SSA 2

Sensor Output

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Goal

- The goal of this SSA is to look at the different sensors for the experiments and how to convert the data to usable numbers.

Conclusion

- The two sensors that are available in the experiment are observed and are well-understand. The usable formulas for these sensors are determined, so we can easily make further progression in our project.
- A lot of info of our SSA can be used in our report, so keep that in mind too.

Problems

- We have encountered a problem, because we don't know how the 2nd sensor (pulse) works. There isn't any information online for the sensor and the course manual gives as little as possible. Here are some features that we just have to discover during testing.
- We do not know what they mean with double tooth and how it works exactly. Still waiting for a reply on the discussions page.

Follow up Steps

- More research can be done into the formulas and the pulse sensor. However this isn't prioritised for the upcoming meetings, but it can be kept in mind.
- The main items for the experiments have been determined. So we can start the experiments and process all the information we get out of them.

Work Division

- We did everything except the theoretical model part completely together. We both thought about how to tackle the problem and we both wrote the text: Mats + Joey
- Check theoretical model of Vito with the Otto-cycle: Joey

Time Division

- Carefully checking project handbook and available document on Canvas: 2 hours
- Pressure sensor research: 1.5 hours
- Pulse sensor research: 1.5 hours
- Writing SSA: 1 hour
- Theoretical model: 0.5 hour

Overleaf Link

1 Experiment 2

1.1 Main goal of the experiment

We need to calculate the torque and pressure over time with the pressure sensor. The crankshaft angle can be determined with the pulse sensor.
These items will be worked out in the upcoming subsections.

1.2 Pressure Sensor

The pressure sensor is a relative sensor that gives measurements in Volt. This sensor is connected to a device that gives the Volt output per time unit. Alexandra already explained this in her SSA. The exact way how the measurements device works is explained clearly in the project handbook. An schematic in how to connect the pressure sensor to the device and details about the sensor can be seen in the figures below. From these details it follows that the sensor needs a supply voltage (Vs) of 5 Volt. Also the pressure range in which the sensor can detect pressure is between 0 and 200 bar. This is more than enough for this experiment. Also do not worry about the delay time of 15 microseconds. This does not matter in this experiment.

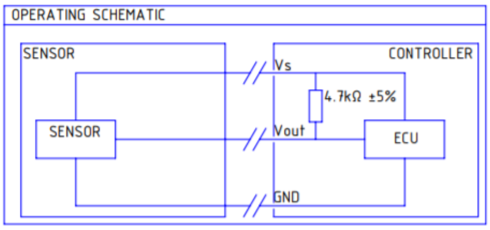

Figure 1: Schematic

SENSOR CHARACTERISTICS

SUPPLY VOLTAGE Vs	5.0±5%V
SUPPLY CURRENT Is	max. 10mA (including pull up)
DELAY TIME	15μs
NOTCH (CHOPPING)	- DISABLED
OPERATING TEMPERATURE RANGE	-40..140°C
OPERATING PRESSURE RANGE	0 to 200bar
PROOF PRESSURE	250bar
BURST PRESSURE	300bar
LOAD RESISTOR	4.7kOhm pull up
DIAGNOSTICS	DIAGNOSTICS PRESENT
MOUNTING TORQUE	10Nm ±1Nm
MOUNTING & HANDLING RECOMMENDATION	TBD
TARGET CUSTOMER PRODUCT	10382378
SENSATA SPECIFICATION REFERENCE:	QMS01218149

Figure 2: Sensor details

On the Canvas page there is a formula given that transfers the voltage into Pressure. The formula is the following:

$$V = (0.115 + 0.00385 * P) * Vs$$

Whereas Vs is a constant, in our experiment 5V. Please note that the outcomes from P are in Bar ($10^5 Pa$). Because this is a relative sensor, the outcome of V will be relative to Vs. So V can be given in a percentage of Vs.
The rest of the formula can easily and nicely be plotted in MATLAB, with the pressure over time. This is the first bit of using the data from the experiment.

Torque

The torque of the engine can be determined by using the following formula:

$$HP = (Torque * RPM)/5252 \tag{1}$$

In the project handbook all needed values to calculate the torque are given. See page 28. The torque would then be 96.29Nm. Keep in mind that this is just an approximation since the formula does not always hold.

There is also another way to calculate the Torque. This is done by dividing the power in [HP] by the RPM [min^-1]. However, first are HP and min^-1 converted to more usable SI-units. These are [Nm/s] and [s^-1].

$$5.5HP = 4.10kW = 4100W \tag{2}$$

$$3000RPM/60s = 50s^-1$$

$$4100/50 = 82Nm$$

As you can see there is a difference between the two calculated torques. The first explanation for these differences is that the first calculation is a estimation of the output. However, this shouldn't get such a big gap.
The main difference between those two Torque outputs can be explained by simple engine knowledge. That is the adaptive motor output by the changing revs. The motor we have produces constantly 3000rpm, that is below the maximum output it should get.

Volume and mass flow

An other important value which is really needed is the volume flow. A first way to calculate this, is to set the motor on full power. When the motor is on full power, the fuel consumption is 1.3L/h, given in project handbook. With the use of 3000rpm, the amount of fuel used per cycle can be calculated. In this case this is 0.000014L/cycle. This thus means that the volume flow per cycle is 0.000014L. With this, also the mass flow can be calculated using following formula:

$$\dot{m} = \rho * \dot{V} \tag{3}$$

The ρ value has to be determined using the air-fuel ratio's.

This method for determining the volume flow can only be used when the motor is at full throttle since for this the fuel consumption is given. When the motor is at half throttle, a different

amount of fuel is used which is unknown. Other formulas are then needed to calculate the volume flow. The formula for the mass flow stays the same. The volume flow can be calculated using the area of the intake and exhaust pipe and the pressure difference. (Moet nog afgemaakt worden).

p-V diagram

With the use of this pressure sensor, pressure and volume (flow) can be determined with respect to time. This means that also an p-V diagram could be made. Eventually this p-V diagram has to be compared to the p-V diagram of the Matlab model. With this it can be seen how good the model is.

1.3 Pulse Sensor

The Bosch pulse sensor is an inductive sensor placed on the crankshaft and creates a voltage if a metal object moves along it. The height of this voltage varies according to the amount of metal that passes and velocity with which it passes. When more metal moves along the pulse sensor, a higher voltage is produced. Then logically it can also be concluded that a higher velocity of the crankshaft, gives a higher voltage.

One of the remaining problems with the pulse sensor is the following: "The data acquisition uses a decoder wheel on the crankshaft to determine the crank angle. This decoder has a double tooth to provide a reference for a complete cycle. However you don't know a priori at which crank angle this double tooth is positioned (it is NOT TDC or BDC)." This was literally cited from the project handbook. There were some things unclear about this part of the handbook. We were not really sure what a double tooth is (we think it is a gear with a double row of teeth) and we do not know what it does example because it does not become clear from the handbook. These 2 questions were asked on the discussion page 2 days ago and we still did not get an answer. So this will still need to be figured out. One other thing about the cited text are the TDC and BDC values. These respectively stand for the Top Dead Center and Bottom Dead Center. These are basically the topmost and bottommost position of the piston in the cylinder. From this it can be concluded that the crank angle difference between TDC and BDC is 180 degrees. This can also be seen in figure 3. It is unknown at which crank angle the double tooth is positioned. This also has to be logically determined when wanting to calculate the crank angle. During the meeting, we will have to discuss ideas on how to tackle the problem and hopefully there will also be an answer on the discussions page.

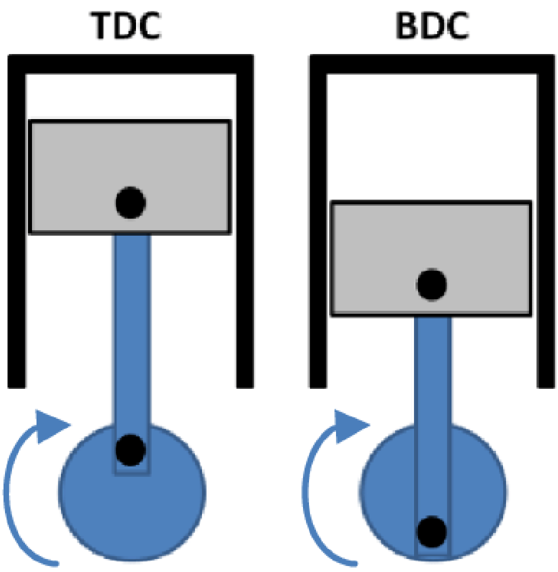

Figure 3: Top Dead Center and Bottom Dead Center

The speed of the crankshaft can easily be determined by the formula

$$v = \omega * r$$

with the ω in [rad/s], so this will be

$$50Hz * 2\pi = 100\pi$$

The r is the distance from the center of the crankshaft to the sensor point. This value has still to be determined from experiment 1 (or 2, I don't know if in experiment 1 the sensor already has been placed). w With those two variables the v can easily be determined.

When the speed v is calculated, there are 2 other formulas that also can be determined. These are

$$m * v = m * v$$

$$0.5 * m * v^2 = 0.5 * m * v^2$$

With the calculated speed and the m probably of the crankshaft. The question remains if we can use this info in our project. Still it could be nice to add them into our report.

Pulse responses

The pulse sensor gives a response in Volt per time unit. So this will give a V/t-diagram as can be seen in the first graph in figure 4. This graph was exactly made that only one Otto-cycle can be seen. As you can see there are two vibrations. These represents two cycles of the piston, and two cycles of the piston represent one Otto-cycle. Between the max. V and min. V values the crank angle is 180 degrees. With the use of the lower graph in figure 4, the pressure can be related to a crank angle. However how to exactly do this, is still very vague for us. This still has to be looked at.

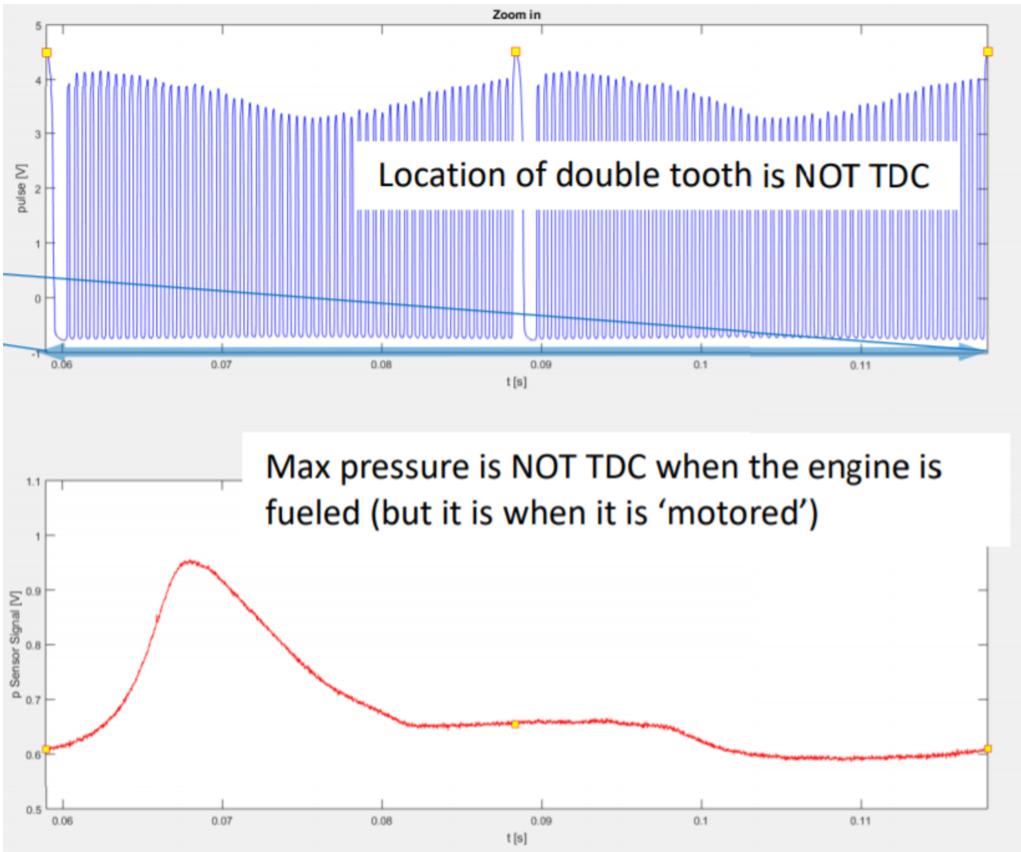

Figure 4: Crank Angle and Pressure Graphs

Checking Vito's theoretical model

I looked at Vito's SSA together with the Matlab model. I checked everything he wrote down and compared it with the Otto-cycle. I think Vito did some good work because I could not find any mistakes. Although, I did see Vito had trouble with the Qlhv value. I did some research for this. Basically Qlhv stands for the heat of combustion; the heat released when the fuel is combusted. This heat released can be calculated looking at both the products and reactants. I found this website: Qlhv, which, in my opinion, explains very clearly how to calculate it. This only has to be written into the model. This would then be a future step.

References

- Inductive sensor
- Video disfunctional Pulse sensor
- TDC and BDC
- Info NI6211
- Difference Power and Torque
- Pressure sensor