ME 306 : 2023 : Brayton Cycles

For standard analysis, assume $c_p = 1.0$ kJ/kg K and $\gamma = 1.4$.

1. Consider a standard Brayton cycle. Derive expressions for the efficiency, work ratio, and specific output in terms of the parameters r_p (pressure ratio) and θ (temperature ratio). For fixed values of compressor inlet temperature and turbine inlet temperature, determine the pressure ratio that maximises the specific output. For this pressure ratio, determine (a) specific output in terms of θ, (b) relation between compressor exit temperature and turbine exit temperature, and (c) Plot numerical values of η, work ratio, and w_{sp}/c_pT_1 against r_p for different values of θ, for $3 \leq r_p \leq 20$ and $3 \leq \theta \leq 5$.

2. Consider a Brayton cycle with reheat. Let r_p and θ be the pressure ratio for the compressor and the temperature ratio, respectively. Let r_{p1} and r_{p2} be the pressure ratios of the two turbines. Determine the values of r_{p1} and r_{p2} that maximise the specific output. For such an optimal-reheat cycle, what is the 'best' value of r_p for fixed θ?

3. Calculate the specific output and thermal efficiency of the following ideal gas turbine plants.
   (a) Basic plant: $r_p = 8$, compressor inlet at 300 K, turbine inlet at 1200 K.
   (b) Reheat plant: Equal pressure ratio for each turbine and the same inlet temperature for each turbine. Other details as in (a).
   (c) Intercooled plant: Equal pressure ratio for each compressor and the same inlet temperature for each compressor. Other details as in (a).
   (d) Regenerative plant: With an ideal regenerator. Other details as in (a).
   (e) A plant with reheat, intercooling, and regeneration, as specified in (a)–(d).
   (f) Compare and comment on the performance of the cycles from (a) to (e).

4. Rework the previous problem with a compressor efficiency of 0.80 and a turbine efficiency of 0.90

5. Air enters the compressor of an air-standard Brayton cycle at 100 kPa, 300 K, with a volumetric flow rate of 5 m^3/s. The turbine inlet temperature is 1400 K. The compressor pressure ratio is 8. Assuming isentropic efficiencies of compressor and turbine to be 85% each, calculate (i) the thermal efficiency of the cycle (ii) the back work ratio, and (iii) the net power developed, in kW

6. The compressor of a regenerative gas turbine has an isentropic efficiency of 90% while the turbine isentropic efficiency is 85%. The compressor pressure ratio is 12. The minimum and maximum temperatures in the cycle are 290 K and 1400 K, respectively. For regenerative effectiveness value of 80%, determine (i) the heat addition per unit mass of air flowing, in kJ/kg and (ii) the thermal efficiency

7. 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 expansion occurs in two stages, with reheat to 1420 K between the stages at a pressure of 300 kPa. The compressor and turbine stage efficiencies are 84% and 82%, respectively. The net power developed is 1.8 MW. Determine (i) the volumetric flow rate at the inlet of each compressor stage, (ii) the thermal efficiency of the cycle and (iii) the back work ratio.

8. A jet engine working on a clipped, standard Brayton cycle has compressor inlet state of 1 bar 300 K and turbine inlet state of 6 bar, 1500 K. The turbine produces just the right amount of power to drive the compressor. The turbine exhaust is expanded through a nozzle to a pressure of 1 bar. The nozzle exit area is 1 m^2. Determine (a) compressor exit temperature, (b) turbine exit temperature, (c) turbine exit pressure, (d) nozzle exit velocity, (e) mass flow rate of the working fluid, (f) power output of the turbine, and (g) static thrust.