ise,feb03/aug06/feb09

Exercise 4

A gas-turbine powerplant is fired with methane. The flue gas is used for steam production. Methane, CH_4, has lower heating value 50 MJ/kg and a chemical exergy of 52,1 MJ/kg. Here, we assume that air, methane, and combustion products (i.e. the exhaust mixture) have constant specific heat capacity C_p =1,1 kJ/(kgK) and specidic heat ratio k=1,4. (Thus, for consitency, the gas constant $R = C_p(1-1/k)$). We also assume that the combustion chamber is adiabatic and with no pressure loss. The amount of air is 45 kg per kg fuel and combustion is complete.

a) Air and methane is available at 25 °C and 1 bar and are compressed to 15 bar prior to the combustion chamber. The isentropic efficiencies for the compressors are 0,85. Determine the temperature of the exhaust gas of the combustion chamber.
b) The exhaust from the combustion chamber is ducted into a turbine. What is the maximum work that theoretically could have been obtained from this gas? (In this instance, we neglect the fact that the composition in the gas is different from the surrounding air.)
c) Determine the irreversibility of the combustion chamber per kg of fuel.
d) The flue (exhaust) gas from the combustion chamber expands through a turbine with an isentropic efficiency of 0,90. The turbine powers the compressor and, in addition, delivers net work from the system. Determine the net work per kg fuel.
e) Determine the the thermomechanical (physical) exergy of the flue gas flowing out of the turbine (per kg flue gas and per kg fuel).
f) After the turbine the flue gas can be utilized in a flue-gas boiler (heat-recovery steam generator, HRSG) to produce steam. An enterprise make use of superheated steam at state 3 bar, 160 ºC. The have access to water at 25 ºC and 1 bar. The minimum temperature difference of the heat exchangers in the boiler must be at least 20 ºC, and the flue gas should not be cooled to a temperature below 60 ºC. We neglect heat losses from the boiler. How much steam can be produced (per kg fuel consumed in the gas-turbine combustion chamber)?
g) Determine the irreversibility of the compressor, turbine and boiler. Determine the exergy lost with the flue gas (i.e. after the boiler).
h) Put up a table over supplied, utilized and lost energy and exergy. (.... and now you have made an exergy analysis of a combined heat and power plant, CHP).
i) Indicate (without calculating) how the heat and power plant can obtain a higher degree of exergy utilization. The amount and state of the steam should be unchanged.