7-1-1 [OIC] A four-cylinder four-stroke engine operates at 4000 rpm. The bore and stroke are 100 mm each, the MEP is measured as 0.6 MPa, and the thermal efficiency is 35%. Determine (a) the power produced by the engine in kW, (b) the waste heat in kW, (c) and the volumetric air intake in L/s.

SOLUTION

The net work of one cylinder can be found after finding the displacement volume

$$V_d = \frac{\pi d^2}{4} L;$$

$$\Rightarrow V_d = \frac{\pi (0.1)^2}{4} (0.1);$$

$$\Rightarrow V_d = 0.0079 \text{ m}^3$$

$$W_{\text{net}} = \text{MEP} \times V_d;$$

$$\Rightarrow W_{\text{net}} = (600)(0.00079);$$

$$\Rightarrow W_{\text{net}} = 0.474 \text{ kJ}$$

The power produced by the engine is obtained as

$$\dot{W}_{\text{net,total}} = n_C \frac{N}{2} W_{\text{net}};$$

$$\Rightarrow \dot{W}_{\text{net,total}} = (4)\frac{(4000)}{(2)(60)}(0.474);$$

$$\Rightarrow \dot{W}_{\text{net,total}} = 63.2 \text{ kW}$$

Knowing the thermal efficiency

$$\dot{Q}_{\text{in}} = \frac{\dot{W}_{\text{net,total}}}{\eta_{\text{th}}};$$

$$\Rightarrow \dot{Q}_{\text{in}} = \frac{63.2}{0.35};$$

$$\Rightarrow \dot{Q}_{\text{in}} = 180.57 \text{ kW}$$

Therefore, the waste heat is

$$\dot{Q}_{\text{out}} = \dot{Q}_{\text{in}} - \dot{W}_{\text{net}};$$

$$\Rightarrow \dot{Q}_{\text{out}} = 180.57 - 63.2;$$

$$\Rightarrow \dot{Q}_{\text{out}} = 117.37 \text{ kW}$$

The volumetric air intake is

$$\dot{V}_{\text{air}} = \dot{n}_C V_d;$$

$$\Rightarrow \dot{V}_{\text{air}} = \frac{(4000)}{(2)(60)}(0.00079);$$

$$\Rightarrow \dot{V}_{\text{air}} = 0.0263\frac{\text{m}^3}{\text{s}} = 26.3\frac{\text{L}}{\text{s}}$$

TEST Solution Use the PG (or IG based on problem statement) reciprocating closed-cycle TESTcalc to verify the solution. The TEST-code for this problem can be found in the problem module of the professional TEST site at www.thermofluids.net.

7-1-2 [OIV] A six-cylinder four-stroke engine operating at 3000 rpm produces 200 kW of total brake power. If the cylinder displacement is 1 L, determine (a) the net work output in kJ per cylinder per cycle, (b) the MEP and (c) the fuel consumption rate in kg/h. Assume the heat release per kg of fuel to be 30 MJ and the thermal efficiency to be 40%.

SOLUTION

The net work output from a single cylinder can be obtained as

$$W_{\text{net}} = \frac{2\dot{W}_{\text{net,total}}}{n_C N};$$

$$\Rightarrow W_{\text{net}} = \frac{(2)(200)(60)}{(6)(3000)};$$

$$\Rightarrow W_{\text{net}} = 1.33 \text{ kJ}$$

The MEP, can be obtained as

$$\text{MEP} = \frac{W_{\text{net}}}{V_d};$$

$$\Rightarrow \text{MEP} = \frac{1.33}{0.001};$$

$$\Rightarrow \text{MEP} = 1333.3 \text{ kPa}$$

Knowing the thermal efficiency

$$\dot{Q}_{\text{in}} = \frac{\dot{W}_{\text{net,total}}}{\eta_{\text{th}}};$$

$$\Rightarrow \dot{Q}_{\text{in}} = \frac{200}{0.40};$$

$$\Rightarrow \dot{Q}_{\text{in}} = 500 \text{ kW}$$

The fuel consumption rate can be obtained as

$$\dot{m}_F = \frac{\dot{Q}_{\text{in}}}{q_{\text{comb}}};$$

$$\Rightarrow \dot{m}_F = \frac{(500)(3600)}{30000};$$

$$\Rightarrow \dot{m}_F = 60 \ \frac{\text{kg}}{\text{hr}}$$

TEST Solution Use the PG (or IG based on problem statement) reciprocating closed-cycle TESTcalc to verify the solution. The TEST-code for this problem can be found in the problem module of the professional TEST site at www.thermofluids.net.

7-1-3 [OIQ] A four-cylinder two-stroke engine operating at 2000 rpm produces 50 kW of total brake power. If the cylinder displacement is 1 L, determine (a) the net work output in kJ per cylinder per cycle, (b) the MEP and (c) the fuel consumption rate in kg/h. Assume the heat release per kg of fuel to be 35 MJ and the thermal efficiency to be 30%.

SOLUTION

The net work output from a single cylinder can be obtained as

$$W_{\text{net}} = \frac{\dot{W}_{\text{net,total}}}{n_C N};$$

$$\Rightarrow W_{\text{net}} = \frac{(50)(60)}{(4)(2000)};$$

$$\Rightarrow W_{\text{net}} = 0.375\text{ kJ}$$

The MEP, can be obtained as

$$\text{MEP} = \frac{W_{\text{net}}}{V_d};$$

$$\Rightarrow \text{MEP} = \frac{0.375}{0.001};$$

$$\Rightarrow \text{MEP} = 375\text{ kPa}$$

Knowing the thermal efficiency

$$\dot{Q}_{\text{in}} = \frac{\dot{W}_{\text{net,total}}}{\eta_{\text{th}}};$$

$$\Rightarrow \dot{Q}_{\text{in}} = \frac{50}{0.30};$$

$$\Rightarrow \dot{Q}_{\text{in}} = 166.67\text{ kW}$$

The fuel consumption rate can be obtained as

$$\dot{m}_F = \frac{\dot{Q}_{\text{in}}}{q_{\text{comb}}};$$

$$\Rightarrow \dot{m}_F = \frac{(166.67)(3600)}{35000};$$

$$\Rightarrow \dot{m}_F = 17.14\ \frac{\text{kg}}{\text{hr}}$$

TEST Solution Use the PG (or IG based on problem statement) reciprocating closed-cycle TESTcalc to verify the solution. The TEST-code for this problem can be found in the problem module of the professional TEST site at www.thermofluids.net.

7-1-4 [OIT] A six-cylinder engine with a volumetric efficiency of 90% and a thermal efficiency of 38% produces 200 kW of power at 3000 rpm. The cylinder bore and stroke are 100 mm and 200 mm respectively. If the condition of air in the intake manifold is 95 kPa and 300 K, determine (a) the mass flow rate of air in kg/s, (b) the fuel consumption rate in kg/s and (c) the specific fuel consumption in kg/kWh. Assume the heating value of the fuel to be 35 MJ/kg of fuel.

SOLUTION

The displacement volume is as follows

$$V_d = \frac{\pi d^2}{4} L;$$

$$\Rightarrow V_d = \frac{\pi (0.1)^2}{4}(0.2);$$

$$\Rightarrow V_d = 0.0016 \text{ m}^3$$

The flow rate of air can be calculated as

$$\rho_i = \frac{p_i}{RT_i}$$

$$\dot{m}_a = \eta_v \frac{\rho_i n_C V_d N}{2};$$

$$\Rightarrow \dot{m}_a = \eta_v \frac{p_i n_C V_d N}{2RT_i};$$

$$\Rightarrow \dot{m}_a = (0.90)\frac{(95)(6)(0.0016)(3000)}{(2)(0.287)(300)(60)};$$

$$\Rightarrow \dot{m}_a = 0.238 \ \frac{\text{kg}}{\text{s}}$$

The fuel consumption rate can be obtained as

$$\dot{Q}_{\text{in}} = \frac{\dot{W}_{\text{net,total}}}{\eta_{\text{th}}};$$

$$\Rightarrow \dot{Q}_{\text{in}} = \frac{200}{0.38};$$

$$\Rightarrow \dot{Q}_{\text{in}} = 526.3 \text{ kW}$$

$$\dot{m}_F = \frac{\dot{Q}_{\text{in}}}{q_{\text{comb}}};$$

$$\Rightarrow \dot{m}_F = \frac{526.3}{35000};$$

$$\Rightarrow \dot{m}_F = 0.015 \ \frac{\text{kg}}{\text{s}}$$

The specific fuel consumption in kg/kW·hr

$$\text{sfc} = \frac{\dot{m}_F}{\dot{W}_{\text{net,total}}};$$

$$\Rightarrow \text{sfc} = \frac{(0.015)(3600)}{200};$$

$$\Rightarrow \text{sfc} = 0.27 \ \frac{\text{kg}}{\text{kW}\cdot\text{hr}}$$

TEST Solution Use the PG (or IG based on problem statement) reciprocating closed-cycle TESTcalc to verify the solution. The TEST-code for this problem can be found in the problem module of the professional TEST site at www.thermofluids.net.