Engine course

Exercise II: Gas engine

Solutions:

1) Total engine displacement: V_{cyl} = 9.96 [L] => 1 cylinder = V_u = 1.66 Liter = L * (Π * D/4))^2

Stroke: *L (=> L/2 = 71 mm)*	**142 [mm]**
Bore: *D*	**122 [mm]**
Compression ratio: χ	**12:1**
Connecting rod length: *l*	**228 [mm]**
Ratio of connecting rod: λ= *(L/2) / l*	**=71 / 228 = 0.311**
Clearance volume: V_0 (Vu + Vo) / Vo = 12 => Vu/Vo = 11	**0.151 [dm^3]**
Displaced volume V_u	**1.66 [dm^3]**
Cylinder volume V_c	**1.811 [dm^3]**

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

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

Air flow rate:

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

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

$$\dot{M}_{CH4} = \dot{M}_{air} \cdot \frac{1}{R_{A/F}} \cdot \frac{1}{\lambda} = 0.1816 \cdot \frac{1}{17.2} \cdot \frac{1}{1.7} = \textbf{6.21 [g/s]}$$

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 (λ=2) is above the operating lambda ratio (λ=1,7). This implicates that this gas engine is indeed operating in **homogenous mixture (lean burn operation)**.

5) Effective power: $\dot{E}_e = \eta_e \cdot \dot{Y}_{comb} = 0.40 \cdot \left(LHV_{CH4} \cdot \dot{M}_{CH4}\right) = 0.40 \cdot 50'020 \cdot 0.00621 =$

= 124.2 [kW] or 169 [hp]

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

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

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

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

Indicated power: $$\dot{E}_i = \eta_i \cdot \dot{Y}_{comb} = 0.44 \cdot \left(PCI_{CH4} \cdot \dot{M}_{CH4}\right) = 0.44 \cdot 50'020 \cdot 0.00621 =$$

= 137.9 [kW] **or** **187.5 [ch]**

Indicated mean pressure: $$IMEP = \frac{\dot{E}_i \cdot 1200}{V_{cyl} \cdot N} = \frac{136.6 \cdot 1200}{9.96 \cdot 1500} = \textbf{11.07 [bar]}$$

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: $$ISFC = \frac{\dot{M}_{CH4}}{\dot{E}_i} = \frac{6.21 \cdot 3600}{137.9} = \textbf{162.1 [g/kWh]}$$

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):

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