SSA 2

Theoretical p-V diagram

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Goal

- The goal of this SSA was to make a pressure volume diagram using the thermodynamic model as described in the lectures. In order to do so, many parts of the thermodynamics model still had to be defined including the thermodynamic states, dimensions and product specific variables.

Conclusion

- Unfortunately, this task was unsuccessful as I did not manage to create a satisfactory pressure volume diagram. However, if someone else investigates the script further, he should be able to easily create a pressure volume diagram thanks to the progress I have made. This task took significantly longer than expected.

Problems

- The reason why I was not able to create the diagram was, that during the final stage of error elimination MATLAB would crash when the script was run. It crashes so severely that the entire operating system locks and only a black screen and a cursor are available. On average, it took the computer roughly twenty minutes to recover each time this occurred. I tried to fix this numerous times but to no avail.

Follow up Steps

to say, I think it would be wise if someone else takes a look at this program with some fresh insight and determines why this script causes a crash and how to plot the pressure volume diagram.

Work Division

- Together with Mihai, we started on working separately on both pressure-volume diagrams. Mihai made the diagram using the experimental approach by using the measured data and converting that into a diagram whereas I took the analytical approach by making a theoretically ideal diagram using a thermodynamic model.

Time Division

- Looking data sheet variables on Canvas, online and at the manufacturer: one hour
- Finding the state values: four hours
- Plotting the diagram: thirty minutes
- Bug fixing: one and a half hours
- Preparing the presentation: thirty minutes
- Writing the SSA: one hour
- Total: eight and a half hours
- I hope to be able to take some slightly less time consuming SSA's in the future.

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1 Assignment 1

1.1 Assumptions

A list follows of assumptions made in the model that influence its results that may lead to inaccuracies:

- The inlet fuel and air mixture is at ambient temperature being 20 degrees Celsius;
- The combustion products leave the exhaust at ambient pressure that being atmospheric pressure;
- No significant heat loss occurs between the combustion and discharge of combustion products;
- The operation frequency is 3000 revolutions per minute and the corresponding exhaust temperature is 205 degrees Celsius. This assumption is based on information available in the following document (Honda, 2005);
- The air fuel mixture can be modeled as an ideal gas;
- The combustion process is assumed to be an ideal Otto cycle with isentropic and isochoric processes;
- The combustion products can also be modeled as an ideal gas.

The assumptions that are most likely to cause inaccuracies are the ideal gas assumptions, the adiabatic processes and the assumption that no heat loss occurs during the cycle. This likelihood comes from their large divergence from reality compared to the others.

1.2 Thermodynamic states

The assumption of an Otto cycle leads to several assumptions that express how each state to state transformation occurs.

- Transformation 1-2: Isentropic comporession: The pressure increases whilst no heat or internal energy is lost. This pressure increase comes from the piston compressing the air-fuel mixture inside the cylinder. Since no entropy is produced this process is reversible;
- Transformation 2-3: Isochoric combustion: The chemical combustion of fuel and air happens while the volume does not change. This causes the heat and pressure to increase;
- Transformation 3-4: Isentropic expansion: Due to the pressure and heat build-up, the gas performs work on the piston increasing the volume of the cylinder. This volume increase and work provides the engine's useful work for the user. In reality, this step coincides with the combustion;
- Transformation 4-1: Isochoric heat rejection: The combustion products are ejected from the combustion chamber and heat leaves the system with it. This causes a drop in temperature and pressure as hot mass leaves the system. In reality the volume also decreases.

These transformations are some words inconsistent with reality mainly due to the complete ignorance of time. In practical cases the piston always moves from the moment the engine is turned on, this makes any isochoric process impossible. Any isentropic process is also impossible from a practical standpoint as there will always be some heat loss. This assumption will, however, remain useful in providing an idealized boundary within which the real engine should perform. It is impossible for the real engine to perform any better than this theoretical model and also shows in what direction performances will tend to go when improvements are made.

A table follows with the symbols used for each state-variable in each phase of the ideal Otto cycle:

	p	V	T
1	p_1	V_1	T_{amb}
2	p_2	V_2	T_2
3	p_3	V_2	T_3
4	p_{amb}	V_1	T_{exh}

Table 1: State variables per phase

The ambient temperature is said to be twenty degrees Celsius and the ambient pressure is taken from a local news report (Weather.com, 2021). The exhaust temperature was determined by using a graph in the user manual (Honda, 2005). The exhaust temperature is 205 degrees Celsius when the engine runs at 3000 revolutions per minute according to this graph.

p_1 was determined using the isochoric ideal gas law.

$$p_1 = p_{amb}T_{amb}T_{exh}^{-1}$$

V_1 can then also be determined using the general ideal gas law.

$$V_1 = T_{amb}R\dot{n}p_1^{-1}$$

$$V_1 = T_{amb}R\dot{m}M^{-1}p_1^{-1}$$

$$V_1 = T_{amb}R(\dot{m}_{fuel}M_{fuel}^{-1} + \dot{m}_{air}M_{air}^{-1})p_1^{-1}$$

$$V_1 = T_{amb}R(m_{fuel}M_{fuel}^{-1} + m_{air}M_{air}^{-1})(RPM)^{-1}0.0167^{-1}p_1^{-1}$$

Since the volume at phase two and three is maximal, it follows that

$$V_{max} = V_{min} + V_{displacement}$$

$$V_2 = V_1 + V_{displacement}$$

Using the ideal adiabatic gas law, p_2 can be determined:

$$p_2 = p_1V_1^{c_{p,@T1}c_{v,@T1}^{-1}}V_2^{-c_{p,@T1}c_{v,@T1}^{-1}}$$

Then the ideal gas law can be completed to obtain T_2.

$$T_2 = p_2V_2R^{-1}(m_{fuel}M_{fuel}^{-1} + m_{air}M_{air}^{-1})^{-1}(RPM)0.0167$$

In order to determine T_3, the work must be computed. The work performed can be computed using the heat minimum and the heat maximum/

$$W = Q_c - Q_H$$

Q_c can also be computed using the an expanded form of the first law.

$$Q_c = c_{v,@T1}(m_{fuel} + m_{air})(RPM)^{-1}0.0167^{-1}(T_{exh} - T_{amb})$$

With this, Q_H can be computed.

$$Q_H = Q_c - W$$

Another use of the first law makes it possible to compute T_3.

$$T_3 = T_2 + c_{v,@T2}(m_{fuel} + m_{air})(RPM)^{-1}0.0167^{-1}Q_H^{-1}$$

Finally, the last remaining variable - p_3 - can be computed using the isochoric ideal gas law.

$$p_3 = p_2T_3T_2^{-1}$$

References

[1] Honda, OWNER'S MANUAL GX120 GX160 GX200 http://cdn.powerequipment.honda.com/engines/pdf/manuals/37Z4F603.pdf

[2] https://weather.com/weather/today/l/51.44,5.47?par=google&temp=c

[3]