Problem Sheet 7: Gas Power Cycles [From Chapter 9 of Moran and Shapiro]

9.3 At the beginning of the compression process of an air-standard Otto cycle, $p_1 = 1$ bar, $T_1 = 290$ K, $V_1 = 400$ cm^3. The maximum temperature in the cycle is 2200 K and the compression ratio is 8. Determine

(a) the heat addition, in kJ.
(b) the net work, in kJ.
(c) the thermal efficiency.
(d) the mean effective pressure, in bar.
(e) Develop a full accounting of the exergy transferred to the air during the heat addition, in kJ.
(f) Devise and evaluate an exergetic efficiency for the cycle.

Let $T_0 = 290$ K, $p_0 = 1$ bar.

9.4 Plot each of the quantities specified in parts (a) through (d) of Problem 9.3 versus the compression ratio ranging from 2 to 12.

9.7 An air-standard Otto cycle has a compression ratio of 7.5. At the beginning of compression, $p_1 = 85$ kPa and $T_1 = 32°$C. The mass of air is 2 g, and the maximum temperature in the cycle is 960 K. Determine

(a) the heat rejection, in kJ.
(b) the net work, in kJ.
(c) the thermal efficiency.
(d) the mean effective pressure, in kPa.

9.8 Consider a modification of the air-standard Otto cycle in which the isentropic compression and expansion processes are each replaced with polytropic processes having $n = 1.3$. The compression ratio is 9 for the modified cycle. At the beginning of compression, $p_1 = 1$ bar and $T_1 = 300$ K. The maximum temperature during the cycle is 2000 K. Determine

(a) the heat transfer and work per unit mass of air, in kJ/kg, for each process in the modified cycle.
(b) the thermal efficiency.
(c) the mean effective pressure, in bar.

9.13 The pressure and temperature at the beginning of compression of an air-standard Diesel cycle are 95 kPa and 300 K, respectively. At the end of the heat addition, the pressure is 7.2 MPa and the temperature is 2150 K. Determine

(a) the compression ratio.
(b) the cutoff ratio.
(c) the thermal efficiency of the cycle.
(d) the mean effective pressure, in kPa.

9.15 The conditions at the beginning of compression in an air-standard Diesel cycle are fixed by $p_1 = 200$ kPa, $T_1 = 380$ K. The compression ratio is 20 and the heat addition per unit mass is 900 kJ/kg. Determine

(a) the maximum temperature, in K.
(b) the cutoff ratio.
(c) the net work per unit mass of air, in kJ/kg.
(d) the thermal efficiency.
(e) the mean effective pressure, in kPa.
(f) To investigate the effects of varying compression ratio, plot each of the quantities calculated in parts (a) through (e) for compression ratios ranging from 5 to 25.

9.17 The displacement volume of an internal combustion engine is 5.6 liters. The processes within each cylinder of the engine are modeled as an air-standard Diesel cycle with a cutoff ratio of 2.4. The state of the air at the beginning of compression is fixed by $p_1 = 95$ kPa, $T_1 = 27°$C, and $V_1 = 6.0$ liters. Determine the net work per cycle, in kJ, the power developed by the engine, in kW, and the thermal efficiency, if the cycle is executed 1500 times per min.

9.20 At the beginning of compression in an air-standard Diesel cycle, $p_1 = 96$ kPa, $V_1 = 0.016$ m^3, and $T_1 = 290$ K. The compression ratio is 15 and the maximum cycle temperature is 1290 K. Determine

(a) the mass of air, in kg.
(b) the heat addition and heat rejection per cycle, each in kJ.
(c) the net work, in kJ, and the thermal efficiency.

9.22 An air-standard dual cycle has a compression ratio of 9. At the beginning of compression, $p_1 = 100$ kPa and $T_1 = 300$ K. The heat addition per unit mass of air is 1400 kJ/kg, with one half added at constant volume and one half added at constant pressure. Determine

(a) the temperatures at the end of each heat addition process, in K.
(b) the net work of the cycle per unit mass of air, in kJ/kg.
(c) the thermal efficiency.
(d) the mean effective pressure, in kPa.

9.25 The thermal efficiency, η, of a cold air-standard dual cycle can be expressed as

$$\eta = 1 - \frac{1}{r^{k-1}}\left[\frac{r_p r_c^k - 1}{(r_p - 1) + k r_p (r_c - 1)}\right]$$

where r is compression ratio, r_c is cutoff ratio, and r_p is the pressure ratio for the constant volume heat addition. Derive this expression.

9.28 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.

9.29 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 turbine inlet temperature is 1400 K. For compressor pressure ratios ranging from 2 to 20, plot

(a) the thermal efficiency of the cycle.
(b) the back work ratio.
(c) the net power developed, in kW.

9.32 The compressor inlet temperature for an ideal Brayton cycle is T_1 and the turbine inlet temperature is T_3. Using a cold air-standard analysis, show that the temperature T_2 at the compressor exit that maximizes the net work developed per unit mass of air flow is $T_2 = (T_1 T_3)^{1/2}$.