Thermodynamics of Energy Conversion

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EXERCISES 6

1) Calculate the Carnot efficiency and "real" efficiency of the steam turbine if the dry steam enters with 500°C and leaves the turbine with 120°C. How much coal does a power station with 1 GW_{el} use per day?

Carnot efficiency = 1-393K/773K = 0.49
Real efficiency = 1 – sqrt(393/773) = 0.29
m(Coal) = P[W]·t[s]/h[J/kg]·g[-] = 1GW·24h/h·9 kWh/kg = $2.7\cdot10^6$ kg/0.51 = 5510 t coal/day

2) Calculate the minimum adiabatic compression from 20°C and 1 bar in order to reach the auto ignition temperature of Methane (632°C)?

Adiabatic compression: $\Delta W = n\cdot c_V\cdot\Delta T$
from Chap. 4 we have:

$$\frac{p}{p_0} = \left(\frac{T}{T_0}\right)^{\frac{c_V}{R}+1}, \frac{c_V}{R} = \frac{7}{2} \textit{ for a polyatomic gas } (CH_4).$$

(905/293)^(9/2) = (p/p_0) = 160; p = p_0 · 160 = 160· 1 bar = 160 bar

3) Calculate the temperature and volume increase due to the combustion in the gas (CH_4) turbine. The combustion takes place with air.

$CH_4 + 2O_2 + 8\ N_2 \rightarrow CO_2 + 2H_2O + 8N_2$
$\Delta H_R = \Delta H_f(CO_2) + 2\Delta H_f(H_2O,g) - \Delta H_f(CH_4) - 2\Delta H_f(O_2)$
$= -393.5 + 2\cdot(-241.8) - (-74.9) – 0 = -802.2$ kJ

$c_p = c_p(CO_2) + 13c_p(H_2O,g) + 8c_p(N_2) = 37 + 2\cdot 34 + 8\cdot 29 = 337$ J/K

$\Delta T = \Delta H_R / c_p = 802200 / 337 = 2380$ K

$V/V_0 = T/T_0 = (2381 + 632 + 273) / (632 + 273) = 3.63$

4) Calculate the acceleration of an airplane, when it reaches 280 km/h in 30 sec. What is the consumption of fuel (m = 550 t) for the takeoff?

a = 280 / 3.6 m/s/30s = 2.6 m/s^2

Kinetic energy = 0.5·m·v2 = 0.5·550000kg·(280/3.6)^2 m^2/s^2 = $1.6\cdot10^6$ kJ = 444 kWh
Kerosene 12 kWh/kg, efficiency 30% -> Fuel consumption: 444kWh/12kWh/kg/0.3 = 124 kg.

5) Calculate the energy consumption of an airplane per passenger and 100 km. (A380, 10'000 km, 550 passenger, 130'000 kg kerosene)?

130000 kg/10000km/550·100km = 2.4 kg/passenger/100km

$2.4\ kg/passenger/100\ km \cdot 12\ kWh/kg = 28.8\ kWh/passenger/100\ km$