Agricultural and Biosystems Engineering, Iowa State University Spring 2009

Homework 2

Question 1: For the following engines:

2 cylinder, 4-cycle; 2 cylinder 2-cycle; 3 cylinder, 4-cycle;
4 cylinder, 4-cycle; 6 cylinder, 4-cycle; 8 cylinder 4-cycle;

(a). Determine the average firing interval (AFI).

2 cylinder, 4-cycle; = 180*4/2 = 360 (Note: This engine does not fire every 360 deg)
2 cylinder 2-cycle; = 180*2/2 = 180 (Note: This engine does fire every 180 deg)
3 cylinder, 4-cycle; = 180*4/3 = 240 (Note: This engine does fire a cylinder at the AFI)
4 cylinder, 4-cycle; = 180*4/4 = 180 (Note: This engine does fire a cylinder at the AFI)
6 cylinder, 4-cycle; = 180*4/6 = 120 (Note: This engine does fire a cylinder at the AFI)
8 cylinder 4-cycle; = 180*4/8 = 90 (Note: This engine does fire a cylinder at the AFI)

(b). Identify those engines with an uneven power strokes.

2 cylinder, 4-cycle;	Uneven Power strokes (both within 360 deg, none for second 360)
2 cylinder 2-cycle;	Even Power strokes (both within 360 deg)
3 cylinder, 4-cycle;	Even Power strokes (Fires every 240 degree, with power stroke lasting 180 deg)
4 cylinder, 4-cycle;	Even Power strokes (Fires every 180 degree, with power stroke lasting 180 deg)
6 cylinder, 4-cycle;	Even Power strokes (Fires every 120 degree, with power stroke lasting 180 deg)
8 cylinder 4-cycle;	Even Power strokes (Fires every 90 degree, with power stroke lasting 180 deg)

(c). Identify those engine with power strokes that overlap. Assuming engines of equal power were available for each of the engine types determine the order of relative size of flywheel required for each engine. (i.e. From largest flywheel to smallest flywheel).

2 cylinder 4-cycle;	No overlap	Largest Flywheel
2 cylinder, 2-cycle;	No overlap	
3 cylinder, 4-cycle;	No overlap	
4 cylinder, 4-cycle;		
6 cylinder, 4-cycle;	Overlapping power cycles	
8 cylinder 4-cycle;	Overlapping power cycles	Smallest Flywheel

(d). For a 5cylinder, 4 cycle engine, determine the crank angle degrees when intake and exhaust valves would open and close for any 3 of the five cylinders. Assume that a crank angle of 0 degrees corresponds with the piston 1 at TDC at the beginning of the intake stroke. Assume that intake valve opens 15° before TDC and closes 45° after BDC; and that exhaust valve closes 15° after TDC and opens 45° before BDC. The firing order of the engine is 1,5,2,4,3

AFI = 180*4/5 = 144

Piston 1: Intake Valve Opens = 0 - 15 = -15 degrees or 705 degrees
Intake Valve Closes = 180 + 45 = 225 degrees
: Exhaust Valve Opens = 540-45 = 495 degrees
Exhaust Valve Closes = 720+15 = 735 degrees or 15 degrees

Piston 5: All delayed by 144 degrees Intake Valve Opens =705 + 144 = 129 degrees
Intake Valve Closes = 225 + 144 = 369 degrees
: Exhaust Valve Opens = 495 + 144 = 639 degrees
Exhaust Valve Closes = 15 + 144 = 159 degrees

Piston 2: All delayed by 288 degrees Intake Valve Opens =705 + 288 = 273 degrees
(Compared to Piston 1) Intake Valve Closes = 225 + 288 = 513 degrees
: Exhaust Valve Opens = 495 + 288 = 63 degrees
Exhaust Valve Closes = 15 + 288 = 303 degrees

Piston 4: All delayed by 144*3 degrees
Piston 3: All delayed by 144*4 degrees

Question 2:

(a). Is the minor diameter (Measured parallel to the piston pin) and the major diameter (measured perpendicular to the piston pin) of a piston the same when the piston is cold? If not, explain the reasons for this difference.

No! The area around the piston pin (minor axis)contains much more material than perpendicular to the piston pin. Therefore, when the piston heats up the minor diameter increases more than the major diameter. The goal is to have both diameters equal when the piston is at its operating temp.

(b) If the exhaust valve clearance is too small, would this cause the valve to prematurely fail? If this is the case, give two different reasons this could cause valve failure.

If clearance is too small the valve will open early and and close late (or not close at all). This will cause the valve to overheat and could cause heat fatigue. Another possibility is that the valve will still be open when the piston reaches TDC and the piston may hit the valve, causing impact damage

(c). After an engine is dismantled the following observations were made on only one of the four engine cylinders (other 3 appeared to have no damage). (1). The front top and back bottom edges of the piston were badly worn in a plane parallel to the crankshaft. Give potential causes for this uneven wear and explain how the wear occurred.

Incorrectly installed bearings.
Bent connecting rod.
Worn piston pin.

Question 3: The stoichiometric A/F ratio for gasoline engines is 15.05 for complete combustion, producing carbon dioxide and water.

(a). If the A/F ratio was decreased to 12, would the air/fuel mixture be considered a rich or a lean mixture, and would complete combustion occur.

Rich Mixture

(b). Name two additional combustion products that may be produced under these conditions.

Carbon Monoxide, Carbon, Unburnt Hydrocarbons

(c). An engine is tested with the following A/F ratios, (10, 15, 20, 25, 50, and 75). It was found that the engine would run satisfactorily at A/F ratios above 25. Is this a SI engine or diesel engine? Explain your answer.

Diesel Engine. A gasoline engine will not run when A/F ratio is greater than 20:1 (or less than 8:1)

(d). When would you use a high cetane fuel in a gasoline engine? Explain your answer.

No. Cetane is used to rate diesel fuels which make very poor gasoline fuel.

Question 4: The point's T10 , T20 , and T90 refer, respectively to the temperatures on the fuel distillation curve at which 10, 50 and 90 % of the fuel has been distilled.

(a). Why is it important that the T10 temperature is not too high? What would the effect of increasing the T10 temperature be on starting an engine in cold weather?

T10 temperature is a measure of the cold start characteristics of the fuel. (i.e. How much of fuel will vaporize in the carburetor) If T10 is too high it will be difficult to start the engine in cold weather.

(b). Engines' warm time up depends on the T50 temperature of the fuel. For gasoline would the T50 temperature be increased or decreased during winter. Explain your reasoning.

Decreased in winter to cause the engine to warm up faster. In addition vapor lock is not a problem in winter so a lower T50 is not a problem.

(c). A fuel is found to cause dilution of the crankcase oil. Which of the three distillation temperature points are associated with this phenomenon How does the fuel enter the crankcase?

T90. If the T90 is too high a significant portion of the fuel may condense on the cylinder walls and eventually find its way into the crankcase.

(d). Gasoline volatility is adjusted by petroleum refiners to suit the season. Give one reason why the volatility of gasoline is increased in winter, and a second reason why the volatility is lower in summer.

In winter, temperatures are lower and cold starting is a problem. In summer starting is not such a problem bit vapor lock may cause problem. The volatility is also decreased in summer to prevent evaporation from the fuel tank of the lighter components to prevent smog and air pollution.

Question 5: The ignition delay of a fuel after the self-ignition temperature is reached, has important effects on the speed of the flame front, rate of combustion and rate of pressure rise in the engine cylinder.

(a). Why would you tend to use a fuel with a relatively long ignition delay in a spark ignition engine?

A long ignition delay gives the flame time to progressively burn from the spark to the extremes of the cylinder walls before auto ignition occurs.

(b). What would be the effect of using fuel with a long ignition delay in a diesel engine?

This will allow most of the fuel to mix with the air before combustion occurs, resulting in a very high percentage of pre-mix combustion which will result in very high rates of pressure rise in the cylinder, (and most likely very high maximum pressure in the cylinder, depending on timing).

Question 6 A diesel engine accelerating under varying loads. The fuel used is cetane $C_{16}H_{34}$

Note: Atomic Mass of Carbon (C) =12, Hydrogen (H) =1 Nitrogen (N) =14, Oxygen (O) =16. Assume for each molecule of oxygen (O_2) in air there are 3.76 molecules of Nitrogen (N_2)

$C_{16}H_{34}$ + ??[O_2 + 3.76N_2] ⇒ ??$C0_2$ + ??H_20+ ??C0 + ??0_2 + ??N_2

a). Determine the Stoichiometric combustion equation and Stoichiometric Air/Fuel ratio.

$C_{16}H_{34}$ +	24.5[O_2 + 3.76N_2]	⇒	16$C0_2$ +	17H_20 +	24.5(3.76)N_2
16(12)+34(1)	**24.5(2(16)+3.76*2(14))**		**16(12+2(16)**	**17(2(1)+16)**	**24.5*3.76*2(14)**
226	**24.5(137.38)**		**16(44)**	**17(18)**	**24.5(105.28)**
226	**3363.36**		**701**	**306**	**2579.36**

Mass Inputs = 3586.36 **Mass Products = 3586.36**

A/F = 3363.36/226 =14.88

b) Determine actual combustion equation at a Fuel Equivalence Ratio of 0.85 and the actual Air/Fuel ratio

FER <1.0 Therefore lean mixture

$C_{16}H_{34}$ +	24.5/0.85*[O_2 + 3.76N_2]	⇒	??$C0_2$ +	??H_20 +	??0_2+	??(3.76)N_2
$C_{16}H_{34}$ +	28.8235...*[O_2 + 3.76N_2]	⇒	16$C0_2$ +	17H_20 +	4.3235$0_2$+	28.8235(3.76)N_2
226	28.8235(137.38)					
226	2956.894					

A/F = 3956.894/226 = 17.50

Check (or) A/F = A/F Stio. / FER = 14.88 / 0.85 = 17.5

c). If the engine fuel consumption is 45.2 kg/hr, determine the mass of carbon dioxide produced per hour.

Moles Fuel = (44.2 kg/hr) / (226 kg/kmol) = 0.195575 kmol fuel / hr

Moles CO2 produced = Moles Fuel * Moles CO2 per Mole fuel
= 0.195575 kmol fuel / hr * 16 mol CO2 per mole fuel
=3.129 kmol CO2

Mass CO2 = mol CO2 / hr * Mass CO2
=3.129 kmol / hr CO2 * 44 kg/kmol CO2
= 137.38 kg / hr CO2

Question 7 Blended fuels are sometimes used in engines. A blend containing 20% Butanol (by volume), in 80% gasoline can be used for automobiles. Given the following information:

	Chemical Formula	Density
Butanol	$C_4H_{10}O$	0.780 kg/L
Gasoline (Octane)	C_8H_{18}	0.740 kg/L

Note: For every mole of an oxygen molecule in air, there are 3.76 moles of nitrogen molecules.

a). Determine the composite fuel molecule $C_{xc}H_{yc}0_{zc}$ which can be used to represent blended fuel.

$r_s = (\rho_s/\rho_p)*(f_s/f_p)*(m_p/m_s) = (.78/.74)*(.2/.8)*(114/74) = 0.406$

$X_c = X_p + r_s\,(Xs) = 8 + 0.406(4) = 9.624$
$Y_c = Y_p + r_s\,(Ys) = 18 + 0.406(10) = 22.06$
$Z_c = Z_p + r_s\,(Zs) = 0 + 0.406(1) = 0.406$

$\underline{C_{9.624}H_{22.06}0_{0.406} \quad \text{or} \quad C_{23.707}H_{54.34}0_1}$

b). Show the balanced Stoichiometric combustion equation for the composite molecule.
Using $C_{23.707}H_{54.34}0_1$

$$\begin{array}{llrclll}
C_{23.707}H_{54.34}0_1 & + & ??[O_2 + 3.76N_2] & \Rightarrow & ??C0_2 + & ??H_20+ & ??N_2 \\
C_{23.707}H_{54.34}0_1 & + & \{(23.707(2)+27.17(1)-1)/2\}*[O_2 + 3.76N_2] & \Rightarrow & 23.707C0_2 + & 27.17H_20+ & 3.76N_2 \\
C_{23.707}H_{54.34}0_1 & + & 36.792*[O_2 + 3.76N_2] & \Rightarrow & 23.707C0_2 + & 27.17H_20+ & 36.792*3.76N_2 \\
354.82 & & 36.792*(137.28) & & & & \\
354.82 & & 5050.806 & & & &
\end{array}$$

c). Calculate the Stoichiometric air to fuel ratio for the fuel blend.

A/F Ratio = Mass air / Mass Fuel = 5050.806/354.82 =$\underline{14.235}$

Question 7

a). A gasoline engine is required to start at an ambient temperature of 0º C. The maximum A/F ratio in the vapor phase, (Mass air / Mass of vaporized fuel) that the engine will start is 20:1. At 0º C only 20% of the fuel mixed with the air will vaporize.

(i)Calculate the actual A/F ratio (Mass Air/Total Mass of Fuel) that is required for starting.

Actual A/F = Required A/F * % Evap
= 20 * 0.20
= 4:1

(ii) If the air to fuel ratio is less than that calculated above will the engine start? Justify your answer!!!!

Yes. 20:1 is the leanest possible ratio therefore a lower A/F ratio will make a richer mixture and approach the optimium. (Until it is too rich)

b). A gasoline engine is required to start at an ambient temperature of 10º C. The minimum A/F ratio in the vapor phase, (Mass air / Mass of vaporized fuel) that the engine will start is 8:1. At 10º C only 40% of the fuel mixed with the air will vaporize.

(i) Calculate the lowest actual A/F ratio (Mass Air/Total Mass of Fuel) that engine will start before "flooding."

Actual A/F = Required A/F * % Evap
= 8 * 0.40
= 3.2 : 1

(ii) If the air to fuel ratio is less than that calculated above will the engine start? Justify your answer!!!!

No. The mixture is already rich therefore decreasing the A/F mixture any further will not allow the engine to start

c). What characteristic of a gasoline fuel is measured by the octane number.

The ability of fuel to resist auto-ignition

d). What characteristic of a diesel fuel is measured by the cetane number.

The ability of the fuel to self-ignite.