KTH Industrial Engineering and Management

EXAMINATION

MJ2414 Energy Systems Analysis in an Environomical Context

Part A: Home Examination
June 7th 2019
09:00-17:00

Part B: Oral Examination
June 8th 2019
10 minutes per student according to individual schedule

Aids allowed for Part A: Home Exam

- **No communication with anyone!**
- Literature, including on-line resources relevant to the course
- Lecture notes, hand-outs, and solved homework assignments from the course

Submission of Part A: Take Home Exam

- One written document (word/pdf) describing your solution to the problem, including the steps of the analysis and key equations, assumptions made and a short motivation of these, results (graphs and tables), and final analysis and discussion. The majority of your grade will be given based on the clarity of this document.
- The "source code" for the computational part, regardless of choice of programme (Excel worksheet, EES or MATLAB code, etc.). ***Source code is NOT a valid document to show your solution.***
- Material will be submitted through a special assignment in "Assignments" in the Canvas course event MJ2414 HT18-1 Energy Systems Analysis in an Environomical

Context.

- **Submission Deadline: 17:00 on June 7th 2019 – No exceptions!**

Aids allowed for Part B: Oral Examination

- Only the student's own copy of the solution submitted via Canvas for Part A.

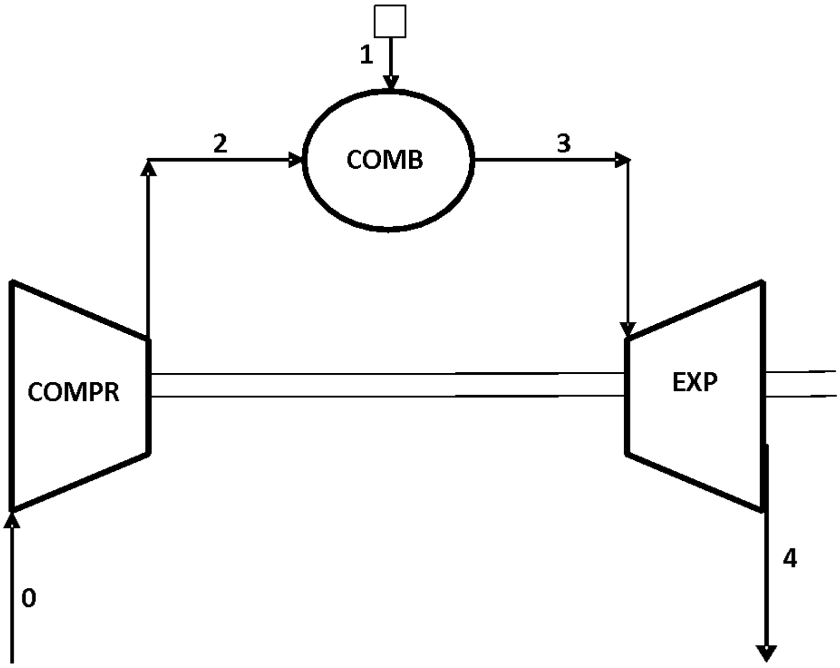
Grading

Maximum Score: 100 points

Grade	
A	100 – 90
B	90 – 76
C	76 – 62
D	62 – 55
E	55 – 50
Fx	50 – 49
F (fail)	< 49

The results will be posted no later than on June 28th 2019.

Good luck!



Physical Model

Simple gas turbine fed by CH_4 fuel:

Figure 1. Physical Model of the power plant

FLOW	TYPE
0	External air
1	Fuel (CH4)
2	Compressed air
3	Gases (mixture)
4	Gases (mixture)

Table 1. Flows

Some technical indications

PLANT PRODUCT: Wel,net = 20 MW
EXTERNAL AIR: T_0=25°C p_0=1 bar

Cost functions

<u>Air compressor</u>

$$Z_1 = \frac{c_{11} \cdot G_a}{c_{12} - \eta_c} \cdot \beta \cdot \ln \beta$$

<u>Combustor</u>

$$Z_2 = \frac{c_{21} \cdot G_a}{c_{22} - r_b} \cdot [1 + \exp(c_{23} \cdot T_3 - c_{24})]$$

<u>Gas Turbine (expander)</u>

$$Z_3 = \frac{c_{31} \cdot G_g}{c_{32} - \eta_t} \cdot \ln r_t \cdot [1 + \exp(c_{33} \cdot T_3 - c_{34})]$$

The economic parameters used in the investment cost functions are reported in Table 2:

c_{11} = 39.5 \$ / (kg/s)	c_{24} = 26.4
c_{12} = 0.9	c_{31} = 266.3 \$ / (kg/s)
c_{21} = 25.6 \$ / (kg/s)	c_{32} = 0.92
c_{22} = 0.995	c_{33} = 0.036 K^{-1}
c_{23} = 0.018 K^{-1}	c_{34} = 54.4

Table 2. Economic parameters in the investment cost functions of the plant components

Economic assumptions

To evaluate the economic cost (of components and fuel), the following terms have to be fixed:

- Capital Recovery Factor (CRF): See Table 3
- Maintenance Factor: φ = 1.05
- Number of operation hours per year: See Table 3
- Fuel (CH_4) cost: See Table 3

PERFORM:

Thermoeconomic optimization of the plant:

1. Perform a thermo-economic optimization of the plant, in nominal conditions
2. Make a sensitivity analysis of the optimal result when varying the cost of the fuel (CH_4) from -50% to +50% of the value indicated in the initial data

Environomic optimization of the plant:

3. Consider the CO as the contaminant emitted by the plant: find in the literature a suitable value of specific CO emissions from natural gas fed gas turbines, then add it in the environomic objective function; consider a pollution penalty factor $f_{p,CO}$ equal to 6.25; impose a cost of CO emission of 10 $/kg; find the optimal result, considering the cost of CH_4 in the nominal conditions
4. Make a sensitivity analysis of the optimum result towards the cost of kg of CO, ranging from 10 to 50 $/kg, still considering the cost of CH_4 in the nominal conditions

Comparison

5. Make a cross comparison between the effects of the cost of CH_4 (from point 2 above) and the imposition of a tax over the CO emissions (from point 4 above): which are your evaluations comparing the two situations?

Write a short report of your results (possibly, making use of graphical representations of the results) and be able to discuss the results in the oral exam.

Individual case data

The individual case data are shown in Table 3.

Table 3. Individual case data

Case no	**Fuel (natural gas) cost (c_f) [10^{-6} USD/kJ]**	**Number of operation hours per year (N)**	**Capital recovery factor**
1	4	6500	0.15
2	5	8000	0.25
3	6	7000	0.20
4	7	8000	0.15