HW Day 3
Problem 2-13

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IC Engines
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Several velocities, time, and length scales are useful in understanding what goes on inside engines. Make estimates of the following quantities for a 1.6-liter displacement four-cylinder spark-ignition engine, operating at wide-open throttle at 2500 rpm.
(a) The mean piston speed and the maximum piston speed.
(b) The maximum charge velocity in the intake port (the port area is about 20 percent of the piston area).
(c) The time occupied by one engine operating cycle, the intake process, the compression process, the combustion process, the expansion process, and the exhaust process. (Note: The process is used here not the word stroke.)
(d) The average velocity with which the flame travels across the combustion chamber.
(e) The length of the intake system (the intake port, the manifold runner, etc.) which is filled by one cylinder charge just before the intake valve opens and this charge enters the cylinder (i.e., how far back from the intake valve, in centimeters, one cylinder volume extends in the intake system).
(f) The length of exhaust system filled by one cylinder charge after it exits the cylinder (assume an average exhaust gas temperature of 425 degrees C).
You will have to make several appropriate geometric assumptions. The calculations are straightforward, and only approximate answers are required.

a.)

$$V_d = \frac{1.6}{4} \text{ [L]} \quad \text{Cylinder Volume}$$

$$Bore = 0.0823 \text{ [m]}$$

$$L = 0.07493 \text{ [m]}$$

$$N = 2500 \cdot \left[0.01667 \cdot \frac{1/sec}{1/min}\right] \text{ [1/sec]}$$

$$\overline{S}_p = 2 \cdot L \cdot N$$

The maximum piston speed will occur when the crank angle is either 90 or 270 degrees.
Assumptions:R=3.5

$$R = 3.5$$

$$\theta = 90$$

$$\frac{S_p}{\overline{S}_p} = \frac{\pi}{2} \cdot \sin[\theta] \cdot \left[1 + \frac{\cos(\theta)}{\left(R^2 - \sin^2[\theta]\right)^{(1/2)}}\right]$$

b.)

It is unclear what this question is exactly asking however I feel that it is asking what is the speed at which the air/fuel mixture inters the cylinder. I am going to answer this accordingly.

$$PistonArea = \pi \cdot \frac{Bore^2}{4} \text{ [m}^2\text{]}$$

$$IntakeArea = 0.2 \cdot PistonArea \text{ [m}^2\text{]}$$

$$ChargeVelocity \cdot IntakeArea = \overline{S}_p \cdot PistonArea \text{ [m/s]}$$

c.)

Since the engine is running at 2500 rpm, and is a four-stroke engine, the time occupied by one engine operating cycle will be equal to the time it takes the crank to turn 2 revs.

$$EngineCycleTime = \frac{60}{2500} \cdot 2 \quad [sec]$$

For the intake, the compression, the expansion, and the exhaust process I am assuming that they are referring to the amount of time that it takes for that part of the engine cycle. Therefore the individual process times take 1/4 of the Engine Cycle Time. The Combustion Process takes very little time as I understand, and I could not locate a specific time that it takes. I would have to say that is approximately zero.

$$ProcessTime = \frac{EngineCycleTime}{4} \quad [sec]$$

$$CombustionTime = 0.0001 \quad [sec]$$

d.)

Again I did not find any specific values for the velocity, but it would have to be extremely fast seeing how the combustion occurs it a fraction of a second

e.)

Assuming that the port in the intake manifold has the same diameter as the intake valve opening....

$$IntakeSystemLength = V_d \cdot \frac{\left[1000 \cdot \frac{cm^3}{L}\right]}{IntakeArea \cdot \left[10000 \cdot \frac{cm^2}{m^2}\right]} \quad [cm]$$

f.)

Assuming that the pressures are equal to find the expansion of gas, and the amount of gas was not changed due to fuel being added....
Pressure*Volume=moles*R*Temperature. Solving for Pressure with moles constant....I get Pressure=Temerature/Volume. I will no set the intake condition equal to the exit conditions and solve for the new volume of gas due to thermal expansion. (Assuming Intake Temperature of 40 degrees C, and the cross-sectional area of the exhaust remains constant.)"

$$\frac{V_d}{55} = \frac{V_{exhaust}}{425} \quad [L]$$

$$IntakeArea = ExhaustArea$$

$$ExhaustSystemLength = V_{exhaust} \cdot \frac{\left[1000 \cdot \frac{cm^3}{L}\right]}{ExhaustArea \cdot \left[10000 \cdot \frac{cm^2}{m^2}\right]} \quad [cm]$$

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

V_d = 0.4 [L]	Bore = 0.0823 [m]	L = 0.07493 [m]
N = 41.67 [1/sec]	$\overline{S}_p$ = 6.244 [m/s]	R = 3.5
θ = 90 [deg]	S_p = 9.809 [m/s]	PistonArea = 0.00532 [m^2]

IntakeArea = 0.001064 [m^2]	ChargeVelocity = 31.22 [m/s]	EngineCycleTime = 0.048 [sec]
ProcessTime = 0.012 [sec]	CombustionTime = 0.0001 [sec]	IntakeSystemLength = 37.6 [cm]
$V_{exhaust}$ = 3.091 [L]	ExhaustArea = 0.001064 [m^2]	ExhaustSystemLength = 290.5 [cm]