Tutorial 10 –Diesel & Brayton Cycles

Note: numerical solution are based on one approach to solving the tutorial questions. Other approaches can also be correct and could lead to slightly different numerical answers.

Conceptual Questions:

1. How does an ideal Otto cycle differ from an ideal Diesel cycle?

2. Is the thermal efficiency of an Otto cycle expected to be higher or lower than that of a Diesel cycle? Why

3. Why does the Otto cycle have a lower compression ratio than the Diesel cycle?

4. An ideal Otto cycle with specified compression ratio is executed using (a) air, (b) argon, and (c) ethane as the working fluid. For which working fluid will the thermal efficiency be the highest? Why?

Problem Solving Questions

5. Consider an air-standard, ideal Diesel cycle has a compression ratio of 14. Air exists at T_1 = 30ºC and 100 kPa at the beginning of the compression process and the temperature increases to T_3 = 1450K at the end of the heat addition process. Assume air behaves as an ideal gas with constant specific heats with R = 0.287 kJ/kgK and C_v = 0.717 kJ.kgK.

a) Determine the cutoff ratio

b) Determine the heat rejected per unit mass

c) Determine the thermal efficiency.

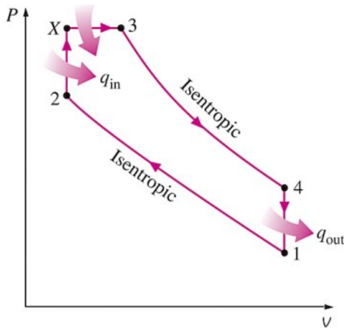
[ans: a) v_3/v_2 = 1.66, b) $\boldsymbol{q_{14} = 226.19\frac{kJ}{kg}}$, c)$\boldsymbol{\eta_{th,Diesel} = 61\%}$]

6. A Diesel engine has 6 cylinders each with a bore of 0.1m and a stroke of 0.11m. The engine has a compression ratio of 19 and is operating at 2000 RPM (revolutions per minute - each cycle takes two revolutions to complete the engine cycle). The mean effective pressure is 1400 kPa. Assume air behaves as an ideal gas with constant specific heats with R = 0.287 kJ/kgK and C_v = 0.717 kJ.kgK.

a. With the total of 6 cylinders, find the engine power in kW and in horsepower (hp).

[ans: a) $\dot{W} = 121kW \rightarrow 162\ hp$]

7. An air-standard dual cycle has a compression ratio of 14 and cutoff ratio of 1.2. The pressure ratio during the constant-volume heat addition process is 1.5. The initial pressure and temperature at the start of the isentropic compression process are 80 kPa and 20°C. Assume air behaves as an ideal gas with constant specific heats with R = 0.287 kJ/kgK and C_v = 0.717 kJ.kgK.



a. Determine the maximum pressure and temperature reached in the cycle.

b. Determine the overall heat added to the system.

c. Determine the thermal efficiency and MEP.

[ans: a) $P_X = 4827.9\ kPa,\ T_3 = 1516.4\ K,$ *b)* $q_{total} = 555.76\frac{kJ}{kg}$ *c)* $\eta_{th,dual} = 69.7\%;$ $MEP = 396.8\ kPa$*]*

8. A gas-turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 9. Air enters the compressor at 300 K, 100 kPa and enters the turbine at 1300 K.

a) Determine the maximum pressure in the cycle.

b) Determine the back work ratio.

c) Calculate the thermal efficiency.

[ans: a) P_{max} *= 900 kPa , b) BWR = 0.43, c)* $\boldsymbol{\eta_{th}} = \mathbf{46.6}\%$*]*

9. Consider an ideal closed Brayton cycle in which air enters the compressor at 300K, 100 kPa. Combustion adds 860 kJ/kg of heat in the burner. The maximum temperature is 1500 K. Assume air as an ideal gas with constant specific heats, C_P = 1.004 kJ/kgK, R = 0.287 kJ/kgK.

a) Determine the pressure ratio.

b) Determine the highest pressure in the cycle.

c) Determine the exhaust temperature (T_4) exiting the turbine.

d) Determine the cycle efficiency.

[ans: a) r_p *= 14.45, b)* P_{max} *= 1445 kPa, c)* T_4 *= 699.4K, d)* $\boldsymbol{\eta_{th}} = \mathbf{53.3}\%$*]*

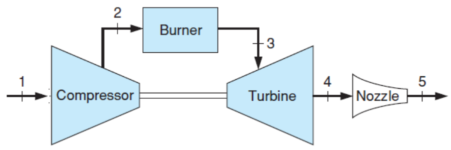
10. A jet aircraft operates on the open Brayton cycle. The aircraft is flying at an altitude of 4900 m where the ambient air pressure is 55 kPa and ambient air temperature is 260 K. The ambient air enters the compressor at these conditions with a mass flow rate of 10 kg/s. The pressure ratio across the compressor is 14. The maximum temperature of the cycle is 1450 K. The air exhausts from the turbine at 250 kPa and enters a nozzle where the air further exhausts to the atmospheric pressure of 55 kPa. Assume air behaves as an ideal gas with *variable* specific heats (i.e. use Table A7.1). Assume the turbine to operate isentropically, while compressor and nozzle operate adiabatically, but *irreversibly*.

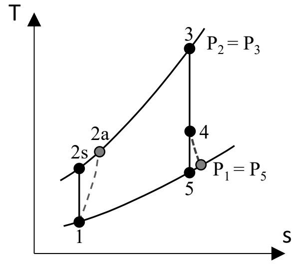
a) Determine energy required to operate the compressor in kW.

b) Determine heat delivered in the combustor in kW.

c) If the nozzle has an isentropic efficiency of 90%, determine the air velocity exiting the nozzle. Assume the velocity entering the nozzle is negligible to that leaving.

d) Determine the thrust force and propulsion efficiency if the aircraft is moving at a speed of 360 m/s.





[ans: a) $\dot{W}_c = 4099.8$*, b)* $\dot{Q}_{32} = 9050.9\ kW$ *c)* $V_{5,a} = 846.9\frac{m}{s}$*; d)* $F_{thrust} = 4869\ N,$ $\eta_{propulsion} = 19.4\%$*]*