SSA 4

Real data PV diagram

Joey, Lars, Alexandra

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Goal

- Discover how to calculate the crank angle, figure out where exactly the double tooth is placed and make a pV diagram

Conclusion

- A test should be performed so the crank angle can be calculated.

Problems

- See last paragraph of Section 2

Follow up Steps

- Perform the crank angle test
- Check SSA4.m script on mistakes
- Carefully check is something is missing or wrong

Work Division

- Writing SSA: All 3
- Researching and discussing: All 3
- Writing Matlab script: All 3

Time Division

- Writing SSA: 2 hours, All 3
- Researching and discussing:2.5 hours, All 3
- Writing Matlab script: 3.5 hours, All 3

Overleaf Link

1 The test

To calculate/model the crank angle in MATLAB so the volume can be plotted, a reference point is needed. This reference point is a point in the otto cycle of the engine where the crank angle and the corresponding time or pressure is know. The test that should be done by Vito and Joey is without fuel, test steps:

1. Make sure the fuel tank and connecting tube are empty.
2. Connect the pressure and the pulse sensor to the engine and a Laptop interface.
3. Experimenter 1 holds the start, while experimenter 2 saves the measurement at the exact moment actual data can be seen on the interface.

Using the data from this test the crank angle can be determined because the maximum pressure will be achieved at the top dead center when running without fuel. This can be used as a reference point.

2 MATLAB script, crank angle

2.1 Testingg.m

Using that one cycle takes 0.04 seconds and the crankshaft is rotating with 3000 RPM (= 50 Rounds/s = 0.02 s/round) the crankshaft rotates 2 times in one otto cycle. The crankshaft rotates 720° (2 rotations = $2 \cdot 360°$) during one otto cycle of 0.04 seconds so the the crankshaft is rotating with an constant velocity of (720/0.04 =) 18000 °/s. The crank angle is tried to be calculated using matlab, this can be seen in Figure 1.

```
%% Formula for angle and volume
%t_theta =

theta_0 = 180; %crank angle at te begin of a cycle [degree]
v_theta= 18000; %[degree/second]
k=1;
for i=0:full_time
    theta = v_theta*full_time(i) + theta_0;
if theta > 360
    theta = theta - 360*k;
    k=k+1;
end
end
```

Figure 1: MATLAB code for calculating the crank angle.

2.2 SSA4.m

Next we did, was looking at the already available SecondExperiment.m script. This script has been filled in completely and saved again as SSA4.m. Both these scripts can be found on Github and Gitkraken. I will now try to explain the basics of this code. Starting with the path and data directories. As can be seen in the code, you will have to say to Matlab where the .txt files (full load, half load and no load) and NASA table files are saved on your computer. This was done at first. What the Matlab script then does, is basically performing the ImportData4GB10.m script on the .txt file. What this file does is making four arrays out of the .txt files, namely a time, pressure sensor voltage, pulse sensor voltage and revolutions array. The first 3 stand for itself, so I will not explain those. However the fourth array could need some explanation. Firstly an array is made with all the end points of each revolution of the piston (so an angle of 0/360 degrees). Then the length of this array is taken to see how many full rotations are in the data because it is logical that the given data does not only contains full cycles, but also incomplete cycles in the beginning and end of measuring. Now that the ImportData4GB10.m code is explained, we will go further to the SSA4.m code. Then for each time period, the code calculates the crank angle. For this the given formula in the intro lecture was used (check page 20). Then with this crank angle per time period, the volume per time period can be calculated using another formula from the intro lecture (also page 20). Lastly a plot of the pressure (already calculated in an earlier SSA) and the volume can be made. This is done in line 90 of the plot. Finally with this pV diagram the work of the Otto cycle can be calculated. This is done in the final lines of the code.

Important things

Before going to the problems section, we would first like to mention some very important things we have found during our research. These are:

- Highest pressure just after ignition (motored). This means highest pressure just after TDC
- Double tooth is placed just before or after TDC or just before BDC
- At TDC and BDC there is a zigzag in the pressure,time graph. We believe this is caused by opening of the exhaust and inlet valves.
- There might be a small time error of around 0.01s in the data.
- One full Otto cycles resembles 720 degrees of rotation of the crankshaft

Problems

It took us a lot of time to figure out what to do exactly and how to do it, but eventually we came up with a plan and starting writing a code, which is explained above. We are still not a 100 percent sure if this is the way to do it. With the SSA4.m we do not get a good pV diagram which is logical, this is quite a big problem. There might be a small mistake in the code, but it could also be enormous. Someone with some more Matlab knowledge then us, should really take a look at the script.

3 Analysing the pressure and pulse graphs

To analyse and determine the phases of the engine, we needed to look at all the pressure and pulse graphs for the cases when the engine is running with no load, half load and full load. We realised that when the engine was running with no load, the graph had more amplified oscillates than in the other cases. As load of an engine is the capacity of the engine to produce power, the amplifications might be because of the noises created by the fact that the engine works on no load.

During a full cycle, the crank rotates 720 degrees (2 full revolutions), meaning that the double tooth passes by the pulse sensor twice in a full cycle. This is the reason why in the pulse graph, the double tooth is present twice in a cycle (see Figure 3, Figure 6, Figure 9).

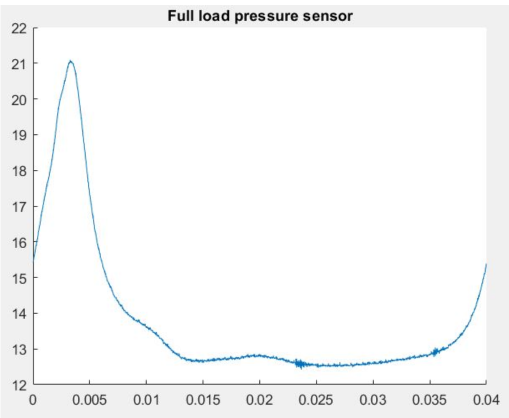

Figure 2: Pressure wrt time (full load)

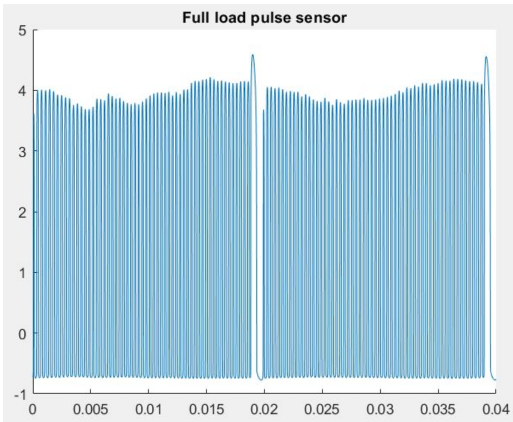

Figure 3: Pulse wrt time (full load)

Figure 4: Full load - one cycle

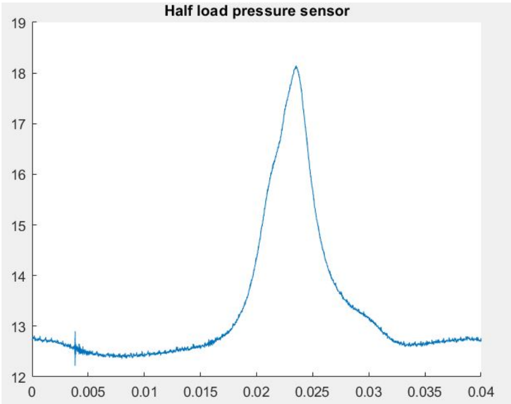

Figure 5: Pressure wrt time (half load)

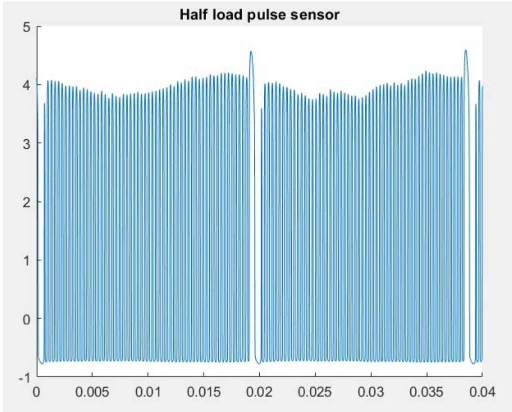

Figure 6: Pulse wrt time (half load)

Figure 7: Half load - one cycle

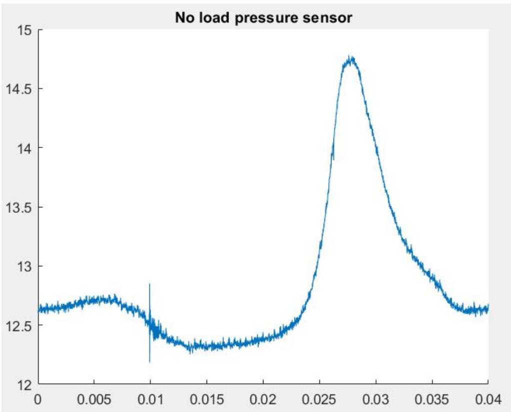

Figure 8: Pressure wrt time (no load)

Figure 9: Pulse wrt time (no load)

Figure 10: No load - one cycle

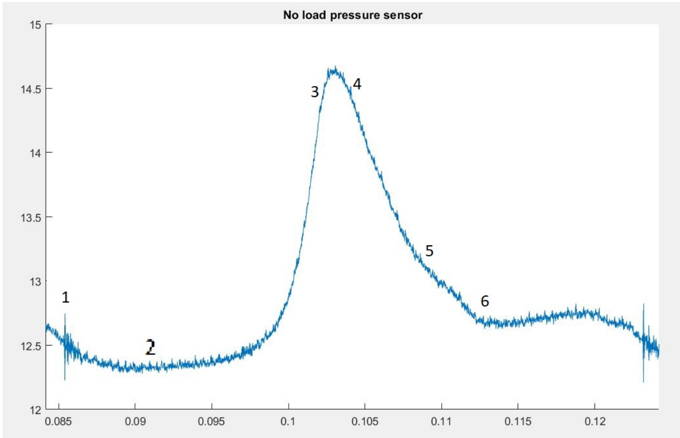

Figure 11: Pulse graph with notations (no load)

State 1: is the opening the inlet valve and closing the exhaust valve after the gases are out

Interval 1-2: this interval represents the state when the air with atmospheric pressure enters the piston.

State 2: around this point we can find the BDC point and the inlet valve is closing in

Interval 2-3: this interval represents the compression state

State 3: the compression is over and TDC point can be found around state 3

Interval 3-4: this interval represents the beginning of the combustion state, as there can be seen fluctuations into the pressure change cause by the combustion action

Interval 4-5: this interval is represented by the expansion of the piston caused by the combustion.

State 5: the combustion state is over (after the point 5, the slope of the curve changes such that the pressure drops slower)

Interval 5-6: the piston is still expanding in the downwards direction after the combustion was over, reaching the BDC point.

State 6: the exhaust valve is opening causing a big drop of pressure.

Interval 6- : the exhaust gas is going out of the piston until the exhaust valve closes and the inlet valve opens.

References