LELME2150 – Thermal cycles

Introduction to Homework 2

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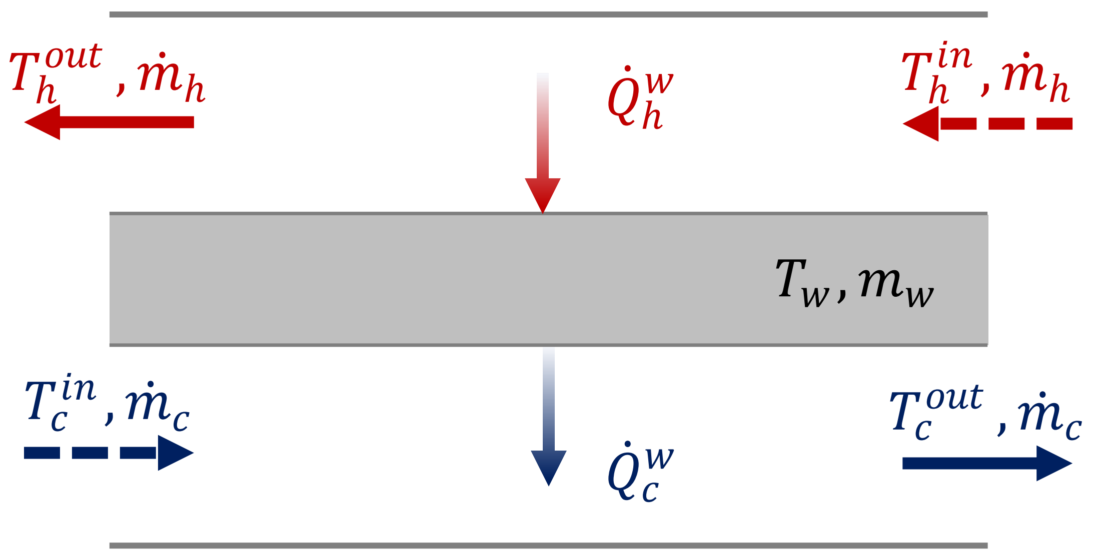
(Gauthier Limpens)

Energetic approach cannot really assess thermodynamic performance

Perfectly insulated heat exchanger ($\dot{Q}_h^w = \dot{Q}_c^w$) without head losses:



What is the heat transfer energy efficiency for different operating conditions?

Exergetic approach integrates entropy

- Quality criterion for energy
  - Compare high T° heat with low T° heat;
  - Heat transfer and combustion irreversibilities;
  - …
- Used to quantify the effect of irreversibilities

- The "exergy" function, e, is defined for a given state w.r.t. a reference state (e.g. $1bar$, $15°C$):

$$\boldsymbol{e = (h - h_0) - T_0(s - s_0)}$$

Apply the exergetic approach and compare it with the energy

- For the GT, compute:
  - Energy approach: mechanical losses, exhaust losses
  - Exergy approach: compressor and turbine irreversibilities, combustion irreversibilities (*see next slides*), exhaust losses
- For the ST, compute:
  - Energy approach: mechanical losses, condenser losses, steam generator losses
  - Exergy approach: keep cool and wait for HW3 ☺

- *Looking for the definitions of the losses, based on the cycle states? Please refer to the reference book.*

The GT model developed in HW1 can be improved to be more realistic

- It must represent the combustion:
  - After the combustion, the working fluid has a new composition, thus a new heat capacity: $c_{p,air} \rightarrow c_{p,gas}$
  - The chamber induces pressure losses: $p_3 = k_{cc} p_2$
- It could provide more information:
  - For a given net power output, what are the air and fuel flow rates?
  - What are the combustion parameters?
  - What are the energy and exergy losses? How do they compare to each other?
  - What are the energy and exergy efficiencies? How do they compare to each other?

Some indications to improve your previous GT model

1. Develop a model for the combustion:

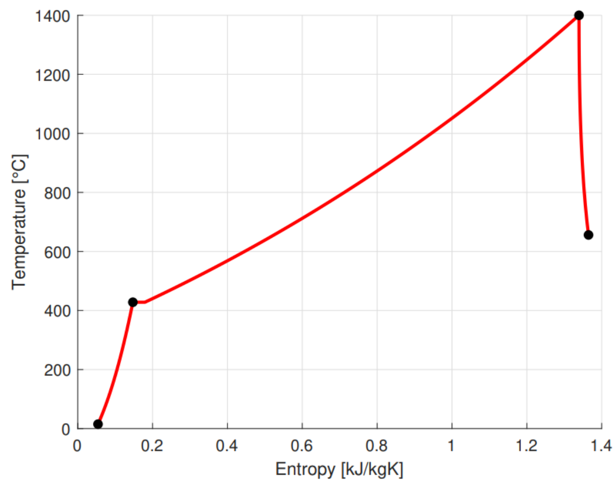
   For a given fuel (for now, you can assume pure CH_4), what will be the flue gas composition?

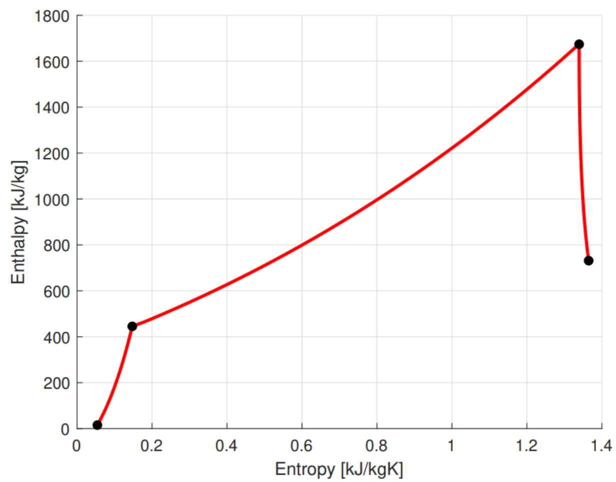
   Hints: derive a combustion model that takes T_3 as input variable. You will have to iterate to find the corresponding excess air ratio (λ). Refer to pp. 113-115 of the text book for more information.

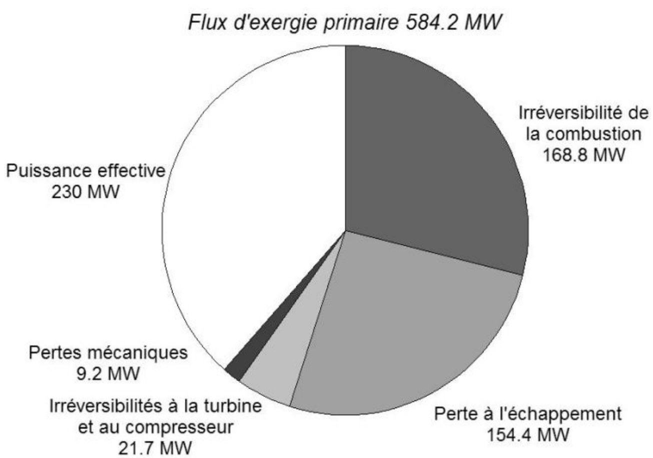
2. Compute the exergy at each state i (ref. state = state 1): $e_i = (h_i - h_1) - T_1(s_i - s_1)$

   Use it to define the exergy losses and efficiencies.

Your code will produce plots like these for the GT (1-3% tolerance)







- Energy pie chart
- Exergy pie chart
- T-s diagram
- H-s diagram

Ref.: «Installations thermiques motrices, analyse énergétique et exergétique», J. Martin and P. Wauters, 2015, presses universitaires de Louvain-DUC, ISBN: 978-2-87463-264-8

They are some points you might struggle with

- An issue that you will certainly encounter with the GT:
  - In the previous p and T ranges, N_2 and O_2 did not undergo any phase change, so the computation of the average c_p was "easy";
  - Now the flue gas (states 3 and 4) will have CO_2 and H_2O in their composition;
  - When computing the average c_p of the flue gas, if you assume a constant pressure (as made so far), phase changes could occur and cause problem to your integration process…
  - So, think about the state of water when writing your code ☺

Whenever facing problems that you can't fix by yourself, come to us through the individual forum!

The deadline is Sunday of S5

1. Go on the Moodle page of the course (*see the announcement for the links*)
   1. Download the new template Python scripts for the GT and ST (GT_group_xx.py, ST_simple_group_xx.py);
   2. Carefully read the signatures (they have changed);
   3. No more test codes (refer to the book pp. 62 & 125).
2. Fill the functions definitions and test <u>your code</u>
3. Submit <u>your Python scripts + report</u> on Moodle

Deadline?

Sunday the 17th of October (**S5**) at 23:59 + *optional Q&A session (SUD01) at 10:45 on Thursday the 13rd*

Report specification

The report must contain the following:

- Formula used to compute the energetical and exergetical efficiencies for each relevant components;
- The numerical values used and obtained;
- The relevant graphs.

This report must be maximum 3 pages (+ unlimited amount of pages for the figures).

Only HW2_group_xx.pdf format will be accepted!