ME410

Internal Combustion Engines

Fall 2002

Test 1

September 19, 2002

Name________________________________

Box_________________________________

Grade___________________________

Instructions

1. Closed text, notes, and neighbor.
2. Partial credit will be given as merited if you show your work.
3. If you are not sure what is being asked, be sure and check with me.
4. Refer as needed to the reference page attached.

1. List four (4) important differences between the design and operating characteristics of spark-ignition and compression ignition engines. For full credit, each difference must be clearly stated.

a) CI inducts air, injects fuel just before combustion.
SI inducts mixture of air and fuel.

b) CI combustion is spontaneous, due to high temperature and pressure at end of compression stroke. SI combustion initiated by spark.

c) CI usually turbocharged. SI usually not turbocharged.

d) CI burns diesel oil, SI burns gasoline. (There are some exceptions.) Also CI runs far leaner.

Also, CI engines must be more heavily built. Compression ratios higher in CI (12-24 vs, 8-12 in SI)

2. A 4-cylinder spark-ignition (2003 Honda Civic DX) engine has the following characteristics.

- Bore = 75.0 mm, Stroke = 95.4 mm
- Each cylinder has clearance volume of 50174 mm^3.
- Maximum brake power of 115 hp (85.76 kW) at 6100 RPM

For the questions below, be sure and give correct units.

a) Calculate the engine's displacement. (All cylinders.)

For one cylinder, $V_{dc} = \frac{\pi}{4} B^2 L = \frac{3.14159(75)^2(95.4)}{4} = 421464 \text{mm}^3$

For engine $V_d = 4V_{dc} = 1.686 \times 10^6 \text{ mm}^3 = 1.686 \text{ L}$

b) Calculate the compression ratio.

$$r_c = \frac{V_{dc} + V_c}{V_c} = \frac{421464 + 50174}{50174} = 9.4$$

c) Calculate the torque at maximum power.

$$T = \frac{P}{2\pi N} = \frac{\left(85.76 \times 10^3 \frac{\text{N} - \text{m}}{\text{s}}\right)}{2\pi\left(\frac{6100}{60} \frac{1}{\text{s}}\right)} = 134.2 \text{ N} - \text{m} = 99 \text{ ft} - \text{lb}$$

d) Calculate the brake mean effective pressure at maximum power.

$$\text{bmep} = \frac{P_b n_R}{N V_d} = \frac{\left(85.76 \times 10^3 \frac{\text{N} - \text{m}}{\text{s}}\right)(2)}{\left(\frac{6100}{60} \frac{1}{\text{s}}\right)\left(1.686 \times 10^{-3} \text{m}^3\right)} = 1.001 \times 10^6 \frac{\text{N}}{\text{m}^3} = 1001 \text{KPa}$$

bmep = 145.1 psi

e) Calculate the mean piston speed.

$$\overline{S}_p = 2LN = 2(95.4 \text{ mm})\left(\frac{6100}{60} \frac{1}{\text{s}}\right) = 19398 \frac{\text{mm}}{\text{s}} = 19.4 \text{ m/s}$$

3. This is a follow up to the previous question. Here is some additional data.

- The PV plot of an individual cylinder has an enclosed area of 500 N-m at the 6100 rpm maximum power engine speed.
- The engine is consuming a fuel whose heating value 42000 kJ/kg at a rate of 0.005 kg/sec.
- The mass flow rate of air is 0.0775 kg/sec. Air density is 1.183 kg/m^3.

a) What is the indicated work per cycle for a cylinder? For the whole engine?

Individual cylinder 500 N-m per cycle.
So for entire engine work per cycle is 2000 N-m.
(You have to remember that enclosed pV area is work per cycle.)

b) Calculate the engine's indicated power.

$$P_i = \frac{W_{c,i} N}{n_R} = \frac{(2000\ \text{N}-\text{m})\left(\frac{6100}{60\ \text{s}}\right)}{2} = 101.7 \times 10^3 \frac{\text{N}-\text{m}}{\text{s}} = 101.7\ \text{kW}$$

c) What is the engine's mechanical efficiency?

$$\eta_m = \frac{P_b}{P_i} = \frac{85.76}{101.7} = .84$$

d) What is the engine's volumetric efficiency?

$$\eta_v = \frac{2\dot{m}_a}{\rho_{a,i} V_d N} = \frac{2\left(0.0775\frac{\text{kg}}{\text{s}}\right)}{\left(1.183\frac{\text{kg}}{\text{m}^3}\right)\left(1.686\times10^{-3}\text{m}^3\right)\left(\frac{6100}{60\ \text{s}}\right)} = 0.764$$

e) What is the F/A ratio?

$$F/A = \frac{\dot{m}_f}{\dot{m}_a} = \frac{0.005\frac{\text{kg}}{\text{s}}}{0.0775\frac{\text{kg}}{\text{s}}} = 0.06452 \qquad \text{A/F}=15.5$$

f) What is the engine's fuel conversion efficiency? (Based on brake power.)

$$\eta_f = \frac{P}{\dot{m}_f Q_{HV}} = \frac{\left(85.76\frac{\text{kJ}}{\text{s}}\right)}{\left(0.005\frac{\text{kg}}{\text{s}}\right)\left(42000\frac{\text{kJ}}{\text{kg}}\right)} = 0.4084$$

4. Ethanol, whose chemical formula is C_2H_5OH (or C_2H_6O) is burned in air with a fuel air equivalence ratio of 1.0. Write a balanced chemical formula which describes this process. Calculate the mole fractions of the exhaust products.

$$C_2H_6O + a(O_2 + 3.773N_2) = bCO_2 + cH_2O + dN_2$$

Carbon: $2 = b$

Hydrogen: $6 = 2c$

Oxygen: $1 + 2a = 2b + c$

Nitrogen: $2a(3.773) = 2d$

Solving, we find that a = 3, b = 2, c = 3, and d = 11.32

Total number of moles of product is 16.32

Moles fractions:

CO2: 2/16.32 = 0.123

H2O: 3/16.32 = 0.184

N2: 11.32/16.32 = 0.694

Useful formulas

$$P = 2\pi N T$$

$$P = \frac{\eta_f \eta_v \rho_{a,i} V_d N Q_{HV} (F/A)}{2}$$

$$P(hp) = \frac{N(RPM)\,T(ft-lb)}{5252}$$

$$T = \frac{\eta_f \eta_v \rho_{a,i} V_d Q_{HV} (F/A)}{4\pi}$$

$$P_i = \frac{W_{c,i} N}{n_R}$$

$$mep = \eta_f \eta_v \rho_{a,i} Q_{HV} (F/A)$$

$$P_{ig} - P_b = P_f$$

$$\frac{P}{A_p} = \frac{\eta_f \eta_v \rho_{a,i} L N Q_{HV} (F/A)}{2}$$

$$\eta_m = \frac{P_b}{P_{ig}} = 1 - \frac{P_f}{P_{ig}}$$

$$\eta_v = \frac{2\dot{m}_a}{\rho_{a,i} V_d N}$$

$$mep = \frac{P n_R}{N V_d}$$

$$mep(psi) = \frac{P(hp)\, n_R \times 396000}{V_d(in^3)\, N\,(RPM)}$$

$$mep(kPa) = \frac{P(kW)\, n_R \times 1000}{V(liter)\, N(rev/s)}$$

$$sfc = \frac{\dot{m}_f}{P}$$

$$\overline{S}_p = 2LN$$

$$\eta_f = \frac{P}{\dot{m}_f Q_{HV}}$$

Air is 1 mole O_2 per 3.773 moles N_2.

$$F/A = \frac{\dot{m}_f}{\dot{m}_a}$$

$$A/F = \frac{\dot{m}_a}{\dot{m}_f}$$