Engine Performance

Engine Design and Operational Parameters

CH. 4

Prepared by: Dr. Assim Adaraje

Cylinder Swept Volume (V_c):

$$V_c = Cylinder\ Area \times Stroke\ Length$$

$$V_c = A_c \times L = (\frac{\pi}{4} d_c^2) \times L$$

where:

V_c = cylinder swept volume [cm^3 (cc) or L]

A_c = cylinder area [cm^2 or cm^2/100]

d_c = cylinder diameter [cm or cm/10]

L = stroke length (the distance between the TDC and BDC) [cm or cm/10]

BDC = Bottom Dead Center

TDC = Top Dead Center

* The ratio between the cylinder diameter/cylinder stroke called “bore/stroke” ratio.

- “bore/stroke” >1 is called *over square engine*, and is used in automotive engines
- “bore/stroke” =1 is called square engine
- “bore/stoke” <1 is called= *under square engine*, and is used in tractor engine

Engine Swept Volume (V_{ec}):

where:

V_c = engine swept volume or Cylinder volume [cm^3 (cc) or L]

n = number of cylinders

V_{ec} = cylinder swept volume [cm^3 (cc) or L] = V_c n

A_c = cylinder area [cm^2 or cm^2/100]

d_c = cylinder diameter [cm or cm/10]

* The units of cylinder swept volume is measured in (cm^3, cubic centimeter (cc), or liter). - V_{ec} for small engines, 4 cylinder engines is (900 cc:2000 cc) - V_{ec} for big engine, 6 or 8 cylinder engines is (2000cc:4500 cc)

Compression Ratio (r):

$$r = \frac{Cylinder\ Volume\ at\ BDC}{Cylinder\ Volume\ at\ TDC}$$

$$r = \frac{(Cylinder\ Volume + Cylinder\ Clearance\ Volume)}{Cylinder\ Clearance\ Volume}$$

$$r = \frac{V_s + V_c}{V_c} = 1 + \frac{V_s}{V_c}$$

where:

r = compression ratio

V_s = cylinder swept volume (combustion chamber volume) [cc, L, or m^3] it is design parameter

V_c = cylinder volume [cc, L, or m^3] it is design paramete

* Increase the compression ratio increase engine power

- r (gasoline engine) = 7:12, the upper limit is engine pre ignition
- r (diesel engine) = 10:18, the upper limit is the stresses on engine parts

Engine Volumetric Efficiency ($_{hv}$):

$$\eta_V = \frac{Volume\ of\ air\ taken\ into\ cylinder}{Maximum\ possible\ volume\ in\ the\ cylindre}$$

$$\eta_V = \frac{V_{air}}{V_c}$$

where: η_V = volumetric efficiency

V_{air} = volume of air taken into cylinder [cc, L, or m^3]

V_c = cylinder swept volume [cc, L, or m^3]

* Increase the engine volumetric efficiency increase engine power

- Engine of normal aspiration has a volumetric efficiency of 80% to 90%

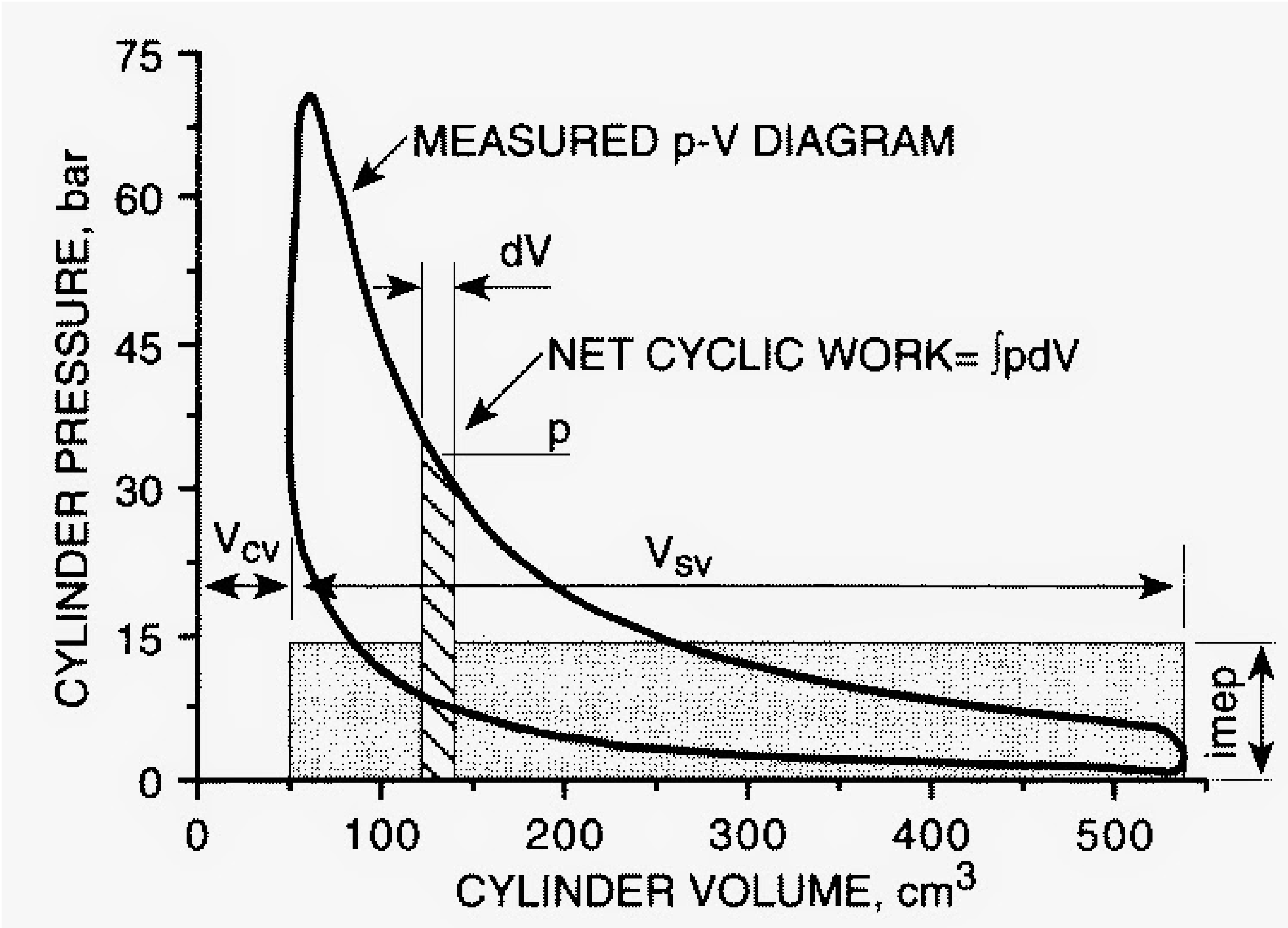
- Engine volumetric efficiency can be increased by using: (turbo and supper charger can increase the volumetric efficiency by 50%)

$$\eta_v = \frac{Volume\ of\ air\ taken\ into\ cylinder}{Maximum\ possible\ volume\ in\ the\ cylindre}$$

$$\eta_v = \frac{V_{air}}{V_c}$$

Mean Effective Pressure:

The definition of BMEP is: ***the average (mean) pressure which, if imposed on the pistons uniformly from the top to the bottom of each power stroke, would produce the measured (brake) power output.***


MEASURED p-V DIAGRAM
dV
NET CYCLIC WORK= ∫pdV
p
V_{cv}
V_{sv}
imep
CYLINDER PRESSURE, bar
75
60
45
30
15
0
0
100
200
300
400
500
CYLINDER VOLUME, cm^3

Mean effective pressure is the ratio of work done (W) during the working stroke(s) of a cycle to the stroke volume or swept volume (V_s) of the cylinder. It is denoted by ‘p_m‘ and its unit is N/m^2.

$$\text{Mean effective pressure}, p_m = \frac{\text{Work Done}}{\text{Stroke Volume}}$$

Brake **mean effective pressure** (**BMEP**) - **Mean effective pressure** calculated from measured brake torque. Brake Mean Effective Pressure (bmep) is, calculated by putting the measured dynamometer torque into the above equation.

Gross indicated **mean effective pressure** (**IMEP**$_g$) - **Mean effective pressure** calculated from in-cylinder **pressure** over compression and expansion portion of engine cycle (360° in a four-stroke, 180° in a two-stroke).

Therefore Indicated mean effective pressure (imep):

is a hypothetical pressure which if acting on the engine piston during the working stroke would results in the indicated work of the engine. This means it is the height of a rectangle having the same length and area as the cycle plotted on a ***p- v*** diagram.

$$\text{imep } (P_i) = \frac{\text{Net area of the indicator diagram}}{\text{Swept volume}} \times \text{Indicator scale}$$

Consider one engine cylinder: Work done per cycle = $P_i AL$

where: A = area of piston; L = length of stroke

Work done per min. = work done per cycle x active cycles per min.

$i.p. = P_i AL$ x active cycles/ min

To obtain the total power of the engine this should be multiplied by the number of cylinder n, i.e.

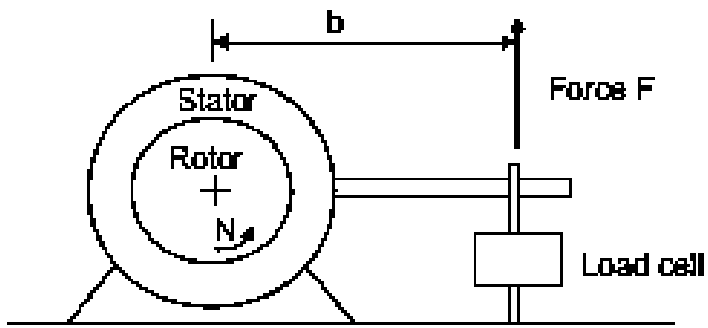
:

Total $i.p. = P_i AL\, Nn/2$ for four- stroke engine.

And $i.p. = P_i AL\, Nn$ for Two- stroke engine

Engine Torque and Power

Torque is measured using a dynamometer.



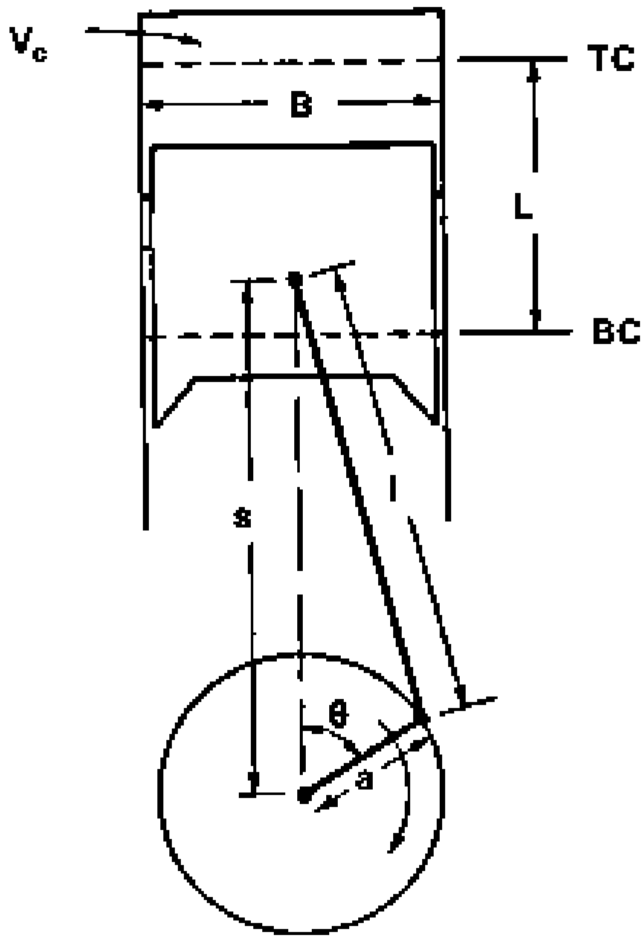
The **torque** exerted by the engine is: $T = F\,b$ *with units: J*

The **power** Wdot delivered by the engine turning at a speed N and absorbed by the dynamometer is:

$$\text{Wdot} = \omega\,T = (2\pi N)\;T \quad \textit{w/units: (rad/rev)(rev/s)(J) = Watt}$$

Note: ω is the shaft angular velocity with units: rad/s

Engine Geometry



For most engines B ~ L (square engine)

$$s = a\cos\theta + \left(l^2 - a^2\sin^2\theta\right)^{1/2}$$

Cylinder volume when piston at TC (*s*=*l*+a) defined as the clearance volume V_c

The cylinder volume at any crank angle is:

$$V = V_c + \frac{\pi B^2}{4}(l + a - s)$$

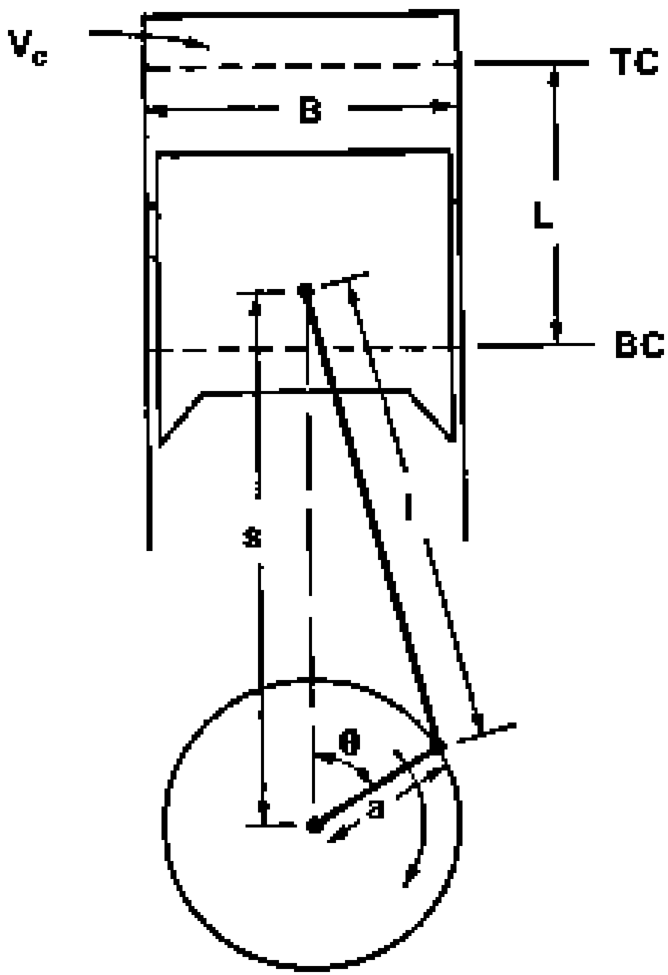
Maximum displacement, or swept, volume:

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

Compression ratio:

$$r_c = \frac{V_{BC}}{V_{TC}} = \frac{V_c + V_d}{V_c}$$

Mean and Instantaneous Piston Speeds



$$s = a\cos\theta + \left(l^2 - a^2\sin^2\theta\right)^{1/2}$$

Average and **instantaneous** piston speeds are:

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

$$U_p = \frac{ds}{dt}$$

Where N is the rotational speed of the crank shaft in units revolutions per second

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

Average piston speed for standard auto engine is about 15 m/s. Ultimately limited by material strength. Therefore engines with large strokes run at lower speeds those with small strokes can run at higher speeds.

ENGINE PERFORMANCE

The basic performance parameters of internal combustion engine (I.C.E) may be summarized as follows:

1. Indicated power (i.p.):

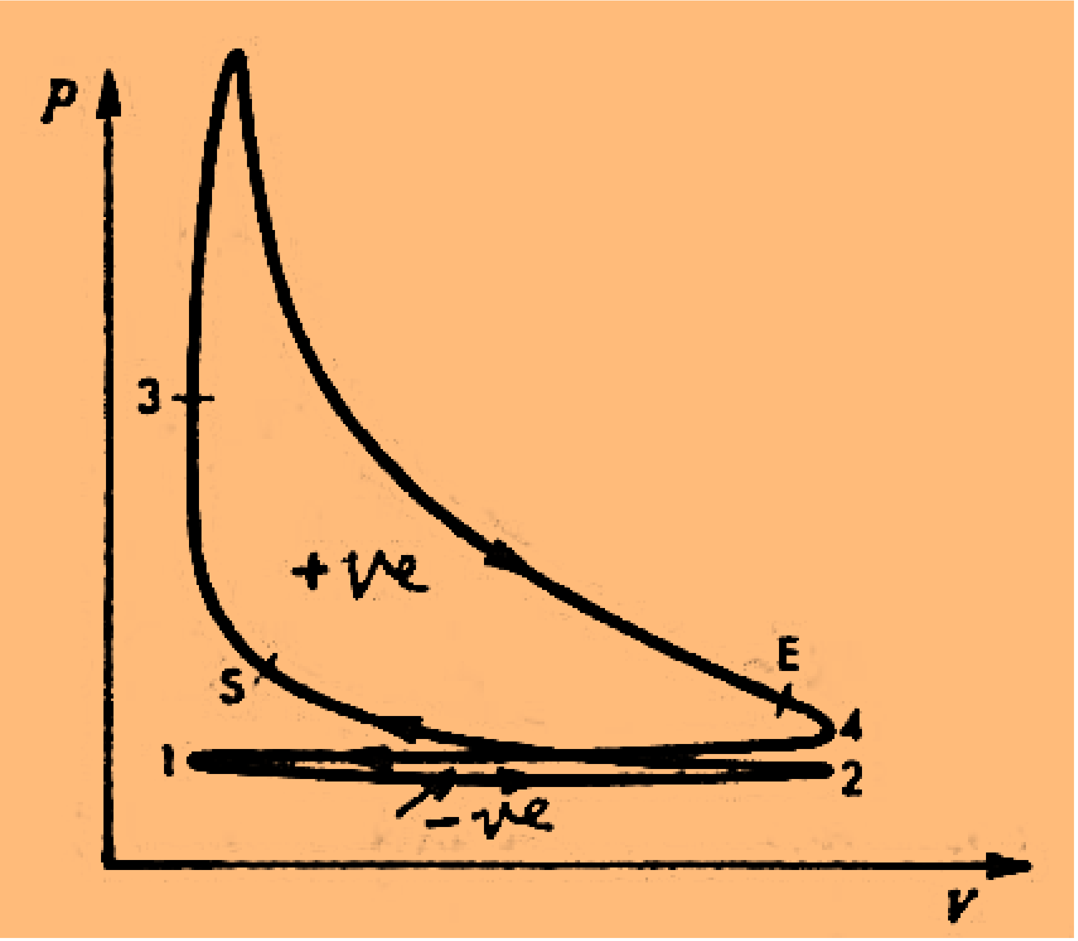


Figure (1): *indicator diagram of SI engine*

Engine Indicated Torque (T_i):

$$T_i = \frac{Work\ (W)}{angle\ (\theta)} = \frac{Work\ per\ one\ revolution}{angle\ of\ one\ revolution} = \frac{Force \times distance}{2\pi} \times n$$

$$T_i = \frac{(imep \times A_c) \times L \times n}{2\pi \times z} = \frac{imep \times V_e}{2\pi \times z}$$

where:

T_i = engine indicated torque [Nm]

imep = indicated mean effective pressure [N/m^2]

A_c = cylinder area [m^2]

L = stroke length [m]

z = 1 (for 2 stroke engines), 2 (for 4 stroke engines)

n = number of cylinders

θ = crank shaft angle [1/s]

Engine Indicated Power (P_i):

$$P_i = \frac{imep \times A_c \times L \times n \times N}{z \times 60}$$

$$P_i = \frac{imep \times (A_c \times L) \times n \times N}{z \times 60} = \frac{imep \times (V_c \times n) \times N}{z \times 60}$$

$$P_i = \frac{imep \times V_e \times N}{z \times 60}$$

$$P_i = T_i \times \omega = T_i \times \frac{2\pi N}{60}$$

where:

imep = is the indicated mean effective pressure [N/m^2],

A_c = cylinder area [m^2],

L = stroke length [m],

n = number of cylinders,

N = engine speed [rpm],

z = 1 (for 2 stroke engines), 2 (for 4 stroke engines),

V_c = cylinder swept volume [m^3],

V_e = engine swept volume [m^3],

T_i = engine indicated torque [Nm], and

ω = engine angular speed [1/s]

Engine Mechanical Efficiency (η_m):

$$\eta_m = \frac{Engien\ Brake\ Power}{Engien\ Indicated\ Power}$$

$$\eta_m = \frac{P_b}{P_i}$$

$$\eta_m = \frac{P_i - P_f}{P_i} = 1 - \frac{P_f}{P_i}$$

where:

$_m$ = mechanical efficiency

P_b = engine brake power [kW]

P_i = engine indicated power [kW]

P_f = engine friction power [kW]

Engine Specific Fuel Consumption (*SFC*):

$$SFC = \frac{mass\ of\ fuel\ consumption}{engine\ brake\ power}$$

$$SFC = \frac{FC}{P_b}$$

where:

SFC = specific fuel consumption [(kg/h)/kW, kg/(3600 s x kW=kJ/s), kg/(3600 kJ)]

FC = fuel consumption [kg/h]

P_b = brake power [kW]

Engine Thermal Efficiency (η_{th}):

$$\eta_{th} = \frac{brake\ power}{fuel\ power}$$

$$\eta_{th} = \frac{3600\ P_b}{FC \times CV}$$

where:

η_{th} = thermal efficiency

P_b = brake power [kW]

FC = fuel consumption [kg/h = (fuel consumption in L/h) x (ρ in kg/L)]

CV = calorific value of kilogram fuel [kJ/kg]

ρ = relative density of fuel [kg/L]

5. Brake mean effective pressure (bmep) and brake thermal efficiency:

The **bmep (Pb)** may be thought of as that mean effective pressure acting on the pistons which would give the measured **b.p.**, i.e.

b.p. = bmep AL x active cycles/ min

The overall efficiency of the engine is given by the brake thermal efficiency, $\boldsymbol{\eta_{BT}}$ i.e.

$$\eta_{BT} = \frac{\text{Brake power}}{\text{Energy supplied}}$$

$$\eta_{BT} = \frac{b.p.}{\dot{m}_f \times Q_{net}}$$

where $\dot{m}_f$ is the mass of fuel consumed per unit time, and Q_{net} is the lower calorific value of the fuel.

7. Indicated thermal efficiency (η_{IT}):

It is defined in a similar way to **(η_{BT})**

$$\eta_{IT} = \frac{i.p.}{\dot{m}_f \times Q_{net}}$$

Dividing η_{BT} by η_{IT} gives

$$\frac{\eta_{BT}}{\eta_{IT}} = \frac{b.p.}{i.p.} = \eta_m$$

$$\therefore \eta_{BT} = \eta_m \times \eta_{IT}$$

Example-1: A four cylinder car engine has bore and stroke = 79 mm and 77 mm respectively.

What is the capacity of the engine in cc?

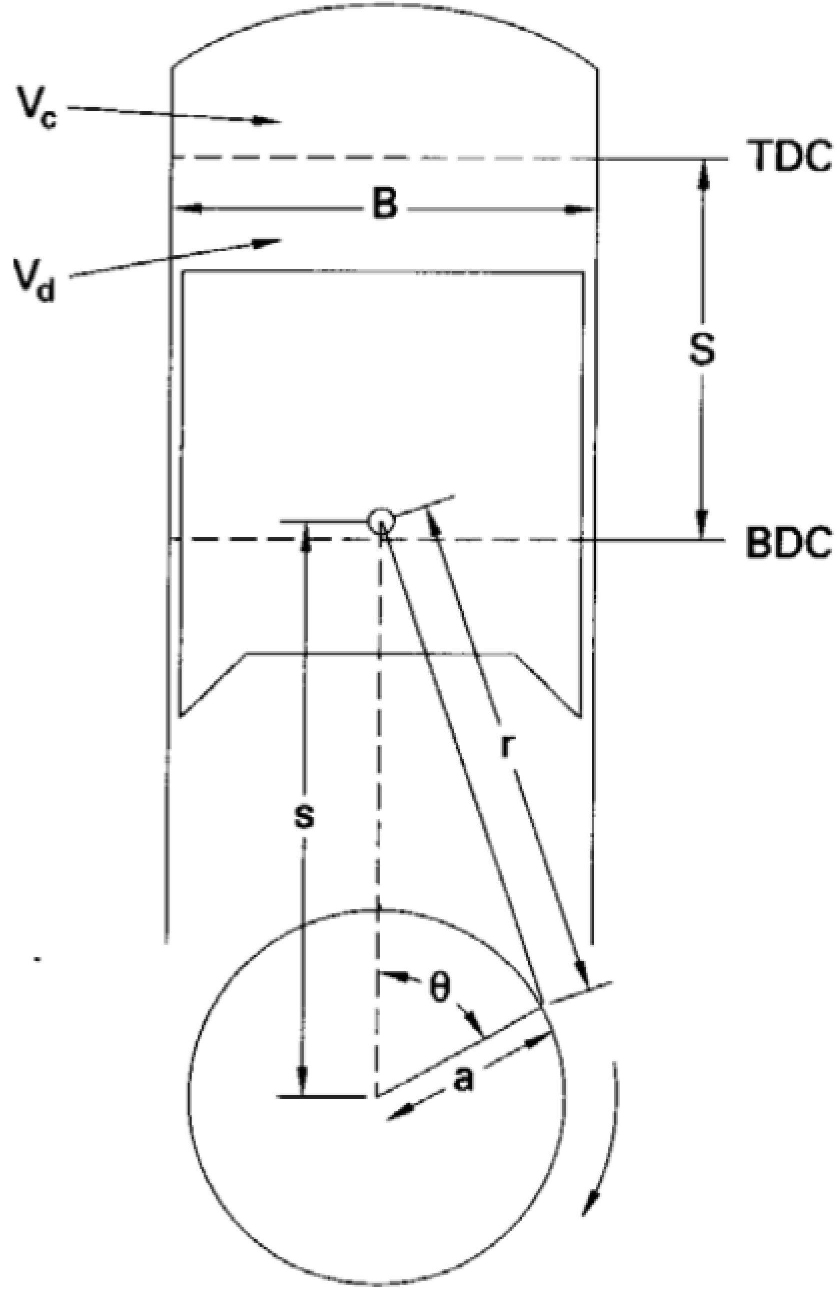
Solution: Capacity in cc = n.(π/4) d squar . S

Here, n= number of cylinders

d= bore diameter in cm

S= stroke length in cm,

Therefore, Engine Capacity in cc = 4 x (π/4) x (7.9)2 x (7.7) = 1509 ≈ **1500 cc Ans.**



Example-2 If the same engine (Ex-2) (i.e., four-stroke, 2 liters) as above produces 76 kW at 5400 rpm, Find its bmep.

Power, $P = T\omega$

$T = P/\omega = (76 \times 10^3)/565.5 = 134.4$ N.m

Here, $P = 76 \times 10^3$ W

$\omega = 2\pi N/60 = 2\pi(5400)/60$

$= 565.5$ rad/s

$$p_{mep} = \frac{T n_c}{V_d} 2\pi$$

$V_d = 2$ liters $= 2 \times 10^{-3}$ m^3

$n_c = 2$ for a 4-stroke engine

So, **bmep** = (134.4 N·m) (4π)/(0.002 m^3)

= 844460 N/m^2 =**844.5 kPa** (8.34 bar).

Example-3: A 4-Cylinder, 2-stroke IC engine has the following particulars: engine speed = 3000 rpm, bore = 120 mm, crank radius = 60 mm, mechanical efficiency = 90% and the engine develops 75 bhp. Calculate the swept volume and mean effective pressure (MEP).

Mechanical efficiency, $\eta = \dfrac{BrakePower(bhp)}{EnginePower(ihp)}$

Or, $0.9 = \dfrac{75}{P}$, i.e., $P = 83.33$ hp

Now, Engine Power, $P = T\,\omega$

Here, $P = 83.33$ hp $= 83.33 \times 746$ W $= 62166.67$ W

$\omega = 2\pi N/60 = 2\pi(3000)/60$

$= 314.16$ rad/s

$T = P/\omega = (62166.67)/314.16 = 197.88$ N.m

We get, Mean Effective Pressure (**MEP** or $\boldsymbol{P_{mep}}$) as follows:

$$p_{mep} = \frac{T n_c}{V_d} 2\pi \quad V_d = N.(\pi/4).B^2.\ S$$

Here Stroke, S = 2 x crank radius

= 2 x 0.06 m = 0.12 m

$V_d = 4.(\pi/4).(0.12)^2(0.12)$

$= 5.43 \times 10^{-3}\ m^3$

= **5.43 liter**

$n_c = 1$ for a 2-stroke engine

Therefore,

MEP = (197.88 N·m) (2π)/(0.00543 m³)

= 228971.77 N/m² =**228.97 kPa**

Example 4:

The peak pressure of a SI engine rotating at 1500 rpm occurs 0.003S after the spark, what will be the spark timing when peak pressure is at TDC. If the inlet valve opens at 10 degrees before TDC and closes at 45 degrees after BDC, how long the inlet valve opening period is in seconds.

Solution:

$$\text{Number of revolutions per second} = \frac{1500}{60} = 25 \text{ rev.}$$

Number of revolutions between spark timing and TDC

$$= 25 \times 0.003 = 0.075 \text{ rev.}$$

Crank shaft angle during this period = 0.075 × 360 = 27

i.e. spark must occurs 27 degree bTDC

inlet valve opening = 10 + 180 + 45 = 235 degrees

inlet valve opening time in seconds $= \frac{235}{360 \times 25} = 0.0265$.

Example 5:

In a four stroke single cylinder gas engine the indicated mean effective pressure is 0.46 MN/m2, the brake power 9 kW, speed 250 rpm, mechanical efficiency, η_m = 0.8, and bore to stroke ratio = 0.66. Calculate cylinder diameter and mean piston speed.

Solution:

$$\eta_m = \frac{bp}{i.p} \quad , \quad \text{i.p} = \frac{9}{0.8} = 11.25 \quad \text{kw}$$

$$\text{i.p} = \frac{\text{P}_\text{i} LANn}{2}$$

$$LA = \frac{2 \times i.p}{P_i Nn} = \frac{2 \times 11.25}{0.46 \times 1000 \times 250 \times 1} = 0.01174 \quad \text{m}^3$$

$$\frac{d}{L} = 0.66 \quad , \quad \text{L} = \frac{\text{d}}{0.66}$$

$$\therefore \frac{d}{0.66} \times \frac{\pi}{4} d^2 = 0.01174$$

$$\text{d}^3 = 0.009866$$

$$\text{d} = 0.2145 \quad \text{m}$$

$$\text{Mean piston speed} = \frac{2LN}{60} = \frac{2 \times 0.2145 \times 250}{0.66 \times 60}$$

$$= 2.71 \quad \text{m/s}$$

Example 6:

A four stroke petrol engine delivers 35.75kW with a mechanical efficiency of 80%, the fuel consumption of the engine is 0.4 kg per brake power hour, and the A/F ratio is 14:1.The heating value of the fuel is 41870 kJ/kg. Find: (a) i.p, (b) f.p., (c)η_{BT}, (d) η_{IT} , (e) fuel consumption per hour, (f) air consumption per hour.

Solution:

a) $\eta_m = \dfrac{b.p}{i.p}$, $i.p = \dfrac{35.75}{0.8} = 44.7 \text{ kW}$

b) f.p= i.p – b.p=44.7– 35.75=8.95kW

c) $\eta_{BT} = \dfrac{b.p}{Q_{added}} = \dfrac{35.75 \times 3600}{0.4 \times 35.75 \times 41870} = 0.215$

d) $\eta_{BT} = \eta_{IT} \times \eta_m$

$$\eta_{IT} = \frac{0.215}{0.8} = 0.2687$$

e) fuel consumption per hour = 0.4 × 35.75=14.32kg

f) air consumption per hour = 14.32 × 14=200.5kg

Note: Specific fuel consumption = 0.4 kg/hr.

Example 7:

The air flow to a four cylinder four – stroke engine is 2.15 m3/min. During a test on the engine the following data were recorded: Bore 10.5cm; stroke 12.5cm; engine speed 1200 rpm, torque 150 N.m, fuel consumption 5.5 kg/h, calorific value of fuel, 43124 kJ/kg, ambient temperature and pressure are 20 degree C and 1.03 bars. Calculate:

1- The brake thermal efficiency.

2- The brakes mean effective pressure.

3- The volumetric efficiency.

Solution:

1- $b.p. = \frac{2\pi NT}{60} = \frac{2\pi \times 1200 \times 150}{60 \times 1000} = 18.85 \quad \text{kW}$

$$\eta_{BT} = \frac{b.p}{Q_{added}} = \frac{18.85 \times 3600}{5.5 \times 43124} = 0.286$$

2- $b.p = \frac{P_i LAN_n}{2}$

$$\therefore P_i = \frac{2 \times 18.85 \times 4 \times 60}{0.125 \times \pi \times (0.105)^2 \times 1200 \times 4} = 435.4 \quad \text{kPa}$$

3- $\eta_v = \frac{\dot{V}}{V_s}$

$$V_s = LA\frac{Nn}{2} = 0.125 \times \frac{\pi}{4}(0.105)^2 \times \frac{1200 \times 4}{2}$$

$$= 2.6 \quad m^3 / min \qquad \therefore \eta_v = \frac{2.15}{2.6} = 0.83$$

Ex.8- 3liters six – cylinders SI engine operates on a four – stroke cycle and run at 3600 rpm. The compression ratio is 9.5 the length of connecting rode is 16.6cm, and the bore equal the stroke. Combustion ends at 20° after TDC calculate: (1) Cylinder bore and stroke, (2) average piston speed, (3) clearance volume of one cylinder, (4) the distance piston has traveled from TDC at the end of combustion, (5) volume of the combustion chamber at the end of combustion.

Solution

1- Volume of one cylinder, $V_s = \frac{3000}{6}$

$$= 500\ \text{cc} = 0.0005\text{m}^3 = \frac{\pi}{4} B^2 S$$

$$0.000637 = B^3 \Rightarrow B = 0.086m = 8.6cm = S$$

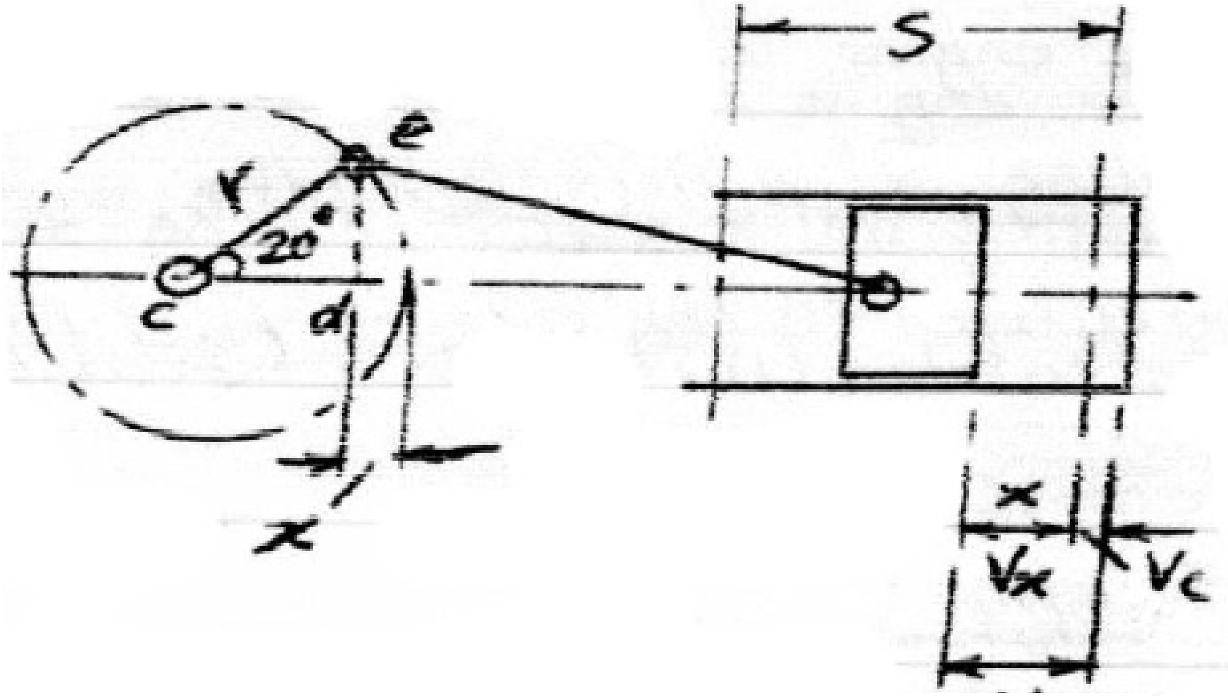
$$2\text{-} V_m = \frac{2SN}{60} = \frac{2 \times 0.086 \times 3600}{60} = 10.32\ \text{m/s}$$

$$3\text{-}\ r = \frac{V_s + V_c}{V_c} = 9.5 = \frac{0.0005 + V_c}{V_c}$$

i.e. $V_c = 0.000059\text{m}^3 = 59\ \text{cm}^2$

4- Volume at any C.A. = $V_c + V_x$

$$V = V_c + x \times \frac{\pi}{4} B^2\ (\text{B=bore})$$



$$5 - x = r(1\text{-}\cos\ \theta), \qquad r = \frac{S}{2} = 4.3\ \text{cm}$$

$$x = 4.3\ (1\text{-}\cos 20) = 0.26\ \text{cm},$$

$$V{=}59{+}\ \frac{\pi}{4}(9)^2 \times\ 0.26 = 75.54\ \text{cm}^3$$

Ex.9- The engine in example 8 is connected to a dynamometer which gives a brake output torque of 205 Nm at 3600 rpm. At this speed air enters the cylinder at 85 kPa and 60ºC, and the mechanical efficiency of the engine is 85%. Calculate: (1) b.p, (2) i.p, (3) bmep, (4) imep, (5)fmep, (6) f.p, (7) engine specific volume.

Solution:

$$1\text{-}\ b.p = 2\pi NT = 2\pi \times \frac{3600}{60} \times 205 = 77.3\ \text{kW}$$

$$2\text{-}\ i.p = \frac{b.p}{\eta_M} = \frac{77.3}{0.85} = 90.9\ \text{kW}$$

$$3\text{-}\ bmep=\frac{b.p\times z}{LANn}=\frac{77.3\times 60\times 2}{0.0005\times 3600\times 6}=859\ \ \text{kPa}$$

$$4\text{-}\ imep=\frac{859}{0.85}=1010.5\ \ \ \text{kPa}$$

$$5\text{-}\ fmep(P_f)=imep-bmep=1010.5-859=151.57\ \ \text{kPa}$$

$$6\text{-}\ f.p=P_f LAN\times\frac{n}{z}=151.57\times 0.0005\times 3600\times\frac{6}{2}\times\frac{1}{60}=$$

$$13.64\ \ \text{kW}$$

$$7\text{-Engine specific volume}=\frac{\text{swept volume}}{\text{brake power}}=\frac{31}{77.3}$$

$$=0.0388\ \ \text{L/kW}$$

The inverse of the specific volume is

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

Ex.10-The engine in example 9 is running with A/F ratio =15,afuel of heating value;44000kJ/kg and a combustion efficiency of 97% calculate: (1) the rate of fuel flow. (2)η_{BT}, (3) η_{IT},(4) η_V, and brake specific consumption.

Solution:

1- The clearance volume of the engine = 0.000059 m^3(example 1)

$$m_\alpha = \frac{PV_{BDC}}{RT} = \frac{P(V_c + V_s)}{RT} =$$

$$\frac{85(kPa)(0.0005 + 0.000059)m^3}{0.287(kJ/kgK)(333K)} = 0.0005 \text{ kg}$$

$$m_f = \frac{m_a}{\frac{A}{F}} = \frac{0.0005}{15} = 0.000033\,\mathrm{kg_f}\ \text{Per cylinder per cycle}$$

$$\dot{m}_f = (0.000033 \frac{kg}{cycle.cylinder})(6\ \text{cylinder})(\frac{3600}{60} rev/s)$$

$$(\frac{1}{2}\ effective\ \text{cycle /cylinder}) = 0.006\ \text{kg/s}$$

2- $$\eta_{BT} = \frac{\text{b.p}}{\dot{m}_f \times C.V \times \eta_c} = \frac{77.3}{0.006 \times 44000 \times 0.97}$$

$$= 0.302\ \text{or}\ 30.2\%$$

3- $$\eta_{IT} = \frac{\eta_{BT}}{\eta_m} = \frac{0.302}{0.85} = 0.355 \text{ or } 35.5\%$$

4- $$\eta_V = \frac{m_a}{\rho_a V_s} = \frac{0.0005\,\text{kg}}{(P/RT)(0.0005\,\text{m}^3)} = \frac{1}{1.181}$$

$$= 0.847 \quad \text{or } 84.7\%$$

5- $$bsfc = \frac{\dot{m}_f}{b.p} = \frac{0.006\,\frac{\text{kg}}{\text{s}}}{77.3\,\text{kw}} = 7.76\,\text{kg/kW.s} = 279\,\text{kg/kW.h}$$

$$\rho_{air} = \frac{P}{RT} = \frac{1.013 \times 10^2}{0.287\,(15 \times 273)}$$

$$\eta_V = 0.76 = 76\,\%$$

Ex.11- A six-cylinder 4-stroke cycle petrol engine is to be designed to develop 300 kW of (b.p) at 2500 rpm the bore / stroke ratio is to be 1:1.25. Assuming η_m=83% and an indicated mean effective pressure of 9.5 bar, determine the required bore and stroke. If the compression ratio of the engine is to be 6.5 to 1, determine consumption of petrol in kg/h and in kg/bp.hr. Take the ratio of the indicated thermal efficiency of the engine to that of the constant volume air standard cycle as 0.55 and the calorific value of the petrol as; 44770kJ/kg.

Solution

b.p=300 kW

$$\eta_m = \frac{b.p}{i.p} \quad ; \qquad \text{i.p} = \frac{300}{0.83} = 361 \; kW$$

$$P_i = 9.5 \text{ bar} \quad \& \quad \text{N} = 2500 \text{ rpm}$$

$$\text{i.p} = \frac{\text{P}_\text{i} \times L \times A \times N \times n}{60} \times \frac{1}{2} \quad (4 - strok \;\; engine\;)$$

$$1000 \times 361 = \frac{9.5 \times 10^5 \times (LA) \times 2500 \times 6}{60 \times 2}$$

$$(LA) = 0.00304 \quad \text{m}^3$$

Let Diameter = D, $\therefore$ L=1.25D &A= $\frac{\pi}{4}$ D^2

$$1.25D \times \frac{\pi}{4} D^2 = 0.00304$$

$r = 6.5$ & $\gamma = 1.4$

$$D^3 = 0.003096 \quad \Rightarrow D = 0.146 \ m$$

$$D = 14.6 \ \text{cm} \quad \& \ \text{L} = 1.25\text{D} = 18.25 \ \text{cm}$$

$$\eta_{a.s} = 1 - \frac{1}{r^{\gamma - 1}} = 1 - \frac{1}{6.5^{1.4-1}} = 52.6\%$$

$$\eta_r = \frac{\eta_{th}}{\eta_{A.S}} \times 100$$

$$55 = \frac{\eta_{th}}{52.6} \times 100$$

$$\eta_{th} = \frac{55 \times 52.6}{100} = 28.9\%$$

$$\eta_{th} = \frac{i.p \times 60}{\text{heat in fuel supplied /min}} \times 100$$

$$\therefore \text{Heat in fuel supplied /min} = \frac{361 \times 60}{0.289} =$$

$$74948 \text{ kJ}$$

$$\therefore \text{Consumption of petrol in kg/h} = \frac{74948}{44770} = 100.4$$

$$\& \quad \frac{\text{kg}}{\text{kW.h}} = \frac{100.4}{300} = 0.33$$

Example 12: A four – cylinder petrol engine has a bore of 57mm and a stroke of 90mm. Its rated speed is 2800 rpm and it is tested at this speed against a brake which has a torque arm of 0.356m. The net brake load is 155N and the fuel consumption is 6.74 l/h. The specific gravity of the petrol used is 0.735 and it has a lower calorific value of;44200 kJ/kg. The indicated load for the engine as calculated by the Morse test method is 187.3N. Calculate for this speed, the engine torque, the bmep, the brake thermal efficiency, the specific consumption, the mechanical efficiency and the imep.

Solution:

$$\text{Torque } T = RP = 0.356 \times 155 = 55.2 \text{ Nm}$$

$$b.p = 2\pi NT = \frac{2\pi \times 2800 \times 55.2}{60 \times 10^3} = 16.2\ kw$$

$$bmep = \frac{b.p \times 2}{ALNn} = \frac{16.2 \times 2 \times 4 \times 60 \times 10^3}{\pi \times 0.057^2 \times 0.09 \times 2800 \times 4 \times 10^5} = 7.55 \text{ bar}$$

$$\eta_{BT} = \frac{b.p}{\dot{m}_f \times C.V} = \frac{16.2}{0.001377 \times 44200} = 0.266 \text{ or } 26.6\%$$

$$\text{Where } m_f = \frac{6.74}{3600} \times 1 \times 0.735 = 0.001377 \quad \text{kg/s}$$

$$\text{sfc} = \frac{\dot{m}_f}{\text{b.p}} = \frac{0.001377 \times 3600}{16.2} = 0.306 \quad \text{kg/kW.h}$$

$$\eta_M = \frac{b.p}{i.p} = \frac{155}{187.3} = 0.828 \quad \text{or} \quad 82.8\%$$

$$i.p = \frac{16.2}{0.828} = 19.57 \quad \text{kw}$$

$$\text{bmep} = \eta_{\text{M}} \times imep$$

$$i.e \quad \text{imep} = \frac{7.55}{0.828} = 9.12 \quad \text{bar}$$