

Analytical Methods and Study Skills

Assignment 1

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BSC in Motorsport Engineering

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Introduction

In this assignment, I am going to choose an engine and produce a report on the different forces that the conrod undergoes in that specific engine. To do this, I will need to research different measurements such as the length of the conrod, the mass of the piston and the radius of the crankshaft. I will then have to calculate how different engine speeds affect these forces. As part of this report, I am going to use the spreadsheet provided to input these measurements and use it to produce various graphs to show how these forces are affected.

Research/Literature View

The engine that I am going to be researching is the Ford 1.6 16v Zetec engine, which is more commonly known as the Sigma engine. The Sigma engine is a naturally aspirated internal combustion engine that produced 115bhp, and was designed in 1995 with help from Yamaha, and was the replacement of the much older Ford Kent engine that was first introduced in 1959.

(Ford Sigma Engine - Wikipedia, 2018)

The Conrod Used in the Ford Sigma engine has a length of 137mm. The crankshaft has a diameter of 47mm which means that it has a radius of 23.5mm. The 1.6 sigma engine had a maximum RPM limit of around 8000 RPM; due to the fact these engine had such a high engine speed, it made them a very common choice in kit cars such as caterhams.

On Burton Performance Centre's website, they state that "The engine is all aluminium and designed in partnership with Yamaha. It is 16 valve and conforms to the current trend of interference fit/no-engine keyways, just like the Duratec I4. It also features a plastic inlet manifold, variable valve timing in the 1.7, solid lifters, aluminium girdle support unit incorporating the main bearing caps, steel crank and powdered metal construction con rods. Despite that almost worrying fact, they'll rev to around 8,000rpm. For these reasons, they are being increasingly fitted in kit cars as a replacement for older engines."

(Ford Zetec SE Tuning Guide, 2018)

Methodology

I am going to use the spreadsheet provided and input my data for the Ford Sigma engine. I am then going to change my RPM value several times and analyse the graphs provided.

Analysis

Using the spreadsheet provided, i have inputted the measurements that I researched for the Ford Sigma engine. Firstly, I inputted the RPM as 1500 to imitate that the engine was idling. When I did this, the spreadsheet calculated the maximum tensile stress of the connecting rod which was 308.8281. The measurement for tensile stress in newtons, meaning the maximum tensile stress at 1500 RPM is 308N. Most connecting rods are constructed using steel, the tensile strength of steel is usually around 400 MPa; this means that if the tensile stress of the conrod becomes greater than the tensile strength, it will cause the connecting rod to break. To convert the 308N into megapascals, I would have to first calculate the area of the conrod. This is because 1 pascal is equal to 1 N/m². For each graph, I repeated this for 1500RPM, 3000RPM, 6000RPM and 8000RPM

(Austenknappmancouk, 2018)

The following graph shows how the distance between the top of the conrod and the crankshaft changes as the crankshaft rotates, a swell as the time it takes for a full revolution of the crankshaft.

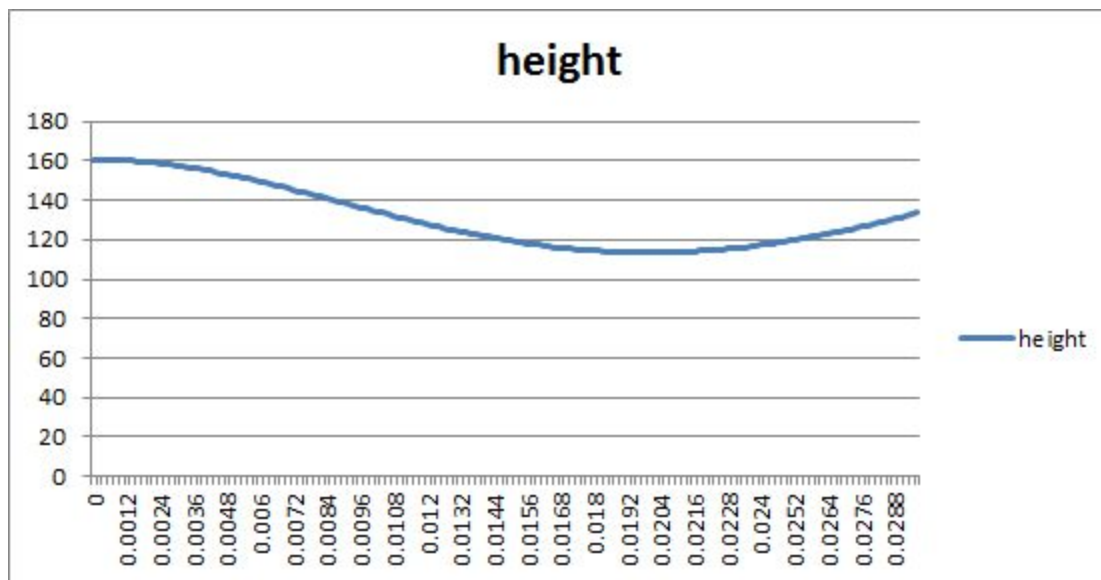


Figure 1

The above graph shows how the distance between the top of the conrod and the crankshaft change as the crankshaft. As you can see, a full revolution takes longer than 0.0288 seconds as a full waveform cannot be seen on the graph. At its peak, the distance is 160.5mm. This figure is calculated from the length of the conrod which is 137mm and the crank radius which is 23.5mm. This gives a total of 160.5mm.

At its lowest point, the distance is 113.5mm; this shows that the distance has changed by 47mm as the piston travels from top dead centre to bottom dead centre.'

Next, I changed the RPM to 3000 to simulate the engine at cruising speed. This changed the maximum tensile stress to 1235.747N.

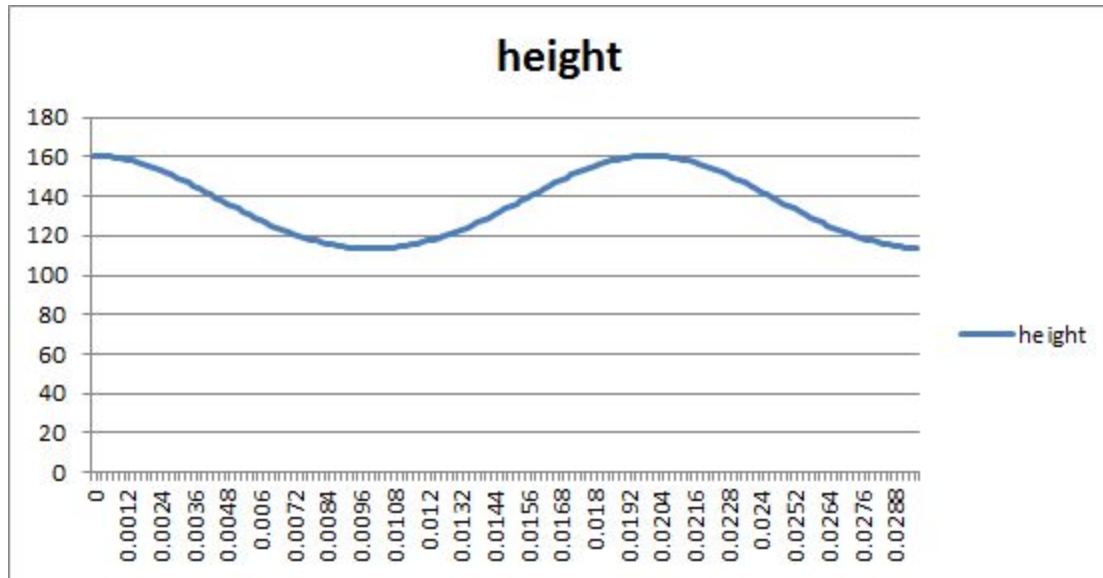


Figure 2.

In figure 2 you can see that once again the distance at its peak is 160.5mm and at its lowest point is 113.5mm. A full revolution of the crankshaft takes 0.02 seconds. Looking at figure 2, you can also see that at its highest and lowest points, the waveform begins to level out. This is due to the piston briefly stopping as it passes top dead centre and bottom dead centre.

Next, I changed the RPM to 6000 RPM to simulate that the vehicle may be accelerating.

Looking below at figure 3, you can see that the waveforms have a higher frequency which means that it is taking less time for a full revolution of the crankshaft. At 6000 RPM it takes 0.01s to complete a full revolution. There is also considerably more tensile stress on the connecting rod, with a total of 4936.037N which is more than triple the value at 3000 RPM.

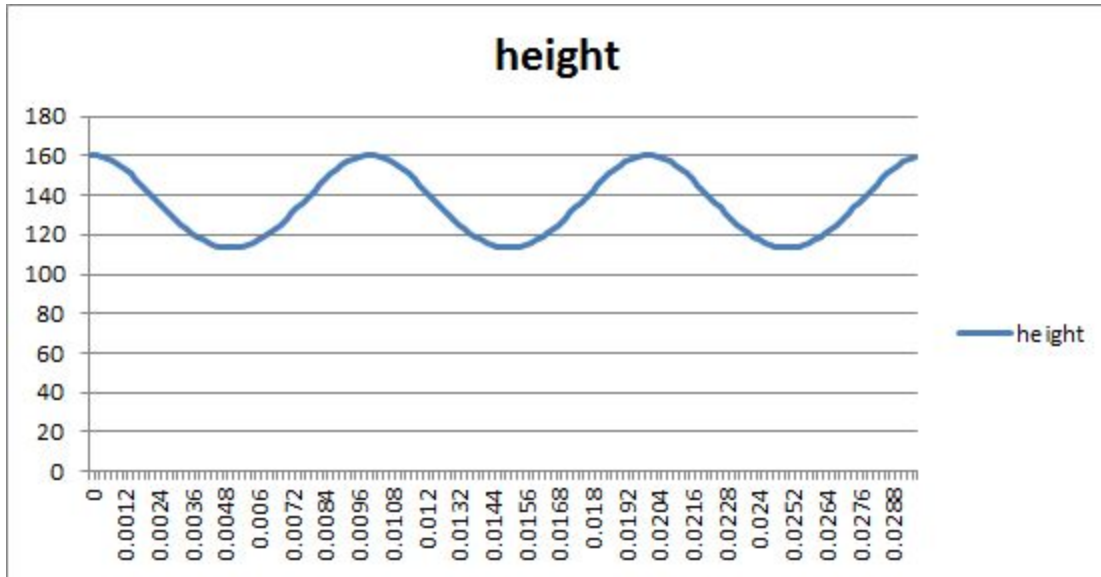


Figure 3.

Finally, I changed the RPM to the maximum RPM limit for the sigma engine of 8000RPM. This gave me a value of 8762.381N for the tensile stress of the connecting rod. Due to this engine being a common choice for kit car enthusiasts, many often choose to use forged engine components. This will give the connecting rod a much higher tensile strength to ensure that it does not break due to the high tensile stress.

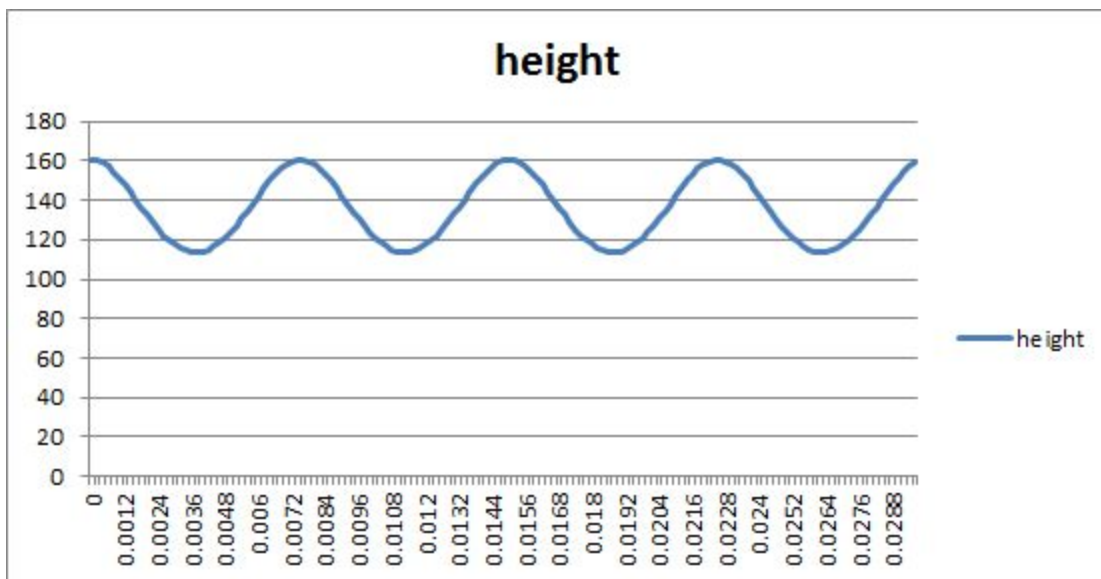


Figure 4.

Figure 4 shows that a full revolution of the crankshaft now only takes 0.0074 seconds

The next set of graphs that I will use are to show the velocity of the connecting rod over a period of time. Once again, I am going to use a graph at 1500 RPM, 3000RPM, 6000 RPM and 8000RPM

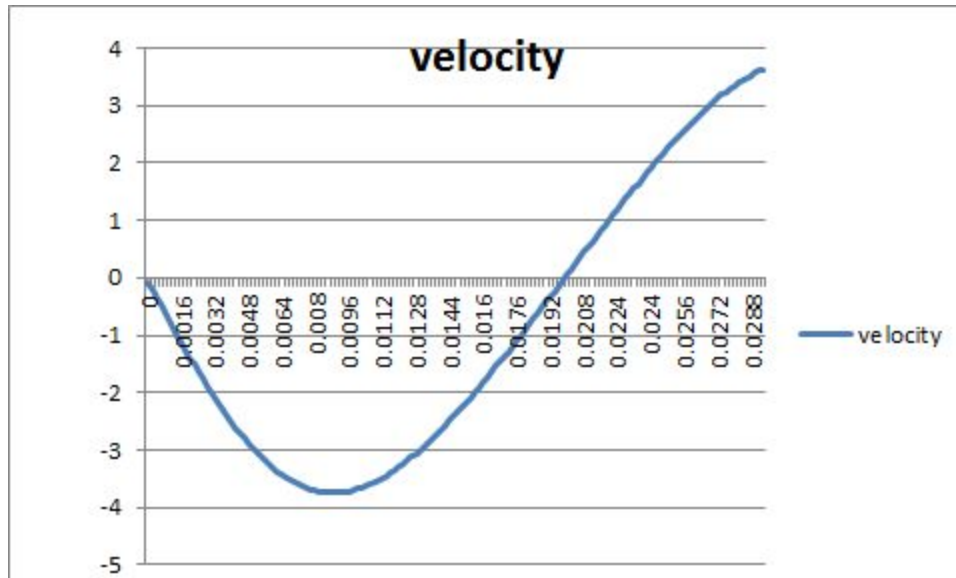


Figure 5.

The graph above shows the velocity of the connecting rod over a period of time at 1500RPM. As you can see velocity is highest at 0.01 seconds which is when the piston is exactly halfway between top dead centre and bottom dead centre. The graph also shows that there is no velocity between 0 seconds and 0.02 seconds which is when the piston is at top dead centre and bottom dead centre.

For the next velocity graph, I changed the value for RPM to 3000 RPM.

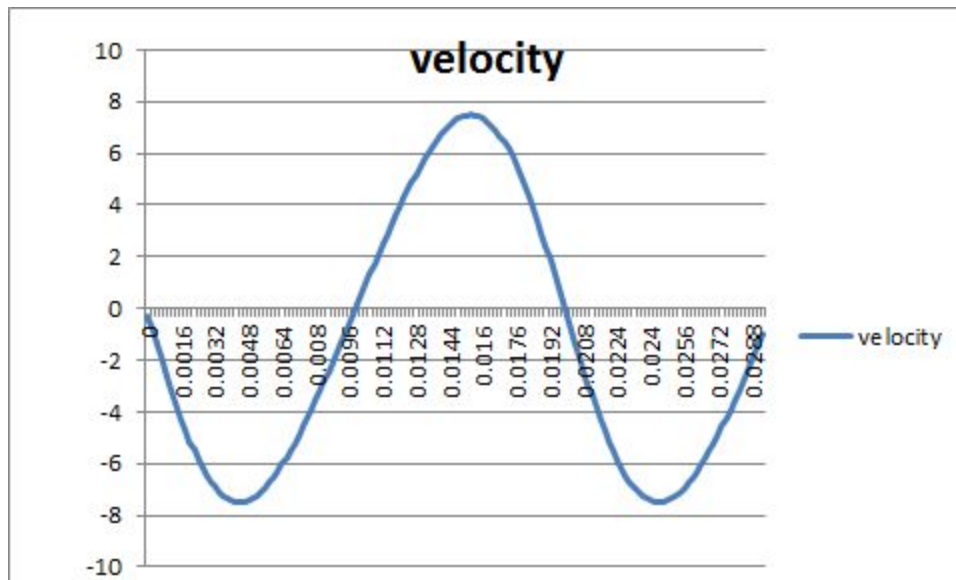


Figure 6.

Figure 6 shows that the waveform is now twice as frequent as the last due to the fact that the engine speed has doubled. As the RPM has increased, the ECU will advance the ignition slightly so that the fuel and air mixture has enough time to properly combust. If this did not occur, the the fuel and air would only experience a partial combustion due to the increased RPM. This graph also showed that the piston reached a velocity of almost 8mm per second, compared to the previous graph where it was just under 4mm per second.

I then changed my RPM value to 6000RPM and once again the waveform became more frequent. This meant that the velocity had to increase as the RPM had increased. At 6000 RPM the velocity had increased to approximately 15mm per second and double the value for the graph at 3000RPM

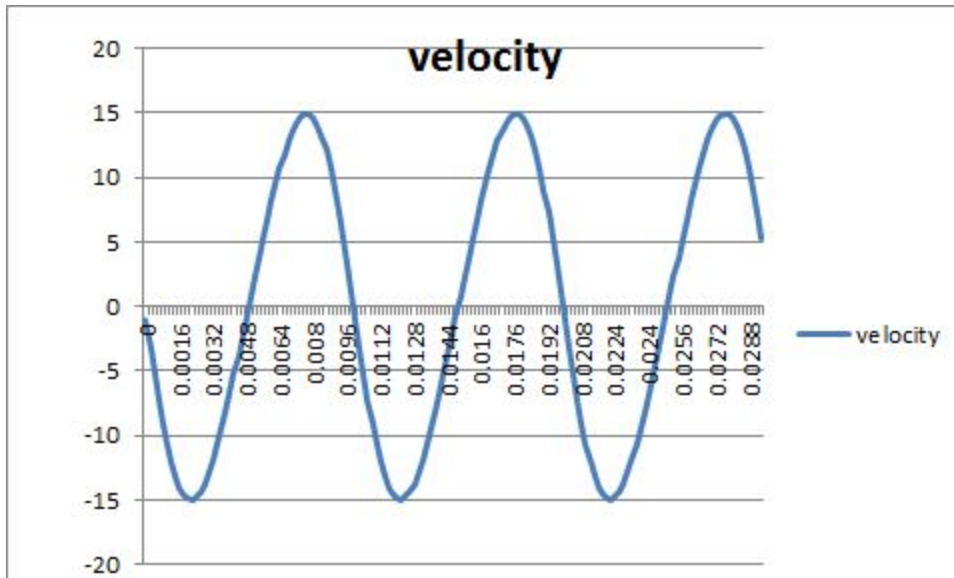


Figure 7.

Figure 8 shows the velocity graph for the Ford Sigma engines maximum RPM limit of 8000RPM.

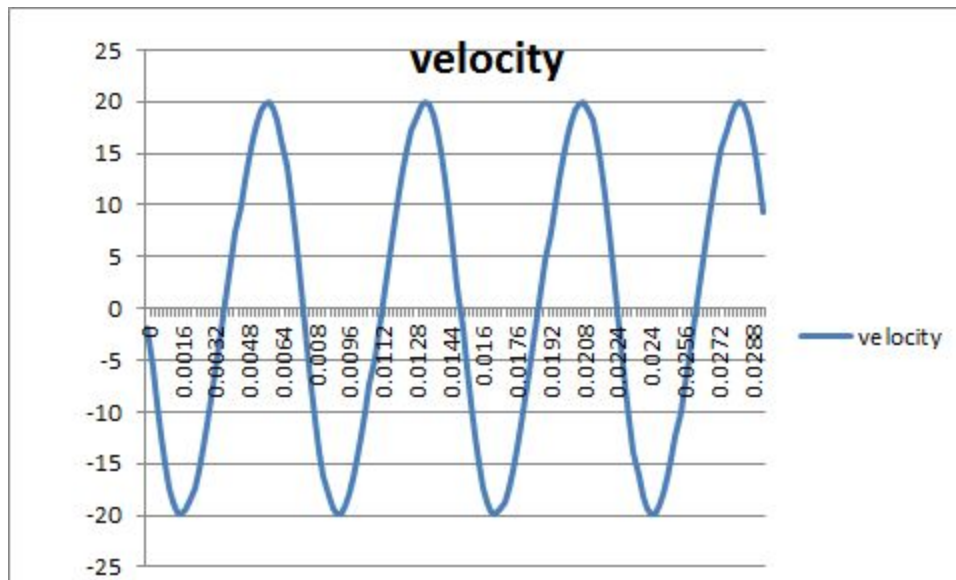


Figure 8

Here the velocity is at its highest as the engine speed is at its maximum limit. Looking at figure 8, you can see the velocity is approximately 20mm per second. The ECU will have to advance the timing so that the point of ignition occurs earlier, this allows the fuel and air mixture to have an appropriate burn time so that complete combustion can occur. At 8000RPM the waveform is most frequent with a full crankshaft rotation taking 0.0074 seconds.

The final set of graphs that I am going to use will plot the force against the acceleration. Again I will use a graph for 1500 RPM, 3000 RPM, 6000 RPM, and 8000 RPM. The acceleration is the change in velocity as the crankshaft rotates, whereas the force is the tensile stress of the crankshaft.

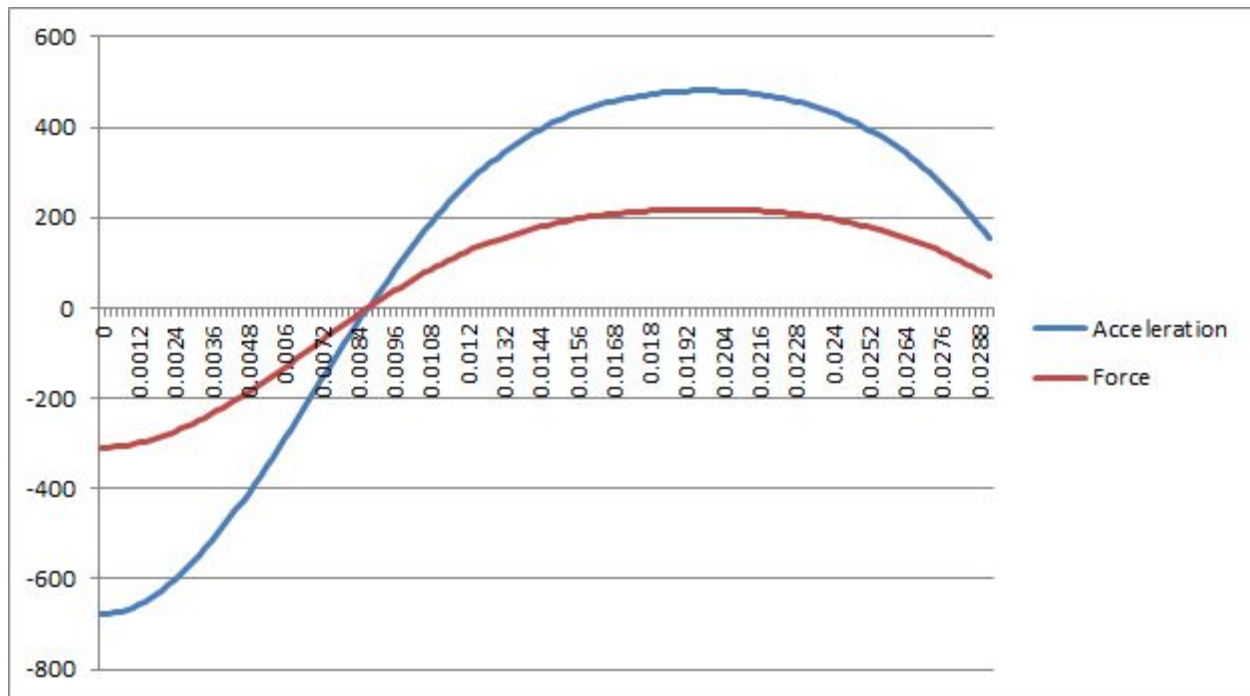


Figure 9.

The above graph shows the acceleration and force of the connecting rod at 1500 RPM. As you can see, the acceleration is proportional to the force. This means that as the acceleration increases, so does the force. The graph shows that the highest acceleration occurs at top dead centre and bottom dead centre. This is also the point of the highest tensile stress in the connecting rod. The lowest tensile strength occurs as the piston is travelling from top dead centre to bottom dead centre.

Next, I changed the RPM value to 3000 RPM and the graph is shown below.

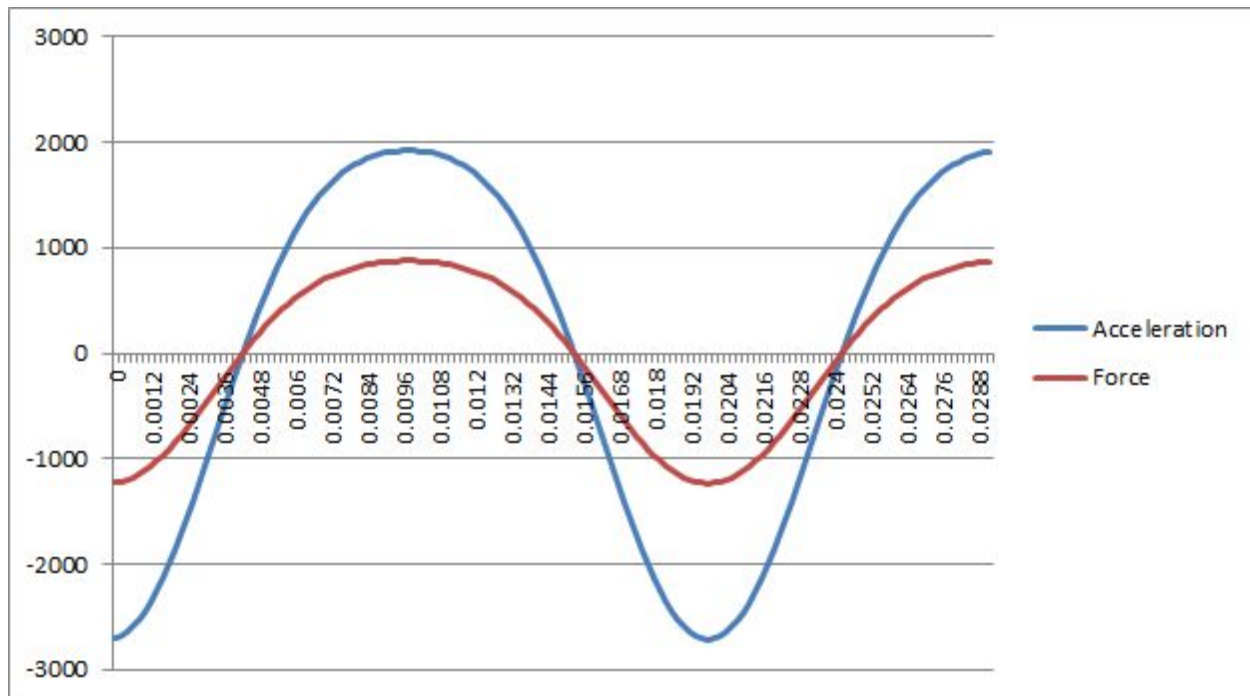


Figure 10.

The graph above shows how the acceleration and tensile strength change as the crankshaft rotates with an engine speed of 3000 RPM. As you can see, the waveforms frequency is more frequent and has a considerably higher acceleration and tensile strength. This suggests that if the connecting rod has a higher acceleration, then it will have a higher tensile stress. This is proven as when the acceleration is equal to 0, so is the tensile stress of the connecting rod.

I then changed the RPM value to 6000 RPM.

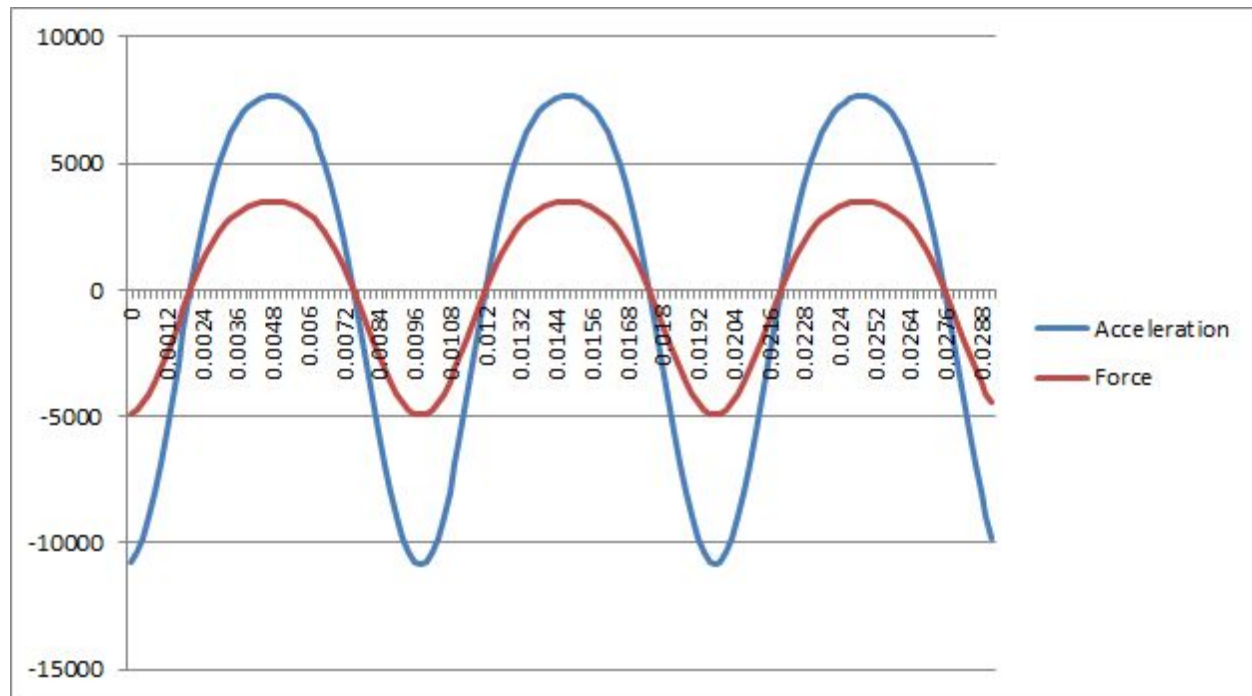


Figure 11.

The graph above shows that the tensile stress is higher at top dead centre than bottom dead centre. This may be due to the fact that as the piston travels upwards, it is compressing the fuel air ratio which would result in a higher tensile stress due to the increased forces acting on the piston. The acceleration is also higher as the piston travels downwards. This is due to the expanding gasses on the power stroke that produce a force and helps to throw the piston downwards.

Finally, I changed the figure for RPM to the Sigma engine's RPM limit of 8000 RPM.

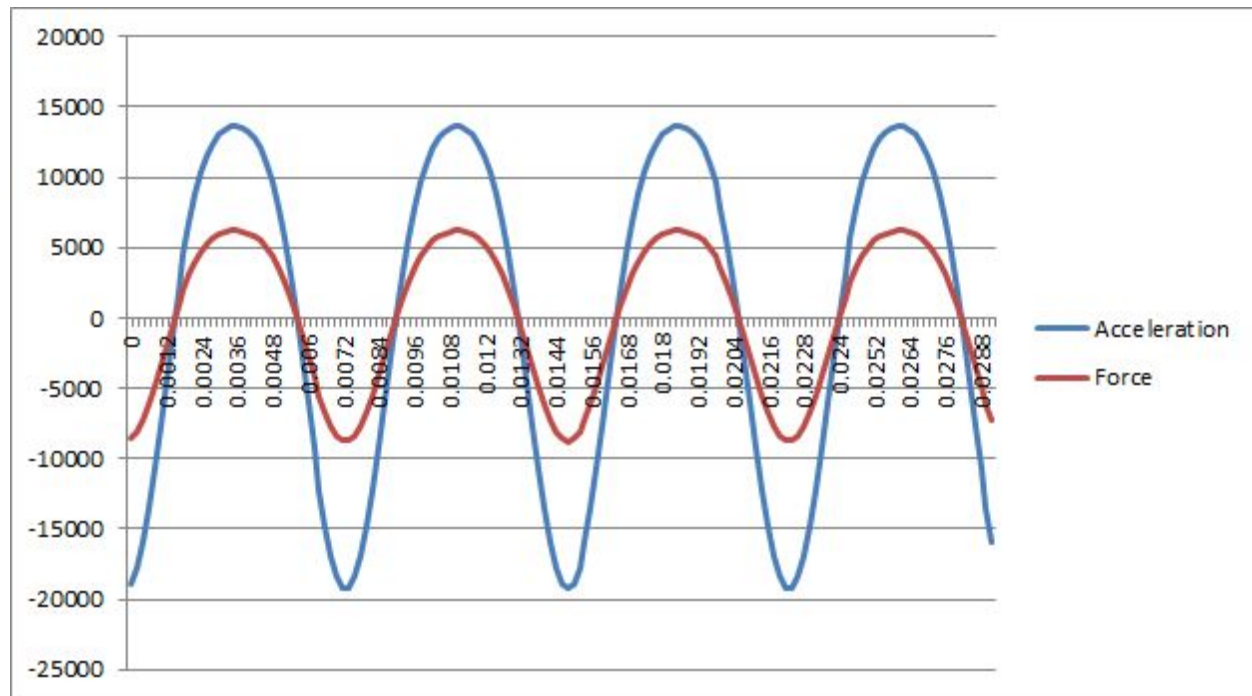


Figure 12.

Figure 12 shows that it takes less time for the connecting rod and piston to travel from top dead centre to bottom dead centre, however the speed of the crankshaft remains the same. This means that as the connecting rod travels to bottom dead centre, there is a much larger tensile stress than if it was to travel from bottom dead centre to top dead centre. You can also see that the acceleration begins to decrease as the piston reaches top dead centre, whereas as it reaches bottom dead centre, the waveform is very sharp.

Conclusion

In conclusion, I have found that, the size of the crankshaft and connecting rod, as well as the weight of the piston, all have an effect on the characteristics of the engine. For example, a longer connecting rod would result in the connecting rod having a higher tensile stress compared to a shorter connecting rod. I can also see that these forces are considerably greater at higher RPM, compared to a lower RPM such as idling. This is important as car enthusiasts often remove RPM limiters to try and gain performance from their vehicle. When this happens, I would suggest replace the engine components with forged internals. This would give the connecting rod a higher tensile strength so that it could withstand the tensile stress at the top of the RPM range

Reference List

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