Subject : Combustion equipment technology	**الموضوع : تكنولوجيا معدات الاحتراق**
Weekly Hours : Theoretical: 2	**الساعات الأسبوعية : نظري :2**
Tutorial:1	**مناقشة : 1**
Experimental : 1	**عملي :1**
Units: 5	**الوحدات 5**

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2.	Basic Engines cycles(CI, Ci & Duel cycles)	الدورات الأساسية للمحركات	.2
3+4	Operations caracaras of Engine Parameters (Work , mean effective pressure, Torque , Power, thermal & Volumetric efficiency, Specific Fuel Consumptions)	خواص التشغيل لمعاملات (الشغل ، معدل الضغط المؤثر ، العزم ...)	.4+3
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1. Classification and Component of Combustion Equipment

Internal Combustion engine (I.C.E) can be classified according to

A. Cycle of operation

1. Otto cycle engines (Spark ignition engine S.I.E) and Diesel cycle engine (Compression ignition engine C.I.E)

2. Four stroke and Two Stroke engines (SIE or CI.E)

B. S.I.E Can be classified according to the fuel used (Gas engines and Petrol engines)

c. S.I.E Can be classified on the base of method of fuel supply

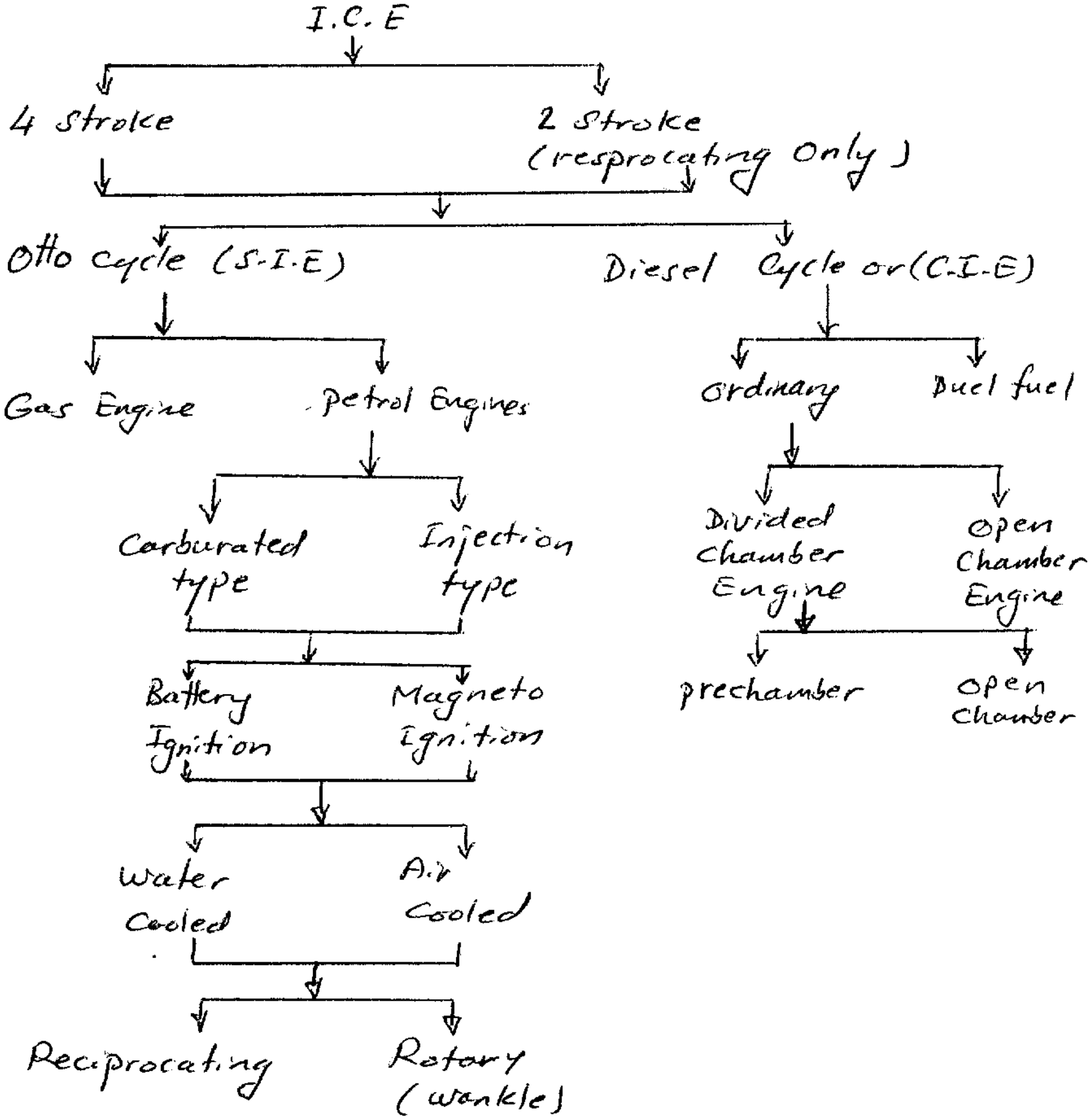
1. Carburetted types (fuel supplied through Carburettor)
2. Injection type
   i) Fuel injected into inlet ports or inlet manifold
   ii) Fuel injected into the cylinders before ignition

d. SIE. Can be classified based on method of ignition (Battery and magneto-ignition)

C-I-E Can be further classified according to

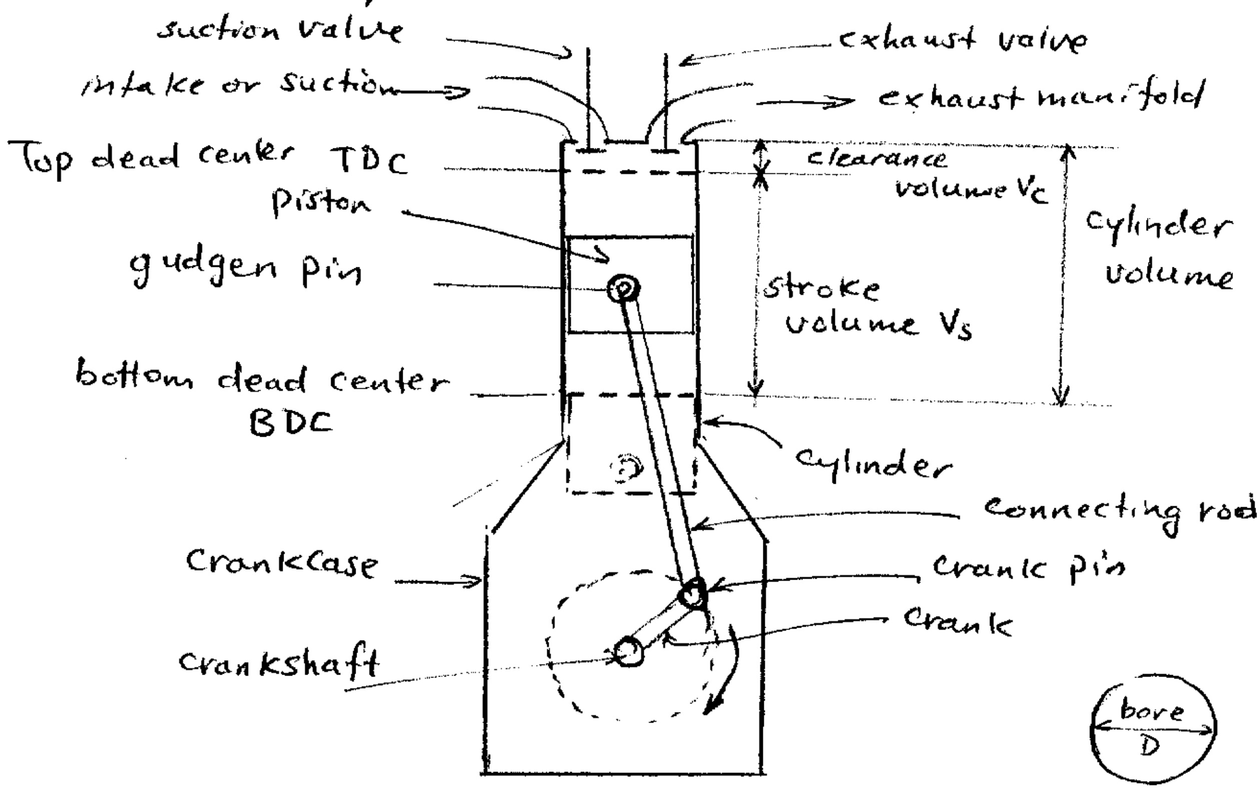
i) Normal type (using liquid fuel) light diesel oil

The mentioned Classification Can be illustrated in the following scheme



Termenology of I.C.E

The important positions and volumes in reaprocating engine are illustrated in Fig. below



1. Cylinder bore (B) or inner diameter of the working cylinder

2. Piston area A, the area of a circle of diameter equal to the ~~working~~ cylinder bore

3. Stroke (L), the nominal distance through which working piston moves between two successive reversals of its direction of motion

4. Dead Centre, position where working piston direction is reversed (at either end point of the stroke), which are

a) BDC (bottom dead centre) when the piston is nearest to the crankshaft

b) Top dead Centre TDC when the piston is

5. piston swept volume or displacement volume V_s is the nominal volume generated by the working piston when travelling from one head centre to next one which is

$$V_s = A \times L$$

6. Clearance volume V_c ; the nominal volume of the space on the combustion side of the piston at top dead centre.

7. Cylinder volume V, the sum of piston swept volume and clearance volume

$$V = V_s + V_c$$

8. Compression ratio (CR or r) The numerical value of the cylinder volume divided by the numerical value of the combustion space volume

$$r = \frac{V}{V_c}$$

<u>Four Stroke Spark Ignition Engine</u>

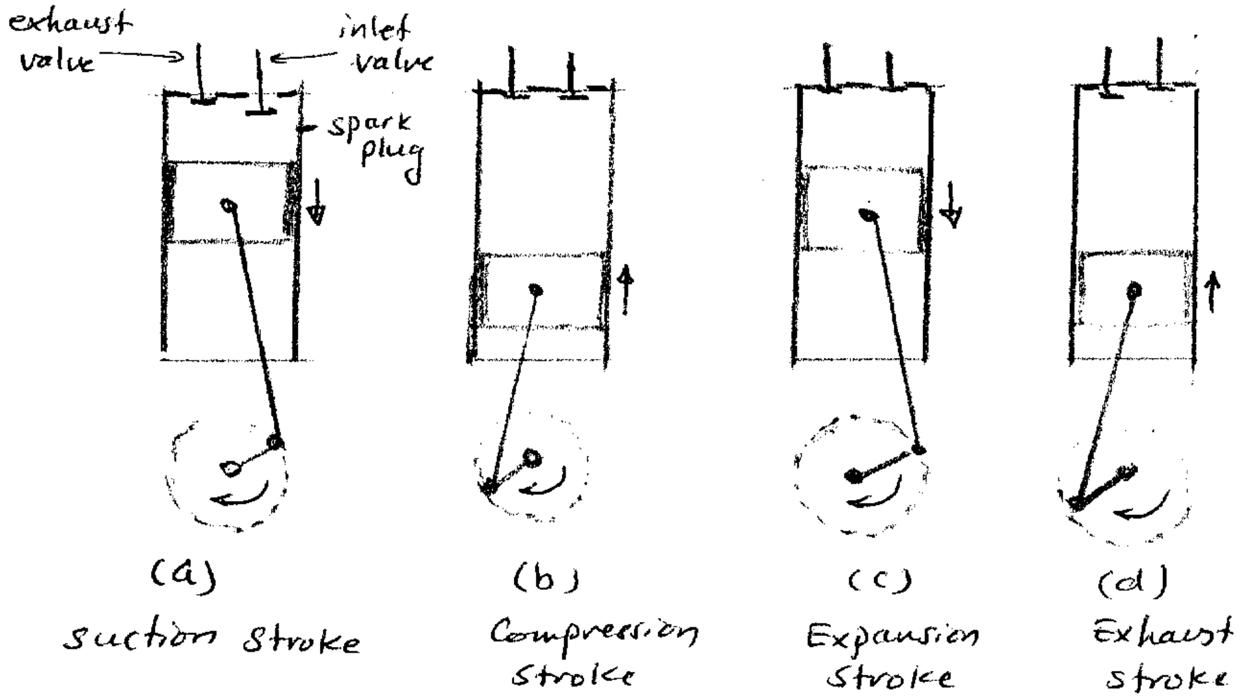
1. Suction stroke ; piston at top D.C start to more downwards. Inlet valve is open and exhaust valve is closed. Charge (fresh air mixed with fuel) is drawn into cylinder. Fig. (a), (0-1) in PV diagram

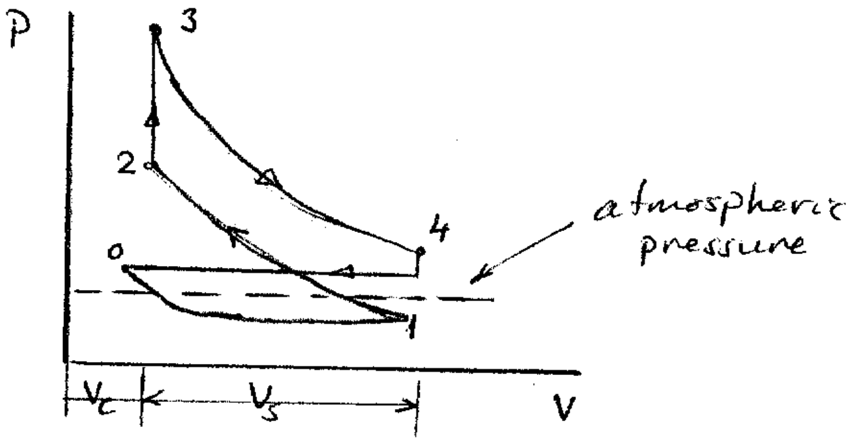
2. Compression stroke: charge is compressed by the return stroke of the piston. Inlet and exhaust valves are closed. The charge compressed into clearance volume. Just before the end of the compression stroke the mixture is ignited by spark plug. burning is take place when the piston is at the TDC. Temp. of burning is about 2000°c and the pressure is considerably increased. Fig. (b) (1-2) in PV

3. Expansion stroke or power stroke: Due to high pressure the burnt gases force the piston towards BDC. Both inlet and exhaust valves remaining closed. power is obtained through this stroke. Both pressure and temp. decreases during expansion. Fig. (c) (3-4) in PV

4. Exhaust stroke: At the end of the expansion stroke the exhaust valve opens. the inlet valve remain closed and the piston in moving from bottom D-C to TDC sweeps out the burnt gases from the cylinder Fig. (d) (4-0)

The above cycle complete with two engine revolution





Four stroke Compression Ignition Engine

It is similar to that of (SIE) except that a high compression ratio is used, and during the suction stroke air alone inducted. Due to high compression ratio, the temp. at the end at compression stroke is sufficient to ignite the injected fuel to the combustion chamber. In CIE a high pressure fuel pump and injectors is provided instead of carburettor

1. Suction stroke: Only air is inducted during this stroke and intake valve is open while exhaust valve is closed.

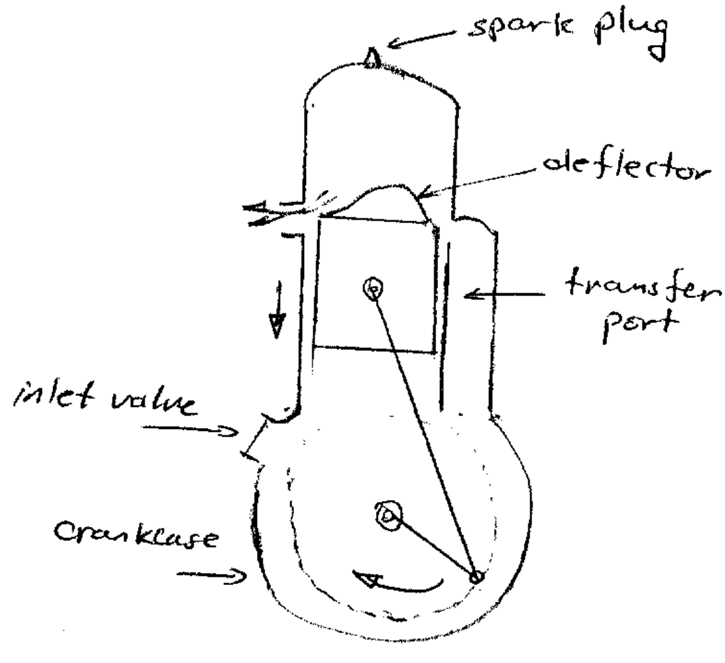
2. Compress Stroke: Both valves remain closed during Compression stroke

3. Expansion or Power Stroke: Fuel is injected in the begining of the stroke. After the injection of fuel is over, the products of Combustion expand. Both Valve remain closed during this stroke.

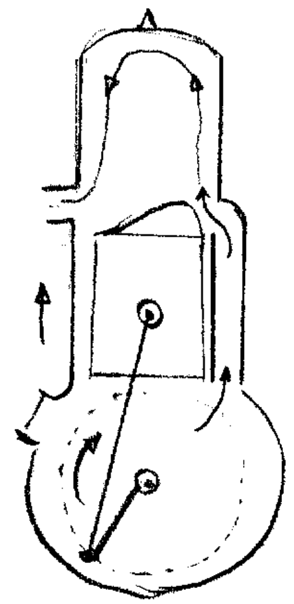
4. Exhaust stroke. The exhaust valve is open and the intake valve remains closed in the exhaust stroke.

Two Stroke Engine

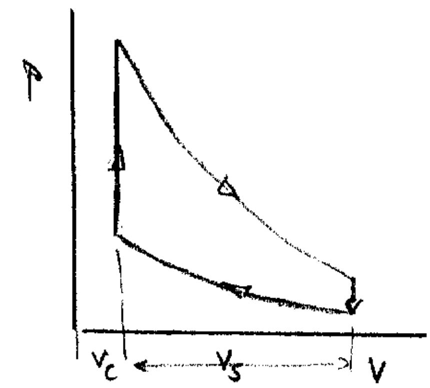
The cycle in two stroke engine is Completed in two Strokes i.e one revolution of the Crankshaft while in four strokes in two revolutions The difference in filling the Cylinder with fresh Charge and removing the burnt gases from the cylinder. The Fig. below shows Simplest type of two stroke engine.



Exhaust Blowdown



Scavenging



indicator diagram

The charge is sucked through inlet valve when the pressure in the crankcase reduces due to upward motion of the piston during compression stroke. After compression ignition and expansion takes place in the usual way

During the expansion stroke the air in the crankcase is compressed. Near the end of expansion stroke piston uncovers the exhaust ports and the cylinder pressure drops to atomospheric as the combustion products leave the cylinder. Further motion of air or mixture in the Crankcase to enter the engine cylinder. The top of the piston deflect the fresh charge up to the top of cylinder before flowing to the exhaust ports.

Performance of Internal Combustion Engine

In reciprocating internal combustion engine fuel is feed in the combustion chamber where it burns in air, converting its chemical energy into heat. The whole of this energy cannot be utilised for driving the piston, losse are

1. to the exhaust
2. to the coolant
3. to the radiation

The remaining energy converted to power is called the indicated horse power (ihp), whis is utilized for driving the piston. The energy applied to the piston passes through the connecting rod to the crankshaft which causes to losses

a) Friction losses
b) pumping losses
c) others

The sum of all these losses, converted to power is termed as friction horse power (fhp)

The remaining energy is the useful mechanical energy termed as brake horse power (bhp)

The engine performance is indicated by efficiency η
5 important engine efficiency are defined below

1. Indicated Thermal Efficiency η_t
which is the ratio of the energy in the indicated horse power to the fuel energy

$$\eta_t = \frac{ihp}{fuel\ hp}$$

$$= \frac{ihp \times 4500}{mass\ of\ fuel/min \times Calorific\ value\ \ C.V}$$

2. Mechanical Efficiency η_m
which is the ratio of brake horse power (delivered power) to the indicated horse power (power provided to the piston) or

$$\eta_m = \frac{bhp}{ihp}$$

and $fhp = ihp - bhp$

3. Brake thermal efficiency η_{tb} which is the ratio of energy in the brake horse power to the fuel energy

$$\eta_{tb} = \frac{bhp}{fuel\ hp}$$

$$= \frac{bhp \times 4500}{mass\ of\ fuel/min \times C.V}$$

The brake thermal efficiency equals the product of the indicated thermal efficiency and the mechanical efficiency

$$\eta_{tb} = \eta_t \times \eta_m$$

4. Volumetric Efficiency η_v

$$\eta_v = \frac{\text{actual air induced at ambient Conditions}}{\text{swept volume}}$$

5. <u>Relative Efficiency or Efficiency Rato</u>

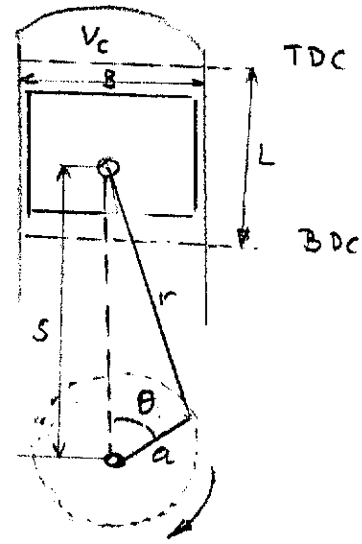
$$\eta_{rel} = \frac{\text{actual thermal efficieny}}{\text{air-standard efficieny}}$$

see next chapter

Other important performance Parameters of engine are

1. Specific fuel Consumption

Engine Parameters and Performance



TDC .. Top dead center

BDC -- bottom dead center

V_c -- clearance volume

B -- bore

L -- stroke length

V_s -- stroke or displacement volume

r -- Connecting rod length

a .. crank offset

S .. piston position

θ -- Crank angle (θ = zero when the piston at TDC)

1. Stroke length

$$L = 2a \qquad (1)$$

2. averange piston speed

$$\bar{U}_p = 2LN \qquad \text{.. } N \text{ engine speed RPM} \qquad (2)$$

Up is between (5 – 15) m/s or (15 – 50) ft/s

3. $$S = a\cos\theta + \sqrt{r^2 - a^2\sin^2\theta} \qquad (3)$$

4. instantnous piston speed

$$U_p = \frac{ds}{dt} \qquad (4)$$

5. $$U_p/\bar{U}_p = (\pi/2)\sin\theta\left[1 + \left(\cos\theta/\sqrt{R^2 - \sin^2\theta}\right)\right] \qquad (5)$$

6. where $$R = \frac{r}{a} \qquad (6)$$

7. Stroke or displacement volume

$$V_s = V_{BDC} - V_{TDC} \qquad (7)$$

which is put for one cylinder or for entire engine. For one cylinder

$$V_s = \pi/4 \, B^2 L \qquad (8)$$

and for multi cylinders N_c

$$V_s = N_c \frac{\pi}{4} B^2 L \qquad (9)$$

V_s can be given in m^3, cm^3, in^3 and mostly in liters(L)

$1\,L = 10^{-3} m^3 = 1000\,cm^3 \simeq 61\,in^3$

typical values for V_s from 0.1 cm^3 (small model airplanes to about 8L (490 in^3) for large automobiles. V_s for modern average automobile engine is about 2 - 3 liters.

8. Minimum cylinder volume occurs when the piston is at TDC and is called the clearance volume V_c

$$V_c = V_{TDC} \qquad (10)$$

$$V_{BDC} = V_c + V_s \qquad (11)$$

9. Compression ratio of an engine is define as

$$r_c = \frac{V_{BDC}}{V_{TDC}} = \frac{V_c + V_s}{V_c} \qquad (12)$$

10. Cylinder Volume V

Cylinder volume V at any crank angle is

$$V = V_c + (\pi B^2/4)(r + a - s) \qquad —(13)$$

V_c -- clearance volume
B -- bore
r -- connecting rod length
a -- crank offset
s -- piston position

The above equation can be written in a non dimensional form by dividing by V_c and subs. for r, a and s and employ the definision of R gives

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$$\frac{V}{V_c} = 1 + \frac{1}{2}(r_c - 1)\left[R + 1 - \cos\theta - \sqrt{R^2 - \sin^2\theta}\right] \qquad —(14)$$

11. Cross-sectional area of a cylinder and the surface area of a flat-topped piston are each given by

$$A_p = (\pi/4) B^2 \qquad —(15)$$

12. The combustion chamber surface area is

$$A = A_{ch} + A_p + \pi B(r + a - s) \qquad —(16)$$

where A_{ch} is the cylinder head surface area which will be somewhat larger than A_p

or $$A = A_{ch} + A_p + (\pi B L/2)\left[R + 1 - \cos\theta - \sqrt{R^2 - \sin^2\theta}\right] \qquad —(17)$$

Example 1 :

A three liters SI V6 engine operate on a four-stroke cycle at 3600 RPM. The Compression ratio is 9.5, the length of connecting rods is 16.6 Cm and the engine is square (B=L). At this speed, combustion ends at 20° a TDC. Calculate :

1. Cylinder bore and stroke length
2. avarage piston speed
3. Clearance volume of one cylinder
4. piston speed at the end of combustion
5. Distance the piston has traveled from TDC at the end of combustion
6. Volume in the combustion chamber at the end of combustion.

Solution :

1. For One Cylinder use Eq. 8

$$V_s = \frac{\pi}{4} B^2 L$$

and $V_s = \frac{V_{total}}{6} = \frac{3L}{6} = 0.5 L = 0.0005 \, m^3$ Ans.

now

$$0.0005 = \frac{\pi}{4} B^2 L = \frac{\pi}{4} B^3 \quad \text{(where } B = L \text{ for square engine)}$$

fromwhich $B = 0.0860 \, m = 8.6 \, Cm = L$

2. Avarage piston speed from Eq. (2)

$$\bar{U}_p = 2LN$$

$= (2 \text{ stroke/rev})(0.086 \text{ m/stroke})(3600/60 \text{ rev/sec})$

$= 10.32 \, m/s$ Ans.

3. Clearance volume of one cylinder from Eq-(12)

$$r_c = \frac{V_c + V_s}{V_c}$$

or $$9.5 = \frac{V_c + 0.0005}{V_c}$$

gives $V_c = 0.000059\ m^3 = 59\ cm^3$ ← Ans

4. piston speed from Eq-(5), but need to evaluate:

$$a = \frac{L}{2} = \frac{0.0860}{2} = 4.30\ cm$$

$$R = \frac{r}{a} = \frac{16.6}{4.30} = 3.86$$

then

$$\frac{U_p}{\bar{U}_p} = \frac{\pi}{2}\sin\theta\left[1 + \left(\cos\theta/\sqrt{R^2 - \sin^2\theta}\right)\right]$$

$$= \frac{\pi}{2}\sin(20^\circ)\left[1 + \left(\cos 20/\sqrt{3.86^2 - \sin^2 20}\right)\right]$$

$$= 0.668$$

or $U_p = 0.668\ \bar{U}_p = (0.668)(10.32\ m/s)$

$= 6.89\ m/s$ ← Ans.

5. piston position from Eq. (3)

$$s = a\cos\theta + \sqrt{r^2 - a^2\sin^2\theta}$$

$$= (0.043\ m)\cos 20 + \sqrt{(0.166\ m)^2 - 0.043^2\sin^2 20}$$

$$= 0.206\ m$$ ← Ans.

Distance from TDC is given by

$$x = r + a - s$$

$= 0.166 + 0.043 - 0.206 = 0.003\ m = 0.3\ cm$ ← Ans

6. Instantaneous volume from Eq. (14)

$$\frac{V}{V_c} = 1 + \frac{1}{2}(r_c - 1)\left[R + 1 - \cos\theta - \sqrt{R^2 - \sin^2\theta}\right]$$

$$= 1 + \frac{1}{2}(9.5 - 1)\left[3.86 + 1 - \cos(20) - \sqrt{(3.86)^2 - \sin^2 20}\right]$$

$$= 1.32$$

$$V = 1.32\,V_c = 1.32\,(59\ cm^3) = 77.9\ cm^3$$

$$= 0.0000779\ m^3$$

Ans.

/ Problem 1 :

A four cylinder, 2.4 Liter engine operates on a four-stroke cycle at 3200 RPM. The compression ratio is 9.4 : 1, the connecting rod length r = 18 cm and the bore and stroke are related as $L_s = 1.06\ B$. Determine

(a) Clearance volume of one cylinder in cm^3, L and in^3

(b) Bore and stroke in cm and in

(c) Avarage piston speed in m/sec and ft/sec.

$$V_s = \frac{\pi}{4} B^2 L = \frac{V_{total}}{4} = \frac{2.4}{4} = 0.6\ L = 0.6 \cdot 10^{-3}\ m^3$$

$$= 0.6 \cdot 1000\ cm^3$$

$$= 0.6 \cdot 61\ in^3$$

$$V_s = \frac{\pi}{4} B^2 (1.06\ B) \Rightarrow B$$

$$r_c = \frac{V_c + V_s}{V_c} \Rightarrow V_c$$

$$L = 1.06\ B \Rightarrow L$$

Work of Engine

Force due to gas pressure on the moving ~~ey~~ piston generates the work in an IC engine cycle

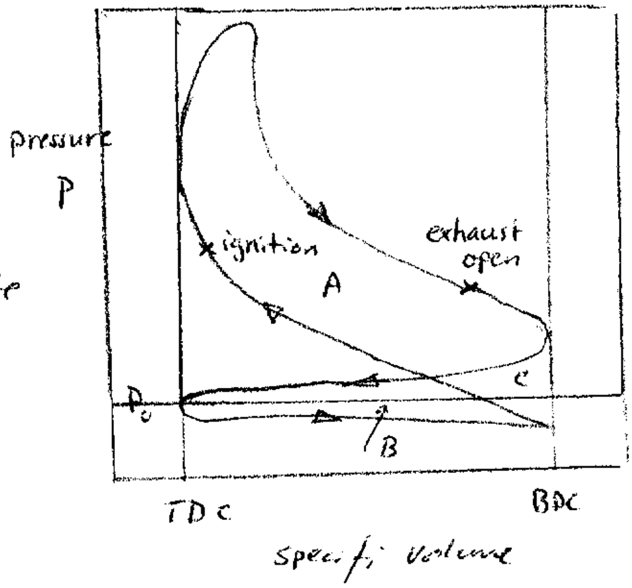
$$W = \int F dx = \int P A_p dx, \quad A_p dx = dV, \quad W = \int P dV$$

1, 2, 3

where p: pressure in combustion chamber
A_p: Area of piston face
x: distance the piston moves

specific work $w = \frac{W}{m}$
specific volume $v = \frac{V}{m}$

then $w = \int P dv$ —(4)



Eq. 4 and the area shown in Fig. give the work inside the combustion chamber Called Indicated work

Actual work is called Brake work w_b,

$$w_b = w_i - w_f \quad —(5)$$

w_i: indicated work (specific) generated inside the combustion chamber

w_f: specific work lost due to friction and parasitic loads (oil pump, supercharger, air conditioner, compressor, alternator, etc

The upper loop in the Fig. consists of compression and power strokes where output work is generated called gross indicated work (Area A and C in Fig.)
lower loop includes intake and exhaust strokes called pump work (Area B and C) which absorbs work from the engine, then

$$w_{net} = w_{gross} + w_{pump} \qquad —(6)$$

Mechanical efficiency

$$\eta_m = \frac{w_b}{w_i} = \frac{W_b}{W_i} \qquad —(7)$$

η_m (75% – 95%)

Mean Effective Pressure

Since the pressure in cylinder is continuously changing during the cycle, mean effective pressure (mep) is given by

$$w = (mep)\Delta v$$

or
$$mep = \frac{w}{\Delta v} = \frac{W}{V_s} \qquad —(8)$$

$$\Delta v = v_{BDC} - v_{TDC}$$

W -- work of one cycle
w -- specific work of one cycle
V_s -- displacement volume

Brake mean effective pressure bmep is

$$bmep = \frac{w_b}{\Delta v} \qquad (9)$$

Indicated mean effective pressure is

$$imep = \frac{w_i}{\Delta v} \qquad (10)$$

Gross and net imep

$$imep)_{gross} = w_i)_{gross} / \Delta v \qquad (11)$$

$$imep)_{net} = w_i)_{net} / \Delta v \qquad (12)$$

pump mean effective pressure

$$pmep = w_{pump} / \Delta v$$

Friction mean effective pressure

$$Fmep = w_f / \Delta v \qquad (13)$$

$$\left.\begin{aligned} nmep &= gmep + pmep & (a)\\ bmep &= nmep - fmep & (b)\\ bmep &= \eta_m \, imep & (c)\\ bmep &= imep - fmep & (d) \end{aligned}\right\} \qquad (14)$$

bmep (850 – 1050) KPa for SIE
(700 – 900) kPa for CI
(1000 – 1200) KPa for turbocharged engine

Torque and Power

Torque is defined as force acting at a moment distance (N·m), it relation to work by

$$2\pi \tau = W_b = (bmep) V_s / n \qquad (15)$$

W_b -- brake work of one revolution

V_s -- displacement volume

n -- number of revolution per cycle

For two-stroke cycle engine with one cycle for each revolution

$$2\pi \tau = W_b = (bmep) V_s$$

$$\tau = (bmep) V_s / 2\pi \quad (\text{two stroke cycle}) \qquad (16)$$

$$\tau = (bmep) V_s / 4\pi \quad (\text{four stroke cycle}) \qquad (17)$$

Power is defined as the rate of work of the engine. If n: number of revolutions per cycle, N: engine speed then

$$\dot{W} = WN/n \qquad (18)$$

$$\dot{W} = 2\pi N \tau \qquad (19)$$

$$\dot{W} = (1/2n)(mep) A_p \bar{U}_p \qquad (20)$$

$$\dot{W} = (mep) A_p \bar{U}_p / 4 \quad \text{for 4 stroke cycle} \qquad (21)$$

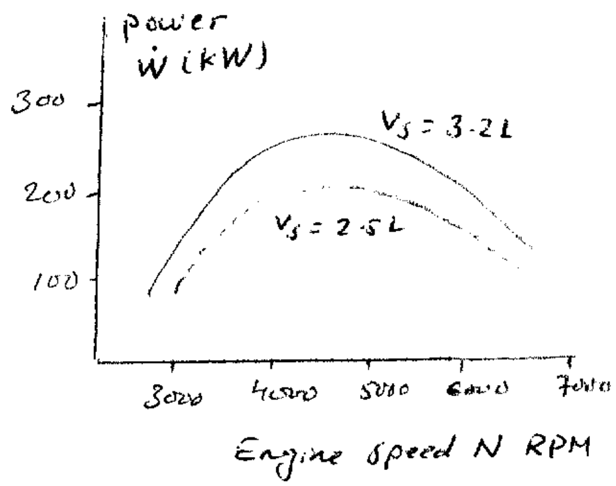
$$\dot{W} = (mep) A_p \bar{U}_p / 2 \quad \text{for 2 stroke cycle} \qquad (22)$$

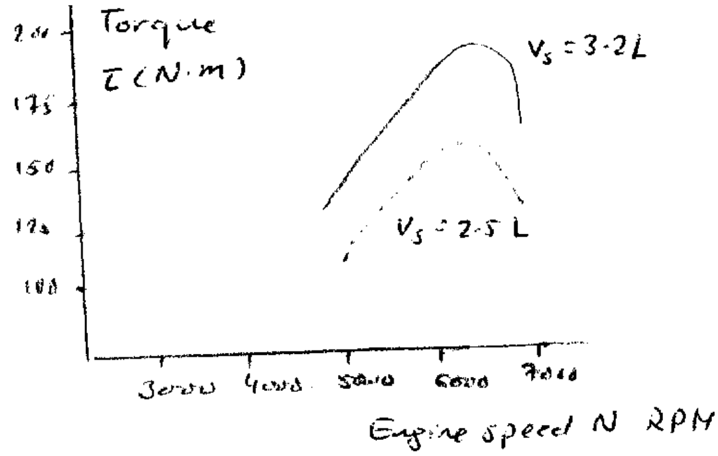
where W: work per cycle

A_p: piston face area of all pistons

$\bar{U}_p$: average piston speed.

representation of power and torque for specific engine are given below





$$\dot{W}_b = \eta_m \dot{W}_i \qquad (23)$$

$$(\dot{W}_i)_{net} = (\dot{W}_i)_{gross} - (\dot{W}_i)_{pump} \qquad (24)$$

$$\dot{W}_b = \dot{W}_i - \dot{W}_f \qquad (25)$$

1 hp = 0.7457 kW = 2545 Btu/hr = 550 ft-lb/s

1 kW = 1.341 hp

brake specific power $bsp = \dot{W}_b / A_p$ (26)

output per displacement $OPD = \dfrac{\dot{W}_b}{V_s}$ (27)

Engine specific volume $SV = \dfrac{V_s}{\dot{W}_b}$ (28)

Example 2:

The engine in Ex. 1 is connected to a dynamometer which gives a brake output torque reading of 205 N.m at 3600 RPM. At this speed air enters the cylinders at 85 kPa and 60°c, and the mechanical efficiency of the engine is 85%. Calculate

1. brake power 2. Indicated power
3. brake mean effective pressure
4. indicated " " "
5. friction " " "
6. power lost to friction
7. brake work per unit mass of gas in the cylinder
8. brake specific power
9. brake output per displacement
10. engine specific volume.

Solution:

1. $\dot{W}_b = 2\pi N T$ eq. (19)

$= 2\pi(3600/60) \cdot 205$

$= 77302 \text{ N.m/s} = 77.3 \text{ kW} = 104 \text{ hp}$

2. Eq. (23)

$\dot{W}_b = \eta_m \dot{W}_i$ or $\dot{W}_i = \dot{W}_b / \eta_m$

$= (77.3 \text{ kW})/0.85 = 90.9 \text{ kW} = 122 \text{ hp}$

3. From eq. (17)

$T = (bmep) V_s / 4\pi$

$-/- = 4\pi (205)/0.003 \text{ m}^3/\text{cycle}$

4. From Eq. 14-c

$$imep = \frac{bmep}{\eta_m} = \frac{859}{0.85} = 1010 \text{ kPa} = 146 \text{ psia}$$

5. From Eq. 14-d

$$fmep = imep - bmep$$
$$= 1010 - 859 = 151 \text{ kPa} = 22 \text{ psia}$$

6. From Eq. 20 and Eq. $A_p = (\pi/4) B^2$

$$A_p = \frac{\pi}{4}(0.086)^2 = 0.00581 \text{ m}^2 \text{ for one cylinder}$$

$$\dot{W}_f = \frac{1}{2n}(fmep)\, A_p\, \bar{U}_p$$
$$= \frac{1}{4}(151 \text{ kPa})(0.00581)(10.32)(6 \text{ cyl})$$
$$= 13.6 \text{ kW} = 18 \text{ hp}$$

or it can be obtained from Eq-(25)

$$\dot{W}_f = \dot{W}_i - \dot{W}_b = 90.9 - 77.3 = 13.6 \text{ kW}$$

7. $$W_b = (bmep)\, V_s = 859\,(0.0005) = 0.43 \text{ kJ}$$

gas entering the cylinders at BDC is air

$$m_a = P V_{BDC} / RT = P(V_s + V_c)/RT$$
$$= 85\,(0.0005 + 0.000059)/(0.287 \cdot 333)$$
$$= 0.0005 \text{ kg}$$

brake specific work per unit mass

$$w_b = W_b / m_a = 0.43/0.0005$$
$$= 860 \text{ kJ/kg} = 370 \text{ Btu/lbm}$$

8. brake specific power Eq. 26

$$BSP = \dot{W}_b / A_p = 77.3 / \pi/4 (0.086)^2 (6 \text{ cylinder})$$

$$= 2220 \text{ kW/m}^2$$

$$= 0.2220 \text{ kW/cm}^2$$

$$= 1.92 \text{ hp/in}^2$$

9. brake output per displacement Eq. 27

$$BOPD = \dot{W}_b / V_s$$

$$= 77.3 / 3L$$

$$= 25.8 \text{ kW/L}$$

10. engine specific volume Eq. (28)

$$BSV = V_s / \dot{W}_b = \frac{1}{BOPD}$$

$$= \frac{1}{25.8} = 0.0388 \text{ L/kW}$$

PROBLEMS AND EXAMPLES

1. An engine car has six cylinders of 82.55 mm bore and 79.5 mm stroke. The compression ratio is 7.8. Determine
   (a) Cubic capacity of the engine or total swept volume in cm^3
   (b) Clearance volume of each cylinder

Solution:

(a) Swept volume of one cylinder

$$V_{sl} = \frac{\pi}{4} B^2 L$$

$$= \frac{\pi}{4} (8.255)^2 \cdot 7.95 = 425.5 \ cm^3 \text{ or } cc$$

Cubic capacity of the engine = total swept volume of all cylinders

$$= 425.5 \times 6 = 2553 \ cm^3$$ Ans.

(b) $$r_c = \frac{V_c + V_s}{V_c}$$

$$7.8 = 1 + \frac{V_s}{V_c} \Rightarrow \frac{V_s}{V_c} = 7.8 - 1 = 6.8$$

Then, clearance volume of each cylinder is

$$V_c = \frac{V_s}{6.8} = \frac{425.5}{6.8} = 62.58 \ cm^3$$ Ans.

2. A certain engine produces 10 ihp. Its mechanical efficiency is 80%. Find
   (a) brake horse power delivered
   (b) Friction horse power

Solution:
(a) $\eta_m = \frac{bhp}{ihp} \Rightarrow 0.8 = \frac{bhp}{10}$

or $bhp = 8$

(b) $fhp = ihp - bhp = 10 - 8 = 2$

3. A certain engine at full load delivers 100 bhp. It requires 25 ihp to rotate it without fuel at the same speed. Find its mechanical efficiency. Assuming that the mechanical losses remain constant what will be the mech. eff. at
   (a) half load
   (b) quarter load.

$$\eta_m = \frac{bhp}{bhp + fhp} = \frac{100}{100+25} = 80\%$$

(a) at half load

$$\eta_m = \frac{50}{50+25} = 0.667 = 66.7\%$$

(b) at quarter load

$$\eta_m = \frac{25}{25+25} = 0.5 \text{ or } 50\%$$

4. A four stroke petrol engine delivers 48 bhp with a mechanical efficiency of 80 percent. The fuel consumption of the engine is 0.3 kg per bhp-hr and the air fuel ratio is 14:1. The heating value of the fuel is 10000 kcal/kg. Find (a) ihp (b) fhp (c) brake thermal eff. (d) indicated thermal eff. (e) fuel consumption per hour (f) air consumption/hr

Solution:

(a) $\eta_m = \frac{bhp}{ihp} = \frac{48}{0.8} = ihp = 60$

(b) $fhp = ihp - bhp = 60 - 48 = 12$

(c) $1 bhp\text{-}hr = 75\ kg_f\text{-}m \times \frac{3600}{427} = 632.5$ kcal/hr

brake thermal eff.

$$\eta_{th} = 632.5/(0.3 \times 10000) = 0.211 \text{ or } 21.1\%$$

(d) indicated thermal eff.

$$\eta_{th} = \eta_i \times \eta_m$$

$$\eta_i = \frac{21.1}{0.8} = 0.264 \text{ or } 26.4\%$$

(e) Fuel consumption per hour

$= bsfc \times bhp = 0.3 \times 48 = 14.4$ kg

(f) Air consumption per hr

$= 14 \times 14.4 = 202$ kg

5. A four-cylinder, two stroke cycle diesel engine with 10.9 cm bore and 12.6 cm stroke produces 88 kW of brake power at 2000 RPM compression ratio $r_c = 18:1$. Calculate

(a) Engine displacement [cm^3, L]

(b) brake mean effective pressure [kPa]

(c) Torque [N-m]

(d) clearance volume of one cylinder

Ans. (a) 4703, 4.703 (b) 561, (c) 420 (d) 69.2

6. A 1500 cm^3 four stroke cycle, four cylinder CIE operating at 3000 RPM produces 48 kW of brake power. Volumetric efficiency is 0.92 and Air fuel ratio AF is 21:1 Determine

(a) Rate of air flow into the engine [kg/s]

(b) Brake specific fuel consumption [gm/kW-hr]

(c) Mass rate of exhaust flow [kg/hr]

(d) Brake output per displacement [kW/L]

(a) 0.0407 (b) 145.5 (c) 153.5 (d) ~~35~~ 32

Problems Sheet 1

1. An engine car has six cylinders of 82.55 mm bore and 79.5 mm stroke. The compression ratio is 7.8. Determine

   (a) Cubic capacity of the engine or total swept volume in cm^3. Ans.

   (b) Clearance volume of each cylinder

   Ans. (a) 2553 cm^3 (b) 62.58 cm^3

2. A certain engine produces 10 ihp. Its mechanical efficiency is 80%. Find

   (a) Brake horse power delivered

   (b) Friction horse power

   Ans. (a) 8 (b) 2.

3. A certain engine at full load delivers 100 bhp. It requires 25 ihp to rotate it without fuel at the same speed. Find its mechanical efficiency assuming that the mechanical losses remain constant, what will be the mechanical efficiency at

   (a) half load

   (b) quarter load

   Ans. (a) 66.7% (b) 50%

4. A four stroke petrol engine delivers 48 bhp with a mechanical efficiency of 80%. The fuel consumption of the engine is 0.3 kg per bhp-hr and the air fuel ratio is 14:1. The heating value of fuel is 10000 kcal/kg. Find (a) ihp (b) fhp (c) brake thermal effeciency (d) indicated thermal effeciency (e) fuel consumption per hour (f) air consumption/hr.

Ans. (a) 60 (b) 12, (c) 21.1% (d) 26.4%

(e) 14.4 kg (f) 202 kg

5. A four-cylinder two stroke cycle diesel engine with 10.9 cm bore and 12.6 cm stroke produces 88 kW of brake power at 2000 RPM and compression ratio r_c = 18:1. Calculate

(a) Engine displacement [cm^3, L]
(b) Brake mean effective pressure [kPa]
(c) Torque [N.m]
(d) Clearance volume of one cylinder

Ans. (a) 4703, 4.703 (b) 561, (c) 420, (d) 69.2

6. A 1500 cm^3 four stroke cycle four cylinder CIE operating at 3000 RPM produces 48 kW of brake power. If volumetric efficiency is 0.92 and Air fuel ratio AF is 21:1 Determine

(a) Rate of air flow into the engine kg/s
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Ans. (a) 0.0407 (b) 145.5 (c) 153.5 (d) 32,