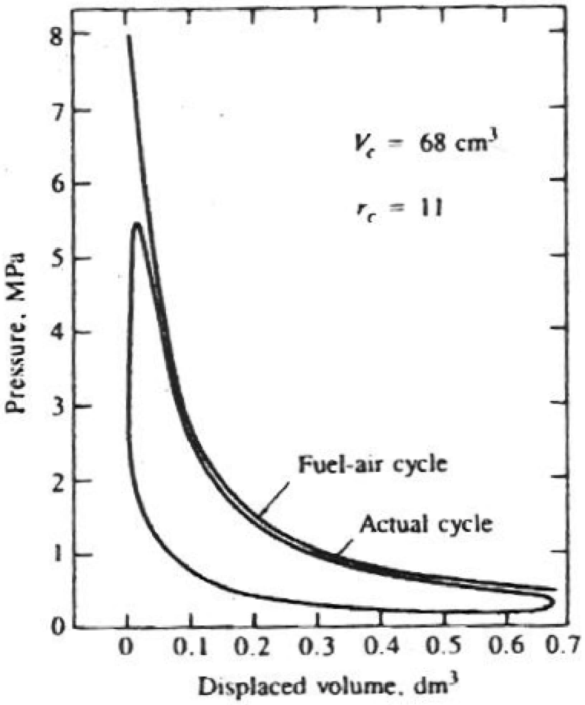
ME 410 Day 28

Comparing Models with Reality

See Figure 5-18. The enclosed area on the actual pv diagram is about 80% of the enclosed area when modeling with a fuel air cycle. Which means that the fuel conversion efficiency will be about 80% of the predicted theoretical value. So this number, 0.8 gets used a lot.



Reasons for Differences (See Page 195)

- Heat transfer, especially from burned gas to cyl. walls. Because of this pressure at end of combustion will be lower in the real cycle. Also, heat transfer will keep the rest of the expansion from being isentropic. Falls below the isentropic line. (T-s diagram would show this most clearly) Result is decrease in efficiency.
- Finite combustion time. Combustion starts before TC, continues long after TC, and so peak pressure in actual engine

is less than predicted values. But after combustion pressure is higher in the actual engine, since less work has been done.

- Exhaust blowdown loss. Exhaust valve opens before BC. Gas pressure falls below isentropic line, causing efficiency loss.
- Crevice effects and leakage. Again, cyl. pressure is reduced during compression, combustion, and expansion.
- Incomplete combustion. Combustion efficiency of 100% has been assumed in the idealizations. I.e. carbon monoxide, hydrogen and other hydrocarbon emisions. Net result is lower pressure in real life. (Combustion efficiency may be about 95% in some SI engines and about 98% in CI)

See Fig. 5-19

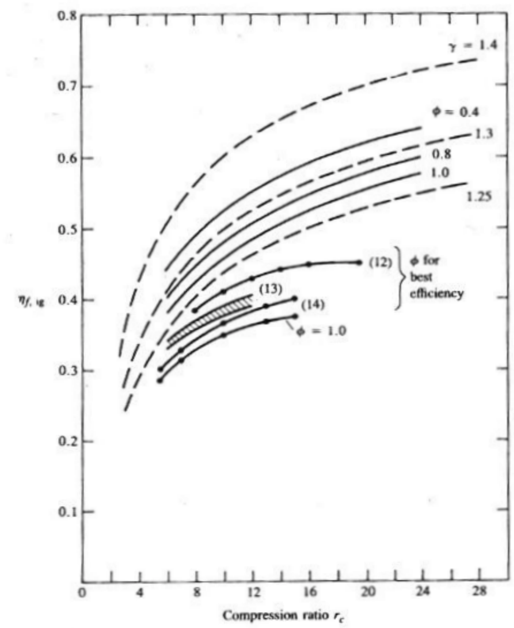


FIGURE 5-19
Indicated fuel conversion efficiency as a function of compression ratio for ideal gas constant-volume cycle (dashed lines, $\gamma = 1.25, 1.3, 1.4$) and fuel-air cycle (solid lines, $\phi = 0.4, 0.8, 1.0$). Also shown are available engine data for equivalence ratios given: best efficiency ϕ;[12–14] $\phi = 1$.[14]

(12) isooctane; (13) gasoline, see range; (14) propane.

Models of ideal cycles discussed so far provide rough approximations, and illustrate some of the thermodynamic principles. Can provide an understanding of trends caused by changing operating parameters such as compression ratio, air-fuel, etc. Weak link: combustion modeling is not adequate.

Combustion in SI Engines - Phenomenology

I. Normal Combustion

II. Abnormal Combustion

Normal Combustion. Basic Process Description

(See Fig. 9-1)

- Spark at -30° BTVC
- Flame appears at -24°
- Circular, ragged looking flame front propagates
- Flame reaches cylinder wall at 15° ATC
- Combustion continues for another 10° of crankshaft rotation

Question:

Assume the engine is rotating at 3000 rpm. How long does the combustion event take?

Answer:

Each revolution takes 0.02 sec. (55/360) x 0.02 = 0.003 sec. It takes about 3 milliseconds.

Spark Timing

Early Ignition

- leads to a major increase in compression work done on the working fluid. Less net work, torque and imep

Late Ignition

- leads to a major decrease in expansion work done by the working fluid. Less net work, torque and imep.

Let's use the applet at CSU

Spark initiation at θ_s =	Imep
-30	12.96
-27.5	13.1
-25	13.2
-22.5	13.27
-20	13.29
-17.5	13.28
-15	13.23
-12.5	13.14

The best compromise is called "Maximum Brake Torque Timing."

Rules of Thumb

With Optimum Spark Timing

- Maximum Pressure occurs about 16^o after TC
- Half the charge burned by 10^o after TC

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. wrinkled flame regime - lower speed - ink roller model burning rate is most closely connected to chem reaction rate
    2. flamelets in eddies. Here at higher speeds it is the turbulent intensity that governs.

- Combustion chamber geomtry is also very important.