ME 410 Day 30

Phases of Combustion

1. Ignition
2. Early flame development $\Delta\theta_d$
3. Flame propagation $\Delta\theta_b$
4. Flame termination

The flame development angle $\Delta\theta_d$ is the crank angle between the initial spark and the time when about 10% of the charge is burned.

Rapid burning angle $\Delta\theta_b$ is the crank angle in which the bulk (90%) of the charge burns.

$$x_b(\theta) = 1 - \exp\left(-a\left(\frac{\theta - \theta_s}{\Delta\theta_d + \Delta\theta_b}\right)^n\right)$$

is an expression for the fraction burned as a function of crank angle. Recall that it was used in last week's model.

Combustion models try to calculate these quantities i.e. the model parameters in terms of many properties such as

1. laminar flame speed
2. laminar flame thickness
3. turbulent flame speed
4. turbulence intensity
5. turbulent integral scales.

This is a very complicated subject.

Keys to understanding:

- The turbulent flow field in the cylinder has a very big influence on the combustion process. An experiment was done in which the intake event and the turbulent flow it generated was removed. Flame propagation speed diminished significantly.

- Understanding the flame structure itself is of major importance. It is a turbulent premixed flame. Flame has ragged edges, finite thickness. That is where the reaction is taking place.

1. Laminar flame : thickness δ_L and speed S_L.
2. Turbulent flame : root mean square value of fluctuating component, u'. (also referred to as the turbulent intensity), integral length scale, L_T, is a measure of largest energy containing structure in the flow. Kolmogorov length scale L_K is the smallest.

- Combustion chamber geometry is also very important.
    1. Swirl. Organized rotation about cyl axis. It's good!
    2. Squish Radial gas motion at end of compression. Also enhances combustion

Bowl in piston amplifies swirl during compression and induces squish.

Causes of Cyclic / Cylinder Variability

- Variations in gas motion during combustion, esp around spark plug.
- Variations in fuel, air, and EGR at a given cylinder
- Variations in mixture composition in cylinder, esp around spark plug

II. Abnormal Combustion

A. Knock - spontaneous ignition of the end gas

B. Surface ignition - Ignition by hot spots in the cylinder other than the plug

C. Combination of A and B.

Spark knock

- is controlled by spark timing. Advancing the spark increases spark knock. Retarding the spark decreases it.

Knocking surface ignition not controlled by spark timing.

Phenomena associated with knock

- noise
- pressure waves
- very rapid combustion. High cylinder pressure and temperature
- Engine damage

Result of knock:

- Various kinds of engine damage. Can be serious and mean a reduction in engine life.

Fuel Factors

Octane rating

Two reference fuels

- n-heptane C_7H_{16}
- isooctane C_8H_{18}

Blend of 40% heptane and 60% isooctane has ON = 60 etc.

Two tests with reference engine

- Motor test
- Research test

The blend is adjusted until the knock behavior is the same with the blend as with the reference fuel.

CI Combustion Notes

Notes: (See Page 492)

1. Knock is not a problem since fuel is injected just prior to the start of combustion. Higher compression ratios are possible.
2. Injection delay must be short and reproducible. Cetane Number (CN) requirement
3. No throttle. Torque controlled by amount of fuel injected. Therefore volumetric efficiency is somewhat greater than for SI.
4. Soot formation is the major constraint. Especially on FA ratio. Engine must run lean.
5. Because engine runs lean, γ is higher for working fluid, fuel conversion efficiency is higher for CI than SI for a given expansion ratio.

Types of CI (Diesel) Engines

1. Direct Inection. Fuel is injected into main combustion chamber.
2. Indirect Injection. Injection of fuel into a smaller pre-chamber which is connected to the main chamber. This is for smaller engines.

The smaller the engine, the more dependent the design on vigorous air motion.

Phases of Combustion

1. Ignition delay
2. Premixed combustion phase
3. mixing controlled combustion phase
4. late combustion phase

Fuel Ignition Quality

Cetane Number CN

CN = %cetane + 0.15 x %HMN

cetane = n-hexadecane CN = 100. Good ignition qualtiy

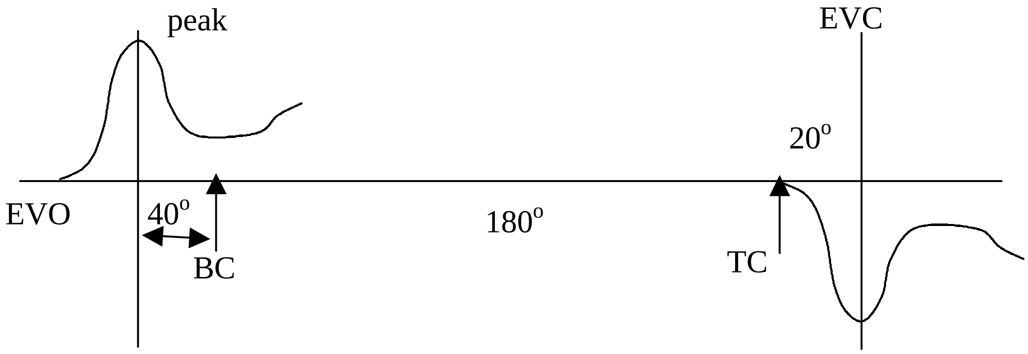
HMN = heptamethylnonane CN = 15. Poor ignition quality

As determined by ASTM D613

- standard engine
- set operating conditions on fuel to be tested
- compression ratio varied until ignition delay is 13^{o}.
- Try blends of reference fuels to match actual fuel's behavior

CCI (calculated cetane index) is also used

Exhaust Tuning



Select an appropriate runner length at the following RPM.
Assume the speed of sound in the exhaust gas is 2200 ft/s

Concept:

Want the pressure wave to travel down the runner reflect and come back as a rarefaction wave just about the time of EVC

Improves volumetric efficiency

RPM = 5000   L = ?