ME 410 FALL 2002
INTERNAL COMBUSTION ENGINES
TEST #4
November 2002

NAME________________________________

INSTRUCTIONS:

This test is open notes. The following formulas are also given with little explanation.

$\bar{S}_p = 2LN$ $\quad r_c = \dfrac{V_d + V_c}{V_c}$ $\quad P_{ig} = P_b + P_f$

$\eta_m = \dfrac{P_b}{P_{ig}}$ $\quad mep = \dfrac{Pn_R}{V_d N}$ $\quad P = 2\pi NT$

$$mep(kPa) = \frac{P(kW)n_R \times 10^3}{V_d(l)N(rev/s)} \qquad mep = \frac{P(hp)n_R \times 396000}{V_d(in^3)N(rev/\min)}$$

$\eta_f = \dfrac{1}{sfc \cdot Q_{HV}}$ $\quad \dfrac{F}{A} = \dfrac{\dot{m}_f}{\dot{m}_a}$ $\quad \eta_v = \dfrac{2\dot{m}_a}{\rho_{a,i} V_d N}$

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

$$T = (1/4\pi) \cdot mep \cdot V_d$$

Additional Ideal Gas Relations

$\gamma = {c_P}/{c_V}$ $\quad PV = mRT$ $\quad R = c_P - c_V$

1. A fuel-air cycle thermodynamic analysis of an SI engine is performed. It has been assumed that the engine is operating at full open throttle and the pumping work may be neglected.

- $V_d = 3.1$ liters, 6 cylinders.
- Work done on working fluid during compression is 410 J / cylinder.
- Work done on piston by working fluid during expansion is 1110 J / cylinder.
- Equivalent heat released into working fluid during combustion is 1450 J / cylinder.
- Mechanical efficiency is estimated to be 65%.

a) Calculate the gross work done in each cylinder per cycle.

W_{cg} = 1110 J - 410 J = 700 J

b) Calculate the fuel conversion efficiency based on this ideal cycle information.

$\eta_f = W_{cg} / Q$ = 700/1450 = 0.48 or 48%

c) Calculate the indicated gross power being developed at 4800 RPM.

4800 RPM = 80/s

$P_g = 6\ (W_{cg}\ N / n_R) = 6\ ((700)(80)/2) =$
168,000 J/s = 168 kW

d) What is your best estimate of the brake power developed by the engine model at 4800 RPM? Explain your estimate.

$P_b = \eta_m P_g$ Pb = 0.65 (168 kW) = 109 kW

e) What is your best estimate of the brake power developed by the actual engine at 4800 RPM? Explain.

Here we use the 80% rule of thumb. That is to say that the actual engine is performing at about 80% of what the fuel air cycle predicts. Consequently,

$P_{bengine}$ = 0.8 (109) = 87 kW

2. Give three reasons why the results of a fuel air cycle analysis must be reduced in order to agree with results from testing an actual engine.

   See pages 194 - 196.

   - Heat transfer during combustion and expansion. Less energy available during power stroke.
   - Finite combustion time. This reduces the peak pressure. Again less work done during power stroke.
   - Exhaust blowdown losses. EV opens before BC. This reduces expansion work, hopefully increases volumetric efficiency.
   - Crevice flow. This results in a pressure reduction during expansion
   - Incomplete combustion. Again, we have less energy available during the power stroke.

3. The following phenomena affect the volumetric efficiency of internal combustion engines. In each case, describe the phenomena, and explain the effect it has on volumetric efficiency, including whether the effect is more noticeable at low engine speed or high engine speed.

a) ram effect

The momentum of the entering gas is equivalent to a ram pressure causing more gas to enter cylinder during intake. Increases vol. eff. More noticeable at high speed.

b) backflow

IV closes after start of compression stroke. (To take advantage of ram effect.) Therefore some gas is pushed back out of cylinder. Decreases vol. eff. More noticeable at low speed.

c) choking

The gas entering through IV approaches the speed of sound. Choked flow results. Vol. eff decreases. More noticeable at high speed.

d) tuning

Pressure waves reflected back from previous valve events reinforce the intake and exhaust process. Vol eff increases, at the speed which is tuned.

See page 217.

4. Estimate an exhaust runner length which will produce tuning in an engine exhaust system.

- The speed of sound in the exhaust gas is estimated to be about 2000 ft/s.
- The crank turns through 230^o between the exhaust pressure peak after EVO until the exhaust valve closes.
- The desired RPM for tuning is 5000.

$$t = \Theta / \omega = 2\,L / a$$

$$(230\,\pi / 180) / (5000\;(2\,\pi / 60)) = 2\,L / 2000$$

$$L = 3.83 \text{ ft}$$