I C Engine

SCAVENGING

Scavenging

Scavenging is a type of gas exchange process in which combustion product of fuel removed by blowing fresh air into the cylinder.

The scavenging takes place during overlapping of valves or ports (when both inlet valve and exhaust valve or both transfer port and exhaust port open at the same time).

This process is necessary for smooth running of the both four-stroke and two-stroke engine. However, it is harder to achieve complete scavenging of the two-stroke engine. The main method used in two-stroke is crankcase scavenging.

Importance of scavenging in IC engine

An efficient scavenging is important to ensure sufficient air supply to the combustion. The more effective scavenging system, the better fuel combustion and output.

If the port is not open for enough time, scavenge is incomplete, and the following stroke begins with a mix of burnt gas (exhaust) and fresh charge leading poor performance of the engine.

The common problem with scavenging is 'short-circuiting loss' and mixing. Short circuiting loss is the expelling of some fresh air directly to exhaust; mixing happens when a small amount of exhaust gets trapped and mix with the fresh charge. There is always a heat transfer between high-temperature burnt gases and low-temperature fresh charge.

Three scavenging models

Perfect scavenging - No mixing, air entirely replace the combustion products.

Short-circuiting - Completely replace exhaust gas and some fresh charge escapes through the exhaust port.

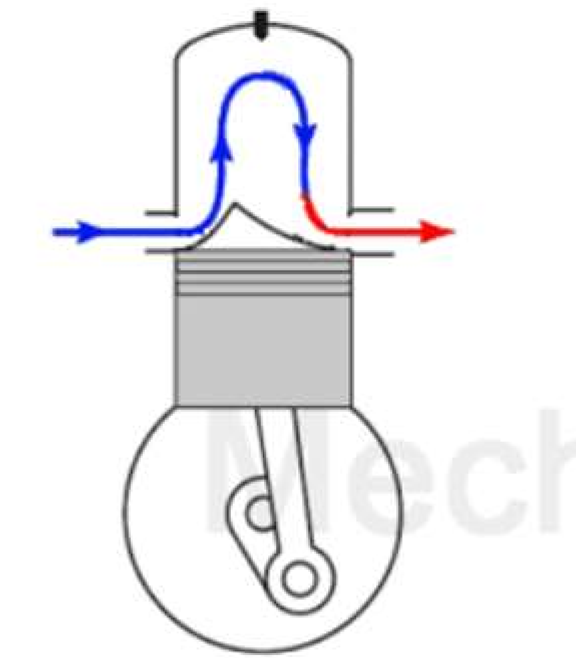
Perfect mixing - Air enters the cylinder, instantaneously mix with burnt gas the expelled by following air flow.

Scavenging Methods

- There are mainly three types of scavenging method on the base of the flow of air
  (I) Cross flow scavenging
  (II) Reverse or Loop scavenging
  (III) Uniflow scavenging

Cross flow scavenging

Cross flow and Revere loop scavenging take place with the help of piston movement. Cross flow scavenging, transfer port (inlet) and exhaust port are situated on the opposite side of the cylinder. The exhaust gas is pushed out by cross flow. The piston head is designed to have a hump shape called deflector. The fresh air enters in the engine cylinder is deflected to the upward by a deflector and pushing exhaust gas down the other side. Before loop scavenging invented, almost all two-stroke engines use this method.



(a) Cross flow scavenge

Advantages and disadvantages of Cross flow scavenging

Advantages:

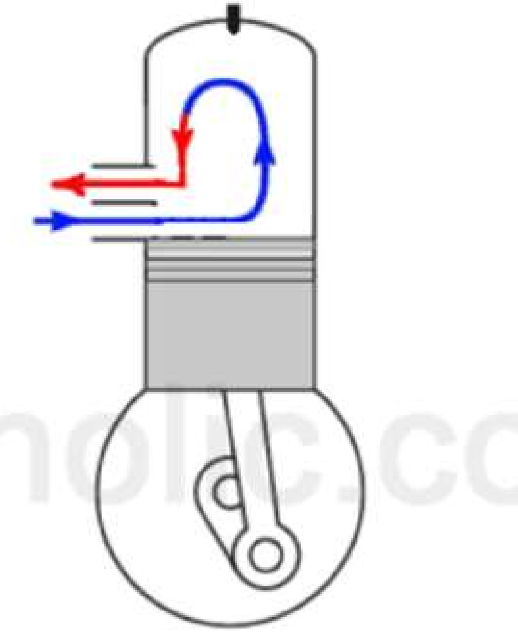
- Low manufacturing cost.
- Good scavenging at low speed and part throttle.
- Low engine volume for the multicylinder arrangement.

Disadvantages:

- Heavy piston with very high heat absorption.
- High tendency to knock.
- Poor scavenging at high speed and full throttle.
- Compulsory water cooling, difficulty in cooling piston crown.

Loop scavenging

Similar to the cross flow scavenging, but the inlet ad exhaust port are placed the same side of the engine cylinder. The gases are encouraged to move loops. This type of scavenging used carefully designed transfer port (inlet) to loop fresh air rise towards the cylinder head on one side and pushes the burnt gas down to the exhaust port installed just above the inlet. It has a flat or slightly domed piston crown. This is the most used type of scavenging system.
Example: *Schnuerle porting*



(b) Loop scavenge

Advantages and disadvantages of Loop scavenging

Advantages:

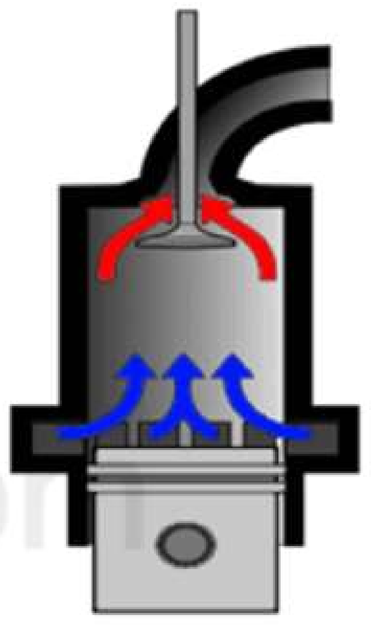
- Low maintenance.
- The low surface area to the volume of the cylinder (hence the heat loss reduced).
- Good scavenging at full throttle.
- Water cooling system not necessary.

Disadvantages:

- Poor scavenging at part throttle operation.
- Scavenging time is short.

Uniflow scavenging

Uniflow scavenging so called because both fresh charge and exhaust gas move in a same upward direction. In this method, fresh air enters from the lower side of the cylinder, and it pushes out exhaust through the exit valve situated at the top of the cylinder. This method is used in large two-stroke diesel engines.



(c) Uniflow scavenge

Advantages and disadvantages of uniflow scavenging

Advantages:

- Extended time for valve operation.
- The possibility of mixing is reduced due to uniflow.
- Increase power output.
- Most efficient of all three methods.
- Good scavenging at all speed ranges and throttle position.
- Low fuel consumption compared to other scavenging types.

Disadvantages:

- Elaborate and costly construction.
- Difficulty in cooling the piston.

Scavenging Parameters

- Delivery Ratio(Rdel)

$$R_{del} = \frac{V_{del}}{V_{ref}}$$

Swept Volume

$$R_{del} = \frac{M_{del}}{M_{ref}}$$

- Trapping Efficiency

$$\eta_{trap} = \frac{V_{ret}}{V_{del}}$$

Some amount of air/air-fuel mixture goes with the exhaust.

Scavenging Parameters

- Relative Cylinder Charge

The air or mixture retained, V_{ret}, together with the residual gas, V_{res}, remaining in the cylinder after flushing out the products of combustion constitutes the cylinder charge, V_{ch}. Relative cylinder charge is a measure of the success of filling the cylinder irrespective of the composition of charge and defined as

$$C_{ret} = \frac{V_{ch}}{V_{ref}} = \frac{V_{ret} + V_{res}}{V_{ref}}$$

The relative cylinder charge may be either more or less than unity depending upon the scavenging pressure and the port heights.

The cylinder charge may also be considered as composed of pure air and residual combustion products. By denoting

$$p_{ar} = \frac{V_{pure}}{V_{ret}}$$

as pure air ratio and

$$\frac{V_{cp}}{V_{ret}}$$

as residual combustion products ratio.

$$C_{rel} = p_{ar} + \frac{V_{cp}}{V_{ret}}$$

$$\eta_p = \frac{V_{pure}}{V_{ch}} = \frac{V_{ch} - V_{cp}}{V_{ch}} = 1 - \frac{V_{cp}}{V_{ch}}$$

Scavenging Efficiency

$$\eta_{sc} = \frac{V_{ret}}{V_{ch}} = \frac{V_{ret}}{V_{ret} + V_{res}}$$

$$R_{del} = \frac{C_{rel} \ \eta_{sc}}{\eta_{trap}}$$

Charging Efficiency

$$\eta_{ch} = \frac{V_{ret}}{V_{ref}}$$

A two-stroke Diesel engine having a stroke to bore ratio of 1.2. The compression ratio is 16 and runs at 1500 rpm. During a trial run the following observations were made:

Exhaust pressure	:	1.05 bar
Inlet air temperature	:	37 °C
Fuel flow rate	:	3 kg/h
Air assumed is	:	130 kg/h
Diameter of the cylinder	:	100 mm

The fuel-air ratio was 0.045. Calculate the scavenging efficiency and the scavenging delivery ratio of the engine.

$$\text{Comp. ratio} = \frac{V_c + V_s}{V_c}$$

$$16 = \frac{\cancel{V_c}}{\cancel{V_c}}^{1} + \frac{V_s}{V_c}$$

$$16 = 1 + \frac{V_s}{V_c}$$

Solution :-

$$V_s = \frac{\pi}{4} d^2 L = \frac{\pi}{4} \times (\cdot 1\,m)^2 \times (1.2 \times 0.1) = 9.4 \times 10^{-4}\,m^3$$

$$\text{Total Volume } V_{tot} = \frac{16}{15} \times V_s = 1.005 \times 10^{-3}\,m^3$$

Ideal gas

$$\rho = \frac{P}{RT}$$

Fuel air ratio $= 0.045$

$$\text{Mass of air} = \frac{3}{0.045} = 66.67 \text{ kg/h}$$

$$\dot{m}_a/\text{cycle} = \frac{66.67}{60 \times 1500} = 7.4 \times 10^{-4} \text{ kg/cycle}$$

$$\dot{m}_{ref} = (1.005 \times 10^{-3}) \times \left(\frac{1.05 \times 10^5}{287 \times 300}\right) = 1.225 \times 10^{-3} \text{ kg}$$

$$\eta_{sc} = \frac{7.4 \times 10^{-4}}{1.225 \times 10^{-3}} = 60.6\%$$

$$\text{Scavenging del. ratio} = \frac{V_{fcu}}{V_{ref}}$$

$$= \frac{\frac{130}{60} \times \frac{1}{1500}}{1.22 \times 10^{-3}} = 1.18$$