Sheet 2

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A. Simple Bryton cycle

1. Air enters the compressor of an ideal air-standard Brayton cycle at 100 kPa, 300 K, with a volumetric flow rate of 5 m^3/s. The compressor pressure ratio is 10. For turbine inlet temperatures ranging from 1000 to 1600 K, plot
   a) the thermal efficiency of the cycle.
   b) the back work ratio.
   c) the net power developed, in kW.

2. Consider an ideal air-standard Brayton cycle with minimum and maximum temperatures of 300 K and 1500 K, respectively. The pressure ratio is that which maximizes the net work developed by the cycle per unit mass of air flow. On a cold air-standard basis, calculate
   a) the compressor and turbine work per unit mass of air flow, each in kJ/kg.
   b) the thermal efficiency of the cycle.
   c) Plot the thermal efficiency versus the maximum cycle temperature ranging from 1200 to 1800 K.

3. Air enters the compressor of a gas turbine plant operating on Brayton cycle at 101.325 kPa, 27°C. The pressure ratio in the cycle is 6. Calculate the maximum temperature in the cycle and the cycle efficiency. Assume $W_T = 2.5\ W_C$, where W_T and W_C are the turbine and the compressor work respectively. Take $k_a = 1.4$.

4. In a gas turbine plant working on Brayton cycle, the air at inlet is 27°C,0.1 MPa. The pressure ratio is 6.25 and the maximum temperature is 800°C. The turbine and compressor efficiencies are each 80%. Find compressor work, turbine work, heat supplied, cycle efficiency and turbine exhaust temperature. Mass of air may be considered as 1 kg. Draw T-s diagram.

5. The compressor and turbine of a simple gas turbine each have isentropic efficiencies of 90%. The compressor pressure ratio is 12. The minimum and maximum temperatures are 290 K and 1400 K, respectively. compare the values of (a) the network per unit mass of air flowing, in kJ/kg, (b) the heat rejected per unit mass of air flowing, in kJ/kg, and (c) the thermal efficiency to the same quantities evaluated for an ideal cycle.

B. With Reheat, Regenerative and intercooling.

6. Air enters the turbine of a gas turbine at 1200 kPa, 1200 K, and expands to 100 kPa in two stages. Between the stages, the air is reheated at a constant pressure of 350 kPa to 1200 K. The expansion through each turbine stage is isentropic.

Determine, in kJ per kg of air flowing

(a) the work developed by each stage.

(b) the heat transfer for the reheat process.

(c) the increase in net work as compared to a single stage of expansion with no reheat.

7. A Brayton cycle with regeneration using air as the working fluid has a pressure ratio of 7. The minimum and maximum temperatures in the cycle are 310 and 1150 K. Assuming an isentropic efficiency of 75 percent for the compressor and 82 percent for the turbine and an effectiveness of 65 percent for the regenerator, determine (a) the air temperature at the turbine exit, (b) the network output, and (c) the thermal efficiency.

8. Consider an ideal gas-turbine cycle with two stages of compression and two stages of expansion. The pressure ratio across each stage of the compressor and turbine is 3. The air enters each stage of the compressor at 300 K and each stage of the turbine at 1200 K. Determine the backwork ratio and the thermal efficiency of the cycle, assuming (a) no regenerator is used and (b) a regenerator with 75 percent effectiveness is used

9. Consider a regenerative gas-turbine power plant with two stages of compression and two stages of expansion. The overall pressure ratio of the cycle is 9. The air enters each stage of the compressor at 300 K and each stage of the tur-bine at 1200 K. Accounting for the variation of specific heats with temperature, determine the minimum mass flow rate of air needed to develop a net power output of 110 MW.

10. Air enters the compressor of a gas turbine at 100 kPa, 300 K. The air is compressed in two stages to 900 kPa, with intercooling to 300 K between the stages at a pressure of 300 kPa. The turbine inlet temperature is 1480 K and the ex- pansion occurs in two stages, with reheat to 1420 K between the stages at a pressure of 300 kPa. The compressor and tur- bine stage efficiencies are 84 and 82%, respectively. The net power developed is 1.8 MW. Determine

    i. the volumetric flow rate, in m^3/s, at the inlet of each com- pressor stage.
    ii. the thermal efficiency of the cycle.
    iii. the back work ratio.

b. Reconsider Problem 10 but include a regenerator with an effectiveness of 75%.

11. A regenerative gas turbine power plant is shown in Fig.1. Air enters the compressor at 1 bar, 27°C with a mass flow rate of 0.562 kg/s and is compressed to 4 bar. The isentropic efficiency of the compressor is 80%, and the regenerator effectiveness is 90%. All the power developed by the high-pressure turbine is used to run the compressor. The low-pressure turbine provides the net power output. Each turbine has an isentropic efficiency of 87% and the temperature at the inlet to the high- pressure turbine is 1200 K. Determine

(a) the net power output, in kW.

(b) the thermal efficiency.

(c) the temperature of the air at states 2, 3, 5, 6, and 7, in K.

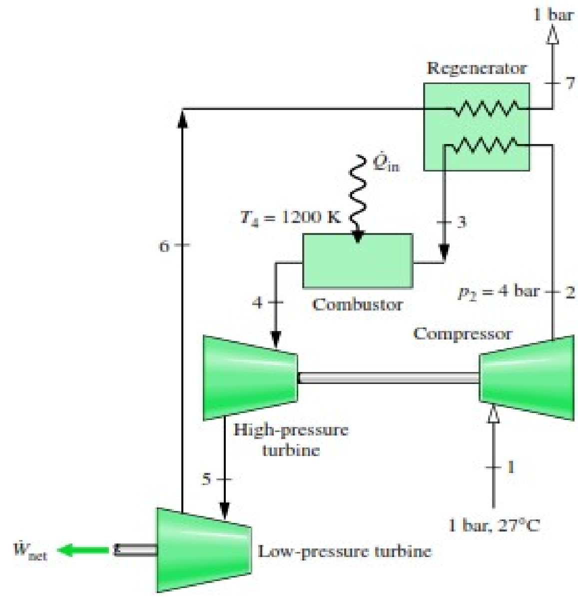

Fig.1

13. A 5400 kW gas turbine generating set operates with two compressor stages, the overall pressure ratio is 9 : 1. A high pressure turbine is used to drive the compressors, and a low-pressure turbine drives the generator. The temperature of the gases at entry to the high-pressure turbine is 625°C and the gases are reheated to 625°C after expansion in the first turbine. The exhaust gases leaving the low-pressure turbine are passed through a heat exchanger to heat the air leaving the high-pressure stage compressor. The compressors have equal pressure ratios and intercooling is complete between the stages. The air inlet temperature to the unit is 20°C. The isentropic efficiency of each compressor stage is 0.8, and the isentropic efficiency of each turbine stage is 0.85, the heat exchanger thermal ratio is 0.8. A mechanical efficiency of 95% can be assumed for both the power shaft and compressor turbine shaft. Neglecting all pressure losses and changes in kinetic energy calculate:

(i) The thermal efficiency (ii) Work ratio of the plant

(iii) The mass flow in kg/s.

Neglect the mass of the fuel and assume the following :

For air : c_{pa} = 1.005 kJ/kg K and k = 1.4.

14. In a closed cycle gas turbine there is a two stage compressor and a two stage turbine. All the components are mounted on the same shaft. The pressure and temperature at the inlet of the first stage compressor are 1.5 bar and 20°C. The maximum cycle temperature and pressure are limited to 750°C and 6 bar. A perfect intercooler is used between the two stage compressors and a reheater is used between the two turbines. Gases are heated in the reheater to 750°C before entering into the L.P. turbine. Assuming the compressor and turbine efficiencies as 0.82, calculate:

(i) The efficiency of the cycle without regenerator.

(ii) The efficiency of the cycle with a regenerator whose effectiveness is 0.70.

(iii) The mass of the fluid circulated if the power developed by the plant is 350 kW. The working fluid used in the cycle is air. For air :

$$K = 1.4 \text{ and } c_p = 1.005 \text{ kJ/kg K.}$$

15. A regenerative-reheat cycle has air entering at 1 bar, 300 K into compressor having intercooling in between the two stages of compression. Air leaving first stage of compression is cooled up to 290 K at 4 bar pressure in intercooler and subsequently compressed up to 8 bar. Compressed air leaving second stage compressor is passed through a regenerator having effectiveness of 0.80. Subsequent combustion chamber yields 1300 K at inlet to turbine having expansion up to 4 bar and then reheated up to 1300 K before being expanded up to 1 bar. Exhaust from turbine is passed through regenerator before discharged out of cycle. For the fuel having heating value of 42000 kJ/kg determine fuel-air ratio in each combustion chamber, total turbine work and thermal efficiency. Consider compression and expansion to be isentropic and air as working fluid throughout the cycle.

16. Air enters a gas turbine with two stages of compression and two stages of expansion at 100 kPa and 178C. This system uses a regenerator as well as reheating and intercooling. The pressure ratio across each compressor is 4; 300 kJ/kg of heat are added to the air in each combustion chamber; and the regenerator operates perfectly while increasing the temperature of the cold air by 208C. Determine this system's thermal efficiency. Assume isentropic operations for all compressor and the turbine stages and use constant specific heats at room temperature.