Chapter 1

ENGINE TYPES AND THEIR OPERATION

1.1

Piston: Transmit the gas pressure force to the connecting rod; seal the cylinder (with piston rings); compress the fuel-air mixture prior to combustion; draw in fresh mixture, expel burned gases (4-stroke cycle).

Connecting rod: Transform the rotating motion of crank to reciprocating motion of piston; transmit forces from crank to piston and piston to crank.

Crankshaft: Transmit the usable mechanical power; crank throws with connecting rods convert reciprocating motion of piston to rotating motion.

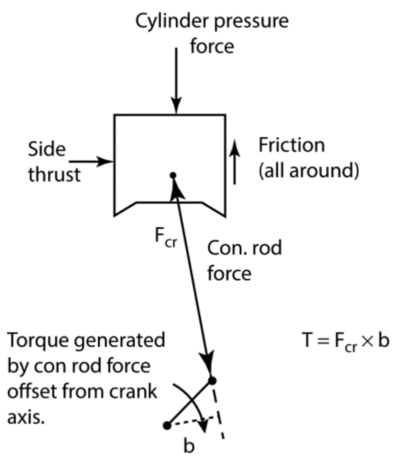
Cams and camshaft: Open and close the valves (inlet and exhaust) at appropriate times in the cycle, via the lifters and rocker arms. Camshaft driven off crankshaft.

Valves: Control the flow of gas into and out of the cylinder.

Intake manifold: Direct approximately equal masses of air (and in some cases fuel) to each cylinder; in SI engines acts as a sub-atmospheric pressure plenum to reduce engine load below WOT levels.

Exhaust manifold: Collect exhaust gases from individual cylinders and feed to common pipe which contains muffler (and sometimes catalytic converter).

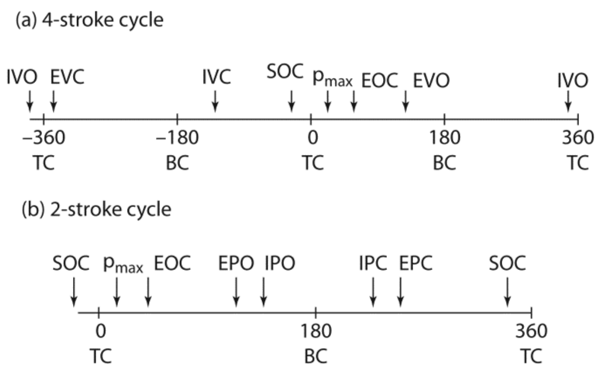
1.2 Note: piston accelerating towards crankshaft axis.



1.3

	Spark-ignition	Diesel
1.	Air enters cylinder; fuel injected in intake port, or cylinder.	Air drawn in; fuel injection into cylinder just before combustion.
2.	Spark-ignition of fuel-air mixture.	Spontaneous ignition of fuel-air mixture in fuel sprays.
3.	Load reduced by throttling air and fuel.	Load reduced by reducing fuel injected per cycle: no throttling.
4.	Fuel: gasoline. Volatile, does not spontaneously ignite easily.	Fuel: distillate oil. Must ignite easily at high temperatures.
5.	Lower compression ratio (~10) due to knock limits.	Higher compression ratio (15 to 22); not knock limited.
6.	Lighter construction since pressure forces lower and less durability required.	Heavier construction; higher forces and durability more important.

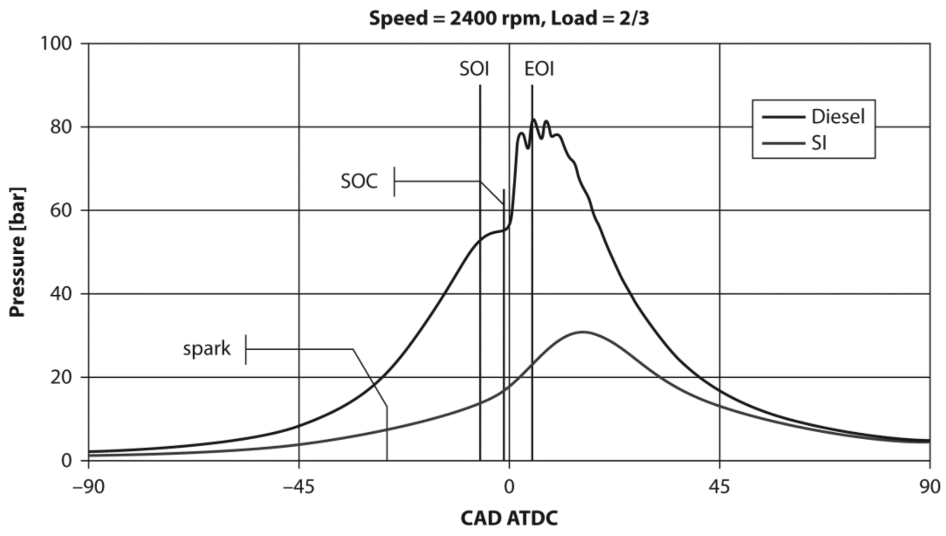
1.4



1.5

1. Differences between spark-ignition (SI) engines and diesel engines

	Standard automobile SI engine	Truck diesel engine
(a) Where the fuel is injected and why	Liquid gasoline is injected into the intake port. Fuel then vaporizes off the port and valve walls flowing into the cylinder largely as vapor when the engine is warmed-up. A homogeneous charge (air, fuel and burned residual) in the cylinder results.	Fuel is injected directly into the cylinder (or into a prechamber which is connected to the cylinder for indirect injection engines), just before (some 5 CAD) the desired start of combustion. High pressure injection produces small, high velocity fuel droplets which vaporize rapidly in the sprays.
(b) How the load is varied at fixed speed	The air-fuel ratio (AFR) is held constant at close to the stoichiometric value. Thus both air and fuel flows are varied (air flow is regulated by a throttle and fuel flow by injector pulse width).	The air flow is held constant (no throttle) in a naturally aspirated engine, and only the fuel flow is varied to vary torque. In TC engines, boost level varies with load.
(c) How the combustion process starts, develops, and ends	The charge is ignited by a spark-discharge-created hot gas kernel. A premixed flame forms around this, propagates across the chamber as a turbulent flame, and extinguishes at the cylinder walls.	Spontaneous ignition occurs shortly after start of injection, as the injected fuel atomizes, vaporizes and mixes with high temperature air. Rapid chemical energy release then occurs in fuel already mixed with air. A diffusion flame then develops around each fuel spray as fuel continues to mix with air, until all fuel is consumed.
(d) How the fuels are different and why	Gasoline: sufficiently volatile to vaporize in the intake port. Resists spontaneous ignition (onset of knock) well.	Distilled oil: less volatile than gasoline. Needs rapid spontaneous ignition characteristics (to auto-ignite at high pressures and temperatures in the absence of a spark).
(e) How the in-cylinder pressure varies as a function of crank angle	See diagram	See diagram



Diesel: Ricardo Hydra MK4, single cylinder 0.45 lt, direct injection
NIMEP = 5.60 bar
lambda = 2
SOI = 6 CAD BTDC
EOI = 5 CAD ATDC

SI: Volvo B5254 FS, single cylinder 0.49 lt
NIMEP = 6.0 bar
lambda = 1
MBT spark timing = 26 CAD BTDC

1.6 Intake and exhaust strokes of four-stroke cycle are much more effective at removing the burned gases from the cylinder and filling the cylinder volume with fresh fuel-air mixture than is two-stroke cycle scavenging process. Hence, full load four-stroke cycle cylinder pressures are substantially higher than two-stroke cycle pressures. Also, power is required to boost scavenging air (mixture) pressure prior to entry to cylinder.

1.7 (1) With multicylinder engine, more firing strokes per crank revolution hence smoother output torque versus time.

(2) Forces on each piston, connecting rod, etc. reduced with multicylinder engine.

(3) Inertia forces that result from the acceleration and deceleration of piston (and connecting rod) reduced <u>and</u> with suitable arrangement of crank throws can be balanced so there is no (or only small) net inertia force. Reduces engine vibration, problems substantially.

(4) For a given displacement, the more cylinders the higher the engine's maximum power. Smaller size cylinders have higher maximum engine speed before intake flow choking occurs: so engine maximum power is increased.

(5) Packaging the engine into a vehicle is easier with multicylinder engines with more, but smaller cylinders.

1.8 (a) Currently, competing "prime movers" are the diesel compression-ignition engine, the gasoline-electric hybrid and the battery-powered all-electric vehicle. Variations in the fuels used exist such as alcohol (ethanol, methanol) in SI engines and biodiesel, often blended with gasoline and diesel fuel, respectively. Other alternative fuels options are: natural gas, LPG, and hydrogen, in SI engines.

(b) Diesel engines are normally more robust and achieve a better fuel economy due to their higher efficiency. Their current problem is their air pollutant emissions: due to the complexity of the NOx and particulates after-treatment emission reduction technologies, these as yet have not been sufficiently developed. All-electric vehicles don't have this vehicle emissions problem, but due to their power source (batteries), they are range limited and have long recharging times. They are currently more expensive. Gasoline – electric hybrids have been growing in popularity, and for a reason. They combine the best of both worlds, achieving lower emissions and higher fuel economy. They are still more expensive. Fuels such as ethanol or biodiesel are good supplements to traditional fuels; they are starting to be used in the U.S., and elsewhere. Price, availability, and sources for their production, are all factors currently affecting the scale of their use.

(c) The most important factors for me "would be price of the fuel, fuel economy, price of the car, and performance. "I definitely like smooth driving, high performance cars, and I would be willing to pay for that." Remember size scales with weight, so bigger vehicles have worse fuel consumption. "A gasoline-electric hybrid would be my choice."

Chapter 2

ENGINE DESIGN AND OPERATING PARAMETERS

2.1 (a) Diesel engines operate at much leaner conditions overall than spark-ignition engines.

$0.056 < (F/A)_{S.I.} < 0.083$

$0.014 < (F/A)_D < 0.056$

From Eq. (2.41)

$$mep = \eta_f \eta_v Q_{HV} \rho_{a,i} (F/A)$$

Although η_f and η_V of a diesel engine are higher than those of an S.I. engine, the maximum bmep of a diesel engine is lower than that of a spark-ignition engine due to lower (F/A).

(b) Maximum rated power occurs at higher speed than does maximum rated torque because the volumetric efficiency is lower at the maximum-rated-power speed, and the friction mep is higher since it increases with increasing speed.

2.2 (a) Engine in Fig. 1.11 (4-stroke SI engine):

$$\bar{S}_p = 2LN = 2 \times 0.086 \times 5300/60 = \underline{15.2 \text{ m/s}}$$

At maximum power:

$$bmep = \frac{Pn_R}{V_d N} = \frac{187 \times 10^3 \times 2}{2.0 \times 5300/60} = \underline{2117 \text{ kPa}}$$

$$P/A_p = P/(n\pi B^2/4) = \frac{187 \times 10^{-3} \times 4}{4 \times \pi \times 0.086^2} = \underline{8.0 \text{ MW/m}^2}$$

(n = no. of cylinders)

At maximum torque:

$$bmep = \frac{6.28 \times 2 \times 353}{2.0} = \underline{2217 \text{ kPa}}$$

Engine in Fig. 1.13 (4 – stroke SI hybrid engine):

$$\bar{S}_p = 2LN = 2 \times 0.085 \times 5000/60 = \underline{14.2 \text{ m/s}}$$

$$\text{bmep} = \frac{Pn_R}{V_d N} = \frac{57\times10^3\times2}{1.5\times5000/60} = \underline{912\text{ kPa}}$$

$$P/A_p = \frac{57\times10^{-3}\times4}{4\times\pi\times0.075^2} = \underline{3.2\text{ MW/m}^2}$$

At maximum torque:

Max. torque not given: likely max. bmep about 1100 kPa (naturally-aspirated engine focussed on high efficiency).

(b) Engine in Fig. 1.31 turbo charged DI diesel,

bore = 135 mm, stroke = 150 mm

$$\bar{S}_p = 2LN = 2\times0.150\times2100/60 = \underline{10.5\text{ m/s}}$$

$$\text{bmep} = \frac{Pn_R}{V_d N} = \frac{294\times10^3\times2}{12.9\times2100/60} = \underline{1302\text{ kPa}}$$

$$P/A_p = \frac{294\times10^{-3}\times4}{6\times\pi\times0.135^2} = \underline{3.4\text{ MW/m}^2}$$

At maximum torque:

$$\text{bmep} = \frac{6.28\times2\times1667}{12.9} = \underline{1623\text{ kPa}}$$

High-speed DI diesel engine (Fig. 1.32):

(assume B = L, 2.2-liter 4-cylinder engine: B = L = 89 mm)

$$\bar{S}_p = 2LN = 2\times0.089\times4500/60 = \underline{13.4\text{ m/s}}$$

$$\text{bmep} = \frac{Pn_R}{V_d N} = \frac{93\times10^3\times2}{2.2\times4500/60} = \underline{1127\text{ kPa}}$$

$$P/A_p = \frac{93\times10^{-3}\times4}{2.2\times\pi\times0.089^2} = \underline{6.8\text{ MW/m}^2}$$

At maximum torque:

$$\text{bmep} = \frac{6.28\times2\times285}{2.2} = \underline{1627\text{ kPa}}$$