

Engine course

Exercise II: Gas engine

Solutions:

- 1) Total engine displacement: $V_{cyl} = 9.96 \text{ [L]} \Rightarrow 1 \text{ cylinder} = V_u = 1.66 \text{ Liter} = L \cdot (\pi \cdot D/4)^2$

Stroke: L ($\Rightarrow L/2 = 71 \text{ mm}$)	142 [mm]
Bore: D	122 [mm]
Compression ratio: χ	12:1
Connecting rod length: l	228 [mm]
Ratio of connecting rod: $\lambda = (L/2) / l$	$= 71 / 228 = 0.311$
Clearance volume: V_o ($V_u + V_o$) / $V_o = 12 \Rightarrow V_u/V_o = 11$	0.151 [dm³]
Displaced volume V_u	1.66 [dm³]
Cylinder volume V_c	1.811 [dm³]

- 2) Pressure inside intake manifold: $P_{intake} = \pi_c \cdot P_0 = \pi_c \cdot P_1 = 1.52 \text{ bar}$

Intake temperature (isentropic relations): $T_{intake} = T_0 \cdot \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} = 298 \cdot (1.50)^{0.286} = 334.6 \text{ K}$

Air flow rate:

$$\dot{M}_{air,real} = \eta_{vol} \cdot \dot{M}_{air,ideal} = \eta_{vol} \cdot \rho_{intake} \cdot V_{cyl} \cdot \frac{N}{120} = 0.92 \cdot \frac{1.52 \cdot 10^5}{287 \cdot 334} \cdot 0.00996 \cdot \frac{1500}{120} = \mathbf{0.1816 \text{ [kg/s]}}$$

3) $R_{A/C} = 4.773 \cdot \left(v + \frac{w}{4} + x - \frac{y}{2} \right) \cdot \frac{28.85}{\tilde{m}_f} \xrightarrow{v=1, w=4} R_{A/C} = 17.2$

$$\dot{M}_{CH_4} = \dot{M}_{air} \cdot \frac{1}{R_{A/F}} \cdot \frac{1}{\lambda} = 0.1816 \cdot \frac{1}{17.2} \cdot \frac{1}{1.7} = \mathbf{6.21 \text{ [g/s]}}$$

- 4) Taking into account the very high octane number of methane (RON = 120), i.e. a very high resistance to autoignition, this engine is operating with **spark ignition mode** meaning that the engine is equipped with an ignition system. Moreover, the lower flammable limit ($\lambda=2$) is above the operating lambda ratio ($\lambda=1,7$). This implicates that this gas engine is indeed operating in **homogenous mixture (lean burn operation)**.

- 5) Effective power: $\dot{E}_e = \eta_e \cdot \dot{Y}_{comb} = 0.40 \cdot (LHV_{CH_4} \cdot \dot{M}_{CH_4}) = 0.40 \cdot 50'020 \cdot 0.00621 =$
= 124.2 [kW] or 169 [hp]

Effective torque: $C_e = \frac{\dot{E}_e \cdot 60}{N \cdot 2\pi} = \frac{124.2 \cdot 1000 \cdot 60}{1500 \cdot 2\pi} = \mathbf{791 \text{ [Nm]}}$

Brake mean effective pressure: $BMEP = \frac{4\pi \cdot C_e}{100 \cdot V_{cyl}} = \mathbf{9.97 \text{ [bar]}}$

Brake specific fuel consumption: $BSFC = \frac{\dot{M}_{CH4}}{\dot{E}_e} = \frac{6.21 \cdot 3600}{124.2} = \mathbf{180 \text{ [g/kWh]}}$

6) Indicated efficiency: $\eta_i = \frac{\eta_e}{\eta_{org}} = \frac{0.40}{0.90} = \mathbf{44.4 \text{ [%]}}$

Indicated power: $\dot{E}_i = \eta_i \cdot \dot{Y}_{comb} = 0.44 \cdot (LHV_{CH4} \cdot \dot{M}_{CH4}) = 0.44 \cdot 50'020 \cdot 0.00621 =$
 $= \mathbf{137.9 \text{ [kW]}} \quad \text{or} \quad \mathbf{187.5 \text{ [ch]}}$

Indicated mean pressure: $IMEP = \frac{\dot{E}_i \cdot 1200}{V_{cyl} \cdot N} = \frac{137.9 \cdot 1200}{9.96 \cdot 1500} = \mathbf{11.07 \text{ [bar]}}$

Note: The BMEP / IMEP ratio gives logically the friction efficiency of the engine:

$$\eta_{org} = \frac{BMEP}{IMEP} = \frac{9.97}{11.07} = 90 \%$$

Indicated specific fuel consumption: $ISFC = \frac{\dot{M}_{CH4}}{\dot{E}_i} = \frac{6.21 \cdot 3600}{137.9} = \mathbf{162.1 \text{ [g/kWh]}}$

Note: For 1000 operating hours, 2223 kg of gas are required to compensate the engine friction losses.

7) Effective power with a supercharging heat exchanger (Outlet temperature of 40°C):

$$\dot{E}_e = \eta_e \cdot \underbrace{\frac{N}{60 \cdot n_{TM}}}_{n_c} \cdot \eta_{vol} \cdot \underbrace{\frac{P_{coll}}{r \cdot T_{coll}} \cdot V_{cyl}}_{M_A} \cdot \underbrace{\frac{LHV}{R_{AF} \cdot \lambda}}_q = \mathbf{132.6 \text{ [kW]}}$$

