SAMPLE STUDY MATERIAL

Mechanical Engineering

ME

Postal Correspondence Course

Internal Combustion Engine

GATE, IES & PSUs

Postal Course (GATE , IES & PSUs) © 2015 ENGINEERS INSTITUTE OF INDIA® . All Rights Reserved
28-B/7, Jia Sarai, Near IIT, Hauz Khas, New Delhi-110016. Ph. 011-26514888. www.engineersinstitute.com

ENGINEERS INSTITUTE OF INDIA
India's Best Institute for IES, GATE & PSUs
A Team of IES & GATE Toppers

CONTENT

SAMPLE ★ SAMPLE ★ SAMPLE ★ SAMPLE

CHAPTER-1

INTRDODUCTION

- An engine is a device which transforms one form of energy in to another form

- Heat engine is a device which transforms the chemical energy of a fuel in to thermal energy and utilizes this thermal energy to perform useful work

- Heat engines can be broadly classified in to two categories :
  (i) Internal combination engines
  (ii) External combustion engines

- External combustion engines are those in which combustion takes place outside the engine where as in internal combustion engines combustion takes place within the engine.

- Engines whether internal combustion or external combustion are of two types :
  (i) Rotary engines
  (ii) Reciprocating engines :

- The main advantages of reciprocating engine is
  (i) All its components work at an average temperature which is much below the maximum temperature of the working fluid in the cycle.
  (ii) Higher thermal efficiency can be obtained with moderate maximum working pressure of the fluid in the cycle.

- The main disadvantage of this type of engine is the problem of vibration caused by the reciprocating components it is not possible to use a variety of fuels in these engines. Only liquid or generous fuels of given specification can be efficiently can be efficiently used. These fuels are relatively more expensive.

Postal Course (GATE , IES & PSUs) © 2015 ENGINEERS INSTITUTE OF INDIA® . All Rights Reserved
28-B/7, Jia Sarai, Near IIT, Hauz Khas, New Delhi-110016. Ph. 011-26514888. www.engineersinstitute.com

ENGINE COMPONENTS :

(i) **Cylinder block:** The cylinder block is the main supporting structure for the various components. The cylinder of a multi-cylinder engine are cast as a single units, called cylinder block. The cylinder head is mounted on the cylinder block. Cylinder head gasket is incorporated between the cylinder block and cylinder lead. The bottom portion of the cylinder block is called crank case.

(ii) **Cylinder :** it is a cylindrical vessel or space in which the piston makes a reciprocating motion.

(iii) **Piston :** it is a cylindrical component filled in to the cylinder forming the moving boundary of the combustion system. It fits perfectly in to the cylinder providing a gas tights space with the piston rings and the lubricant.

(iv) **Combustion chamber:** The space enclosed in the upper part of the cylinder, by the cylinder head and the piston top during the combustion process, is called the combustion chamber.

(v) **Inlet manifold:** The pipe which connects the intake system to the inlet valve of the engine and through which air or air fuel mixture is drawn in to the cylinder is called the inlet manifold.

(vi) **Exhaust manifold:** The pipe which connects the exhaust system to the exhaust valve of the engine and through which the products of combustion escape in to the atmosphere is called the exhaust manifold.

(vii) **Inlet and exhaust valve:** valves are commonly mushroom shaped and puppet type. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming in to the cylinder (inlet valve) and for discharging the products of combustion (exhaust valve)

(viii) **Spark plug :** it is an component to initiate the combustion process in spark – ignition (SI) engines and is usually located on the cylinder head.

(ix) **Connecting rod :** it interconnects the piston and the crank shaft and transmits the gas force from the piston to the crankshaft. The two ends of the connecting rod are called as small end and the big end. Small end is connected to the piston by gudgeon pin and the big end is connected to the crankshaft by crankpin.

(x) **Camshaft :** the camshaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. The camshaft is driven by the crankshaft through timing gears.

SAMPLE SAMPLE SAMPLE SAMPLE

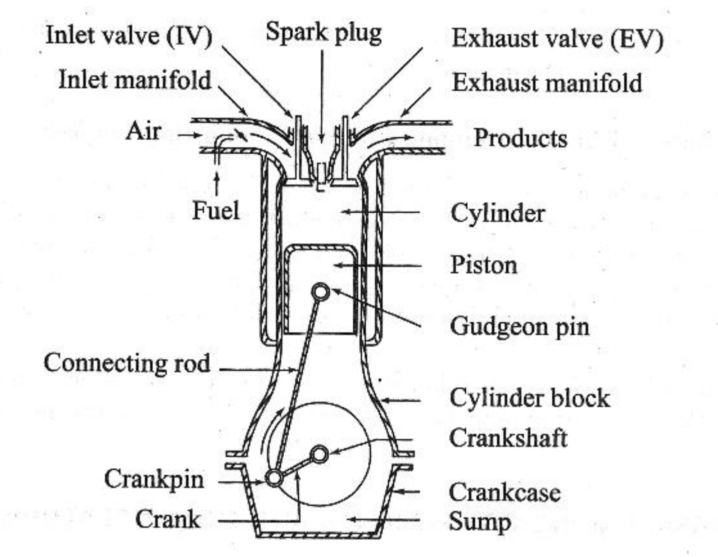


Figure: Cross-section of a Spark-Ignition Engine

SAMPLE ★ SAMPLE ★ SAMPLE ★ SAMPLE

NOMENCLATURE:

(i) Cylinder bore (d): the nominal inner diameter of the working cylinder is called the cylinder bore and is designated by the letter 'd'.

(ii) Piston area (a): The area of a circle of diameter equal to the cylinder bore is called the piston area.

(iii) Stroke (L): The nominal distance through which a working piston moves between two successive reversals of its direction of motion is called the stroke.

(iv) Stroke Ration (L/d): ratio is known as the stroke ratio if d< L it is called under-square engine. If d= L, it is called square engine. If d > L it is called over square engine. An over square engine can operate at higher speeds because of larger bare and shorter stroke.

(v) Swept Volume (Vs) : The nominal volume swept by the working piston when traveling from one dead centre to the other is called the swept volume (Vs).

$$V_s = A \times L = \frac{\text{®}}{4} d^2 \times L$$

(vi) Engine Capacity: The displacement volume of a cylinder multiplied by number of cylinders in an engine will give the cubic capacity or the engine capacity. Engine capacity : Vs × k

Where k = no of cylinders in an engine

(vii) Clearance Volume: The nominal volume of the combustion chamber above the piston when it is at the top dead centre is the clearance volume.

(viii) Compression ratio (r): It is the ratio of the total cylinder volume when the piston is at the bottom dead centre, V_t , to the clearance volume V_c.

$$r = \frac{V_T}{V_C} = \frac{V_L + V_S}{V_L} = 1 + \frac{V_S}{V_C}$$

FOUR STROKE SPARK IGNITION ENGINE :

(i) Suction Stroke : Suction stroke 0-1 starts when the piston is at the top dead centre and about to move downwards. The inlet valve is open at this time and the exhaust valve is closed. Due to the suction created by the motion of the piston towards the bottom dead centre, the charge consisting of fuel air mixture is drawn in to the cylinder.

(ii) Compression Stroke: The charge taken in to the cylinder during the suction stroke is compressed by the return stroke of the piston $1 \rightarrow 2$. During this stroke, both inlet and exhaust valves are in closed position. At the end of the compression stroke the mixture is ignited with the help of a spark plug located on the cylinder head. During the burning process, the chemical energy of the fuel is converted in to heat energy producing a temperature rise of about 2000ºC (process 2-3). The pressure at the end of the combustion process is considerably increased due to the heat release from the fuel.

SAMPLE ★ SAMPLE ★ SAMPLE ★ SAMPLE

(iii) Expansion or power stroke: The high pressure of the burnt gases forces the piston towards the BDC (Stroke 3-4). Both the valves are in closed position. Both pressure and temperature decrease during expansion.

(iv) Exhaust Stroke: At the end of the expansion stroke, the exhaust valve opens and the inlet valves remains closed. The piston starts moving from the bottom dead centre to top dead centre (stroke 5-0). The exhaust valve closes when the piston reaches TDC at the end of the exhaust stroke and some residual gases trapped in the clearance volume remain in the cylinder.

Postal Course (GATE , IES & PSUs) © 2015 ENGINEERS INSTITUTE OF INDIA® . All Rights Reserved
28-B/7, Jia Sarai, Near IIT, Hauz Khas, New Delhi-110016. Ph. 011-26514888. www.engineersinstitute.com

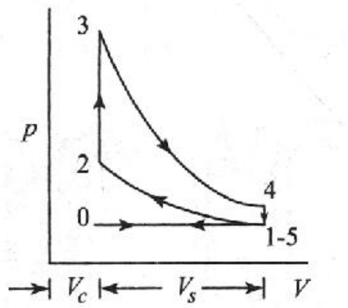


Figure: Ideal p-V Diagram of a Four-Stroke SI Engine

FOUR STROKE COMPRESSION IGNITION ENGINE

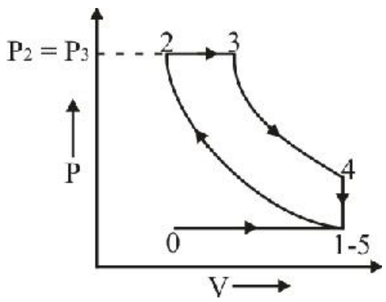
- The four stroke CI engine is similar to the four stroke SI engine.

(i) **Suction Stroke :** Air alone is inducted during the suction stroke. During this stroke, intake valve is open and exhaust valve is closed

(ii) **Compression stroke :** Air inducted during the suction stroke is compressed in to the clearance volume. Both valves remain closed during this stroke.

(iii) **Expansion Stroke:** fuel injection stars nearly at the end of the compression stroke. The rate of injection is such that combustion maintains the pressure constant in sprite of the piston movement on its expansion stroke increasing the volume.

(iv) **Exhaust stroke:** The piston travelling from BDC to TDC pushes out the products of combustion. The exhaust valve is open and the intake valve is closed during this stroke.



COMPERISON OF SI & CI ENGINE:

Description	SI engine	CI engine
Basic cycle	Works on otto cycle, or constant volume heat addition cyle	Works on diesel cycle or constant pressure heat addition cycle.
fuel	Gasoline, a highly volatile self ignition temperature is high	Diesel oil, a non-volatile fuel. Self ignition temperature is comparatively low.
Introduction of fuel	A gaseous mixture of fuel-air is introduced during the suction stroke. A carburetor and an ignition system are necessary. Modern engine have gasoline injection.	Fuel is injected directly in to the combustion chamber at high pressure at the end of the compression stroke. A fuel pump and injector are necessary.
Load control	Throttle controls the quantity of fuel air mixture introduced.	The quantity of fuel is regulated. Air quantity is not controlled
Compression ratio	6 to 10. upper limit is fixed by antiknock quality of the fuel	16 to 20 upper limits is limited by weight increase of the engine.
Speed	Due to light weight and also due to homogeneous combustion , they are high speed engine.	Due to heavy weight and also due to heterogeneous combustion, they are low speed engines.
Thermal efficiency	Because of the lower compression ratio, the maximum value of thermal efficiency that can be obtained is lower	Because of the higher compression ratio, the maximum value of thermal

SAMPLE ★ SAMPLE ★ SAMPLE

		efficiency that can be obtained is higher
weight	lighter due to lower peak pressure	Heavier due to higher peak pressure.

TWO STROKE ENGINE

- In two stroke engines, the cycle is completed in one revolution of the crankshaft.
- In a two-stroke engines, the filling process is accomplished by the charge compressed in crankcase or by a blower. The induction of the compressed charge moves out the product of combustion through exhaust ports. Therefore, no piston strokes are required for these two operations.
- Two strokes are sufficient to complete the cycle one for compressing the fresh charge and the other for expansion or power stroke.

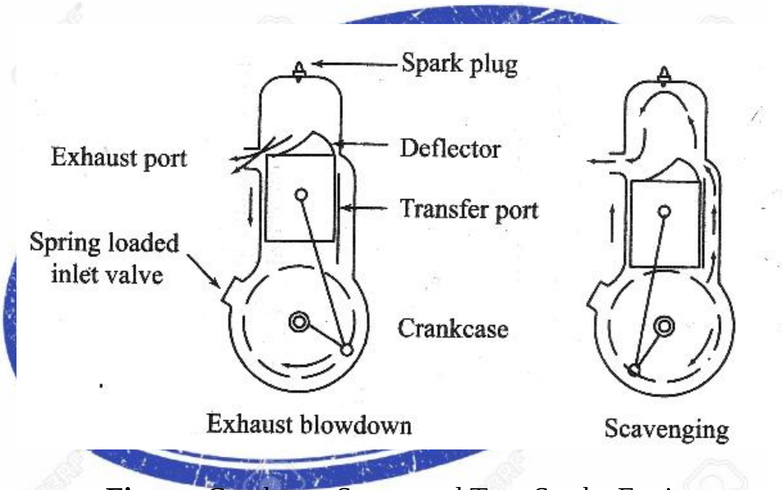


Figure: Crankcase Scavenged Two-Stroke Engine

- The air or charge is inducted in to the crankcase through the spring loaded inlet valve when the pressure in the crankcase is reduced due to upward motion of the piston during compression stroke. After compression and ignition, expansion takes place in the usual way.
- During the expansion stroke, the charge in the crankcase is compressed. Near the end of the expansion stroke, the piston uncovers the exhaust parts and the cylinder pressure drops to atmospheric pressure as the combustion products leave the cylinder. Further movement of the piston uncovers the transfer port, permitting the slightly compressed charge in the crankcase to enter the engine cylinder.
- The top of the piston has usually a projection to deflect the fresh charge towards the top of the cylinder before flowing to the exhaust ports. This serves the double purpose of scavenging the upper part of the

cylinder of the combustion products and preventing the fresh charge from flowing directly to the exhaust ports.

COMPARISON OF FOUR STROKE AND TWO STROKE ENGINES

Four stroke engine	Two stroke engine
The thermodynamic cycle is completed in four strokes of the piston or in two revolution of the crankshaft. Thus one power stroke is obtained in every two revolution of the crankshaft.	The thermodynamic cycle is completed in two strokes of the piston or in one revolution of the crankshaft. Thus one power stroke is obtained in each revolution of the crankshaft.
Because of the above, turning moment is not so uniform and hence a heavier fly wheel is used.	Because of the above turning moment is more uniform and hence a lighter fly wheel can be used.
Because of one power stroke for two revolutions power produced for same size of engine is less or for the same power, the engine is heavier and bulkier.	Because of one power stroke for every revolution power produced for same size of engine is twice or for the same power the engine is lighter and more compact.
Because of one power stroke in two revolutions, lesser cooling and lubrication requirements. Lower rate of wear and tear.	Because of one power stroke in one revolution greater cooling and lubrication requirements. Higher rate of wear and tear.
Four stroke engines have valves and valve actuating mechanisms for opening and closing of the intake and exhaust valves.	Two stroke engines have no valves but only ports.
Because of comparatively higher weight and complicated valve mechanism. The initial cost of the engine is more.	Because of light weight and simplicity due to the absence of valve actuating mechanism, initial cost of the engine is less.
Volumetric efficiency is more due to more time for induction	Volumetric efficiency is low due to lesser time for induction.
Thermal efficiency is higher part load	Thermal efficiency is lower's part load efficiency

efficiency is better	is poor.
Used where efficiency is important i.e. in cars, buses, trucks	Used where low cost, compactness and light weight are important i.e., in mopeds, scooters, motorcycles

- In actual practice power output is not exactly doubled but increased by only about 30% because of
  (i) Reduced effective expansion stroke
  (ii) Increased heating caused by increased number of power stroke which limits the maximum speed

ACTUAL ENGINES

SAMPLE ★ SAMPLE ★

- Actual engines differ from the ideal engines because of various constraints in their operations.

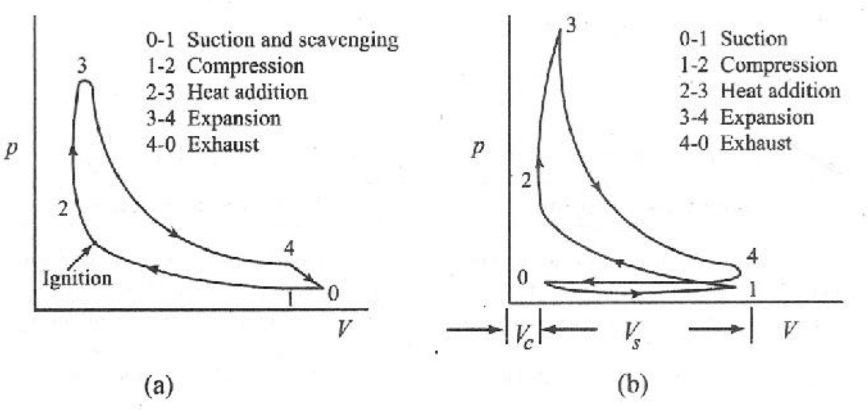


Figure: Actual Indicator Diagrams of a Two-Stroke and Four-Stroke SI Engine

ENGINE PERFORMANCE PARAMENTS:

(i) Indicated thermal efficiency: it is the ratio of energy in the indicated power, iP to the input fuel energy in appropriate units

$$\eta_{ith} = \frac{ip}{(\text{mass of fuel / sec}) \times (\text{calorific valve of fuel})}$$

ip = indicated power

(ii) Brake thermal efficiency: it is the ratio of energy in the brake power bp to the input fuel energy in appropriate units.

$$\eta_{bth} = \frac{bp}{(\text{mass of fuel / sec}) \times (\text{calorific valve of fuel})}$$

$bp = \text{break power}$

(iii) Mechanical efficiency: it is defined as the ratio of brake power (delivered power) to the indicated power (power provided to the piston).

$$\eta_{meu} \frac{bp}{IP} = \frac{bp}{bp + Fp}$$

$Fp = \text{friction power}$

It can also be defined as the ratio of the brake thermal efficiency to the indicated thermal efficiency.

(iv) Volumetric Efficiency: it is defined as the volume flow rate of air into the intake system divided by the rate at which the volume is displaced by the system.

$$\eta_{vol} = \frac{M_a}{\rho_a \times V_{disp} \times \frac{N}{2}}$$

Where ρ_a is the density of the air at the inlet

SAMPLE ★ SAMPLE ★ SAMPLE ★ SAMPLE ★

- It is to be noted irrespective of the engine whether SI, CI or gas engine volumetric rate of air flow is what to be taken in to accounts and not the mixture flow.

(v) Relative efficiency: it is defined as the ratio of thermal efficiency of an actual cycle to that of the ideal cycle

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

- It indicate the degree of development of the engine

(vi) Mean effective pressure : it is the average pressure inside the cylinders of an internal combustion engine based on the calculated or measured power output

$$P_{im} = \frac{60000 \times ip}{L\,A \times n \times K}$$

Where

L = length of the stroke

A = area of the piston

N = speed in revolution per minute (rpm)

n = number of power stroke

$\frac{N}{2}$ = for four stroke engine & N for two stroke engine

Ip = indicated power (kw)

P_{im} = indicated mean effective pressure $\left(N/m^2\right)$

- It increases as manifold pressure increases
- Indicated mean effective pressure P_{im} can also be defined as

$$P_{im} = \frac{\text{area of the indicator diagram}}{\text{length of the indicator digram}}$$

(vii) Mean piston speed $\left(\bar{s}_p\right)$ it is defined as

$$\bar{S}_P = 2\,L\,N$$

- It may be noted that $\bar{S}_P$ is often a more approximate parameter than crank rotational speed for correlating engine behavior as a function of speed.

(viii) Specific power output (Ps): it is defined as the power output per unit piston area and is a measure of the engine designer's success in using the available piston area regardless of piston size.

Specific power output $(Ps) = \frac{bP}{A}$

To Buy Postal Correspondence Package call at 0-9990657855