PROBLEM 9.22

KNOWN: An air-standard Diesel cycle has a known compression ratio and a specified state at the beginning of compression. The maximum cycle temperature is given.

FIND: Determine (a) the net work, (b) the thermal efficiency, (c) the mean effective pressure, and (d) the cutoff ratio.

SCHEMATIC & GIVEN DATA:

![Diagram of the Diesel cycle with states 0, 1, 2, 3, and 4, and given values for pressure, volume, and temperature.]

ENGINEERING MODEL: See Example 9.2.

ANALYSIS: Begin by fixing each principal state of the cycle. (Table A-72.)

State 1: \( T_1 = 520^\circ R \Rightarrow u_1 = 86.62 \text{ Btu/lb}, v_{r1} = 188.58 \)

State 2: For the isentropic compression

\[ v_{r2} = \left( \frac{V}{V_1} \right) v_{r1} = \left( \frac{1}{\eta_2} \right) 188.58 = 9.3282 \]

Thus, \( T_2 = 1534.5^\circ R, h_2 = 378.32 \text{ Btu/lb} \)

State 3: \( T_3 = 4000^\circ R \Rightarrow h_3 = 1088.3 \text{ Btu/lb}, v_{r3} = .4518 \)

State 4: For the isentropic expansion

\[ \frac{V_4}{V_3} = \frac{V}{V_2} = \frac{V}{V_3 - T_3} = (17) \frac{1534.5}{4000} = 6.522 \]

and \( v_{r4} = \frac{v_4}{v_3} v_{r3} = 2.4466 \)

Thus, \( T_4 = 2253.7^\circ R, u_4 = 421.25 \text{ Btu/lb} \)

(a) For the cycle, \( W_{cycle} = Q_{cycle} \). Thus

\[ W_{cycle} = Q_{23} - Q_{41} = m \left[ (h_3 - h_2) - (u_4 - u_1) \right] \]

Evaluating \( m \)

\[ m = \frac{P_0 V_1}{R T_1} = \frac{(410 \text{ lb/lft}^2) (2 \text{ ft}^3)}{(28.7 \text{ lb} \cdot \text{R})(520^\circ R)} = 0.1454 \text{ lb} \]

Thus

\[ W_{cycle} = \left[ (1088.3 - 378.32) - (421.25 - 86.62) \right] \frac{\text{Btu}}{\text{lb}} = 54.87 \text{ Btu} \]

(b) The thermal efficiency is

\[ \eta = \frac{W_{cycle}}{Q_{23}} = \frac{W_{cycle}}{m(h_3 - h_2)} = \frac{54.87 \text{ Btu}}{(0.1454 \text{ lb})(1088.3 - 378.32) \text{Btu/lb}} = 0.531 (53.1\%) \]

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Problem 9-22 continued

(c) The mean effective pressure is

\[
\text{mep} = \frac{W_{\text{cycle}}}{(V_1 - V_2)} = \frac{W_{\text{cycle}}}{V_1(1 - V_2/V_1)}
\]

\[
= \frac{54.87 \text{ Btu}}{(2 \text{ ft}^3)(1 - \frac{1}{7})} \bigg| \begin{array}{c}
178 \text{ ft} \cdot \text{lb} \\
1 \text{ Btu}
\end{array} \bigg| \frac{144 \text{ in.}^2}{144 \text{ in.}^2} \bigg| \frac{144 \text{ in.}^2}{144 \text{ in.}^2} \bigg| \text{mep}
\]

\[
= \frac{157.5 \text{ lb} \cdot \text{in.}^2}{\text{mep}}
\]

(d) The cutoff ratio is determined as follows:

\[
r_c = \frac{V_2}{V_2} = \frac{T_2}{T_2} = \frac{4000}{1534.5} = 2.61 \frac{\text{lb} \cdot \text{in.}^2}{\text{mep}}
\]