2.61 Internal Combustion Engines
Spring 2008

Diesel Engine Combustion

1. Characteristics of diesel combustion
2. Different diesel combustion systems
3. Phenomenological model of diesel combustion process
4. Movie of combustion in diesel systems
5. Combustion pictures and planar laser sheet imaging

DIESEL COMBUSTION PROCESS

PROCESS

- Liquid fuel injected into compressed charge
- Fuel evaporates and mixes with the hot air
- Auto-ignition with the rapid burning of the fuel-air that is “premixed” during the ignition delay period
  - Premixed burning is fuel rich
- As more fuel is injected, the combustion is controlled by the rate of diffusion of air into the flame

DIESEL COMBUSTION PROCESS

NATURE OF DIESEL COMBUSTION

- Heterogeneous
  - liquid, vapor and air
  - spatially non-uniform
- turbulent
- diffusion flame

The Diesel Engine

- Intake air not throttled
  - Load controlled by the amount of fuel injected
    - >A/F ratio: idle ~ 80
    - >Full load ~19 (less than overall stoichiometric)
- No “end-gas”; avoid the knock problem
  - High compression ratio: better efficiency
- Combustion:
  - Turbulent diffusion flame
  - Overall lean

Diesel as the Most Efficient Power Plant

- **Theoretically, for the same CR, SI engine has higher η_f; but diesel is not limited by knock, therefore it can operate at higher CR and achieves higher η_f**
- **Not throttled - small pumping loss**
- **Overall lean - higher value of γ - higher thermodynamic efficiency**
- **Can operate at low rpm - applicable to very large engines**
  - slow speed, plenty of time for combustion
  - small surface to volume ratio: lower percentage of parasitic losses (heat transfer and friction)
- **Opted for turbo-charging**

Large Diesels: η_f~ 55%
~ 98% ideal efficiency !

Disadvantages of Diesel Engines

- Cold start difficulty
- Noisy - sharp pressure rise: cracking noise
- Inherently slower combustion
- Lower power to weight ratio
- Expensive components
- NO_x and particulate matters emissions

Diesel Engine Characteristics (compared to SI engines)

- **Better fuel economy**
  - Overall lean, thermodynamically efficient
  - Large displacement, low speed – lower FMEP
  - Higher CR
    - > CR limited by peak pressure, NOx emissions, combustion and heat transfer loss
  - Turbo-charging not limited by knock: higher BMEP over domain of operation, lower relative losses (friction and heat transfer)
- **Lower Power density**
  - Overall lean: would lead to smaller BMEP
  - Turbocharged: would lead to higher BMEP
    - > not knock limited, but NOx limited
    - > BMEP higher than SI engine
  - Lower speed: overall power density (P/V_D) not as high as SI engines
- **Emissions: more problematic than SI engine**
  - NOx: needs development of efficient catalyst
  - PM: regenerative and continuous traps

Applications

- Small (7.5 to 10 cm bore; previously mainly IDI; new ones are high speed DI)
  - passenger cars
- Medium (10 to 20 cm bore; DI)
  - trucks, trains
- Large (30 to 50 cm bore; DI)
  - trains, ships
- Very Large (100 cm bore)
  - stationary power plants, ships

Common Direct-Injection Compression-Ignition Engines

(Fig. 10.1 of text)

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(a) Quiescent chamber with multihole nozzle typical of larger engines
(b) Bowl-in-piston chamber with swirl and multihole nozzle; medium to small size engines
(c) Bowl-in-piston chamber with swirl and single-hole nozzle; medium to small size engines

Common types of small Indirect-injection diesel engines
(Fig. 10.2 of text)

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(a) Swirl prechamber

(b) Turbulent prechamber

Common Diesel Combustion Systems (Table 10.1)

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Typical Large Diesel Engine Performance Diagram

Sulzer RLB 90 - MCR 1

Turbo-charged 2-stroke Diesel

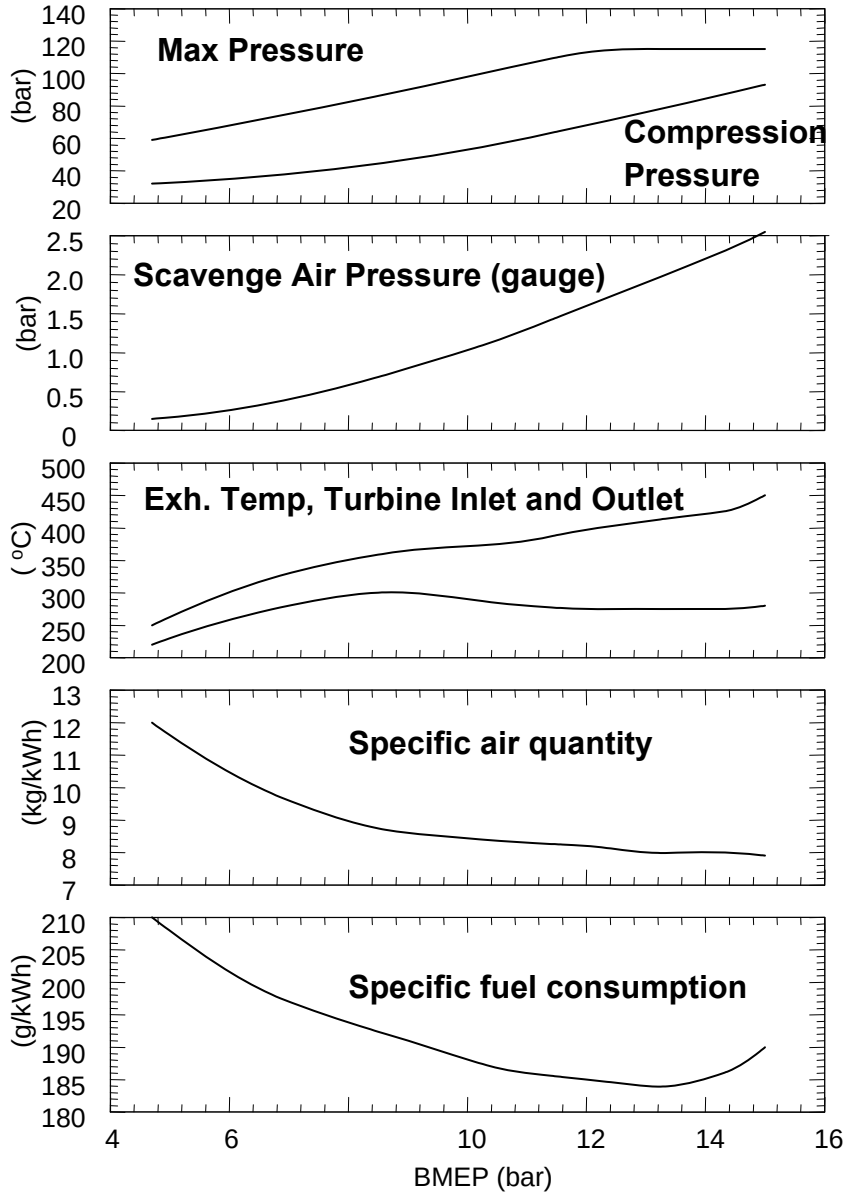
- **1.9 m stroke; 0.9 m bore**

Rating:

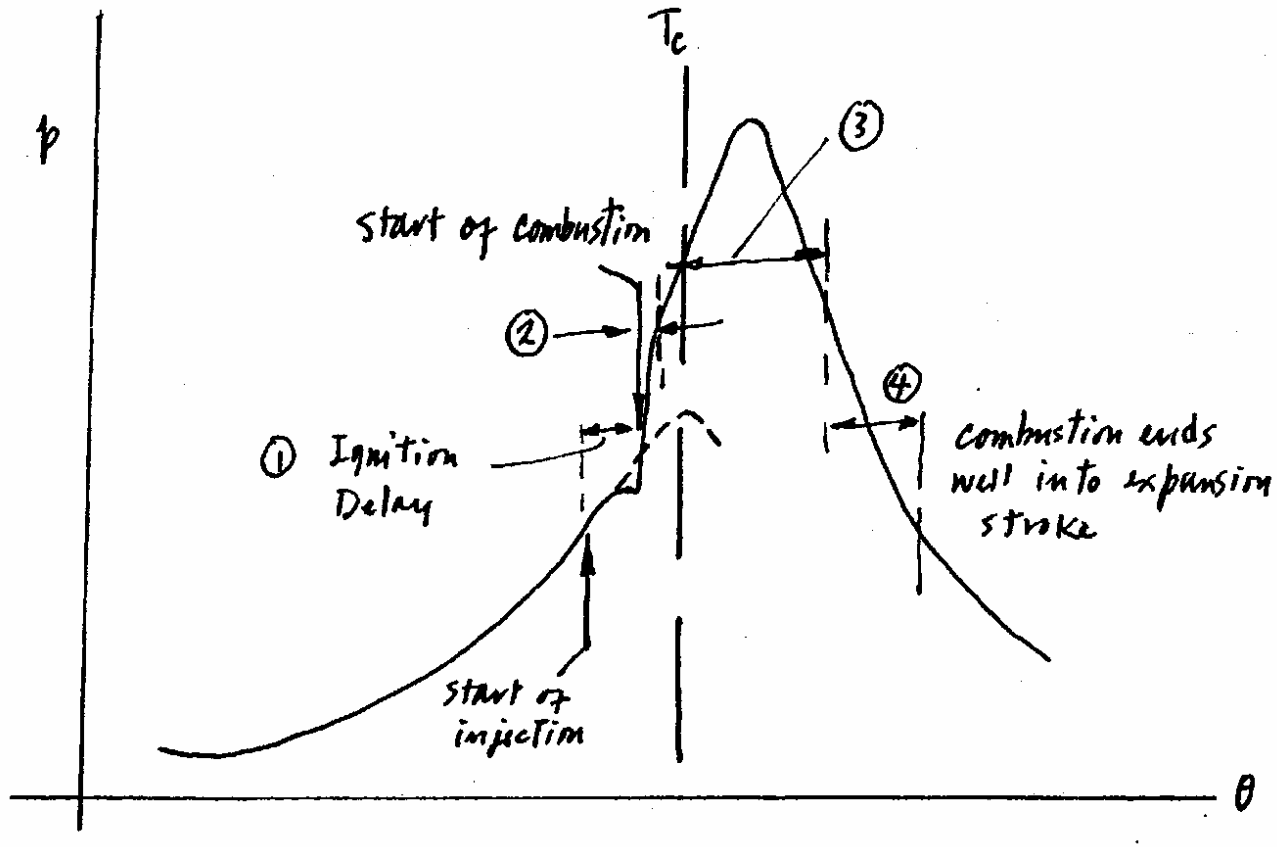
- **Speed: 102 Rev/ min**
  - **Piston speed 6.46 m/s**
- **BMEP: 14.3 bar**

Configurations

- **4 cyl: 11.8 MW (16000 bhp)**
- **5 cyl: 14.7 MW (20000 bhp)**
- **6 cyl: 17.7 MW (24000 bhp)**
- **7 cyl: 20.6 MW (28000 bhp)**
- **8 cyl: 23.5 MW (32000 bhp)**
- **9 cyl: 26.5 MW (36000 bhp)**
- **10 cyl: 29.4 MW (40000 bhp)**
- **12 cyl: 35.3 MW (48000 bhp)**



Diesel combustion process — direct injection



1) Ignition delay — no significant heat release

emixed" rapid combustion

xing controlled" phase of ıbustion

te" combustion phase

Note:
(2) is too fast;
(4) is too slow

Rate of Heat Release in Diesel Combustion

(Fig. 10.8 of Text)

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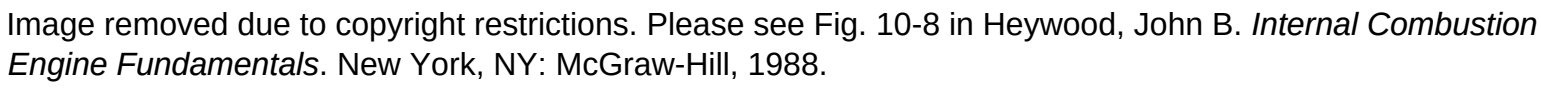
A Simple Diesel Combustion Concept (Fig. 10-8)



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