

A Report on the Forces Acting on a Connecting Rod and the Effects of Engine Modifications

Jakub Kot

Student Number: 1701919

BSc Motorsport Engineering – Year 1

University of Wales Trinity Saint David

Contents

Abstract	2
Introduction	3
Research	4
Methodology	6
Analysis	7
Conclusion	10
References	11

Abstract

The connecting rods of an engine are subject to large compressive and tensile forces when the engine is running and are a critical part. This report was written to find out what these forces are and how they can be affected by certain design parameters such as the crank radius, connecting rod length, engine speed and mass of the piston assembly. Using Microsoft Excel graphs It was found that modifications to those parameters can have various effects on the forces, and can sometimes have effects on the tensile forces which are different to the effects on the compressive forces.

Introduction

This report will focus on the different forces that a connecting rod of an internal combustion reciprocating piston engine is subject to, and some factors that will affect those forces. The factors that will be considered are the piston mass, the conrod length, the crank radius, and the angular velocity. Using an Excel sheet for calculations and graphs it will be established what effect changing those values has on the forces that the conrod is subjected to. This will be based on the values for a circa 2001 Fiat Seicento 1108cc Fully Integrated Robotised Engine. The aims of this report are to present research findings on the topic, and to establish and analyse the effects that the piston mass, conrod length, crank radius and angular velocity have on the conrod.

Research

The research for this project involved finding information on the Fiat FIRE engine along with the figures required for the calculations, and some information on how engine internal modifications can be used to increase power and how these affect the forces acting on the conrod.

The FIRE series of engines developed and produced by Fiat was a successor to the Over-Head Valve engines used up until the mid-1980's. These engines use the more modern Over-Head Camshaft and used a variety of fuelling systems, starting with carburettors, and then utilising single and multi-point injection. (Unknown Author - Motor-car.net)

The engine used for this report is the 1108cc FIRE series engine, with a 72mm stroke and 70mm bore. The mass of the piston is approximately 600 grams, and the conrod length is 145mm. This engine uses a multi-point injection fuel system and produces 40kW at 5000rpm, and 88Nm of torque. (Unknown Author – motorparks.co.uk)

Some modifications often used to increase power include altering the crank radius, changing the conrod length, increasing the maximum engine rpm, and reducing reciprocating mass.

$$\text{Power} = \text{Torque (T)} \times \text{Angular Velocity } (\omega)$$

$$\text{Torque} = \text{Force} \times \text{Distance}$$

According to those equations, A higher power output can be achieved by increasing the rpm (angular velocity) increasing the combustion force, or increasing the distance (Crank radius).

By increasing the crank radius, as shown in the torque equation, the distance that the combustion force is acting over is greater, resulting in more torque being produced.

Another factor is the conrod length, which can be shortened to reduce the mass of the rod. This would also reduce the cylinder block height, therefore significantly reducing the mass of the engine while lowering its centre of gravity. (Ward, 2012)

A similar effect with regard to the cylinder block height can be achieved by changing the material used for the piston, as the piston height can be reduced by using stronger materials. (Tingwall, 2014)

The conrod length needs to be considered very carefully when designing an engine due to the rod angle compared to the cylinder axis. The higher the rod length to

crank radius ratio, “the greater the angle of the rod when maximum cylinder pressure occurs” (Ward, 2012).

According to Reher (2013) raising the engine speed is equal to increasing its displacement, due to the fact that more air and fuel can be burnt over a certain time.

Reducing the mass of the piston is desirable in order to increase the maximum rpm and improve the engine’s acceleration, or response. (Bolles, 2007)

Methodology

The method used to establish the forces acting on the conrod, and how these forces are affected by modifications will be using Microsoft Excel. A spreadsheet was created to calculate Height of the small end of the conrod, the piston/conrod velocity, the acceleration and the force on the conrod. Excel then creates three graphs based on those figures, plotting the acceleration and force on the same graph.

The aim of this report is to establish how those graphs and figures are affected by modifying the values mentioned earlier.

Analysis

Figure 1 below, shows the graph for acceleration and force produced when the engine's standard figures are entered for the calculations. As the mass is constant, acceleration and force should always be directly proportional to each other. In figure 1, it can be seen that the force increases and plateaus to quite a wide peak. The maximum compressive force that the conrod is subjected to is 4451.242N. As the piston changes direction, the force quickly becomes tensile with a much sharper peak of 7381.464N. The tensile force on the conrod is approximately 1.65x greater than the compressive force.

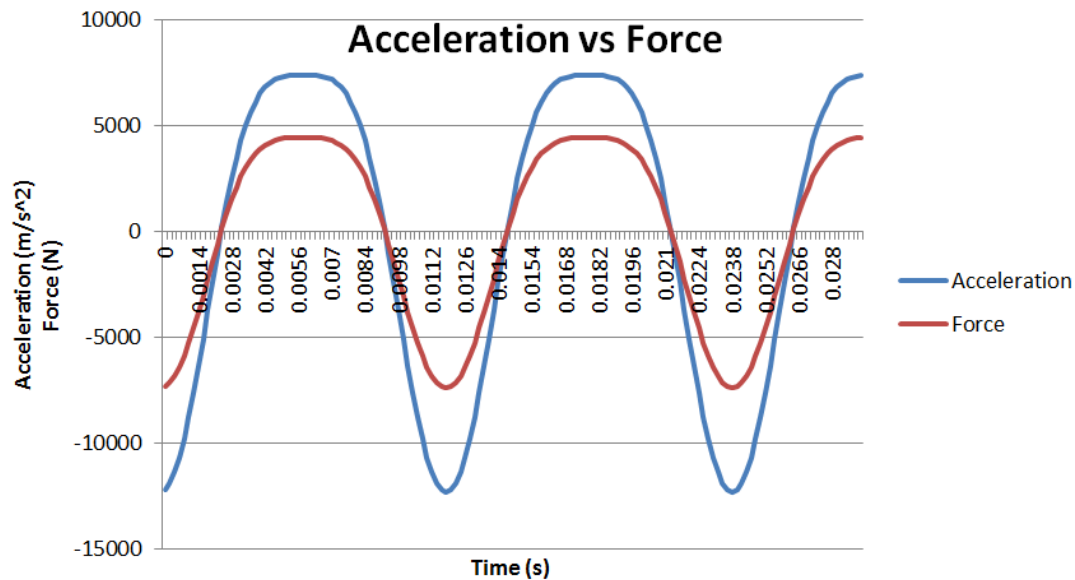


Figure 1: Graph showing acceleration and force

Figure 2 below shows the same information but when the crank radius is increased by 10mm, to 46mm. The tensile force pattern does not change significantly, although the maximum tensile force increases to 9952.15N. The compressive force however, now involves a dip at the wide peak. The maximum compressive force increases slightly to 5306.85N, and dips to 5167.42N before rising to the maximum value again. At this point the piston changes direction and the rod is subjected to tensile force. The maximum tensile to compressive force ratio is approximately 1.9.

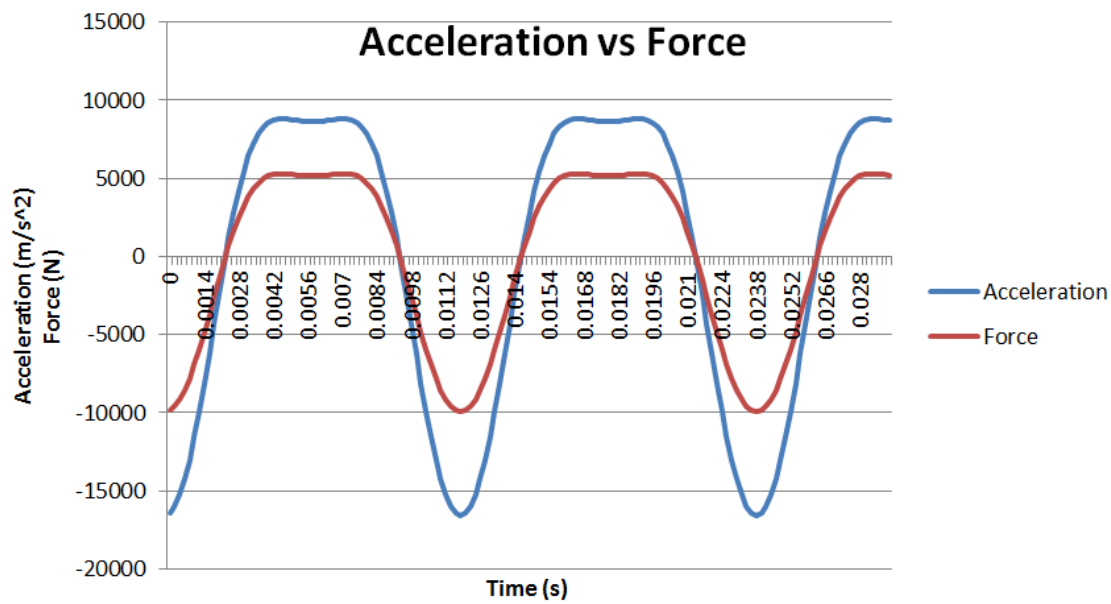


Figure 2: Graph showing acceleration and force for 46mm crank radius

Figure 3 below shows the acceleration and force again, this time with the conrod shortened by 15mm, to 130mm. A similar pattern can be seen as increasing the crank radius, with the peak of the compressive force having a slight dip. This time, the maximum tensile force is 7550.58N, only a small increase from the standard specification figure. The maximum compressive force has actually decreased this time, by a similar amount, to 4289.02N. This means that the maximum tensile to compressive ratio is approximately 1.8. This information suggests that slight changes in the conrod length do not have major effects on the forces alone, but can increase the ratio between maximum tensile and compressive forces.

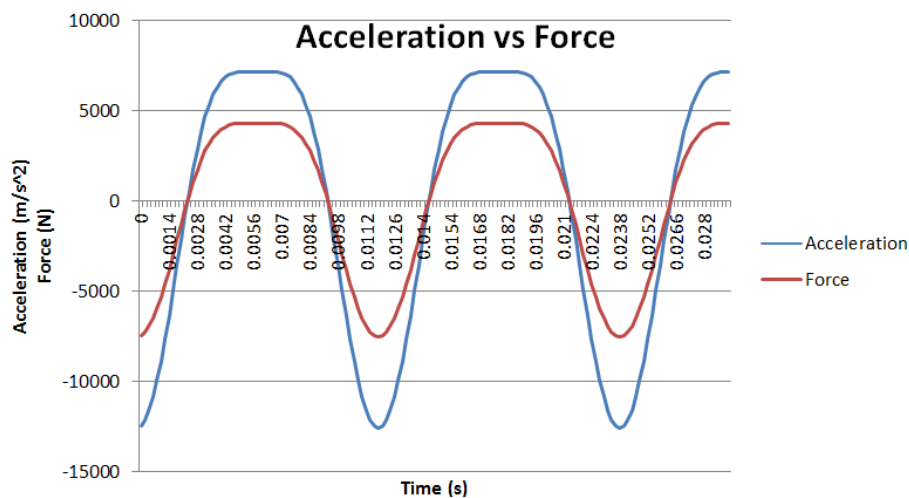


Figure 3: Graph showing acceleration and force for 130mm conrod length

Figure 4 shows the graph when the engine speed is raised to 7000rpm (733rad/s). The force magnitude has increased significantly with the increased angular velocity, for both tensile and compressive forces. The peak of the compressive force now looks more similar to the peak for the standard figures, but slightly narrower. The maximum compressive force is 8723.73N, almost double the standard figures despite only a 40% increase in rpm. The maximum tensile force is 14,442.95N, again almost double the force compared to the standard figures. The ratio between the forces is approximately 1.65, very similar to the standard figures. This would suggest that the increase in force magnitude is very high compared to the increase in rpm, but the ratio between maximum tensile and compressive forces remains very similar.

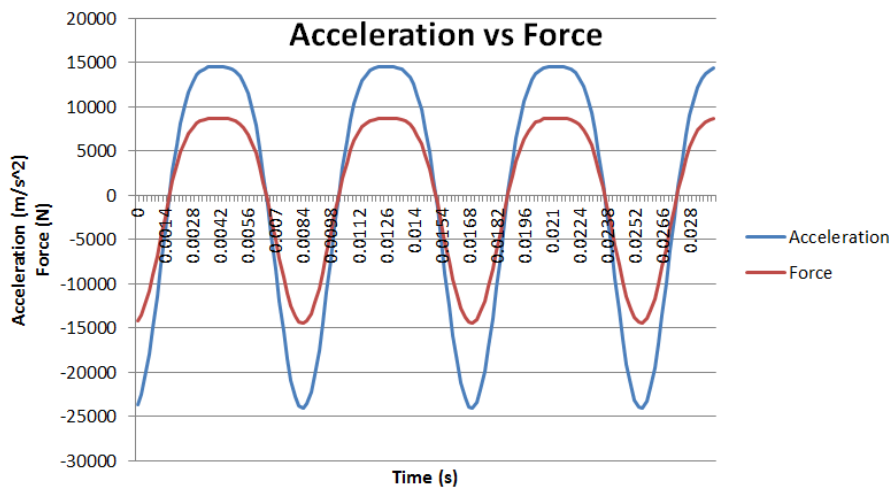


Figure 4: Graph showing acceleration and force for 7000rpm engine speed

Figure 5 shows the acceleration and force with the piston mass reduced by 150g, to 0.45kg. The peak of the compressive force is now wider again, similar to the standard figures. The force magnitude has now been decreased, with a maximum tensile force of 5536.10N and a maximum compressive force of 3338.43N. This gives a ratio of approximately 1.65, again very close to the standard figures.

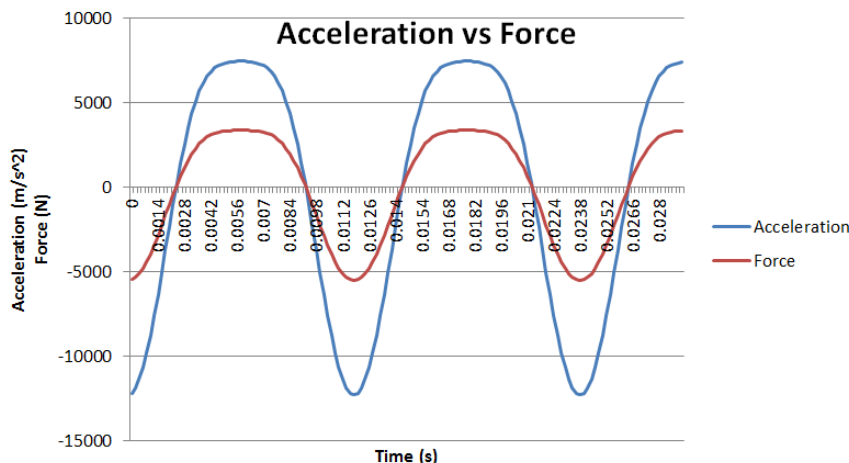


Figure 5: Graph showing acceleration and force for 0.45kg piston mass

Conclusion

To conclude, the forces acting on a connecting rod have been analysed with the use of a Microsoft Excel spreadsheet and graphs. Some engine design parameters were altered to show what effects they would have on the forces that a conrod is subjected to. The analysis of the graphs revealed that:

- the compressive force is at a high magnitude for a much longer time than the tensile force
- the max. tensile force is always greater than the max. compressive force
- the compressive force can decrease slightly before increasing again at its peak when the crank radius is increased or conrod length reduced
- the crank radius has a bigger effect on tensile force than compressive force
- altering the conrod length has opposite effects on the two forces
- raising the rpm has a significant, but very similar impact on both forces
- decreasing the piston mass has a fairly large, and very similar effect on both forces

To confirm and further develop these findings, more calculations should be done with more values entered for each modification. These calculations should also be backed up with physical testing to confirm the accuracy of the graphs and results.

References

Http: 1. 'Fiat F.I.R.E. Engine Explained', [online]. Available: <https://motor-car.net/flat-engines/item/13711-fiat-fire-engine>, [2017, December, 12]

Http: 2. 'Fiat Seicento Technical Data' [online]. Available: [http://www.motorparks.co.uk/technical-data/flat/seicento/1.1i-active-3dr-\(2003-2004\)](http://www.motorparks.co.uk/technical-data/flat/seicento/1.1i-active-3dr-(2003-2004)), [2017, December, 12]

Bolles, B. (2007) 'Racing Pistons – Advanced Piston Technology', [online]. Available: <http://www.hotrod.com/articles/ctrp-0708-advanced-piston-technology/>, [2017, December, 12]

Reher, D. (2013) 'Raising the Redline: Why RPM Matters', [online]. Available: <http://rehermorrison.com/tech-talk-47-raising-the-redline-why-rpm-matters/>, [2017, December, 12]

Tingwall, E. (2013) 'Everything You Ever Wanted To Know About Modern Pistons', [online]. Available: <https://www.caranddriver.com/features/everything-you-ever-wanted-to-know-about-pistons-feature>, [2017, December, 12]

Ward, W. (2012) 'The Effect of Con Rod Length', [online]. Available: <https://www.highpowermedia.com/blog/3332/the-effect-of-con-rod-length>, [2017, December, 12]