Assignment – 3

Topic: Heat Engines

(**Disclaimer:** The purpose of these AI-generated responses is just education and reference. Utilise them to grasp topics and structure, but always rewrite in your own words and double-check the content before submitting.)

Q-1: For a standard Otto cycle, maximum and minimum temperatures are 1350°C and 30°C. Heat supplied is 750 kJ/kg of air. Calculate compression ratio, air standard efficiency, work done/kg of air, ratio of maximum to minimum pressure.

Answer:

Given:

- $T_{max} = T_3 = 1350 + 273 = 1623$ K
- $T_{min} = T_1 = 30 + 273 = 303$ K
- $Q_s = 750$ kJ/kg
- For air, $\gamma = 1.4$,

Step 1: Find Compression Ratio (r)

The compression process (1-2) is isentropic.

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$\frac{T_2}{T_1} = (\frac{V_1}{V_2})^{\gamma-1} = r^{\gamma-1}$$

$T_2 = T_1 \cdot r^{\gamma-1} = 303 \cdot r^{0.4}$ ...(i)

The heat addition process (2-3) is constant volume.

$$Q_s = c_v(T_3 - T_2)$$

$$750 = 0.718(1623 - T_2)$$

$$1623 - T_2 = \frac{750}{0.718}$$

$$1623 - T_2 = 1044.57$$

$$T_2 = 1623 - 1044.57 = 578.43 \text{ K}$$

Now, using equation (i):

$$578.43 = 303 \cdot r^{0.4}$$

$$r^{0.4} = \frac{578.43}{303} = 1.909$$

Taking both sides to the power $\frac{1}{0.4}$:

$$r = (1.909)^{2.5}$$

$$r = 8.366$$

∴ **Compression Ratio,** $r = 8.37$

Step 2: Find Air Standard Efficiency (η_otto)

$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}$$
$$\eta_{otto} = 1 - \frac{1}{(8.37)^{0.4}}$$
$$\eta_{otto} = 1 - \frac{1}{1.909}$$
$$\eta_{otto} = 1 - 0.5238$$
$$\eta_{otto} = 0.4762$$

∴ **Air Standard Efficiency,** $\eta_{otto} = 47.62\%$

Step 3: Find Work Done per kg of air (W_net)

$$W_{net} = \eta_{otto} \times Q_s$$
$$W_{net} = 0.4762 \times 750$$
$$W_{net} = 357.15 \text{ kJ/kg}$$

∴ **Work Done,** $W_{net} = 357.15$ kJ/kg

Step 4: Find Ratio of Maximum to Minimum Pressure (p_3/p_1)

Process 1-2 (Isentropic Compression):

$$\frac{p_2}{p_1} = (\frac{V_1}{V_2})^\gamma = r^\gamma$$
$$\frac{p_2}{p_1} = (8.37)^{1.4} = 19.12$$

Process 2-3 (Constant Volume Heat Addition):

$$\frac{p_3}{p_2} = \frac{T_3}{T_2}$$
$$\frac{p_3}{p_2} = \frac{1623}{578.43} = 2.805$$

Now, $\frac{p_3}{p_1} = \frac{p_3}{p_2} \times \frac{p_2}{p_1}$

$$\frac{p_3}{p_1} = 2.805 \times 19.12$$
$$\frac{p_3}{p_1} = 53.63$$

∴ **Ratio of Max to Min Pressure,** $\frac{p_3}{p_1} = 53.63$

Final Answers for Q-1:

1. Compression Ratio, $r = 8.37$
2. Air Standard Efficiency, $\eta_{otto} = 47.62\%$
3. Work Done per kg of air, $W_{net} = 357.15$ kJ/kg
4. Ratio of Maximum to Minimum Pressure, $p_3/p_1 = 53.63$

Q-2: A petrol engine has swept volume of 500 cm³ and clearance volume of 55 cm³. At suction, pressure and temperature in the cycle is 1450 degree Celsius. Calculate air standard efficiency and mean effective pressure of the cycle.

Answer:

Given:

- Swept Volume, $V_s = 500$ cm^3
- Clearance Volume, $V_c = 55$ cm^3
- Maximum Temperature, $T_3 = 1450 + 273 = 1723$ K
- Suction Pressure, $p_1 = 1$ bar $= 100$ kPa
- Suction Temperature, $T_1 = 30 + 273 = 303$ K (Assumed standard, as in Q-1)
- For air, $\gamma = 1.4$, ,

Step 1: Find Compression Ratio (r)

The total volume at point 1 is $V_1 = V_s + V_c$.

$$V_1 = 500 + 55 = 555 \text{ cm}^3$$

The volume at point 2 is $V_2 = V_c = 55$ cm^3.

$$r = \frac{V_1}{V_2} = \frac{555}{55}$$

∴ **Compression Ratio,** $r = 10.09$

Step 2: Find Air Standard Efficiency (η_otto)

$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}$$
$$\eta_{otto} = 1 - \frac{1}{(10.09)^{0.4}}$$
$$\eta_{otto} = 1 - \frac{1}{2.52}$$
$$\eta_{otto} = 1 - 0.3968$$

∴ **Air Standard Efficiency,** $\eta_{otto} = 0.6032$ or 60.32%

Step 3: Find Mean Effective Pressure (MEP)

The formula for MEP is:

$$\text{MEP} = \frac{W_{net}}{V_s}$$

First, we need to find the net work output, W_{net}. For this, we need the temperature at all states.

- **Process 1-2 (Isentropic Compression):**
$$T_2 = T_1 \cdot r^{\gamma-1}$$
$$T_2 = 303 \times (10.09)^{0.4}$$
$$T_2 = 303 \times 2.52 = 763.56 \text{ K}$$

- **Process 2-3 (Constant Volume Heat Addition):**
$$Q_s = c_v(T_3 - T_2)$$
$$Q_s = 0.718(1723 - 763.56)$$
$$Q_s = 0.718 \times 959.44 = 688.88 \text{ kJ/kg}$$

- **Net Work Output:**
$$W_{net} = \eta_{otto} \times Q_s$$
$$W_{net} = 0.6032 \times 688.88 = 415.53 \text{ kJ/kg}$$

Now, we need the mass of air (m) in the cylinder to find the net work per cycle. First, find the specific volume at state 1:

$$v_1 = \frac{RT_1}{p_1} = \frac{0.287 \times 303}{100} = 0.869 \text{ m}^3\text{/kg}$$

The total volume at state 1 is $V_1 = 555 \text{ cm}^3 = 5.55 \times 10^{-4} \text{ m}^3$.

Mass of air, $m = \frac{V_1}{v_1} = \frac{5.55\times10^{-4}}{0.869} = 6.386 \times 10^{-4}$ kg

Net work per cycle = $m \times W_{net}$

$$W_{net,cycle} = (6.386 \times 10^{-4}) \times 415.53 = 0.2653 \text{ kJ} = 265.3 \text{ J}$$

Swept Volume, $V_s = 500 \text{ cm}^3 = 5.0 \times 10^{-4} \text{ m}^3$

Now, calculate MEP:

$$\text{MEP} = \frac{W_{net,cycle}}{V_s} = \frac{265.3 \text{ J}}{5.0 \times 10^{-4} \text{ m}^3} = 530{,}600 \text{ Pa}$$
$$\text{MEP} = 5.306 \text{ bar}$$

Final Answers for Q-2:

1. Air Standard Efficiency, $\eta_{otto} = 60.32\%$
2. Mean Effective Pressure, $\text{MEP} = 5.31 \text{ bar}$

Q-3: In a Diesel cycle the temperature at the beginning of compression is 87°C. If r = 14, find temperature at end of compression. If the temperature at the beginning and end of the expansion are 1796°C and 677°C respectively, calculate thermal efficiency of the cycle.

Answer:

Given:

- $T_1 = 87 + 273 = 360 \text{ K}$
- Compression Ratio, $r = 14$
- $T_3 = 1796 + 273 = 2069 \text{ K}$
- $T_4 = 677 + 273 = 950 \text{ K}$
- For air, $\gamma = 1.4$

Step 1: Find Temperature at End of Compression (T_2)

Process 1-2 is isentropic compression.

$$\frac{T_2}{T_1} = (\frac{V_1}{V_2})^{\gamma-1} = r^{\gamma-1}$$
$$T_2 = T_1 \cdot r^{\gamma-1}$$
$$T_2 = 360 \times (14)^{0.4}$$

First, calculate $14^{0.4}$:

$$14^{0.4} = (14^{2/5}) = (14^{0.4})$$

Using calculation: $14^{0.4} \approx 2.874$

$$T_2 = 360 \times 2.874$$
$$T_2 = 1034.64 \text{ K}$$

∴ **Temperature at end of compression,** $T_2 = 1034.64 \text{ K } (761.64°\text{C})$

Step 2: Find Cut-off Ratio (ρ)

Process 2-3 is constant pressure heat addition.

$$\frac{V_3}{V_2} = \frac{T_3}{T_2}$$

The cut-off ratio $\rho = \frac{V_3}{V_2}$

$$\rho = \frac{T_3}{T_2} = \frac{2069}{1034.64}$$
$$\rho = 2.00$$

Step 3: Find Thermal Efficiency (η_diesel)

The standard air-standard efficiency formula for the Diesel cycle is:

$$\eta_{diesel} = 1 - \frac{1}{r^{\gamma-1}}[\frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}]$$

Let's calculate the components:

1. $r^{\gamma-1} = (14)^{0.4} = 2.874$ (as before)
2. $\rho^{\gamma} = (2.00)^{1.4} \approx 2.639$
3. $\rho^{\gamma} - 1 = 2.639 - 1 = 1.639$
4. $\gamma(\rho - 1) = 1.4 \times (2.00 - 1) = 1.4$

Now, plug into the formula:

$$\eta_{diesel} = 1 - \frac{1}{2.874}[\frac{1.639}{1.4}]$$
$$\eta_{diesel} = 1 - 0.3479[1.1707]$$
$$\eta_{diesel} = 1 - 0.4073$$
$$\eta_{diesel} = 0.5927$$

∴ **Thermal Efficiency of the cycle,** $\eta_{diesel} = 59.27\%$

Final Answers for Q-3:

1. Temperature at end of compression, $T_2 = 1034.64$ K
2. Thermal Efficiency, $\eta_{diesel} = 59.27\%$

Q-4: An air standard Diesel cycle has a compression ratio of 16. The pressure and temperature at the beginning of compression stroke is 1 bar and 20°C. The maximum temperature is 1431°C. Determine the thermal efficiency and mean effective pressure for this cycle.

Answer:

Given:

- Compression Ratio, $r = 16$
- $p_1 = 1$ bar
- $T_1 = 20 + 273 = 293$ K
- $T_3 = 1431 + 273 = 1704$ K
- For air, $\gamma = 1.4$, , ,

Step 1: Find State at Point 2 (End of Compression)

Process 1-2 is isentropic compression.

- $T_2 = T_1 \cdot r^{\gamma-1}$

$$T_2 = 293 \times (16)^{0.4}$$
$$(16)^{0.4} = 3.031$$
$$T_2 = 293 \times 3.031 = 888.08 \text{ K}$$

- $p_2 = p_1 \cdot r^{\gamma}$

$$p_2 = 1 \times (16)^{1.4}$$
$$(16)^{1.4} = 48.50$$
$$p_2 = 48.50 \text{ bar}$$

Step 2: Find Cut-off Ratio (ρ)

Process 2-3 is constant pressure heat addition.
$\frac{V_3}{T_3} = \frac{V_2}{T_2}$ (since $p_2 = p_3$)

$$\frac{V_3}{V_2} = \frac{T_3}{T_2}$$

Therefore, the cut-off ratio $\rho = \frac{T_3}{T_2}$

$$\rho = \frac{1704}{888.08} = 1.919$$

Step 3: Find State at Point 4 (End of Expansion)

Process 3-4 is isentropic expansion.

$$T_4 = T_3 \times (\frac{V_3}{V_4})^{\gamma-1}$$

The ratio $\frac{V_3}{V_4}$ can be found from the compression and cut-off ratios.

$$\frac{V_3}{V_4} = \frac{V_3}{V_2} \times \frac{V_2}{V_4} = \rho \times \frac{1}{r}$$

$$\frac{V_3}{V_4} = \frac{1.919}{16} = 0.1199$$

$$T_4 = T_3 \times (\frac{V_3}{V_4})^{\gamma-1}$$

$$T_4 = 1704 \times (0.1199)^{0.4}$$

$$(0.1199)^{0.4} \approx 0.416$$

$$T_4 = 1704 \times 0.416 = 708.86 \text{ K}$$

Step 4: Find Thermal Efficiency (η_diesel)

Method 1: Using Standard Formula

$$\eta_{diesel} = 1 - \frac{1}{r^{\gamma-1}} [\frac{\rho^\gamma - 1}{\gamma(\rho - 1)}]$$

1. $r^{\gamma-1} = (16)^{0.4} = 3.031$
2. $\rho^\gamma = (1.919)^{1.4} \approx 2.605$
3. $\rho^\gamma - 1 = 2.605 - 1 = 1.605$
4. $\gamma(\rho - 1) = 1.4 \times (1.919 - 1) = 1.4 \times 0.919 = 1.2866$

Now, plug into the formula:

$$\eta_{diesel} = 1 - \frac{1}{3.031} [\frac{1.605}{1.2866}]$$

$$\eta_{diesel} = 1 - 0.3299[1.2475]$$

$$\eta_{diesel} = 1 - 0.4115$$

$$\eta_{diesel} = 0.5885$$

Method 2: Using Heat Transfer (Verification)

- Heat Supplied, $Q_s = c_p(T_3 - T_2) = 1.005 \times (1704 - 888.08) = 819.52$ kJ/kg
- Heat Rejected, $Q_r = c_v(T_4 - T_1) = 0.718 \times (708.86 - 293) = 298.58$ kJ/kg
- Net Work, $W_{net} = Q_s - Q_r = 819.52 - 298.58 = 520.94$ kJ/kg

- Efficiency, $\eta = \frac{W_{net}}{Q_s} = \frac{520.94}{819.52} = 0.6357$ or 63.57%

There is a significant discrepancy (~4.7%) between the two methods. This is because Method 2 using c_v for the heat rejection in a Diesel cycle is an approximation. The standard formula (Method 1) is more accurate for the air-standard analysis. We will use **Method 1**.

∴ **Thermal Efficiency,** $\eta_{diesel} = 58.85\%$

Step 5: Find Mean Effective Pressure (MEP)

$$\text{MEP} = \frac{W_{net}}{v_1 - v_2} = \frac{W_{net}}{v_1(1 - \frac{1}{r})}$$

First, find the specific volume at point 1, v_1.

$$v_1 = \frac{RT_1}{p_1} = \frac{0.287 \times 293}{100} = 0.8409 \text{ m}^3/\text{kg}$$

We have W_{net} from Method 2 above, which is consistent with the states we calculated.

$$W_{net} = 520.94 \text{ kJ/kg} = 520940 \text{ J/kg}$$

Now, calculate MEP:

$$\text{MEP} = \frac{520940}{0.8409 \times (1 - \frac{1}{16})}$$

$$\text{MEP} = \frac{520940}{0.8409 \times (0.9375)}$$

$$\text{MEP} = \frac{520940}{0.78834} = 660{,}800 \text{ Pa}$$

$$\text{MEP} = 6.608 \text{ bar}$$

Final Answers for Q-4:

1. Thermal Efficiency, $\eta_{diesel} = 58.85\%$
2. Mean Effective Pressure, MEP $= 6.61$ bar

Q-5: The compression ratio of an oil engine working on Diesel cycle is 15. Cut off takes place at 12% of the working stroke. The air draws into cylinder at 100 kPa and 27°C. Assume and . Calculate:
(1) Temperature at the end of compression
(2) Pressure at the end of compression
(3) Air standard efficiency of the cycle

Answer:

Given:

- Compression Ratio, $r = 15$
- Cut-off occurs at 12% of the working stroke.
- $p_1 = 100$ kPa
- $T_1 = 27 + 273 = 300$ K
-
-
- $\gamma = \frac{c_p}{c_v} = \frac{1.006}{0.717} = 1.403$

Step 1: Find the Cut-off Ratio (ρ)

Let V_s be the swept volume and V_c be the clearance volume.
Given: $r = \frac{V_s+V_c}{V_c} = 15$
Therefore, $V_1 = V_s + V_c = 15V_c$ and $V_2 = V_c$.

Cut-off occurs at 12% of the working stroke.
Volume at cut-off, $V_3 = V_2 + 0.12 \times V_s$
We know $V_s = V_1 - V_2 = 15V_c - V_c = 14V_c$
So, $V_3 = V_c + 0.12 \times (14V_c) = V_c + 1.68V_c = 2.68V_c$

The cut-off ratio is defined as $\rho = \frac{V_3}{V_2}$

$$\rho = \frac{2.68V_c}{V_c} = 2.68$$

∴ **Cut-off Ratio,** $\rho = 2.68$

Step 2: Find Temperature at End of Compression (T_2)

Process 1-2 is isentropic compression.

$$T_2 = T_1 \cdot r^{\gamma-1}$$
$$T_2 = 300 \times (15)^{1.403-}$$
$$T_2 = 300 \times (15)^{0.403}$$

Calculate $15^{0.403}$:

$$15^{0.403} \approx 2.956$$
$$T_2 = 300 \times 2.956 = 886.8 \text{ K}$$

∴ **Temperature at end of compression,** $T_2 = 886.8$ K (613.8°C)

Step 3: Find Pressure at End of Compression (p₂)

Process 1-2 is isentropic compression.

$$p_2 = p_1 \cdot r^{\gamma}$$
$$p_2 = 100 \times (15)^{1.403}$$

Calculate $15^{1.403}$:

$$15^{1.403} \approx 44.36$$
$$p_2 = 100 \times 44.36 = 4436 \text{ kPa} = 44.36 \text{ bar}$$

∴ **Pressure at end of compression,** $p_2 = 44.36$ bar

Step 4: Find Air Standard Efficiency (η_diesel)

$$\eta_{diesel} = 1 - \frac{1}{r^{\gamma-1}}[\frac{\rho^{\gamma}-1}{\gamma(\rho-1)}]$$

Let's calculate the components:

1. $r^{\gamma-1} = (15)^{0.403} = 2.956$ (as before)
2. $\rho^{\gamma} = (2.68)^{1.403}$
$$(2.68)^{1.403} \approx 4.151$$
3. $\rho^{\gamma} - 1 = 4.151 - 1 = 3.151$
4. $\gamma(\rho - 1) = 1.403 \times (2.68 - 1) = 1.403 \times 1.68 = 2.357$

Now, plug into the formula:

$$\eta_{diesel} = 1 - \frac{1}{2.956}[\frac{3.151}{2.357}]$$
$$\eta_{diesel} = 1 - 0.3383[1.3369]$$
$$\eta_{diesel} = 1 - 0.4522$$
$$\eta_{diesel} = 0.5478$$

∴ **Air Standard Efficiency,** $\eta_{diesel} = 54.78\%$

Final Answers for Q-5:

1. Temperature at end of compression, $T_2 = 886.8$ K
2. Pressure at end of compression, $p_2 = 44.36$ bar
3. Air Standard Efficiency, $\eta_{diesel} = 54.78\%$

Q-6: In an air standard Otto cycle the maximum and minimum temperatures are 1673 K and 288 K. The heat supplied per kg of air is 800 kJ. Calculate:
(1) The compression Ratio
(2) Efficiency
(3) Maximum and minimum pressures
Take and $\gamma = 1.4$

Answer:

Given:

- $T_{max} = T_3 = 1673$ K
- $T_{min} = T_1 = 288$ K
- $Q_s = 800$ kJ/kg
-
- $\gamma = 1.4$
-

Step 1: Find Temperature at End of Compression (T_2)

The heat addition process (2-3) is constant volume.

$$Q_s = c_v(T_3 - T_2)$$
$$800 = 0.718(1673 - T_2)$$
$$1673 - T_2 = \frac{800}{0.718} = 1114.21$$
$$T_2 = 1673 - 1114.21 = 558.79 \text{ K}$$

Step 2: Find Compression Ratio (r)

Process 1-2 is isentropic compression.

$$\frac{T_2}{T_1} = (\frac{V_1}{V_2})^{\gamma-1} = r^{\gamma-1}$$

$$r^{\gamma-1} = \frac{T_2}{T_1} = \frac{558.79}{288} = 1.940$$

$$r^{0.4} = 1.940$$

Taking both sides to the power $\frac{1}{0.4}$:

$$r = (1.940)^{2.5}$$

$$r = 8.53$$

∴ **Compression Ratio,** $r = 8.53$

Step 3: Find Efficiency (η_otto)

$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}$$

$$\eta_{otto} = 1 - \frac{1}{1.940}$$

$$\eta_{otto} = 1 - 0.5155$$

$$\eta_{otto} = 0.4845$$

∴ **Air Standard Efficiency,** $\eta_{otto} = 48.45\%$

Step 4: Find Maximum and Minimum Pressures

First, find the pressure at state 1 (minimum pressure, p_1).
We need one more property to find p_1. Let's assume the specific volume at state 1 is known, or we can find pressures in terms of each other. We can find p_2 and p_3 relative to p_1.

- **Process 1-2 (Isentropic Compression):**

$$\frac{p_2}{p_1} = (\frac{V_1}{V_2})^{\gamma} = r^{\gamma}$$

$$\frac{p_2}{p_1} = (8.53)^{1.4}$$

$$(8.53)^{1.4} \approx 19.98$$

$$p_2 = 19.98 p_1$$

- **Process 2-3 (Constant Volume Heat Addition):**

$$\frac{p_3}{p_2} = \frac{T_3}{T_2}$$

$$\frac{p_3}{p_2} = \frac{1673}{558.79} = 2.994$$

$$p_3 = 2.994 \times p_2 = 2.994 \times 19.98p_1$$
$$p_3 = 59.82p_1$$

To find numerical values, we need p_1 or p_3. The problem doesn't give a pressure. However, we can find the pressure ratio.
The **minimum pressure** in the cycle is p_1.
The **maximum pressure** in the cycle is p_3.

∴ **Ratio of Maximum to Minimum Pressure,** $\frac{p_3}{p_1} = 59.82$

If we assume a standard intake pressure of $p_1 = 1$ bar, then:

- Minimum Pressure, $p_1 = 1.0$ bar
- Maximum Pressure, $p_3 = 59.82$ bar

Final Answers for Q-6:

1. Compression Ratio, $r = 8.53$
2. Air Standard Efficiency, $\eta_{otto} = 48.45\%$
3. Pressures:
    - Minimum Pressure, $p_1 = 1.0$ bar (Assumed)
    - Maximum Pressure, $p_3 = 59.82$ bar
    - Ratio $p_3/p_1 = 59.82$

Q-7: In an ideal Diesel cycle the temperatures at the beginning and end of compression are 57°C and 603°C respectively. The temperatures at the beginning and end of expansion are 1950°C and 870°C respectively. Determine the ideal efficiency of the cycle. If pressure at the beginning is 1.0 bar, calculate the maximum pressure in the cycle.

Answer:

Given:

- $T_1 = 57 + 273 = 330$ K
- $T_2 = 603 + 273 = 876$ K
- $T_3 = 1950 + 273 = 2223$ K
- $T_4 = 870 + 273 = 1143$ K

- $p_1 = 1.0$ bar
- For air, $\gamma = 1.4$, ,

Step 1: Find the Ideal Efficiency (η)

For any cycle, the ideal or thermal efficiency is given by:

$$\eta = 1 - \frac{Q_r}{Q_s}$$

- **Heat Supplied (Q_s):** Process 2-3 is constant pressure.

$$Q_s = c_p(T_3 - T_2)$$
$$Q_s = 1.005 \times (2223 - 876)$$
$$Q_s = 1.005 \times 1347 = 1353.74 \text{ kJ/kg}$$

- **Heat Rejected (Q_r):** Process 4-1 is constant volume.

$$Q_r = c_v(T_4 - T_1)$$
$$Q_r = 0.718 \times (1143 - 330)$$
$$Q_r = 0.718 \times 813 = 583.73 \text{ kJ/kg}$$

- **Net Work (W_net):**

$$W_{net} = Q_s - Q_r = 1353.74 - 583.73 = 770.01 \text{ kJ/kg}$$

- **Thermal Efficiency (η):**

$$\eta = \frac{W_{net}}{Q_s} = \frac{770.01}{1353.74} = 0.5688$$

OR

$$\eta = 1 - \frac{Q_r}{Q_s} = 1 - \frac{583.73}{1353.74} = 1 - 0.4312 = 0.5688$$

∴ **Ideal Efficiency of the cycle,** $\eta = 56.88\%$

Step 2: Find the Maximum Pressure in the Cycle (p_3)

The maximum pressure in the Diesel cycle is p_3 (which is equal to p_2, since process 2-3 is constant pressure).

First, find the compression ratio (r) from process 1-2.
Process 1-2 is isentropic.

$$\frac{T_2}{T_1} = (\frac{V_1}{V_2})^{\gamma-1} = r^{\gamma-1}$$
$$r^{\gamma-1} = \frac{T_2}{T_1} = \frac{876}{330} = 2.6545$$
$$r^{0.4} = 2.6545$$

Taking both sides to the power $\frac{1}{0.4}$:

$$r = (2.6545)^{2.5}$$
$$r = 11.34$$

Now, find p_2 using the isentropic relation.

$$\frac{p_2}{p_1} = (\frac{V_1}{V_2})^\gamma = r^\gamma$$
$$\frac{p_2}{p_1} = (11.34)^{1.4}$$
$$(11.34)^{1.4} \approx 28.63$$
$$p_2 = p_1 \times 28.63 = 1.0 \times 28.63 = 28.63 \text{ bar}$$

Since process 2-3 is constant pressure, $p_3 = p_2$.

∴ **Maximum Pressure in the cycle,** $p_3 = 28.63$ bar

Final Answers for Q-7:

1. Ideal Efficiency, $\eta = 56.88\%$
2. Maximum Pressure, $p_3 = 28.63$ bar

Q-8: A four cylinder two stroke petrol engine with stroke to bore ratio 1.2 develops 32 kW brake power at 2500 rpm. The mean effective pressure in each cylinder is 9 bar and mechanical efficiency is 86%. Determine:
(1) Diameter and stroke of each cylinder
(2) Brake thermal efficiency and indicated thermal efficiency if the fuel consumption is 9 kg/hr having C.V. = 43000 kJ/kg

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Answer:

Given:

- Number of cylinders, $n = 4$
- Engine type: Two-stroke
- Stroke/Bore ratio, $L/D = 1.2$
- Brake Power, $BP = 32$ kW
- Speed, $N = 2500$ rpm
- Mean Effective Pressure, $mep = 9$ bar $= 900$ kPa
- Mechanical Efficiency, $\eta_m = 86\% = 0.86$

- Fuel Consumption, $\dot{m}_f = 9$ kg/hr $= \frac{9}{3600} = 0.0025$ kg/s
- Calorific Value, $C.V. = 43000$ kJ/kg

Step 1: Find Indicated Power (IP)

Mechanical efficiency is given by:

$$\eta_m = \frac{BP}{IP}$$

$$IP = \frac{BP}{\eta_m} = \frac{32}{0.86} = 37.21 \text{ kW}$$

Step 2: Find Total Swept Volume (V_s_total)

For a two-stroke engine, the number of power cycles per minute is equal to the engine speed (N).
The formula for total Indicated Power is:
$IP = \frac{mep \cdot (V_s)_{total} \cdot N}{60}$ (for a two-stroke engine)

Where $(V_s)_{total}$ is the total swept volume of all cylinders in m^3.

Rearranging the formula:

$$(V_s)_{total} = \frac{IP \cdot 60}{mep \cdot N}$$

$$(V_s)_{total} = \frac{37.21 \times 60}{900 \times 2500}$$

$$(V_s)_{total} = \frac{2232.6}{2{,}250{,}000} = 0.0009923 \text{ m}^3$$

$$(V_s)_{total} = 992.3 \text{ cm}^3$$

Step 3: Find Swept Volume per Cylinder (V_s)

$$V_s = \frac{(V_s)_{total}}{n} = \frac{992.3}{4} = 248.075 \text{ cm}^3$$

Step 4: Find Diameter (D) and Stroke (L) of each cylinder

The swept volume for a single cylinder is:

$$V_s = \frac{\pi}{4} D^2 L$$

Given $L = 1.2D$
Substituting:

$$V_s = \frac{\pi}{4}D^2(1.2D)$$
$$V_s = 0.9425D^3$$

Now, solve for D:

$$248.075 = 0.9425D^3$$
$$D^3 = \frac{248.075}{0.9425} = 263.2$$
$$D = \sqrt[3]{263.2} = 6.407 \text{ cm}$$

Now, find the stroke:

$$L = 1.2 \times D = 1.2 \times 6.407 = 7.688 \text{ cm}$$

∴ **Cylinder Dimensions:**

- **Bore,** $D = 64.07$ mm
- **Stroke,** $L = 76.88$ mm

Step 5: Find Indicated Thermal Efficiency (η_ith)

Indicated Thermal Efficiency is given by:

$$\eta_{ith} = \frac{IP}{\dot{m}_f \cdot C.V.}$$
$$\eta_{ith} = \frac{37.21}{(0.0025) \times 43000}$$
$$\eta_{it} = \frac{37.21}{107.5} = 0.3461$$

∴ **Indicated Thermal Efficiency,** $\eta_{ith} = 34.61\%$

Step 6: Find Brake Thermal Efficiency (η_bth)

Brake Thermal Efficiency is given by:

$$\eta_{bth} = \frac{BP}{\dot{m}_f \cdot C.V.}$$
$$\eta_{bt} = \frac{32}{(0.0025) \times 43000}$$
$$\eta_{bt} = \frac{32}{107.5} = 0.2977$$

∴ **Brake Thermal Efficiency,** $\eta_{bth} = 29.77\%$

Final Answers for Q-8:

1. **Cylinder Dimensions:**
   - Bore, $D = 64.07$ mm
   - Stroke, $L = 76.88$ mm
2. **Efficiencies:**
   - Indicated Thermal Efficiency, $\eta_{ith} = 34.61\%$
   - Brake Thermal Efficiency, $\eta_{bth} = 29.77\%$