SSA 5

Improving Matlab model

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Goal

- Implementing losses to the wall.
- Implementing effeciency calculations.
- Use different fuels in the model.
- Try to look at SS4.m to make a PV-diagram out of the data.

Conclusion

- A PV-diagram has been made, with certain assumptions.

Problems

- The data collected by us has two columns switched around compared to the test data. Which is the root of all the problems in SSA, however this was only found out after we had spent after writing the majority of the SSA. So little progress has been booked.

Follow up Steps

- A lot of our original SSA still has to be done. Think about the implementation of the losses to the wall and efficiency calculations. However, we didn't do this due to missing information that will come with the time. So maybe it is better to wait another week with this.

Work Division

- We worked together on solving the Matlab problems on discord.

Time Division

- Mats spent 3 hours on solving the problem and 1 hour on typing the SSA.
- Dolf Thomas had a meeting from 12:00 till 15:30
- Mats joined at 13:00 the meeting
- Dolf spent another hour investigating the problem.
- Thomas spent 1 hour on typing a part of the SSA

Overleaf Link

PV-diagram out of measuring data

There was briefly looked to script SSA4.m made by Joey, Alexandra and Lars. After this was done, a follow-up to this SSA could be done by us. First of the function for the volume, defined in SSA 4 of Dolf and Thomas, will be uses the crank angle as its variable. To set up a PV-diagram the volume must correspond to a certain value of the measured pressure. To do this the crank angle at a specific point in the cycle needs to be defined. This can be done by the use of defining a double tooth. First of with the given example data given we where able to determine the locations of these double tooths as a reference point. But when using the same model on the measured data something wrong happened. The data gave us over more than 700 double thooths located in one cycle. Out of the example data we saw that in one cycle two double tooth points will be defined. When defining the double tooth points the peaks points of the pressure will be defined first, so this could be the problem for our measured data-set. Since the measured data is fluctuating a lot it will define many more peaks than in the example data. In figure **??**. there can be seen that the the overall pressure is as we expect it to be over time but the number and locations of the double tooths are completely none sense.

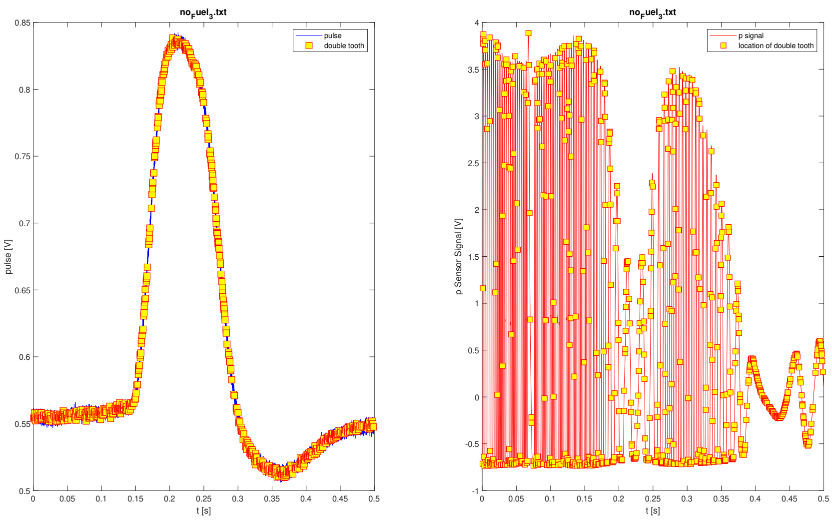


Figure 1: Problem in defining the double tooth points.

An method we thought could solve the problem of the fluctuation in the measurements, is to use a filter over the data to make it more smoother. In this way there will be not as many peaks defined as in the example data, which will be used to define the double tooth points. We used two different methods which are inbuilt functions in Matlab. The first used method is the filter function defined as $filter(b, a, x)$, in which x is the variable which need to be filtered. The variables a and b are the filter coefficient vectors. This filter function describes a tapped delay-line filter. For more in formation of how this function is defined or can be used see [1]. After all we where able to filter the data such that less double tooth points where defined, but the locations made no sense at all. There also was no repetition visible of the double tooth pionts.

After the use of this filter function another function was used defined as $smooth(y, span, method)$ in which y is the variable which has to be smoother, span is the length over which a certain method of 'smootening' will be applied and method is the method which will be used to make the data more smooth. Two methods where used the Savitzky-Golay filter and local regression using weighted linear least squares and a 2nd degree polynomial model. For more in formation of how this function is defined or can be used see [2]. Sadly this gave the same problem as the filter function...

See end of SSA for explanation on mistake made

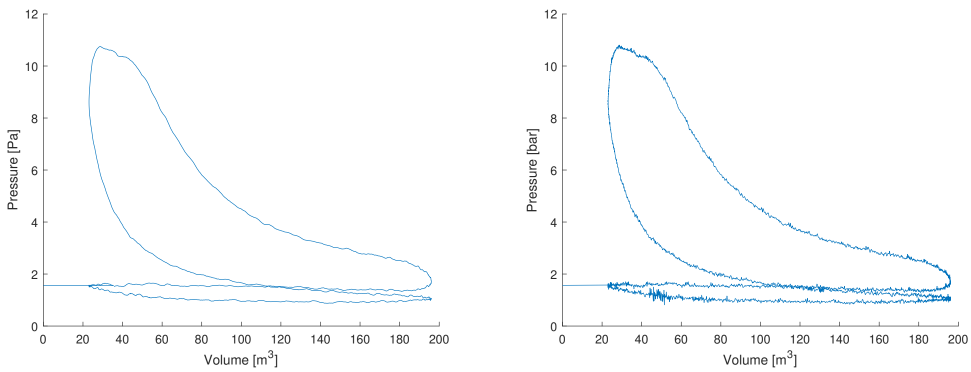
Solution PV diagram

In the end it was possible for us to make a good proper PV diagram. The one that we created is visible below in figure 1. A theoretical Otto cycle has been plotted below in picture 2. It can be seen clearly that there is a huge difference between those two. We now also have some rough numbers on the axes of the diagram. For example on the y-axis we have pressure differences between 0.7 and 11 Bar. The x-axis shows variables in cm^3.

The main breakthrough to making an own graph was determining the place of the double tooth somewhere in the cycle. It has been determined by not just some Matlab skills, but also some own knowledge that has been applied. The double tooth was determined by comparing two tops in a graph. Matlab wouldn't give us the two tops, so we had to figure these out by ourselves. When the tops were determined, together with the place of the double tooth, it could be determined on what angle the double tooth is fitted. With this determined the PV diagram could be made. The double tooth is exactly located at 154°after the top-point of pressure. This is probably just before BDC.

The graph that we have made is the visual representation of one cycle. That means that it is not the average of 5000 cycles or a good approximation of it. Therefore this can still be a point of improvement. However the result we have made is good enough for the report and can be used as a reference point.

Things that have to be concluded from the graph are of course that the lines are not so smooth and the edges not that crisp. What also can be noticed is the pressure below 1 atmosphere in the bottom of the graph. That means that the fuel mixture is literally sucked into the cylinder compartment. The intake and exhaust stroke also don't walk exact the same route, that could be very logical, but that is not the same as a theoretical model. All these small differences can be seen as imperfections in the model.



(a) Smoothed Graph

(b) Un-smoothed graph

Figure 2: Half load training set data PV diagram

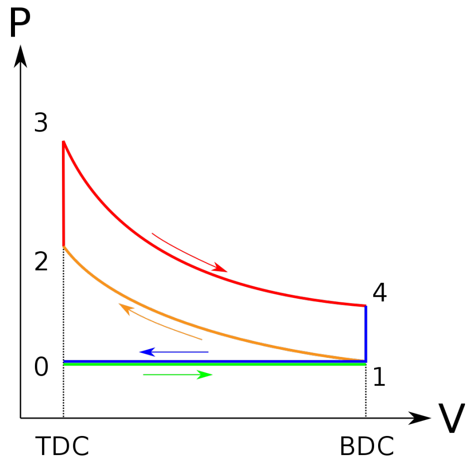
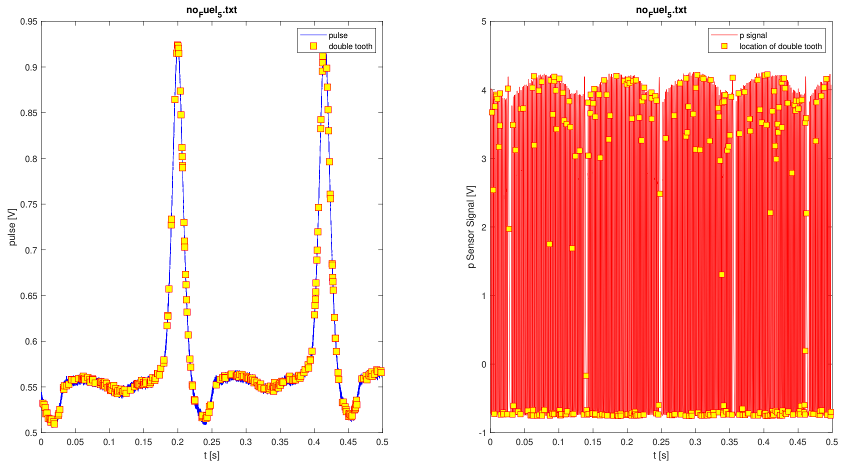


Figure 3: Theoretical Otto cycle

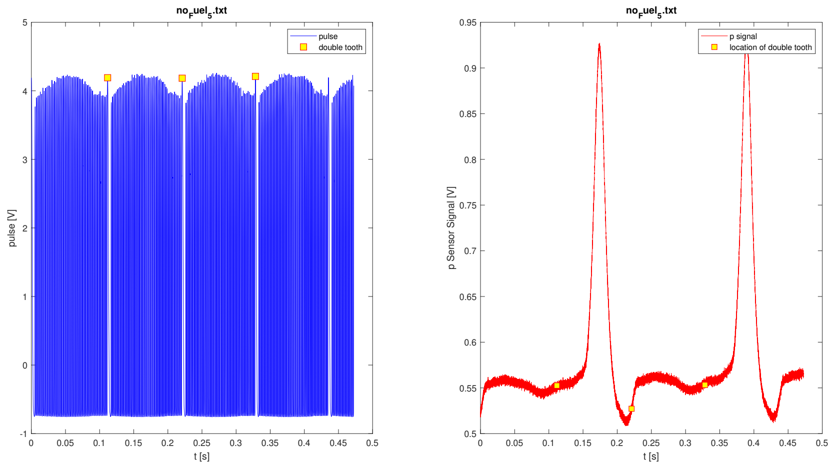
1 Root of the Problem...

During the process of attempting to determine the double tooth, it seemed as if the data was very bad and a lot sensor noise was present. As described in the first section, our instinct told us to try filtering this. However, this led us nowhere (see Figure 1). The eventual problem was solved after we sort of gave up on trying to determine the double tooth for our data. It was solved through switching the pressure, and rotary encoder around in the "ImportData4GB10" function for our data. The difference can be seen on Figure 4. The immediate difference between the two is that you can see that the "faulty" graphs have many more double tooth positions located and have the wrong labels. This was noticed by us but only after working on the SSA it occured to us that the columns were switched around. Modifying the code and switching the two columns around when creating the variables results in better results which correspond much better with the expected results, as seen in Figure4b. With this in mind all the previously discussed issue with the potential measurement errors in the data can be disregarded for now.

Due to time we have not created PV diagrams for the other graphs, but it is possible through the code provided at the end of the SSA. Essentially it comes down to using through dividing the filtered data (complete revelutions) from "ImportData4GB10" functions by the number of cycles. This number dictates the number of steps per 360 degrees, each revolution is from one tooth to another tooth to determine the step size of the angle ("dCa"). This can then be used to determine the volume using the volume function described in the previous SSA. The difficulty here is determining the angle ϕ which is the angle of the double tooth relative to the TDC. We estimated this to be 154, which can be used to shift the function to start at that volume.



(a) Faulty Graph



(b) Fixed Graph

Figure 4: Graphs for no fuel starter

MATLAB Code

```
N = round(length(Data.Volt)/Data.NRevs);
dCa = 360/N
r       = 8.5;
Vt      = 196;                               % [m^2]
Vc      = Vt/r;                                 % [m^2]
Vd      = Vt-Vc;

V_s = 5; %V, constant

%1 complete cycle is 0.04s = 1/25

p = (((Data.Volt/V_s)-0.115)/0.00385);



Ca(1) = 0;
Ptest = smooth(p([1:2*N]), 24, 'sgolay');
Ptest =p([1:2*N])
```

```

for i = 2:2*N
    Ca(i) = Ca(i-1) + dCa;
    V_test(i) = Vcyl(Ca(i), Vc, Vd);
end
figure()
hold on;
plot(V_test, Ptest);
xlabel('Volume [m^3]')
ylabel('Pressure [bar]')
```

References

[1] https://nl.mathworks.com/help/matlab/data_analysis/filtering-data.html

[2] https://nl.mathworks.com/help/curvefit/smooth.html#mw_ad6b65fd-4dac-46c4-a649-a7a0b301eb80

[3]