2.61 Internal Combustion Engines
Spring 2008

Lecture 10
SI Combustion (continue)
SI Engine Knock

- Entrainment-and-Burn Model for SI engine combustion
- Cycle-to-cycle fluctuation of SI engine heat release
- SI engine knock
  - Spark knock and surface ignition
  - Spark knock mechanism
  - Knock chemistry and fuel effects
  - Knock control

Model of turbulent combustion

Schematic of entrainment-and-burn model

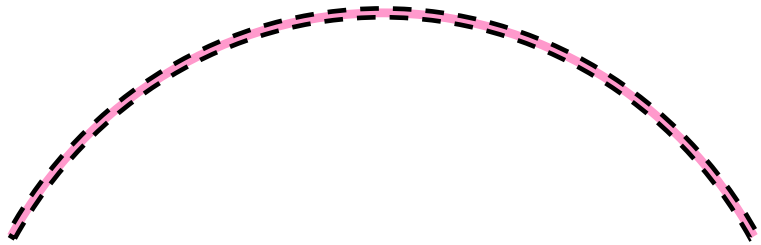

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Fig. 14-12

SI engine flame propagation
Entrainment-and-burn model

Rate of entrainment:

$$\frac{dm_e}{dt} = \rho_u A_f S_L + \rho_u A_f u_T (1 - e^{-t/\tau_b})$$

Laminar diffusion through flame front

Turbulent entrainment

Rate at which mixture burns:

$$\frac{dm_b}{dt} = \rho_u A_f S_L + \frac{m_e - m_b}{\tau_b} \; ; \qquad \tau_b = \frac{\ell_T}{S_L}$$

Laminar frontal burning

Conversion of entrained mass into burned mass

Critical parameters: u_T and ℓ_T

Cycle-to-cycle variations

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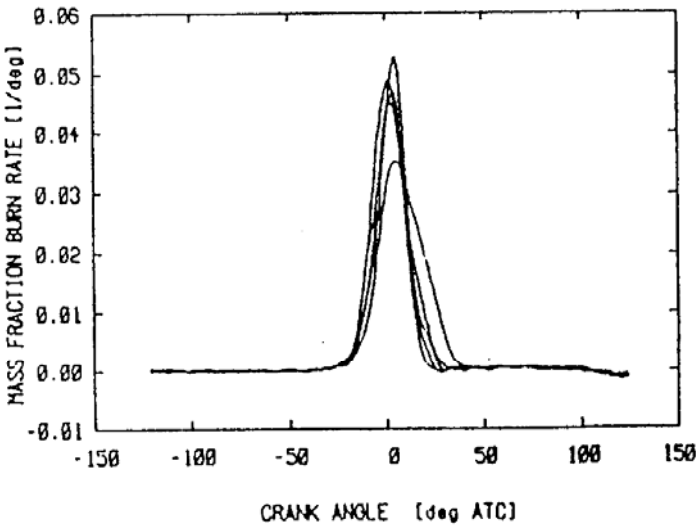
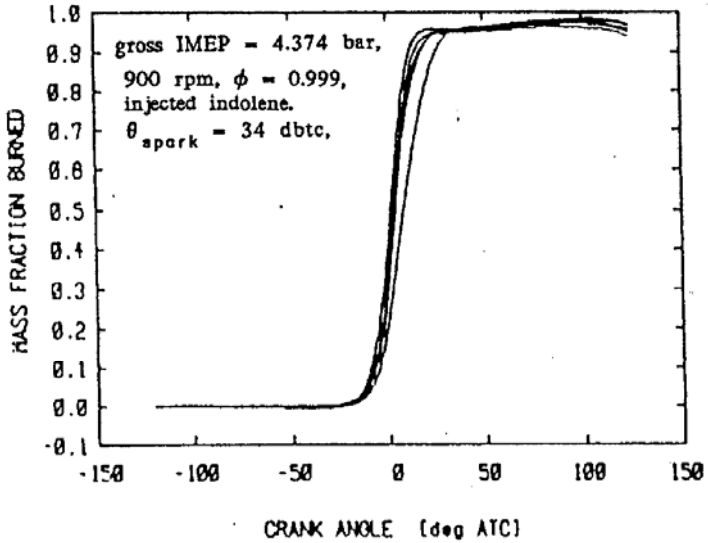
Crank angle (º ATDC) **Crank angle (º ATDC)**

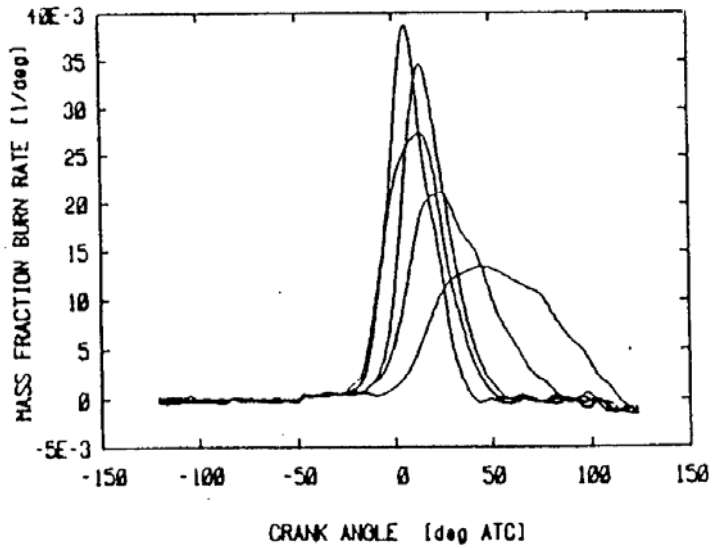
Fig. 9-31

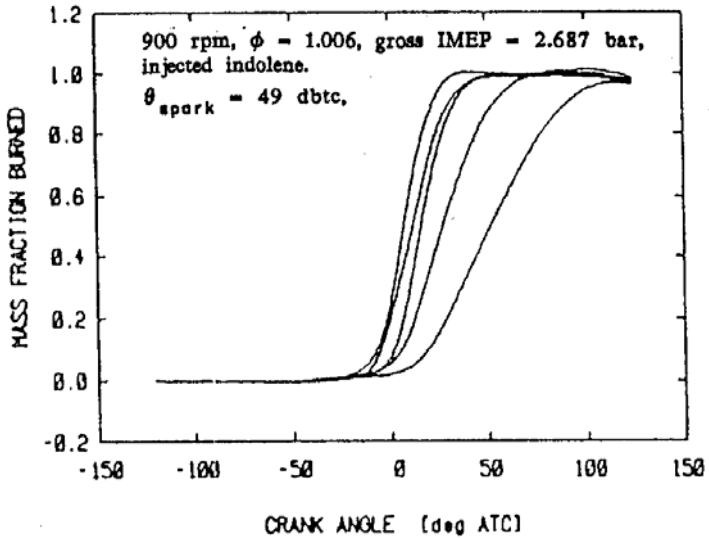
Measured cylinder pressure and calculated gross heat-release rate for ten cycles in a single-cylinder SI engine operating at 1500 rpm, Φ = 1.0, MAP = 0.7 bar, MBT timing 25ºBTC

Cycle-to-cycle change in combustion phasing









SI ENGINE CYCLE-TO-CYCLE VARIATIONS

Phases of combustion

1. Early flame development
2. Flame propagation
3. Late stage of burning

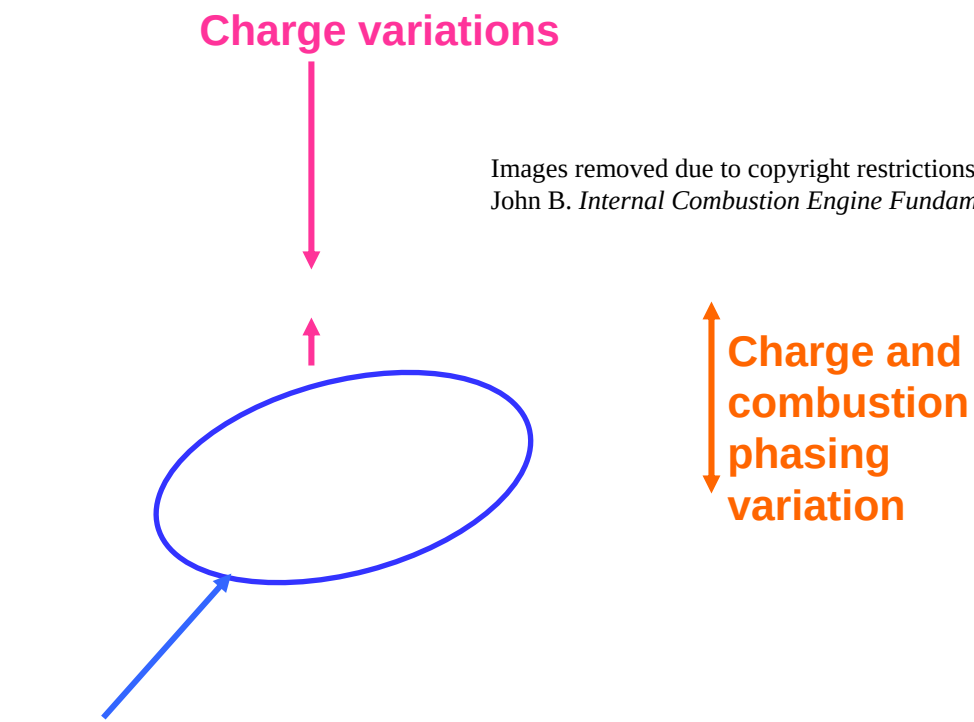
Factors affecting SI engine cycle-to-cycle variations:

(a) Spark energy deposition in gas (1)
(b) Flame kernel motion (1)
(c) Heat losses from kernel to spark plug (1)
(d) Local turbulence characteristics near plug (1)
(e) Local mixture composition near plug (1)
(f) Overall charge components - air, fuel, residual (2, 3)
(g) Average turbulence in the combustion chamber (2, 3)
(h) Large scale features of the in-cylinder flow (3)
(i) Flame geometry interaction with the combustion chamber (3)

Cycle distributions

Fig,. 9-36 (b)

Fig,. 9-33 (b)



Partial burn – substantial combustion inefficiency (10-70%)
Misfire – significant combustion inefficiency (>70%)
(No definitive value for threshold)