Engine Performance Calculation

Otto Cycle

An engine working on the constant volume cycle is 150 mm bore by 165 mm stroke, and its clearance volume is 0.5 litre. The fuel used has a calorific value of 45250 kJ/kg, and the consumption is 0.334 kg/kWh. The mechanical efficiency of the engine is 81%. Take = 1.4

Calculate:

1. The compression ratio
2. The ideal efficiency
3. The indicated thermal efficiency
4. The efficiency ratio.

Given

Bore = 150 mm = 0.150 m

Stroke = 165 mm = 0.165 m

Clearance volume $V_c = 0.5$ L $= 0.0005$ m^3

Calorific value $CV = 45\,250$ kJ/kg

Fuel consumption = 0.334 kg/kWh (assume **brake** specific fuel consumption)

Mechanical efficiency $\eta_m = 0.81$

Ratio of specific heats $\gamma = 1.4$

Find:

1. Compression ratio r
2. Ideal (Otto) thermal efficiency η_{ideal}
3. Indicated thermal efficiency η_{ind}

4. Efficiency ratio $= \dfrac{\eta_{\text{ind}}}{\eta_{\text{ideal}}}$

1. Compression ratio

Swept volume (displacement) of one cylinder:

$$V_d = \frac{\pi}{4}D^2 \times \text{stroke} = \frac{\pi}{4}(0.150)^2(0.165) = 0.00291579 \text{ m}^3.$$

Compression ratio

$$r = \frac{V_d + V_c}{V_c} = \frac{0.00291579 + 0.0005}{0.0005} = 6.8316.$$

2. Ideal (Otto) thermal efficiency

For a constant-volume (Otto) cycle:

$$\eta_{\text{ideal}} = 1 - \frac{1}{r^{\gamma-1}}.$$

With $r = 6.8316,\ \gamma = 1.4$,

$$\eta_{\text{ideal}} = 1 - r^{1-\gamma} = 1 - r^{-0.4} \approx 0.53635 = 53.635\%.$$

3. Indicated thermal efficiency

First calculate the brake (output) energy per kWh of output: 1 kWh=3600 kJ

Fuel energy input per kWh of brake output:

$$E_{\text{fuel}} = \text{SFOC} \times CV = 0.334 \text{ kg/kWh} \times 45\,250 \text{ kJ/kg} = 15\,113.5 \text{ kJ/kWh}.$$

For 1 kW break power, $E_{\text{fuel}} = 15\,113.5$ kJ/h.

$$E_{\text{fuel}} = \frac{15\,113.5}{3600} = 4.1982 \text{ kJ/s} = 4.1982 \text{ kW}$$

$$\eta_m = \frac{BP}{IP} = \frac{1}{IP} = 0.81\%.$$

$$IP = \frac{1}{0.81} = 1.2346 \text{ kW}$$

$$\eta_{\text{ind}} = \frac{IP}{E_{\text{fuel}}} = \frac{1.2346\ kW}{4.1982\ kW} = 29.4\%$$

4. Efficiency ratio

$$\text{Efficiency ratio} = \frac{\eta_{\text{ind}}}{\eta_{\text{ideal}}} = \frac{0.294}{0.5363} \approx 0.5482 \quad (54.82\%).$$

Final Answers

- **A. Compression ratio:** $\boxed{r \approx 6.832}$
- **B. Ideal (Otto) efficiency:** $\boxed{\eta_{\text{ideal}} \approx 0.5363 = 53.63\%}$
- **C. Indicated thermal efficiency:** $\boxed{\eta_{\text{ind}} \approx 0.2941 = 29.4\%}$
- **D. Efficiency ratio:** $\boxed{\frac{\eta_{\text{ind}}}{\eta_{\text{ideal}}} \approx 0.5482 = 54.82\%}$