Thermodynamics of Energy Conversion

Prof. Dr. Andreas ZÜTTEL
Assistant: Yasemen Kuddusi

EXERCISES 5

1) What gas should be used and how should the Stirling engine be constructed in order to optimize the efficiency?

The smaller the term $c_V/ (R \cdot \ln(V_2/V_1)$ the larger the efficiency. Therefore, a monoatomic gas (He) and V_2 as large as possible compared to V_1.

2) What reduces the efficiency of a real Otto engine as compared to the calculated efficiency?

Temperature of the exhaust gas is higher than in the calculated cycle and the compression is limited due to self ignition.

3) The efficiency of the Diesel engine depends on the ratio V_1/V_4 and the ratio V_2/V_1. Calculate how the efficiency is maximized?

By maximizing the compression (V_4/V_1) up to 22 and minimize the injection (V_2/V_1). Technically, minimize the weight of the piston and the valves.

4) Calculate the temperature increase in the adiabatic compression of a diesel engine (1:22) and compare it with the autoignition temperature of 600 F = 315°C.

$(T/T_0) = (p/p_0)^{(R/(c_V+R))}$
$(T/T_0) = 22^{1/(3.5)} = 2.42$
$T = T_0 \cdot 2.42 = 293 \cdot 2.42 = 709$ K

The temperature is high enough for auto ignition.

5) Calculate the adiabatic temperature of the combustion of diesel ($C_{12}H_{26}$).

$C_{12}H_{26} + 18.5\ O_2 \rightarrow 12\ CO_2 + 13\ H_2O$

$\Delta H_R = c_p \Delta T$
$12\Delta H_f(CO_2) + 13\Delta H_f(H_2O,g) - \Delta H_f(C_{12}H_{26}) - 18.5\Delta H_f(O_2) = 12[c_p(CO_2)\cdot\Delta T + 13cp(H_2O)]\cdot\Delta T$
$\Delta H_R = 13 \cdot (-241.8) + 12 \cdot (-393.51) - 1 \cdot (-291) = -7574.5$ kJ
heat capacity of products in oxygen:
$c_p = 13 \cdot 34 + 12 \cdot 37 = 886$ J/K
$\Delta T = \Delta H_R / c_p = 7574.5 / 886 = 8549$ K
compustion in air (with nitrogen):
$c_p(N_2) = 74 \cdot 29 = 2146$ J/K
$\Delta T = \Delta H_R / c_p = 7574.5 / (886 + 2146) = 2498$ K