Process Systems Engineering

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Exercise #4

Calculate the economic potential of the third level considering the following correlations for the installation and operation of the reactor and the compressor.
Consider that the index of Marshall & Swift is worth 1110. The costs are expressed in [€]. The factor allows to consider the influence of pressure and material cost.
Consider that the period of depreciation of equipment is 5 years for both the reactor and the compressor.
For the calculation of the investment costs of the reactor, the suggested ratio H/D = 6-10.

❖ Cost of installation of pressure vessels:

$$C.I._{\text{recipiente}} = \frac{M\,\&\,S}{280} 101.9 \cdot D^{1.066} H^{0.802} \left(2.18 + F_c\right)$$

with D and H in [ft].

P [psia]	≤ 50	100	200	300	400	500	600	700	800	900	1000
F_p	1.00	1.05	1.15	1.20	1.35	1.45	1.6	1.8	1.9	2.3	2.5

Material	Carbon Steel	Stainless steel (316)	Monel	Titanium
F_m	1.00	3.67	6.34	7.89

The cost of the reactor should be increased by 15% for refractory metal placed externally on the body for the purpose of thermal insulation.

Cost of installation of the centrifugal compressor

$$C.I._{\text{compressore}} = \frac{M\,\&\,S}{280} 517.5 \cdot bhp^{0.82} \left(2.11 + F_c\right)$$

with bhp (power of the motor shaft) in [hp] and $F_c = 1$.

The ideal work of compression for single stage units, whereas the isentropic adiabatic conditions, can be calculated as:

$$\tilde{\ell} = RT_1 \frac{\beta^{\gamma_{mix}} - 1}{\gamma_{mix}}$$

with $\beta = P_2 / P_1$ which considers an overall pressure drop of 6 atm equally distributed in sections downstream of the reactor and downstream of the compressor. The compressor sees the inlet gas at a temperature of 35 °C.

The γ_{mix} can be calculated as $\gamma_{mix} = \sum_{i=1}^{NC} x_i \gamma_i$, in which $\gamma_i = \left(c_{p,i} - c_{v,i}\right) / c_{p,i}$ (see table).

GAS	γ
monoatomic	0.4
Biatomic	0.29
More complex (CH_4, CO_2)	0.23

Consider that both the efficiency of real transformation (transformation deviation from ideal isentropic adiabatic) than that of the electric motor shaft is of 0.9.

The cost of electricity is 0.061095 €/kWh.

Provide the following plots:

- molar fraction of hydrogen in vent / Volume of the reactor as a function of temperature
- molar fraction of hydrogen in vent / Diameter of the reactor as a function of temperature
- molar fraction of hydrogen in vent / C. I. of the reactor as a function of temperature
- molar fraction of hydrogen in vent / Recycle flowrate R as a function of temperature
- molar fraction of hydrogen in vent / C. I. of the compressor as a function of temperature
- molar fraction of hydrogen in vent / O. C. of the compressor as a function of temperature
- molar fraction of hydrogen in vent / EP3 as a function of temperature

Compare the trends of the economic potential of the second and third level.