PhD degree obtained from the University of Cape Town (UCT) in 2013. He holds a year-long experience as a Postdoctoral researcher at UCT. At the start of 2014 Dr Kallon was formally employed by the Centre for Minerals Research (CMR) at UCT as a Scientific Officer. In May 2014 Dr Kallon transferred to the University of Johannesburg as a full-time Lecturer and later a Senior Lecturer in the Department of Mechanical and Industrial Engineering Technology (DMIET). Dr Kallon has more than twelve (12) years of experience in research and six (6) years of teaching at University level, with industry-based collaborations. He is widely published, has supervised from Masters to Postdoctoral and has graduated seven (7) Masters Candidates. Dr. Kallon's primary research areas are Acoustics Technologies, Mathematical Analysis and Optimization, Vibration Analysis, Water Research and Engineering Education.

Bai Kamara is a Sierra leonean and holds an undergraduate degree (Bachelor of Science with Honours in Physics) and a Master of Philosophy (MPhil) in Energy Studies from Fourah Bay College (University of Sierra Leone). He is currently a PhD candidate at the department of Mechanical and Industrial Engineering Technology (MIET) Faculty of Engineering and the Built Environment at the University of Johannesburg, South Africa. He is presently working on a research on the development of a Supervisory Control and Data Acquisition (SCADA) program of fouling load for acoustic cleaning of boilers. His research interest has been renewable and non-renewable energy generation, efficient energy utilization for domestic and industrial consumption and energy reform processes.