SSA 1

Thermodynamics of Otto combustion engine

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Goal

- Determine the thermodynamics relations of the Otto combustion engine

Conclusion

- Each step of the Otto cycle is explained using figures. Formulas that could be used to make calculations during each step are given as well. Some research on the working of a carburetor has been done.

Problems

- No real problems were encountered. Only had some trouble with writing the text in such a way that someone else would also understand it.

Follow up Steps

- Use the information in this SSA, to make even more assumptions and calculations.

Work Division

- I looked at the thermodynamics process of the Otto cycle
- Lars looked at different types of fuels and the stoichiometric ratio

Time Division

- RPC list: 0.5 hour
- Research on Otto cycle: 2 hours
- Research on Carburetor: 0.5 hour
- Writing this document: 1 hour

Overleaf Link

Otto combustion engine

The type of combustion engine that is used for this project is a so-called Otto combustion engine. Here an air-fuel is ignited with a spark. The name Otto comes from the thermodynamic process that describes the operation of the engine, also known as Otto cycle. This cycle is described more detailed below and assumptions are provided.

Otto cycle

The Otto cycle can basically be described using the four strokes and figures 1 and 2 below. The cycle can be explained using five steps;

(1) The air-fuel mixtures comes in the combustion chamber

(2) The mixture is compressed by the piston

(3) Spark plug ignites the compressed mixture

(4) Ignited mixture is then used as power (piston pushed down)

(5) Left-over exhaust gasses are pushed out of the combustion chamber by the piston

These steps are more thoroughly explained in the next sections. Step 1 will not be explained more since it stands for itself. This step is shown in figure 1 between points 1-5.

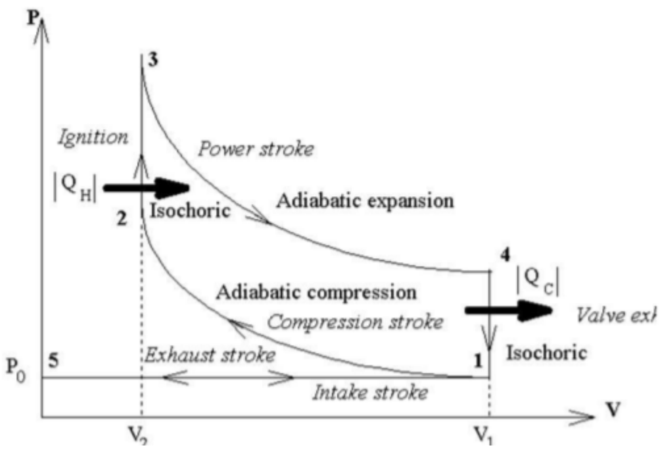

Figure 1: Otto cycle

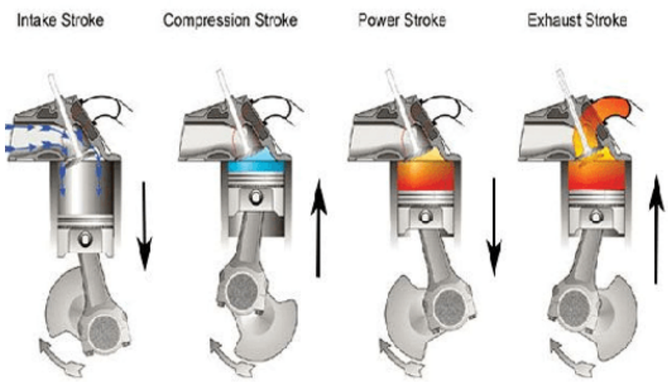

Figure 2: Four strokes Otto combustion engine

Step 2

In this step, the air-fuel mixture in the combustion chamber will be compressed by the piston, this is also known as the compression stroke. This process can be seen in figure 1 between points 1-4. This compression is adiabatic so it means that dQ=0. Also the compression is reversible which means it is isentropic. Because it is isentropic the well-known Poisson relations can be used to make calculations. It has to be kept in mind that this process is not perfectly adiabatic since heat can be lost to the cold cylinder and piston. The value of gamma is a very important parameter in this process since the high-pressure and high temperature conditions at the beginning of combustion are defined by the calculations based on compression. In the handbook it was suggested to take a look at Heywood [1]. Heywood is a book that describes all the fundamentals of a combustion engine. It could be handy to read some parts of it, which I have not done yet. I only looked globally over it.

Step 3

The next step in the process is the ignition of the compressed fuel. This step is shown in figure 1 between points 2-3. This is an isochoric process (dV=0). The ignition adds heat to the system and so also pressure. The air-fuel mixture is firstly compressed so that more energy can be released. For this isochoric process the ratio pressure divided by temperature will always be constant. The increase in heat and temperature can be calculated using the formula below.

$$Q1 = cv * (ma + mf) * dT23 \tag{1}$$

Where ma and mf are respectively the fuel and air mass in the cylinder.

Step 4

When the ignited fuel is ignited, it expands pushing the piston down (power stroke). This is step 4 of the process. This step is shown in figure 1 between points 3-4. The expanding of the ignited fuel happens in the form of adiabatic expansion. It can be assumed that this is a reversible process, so it is again an isentropic process which means that the Poisson relations can be used to make calculations.

Step 5

The last step of the process is removing the left-over gases in the combustion chamber. This is shown in figure 1 in steps 4-1 and 1-5. Firstly an exhaust valve is opened for some gases to escape, this makes the pressure go down. This is also known as rejecting heat. The amount of heat rejected can be calculated using the following formula:

$$Q2 = cv * (ma + mf) * dT41 \tag{2}$$

Finally the piston will move up again and push out the left-over gases through the exhaust valve.

The work of each Otto cycle can then be calculated by:

$$W = Q1 - Q2 \tag{3}$$

[1] https://gctbooks.files.wordpress.com/2016/02/internal-combustion-engine-fundamentals-by-j-b-heywood.pdf

Air-fuel mixture

Before the air-fuel mixture enter the Otto cycle. It first has to be ”made”. This is nowadays mostly done using fuel injection, but in our case a carburetor is used. In the project handbook it is quite good described how to do calculations with a carburetor, but the exact way how a carburetor works is missing. Intentionally it was my idea to explain how a carburetor works, but after watching some videos I decided not to do this since it will be too complicated to just write down in words. Instead I will put a link to a Youtube video which in my opinion explains it well. Please watch the following two videos:

Link 1

Link 2