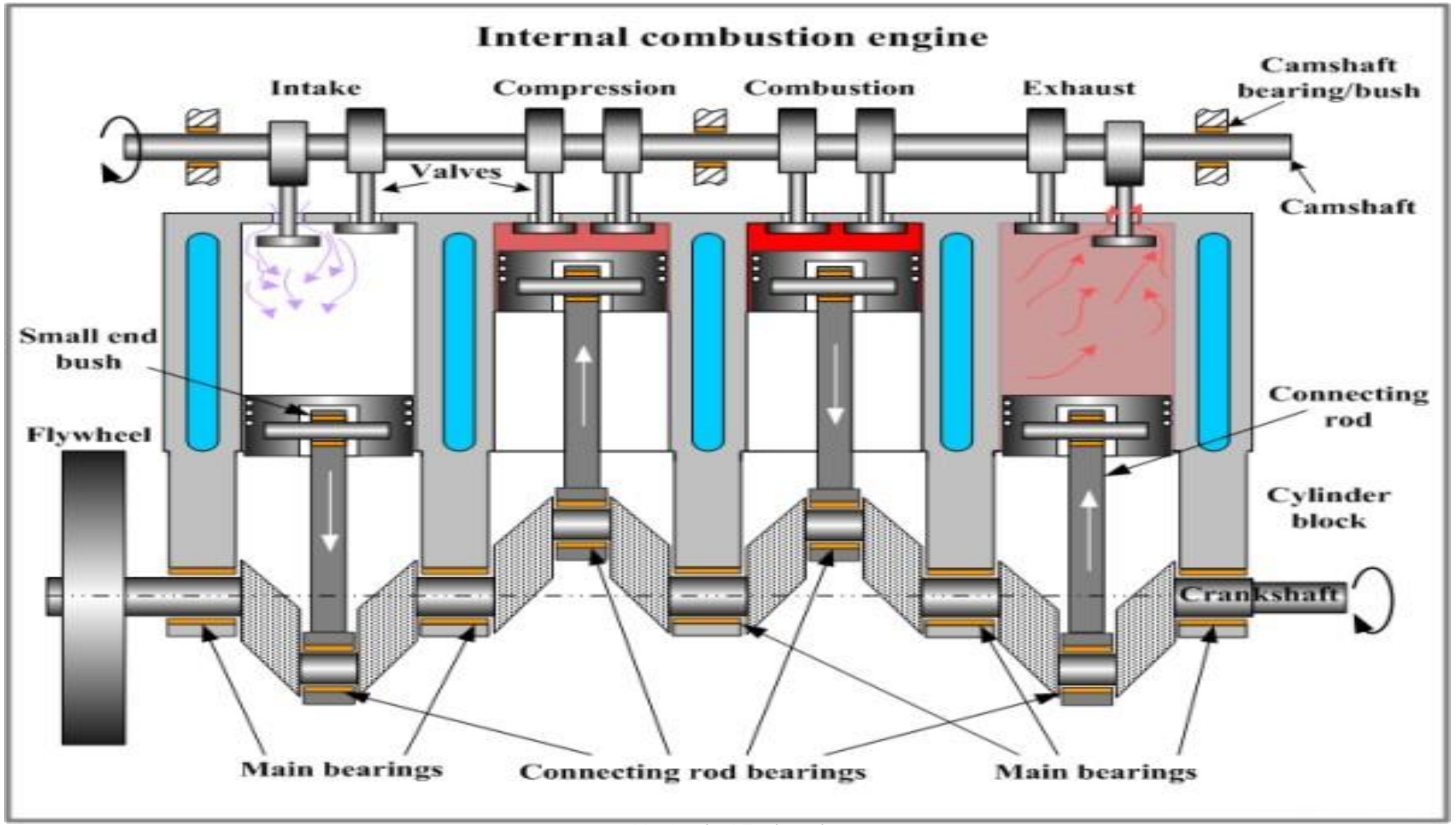
23ME404 : Thermal Engineering-1

Topic: IC Engines

Mrs. D.Simhana Devi

Assistant Professor, Mechanical Engineering
Narsimha Reddy Engineering College (Autonomous)
Secunderabad, Telangana, India- 500100.


Internal combustion engine
Intake
Compression
Combustion
Exhaust
Camshaft bearing/bush
Valves
Camshaft
Small end bush
Flywheel
Connecting rod
Cylinder block
Crankshaft
Main bearings
Connecting rod bearings
Main bearings

CASSIFICATION OF IC ENGINE

1. Type of Fuel
2. Method of ignition
3. Number of storkes
4. Cycle of operation
5. Speed of engine
6. Cooling system
7. Number of cylinders

Components of IC Engine

1. ***Cylinder*** :

- withstand 50 bar pressure and 2000 centigrade temperature.
- Material : cast iron , steel alloy , aluminium alloy

2. **Cylinder Head :**

- Contain Spark plug for petrol engine and nozzle for Diesel Engine.
- Material : cast iron , steel alloy , aluminium alloy
- Gasket : copper or asbestos for air tight seal.

Components of IC Engine

3. **Piston :**

- Function : Transmit force to connecting rod.
- Material : Aluminium

4. **Connecting rod** :

- Function : Transmit force from piston to crankshaft
- Material : Special steel alloy or Aluminium alloy

Components of IC Engine

5. **Piston rings :**

- Construction : Two sets of rings
- Function : To provide air tight seal to prevent leakage of burnt gases or oil
- Material : Special steel alloy.

6. **Crankshaft :**

- Power is developed during working stroke.
- Material : Special steel alloy.

Components of IC Engine

7. **Crankcase :**

- Act as a sump for lubricating oil.
- Material : cast iron

8. **Flywheel :**

- Function : It stores excess energy during power stroke and return energy during other stroke

  It maintain the speed of crankshaft constant.

Four stroke Engine

Petrol or Spark Ignition Engine

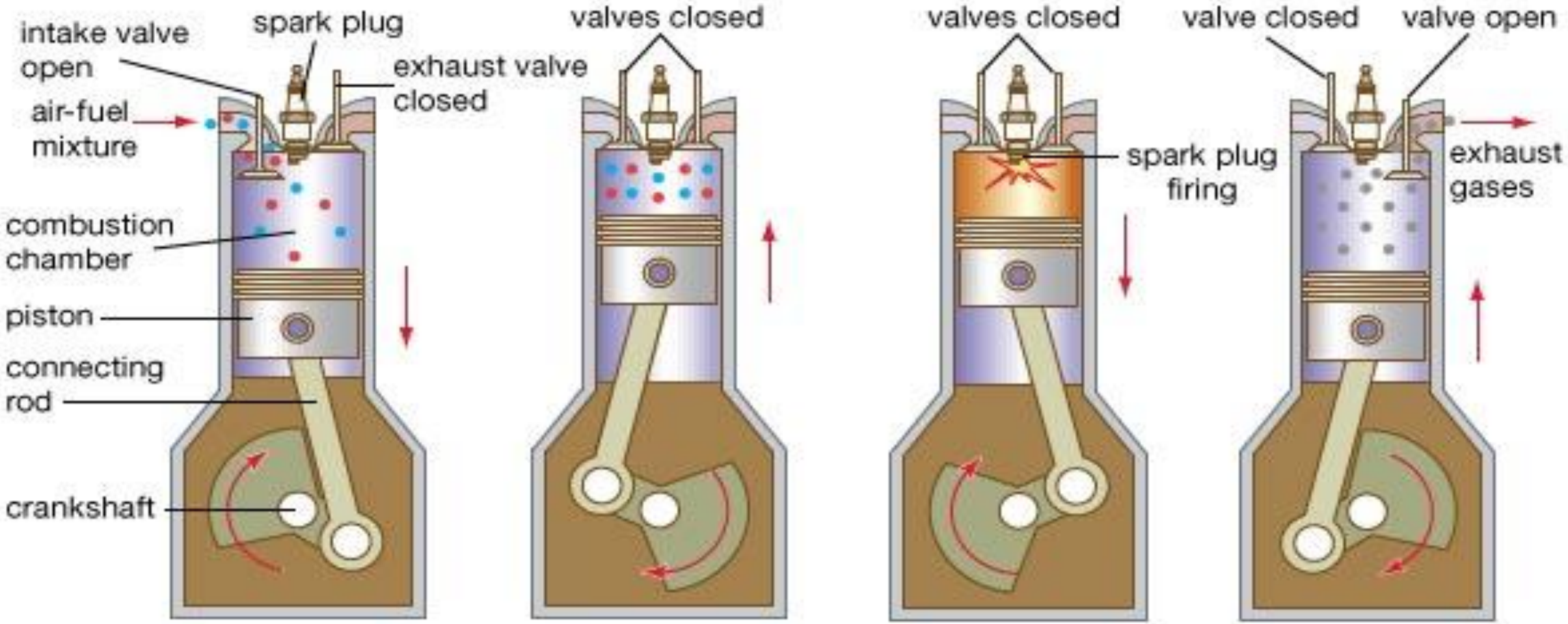
(S.I. Engine)

Construction

1. It consists of

- Cylinder piston assembly
- Connecting rod
- Crankshaft
- Cylinder head
- Crank case
- Inlet and Exhaust valve.
- Fins (for cooling purpose)

Four-stroke cycle



intake
Air-fuel mixture is drawn in.

compression
Air-fuel mixture is compressed.

power
Explosion forces piston down.

exhaust
Piston pushes out burned gases.

Working

1. **Suction stroke :**

- Due to pressure difference inlet valve opens and charge is sucked into the cylinder
- Piston moves from TDC to BDC.
- Crankshaft rotates through 180 degree.

2. **Compression stroke :**

- Inlet and Exhaust valve are closed
- Piston moves from BDC to TDC.

Working

- Pressure and temperature of charge increases.
- Crankshaft rotates through 360 degree i.e. one complete revolution.

3. **Expansion stroke :**

- Charge is ignited by spark plug before the piston reaches TDC.
- Sudden increase in the temperature and pressure but volume remains constant.

Working

- Combustion products pushes the piston in the downward direction due to high pressure.
- Heat energy transform to mechanical energy.
- Piston moves from TDC to BDC
- Crankshaft rotates through 540 degree.
- Both inlet and exhaust valves are closed.

4. Exhaust stroke :

- Exhaust valve opens as the piston moves from BDC to TDC

Working

- Piston pushes the product of combustion through exhaust valve into atmosphere.

Examples of Four stroke engines:

For Light vehicles:

- Cars
- Jeep
- Aeroplanes.

Four stroke Engine

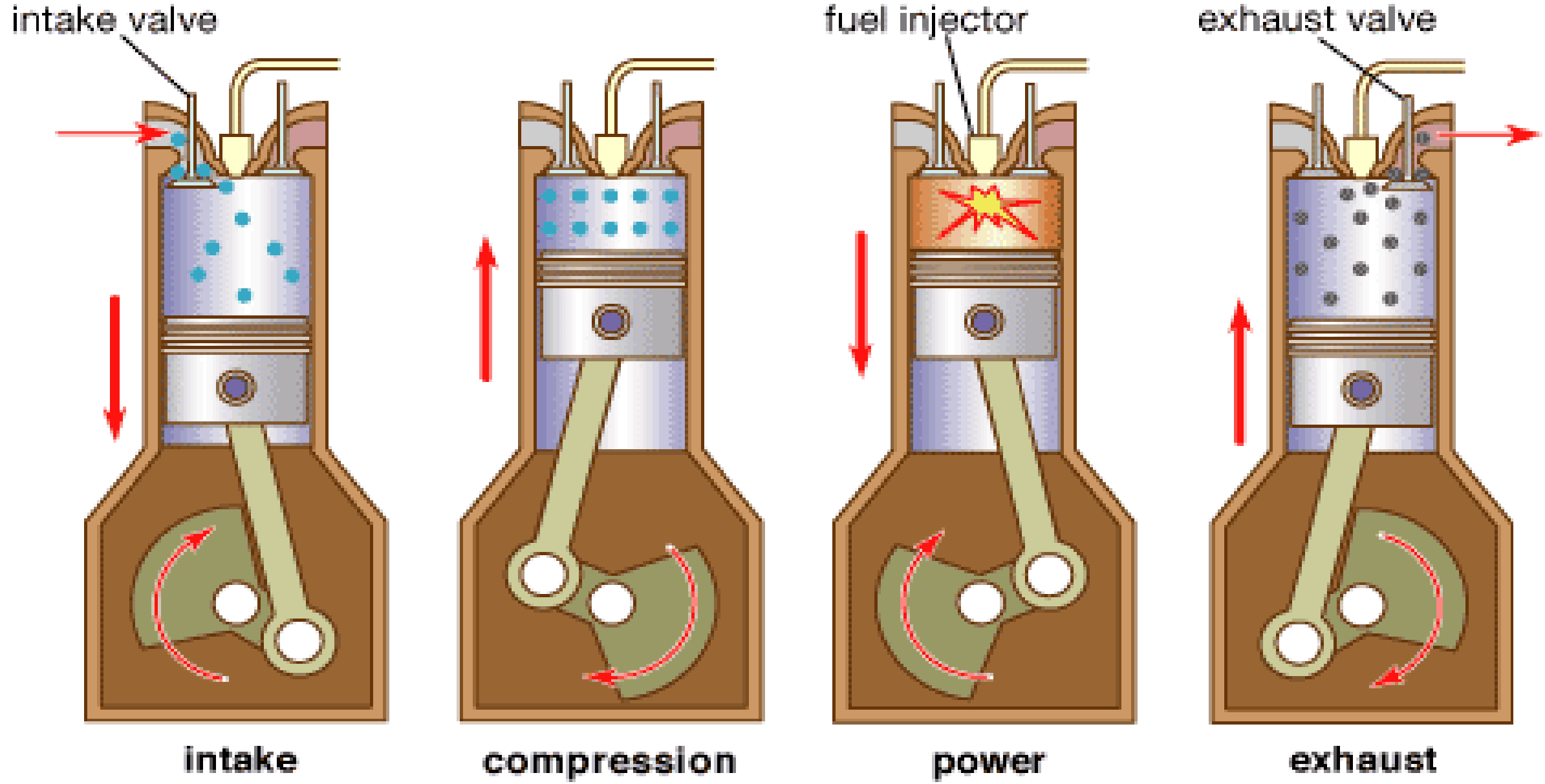
Diesel or Compression Ignition

(C.I. Engine)

Construction

1. It consists of

- Cylinder piston assembly
- Connecting rod
- Crankshaft
- Cylinder head
- Crank case
- Inlet and Exhaust valve.
- Fins (for cooling purpose)


intake valve
fuel injector
exhaust valve
intake
compression
power
exhaust
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Working

1. **Suction stroke :**

- Due to pressure difference inlet valve opens and air is sucked into the cylinder
- Piston moves from TDC to BDC.
- Crankshaft rotates through 180 degree.

2. **Compression stroke :**

- Inlet and Exhaust valve are closed
- Piston moves from BDC to TDC.

Working

- Pressure and temperature of charge increases.
- Crankshaft rotates through 360 degree i.e. one complete revolution.

3. Expansion stroke :

- Fuel is injected through fuel injector before the piston reaches TDC.
- Temperature of air is high enough to ignite the Fuel.
- Sudden increase in the temp. and pressure.

Working

- Combustion products pushes the piston in the downward direction due to high pressure.
- Heat energy transform to mechanical energy.
- Piston moves from TDC to BDC
- Crankshaft rotates through 540 degree.
- Both inlet and exhaust valves are closed.

4. Exhaust stroke :

- Exhaust valve opens as the piston moves from BDC to TDC

Working

- Piston pushes the product of combustion through exhaust valve into atmosphere.

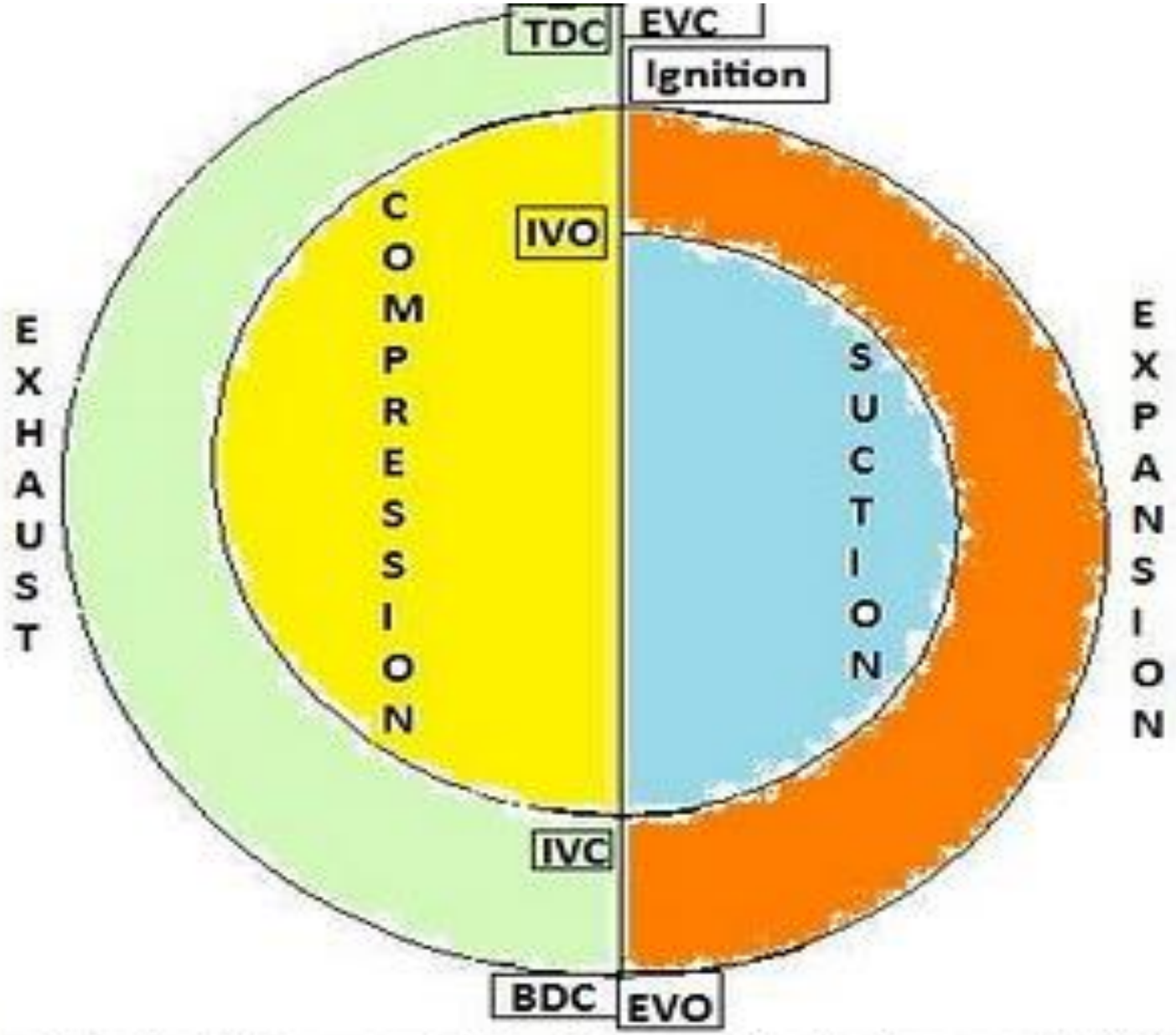
Examples of Four stroke engines:

For Heavy vehicles:

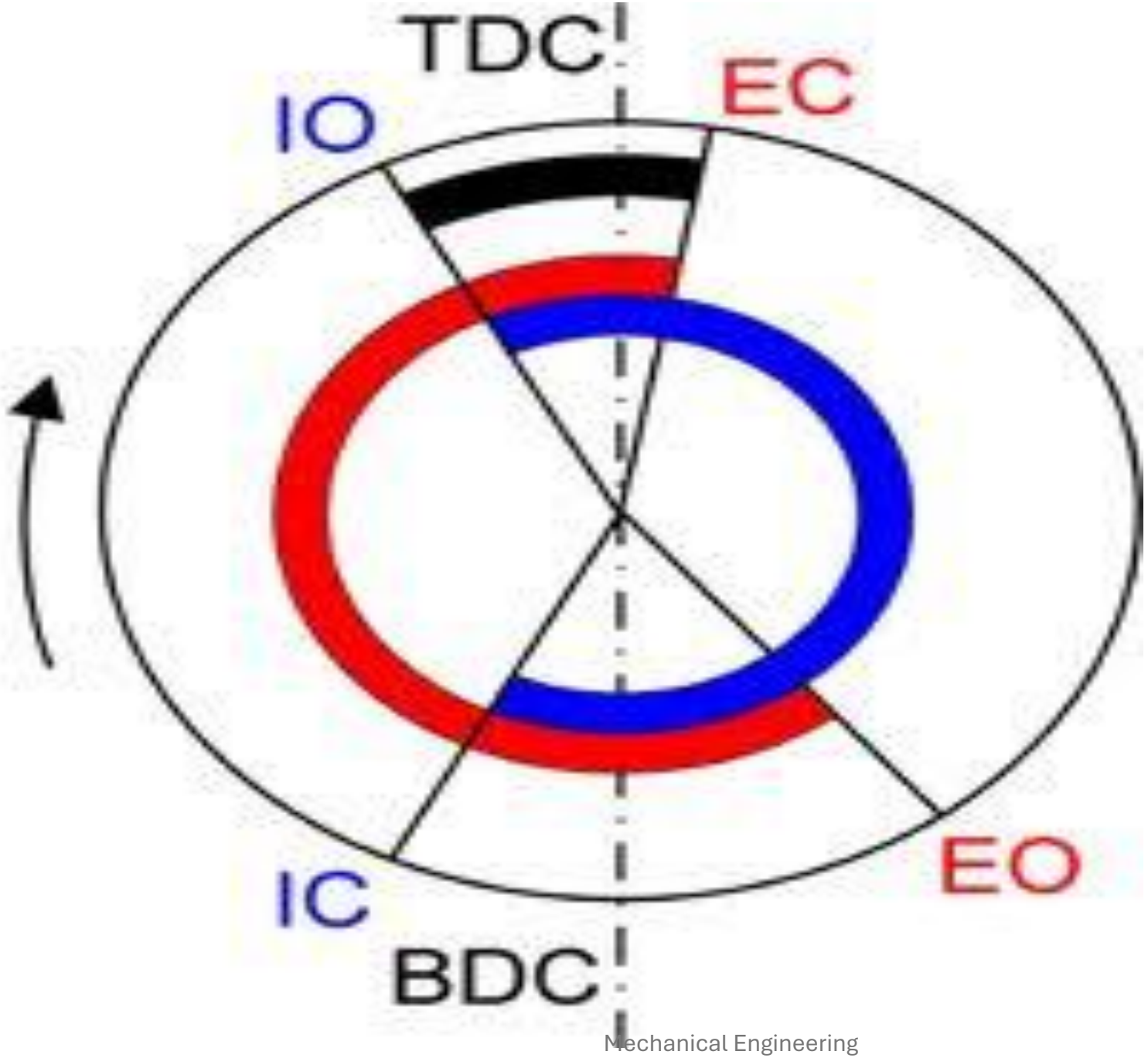
- Buses
- Trucks
- Tractors.
- Earth moving machines.

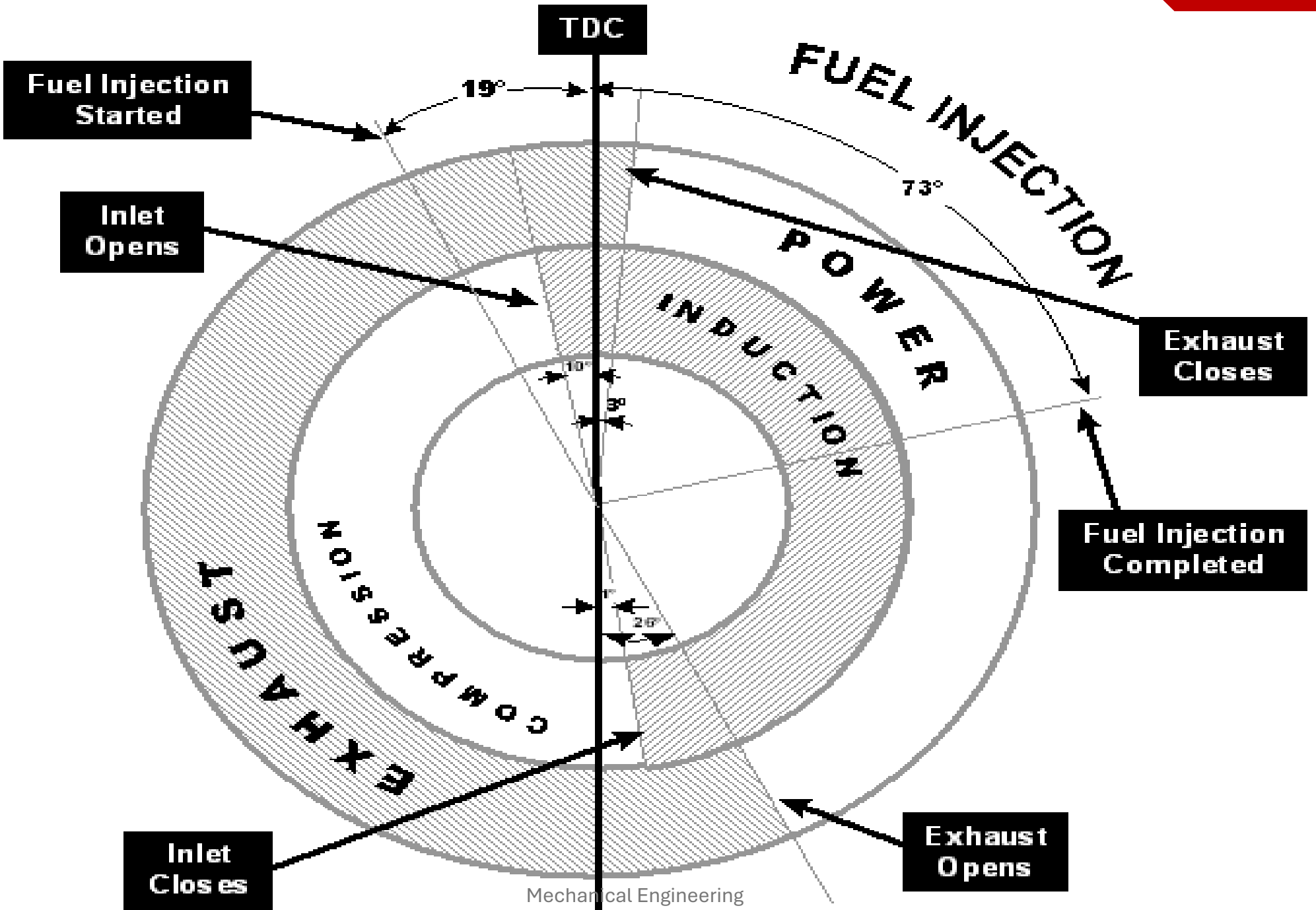
Valve Timing Diagram

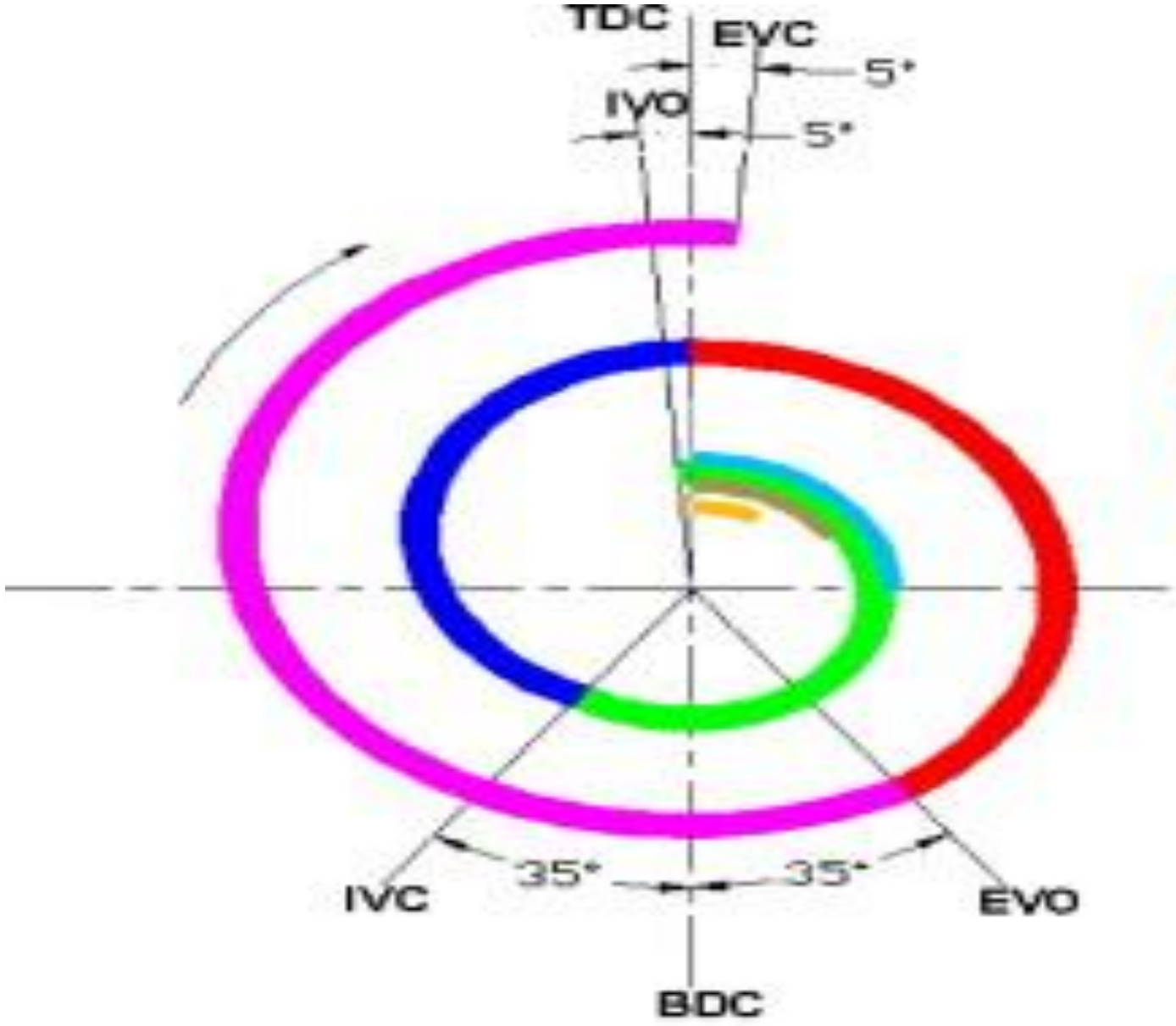
Petrol & Diesel Engine



Valve Timing Diagram-4stroke engine/otto cycle (Theoretical)


TDC
IO
EC
IC
EO
BDC


TDC
Fuel Injection Started
19°
FUEL INJECTION
73°
Inlet Opens
POWER
Exhaust Closes
INDUCTION
10°
3°
COMPRESSION
EXHAUST
1°
26°
Fuel Injection Completed
Inlet Closes
Exhaust Opens



TDC - Top Dead Centre

BDC - Bottom Dead Centre

IVO - Inlet Valve Open

IVC - Inlet Valve Close

Four stroke Petrol Engine

1. IVO : 10 to 20 Deg. Before TDC
2. IVC : 30 to 40 Deg. After BDC
3. IGN : 20 to 30 Deg. Before TDC
4. EVO : 30 to 50 Deg. Before TDC
5. EVC : 10 to 15 Deg. After TDC

Four stroke Diesel cycle

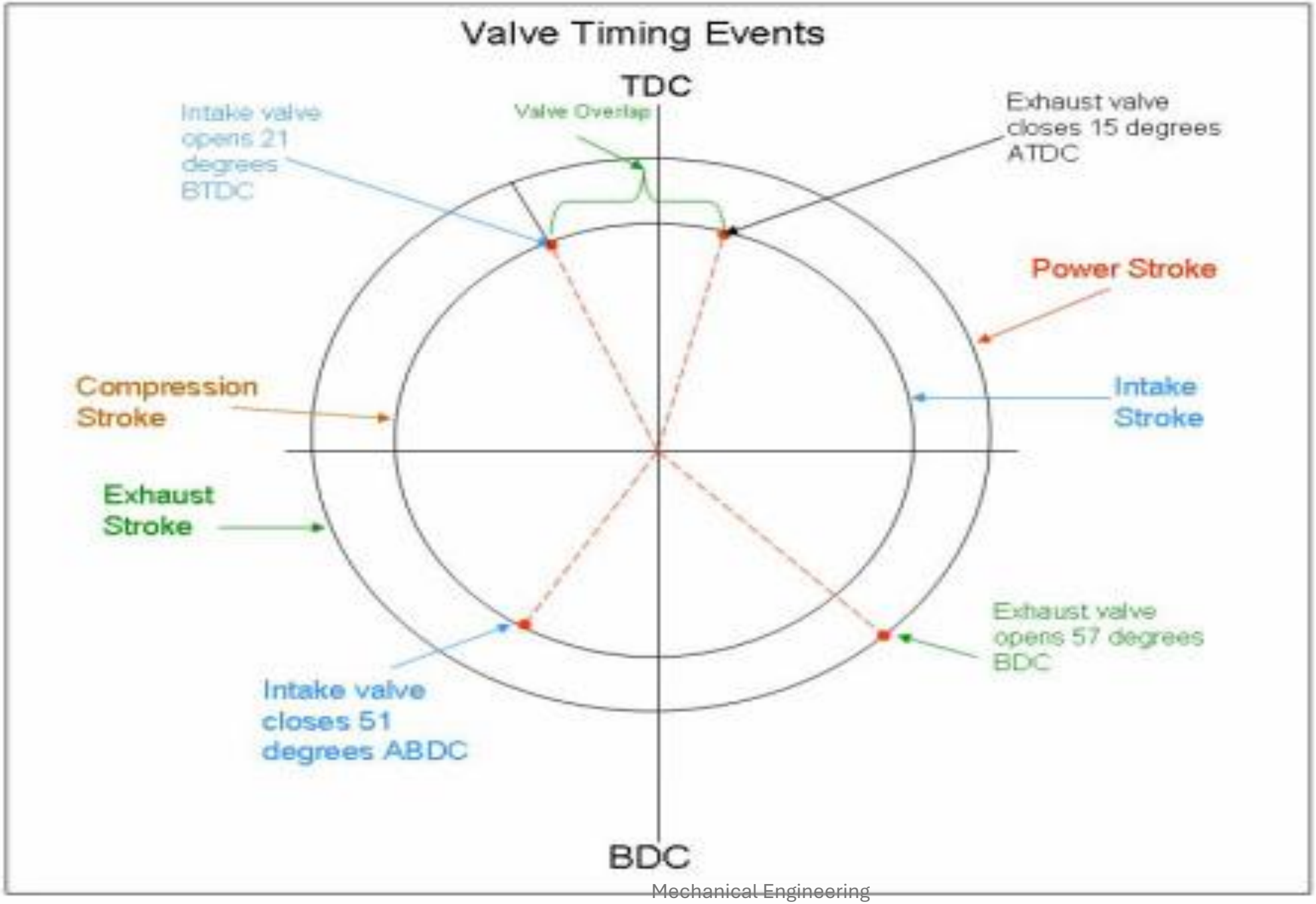
1. IVO : 10 to 20 Deg. Before TDC
2. IVC : 25 to 40 Deg. After BDC
3. FVO : 10 to 15 Deg. Before TDC
4. FVO : 15 to 20 Deg. After TDC
5. EVO : 39 to 50 Deg. Before TDC
6. EVC : 10 to 15 Deg. After TDC

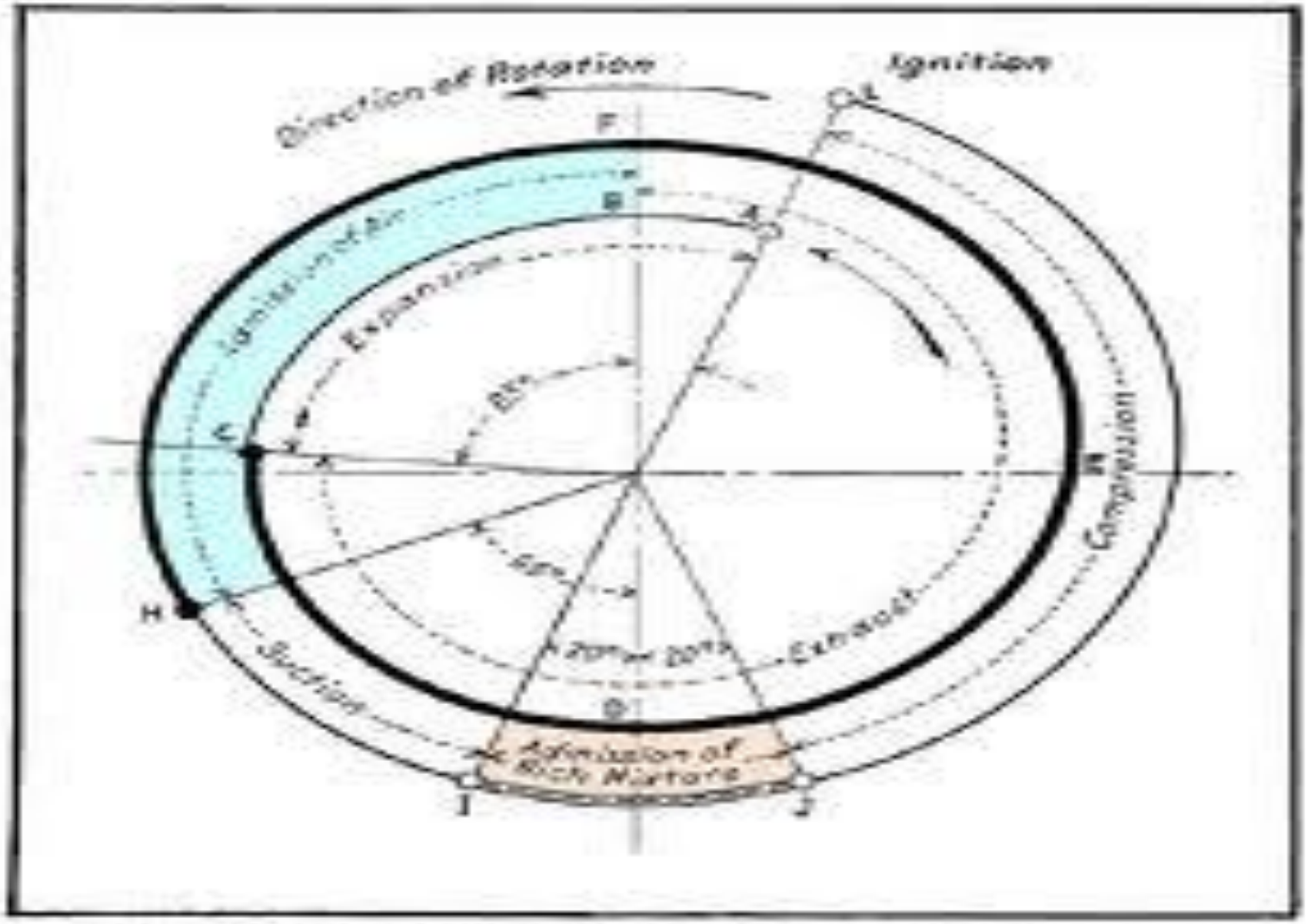
Two stroke Petrol engine

1. EPO : 35 to 50 Deg. before BDC
2. TPO : 30 to 40 Deg. before BDC
3. TPC : 30 to 40Deg. after BDC
4. EPC : 35 to 50 Deg. after BDC
5. IGN : 15 to 20 Deg. before TDC

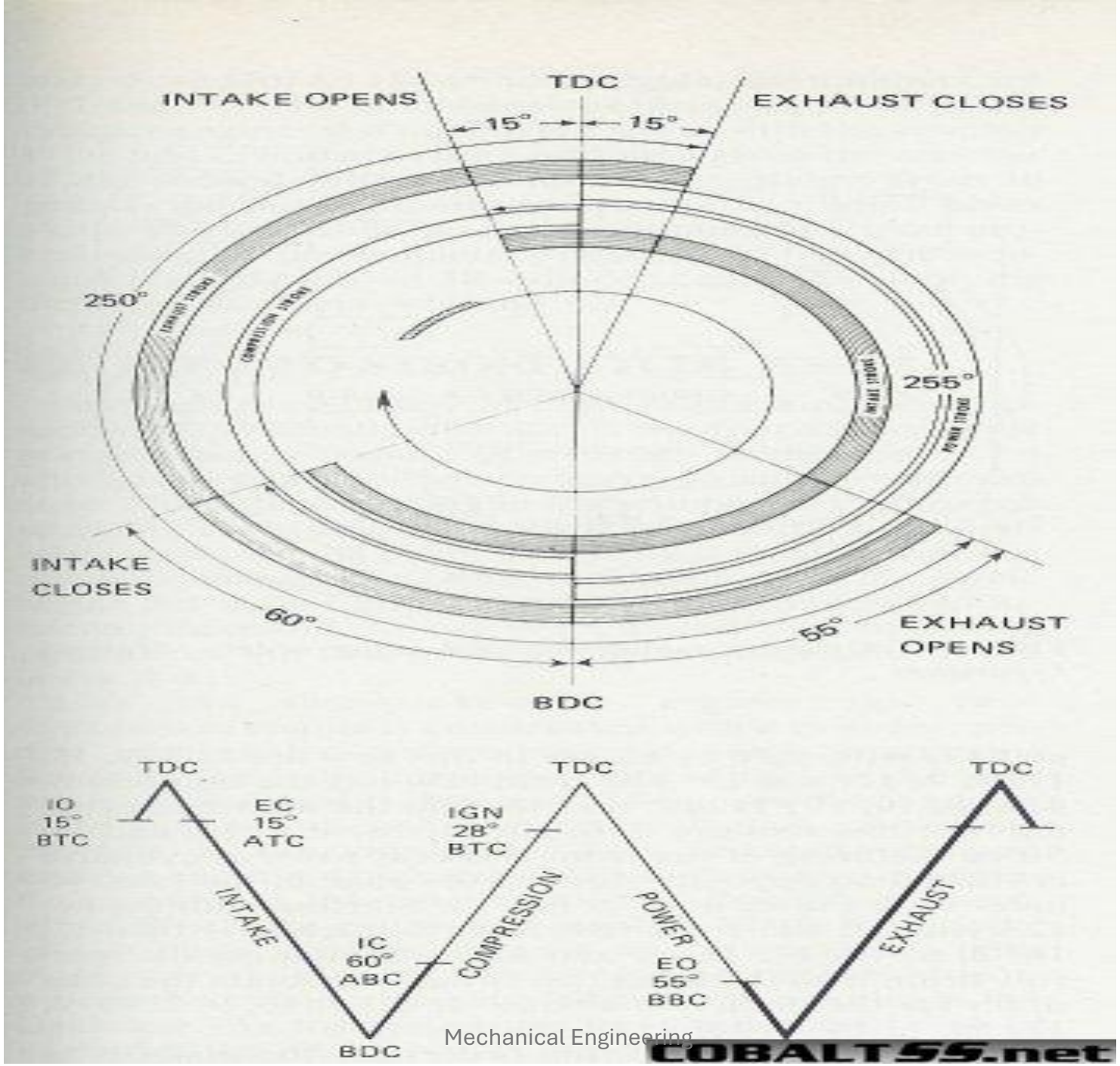
Two stroke Diesel engine

1. EPO : 30 to 45 Deg. before BDC
2. TPO : 30 to 40 Deg. before BDC
3. TPC : 30 to 40 Deg. after BDC
4. EPC : 35 to 50 Deg. after BDC
5. FVO : 10 to 15 Deg. before TDC
6. FVO : 15 to 20 Deg. After TDC

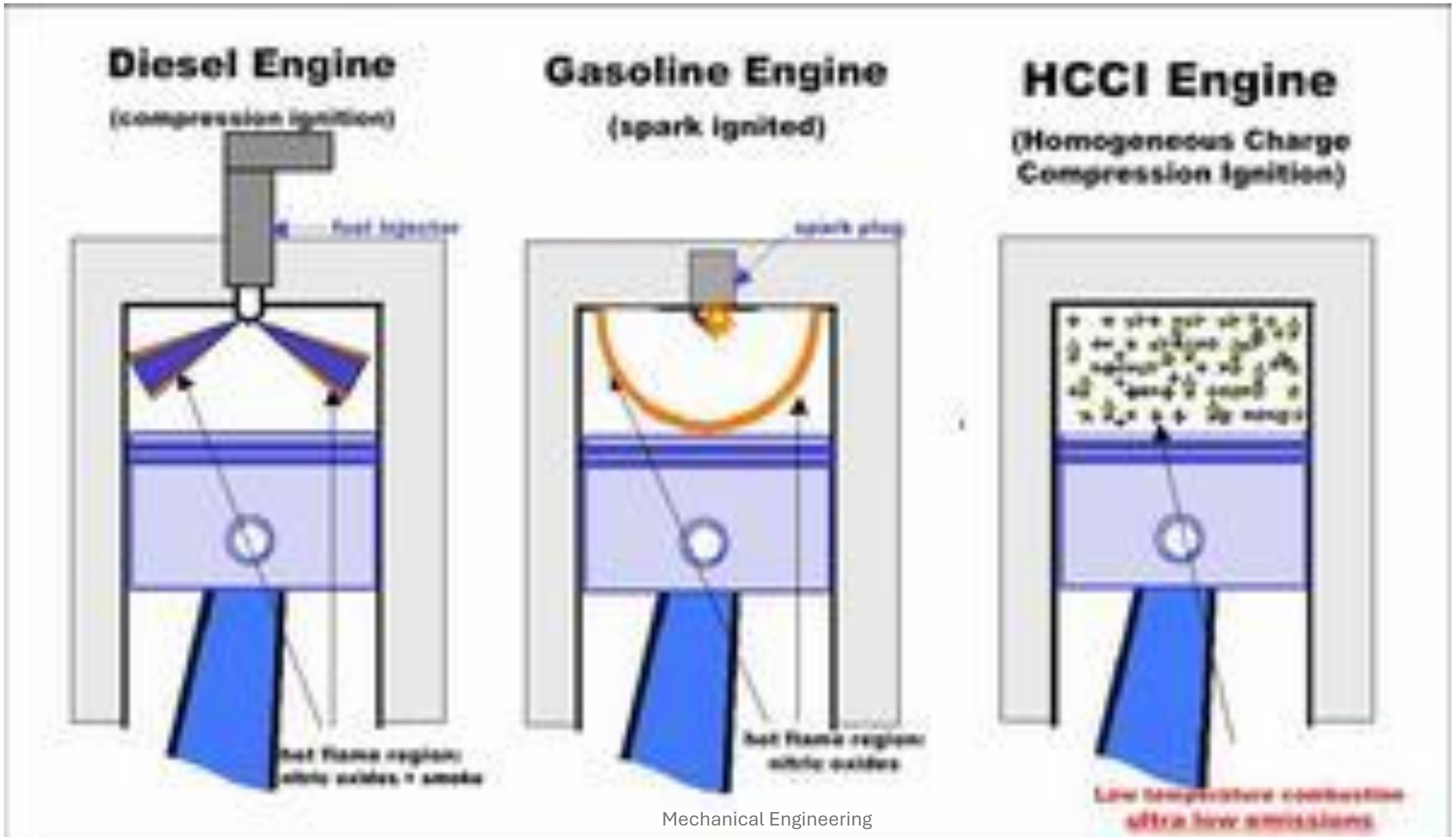

Valve Timing Events
TDC
Intake valve opens 21 degrees BTDC
Valve Overlap
Exhaust valve closes 15 degrees ATDC
Power Stroke
Compression Stroke
Intake Stroke
Exhaust Stroke
Exhaust valve opens 57 degrees BDC
Intake valve closes 51 degrees ABDC
BDC



Timing Diagram Showing Peculiar Valve Timing of Gnome "Monosteppage" Rotary Motor.

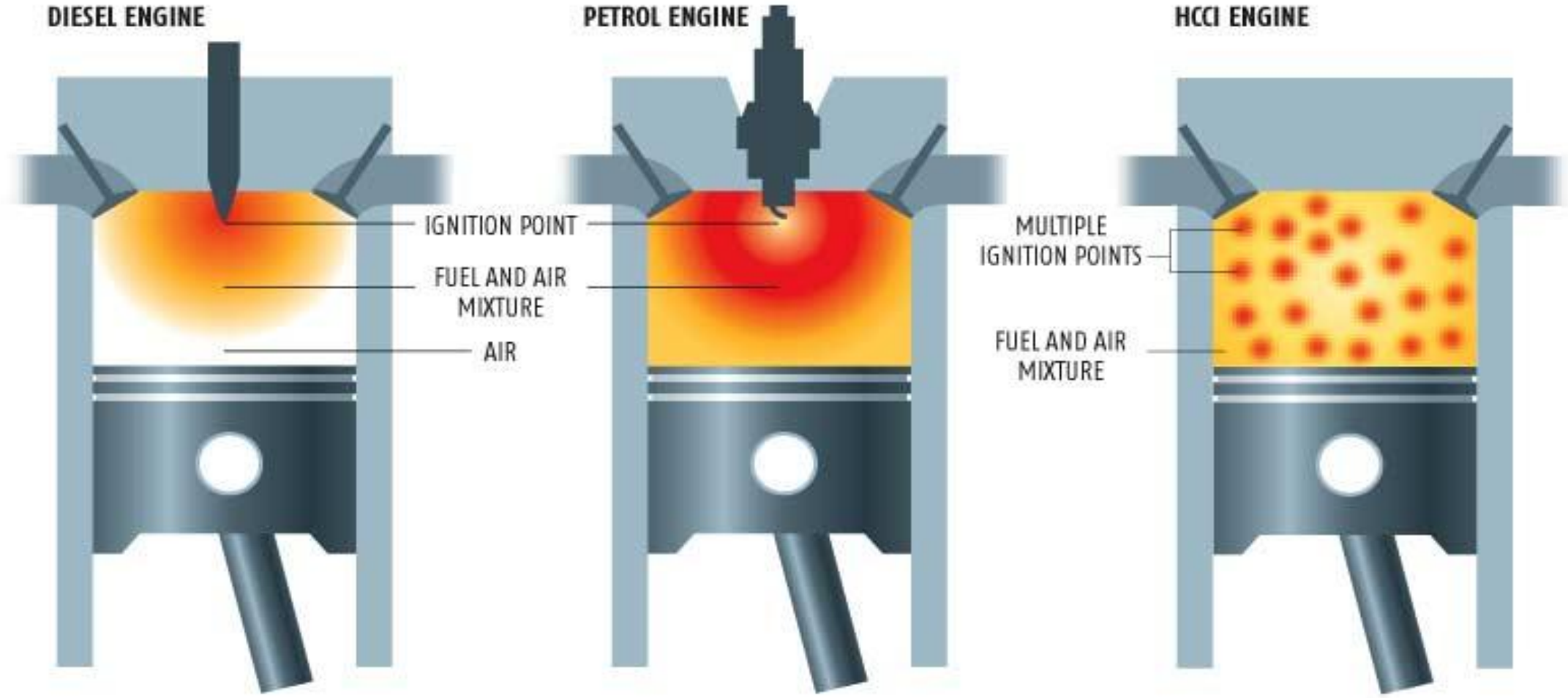


Combustion in SI engine

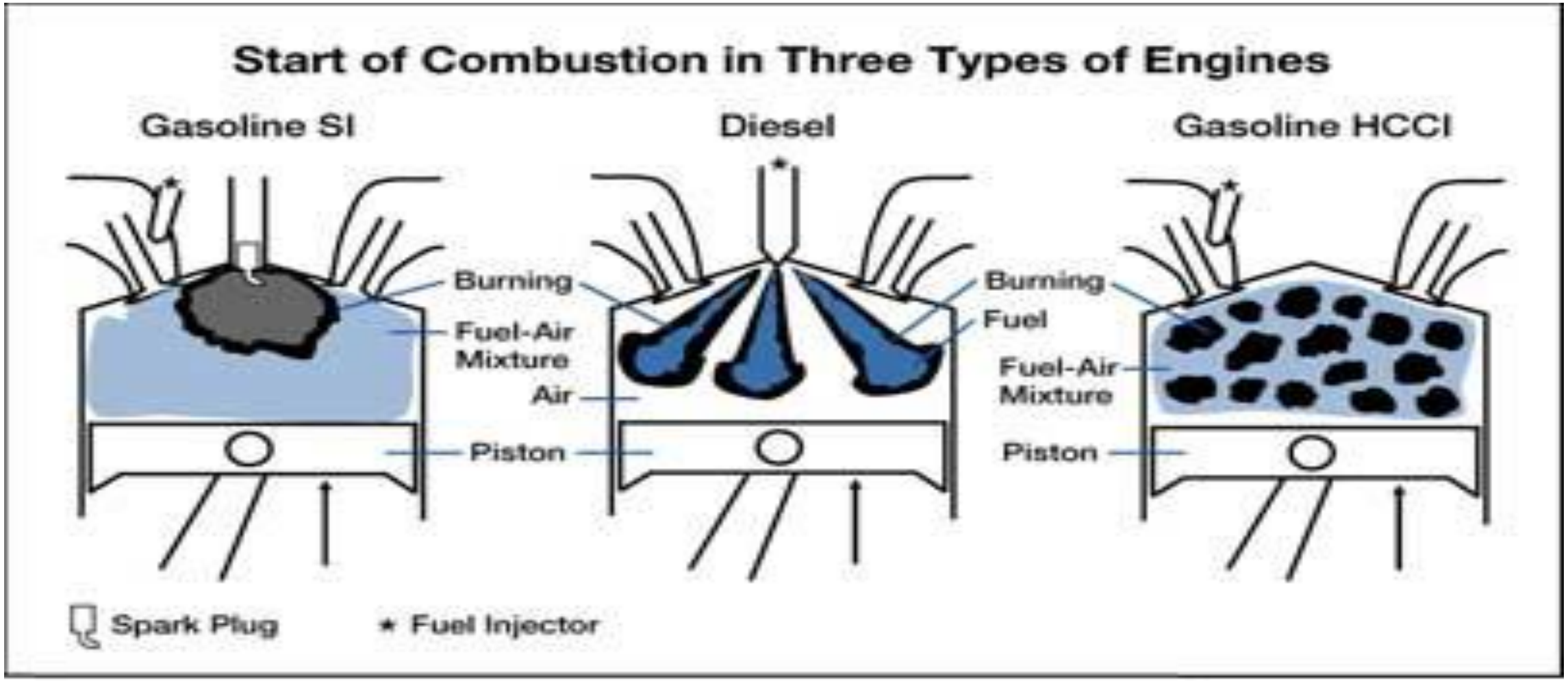

Diesel Engine
(compression ignition)
fuel injector
hot flame region:
nitric oxides + smoke
Gasoline Engine
(spark ignited)
spark plug
hot flame region:
nitric oxides
HCCI Engine
(Homogeneous Charge
Compression Ignition)
Low temperature combustion
ultra low emissions

REDUCING SOOT AND NOx EMISSIONS

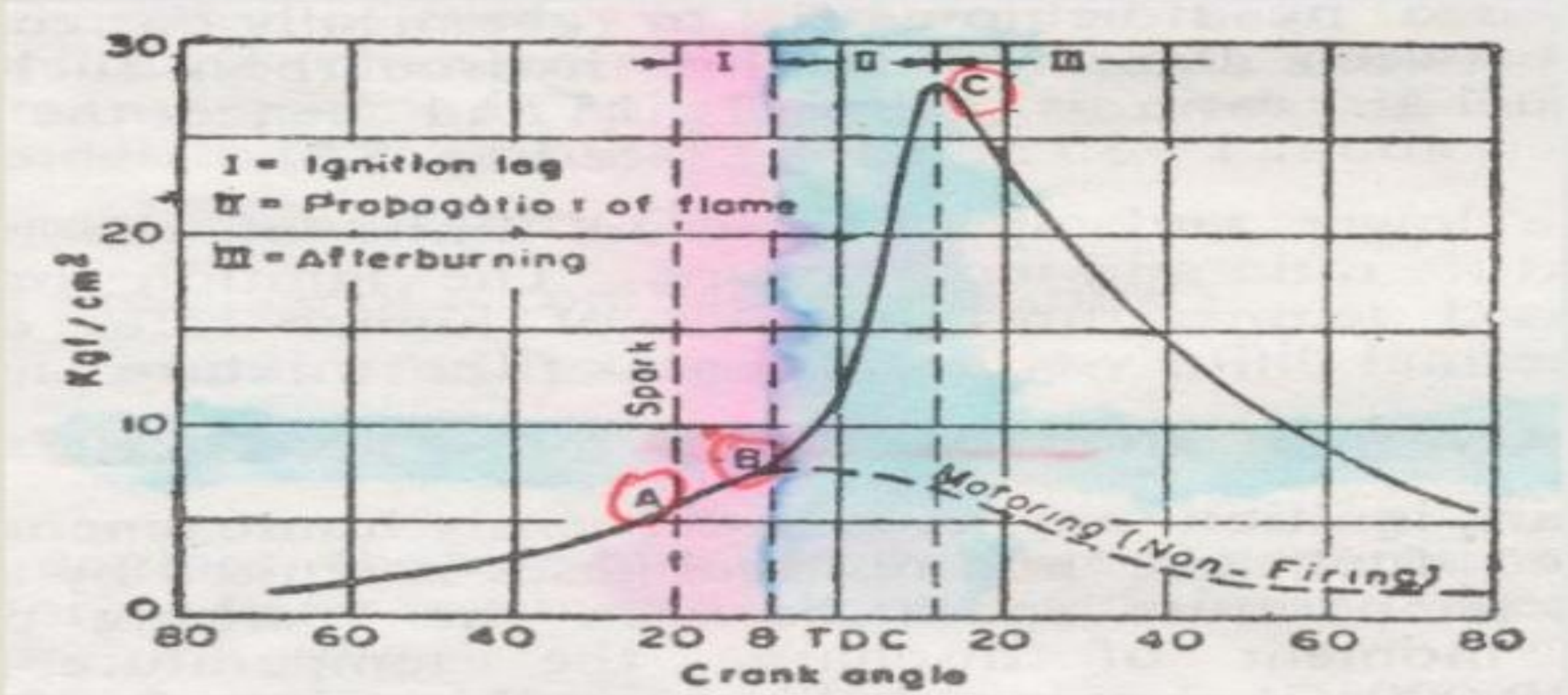
In HCCI and petrol engines, the fuel and air are mixed before combustion, preventing the soot emissions of diesel engines. Only HCCI engines have multiple ignition points throughout the chamber. This plus their lean burn keeps temperatures low, preventing formation of nitogen oxides (NOx)



SI –Spark ignition,CI – compression Ignition,
HCCI –Homogeneous charge compression ignition



Stages of combustion in SI engine



Combustion phenomenon in SI engine

- In SI Engine homogeneous mixture of air and fuel is formed by the carburetor.
- Air – fuel mixture is compressed upto compression ratio 8 to 12.
- Mixture is ignited by spark plug.
- A turbulent flame is developed which propagates through the charge.

Three stages of combustion

1. Ignition Lag :

- It consists of growth and development of propagated flame.
- It depends on temperature,pressure and nature of fuel.
- It also depends on propagation of exhaust gas residue.

2. Propagation of flame :

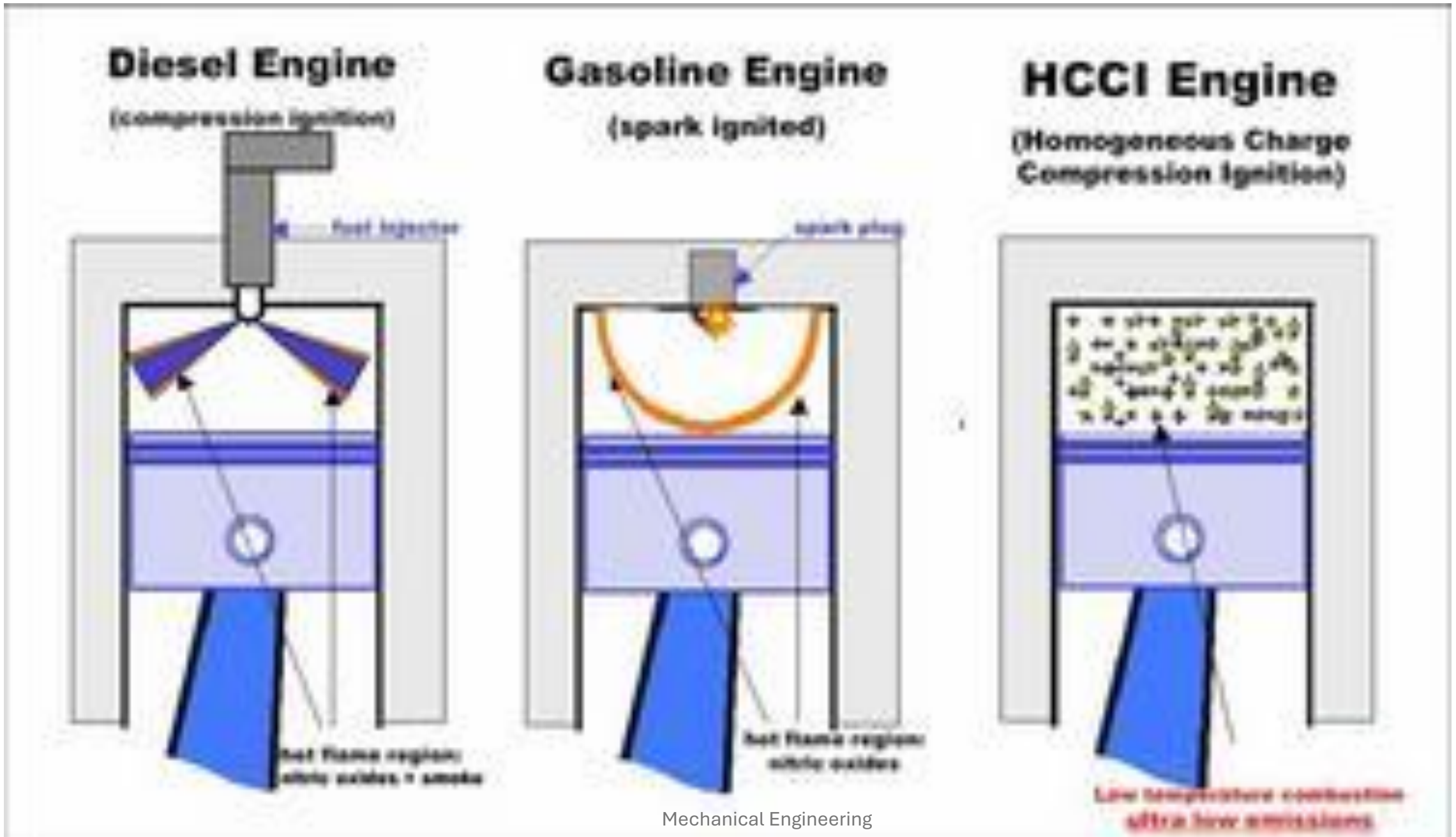
- In this stage there is sudden rise in pressure and temperature.

- Velocity of flame is constant.
- Heat release rate depends on reaction rate of charge.
- heat transfer to cylinder wall is low.

3. After burning ：

- In this stage highest pressure is reached.
- Velocity of flame decrease.
- Combustion rate also decrease.

Combustion in SI engine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(compression ignition)
fuel injector
hot flame region:
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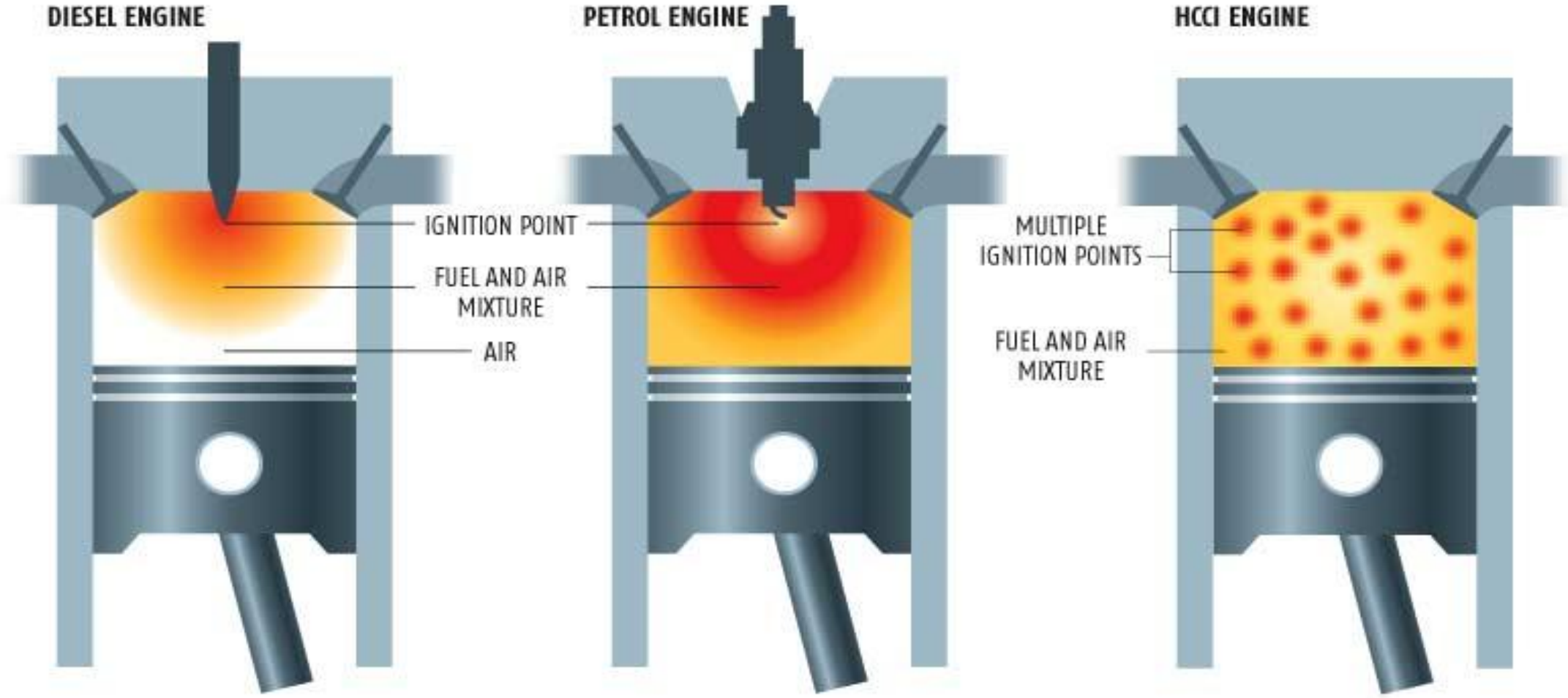

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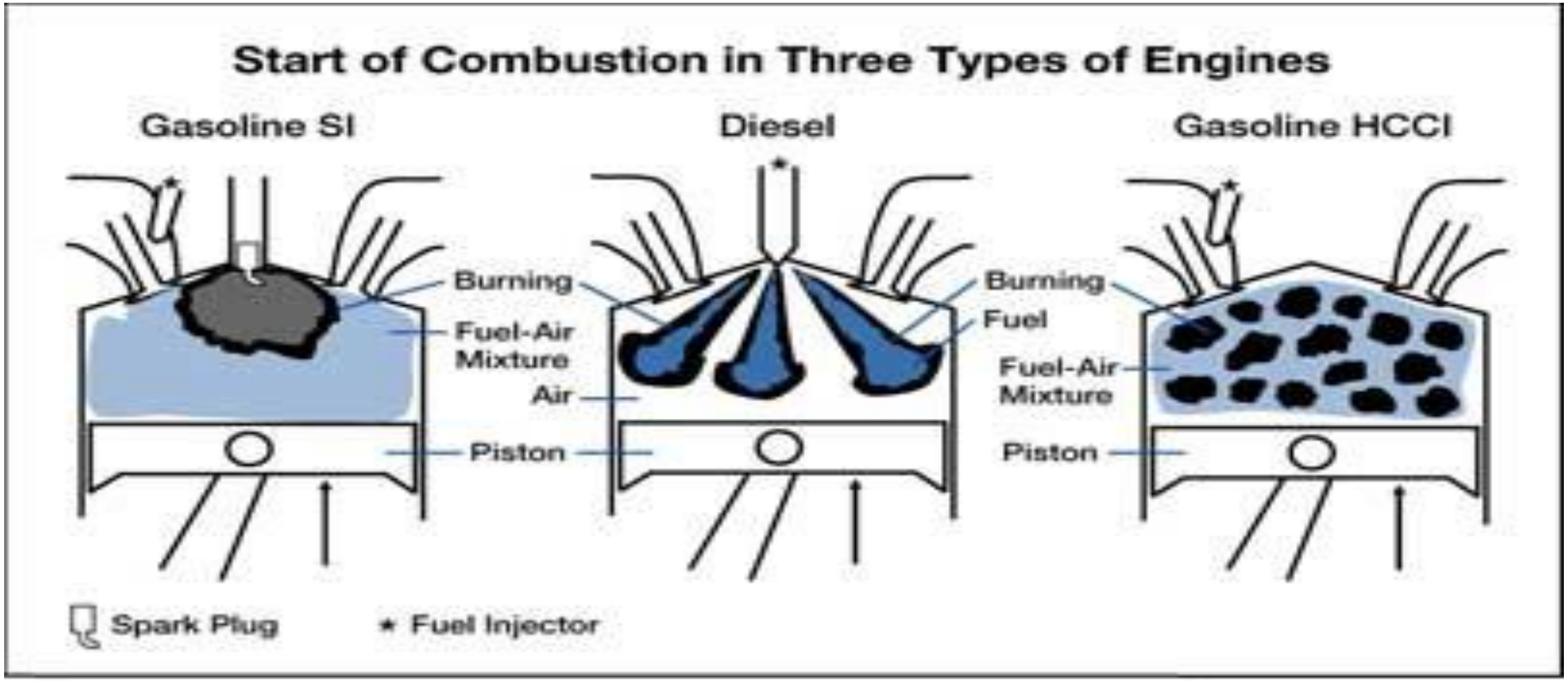
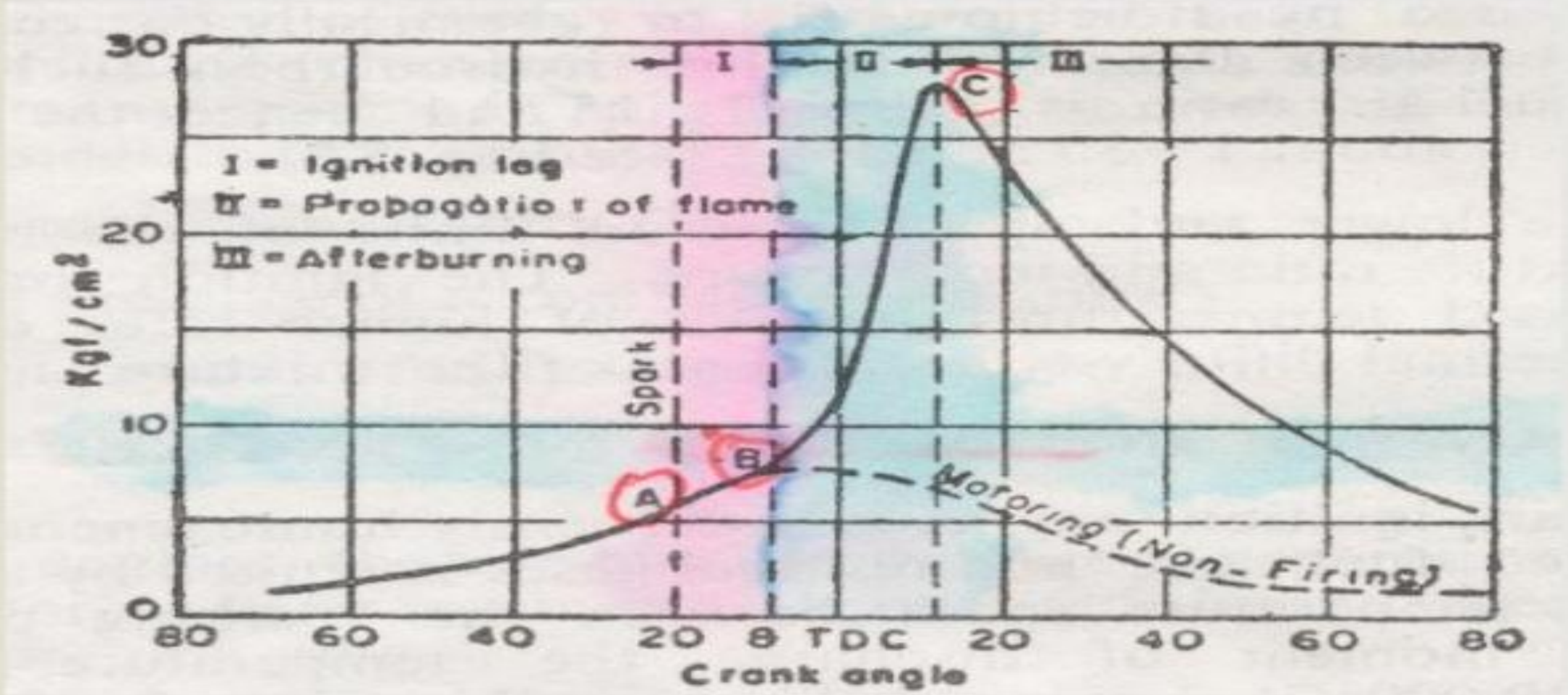


Stages of combustion in SI engine



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- heat transfer to cylinder wall is low.

3. After burning ：

- In this stage highest pressure is reached.
- Velocity of flame decrease.
- Combustion rate also decrease.

Supercharging

What is supercharging ?

- It is the process of increasing the mass or density of air fuel mixture in S.I.engine or air in C.I. engine sucked into the engine cylinder.
- It is done with the help of compressor or blower called as supercharger.
- In S.I. engine it is mounted before carburetor which reduce the size of carburator.

Effect of Supercharging

1. To maintain power o/p of an engine working at high altitude, where less oxygen is available for combustion.
2. To reduce the space occupied by the engine.
3. To reduce the consumption of lubricating oil.
4. To reduce the mass of engine per B.P.
5. To increase mechanical and thermal efficiency.
6. To increase volumetric efficiency.
7. Specific fuel consumption is less.
8. Chances of detonation due to high pressure.

Turbocharging

What is Turbocharging

- It is the process in which energy extracted from the exhaust gases by the turbine is utilized to drive the supercharger i.e. centrifugal compressor.
- About 30 % of heat goes out through the exhaust gas.It depends on type of engine and operating conditions.
- This gas turbine is directly coupled to the centrifugal compressor.

Advantages of Turbocharger

1. Reduce pollution from exhaust gases.
2. Reduce fuel consumption.
3. Reduction in power loss due to decrease in air density at higher altitude.
4. Increase power o/p of engine.
5. More power to weight ratio.
6. Better torque characteristics.

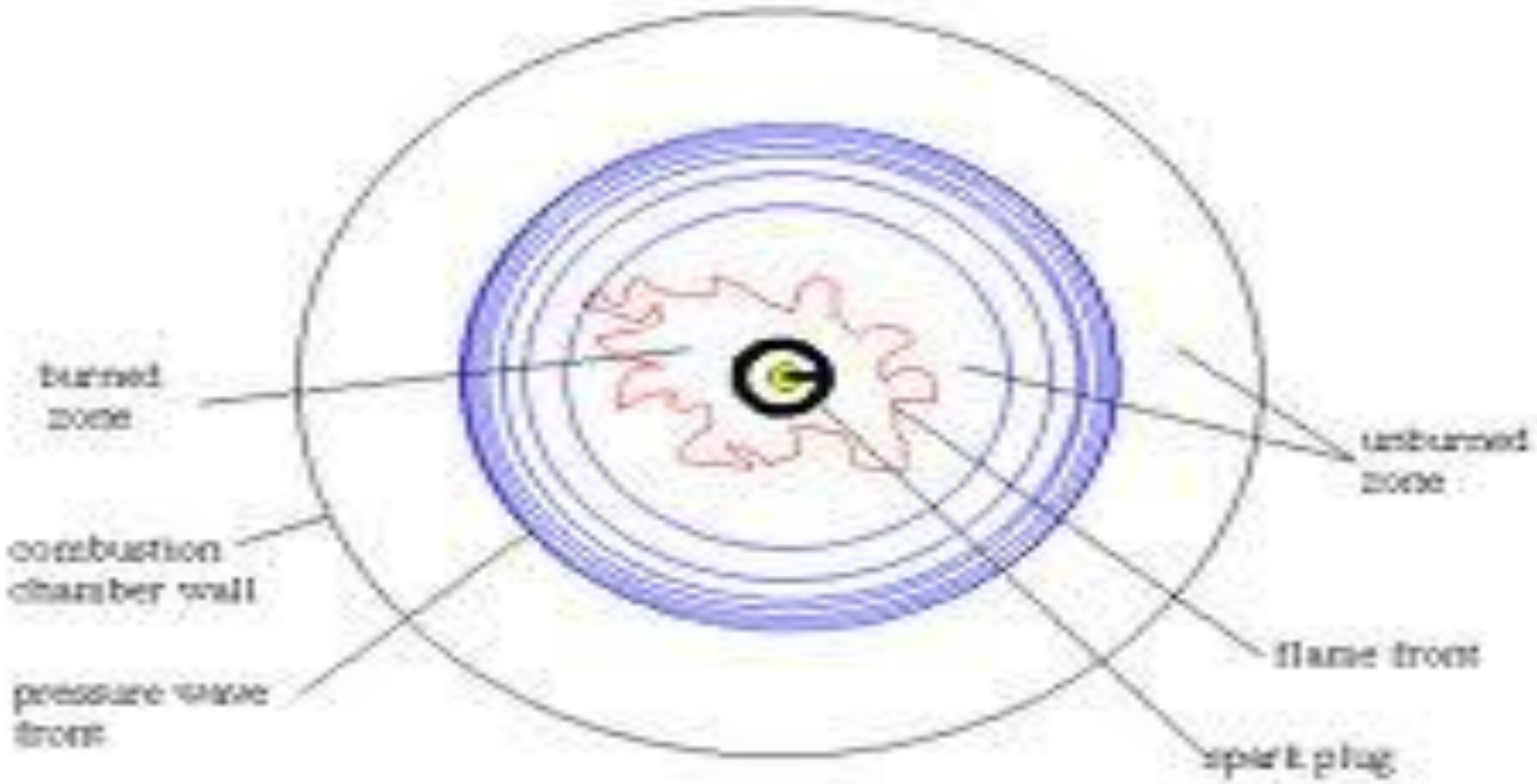
Detonation in IC Engine

Knocking or pinking

What is Detonation

- The loud pulsating noise heard within the engine cylinder.
- Due to auto-ignition of unburnt fuel high pressure waves are created.
- These high pressure waves may break the piston.

Fig. 1 – Combustion Process – Top View



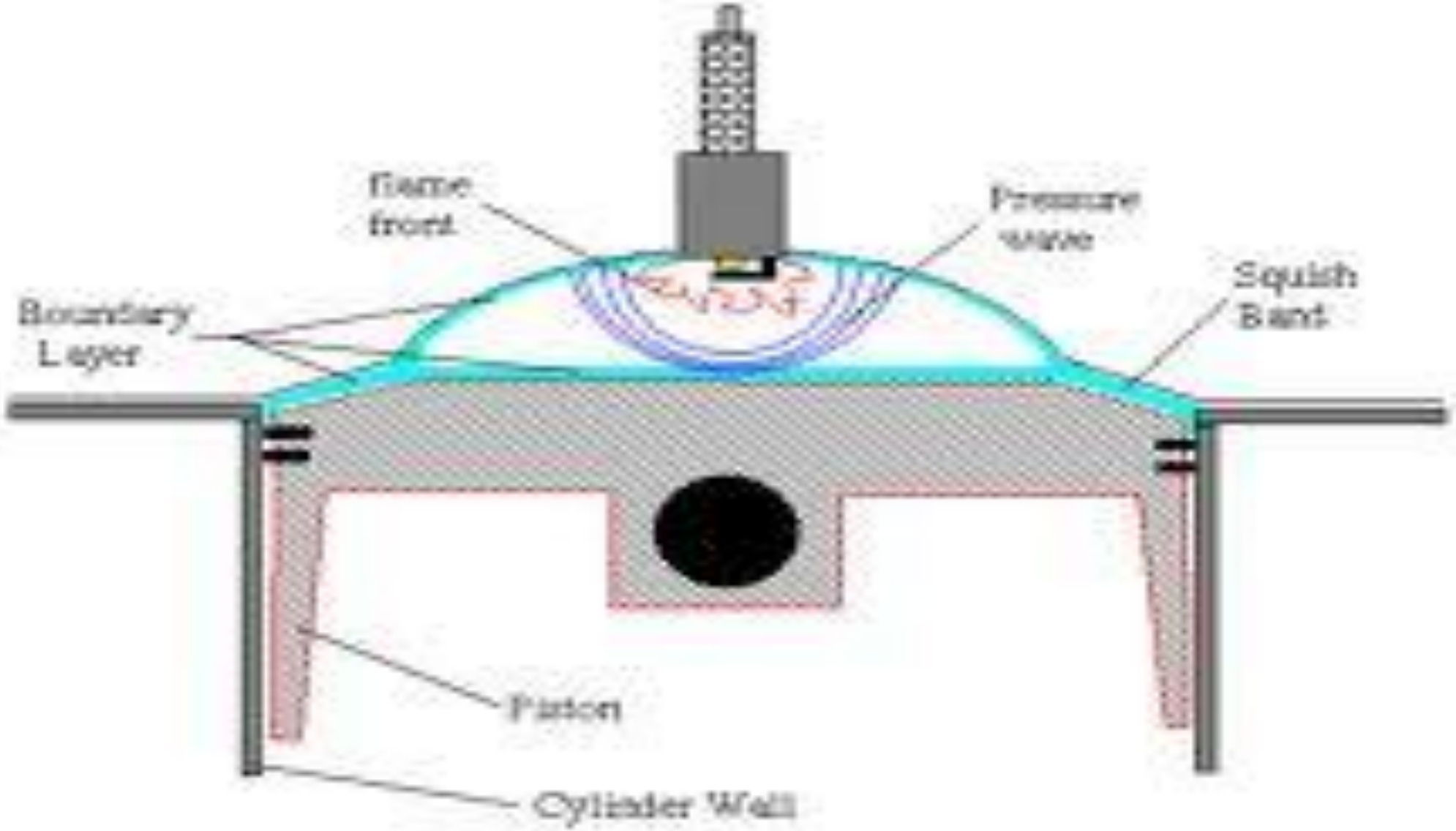
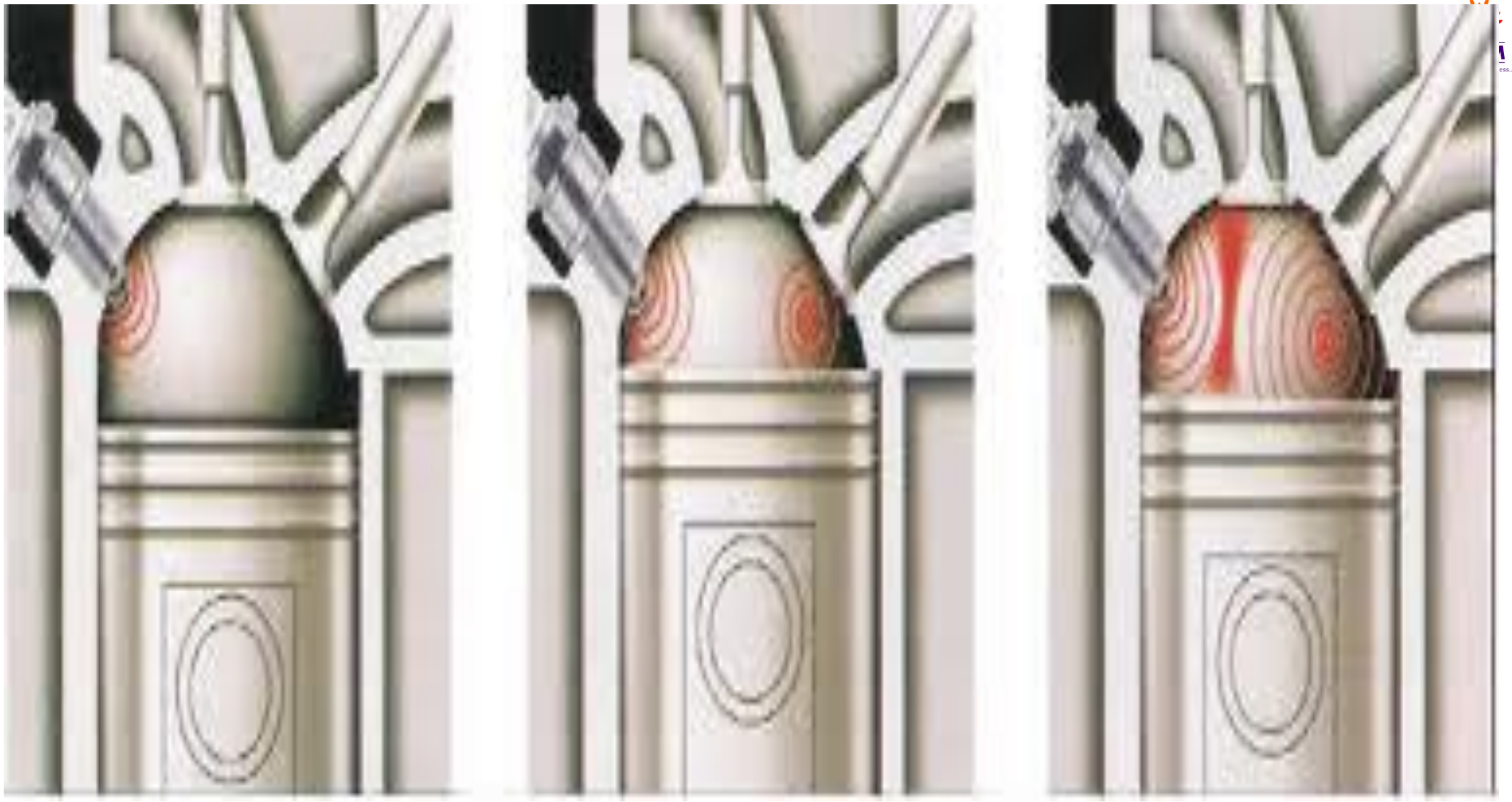
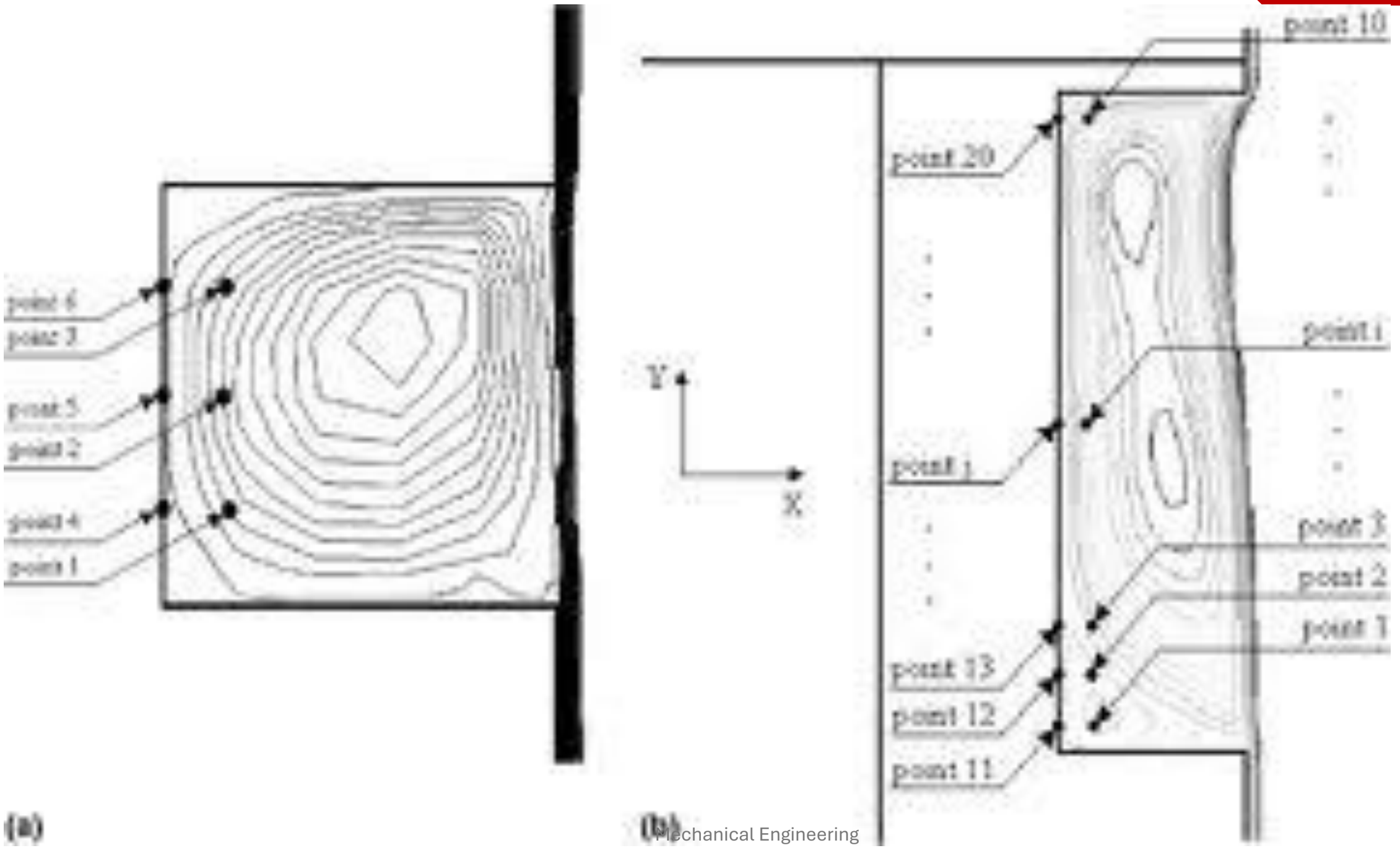
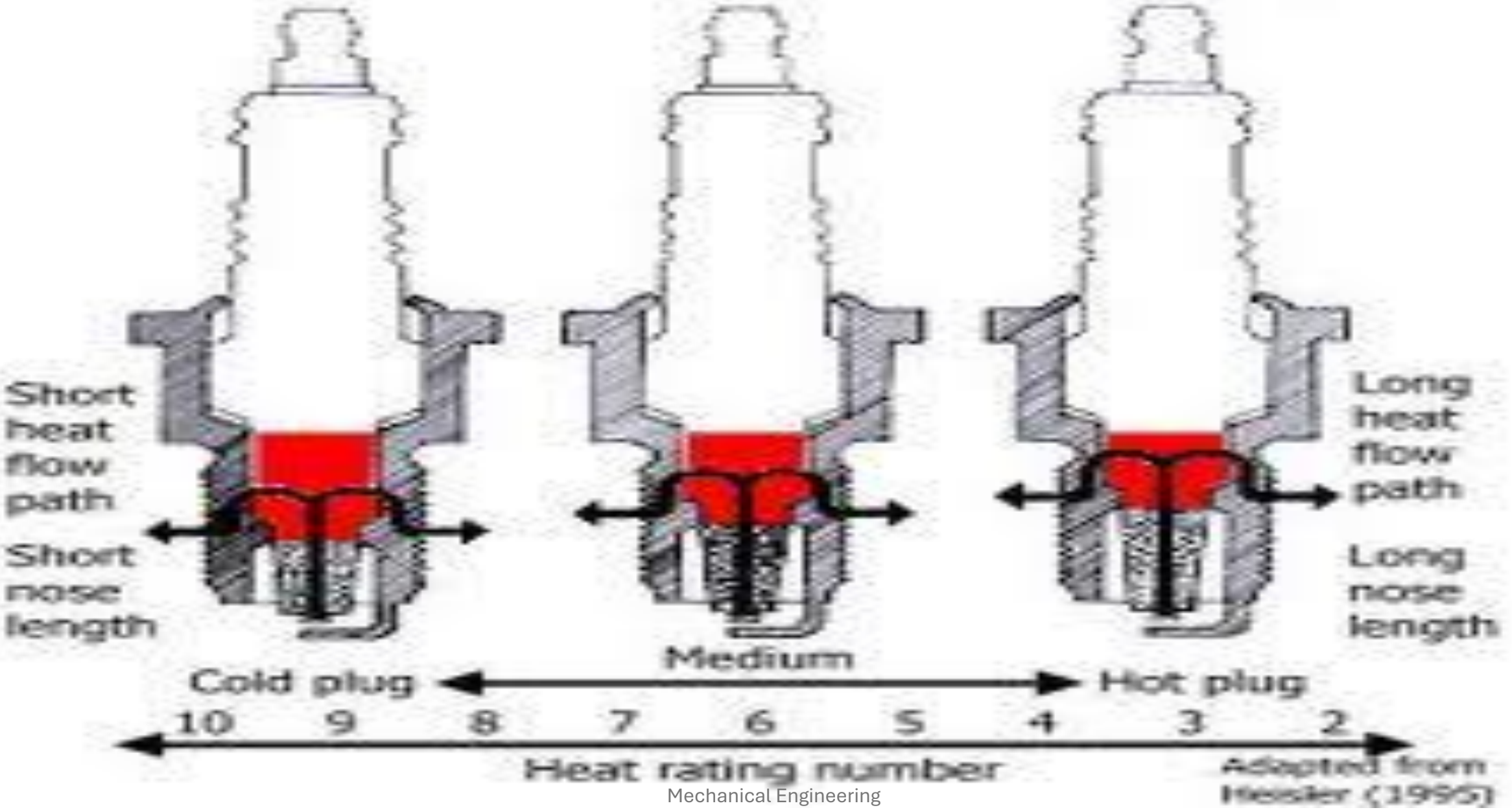


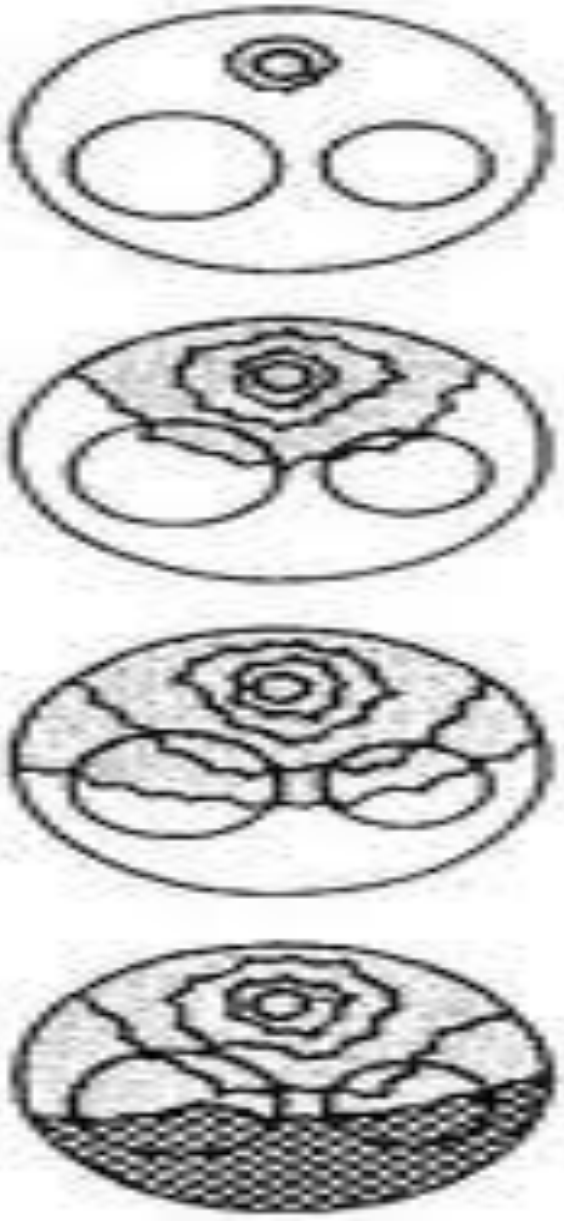
Fig. 2 – Combustion Chamber Side View

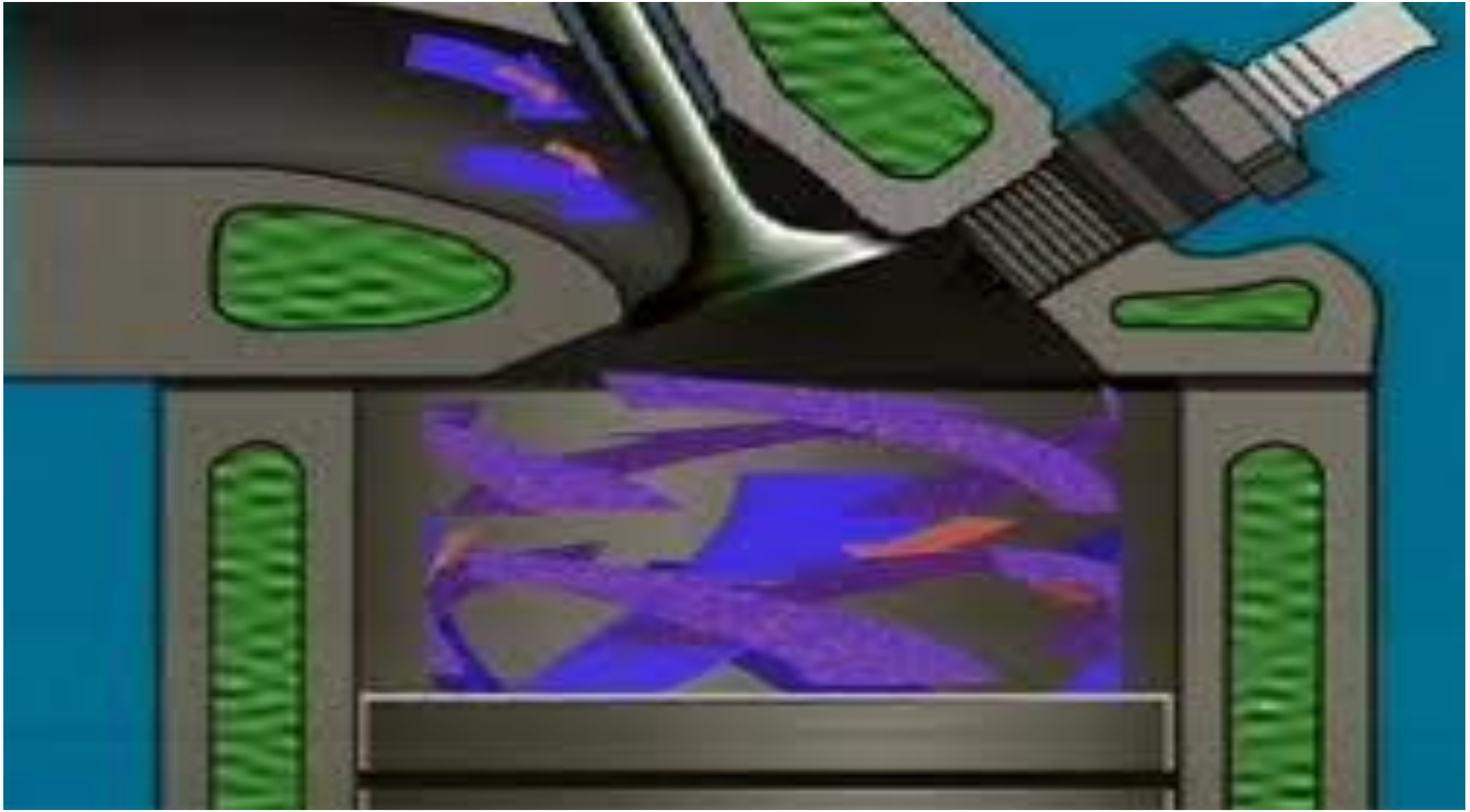



point 6
point 3
point 5
point 2
point 4
point 1
(a)
point 10
point 20
point i
point 1
point 3
point 2
point 1
point 13
point 12
point 11
Y
X
(b)

Firing-end Temperature Heat Range




SPARK OCCURS,
COMBUSTION BEGINS
FLAME FRONT
MOVES OUT
COMBUSTION
NEARLY COMPLETE
END GASES
DETONATE



Factors for Detonation

- The shape of combustion chamber.
- Relative position of spark plug.
- Chemical nature of fuel.
- Initial temperature and pressure of fuel.

Effects of Detonation

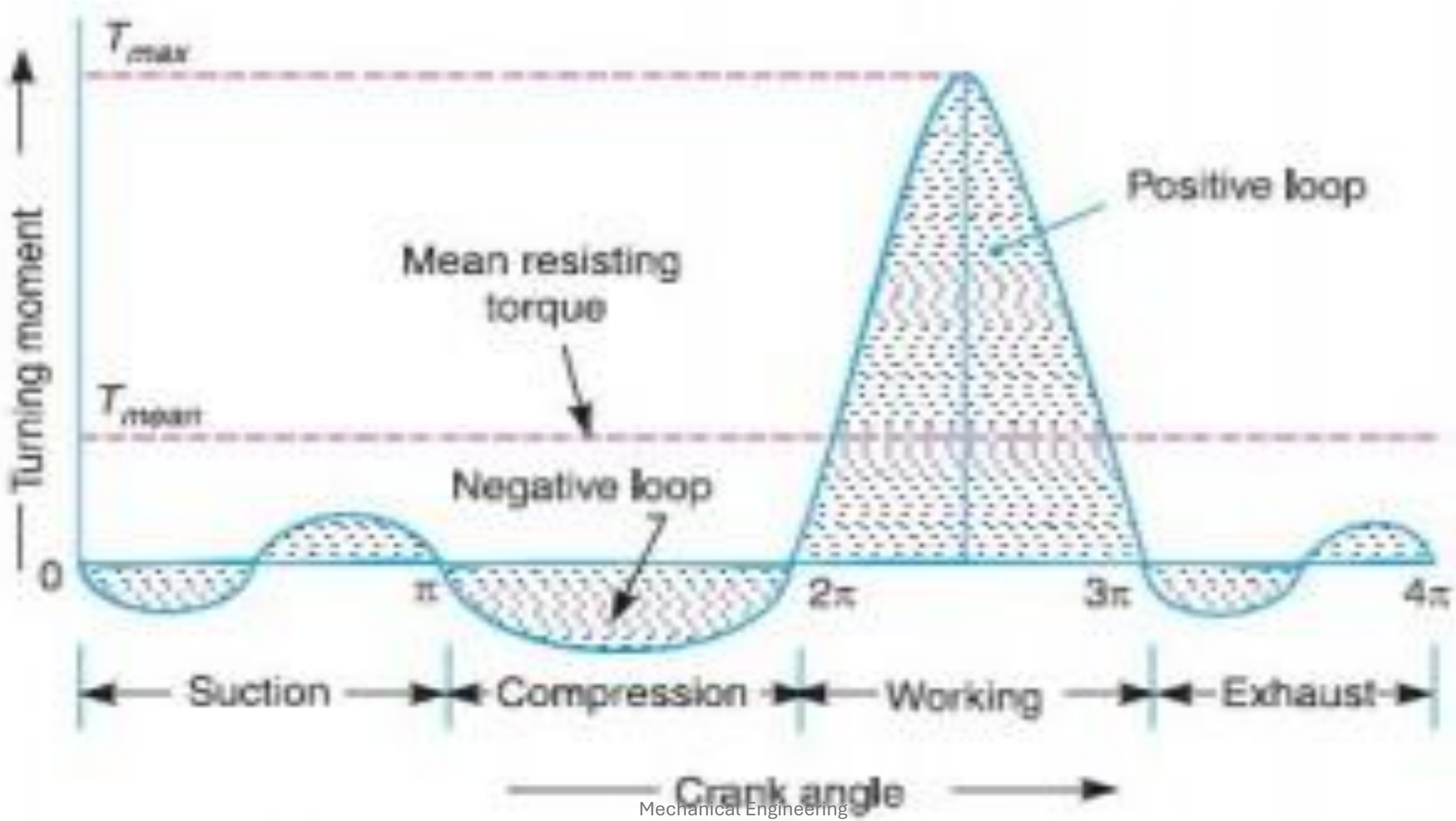
1. Noise : Due to detonation sound intensity increases.
2. Pre-ignition : Due to overheating of spark plug.
3. Increase heat transfer : Due to high temperature increases heat trasfer.
4. Mechanical damage : High pressure shock waves may damage piston
5. Decrease in power o/p : Due to abnormal combustion decreases power o/p.

Remedies or Detonation is controlled by

- By increasing engine r.p.m.
- Retarding (decelerating) spark.
- Reducing pressure in inlet manifold.

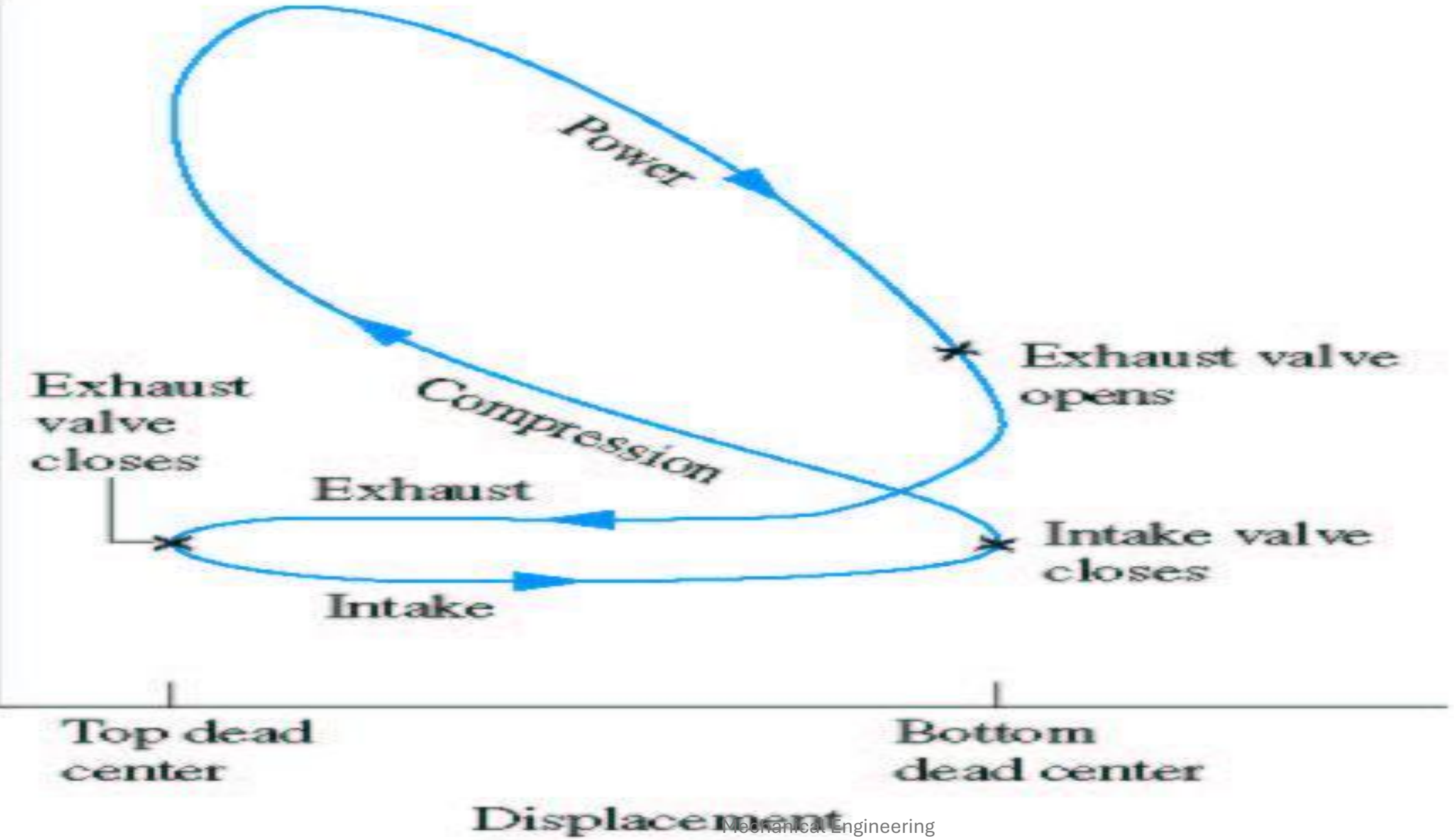
Turning moment diagram

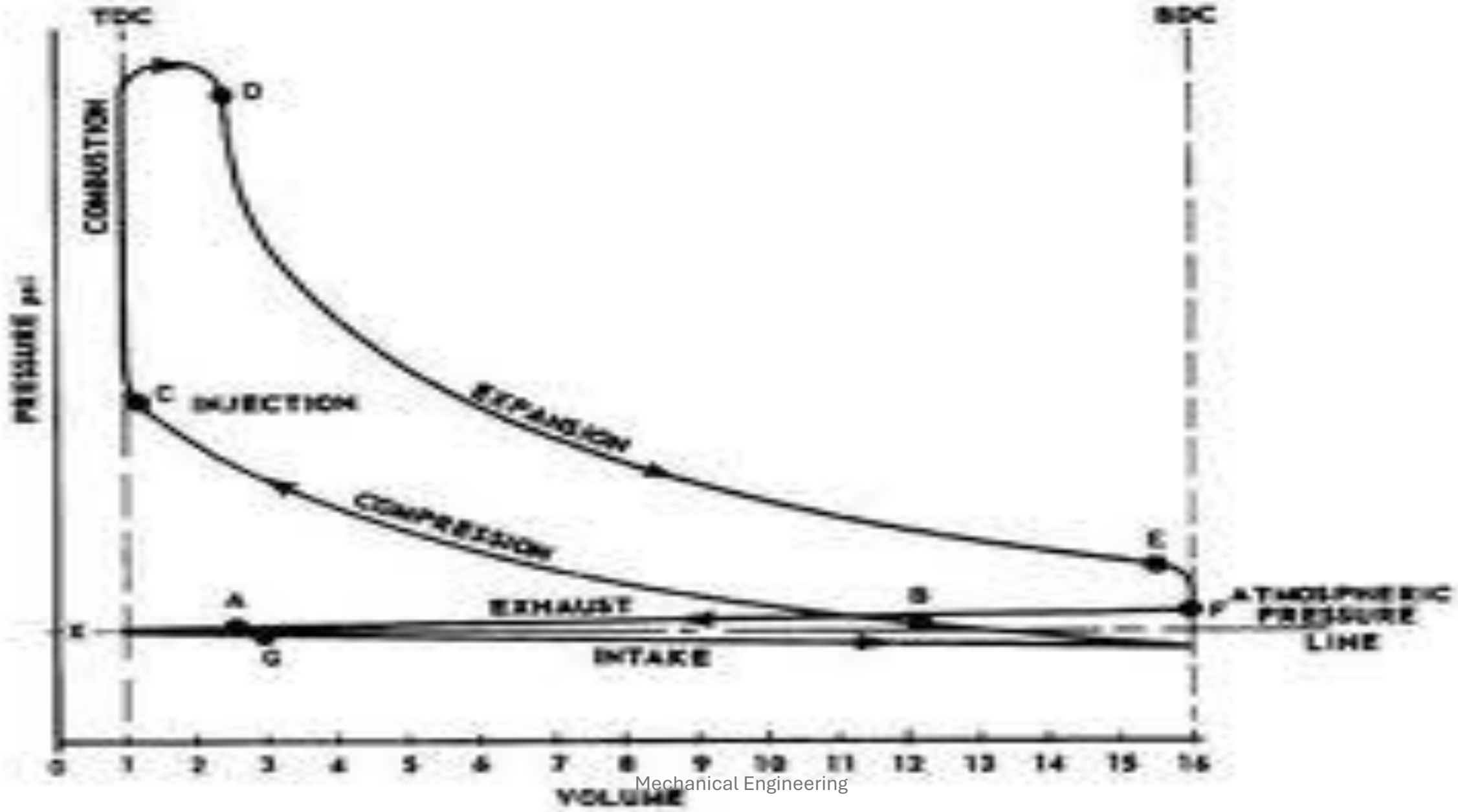
For fou stroke I.C. Engine

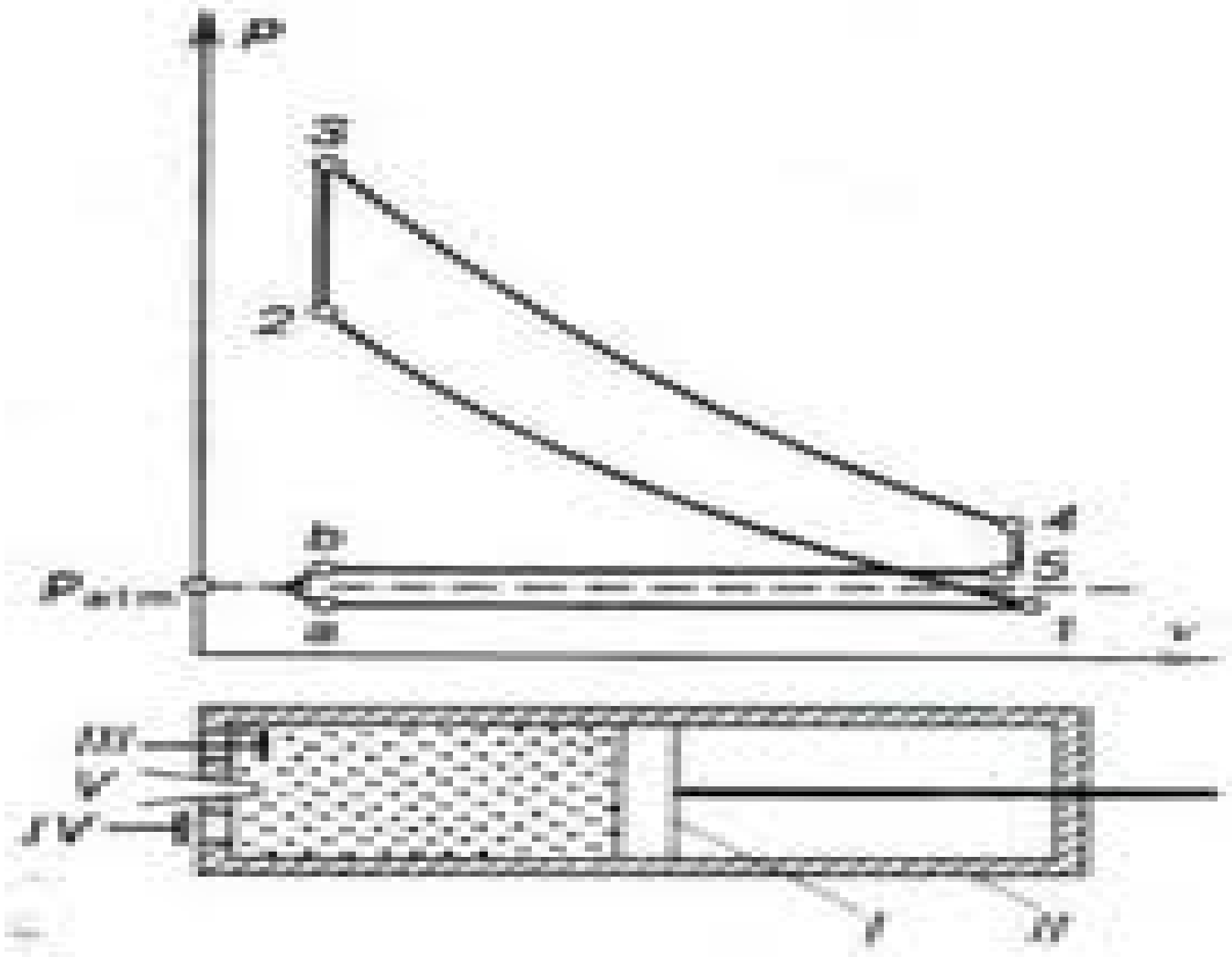

T_{max}
T_{mean}
Turning moment
0
Mean resisting torque
Positive loop
Negative loop
π
2π
3π
4π
Suction
Compression
Working
Exhaust
Crank angle

1. In four stroke there is one working stroke after the crank has turned through 720 degree or 4 Π radian.
2. Suction stroke : As the pressure is less than atmospheric pressure therefore negative loop is obtained.
3. Compression stroke : As work is done on the gases due to compression therefore higher negative loop is obtained.
4. Expansion stroke : As work is done by the gases due to expansion therefore positive loop is obtained.
5. Exhaust stroke : As work is done on the gases therefore negative loop is obtained.

Actual Indicator Diagram


Power
Exhaust valve opens
Exhaust valve closes
Compression
Exhaust
Intake valve closes
Intake
Top dead center
Bottom dead center
Displacement


TDC
BDC
COMBUSTION
D
C
INJECTION
EXPANSION
COMPRESSION
E
A
EXHAUST
B
ATMOSPHERIC
PRESSURE
LINE
F
G
INTAKE
PRESSURE (p)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
VOLUME


p
3
2
b
4
5
1
v

Actual Indicator diagram for Four stroke Petrol engine

- Line 1-2 : Suction stroke :

1. It is shown below atmospheric pressure line.
2. Inlet valve offers some resistance to the incoming charge. Therefore pressure inside the cylinder is below atmospheric pressure.
3. Due to pressure difference inlet valve opens and suction of charge takes place.

- Line 2-3 : Compression stroke :

1. It indicates inlet valve closes a little beyond point 2 i.e after piston reaches BDC.
2. Before the end of this stroke i. e. before piston reaches TDC fuel is ignited by spark plug and combustion at constant volume takes place.

- Line 4-5: Expansion stroke :

1. It indicates exhaust valve opens a little before 5 i.e. before the piston reaches BDC.

2. Burnt gases escapes through the exhaust valve.

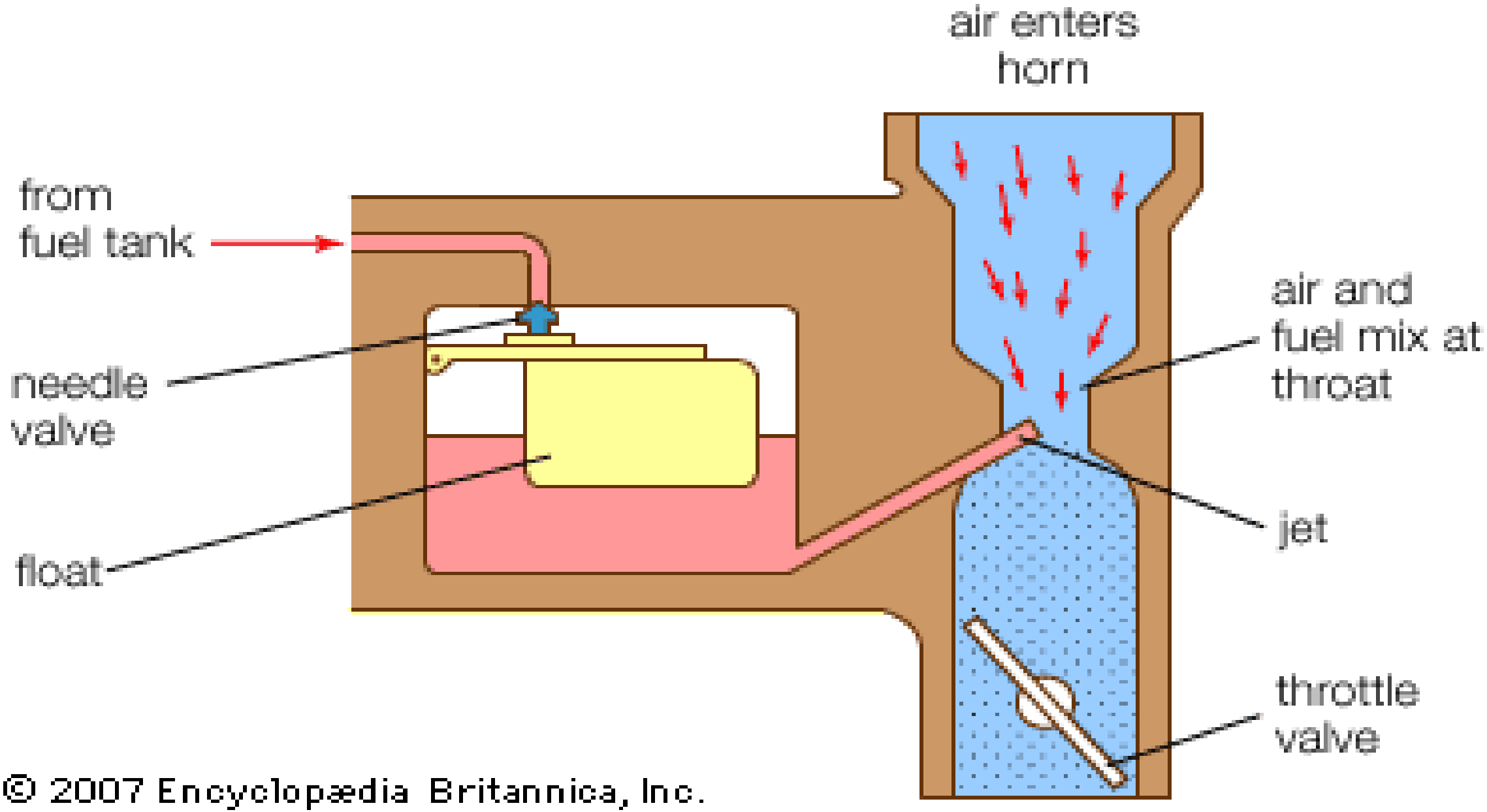
- <u>Line 5 – 1 : Exhaust stroke :</u>

1. It lies above atmospheric line.
2. Due to pressure difference burnt gases flow outside the cylinder.

Simple Carburettor

Function of carburettor

- To form a mixer of air and fuel


air enters horn
from fuel tank
needle valve
float
air and fuel mix at throat
jet
throttle valve
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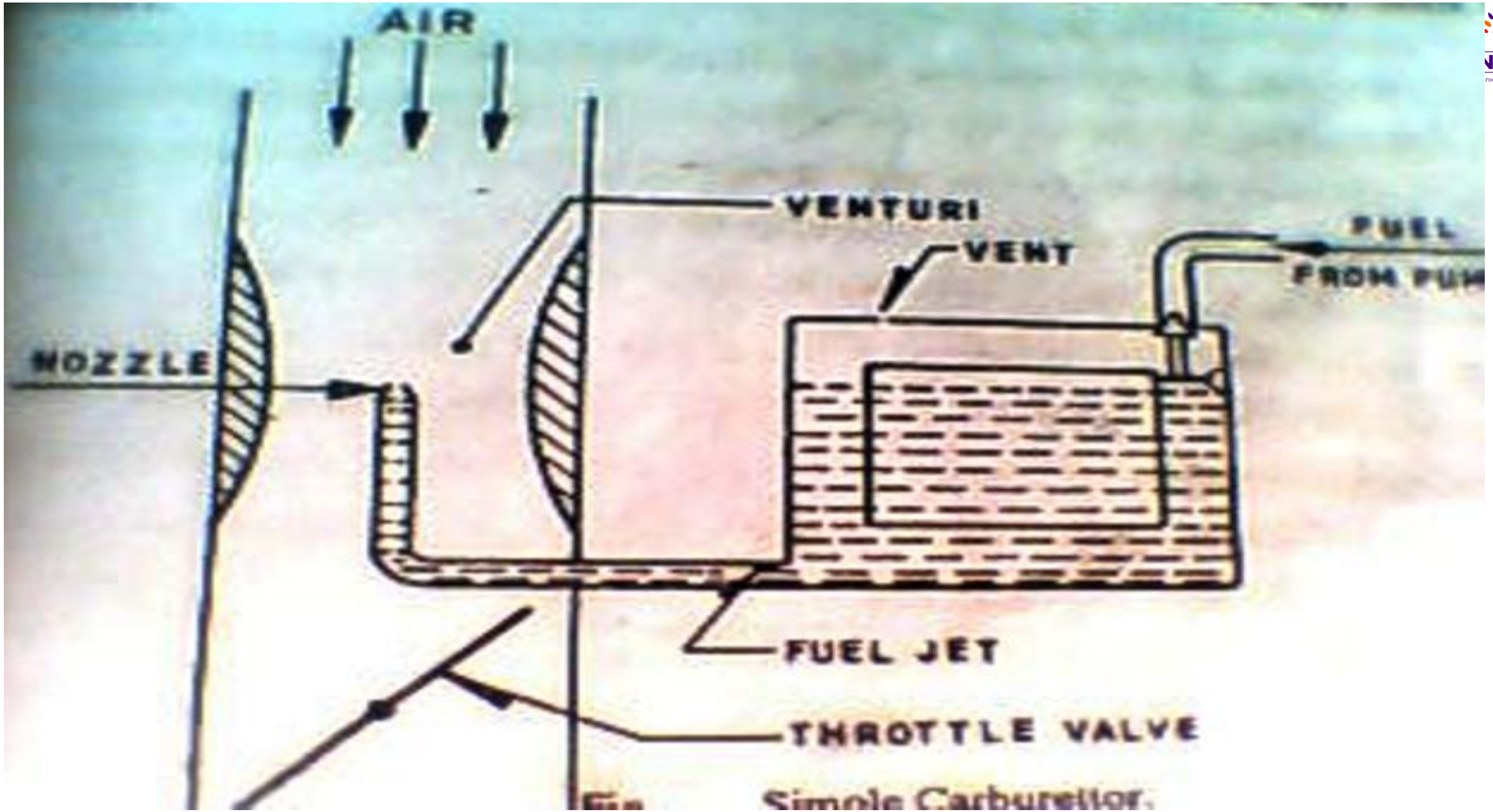
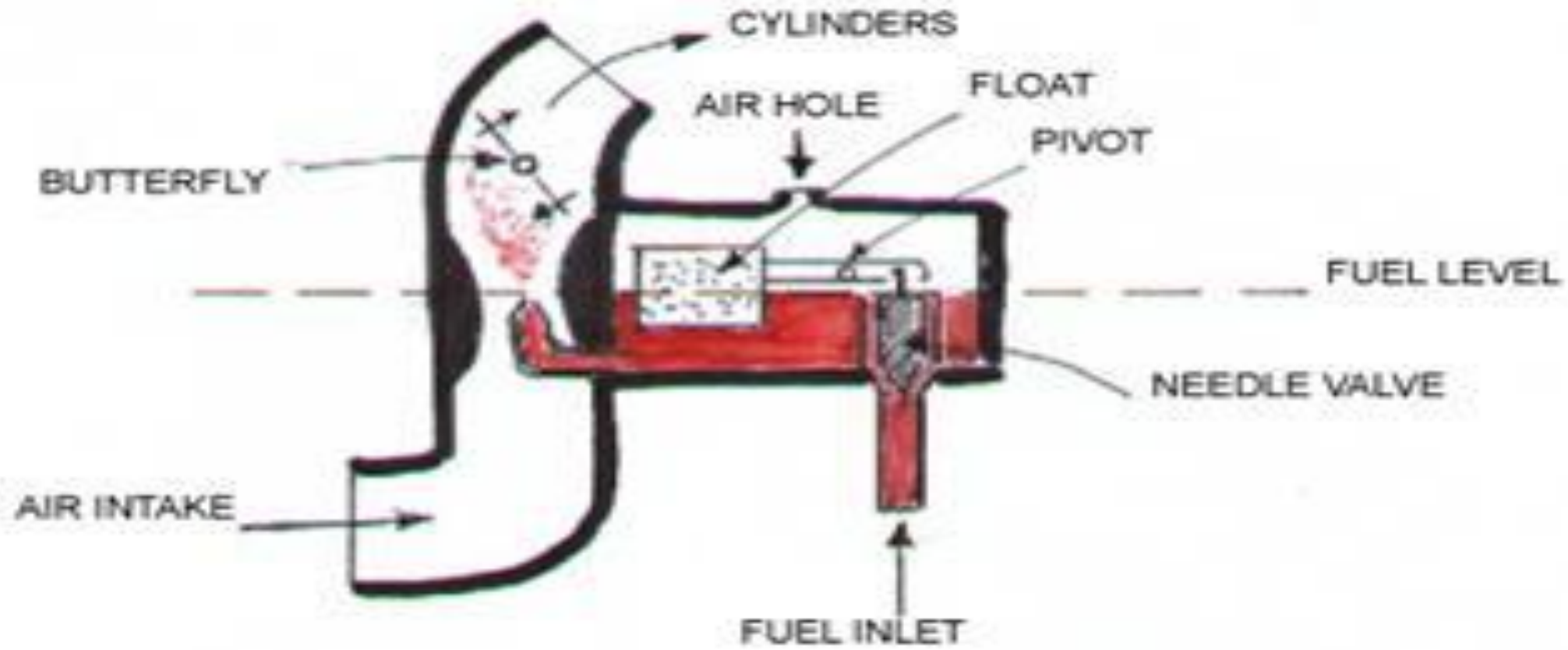
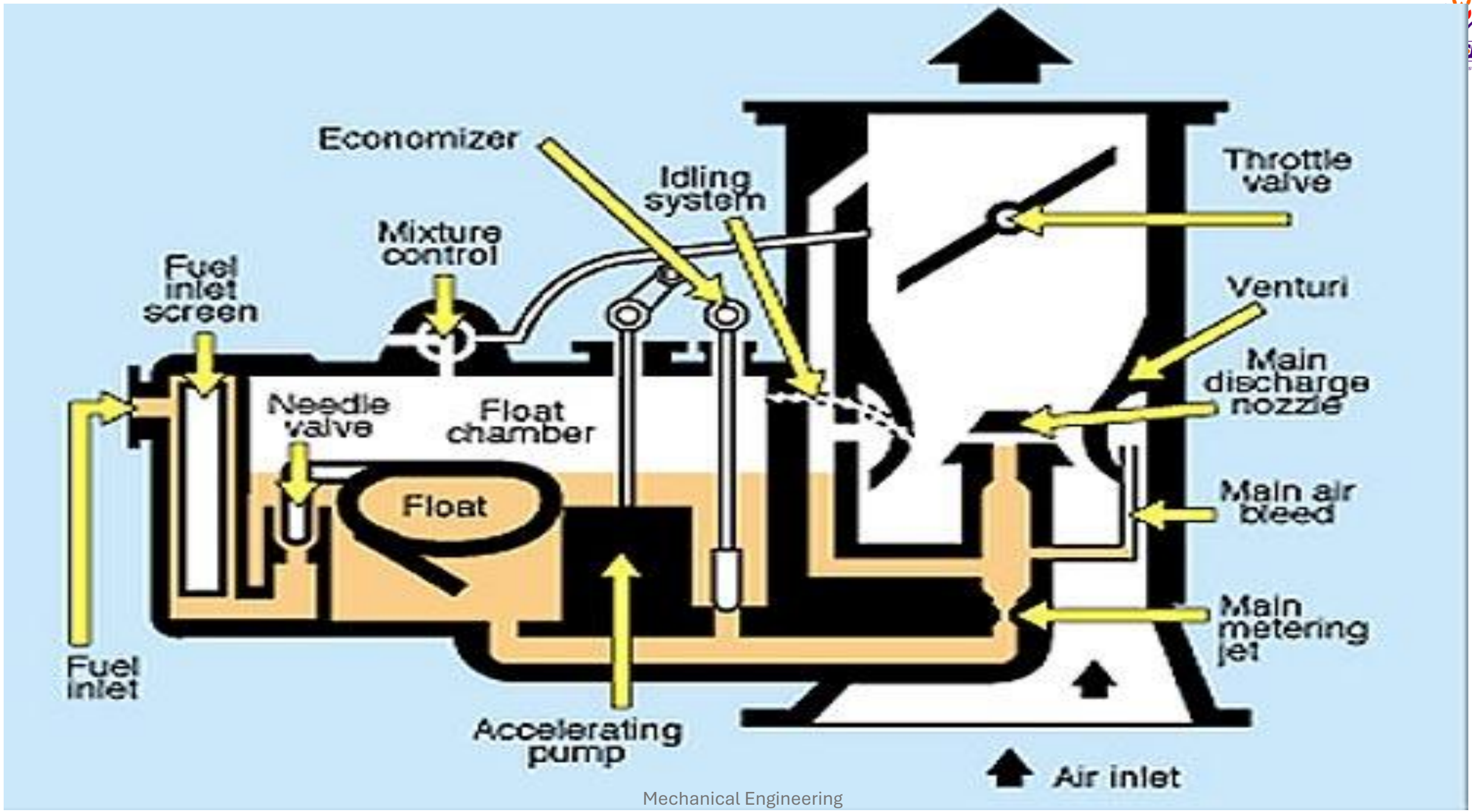


Fig. Simple Carburettor.



SIMPLE UPDRAFT CARBURETTOR


Economizer
Idling system
Throttle valve
Mixture control
Fuel inlet screen
Venturi
Main discharge nozzle
Needle valve
Float chamber
Float
Main air bleed
Main metering jet
Fuel inlet
Accelerating pump
Air inlet

Construction of simple carburetor

1. It consists of

- Float chamber , nozzle with metering orifice,

  venturi and throttle valve.

2. Float chamber and needle valve system maintains a constant level of petrol in the float chamber

   If fuel level lowers then float lowers thereby opens the fuel supply valve till the designed level reach in the float chamber.

   Float chamber is vented to the atmosphere.

3. Venturi tube gives minimum resistance to air flow.

Working

1. During suction stroke air is drawn through the venturi , which has minimum cross section at throat.
2. Velocity of the air passing through venturi increases and its pressure decreases.
3. Due to pressure difference in throat and float chamber the fuel from float chamber is discharged at throat.
4. This pressure difference is called carburetor depression

5. The rate of flow is controlled by discharge jet or nozzle.
6. To avoid overflow of the fuel the level of the fuel in the float chamber is kept below the tip of the nozzle.
7. Throttle valve regulate the quantity of fuel discharged.
8. If load is partial throttle valve is partialy open and less air-fuel mixture is provided to the engine.
9. If load is full throttle valve is fully open and more air-fuel mixture is provided to the engine.

Fuel Pump


nipple
oil outlet valve
oil outlet valve seat
pump body
spring
tooth ring
barrel
rack
plunger
rotating sleeve
retainer
spring
retainer
roller body
adjusting screw
roller
camshaft body

Construction of Fuel Pump

It consist of :

- Tappet which is in contact with cam shaft.
- Barrel
- Plunger (single acting)and plunger spring.
- Inlet port and spill port.

Working of Fuel Pump

- When the plunger is at bootom of its stroke , fuel flows through the inlet port and fill the fuel chamber, vertical groove,helix.
- When the plunger starts moving up , a certain amount of fuel goes out through the ports until the plunger close the ports.
- Then plunger compress the fuel and forced out through the delivery valve to the pipe leading to the injector.
- Injection process continues till the lower end of the helix uncovers the spill port.

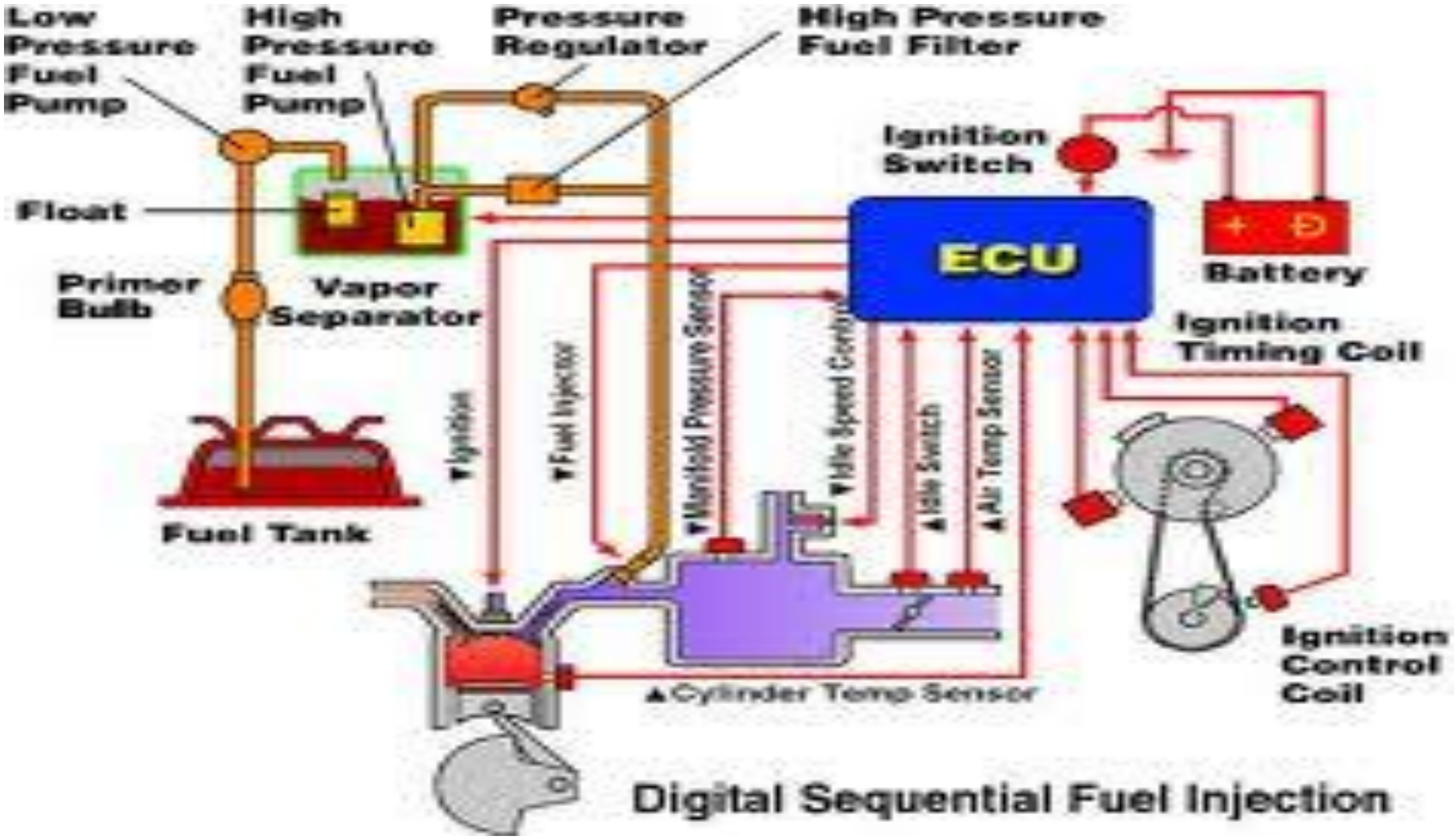
Multi Point Fuel Injection

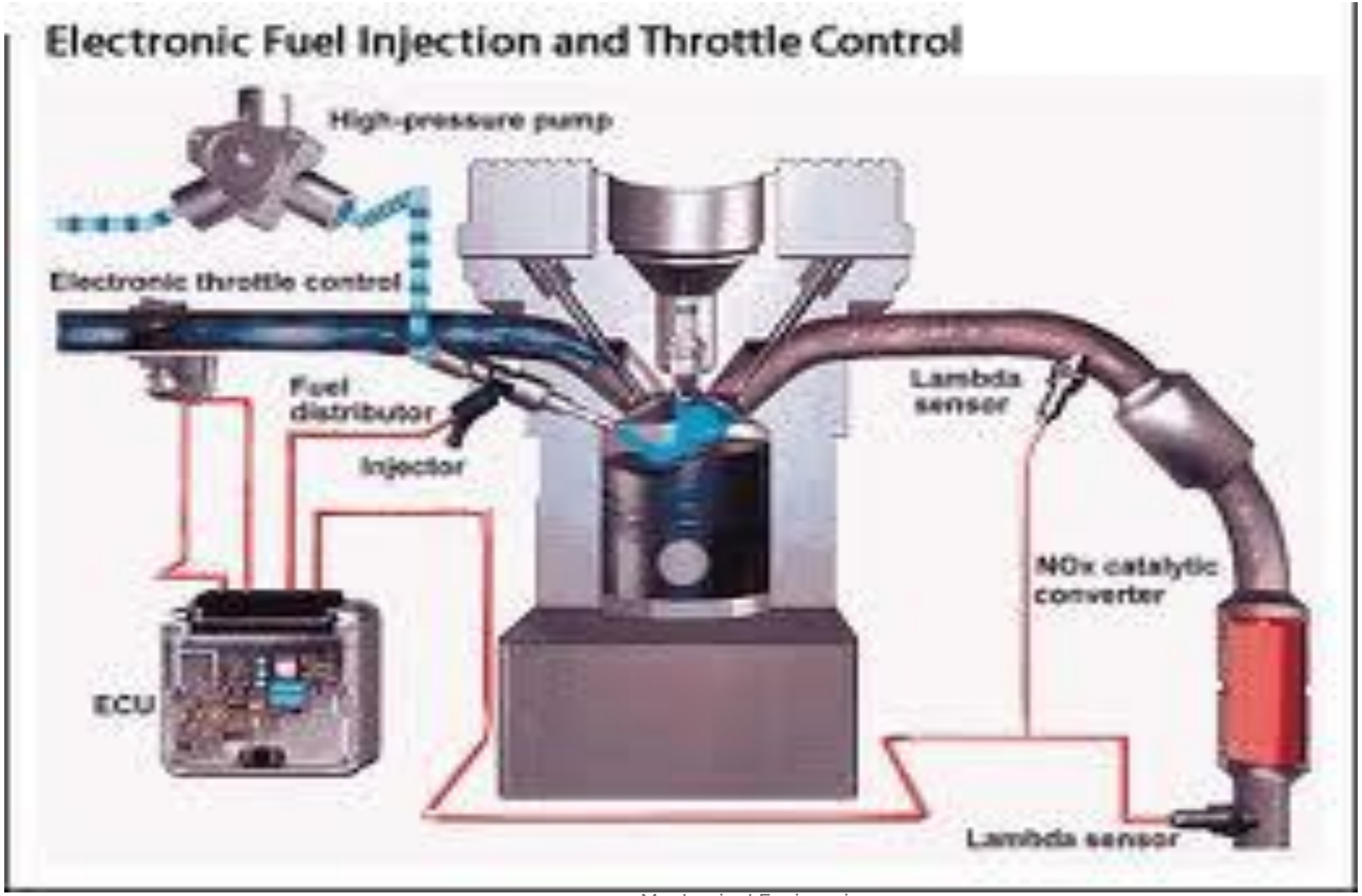
MPFI

- It supply the proper ratio of air and fuel to the engine cylinder.

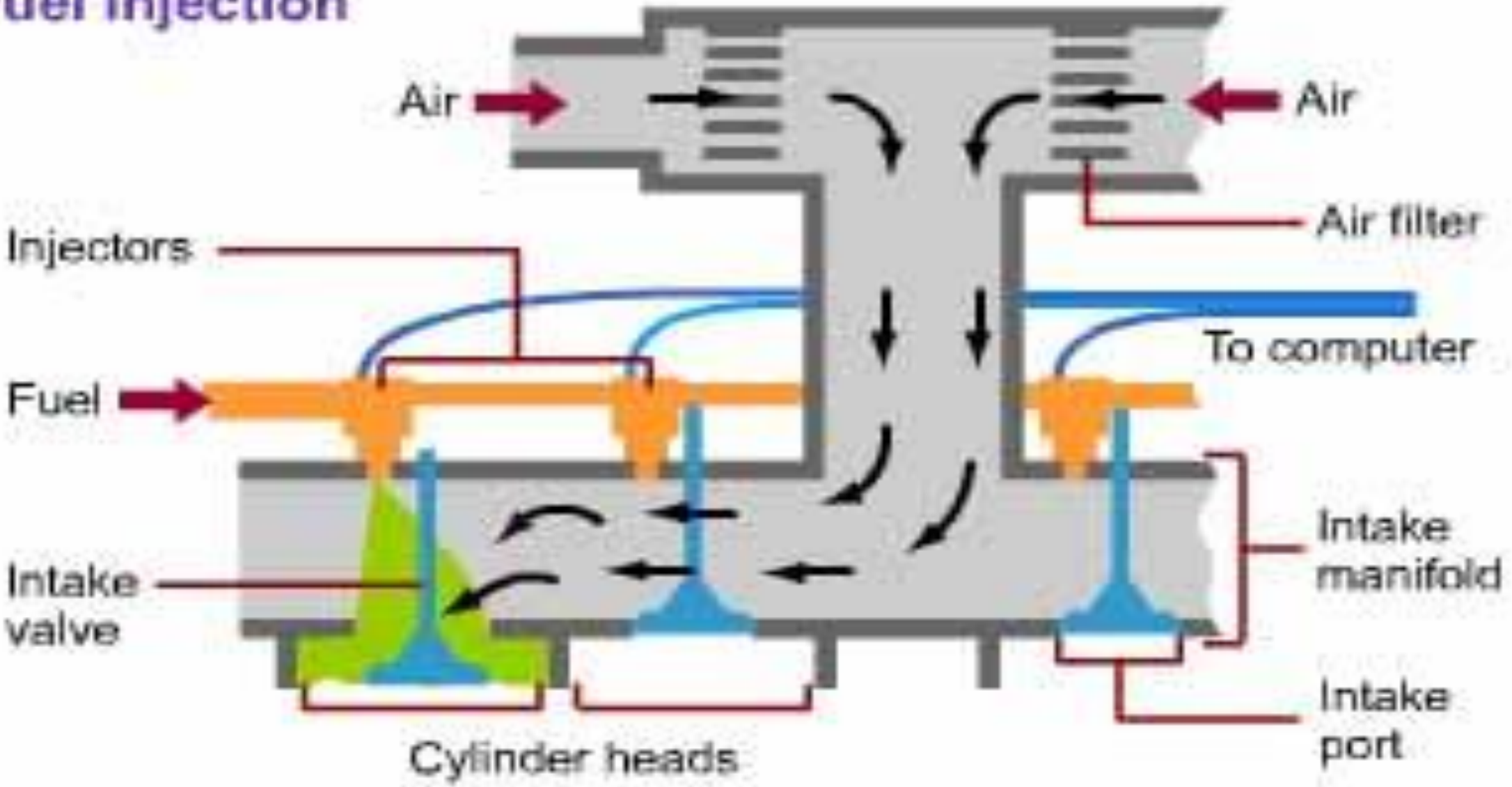
There are two types :

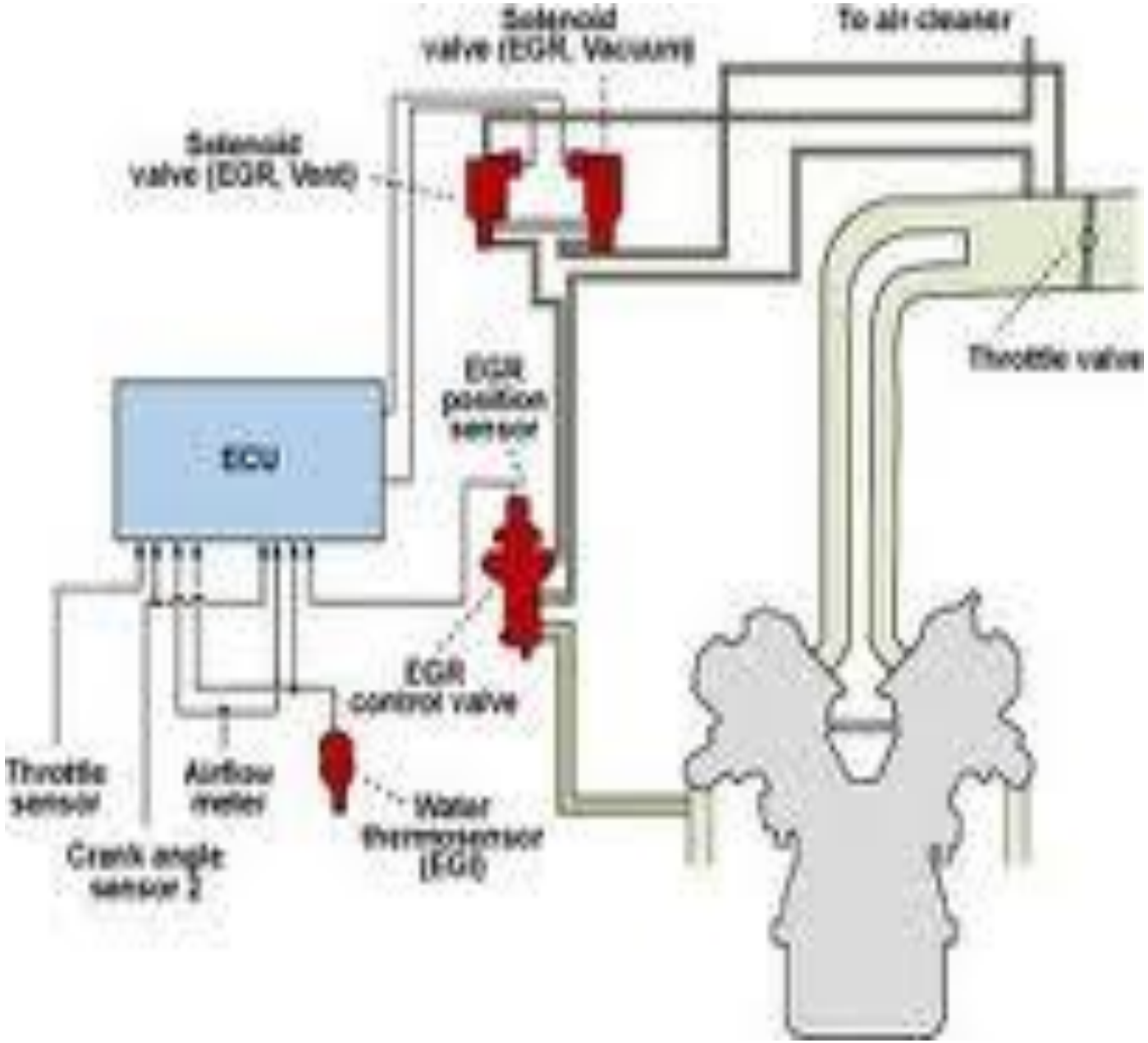
1. Port injection.
2. Throttle body injection.


Low Pressure Fuel Pump
High Pressure Fuel Pump
Pressure Regulator
High Pressure Fuel Filter
Ignition Switch
Float
ECU
Battery
Primer Bulb
Vapor Separator
Ignition Timing Coil
Fuel Tank
Ignition
Fuel Injector
Manifold Pressure Sensor
Idle Speed Control
Idle Switch
Air Temp Sensor
Cylinder Temp Sensor
Ignition Control Coil
Digital Sequential Fuel Injection


Electronic Fuel Injection and Throttle Control
High-pressure pump
Electronic throttle control
Fuel distributor
Injector
Lambda sensor
NOx catalytic converter
ECU
Lambda sensor

Multi-Point Fuel Injection




Solenoid valve (EGR Vacuum)
To air cleaner
Solenoid valve (EGR Vent)
Throttle valve
EGR position sensor
ECU
EGR control valve
Throttle sensor
Airflow meter
Water thermosensor (EGI)
Crank angle sensor 2

Port injection System

- Injector is placed on the side of intake manifold.
- Injector sprays petrol into the air.
- Mixture of air and fuel through the intake valve enters into the cylinder.
- Every cylinder is Provided with an injector.

Throttle Body Injection
(Single point Injection)

- Throttle valve control the amount of air.
- Injector is placed above the throttle body.
- Injector sprays petrol into the air.
- This mixture then passes trough the throttle valve and then enters into the intake manifold.

D - MPFI

- Pressure sensor in the intake manifold detects the intake manifold vacuum and sends the signal to ECU.
- Speed sensor also send the signal about speed of engine to ECU.
- ECU processes the information received sends the proper signal to injector.
- Injector regulate the amount of petrol supply for injection.

D - MPFI

- After injection the petrol mixes with the air in the intake manifold and the mixture enters in the cylinder.

L - MPFI

- It consists of air flow meter which regulate the amount of air entering into cylinder.
- Air flow sensor measures the amount of air enters in the intake manifold.
- Air flow sensor sends the signal to ECU.
- Speed sensor also send the signal about speed of engine to ECU.
- ECU processes the information received sends the proper signal to injector.
- Injector regulate the amount of petrol supply for injection.

L - MPFI

- After injection the petrol mixes with the air in the intake manifold and the mixture enters in the cylinder.

List of fuels

Classification of fuels

1) Liquid fuels :

- Natural : Petroleum
- Artificial :

a) Petroleum based : Gasoline (Petrol), Diesel , Kerosene.

b) Non Petroleum based : Benzol , Alcohols,Acetones

Thank You..