Sr. No.	Date	Title	Page No.	Teacher's Signature/Remarks

Date
10/1/2016

Engines:- It is a devices which transforms one form of energy to another form.

Heat Engine:- It is a device which transform chemical energy of a fuel into thermal energy and utilize this thermal energy to perform usefull work. Thus thermal energy is converted to ~~chemical~~ energy to mechanical energy in heat engine.

These are two types of heat engine:-

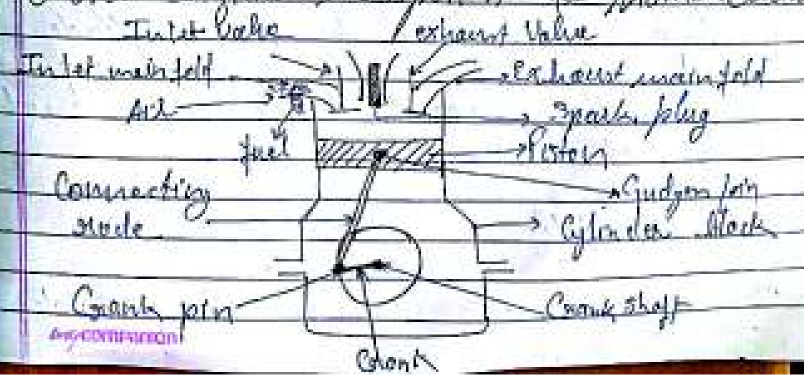
1) external combustion engine:-

These are those engine in which combustion takes place outside the engine.

2) Internal combustion engine:-

These are those engine in which internal combustion occurs.

Basic engine component & nomenclature:-



i) Cylinder block

The cylinder block is the main supporting structure to the various components.

ii) Cylinder:-

It is a cylindrical vessel of space in which the piston makes its reciprocating motion. The varying volume created in the cylinder during the operation of the engine, is filled with the working fuel and subjected to diff. thermodynamic process.

iii) Piston:

It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system.

iv) Comb. Chamber

The space enclosed in upper part of the cylinder, by the cylinder head and the piston top during the comb. process is called comb. chamber.

v) Inlet manifold

The pipe which connect the intake system to the inlet valve of the engine and through which air or fuel mixture is drawn into the cylinder is called inlet manifold.

vi) Exhaust manifold

The pipe which connect the exhaust system to the exhaust valve of the engine & through which the product of comb. escape into the atmosphere is called exhaust manifold.

vii) Inlet & exhaust valves

Valves are commonly mushroom shaped. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming into the cylinder (inlet valve) & for discharging a product of comb. (exhaust valve) from the cylinder.

viii) Spark plug

It is a component to initiate the comb. process in spark ignition (SI) engine & is usually located on the cylinder head.

ix) Connecting rod

It inter connect the piston

and the crank shaft and transmitted the gas forces from the piston to the crank shaft.

The two ends of the connecting rod are called as small end & the big end.

Small end is connected to the piston by the gudgeon pin & the big end is connected to the crank shaft the crank pin.

x) Crank shaft

It convert the reciprocating motion of the piston into useful rotatory motion of the output shaft.

* Nomenclature *

1) Cylinder Bore (d)

The nominal inner ~~dia~~ diameter of the working cylinder is called cylinder bore.

2) Piston Area

The area of a circle of a diameter equal to the cylinder bore is called piston area.

$A = \frac{\pi}{4} d^2$

3) Stroke (L)

The nominal distance through which a working piston moves through the two successive reversal of its direction of motion is called stroke (L).

$\frac{L}{d}$ → stroke to bore ratio.

d > L → over-square engine.
d = L → square engine
d < L → under square engine.

4) Dead Centre:-

The position of the working piston & the moving parts which are mechanically connected to it, at the movement when the direction of the piston motion is reversed at either end of the stroke is called dead center.

There are two dead centre in the engine.

① Top dead centre (TDC)

It is the dead centre when the piston is farthest from the crankshaft. It is designated as TDC for vertical engine & inner dead centre (IDC) for horizontal engine.

② Bottom dead centre:-

It is the dead centre

when piston is see nearest to the crank shaft. It is also designated as outer dead centre for horizontal engine.

5) **Displacement or swept volume:-**

The nominal volume swept by the working piston when travelling from one dead centre to the other is called displacement volume.

$$V_s = A \times l = \frac{\pi}{4} d^2 \times l$$

Cubic capacity $= V_s \times K$

where, $K \rightarrow$ no. of cylinder.

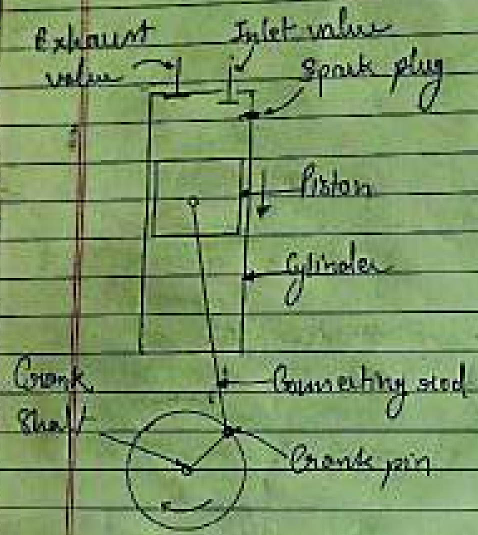
⑥ **Clearance Volume:- (V_c)**

The nominal vol. of the comb. chamber above the piston when it is at TDC is the clearance volume.

⑦ **Compression ratio:- (r)**

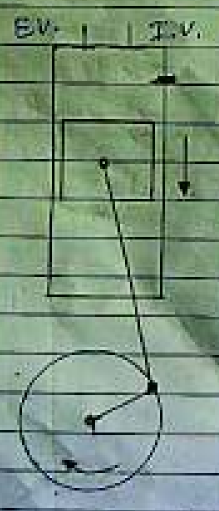
$$r = \frac{V_c + V_s}{V_c}$$

It is the ratio of total cylinder vol. when the piston is at BDC to the clearance volume.

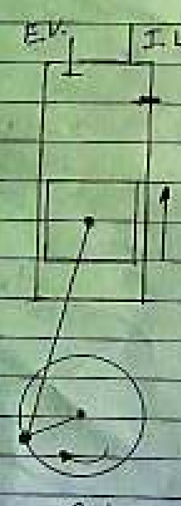


Suction Stroke

Compression Stroke



Power stroke or Expansion stroke



Exhaust Stroke

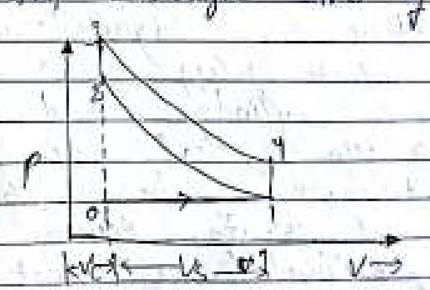
* Working Principles of Engines *

* **Four-Stroke S.I. Engine :-**
  - Suction stroke
  - Compression stroke
  - Expansion or Power stroke
  - Exhaust.

⇒ In a four stroke engine the cycle of operation is completed in four strokes of the piston or two revolution of the crank shaft. During the four stroke there are five event to be completed i.e.

Suction, compression, combustion, expansion & exhaust.

Each stroke consist of 180° of crankshaft rotation & hence a four stroke cycle is completed through 720° of crank rotation.



Suction or Intake Stroke :- [0-1]

Start from [0-1] when the piston is at

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TDC is about to move downwards. The inlet valve is assumed to open instantaneously and at this time the exhaust valve is in the closed position. Due to suction created by motion of the piston towards the bottom dead centre, the charge consisting of fuel-air mixture is drawn into the cylinder. When the piston reaches the BDC the suction stroke ends & the inlet valve closes instantaneously.

② Compression Stroke:-

The charge taken into the cylinder during the suction stroke is compressed by the return stroke of the piston. During this stroke both inlet & outlet valves are closed. The mixture which fills the entire cylinder vol. is now compressed into the clearance volume. At the end of the compression stroke the mixture is ignited with the help of spark plug which is located on the cylinder head. In ideal engine it is assumed that burning takes place instantaneously when the piston is at TDC and hence burning process can be approximated as heat addition at const. volume.

③ Expansion or power Stroke:-

The high pressure of the burned gases forces the piston towards the BDC. Both the valves are closed position. of the stroke only during this stroke power is produced. Both pressure & temp decrease during expansion.

④ Exhaust Stroke:- 4-5

At the end of the expansion stroke the exhaust valve open instantaneously & the inlet valve remain closed. The pressure falls to atm. level & a part of the burnt gases are escaped. The piston start moving from the B.DC to TDC (Stroke 5-0), & sweeps the burnt gases out from the cylinder almost at atm pressure. The exhaust valve closes when the piston reaches T.D.C, & at the end of the exhaust stroke. & some residual gases trapped in the clearance volume remain in the cylinder.

* Four Stroke compression (CI) engine *

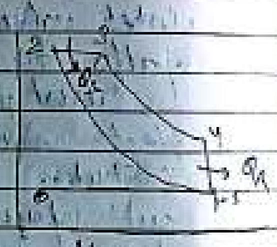
Four stroke C.I. engine is similar to the 4-Stroke S.I. engines but it operates at a much higher compression ratio.

($r = 16$–22) → CI

The compression ratio of S.I. engine is 6-10

In the CI engine during the suction stroke, air, instead of fuel air mixture, is inducted. Due to higher compression ratio is employed, the temp at the end of comp. stroke is sufficiently high to self ignite the fuel which is injected to the comb. chamber. In CI engine, a high pressure fuel pump & an injector are provided to inject the fuel into the comb. chamber. The carburetor & the ignition system is necessary in SI engines are not required in CI engine.

① Suction Stroke :-
Air alone is inducted during the suction stroke. During the stroke inlet valve is open and exhaust valve is closed.



② Compression Stroke :-

Air inducted during the suction stroke is compressed into the clearance vol. Both valves remain closed during this stroke.

③ Expansion Stroke :-

Fuel injection start nearly at the end of the compression stroke. The rate of injection is such that comb. maintain

the pressure constant in spite the piston movement on its expansion stroke increasing the volume. Heat is assumed to have been added at const. pressure. After the injection of fuel is completed (i.e. cut off) the products of the comb. expand.

④ Exhaust Stroke :-

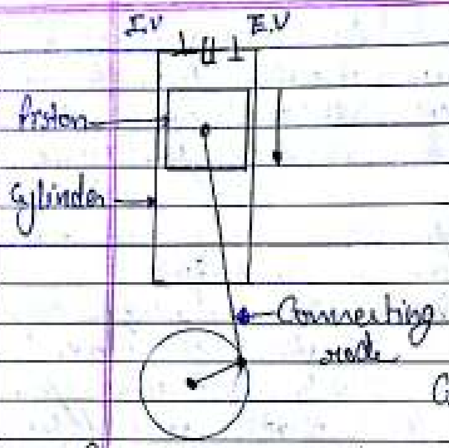
The piston travelling from BDC to TDC pushes out the products of combustion. The exhaust valve is open & the intake valve is closed during this stroke.

Comparison of S.I. & C.I. Engine

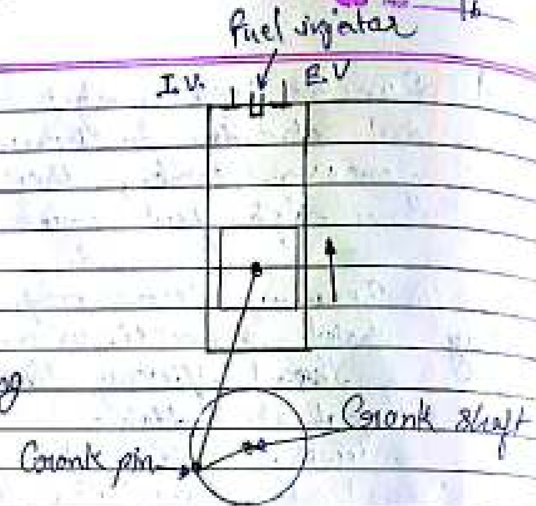
Description	S.I.	C.I.
Basic Cycle	Works on Auto cycle or constant heat addition cycle.	Works on diesel cycle or const. pressure heat addn. cycle
Fuel	Gasoline, a highly volatile fuel. Self ignition temp. is high.	Diesel oil, a non volatile fuel. Self ignition temp. is comparatively low
Introduction of fuel	A gaseous mixture of fuel and air introduced during the suction stroke. A carburetor & ignition system are necessary	Fuel is injected directly into the combustion chamber at high pressure at the end of the comp. stroke. A fuel pump and injector are necessary
Load Controlled	Throttle controls the quantity of fuel to control the load	The quantity of fuel is regulated to control the load. Air quantity is not controlled.
Ignition	require an ignition with spark plug	Self ignition occurs due to high temp of air because of the high comp.

Speed	Due to light weight and also due to homogeneous comb., they are high speed engine	Due to heavy weight & also due to heterogeneous comb., they are low speed engine.
Thermal efficiency	Because of lower comp. ratio, the maxi. value of thermal efficiency that can be obtained is lower.	Because of high comp. ratio, the max. value of thermal effici. that can be obtained is higher.

C.I.

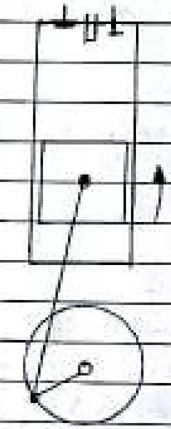


Compression Suction Stroke



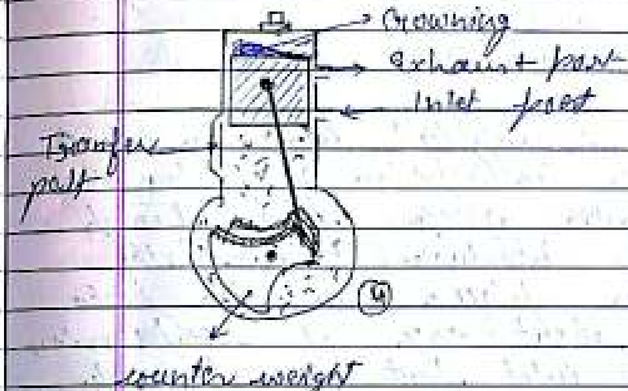
Compression stroke

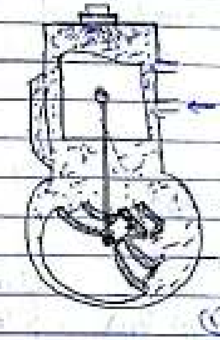
Expansion or power Stroke

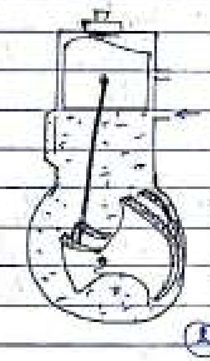


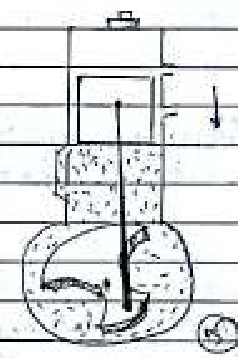
Exhaust stroke

TWO STROKE ENGINE









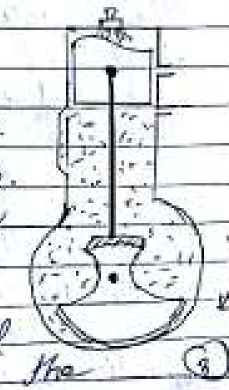


Figure 3: Piston is at BDC both transfer port and exhaust port are open at the same time. Some exhaust gas of the previous cycle remain in the piston. The partially compressed air-fuel mixture rises up through the

transfer port, pushes the exhaust gas out and occupies space on the top side.

Figure:2 The energy is supplied from the counter weight through the piston & piston moves up. Compression of air fuel fresh air fuel mixture (above the piston) takes place. When the piston has reach about 80% of compression stroke, the inlet port is open & suction takes place in the space below the piston.

Figure:3 At the end of compression, piston is at TDC & heat addn. takes place at const. volume

Figure:4 After heat addn. expansion takes place. When 70% of expansion is over the inlet port is closed. For further expansion, the fresh air fuel mixture below the piston get partially compressed

Figure:5 When the piston has completed about 90-95% of the exp. stroke, the exh. port is open & the measure portion of the exhaust gas leaves the

cylinder. When the piston reaches at BDC, the pressure of the exh. gas equal to the atm. pressure & the operations there after are repeated as before.

* Scavenging :-

The process of removing the left over gas of the previous cycle by the fresh fresh air-fuel mixture rising to the top of the cylinder due to moving of the piston is called scavenging.

* Misfiring :- during combustion the fuel does not burn completely. Some fuel partical which remain unburnt will be at a higher temp. & is in circulation with the other gases. Due to this region the hot unburnt fuel partical stick to the inner wall of the cylinder. The fuel in the fresh air-fuel mixture of the next cycle of the next cycle contacts the carbon partical on the cylinder wall & get ignited. This happens before compr. process is over and is known as pre-ignition or misfiring.

Due to misfiring, the air surrounding the igniting fuel gets heated and expands in all direction. When the piston retreats collides with the expanding air, then axle is about under worst circumstances, this work stroke we will get a lot completely.

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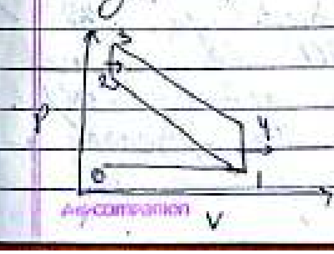
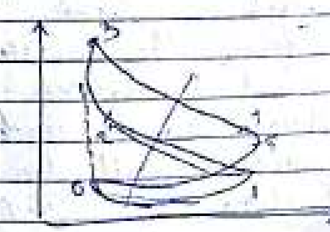
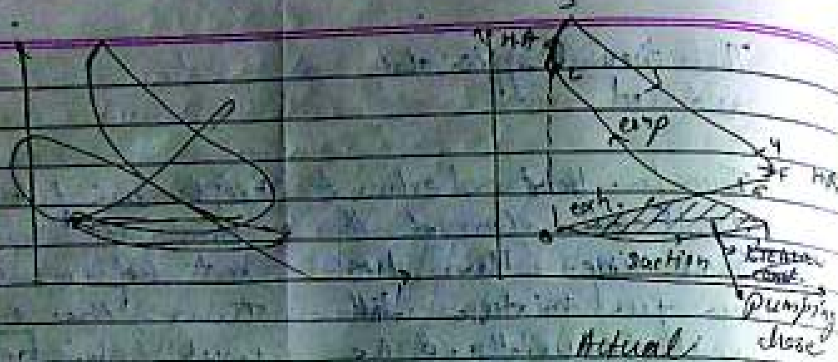
Difference b/w 2-Stroke and 4-Stroke engine

Two-Stroke	Four-Stroke
One cycle one revolution	One cycle is completed in two revolution.
There are three ports no valves	two valves operated by cam mechanisms.
Operation takes place on both sides of the piston	Operation is happen only one side while the other side is open.
Fuel & lubricating oil are mixed. Thus the lubricating oil enters the combustion chamber during heat addition. Some of the lubricating oil partial got burnt. The lubrication of engine is reduced & friction is ... Thus thermal eff. also reduced	lubricating oil & fuel does not mix.
Transfer port and exhaust port are open at the same time. Thus, fresh air fuel mixture will leave the cycle through exh. port. Due to this reason mileage of this engine is less	Fresh air fuel mixture does not escape out before combustion. Thus, the mileage is much higher.
Power is available once in every two strokes, the flywheel of this engine is smaller.	There is one power stroke for a total of four strokes. Thus a bigger flywheel is used. The size of the flywheel is reduced when the no. of cylinder increased.
	Due to the above reason the overall efficiency is much higher than 2-stroke engine.

- Theoretical and Actual P.V. for a four Stroke engine.







* Actual suction stroke :-

At the start piston speed is less. Hence, less air will enters at the start of suction stroke. The piston moves at high speed during the middle of the suction stroke, more air enters during the stage. Finally less air will come in.

During suction the pressure inside the cylinder will slightly below atmospheric pressure. The difference in pressure is more in the middle of suction stroke. The actual suction stroke is given by (0-1).

* Actual compression stroke :-

Due to heat carrying away by cooling water, the work input for the actual compression will be more. Thus area under the actual comp. process will be more. The process is given by (1-2)

* Actual heat addition :-

There is a small change in volume during this process. At the start volume is decrease and at later increases slightly. The heat addition begins little before the end of compression and little after start of expansion. The heat addⁿ process is given by (2-3).

* Actual expansion process :-

Due to heat recieved by the circulating water, the useful work out during expansion is less. Hence, the area under the actual exp. process is less & is given by (3-4)

* Actual heat rejection :-

This operation is reverse of heat addⁿ process. vol. increases at the start & decreases later. The pressure decreases through out the heat rejection process. It is given by (4-7-5)

* Actual exhaust process :-

The left over gas after heat rejection is pushed out by the upward motion of the piston. Hence, the pressure inside the cylinder will be slightly above the atm. pressure during exhaust. The process is given by (5-0)

The area covered by the actual suction and the exhaust stroke is known as pumping loss of the engine.

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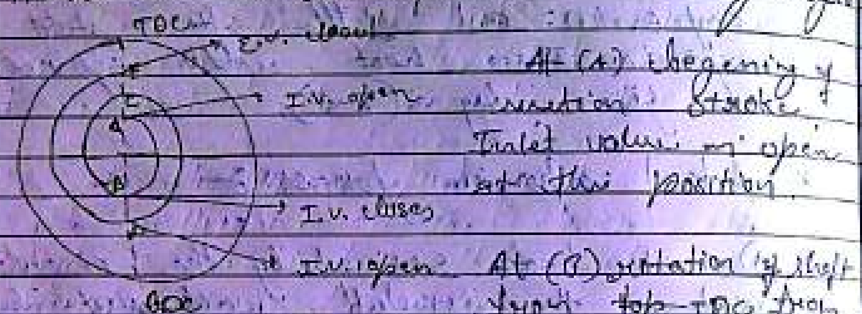
Theoretical

Theoretical and Actual/Ideal Value timing diagram.



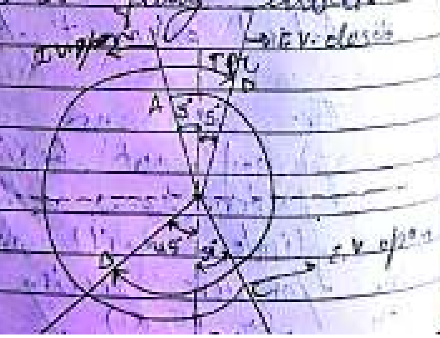
At (A) begening of suction stroke. Inlet value is open at this position.

At (B) rotation of shaft from top-TDC from BDC. At this pt - I.V. closes.

At (C) ignition takes place, both value is closed at this position.

At (D) piston is at BDC exhaust value is fully opened and heat rejection takes place at const. volume.

At (E) exhaust value is fully closed.



Value lead = 5° (before TDC) during suction

Value lag = 45° (after BDC)

I.V. period = 5° + 180° + 45°
= 230°

value lead = 50° (before BDC) during exhaust

Value lag = 5° (after TDC)

E.V. period = 50° + 180° + 5° = 230°

| A-D ⇒ value overlap | C-B → value overlap |

* It may be seen from the actual diagram that both values are fully or partially opened from the end of exhaust to the begening of suction & is known as value overlap of the engine.

The value overlap must be as small as possible so, that minimum amount of fresh air-fuel mixture can escape out from the exhaust value.

• FUELS •

* The engine converts heat energy which is obtain from the chemical combination of the fuel with the oxygen, into mechanical energy. Since, the heat energy is derived from the fuel, a fundamental knowledge of the types of fuel & their characteristic is essential in order to understand the combustion phenomenon.

The characteristics of fuel used have considerable enfluence on the design, efficiency, output & particularly the reliability & durability of the engine.

* Internal combustion engine can be operated on diff. types of fuel such as liquid, gaseous, solid fuel

* Solid fuels :-

It is reffers to the various types of solid material that are used as fuel to produce energy and provid heating, usually released through combustion. Solid fuel includes charcol, wood, peat, coal etc. The solid fuels find little practical aplication at present because of the problem of handling the solid fuel as well as in disposing of, the residue or ash after combustion.

* Gaseous fuel :-

It is ideal and pose few problem in using them in I.C. engines. Being they mixed homogeneously with air and eliminate the distribution & starting problems that are encounder with liquid fuel. Even though the gaseous fuel are most ideal for I.C engine, storage and handling problem restrict their use in automobile.

Consequently, they are commonly used for stationary power plant located near the source of availability of the fuel. Some of the gases fuel can be liquified under pressure for reducing the storage volume but this arrangement is very expansive as well as risky.

* Liquid fuels :-

In most of the modern I.C engine, liquid fuel which are derivative of liquid petrolium are being used. The three principle commercial type of liquid fuel are benzole, alcohol & petrolium product. However, petrolium product form the main fuel for internal comb. engines as on today.

Date 19/1/2017

Chemical Structure of Petroleum

Petroleum as obtained from the oil wells is a mixture of many hydrocarbons with differing molecular structure. It also contain small amount of sulphur, oxygen, nitrogen and many impurities such as water and sand.

The carbon & hydrogen atom may be link in different ways in a hydrocarbon molecule & this linkage influence the chemical & physical properties of different hydrocarbon groups.

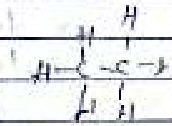
Depending upon the no. of carbon and hydrogen atom the petroleum products are classified into different groups.

Family of hydrocarbon	General formula	Molecular Structure	Saturated / unsaturated	Stability
Paraffin	C_nH_{2n+2}	chain	saturated	stable
Olefin	C_nH_{2n}	chain	unsaturated	unstable
Napthalene	C_nH_{2n}	ring	saturated	stable
Aromatic	C_nH_{2n-6}	ring	highly unsaturated	highly unstable

* **Paraffin** :- the normal paraffin hydrocarbon are of straight chain molecular structure. They are represent by general chemical formula C_nH_{2n+2}.

The molecular structure of of first few member of paraffin family of diff. hydro carbons are as shown below.

$n=1$, CH_4 — Methane 

$n=2$, C_2H_6 – ethane 

ethane

$n=3$, C_3H_8 → Propane

$n=4$, C_4H_{10} → Butane

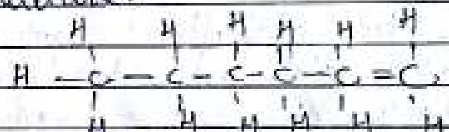
Isobutane →

In these hydro-carbon the valency of all the carbon atom is fully utilize by single bond with hydrogen atom. Therefore, the paraffin hydrocarbon are saturated compound & are characteristically very stable. The hydrocarbon which have the same chemical formula but diff. chemical structure formula are known as isomer. Isobutane shown below as the same general chemical formula & molecular weight structure & physical characteristics and it is called as an Isomer of butane and also known as Iso-butane.

* Olefin Series C_nH_{2n}

Olefin are also straight chain compounds similar to peraffins but are un-saturated because they contain one or more double-bond b/w carbon atoms. Their chemical formula is C_nH_{2n}.

Mono-olefin has one-double-bond where as di-olefin have 2-bond in there structure.



Hexene

Butadiene

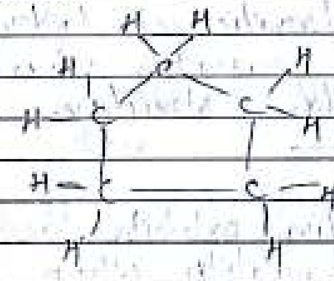
Olefins are not as stable as the single bond peraffins because of the presence of double-bond in this structure. Consequently, these are readily oxidised in storage to form gummy deposits. Hence, olefin contain in certain petrolium petrol is kept low by specification.

* Nepthene Series:-

They have the same chemical formula as the olefin series of hydro-carbon but have a ring structure & therefore, often they

called as cyclo-peraffins. They are saturated & tend to be stable. The nepthene are saturated compound, where as olefins are unsaturated.

Cyclopentane is one of the compound in nepthene series.

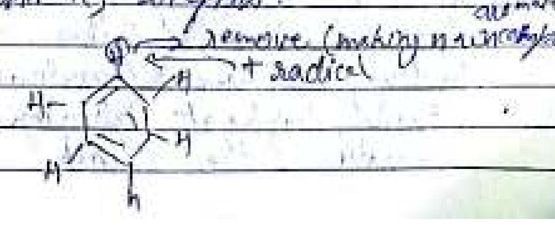


Cyclo-Pentane

* Aromatic Series:-

Aromatic compounds are ring structure having a benzene molecules as their central structure & have their chemical formula C_nH_{2n-6}.

Though, the presence of double-bond indicate that they are un-saturated, a peculiar nature of there double-bond causes them to be more stable than the other unsaturated compound. Various aromatic compound are formed by replacing one or more the hydrogen atom of the benzene molecules with an organic radical such as peraffin, nepthene, olefins.



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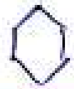
 toulene

By adding methyle group (CH_3), benzene is converted to toulene ($C_6H_5CH_3$), the base for the preparation of tri-nitro toulene, which is a highly explosive compound.

** The above families of hydro-carbon exhibit some the general characteristic due to their molecular structure, which are given as —

(1) Normal paraffin exhibits the poorest ~~anti~~ anti-knock quality when used in SI engine. ~~F~~ But the anti-knock quality improves with the increasing no. of carbon atom and the compactness of the molecular structure. The aromatic offer the best resistance to knocking in SI engine.

(2) For CI engine the order is reversed i.e. the normal paraffin are the best fuels and aromatic are the least desirable.

(3) The heating value generally increase as the proportion of hydrogen atom to carbon atoms in the molecules increases due to the higher heating value of hydrogen than carbon. Thus, paraffin have the highest heating value & the aromatic the least.

Date 24/1/2017

- Properties of fuels used in S.I. Engines:

Gasoline :— it is the ~~measured~~ major product of the petroleum industry and forms most of the S.I engine fuel. It is a mixture of organic compound such naphthene, paraffins etc. including heptane & octane, plus additive to provide improved cold start and knock registivity.

* Requirement of an ideal gasoline :—

- It should mixed with readily with air and afford uniform manifold distribution i.e. it should vaporised easily.
- It must be knock resistance, it should not tend to decrease the volumetric efficiency of engine.
- It should be easy to handle, it must be cheap & should be available every ~~where~~ where.
- It must burnt clean & produce no corrosion etc. on engine parts.
- It must have high calorific value.
- It should not form gum & varnish.

Volatility of liquid fuel

Volatility of a liquid is its tendency to ~~evaporate~~ evaporate under a given setup condition. The constituents of gasoline, which is a mixture of multi-hydrocarbon, boil off at a wide range of temp.

If a fuel is heated at a steadily increasing temp & the % of evaporated is plotted against temp, the obtained is curve which is known as distillation curve.

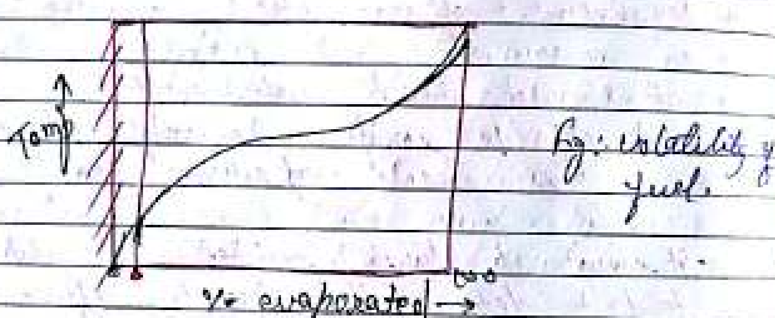


Fig: volatility of fuel.

* Distillation curve is not a true boiling pt curve but is commonly used to define & describe the volatility of fuel

⇒ The distillation curve can be divided into three portion –

① Front end (0–20% evaporated) –
② Mid range (20–80% ,,)
③ Tail end (80–100% evaporated).

8:1 → fuel rich mixture
20:1 → lean mixture
12:1 → fastest burning/most suitable for starting.

air-fuel
20:1

* Cold Start :– Cold start in order to start an engine a combustible mixture rich enough to ignite easily at starting temp must be supply near the spark plug. The approximate limits of inflameability of air-gasoline vapour mixture are about 8:1 for fuel-rich mixture & 20:1 for lean mixture. A mixture ratio of 12:1 is the fast burning mixture & most suitable for starting.

At low ambient temp, only a small portion of the fuel fed into the comb. chamber evaporates so that air-fuel vapour mixture is very lean. Therefore choke is used to reduce the air quantity going to the engine and thereby bring the mixture ratio within combustible range.

* Hot Starts :–
When a hot engine is shut down due to heat from other hot parts of the engine the fuel in the fuel pump, fuel lines and carburetor bowl boil & evaporate. If the carburetor bowl ventilation is inadequate to vent out the vapour so formed, a pressure is built up which let up the middle of the float and vapour goes to the inlet manifold. If the vapour handling capacity of the fuel pump is inadequate, the vapour

form in the fuel pump during the hot shut down period & also goes into the intake manifold when the engine started.

If the front end volatility of the fuel is made high to give good cold starting, the amount of fuel evaporating & going to the intake manifold under hot shut condition is high & the mixture formed is too rich to ignite causing hot starting problems. This phenomenon where it is impossible to start a vehicle specially on hot days, which have been stopped for a short time after a long time fast run in some time is called percolation.

* Vapour lock :-

In contrast to percolation, where too rich air-fuel mixture is fed into intake manifold where vapour lock situation, where too lean a mixture is supplied to the engine.

A fuel system vapour lock occurs where the fuel is in vehicle changes from a liquid to gaseous state, where it is still in the fuel lines of the fuel in gaseous state, the fuel pump can't process the liquid fuel to the engine.

It is typically caused by the fuel overheating somewhere in the fuel delivering system. The vapour lock liquid ratio of a gasoline defined as the amount of vapour produced from a gasoline to the liquid remaining at a given time temp., directly co-relates with the degree of vapour lock. If the vapour liquid ratio of 20 vapour lock may start and at vapour liquid ratio is 36 vapour lock may be serious. Therefore the volatility of the gasoline should be maintained as well to prevent this type of difficulty.

* Crank Case Dilution :-

It is the phenomenon in which unburned diesel or gasoline accumulate in the crank case. Excessively rich fuel mixture or incomplete combustion allows a certain amount of fuel to pass down b/w the piston & cylinder wall & dilute the engine oil & lowers its viscosity. It also washes away the lubricating oil film on the cylinder walls.

It is more at low engine operating temp. such as those encountered in cold weather, stop & go driving where the oil temp. never get high enough to evaporate the diluent.

Anti-knock Quality :-

Abnormal burning or ~~detern~~ detonation in SI engine comb. chamber causes a very high rate of energy released, excessive temp. & pressure inside the cylinder adversely affects its thermal efficiency. Therefore, the character of the fuel used should be ~~of~~ such that it reduces resist the tendency to produce detonation & this property is called its antiknock property.

The antiknock property of a fuel depends on the self ignition charac. of its mixture and ~~they~~ vary largely with the chemical composition & molecular structure of the fuel.

* Gum Deposites :-

Reactive hydrocarbons and impurities in the fuel have a tendency to oxydise upon storage and form liquid and ~~to~~ solid gumy substances. The gasoline containing hydrocarbons of the paraffin, napthines and aromatic families form little gum while gasoline containing unsaturated hydrocarbon is the worst offender. A gasoline with high ~~cance~~ content will cause operating difficulties such as sticking walls at piston rings, carbon deposited in the engine, gum diposits in the manifold, clogging of carburetor jets and intaping of the valve stems, cylinder & piston. The amount of gum increases with increased concentration of oxygen with rise in temp. with exposed to sun light and also in contact with metals.

* Sulphur Content :- (causing corrosion)

Hydrocarbon fuels may contain free sulphur, hydrogen sulphide and other ~~sulp~~ sulphur compound which are objectionable for several reason. The sulphur is a corrosive element of the fuel that can corrode the fuel lines, carburators and injector pump and it will ~~derive~~ ignite with oxygen to form sulphur dioxide that in the presence of water at low temp.

may for sulphurous acid. Since sulphur had a low ignition temp., the presence of sulphur can reduce the self ignition temp. & thus promoting knock in the SI engine.

Properties of C.I. Engine fuel

* **Knock Characteristics :-**

Knock in the CI engine occurs because of the ignition lag in the combustion of the fuel b/w the time of injection & the time of actual burning. As the ignition lag increases the amount of fuel accumulated in the combustion chamber increases & when combustion actually takes place, abnormal amount of energy is certainly released causing excessive range of pressure rise which result in a audible knock. Hence a good C.I. engine fuel should have a short ignition lag and will ignite more readily.

* **Volatility :-**

The fuel should be sufficient volatile in the operating range of temp. to produce good mixing and combustion.

* **Starting Characteristics :-**

The fuel should help in

starting the engine easily. This requirement demands high volatility to form a combustible mixture readily and a high cetane rating in order to have low self ignition temp.

* **Smoking and odour :-**

The fuel should not promote either smoke or odour in the engine exhaust. Generally, good volatility is the first pre-requisit to ensure good mixing and then for complete combustion.

* **Viscosity :-**

C.I. engine fuel should be able to flow through the fuel system and the strainers under the lowest operating temp. range to which the engine is subjected too.

* **Corrosion and wear :-**

The fuel should not cause corrosion and wear of the engine component before or after combustion. These requirements are directly related to the presence of sulphur and residue in the fuel.

* **Handling ease :-**

The fuel should be a liquid that will readily flow under all condition that are encounter to actual used. This requirement is measured by the viscosity of the fuel and by the pour point.

31/1/2017

• Rating of S.I Engine fuels

Resistance to knocking is a imp. chara. of fuel for SI engine. The fuels differ widely in their ability to resist knock depending on their chemical composition.

A satisfactory rating method for comparing the anti knock qualities of the various fuel has been established. In addition to the chemical characteristics of hydrocarbon in the fuel, other operating parameter such fuel - air ratio, ignition timing, dilution, engine speed, shape of the comb. chamber, compression ratio etc effect the tendency to knock in the engine cylinder.

Acc. to standard character practice, the anti-knock value of SI engine fuel is determined by comparing its anti-knock property with a mixture of two primary reference fuel, isooctane (C_8H_{18}) and normal heptane) iso-octane chemical being a very good anti-knock fuel, is arbitraly assigned as rating of 100 octane no. Normal heptane had

very poor anti-knock qualities and is given a rating of zero-octane no.

The octane no. fuel is defined as the % volume of iso-octane in a mixture of iso-octane and normal heptane, which exactly matches the knocking intensity of the fuel in an standard engine under the set of standard condition.

octane no. can be increased by anti-knock agents, at less expense than modified hydrocarbon composition by refinary process. Most effective agents are lead alkyles.

- tel (Tetra ethyle lead)
- TML (Tetra methyle lead)

Rating of CI Engine fuel

In compression ignition engine the knock resistance depends on chemical chara. as well as on the operating and diesel conditions of the engine. Therefore the knock rating of diesel fuel is found by comparing the fuel under prescribed condition of operation in a special engine with primary reference fuel.

The reference fuel are - normal cetane, $C_{16}H_{34}$, which arbitraly assigned a centane no. of 100 and α-methyle nepthaline ($C_{11}H_{10}$) with an assigned cetane no. of zero.

Cetane no. of fuel is defined as %/vol. of normal cetane in a mixture of normal cetane & α-methyle nepthaline which have the same ignition characteristic (ignition delay) as the gas-test fuel when comb. is carried out in an standard engine under specified operating condition. Since, ignition delay is the primary factor in controlling the initial auto-ignition in the CI engine, it is reasionable to conclude that knock should be directly related to ignition delay of the fuel. Knock resistance property of the diesel oil can be improved by adding small quantities of compound like amyl nitrate, ethyl nitrate or ether.

1st Unit END

2/2/2017

Carburettors

Carburation :-

The process of formation of combustible fuel-air mixture by mixing the proper amount of fuel with air before addmission to engine cylinder is called carburation & the device used for mixing the air-fuel in proportion is known as carburator.

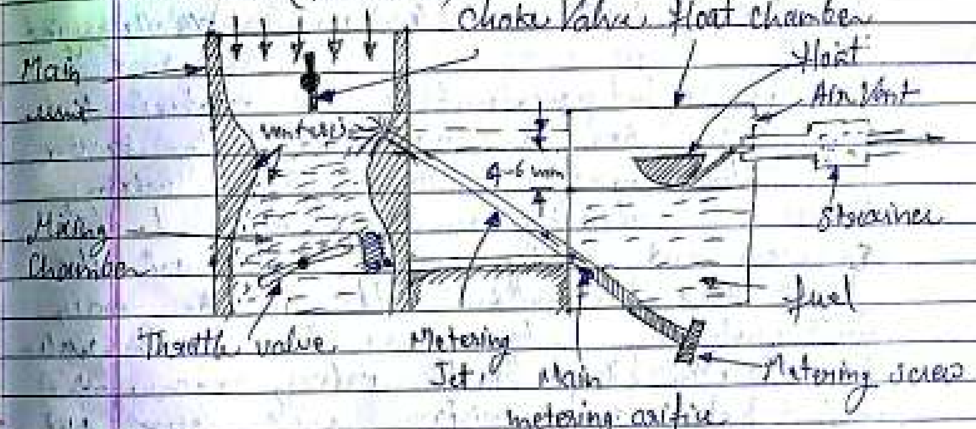


Fig:- Carburator

The carburetor consist of two diff. chamber one is main unit & another is the float chamber. Atmospheric air enters the main unit of carburator when suction takes place inside the engine & the air flows down, the air of the main unit keeps decreasing. The pt where the area is min. is called venturi of the main unit. At the venturi, the velocity of air is rich.

The fuel from the float chamber enters the main unit at the venturi. The flow is caused due to vacuum created by the high velocity of air at the venturi. The flow of fuel takes place through a pipe is known as metering jet. The tape of the metering jet which is at the venturi is known as discharge jet.

The air & fuel mix below the venturi & this space in the main unit is known as the mixing chamber. During mixing, there is atomisation, vaporisation & homogeneous mixing of the air and the fuel. There is a wall in the main unit which is known as the throttle valve. On opening the throttle valve, more or less fuel air mixture will come out. The main unit goes into the engine cylinder through a pipe called intake manifold.

In the float chamber there is a ball that floats on the surface of the fuel & is known as the float. A lever is attached to the float and the other side of the lever is connected to a valve known as the middle valve. When the level of the fuel decrease in the float chamber, the level float lower down & the lever open the middle valve. Fuel from the fuel tank enters the float chamber through the middle valve, the fuel level will rise and the middle wall gets closed. Thus the level of the fuel is maintained in float chamber.

The flow of fuel in the metering jet is controlled by the adjustment of the screw known as metering screw. There is a gape in the float chamber through which atmospheric pressure is always act on the fuel and this gape is known as air vent.

17/2/17

* Elential parts of a carburetor :-

(1) Fuel strainer :- As the gasoline has to passed through a narrow nozzle exit, there is a every possibility that the nozzle may get clogged during prolong operation by the engine. To prevent possible blockage of the nozzle by dust particle the gasoline is filtered by installing a fuel strainer at the inlet to the float chamber. The strainer consist of a fine wire mesh or other type of filter device. The strainer is usually removable so that it can be taken out & clean thoroughly. It is retained in its seat

by a strainer plug or a compression spring.

* **Float Chamber :-** The function of a float chamber in a carburetor is to supply the fuel to the nozzle at a const. pressure head. This is possible by maintaining a const. level of the fuel in the float chamber bowl. Float in a carburetor is designed to control the level of fuel in the float chamber. This fuel level must be maintained slightly below the discharge level of nozzle outlet holes in order to provide the correct amount of fuel flow and to prevent the leakage of fuel from the nozzle when the engine is not operating. The arrangement of float chamber in relation to the discharge nozzle is shown in the given fig. When the float rises with the fuel coming in, the fuel supply valve closes it & stops the fuel of fuel into the chamber at that point.

(3) **The Main Fuel Metering System :-**

The main metering system of the carburetor controls the fuel feed for economical & full throttle operation. It consist of three principle units-

(1) The fuel maintenance orifice through which fuel is drawn from the float chamber.

(2) The main discharge nozzle.

The passage leading the idling system.

The three function of the main metering system are -

(1) To proportion the air - fuel mixture.
(2) To decrease the pressure at the discharge nozzle exit.
(3) To limit the air flow at full throttle.

(4) The Choke and the throttle :-

At low cranking speed and intake temp. a very mixture is required to initial the the comb. The main reason is that very large fraction of the fuel may remain in liquid suspended in air than in the cylinder for initiating comb. fuel vapour and air in the form of mixture at a ratio that can sustain comb is required. The most popular method of providing mean method is by use of choke valve. This is so simple butterfly valves located b/w the interance to the carburetor at & the ventury throught when the choke is partially closed, a large pressure drop occurs at the ventury throught

Stoichiometric A/F Ratio (no unburnt part, chemically correct mixture)

that would normally result from the quantity of air passing through the venturi throught. The very large depression at the throught inducts large amount of fuel from the main nozzle and provides a very rich mixture so that the ratio of evaporated fuel to air in the cylinder is within the combustible limit.

The speed & the o/p of an engine are controlled by throttle valve, which is located on the down stream side of the venturi. The more the throttle is closed the greater is the obstruction to the flow of the mixture placed in the passage & the less is the quantity of the mixture that delivered to the cyl. The decreased quantity of mixture gives a less powerful impulse to the piston and the output of the engine is reduced accordingly. As the throttle is opened, the o/p of the engine increases which actually increase the speed of the engine.

Air-fuel mixture

① Stoichiometric A/F ratio :–

when the combustion of fuel takes place in such a manner that no fuel in any form will remain after combustion nor be any oxygen left out, the combustion is known as ideal combustion & the A/F ratio for this type of combustion is known as stoichiometric A/F mixture ratio.

A/F ratio for different condition :–

- Cold starting → 2 to 3
- Idling condition → 5 to 9
- Maximum power → 12 to 13
- Economical condition → 16
- Stoichiometric A/F ratio → 15
- lean mixture → 17 to 21

7/2/23 fuel and air are mixed to form three different types of mixture–

① Chemically correct mixture :– complete comb. (stoichiometric) occurs in this type of mixture which means all carbon in the fuel is converted to CO_2 and all hydrogen to H_2O

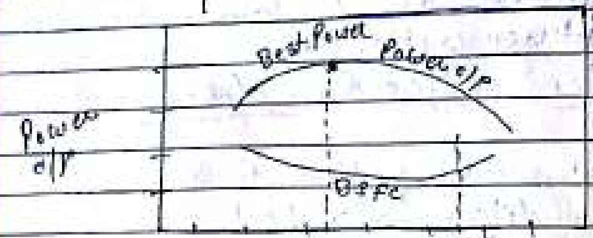
② Rich mixture :–
A mixture which contains less air than the stoichiometric requirement is called as rich mixture.

③ lean mixture :–
A mixture which contains more air than the stoichiometric requirement is known as lean mixture.

Brake Specific fuel consumption

$$BSFC = \frac{\dot{m}_f}{BP}$$

* Mixture requirement at diff. load & speed :-



The air fuel ratio at which an engine operates has a considerable influence on its performance. Consider an engine operating at full throttle & at const. speed with varying A/F ratio. Under these condn, the A/F ratio will effect both the power o/p & the BSFC. The mixture corresponding to the max o/p on the curve is called best power mixture with an A/F ratio of 12:1. The mixture corresponding to the mini. pt on the BSFC curve is called the best economy mixture. The A/F ratio is approximately 16:1.

(*) Calculation of Air fuel ratio (*)

* Calculation for air :-
Case :1 – when flow is isentropic.

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$\Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma = \left(\frac{m/\rho_1}{m/\rho_2}\right)^\gamma$$

$$\Rightarrow \frac{P_2}{P_1} = \left(\frac{\rho_2}{\rho_1}\right)^\gamma$$

$$\Rightarrow \boxed{\rho_2 = \rho_1 \left(\frac{P_2}{P_1}\right)^{1/\gamma}} \quad --- (1)$$

$$\boxed{\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}} \quad --- (2)$$

Applying steady flow energy equation –

$$Q = W = 0$$

$$H_1 + \frac{1}{2} m c_1^2 = H_2 + \frac{1}{2} m c_2^2$$

neglecting

$$\Rightarrow \frac{1}{2} m c_2^2 = H_1 - H_2 = m C_p (T_1 - T_2)$$

$$\Rightarrow \boxed{C_2 = \sqrt{2 C_p (T_1 - T_2)}} \quad --- (3)$$

$$C_2 = \sqrt{2 C_p T_1 \left(1 - T_2/T_1\right)}$$

$$\Rightarrow \boxed{C_2 = \sqrt{2 C_p T_1 \left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right)} \times C_V} \quad --- \text{by eq}^n - (2)$$

$C_V \rightarrow$ Co-eff. of velocity

In actual

[In theoretical $C_V = 1$]

Acc. to continuity eq^n.

Actual $\dot{m}_a = C_d \times (\rho_2 \times A_2 \times C_2)$ (→ const., → velocity)

$$= C_d \times \left[\rho_1 \left(\frac{P_2}{P_1}\right)^{1/\gamma}\right] \times A_2 \times C_2$$

$$\text{Actual } \frac{m}{s} = C_d \times \left[\rho_1 \left(\frac{P_2}{P_1}\right)^{1/\gamma} \right] \times A_2 \times \sqrt{2 c_p T_1 \left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right)} \times C_v$$

Case :- 2 when flow is incompressible.

Assumption :-

① $T_1 = T_2$, ② $P_1V_1 \neq P_2V_2$ & $\rho_1 = \rho_2 = \rho$

Applying SFEE :-

$$H_1 + \frac{1}{2}mc_1^2 = H_2 + \frac{1}{2}mc_2^2 \quad (\tfrac{1}{2}mc_1^2 \rightarrow \text{neglect})$$

$$\Rightarrow U_1 + P_1V_1 = U_2 + P_2V_2 + \frac{1}{2}mc_2^2$$

$$\Rightarrow (P_1V_1 - P_2V_2)\,2 = mc_2^2$$

$$\Rightarrow \left(P_1\frac{m}{\rho} - P_2\frac{m}{\rho}\right)\times 2 = m\,c_2^2$$

$$\Rightarrow C_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

$$\text{Actual } \frac{m}{s} = C_d \times \rho A_2 C_2$$

$$= C_d \times \rho A_2 C_v \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

$$\boxed{\text{Actual } \frac{m}{s} = C_d \times A C_v \sqrt{2\rho (P_1 - P_2)}}$$

Assumption

* Calculation for fuel :- (incompressible)

↳ As fuel is a liquid, only incompressible flow is possible.

Applying SFEE :-

$$H_1 + \frac{1}{2}mc_1^2 + gz_1 = H_2 + \frac{1}{2}mc_2^2 + gz_2 \quad (\tfrac{1}{2}mc_1^2 \rightarrow \text{neglect})$$

$$\Rightarrow U_1 + P_1V_1 + mgz_1 = U_2 + P_2V_2 + \frac{1}{2}mc_2^2 + mgz_2$$

$$(P_1V_1 - P_2V_2) - mg(z_2 - z_1) = \frac{1}{2}mc_2^2$$

$$\Rightarrow \left(P_1\frac{m}{\rho} - P_2\frac{m}{\rho}\right) - mg(z_2 - z_1) = \frac{1}{2}mc_2^2$$

Divided by m —

$$\Rightarrow \left(\frac{P_1 - P_2}{\rho}\right) - g(z_2 - z_1) = \frac{1}{2}c_2^2$$

$$\Rightarrow C_2 = \sqrt{2\left(\frac{P_1 - P_2}{\rho} - g(z_2 - z_1)\right)} = \sqrt{2\left(\frac{(\Delta P)}{\rho} - g(\Delta z)\right)} \times C_v$$

$$\text{Actual } \frac{m}{s} = C_d \times (\rho A_2 C_2)$$

$$= C_d \times \rho A_2 \sqrt{2\left(\frac{\Delta P}{\rho} - g\Delta z\right)}$$

$$\boxed{\frac{m}{s} = C_d \times A_2 \sqrt{2\rho(\Delta P - g\rho\Delta z)}}$$

$$\text{Air fuel ratio} = \frac{m_a}{m_f}$$

$$= \frac{C_{d_a} \times A_{2a} \times \sqrt{2(\Delta P)\rho_a}}{C_{d_f} \times A_{2f} \times \sqrt{2\rho(\Delta P - g\rho_f(\Delta z))}}$$

If z is negligible —

$$\boxed{A/F \text{ ratio} = \frac{C_{d_a} \times A_{2a}}{C_{d_f} \times A_{2f}} \sqrt{\frac{\rho_a}{\rho_f}}}$$

9/2/2017 $\pm$ ρ 0.287 / Aer   56

Ques) A simple carburator as to supply 5 kg air per min. The atm. air is 1.013 bar and 27°C. Calculate the dia at the throat of the air flow velocity at the point is 90 m/s. The coefficient of velocity is 0.8 & assume the flow is isentropic. Take c_p = 1000 J/kg K.

$\dot m_a = 5$ kg/min

$P_1 = 1.013$ Bar $= 1.013\times10^5$ N/m²

$T_1 = 27°C = 300$ K

$C_v = 0.8$, $C_2 = 90$ m/s

$\frac{P_2}{P_1} = 0.93$

$\rho_1 = 1.176$ kg/m³

$A = \frac{\pi}{4} d_2^2$ $d = ?$

$d = 0.032$ m

$C_2 = C_v \sqrt{2 C_p T_1 \left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right)}$

$\dot m = \rho_2 A_2 C_2$

$90 = 0.8 \sqrt{2\times1000\left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{1.4-1}{1.4}}\right]}$

$\frac{5}{60} = \rho_1 \left(\frac{P_2}{P_1}\right)^{1/\gamma} \times 90 \times \frac{\pi d^2}{4}$

$187.5 = \sqrt{2000\left(1 - \frac{P_2}{P_1}\right)^{1.4}}$

$17.58 = \left(1 - \left(\frac{P_2}{P_1}\right)\right)^{2/7}$

$PV = mRT$

$P = \frac{mRT}{V}$

$16.58 = \left(\frac{P_1}{P_2}\right)^{2/7}$

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

$(16.58)^{7/2} = \left(\frac{P_1}{P_2}\right)$

(i) $\dot m_f = 9.55$ kg

(ii) 8.5 m/s

$\Delta P = 44.4$ N/m²

57

Ques) The venturi of a simple carburetor has a throttle dia of 20 mm and fuel orifice dia is 1.2 mm. The level of petrol surface is in the float chamber and below the float. Take $\rho_f = 750$ kg/m³

$C_{da} = 0.85$

$C_{df} = 0.78$

Calculate –

(1) A/F ratio, (2) petrol consumption, (3) critical air vel. The intake air velocity is at 1 bar and 290 K & the pressure drop is 0.08 bar.

$\Delta P = 0.08$ bar.

$Z = 6$ mm, $d_a = 20$ mm, $d_f = 1.12$ mm

(i) A/F ratio $= \frac{0.85 \times \frac{\pi}{4} d_a^2}{0.78 \times \frac{\pi}{4} d_f^2} \sqrt{\frac{1.21}{750}}$

$= 13.95$ kg/s

(iii) for $m_f = 0$ [critical air velocity)

INJECTION System [IN 8]

The purpose of carburation and fuel injection is the same i.e. preparation for of the combustible charge. But in case of carburation fuel is automized by processes relying on the air speed greater than fuel speed at the fuel nozzle, where as in fuel injection the fuel speed at the pt of delivery the is greater than the air speed to atomized the fuel.

In a fuel injection system, the amount of fuel delivered into the air stream going to the engine is controlled by a pump which forces the fuel under pressure.

When the fuel is injected into the combustion chamber toward the end of compression stroke, it is ~~auto~~ atomized into fine droplets. This droplets vaporized due to heat transfer from the compressed air & form a air F/A mixture. Due to continue heat transfer from hot air to the fuel, the temp. reaches a value higher than its self ignition temp. This causes the fuel to ignite spontaneously initiating the combustion process.

13/2/2017

Functional requirements of an injection system

1. Accurate metering of the fuel injected per cycle. Metering errors may cause drastic variation from the desired output. The quantity of fuel metered should vary to meet changing speed & load requirements of the engine.

2. Timing the injection of the fuel correctly in the cycle so that max. power is obtained ensuring fuel economy & clean burning.

3. Proper control of rate of injection so that the desired heat released pattern is achieved during combustion.

4. Proper atomization of fuel into very fine droplets

5. Proper spray pattern to ensure rapid mixing fuel & air

6. Uniform distribution of fuel droplets in the combustion chamber

7. To supply equal quantities of metered fuel to all cylinders in case of multi-cylinder engines. when

8. No lag during beginning and end of injection i.e. to eliminate dribbling of fuel droplets into the cylinder.

Classification of Injection System

In const. pressure cycle or diesel engine only air is compressed & then fuel is injected into the cylinder by means of a fuel injection system.

For producing the required pressure for atomizing the fuel either air or a mechanical device be used. Accordingly the injection syst. can be classified as —

1. Air I.S.
2. Solid injection Sys

→ Air injection System :-

In this system, fuel is forced into the cylinder by means of compressed air. This system is little used now days, because it required a multi-bulky multi-stage air compression. This causes an increase in engine weight & reduces the also the brake power o/p further. One advantage that is claimed for Air I.S. is good mixing of F/A with higher mean effective pressure. Another is the ability to utilise fuels of high viscosity which are less expensive than those used by the engine with solid injection system. These advantages are offset by the requirement of a multistage compressor thereby making the air I.S. absolete.

Solid Injection System

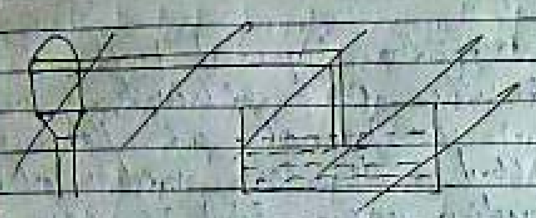
In this system the liquid fuel is injected directly into the comb. chamber without the help of compressed air. Hence, it is also called as airless mechanical injection or solid injection system. Solid I.S. can be classified as

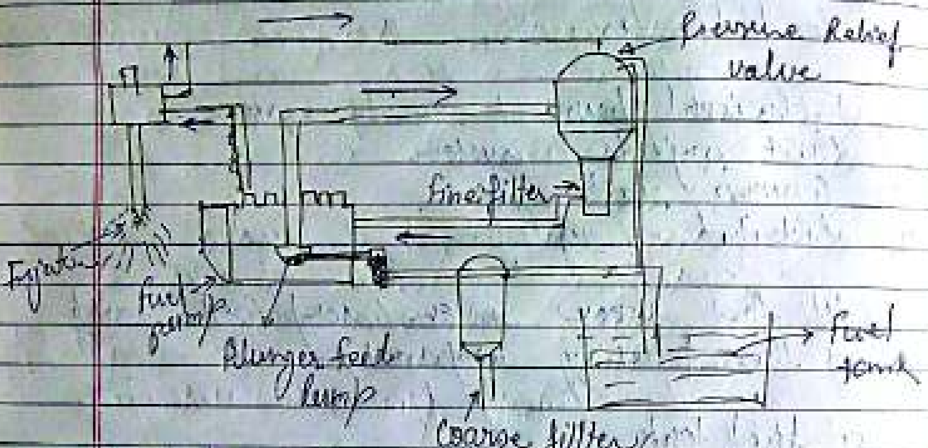
1. Individual pump & nozzle system :-
2. Unit injector system
3. Common rail system.
4. Distributor system.

All the above system comprised mainly of the following components :-

1. Fuel tank :-
2. Fuel feed pump to supply fuel from the main fuel tank to the injection system.
3. Injection pump to meter and pressurised the fuel for injection.
4. Governor to ensure that the amount of fuel injected is in accordance with variation of load.
5. Injector to take the fuel from the pump & distribute it in the comb. chamber by atomizing it into fine droplets.
6. Fuel filter to prevent dust & abrasive particles from entering the pump

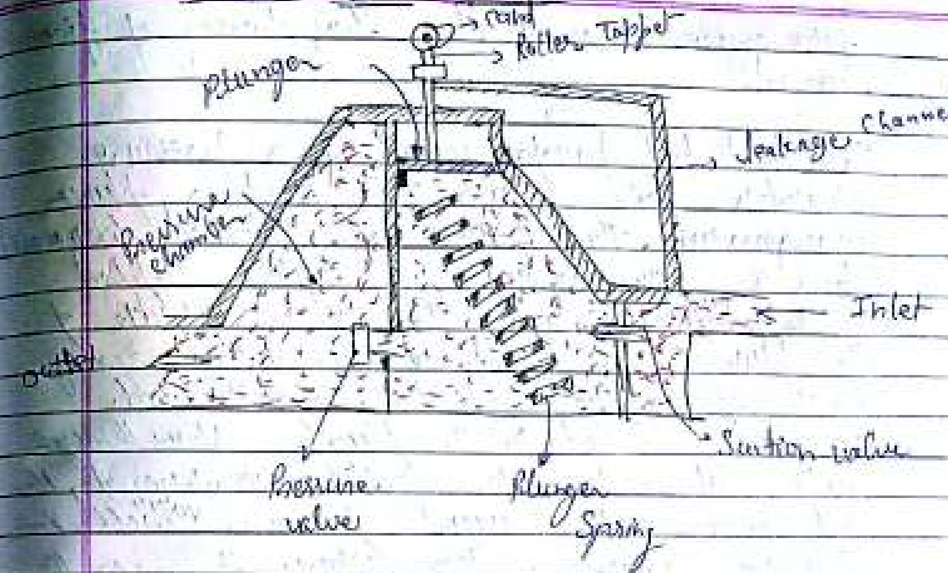
& injector there by minimising the wear
& tear of the component





Fuel from the fuel tank first enters the coarse filter from which is drawn with the plunger feed pump where the pressure is raised very slightly. Then the fuel enters the fine filter where all the dust particles are removed. Then the fuel enters the fuel pump from where it is pressurised about 200 bar and injected into the engine cyl. by means of the injector. Any spill over in the injector is sent (return) to the fine filter. A pressure relief valve is also provided for the safety of the system.

Fuel Feed Pump



The fuel is firstly stored in a fuel tank and then it is led to injection system through fuel filters. The fuel is supplied to the injection system either by gravity or by mechanical pressure. In case of gravity feed system, the fuel tank is placed at a higher level than the engine so that fuel may flow to the injection pump under gravity head. Such an arrangement is employed in stationary engines. In other arrangement, fuel is sucked from the fuel tank by a mechanically operated fuel feed pump and is forced into the injection pump. In this case the fuel tank is placed at a lower level than the engine and some time away from the engine as in the case of automobiles using diesel oil. The fuel is placed away from the cpt engine avoid the chances of fire hazard.

The fuel feed pump consist of a pressure chamber in which is fed a plunger arrangement. The plunger is activated downward by a cam through a roller tappet & plunger rod. The return stroke of the plunger is performed by plunger spring which is fitted on the opposite side. The fuel is fed to the plunger space through suction valve & after getting compressed, the fuel moves out through pressure valve into pressure chamber from where it goes to the filter and then to the injection pump. A leakage channel is provided which collects leaked fuel from the stuffing box & feed it again to the inlet pipe to thus avoid wastage of fuel.

Jerk Type Pump System

① Separate mittering and compression pump is used for each cylinder.

② Reciprocating fuel pump is used to mitter and set the injection pressure of the fuel.

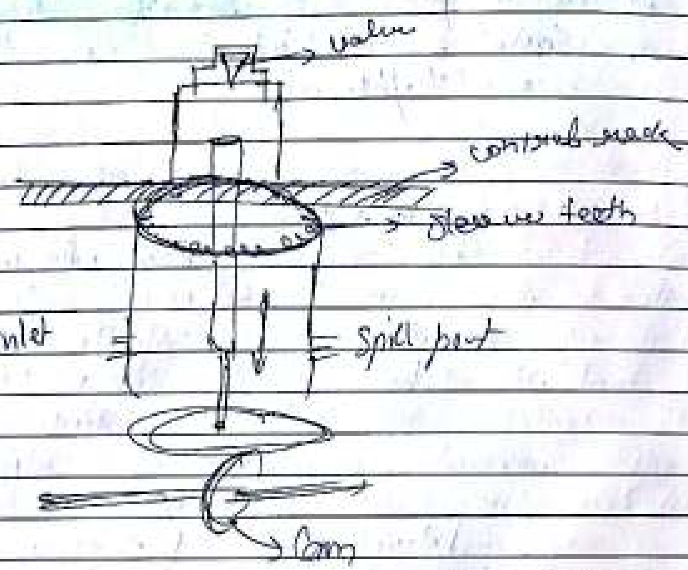
③ Heavy gear arrangement is used which gives jerking noise, hence it is named as jerk pump.

④ Jerk pump is used for medium & high speed diesel engine.

⑤ It consist of a reciprocating plunger inside a barrel. The plunger is driven by a cam shaft.

Control rack meshes with the tooth portion of the sleeve and control the rotation of sleeve and also the piston. Spring presses the cam follower on the cam surface. The orientation of piston decide the quantity of fuel and the stroke.

When the piston moves up at first spill port open. Excess fuel exist through the spill port and the valve remains closed. Once the spill port is covered, fuel is trapped within the cylinder & pressure created as piston rises. Piston overcomes spring force and valve gets opened, fuel flows to outlet. The duration for which the valve is opened in each stroke is known as effective stroke. Once the spill opens again, the valve closes back down.



Date 14/2/2017

Distributor Type Pump System :-

Distributed type pump has a only single pumping element and the fuel is distributed to each cylinder by means of rotor. There is a central longitudinal passage in the rotor & two sets of radial holes located at different heights. One set is connected to pump inlet via central passage whereas the second set is connected to delivery line leading to injectors of various cylinder.

As inlet passage aligned with inlet port plunger moves out drawing into the

central cavity and when the outlet passage aligned with outlet port plunger moves in pushing out fuel from the cavity.

[Fig. 8.7 (879)]

Injection Pump Governor

In a CI engine the fuel delivered is independent of the injection pump chain & the air intake. Fuel delivered by a pump increases with speed whereas the opposite is true about the air intake. This results in over fueling at higher speeds and that at idling speed (slow speed) the engine tends stall due to insufficiency of fuel. Quantity of fuel delivered increases with load causing excessive carbon deposites and high exhaust temp. Drastic reduction in load will cause over speeding to dangerous values. It is the duty of the injection pump governor to care of the the above limitation.

Governor are of two types –

① Mechanical Governor, ② Pneumatic Governor

When the engine speed tends to exceed the limit the weights fly apparts. This causes the bell crank levers to raise the sleeve and operat the control lever in downward direction. This activates the control rack on the fuel injection pump in a direction which reduces the ~~at~~ amount of fuel delivered. Lesser fuel causes the engine speed to decrease. The reverse happens when engine speed tends to decrease.

Fig. 8.9 (851)

* Pneumatic Governor

The amount vacuum applied in the diaphragm is controlled by the excelerator paddle through the position of the butterfly valve in the ventury unit. A diaphragm is connected to the fuel pump control rack. Therefor the position of the accelerator paddle also determine the position of pump control rack and hence the amount of fuel injected.

Fig. 8.10 (852)

Nozzle

Nozzle :- that part of an injector through which fuel is spread into the combustion chamber. These nozzle should fullfil the following function -

① Atomization :- This is a very imp. function since it is the first phase in obtaining proper mixing on the fuel & air in the combustion chamber.

② Distribution of fuel :- distribution of fuel to the

required areas within the comb. chamber. Factors affecting this are -

a) Injection pressure :- higher the injection pressure better the dispersion and penetration of the fuel into all the desired location in combustion chamber.

b) Density of air in the ~~air~~ cylinder :-

If the density of compressed air in the comb. chamber is high then the resistance to the movement of the droplets is higher and dispersion of fuel is better.

c) Physical properties of fuel :-

The properties like self ignition temp., vapour pressure, viscosity etc. play an imp. role in the distribution of fuel.

③ Prevention of impingement of ~~value~~ wall :-

Prevention of fuel from impinging directly on the walls of comb. chamber or piston. This is necessary because fuel striking the walls ~~becomes~~ decomposes and produces carbon deposites. This causes smokey exhaust as well as increase fuel ~~combd~~ consumption.

④ Mixing :- Mixing the fuel and air in case of non-turbulent type of comb. chamber should be taken care of by the nozzle.

Types of Nozzle :

The design of the nozzle is closely inter related to the type of combustion chamber used. It is sufficient to state that the turbulent type of comb. chamber depends upon chamber turbulence to produce the required mixing of the fuel and air. The non-turbulent type of comb. chamber depends all most entirely on both the nozzle design and injection pressure to secure the desired mixing in the comb. chamber. The various types of nozzle are used in C.I engines.

(1) Pintle Nozzle : 8.12(257)

The stem of the nozzle, valve is extended to form obtained a pin or pintle which protudes through mouth of the nozzle. It provides a spray operating at low injection pressure of (8-10) MPa. The spray cone angle is generally 60°. The advantage of its is that it avoids weak injection & dribbling. It prevents carbon deposition on the nozzle hole.

(2) Single hole nozzle :-

At the centre of the nozzle body there is a

single hole which is closed by the nozzle valve. The size of the hole is usually of the order 0.2 mm. Injection pressure is of the order of 8-10 MPa and spray cone angle is about 15°. Heavens Major disadvantage with such nozzle is that they tends to dribble. Besides their spray angle is too narrow to facilitate good mixing unless higher velocity are used.

(3) Multi hole nozzle :-

It consists of a no of holes bore bored in the tipe on the nozzle. The no of holes varies from 4-18 and the size from 35-200 μm. The hole angle may be from 20° upwards. These nozzles operate at high injection pressure of the order of 18 MPa. Their advantage lies in the ability to distribute the fuel properly even with lower air motion available in open comb. chamber.

(4) Pintaux nozzle :-

It is a type of pintle nozzle which has an auxilliary hole drill in the nozzle. It inject a small amount of fuel through this addi'al hole which is called pilot injection in the extreme upstream direction slightly before the main injection. The needle seat valve does not lift fully at low speed & most of the fuel is injected through the auxiliary hole. Main advantages of this nozzle is that better cold starting performance. A major drawback of this nozzle is that its injection char. are poorer than the multihole nozzle.

• Injection in S.I. Engine

16/2/2017

Fuel injection systems are commonly used in C.I engines. Presently gasoline injection system is coming into vogue in S.I engine because of the following drawbacks of the carburettor —

① Non uniform distribution of mixture in multicylinder engine.

② Loss of volumetric efficiency due to restriction for the mixture flow.

A gasoline injection system eliminates all these drawbacks. The injection of fuel in to an S.I engine can be employed by the following methods:-

a) Direct injection of fuel into the cylinder

b) Injection of fuel close to inlet valve

c) Injection of fuel into the inlet manifold.

There are two types of gasoline injection system

1) Continuous injection :-

Fuel is injected continuously. It is adopted when manifold injection is used.

2) Timed injection :-

Fuel is injected only during the induction stroke over a limited period.

Major advantages of fuel injection in S.I engine are —

- better thermal efficiency
- lower exhaust emission.
- High quality fuel distribution.
- increased volumetric efficiency.

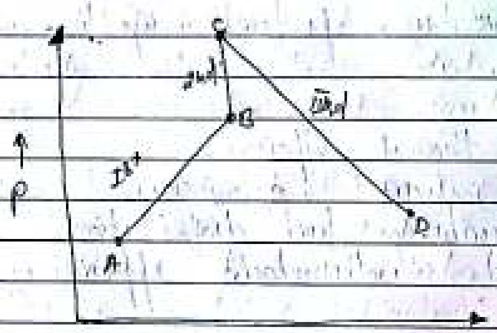
Combustion in S.I. Engine

① Equivalence ratio (ϕ)

It is the ratio of fuel air under normal combustion to the fuel air ratio under stoichiometric condition.

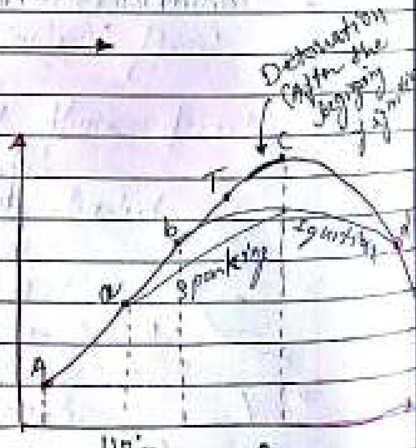
$$\phi = \frac{\text{Actual F/A ratio}}{\text{stoichiometric ratio}} = (1.2) \rightarrow \text{Max. power.}$$

Theoretical P-θ diagram for petrol engine



At (A) → start of compression

(a) → 110° of compression is over and sparking begins at this pt. increase in pressure is higher.



(a-b) → 12° of rotation is over and sparking takes place during this point.

(b) → ignition begins

(A-b) → first stage of combustion over.

(b-T) → 8° rotation is over. Both sparking & ignition takes place. Rise in pressure is very sharp.

(b) → Second stage of combustion start.

(T-C) → 12° of rotation takes place from TDC. Both sparking and combustion occurs.

(C) → Sparking stops.

(B-T) & (T-C) → Second stage of comb. is over.

(D) → 40° of expansion is over from TDC. Ignition stops at this point.

(C-D) → Third stage of combustion is over.

When the spark from the spark plug collides with the fuel then chemical action starts this is the beginning of the first stage comb. The chemical action extends to the different parts of the fuel. The heat developed during the chemical reaction gets distributed to other area. At the end of the chemical action. The different area will have different quantity the heat stored in it.

Detonation (Knocking)

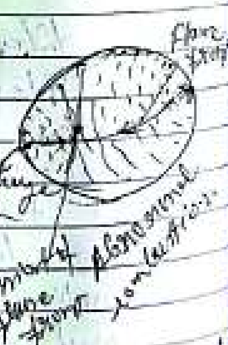
If the temp at the end of chemical action is below the ignition temp, then the fuel particle will never get ignited. It remains as unburnt fuel.

On the other hand, if the temp of the fuel at the end of chemical action becomes equal to ignition temp. of the fuel, then the heat collected from their different ones will meet at a particular pt i.e. at the nucleus and then will get distributed equally in all different part of the fuel particle. Immediately after this distribution of heat the fuel particles gets ignited.

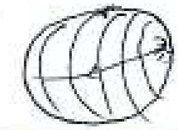
23/8/17

Due to sparking, fuel particle near the spark plug gets ignited. The line joining the different fuel particles under ignition is known as the flame front.

After the formation of first flame front, there will be heat transfer to the neighbouring fuel particle, another flame front will be formed. But it will appear that the first flame front has moved forward and changed. This movement is known as the propagation of the flame front.



When the flame front is propagating forward



The air fuel mixture on the opposite end is known as the end charge.

The following operation takes place for the end charge when there is propagation of ~~frem~~ flame front

- The air particles near the flame front expands and compresses the air fuel mixture in the end charge. The temp of the end charge will increase.

- Chemical ~~are~~ action begins for the end the end temp increases further.

- There is heat transfer from the flame front to the end charge. Temp of the end charge will continue to increase.

- Due to the above ~~set~~ reason the temp of the end charge may become equal to the ignition temp of the fuel. If the flame front reaches the end charge before ~~in the~~ the fuel in the end charge gets ignited. Then the comb. is said to be ~~Smoth~~ smooth. On the other hand if the fuel in the end charge gets ignited before the flame front reaches it, a ~~st~~ separate flame front is developed at the end charge.

The two flame front moves in opposite direction & ultimately collides with one other. This collision is known as knocking or detonation.

During detonation a high energy wave is created from a point i.e. the collision which strikes contact the cyl. and the no. disadvantages takes place.

Date 21/2/2017

Effects of Detonation / Knocking

(i) Noise and Roughness :-

When the intensity of the knock increases at a loud pulsating noise is produced due to the development of a pressure wave which vibrates back and forth across the cyl. The presence of vibratory motion causes crank shaft vibrations & the engine runs rough.

(ii) Mechanical damages :-

a) In most cases of knocking a local and very rapid pressure rise is observed with subsequent waves of large amplitude. This gives rise to increase rate of wear. Erosion of piston crown at also occurs

b) Detonation is very dangerous in engine having high noise level. In small engines the knocking noise is easily detected and the corrective measures can be taken. But even in large high duty engine, it is difficult to detect knocking noise and hence corrective measures cannot be taken. Hence, severe detonation may persist for a long time which may ultimately result in complete wreckage of the piston

(iii) Increase in heat transfer :-

Knocking is accompanied by increase in the rate heat transfer to the comb. chamber wall. The increase in heat transfer is due to two reasons:-

i) The minor reason is that the max. temp. in a detonating reason engine is about 150°C higher than in a non-detonating engine, due to rapid completion of comb.

The major reason for increased heat transfer is the scouring away of protective layer of inactive stagnant gas of on the cylinder walls due to pressure waves. The inactive layer of gas normally reduces the heat transfer by protecting the comb. chamber walls and piston crown from direct contact with flame.

(iv) ii) Decrease in power output & Efficiency :-

Due to increase in the rate of heat transfer the power output as well as efficiency of detonating engine decreases.

(v) Pre-ignition :-

The increase in the rate of heat transfer to the walls may cause local over heating, specially of the sparking plug which may reach a temp high enough to ignite the charge before the passage of spark, thus causing pre-ignition. An engine detonating for a long period would most probably lead to pre-ignition and this is the real danger of detonation.

Theories of abnormal Combustion

1) The detonation theory :-

i) The flame front is progressing in a normal manner (vel. of flame is constant)

2) The fuel partical in the end charge gets ignited simultaneously

(2) Pre-ignition theory :-

The heat is developed during the chemical

ignition delay (ignition) —

action of the fuel near the spark plug extend towards the end charge and it is cause of knocking.

This heat travels at a speed of down the speed of sonic velocity

Factors affecting detonation in Petrol engine

1) Increasing the compression ration :-

Increasing the compression ratio will increase the temp & pressure. Increase in temp reduces delay period of the end gas. Increase in temp as well increase in pressure lead to greater collision of molecules resulting in greater formation of chemical species responsible for knocking and hence, tendency to knock increase.

2) Increasing the load :- (opening the throttle)

More fuel will be used when increasing the temp. of comb. chamber and cylinder liner by reducing the mixture & oxygen temp. Hence the tendency to knock will increase

3) advancing the Spark timing :-

When spark is advance pressure gas is more compressed by the rising piston and there temp & pressure also increases. Thus detonation will be more. [increase]

4) **Distance of flame travel:-**

For more distance covered by the flame front, more time will be taken for the flame travel. Thus, flame front will be developed at the end charge and knocking will occurs. Due to this reason, the cyl. dia of petrol engine is limited to a max. of 15cm.

5) **Location of spark plug:-**

A spark plug which is centrally located in the combustion chamber, is min. tendency to knock as the flame travel is mini.

6) **Location of exhaust valve:-**

The exhaust valve should be located close to the spark plug so that it is not in the end gas region (as spark plug & exhaust valve are the hotest part in the combustion chamber), otherwise there will be tendency to knock.

7) **Increasing the speed:-**

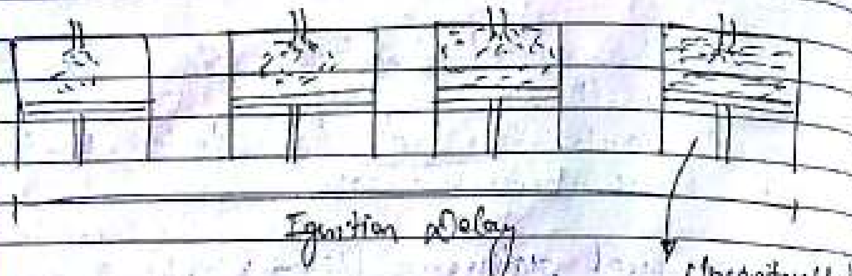
When the speed of petrol engine increased, there will be turbulence. The flame front will reach the end charge faster & tendency to knock will [decrease.]

8) **Air fuel ratio:-** [1:2 → Max. power]

When the equivalence ratio is 1:2 than both temp & velocity will be higher. The present design of comb. chamber is such that the hemispherical shape suppl the high velocity & oppose the rise in temp. Thus, for about equivalence ratio, power is max. and knocking becomes minimum.

23/5/2017 A C.I.

Combustion in C.I. Engine



1. Ignition lag
2. Uncontrolled combustion (I.C.U.A)
3. Controll
4. After burning

Ignition delay :-

Ignition delay is the time duration b/w initiation of fuel injection (diesel molecules) to the beginning of combustion. It can be divided into two parts-

1) Physical delay :- The period of physical delay is the time interval b/w the beginning of injection and the attainment of chemical reaction condition. In the physical delay period fuel is automized, vaporised & mixed with air and raise in temp↑

2) Chemical delay :- The second part of the delay is called chemical delay. In which pre-flame

reactions start slowly and then accelerat untill local inflammation or ignition takes place. Generally chemical delay is longer than physical delay. However, it depends on temp. At high temp. chemical reaction is quicker and physical delay is longer the chemical delay. phy. delay ✗ chemical delay generally

* Stages of Combustion :-

1. Ignition delay :-

During comb. in first stage, the following operation takes place

— Heat from the air flows to the fuel (after crossing the fuel spray)

— After receiving the heat, chemical reaction takes place within the fuel

— The temp. of air decreases or there fore take the heat from surrounding air particles.

The temp. of the comb. chamber at end of the first stage is much higher.

2. Uncontrolled Combustion :-

The air crosses the fuel spray in batches during the second stage. The temp.

of the comb. chamber during the second stage of comb. is much higher. Hence the chemical delay is short during the second stage.

If the comb. takes place for the diff. batches one after another, then the comb. is said to smooth. On the other hand, due to some reason if there is improper comb. for a particular batch of A/F mixture, then more A/F mixture from diff. batches will all get collected together & will release enormous amount of energy after comb. which the piston is not able to handle and detonation occurs. The second stage of comb. is known as uncontrolled comb.

(3) Controlled Combustion:- Already flame is developed in uncontrolled comb., so fuel entering will burnt automatically. Hence the A/F mixture from diff. batches will not get collected together & there is no detonation during the third stage of comb. which is also known as controlled comb.

(4) After burning:- Theoretically, it is expected that comb. process shall end after the third stage. However, because of poor

distribution of fuel particles, comb. continues during part of the remainder of the expansion stroke.

* Factors affecting diesel knock * [ICE 9IA4]

(1) Compression ratio:- Higher compression ratio will result in higher temp. of the charge. The tendency of knock will be [decrease]

(2) Engine Speed:- with increase engine speed the quantity of fuel injected during the delay period increase. thus knocking will [increase]

(3) Increasing the load:- Increasing the load will increase the power o/p for more fuel has to be supplied & thus temp. will be higher which will [decrease] knocking.

(4) Ignition delay:- greater the duration of ignition delay, greater will be amount of fuel accumulation for uncontrolled comb. which will lead to high pressure rise & [increases] knocking.

(5) Advancing the fuel injection:- when the fuel injection is advance, the compression will be more during fuel injection. Hence, there will be higher temp. rise, & knocking will [de]

(6) Atomization :- When there is more atomization, the fuel spray will occupy more space. Physical delay will be more, and then fuel with air combustion will be higher & so the temp which will lessen knocking.

(7) Quality of fuel :- Higher the cetane no. of fuel, it will shorten the ignition delay which would lead to knocking.

* Performance Parameters and Characteristics *

* **Indicated power** :- I.P is the theoretical maximum o/p power of the engine. The I.P. is the total power available from the expanding of the gases in the cylinders negating any friction, heat loss or entropy within the system.

* **Break power** :- B.P is the power output of the drive shaft of an engine without the power loss caused by gear, transmission etc. It is also called pure power, useful power, true power or shaft power.

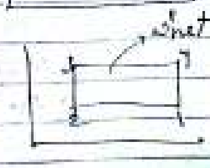
* **Mechanical Efficiency** :- Mechanical efficiency is how much of the power delivered by the expanding exp of the gases in the cylinder is actually delivered as useful power. It

$$\eta_m = \frac{B.P}{I.P}$$

* **Indicated Mean Effective pressure** :-

$W'_{net} = W''_{net}$

$W_{net} = P \times V_s$



$V_s = V_1 - V_2$

Imean p = b mean p. + f mean p.

Indicated mean effective pressure is the uniform pressure that would be required throughout the power stroke of an engine to do the same amount of work as is done by the varying pressure that are infact obtained during the stroke.

Break mean effective pressure is the proportion of indicated mean effective pressure is available to perform external work at the flywheel.

The difference b/w IMP & BMP is equal to mean pressure required to overcome engine friction and to perform the function of filling & emptying the cylinder and of driving the auxiliaries such as oil & water pumps, generator and so on. These are generally known as friction & pumping ~~losses~~ losses.

$$imp = bmep + fmep$$

Indicated net work/cycle, $W_{net} = P_{im} \times V_s$

Indicated power ; IP = Indicated net work/cycle × $\frac{cycle}{s}$

$$I.P = \frac{P_{im} \times V_s \times n \times K}{60 \times 1000} \ kW$$

: $K \rightarrow$ no. of cylinder

n = no. of power strokes per minute

$n = \frac{N}{2}$ (4 stroke)

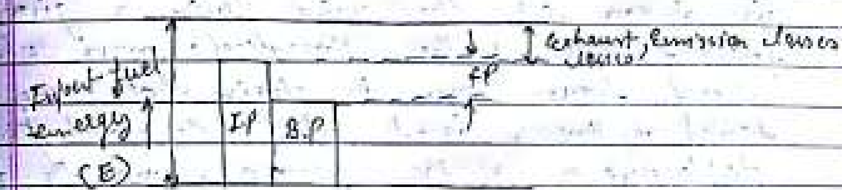
$n = N$ (2-stroke)

N in rpm

L – stroke length

$$I.P = \frac{P_{im} \times LANK}{60,000} \ kW$$

$$B.P = T\omega = \frac{2\pi NT}{60,000} = \frac{P_{bm} \ LANK}{60,000} \ kW$$



$$\eta_{Ith} = \frac{IP}{E} = \frac{IP}{\dot{m}_f \times CV}$$ indicated thermal efficiency.

$$\eta_{Bth} = \frac{BP}{E} = \frac{BP}{\dot{m}_f \times CV}$$

Indicated thermal efficiency is the ratio of energy in the indicated power to the input fuel energy.

Break thermal efficiency is the ratio of energy in the break power to the input fuel energy.

(*) Indicated specific fuel consumption (*) $ISFC = \frac{\dot{m}_f}{IP}$

ISFC is a amount of mass flow required to delivered ~~one~~ 1 kW indicated power.

$\dot{m}_f \rightarrow kg/s$, $I.P \rightarrow kW$ } $\frac{kg}{kWs} \times 3600$ } $\frac{kg}{kWhr}$

* **Brake specific fuel consumption**

It is the amount of mass flow rate of fuel required to produce 1 kW brake power.

* **Volumetric efficiency**

It is defined as the ratio of actual mass of air drawn into the engine during a given period of time to the theoretical mass which should have been drawn during that same period of time, based upon the total piston displacement of the engine, and the temperature & pressure of the surrounding atm.

It indicates the breathing ability of the engine.

$$\eta_v = \frac{m_{actual}}{m_{theoretical}} = \frac{V_{air}}{V_s}$$

$$\boxed{V_s = \frac{\pi}{4} d^2 l}$$

$d \to$ bore

$l \to$ stroke

* **Scavenging Efficiency** –

It is defined as the ratio of the amount of air or gas air mixture which remains in the cylinder, at the actual beginning of the compression to the product of total volume and the air density of the inlet.

$$\eta_{sc} = \frac{\text{Actual air/gas mixture}}{\text{air density} \times \text{Total volume}}$$

Combustion efficiency – It is defined as the ratio heat liberated to the theoretical heat in the fuel. The amount of actual heat liberated is less than the theoretical value because of incomplete combustion due to lack of available oxygen.

Ques) A single cylinder engine running at 1800 rpm develops a torque of 8 Nm. The I.P. of the engine is 1.8 kW. Find the loss due to friction power and as the percentage of B.P.

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 1800}{60}$$

~~B.P. = 2πN~~

$$= 188.5$$

B.P. = T×ω

~~= 8×188.5 = 1508~~ 1507.96

$$= \frac{2\pi NT}{60000} = \frac{2\pi \times 1800 \times 8}{60000} = 1.508 \text{ kW}$$

Given

I.P. = 1.8 kW, F.P. = 0.

imp = Bmep + fp

1.8 kW = 1.508 + F.P.

F.P. = 0.292

$$\% \ F.P. = \frac{0.292}{1.507} \times 100$$

$$= 19.44\%$$

Que. A gasoline engine working on otto-cycle consumes 8 litre gasoline per hour. It develops 25 kW. The specific gravity of gasoline is 0.75 & calorific value is 44000 kJ/kg. Determine the indicated thermal efficiency of the engine.

Solution →

$$\eta_{ith} = \frac{IP}{E} = \frac{IP}{\dot m_f \times CV}$$

$$\rho = 0.75 \times 1000 = 750\ kg/m^3$$

$$V = 8\ lt/hr = 8\times10^{-3}\ m^3/hr = \frac{8\times10^{-3}}{3600} = 2.22\times10^{-6}$$

$$\dot m_f = 2.22\times10^{-6}\times 750 = 1.666\times10^{-3}$$

$$\eta_{ith} = \frac{25}{1.666\times10^{-3}\times 44000} = 0.3410$$

$$= 34\%$$

Ques → The bore and stroke of a water cooled vertical, single cylinder, four stroke diesel engine are 80 mm & 110 mm respectively & the torque is 23.5 Nm. Calculate the brake mean effective pressure of the engine.

$$BP = \frac{2\pi NT}{60{,}000} = \frac{P_{mb} LANK}{60{,}000}$$

$$\frac{2\times\pi NT}{60{,}000} = \frac{P_{mb} LANK}{60{,}000} \quad K=1$$

$$2\pi NT = P_{mb}\cdot L\times A\times\frac{N}{2}\times 1$$

$$2\pi T = P_{mb}\cdot L\times\frac{\pi}{4}(d)^2\times\frac{1}{2}$$

$$4\pi T = P_{mb}\times 110\times\frac{\pi}{4}(80)^2\times\frac{1}{2}$$

~~$4\pi(23.5)$~~

$$295 =$$

$$\boxed{P_{bm} = 5.34\ bar}$$

Find the mean effective pressure and torque developed by the engine in the previous problem if its rating are 4 kW at 1500 rpm.

$$B.P = \frac{2\pi NT}{60{,}000}$$

$$\frac{4\times10^7\times60{,}000}{2\pi N} = T$$

$$\boxed{T = 25.46\ Nm}$$

$$\frac{2\pi NT}{60{,}000} \quad 25.46 = \frac{P_{bm} LANK}{60{,}000}$$

$$\frac{25.46\times60{,}000}{LANK} = P_{bm}$$

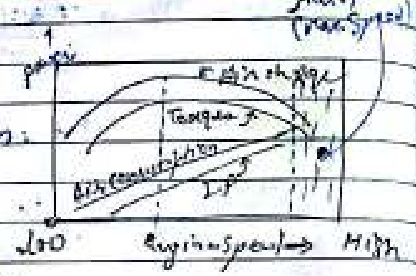
$$\frac{25.46\times60{,}000}{0.11\times\frac{\pi}{4}(80)^2\times\frac{N}{2}\times1} = P_{bm}$$

$$2\times25.16\times4\times2$$

5.78 bar

* Engine Performance Characteristics *

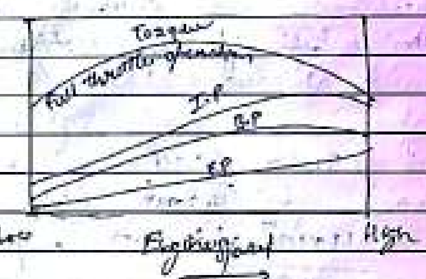
(I) At certain speed charge inducted per cyl. per cycle will be maximum. At this point max. force can be exerted on the piston and those the torque an engine capacity to do work will be maximum.



Increase in air consumption means that increased quantities of fuel can be added per unit time increasing the power output.

Date 9/3/2017

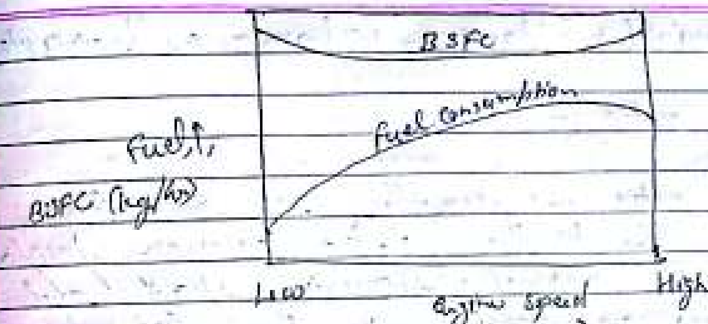
(II)



At low engine speed B.P. relatively low & B.P is close to I.P. As engine speed increases F.P increases at a greater rate.

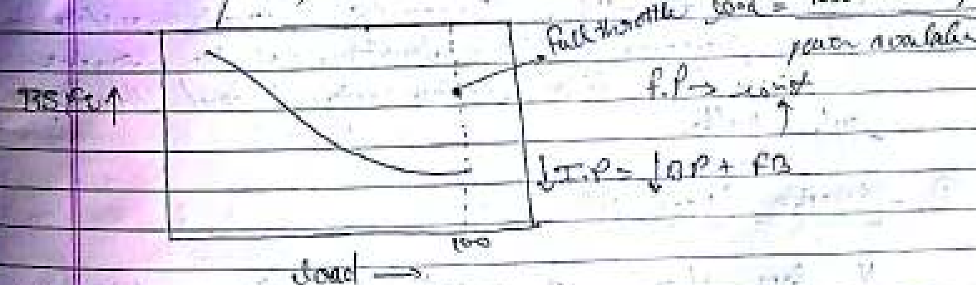
$\uparrow$ I.P = B.P + F.P $\uparrow$

(III)



The quantity of fuel consume increases with increasing engine speed. BSFC drops as the speed increase in the low speed range, levels off at medium speed and increases in the high speed range.

(IV) Constant speed, constant A/F ratio, Variable load



At const. speed and variable load and at const. A/F ratio, BSFC will rise consistently and rapidly as the load (and throttle opening) is decreased. The B.P drops more rapidly than fuel consumption & hence by BSFC rises.

Variables Effecting Performance Characteristics

① A/F ratio :-

A/F ratio is usually set as close as possible to the best economy proportion during normal cruising speed and as close as possible to the best power proportion when max. performance is required.

② Compression ratio :-

An increase in compression ratio increases the thermal efficiency. The compression ratio in most SI engines is limited by knock & the use of economically feasible anti-knock quality. Increasing comp. ratio also increases the friction of the engine particularly the piston rings and the cyl. walls.

③ Engine Speed :-

At low speed a greater length of time is available for heat transfer to the cyl. walls & there for a greater proportion of heat loss occurs. Higher speed produce greater air consumption and there for greater indicated power which are accompanied by rapidly increasing system power loss by greater inertia in the moving parts.

④ Mass of inducted Charge :-

The greater the mass of the charge inducted the higher the power produced, for a given engine, the geometric is fixed, and it is desirable to induct a charge to the max. possible density giving the highest volumetric efficiency.

⑤ Heat losses :-

It should be noted that the large proportion of the available energy is lost in a non usable form i.e. heat losses. Any method can be employed to prevent the excessive heat loss and cause this energy to leave the engine in a usable form which will tend to increase engine performance. Higher coolant temp. will provide a smaller temp. gradient around the comb. chamber wall which will lead to reduction in heat losses.

$\downarrow Q \propto \frac{dT}{dx}$

* Methods of improving engine performance *

Heat input ↑ → mass of air charge ↑ &

Eff ↑
→ CR — Vol. ↑, piston disp ↑, Better quality fuel
→ Turbo

→ Engine performance can be increased by two ways.

① The energy put into the engine at the start may be increased

② The efficiency with which the fuel energy is converted to mechanical energy may be increased

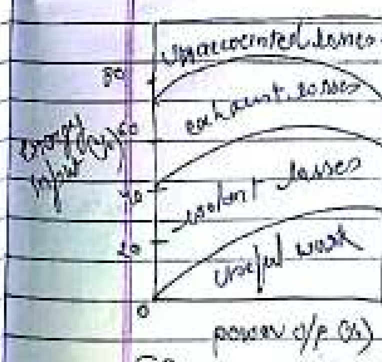
Energy supply may be increased by increasing the mass of charge entering the comb. chamber. Larger piston displacement is also one of the method to increase the mass of charge intake, but is limit by the engine's weight & cooling problem. Improvement in volumetric efficiency would also increase the mass of charge. Higher engine speed may be utilized, but these result in increase further losses. Improvement in fuel result in greater usable energy obtain without detonation will would also help.

The use of higher comp ratios would increase the efficiency of conversion of the energy in the fuel into usefull mechanical energy. This requires the development of economically feasible higher anti-knock quality fuel.

Turbo compound engine are also used to ↑ the efficiency of fuel energy to convert into mechanical energy

Turbo compound engine is a reciprocating engine that employs a turbine to recover energy from the exhaust gases which is connected to the engine crank shaft, also increasing the engine output which acts as power booster. It is placed b/w exhaust manifold & exhaust pipe.

→ Heat balance :-



[for CI engine]

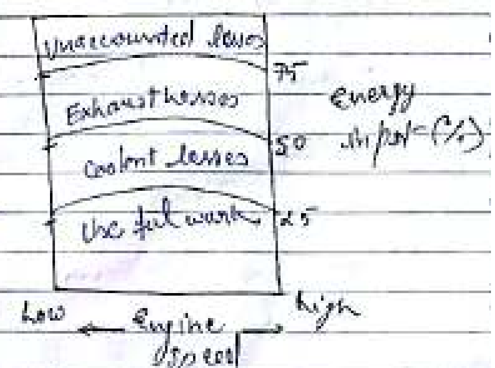


Fig: for S.I. Engine.

Energy supplied to an engine is the heat value of the fuel consume. As we know only a part of this energy is transformed into useful work. The rest of it either wasted or utilized in special application like turbo compounding.

Gas turbine

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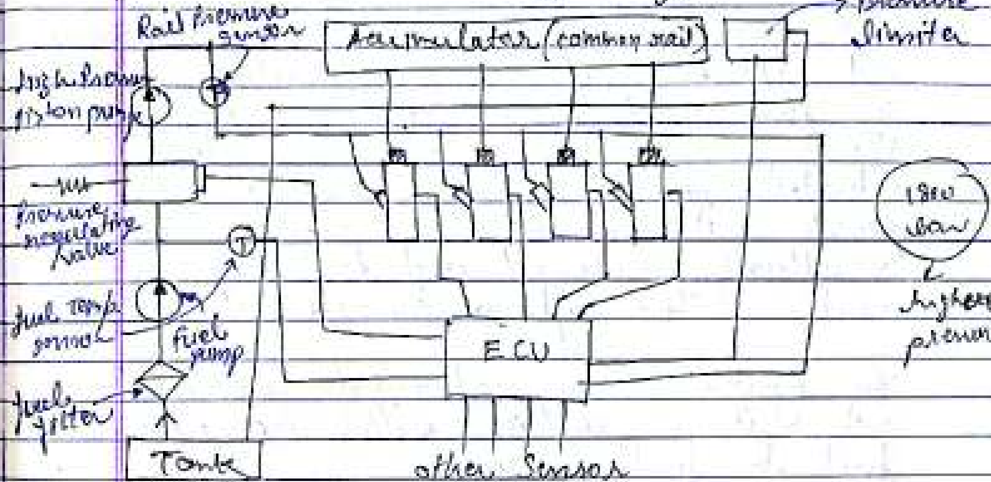
Electronically controlled unit (ECU)

Changes in fuel injection method

1) * Common rail diesel injection system :-



CRDI is used for direct injection of the fuel into the cyl. of an diesel engine via single common line called the common rail which is connected to all fuel injectors. Fuel from the fuel tank passes through a fuel filter through a low pressure pump where the the pressure is raised to reasonable higher value. The fuel temp. is monitored by temp. sensor. Then the fuel goes to higher pressure pump. A pressure regulator valve controls the pressure.

In modern CRDI system, the outlet pressure can be high as 1900 bar. The highly pressurised fuel goes to accessory accumulator, which is called common rail. The pressure in the common rail is monitored by the rail pressure sensor.

In the CRS, a high pressure pump stores a reservoir of fuel at very high pressure and supplies fuel to the multiple injectors. The fuel injectors are typically ECU controlled. When the fuel injectors are electrically activated, a hydraulic valve (consisting of a nozzle and plunger) is mechanically or hydraulically opened and fuel is sprayed into the cyl. at the desired pressure.

The injector is an electronically controlled valve, and it is supplied with pressurised fuel by fuel pump.

At the end of each injector, rapid acting solenoid valve adjust both the injection timing and the amount of fuel injected. The amount of fuel supplied to the engine is determined by amount of time the fuel injector stays opened this is called the pulse width, and it is controlled by ECU.

ECU can optimise the injector timing the quantity considering the variations in fuel quantity, cold starting etc.

Because of the precised timing controlled by ECU,

	W_1	W_2	Speed (rpm)	Time for 10cc of fuel (sec)
1	0	1		
2	0.5	2.5		
3				

CRDI system introduced forced comb. process. During this process, a small amount of fuel is injected during the expansion stroke thus creating small scale comb. after the normal comb. ends, which eliminate the exhaust particals and increases the exhaust gas temp. and hence reduce emissions.

⇒ Advantages of CRDI system

1. Improve power, increase fuel efficiency & reduce noise
2. Less emissions and reduced particulates in the exhaust
3. Precised injection timing, very high injection pressure and better stability
4. Better atomization of fuel

* Gasoline Direct injection system

In a multicylinder engine with the carburetor it is difficult to obtain uniform mixture in each cylinder. The various cylinder receives the air-gasoline mixture in varying quantity & richness. This problem is called mal distribution and can be solved by port of injection system by the same amount of gasoline injected at each cylinder.

The adopting gasoline injection each cylinder can get the same richness of the air-gasoline mixture and the mal distribution can be avoided to a great extend.

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* Reasons for Gasoline Direct injection system :-

- To have uniform distri. of fuel in a multi-cyl. engine.
- To prevent fuel loss during scavenging. & also to reduce or eliminate detonation.

\# In GDIS, gasoline is pressurised and injected by a common rail fuel line, directly into the comb. chamber of each cyl. This different from the conventional multipoint fuel injection System. In which injection takes place in the intake manifold or cyl. port.

In GDIS less fuel is required to produce equivallent horse power specially at normal crossing speed compare to conventional injection system. In some application gasoline direct injection enables a stratified fuel charge (ultra-lean burnt) comb. for improved fuel efficiency and reduced emission level at low load.

\# Advantages of GDIS :-

1. Increase fuel efficiency and higher power output.
2. Emission levels can also be more accurately controlled.
3. There are no throttling losses and pumping losses are considerably reduced.

(c) Engine speed is controlled the engine control unit and engine management system which regulates fuel injection function & injection timing.

* EMS changes among three comb. modes —
- Ultra lean mode, stoichiometric & full power output.

- Ultra-lean burnt mode :-
Ultra lean burnt mode is used for light load running condⁿ, at const. or reducing road speed where no accⁿ is required. The fuel is injected at the latter stages of compression stroke. By this a small amount of air-fuel mixture is optimally placed near the spark plug. This stratified charge is surrounded mostly by air. This leaves keep the fuel and flame away from the cyl. walls by which lowest emission & heat losses are achieved. This technique enable the use of ultra lean mixture that would be impossible with carburetor or conversional fuel injection system.

Stoichiometric mode is used for moderate load condⁿ. Fuel is injected during the intake stroke and a homogeneous fuel-air mixture is formed in the cyl.

Full power mode is used for rapid acc. and heavy loads. The A/F mixture is homogeneous & ratio is slightly richer the stoichiometric mixture.

* Variable valve Technology (VVT) *

VVT is the process of altering the timing of a valve lift event and is often used to improved performance, fuel economy or emission. It is being used in combination with VV lift system. There are many ways in which this can be achieved ranging from mechanical devices to electro hydraulic and cam less system.

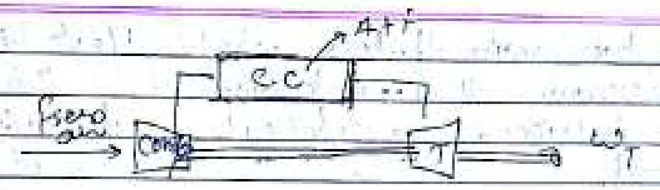
The valves within in IC engine are used to control the flow of intake and exhaust gases into & out of the comb. chamber. The timing, duration and lift of these valve event has a significant impact on engine performance.

Piston engine normally used valves which are driven by cam shaft. Cam to open the valve for a certain amount of time during each intake and exhaust cycle. The timing of the valve opening and closing is also imp. The cam shaft is driven by the crank shaft through timing belts, gears, chains.

In engine require large amount of air when operating at high speed. However, the intake valves may close before enough air enters the comb. chamber, reducing performance. On the other hand if the cam shaft keeps the valve open for longer period of time, problem start to occur at the lower engine speed & it will lead to loss engine performance & increase emission.

* —— * —— * —— *

UNIT-IV



Simple GC

Gas turbine: The first step in the cycle of a gas turbine plant must be compression of working fluid. If after the compression the working fluid is directly expanded in turbine & there be no losses in other component the power developed by the turbine it would just be equal to that absorbe by the compressor.

The power developed by the turbine can be increased by the addition of energy to raise the temp of the fluid prior to expansion. When the working fluid is air, a very suitable means of doing this is by the comb. of fluid in fuel in the air which has been compressed. Expansion of hot working fluid then produces a greater power o/p from the turbine than the power necessary to drive the compressor.

The three main component are, a compressor, a comb. chamber, and a turbine connected together as shown in the above figure.

The two main factors which affect the performance of gas turbine are the eff. of various components and turbine working temp.

+ Classification of gas turbine cycle :-

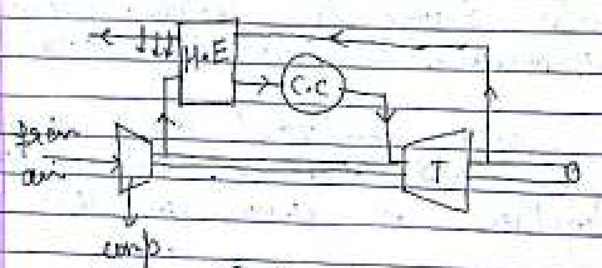
It can be classified into two categories

① Open cycle arrangement

② Closed ,,

Open cycle arrangement :-

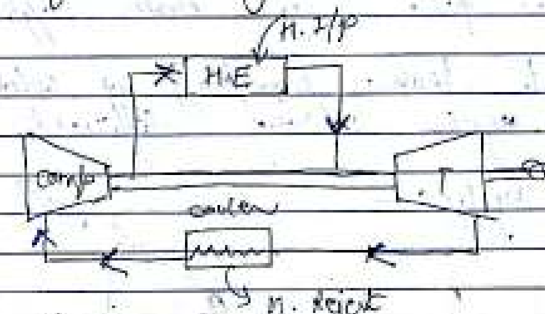
① fig: A simple gas turbine with single shaft arrangement.



② fig: A simple gas turbine with heat exchanger.

In this arrangement fresh atm. air is drawn into the system continuously and energy is added by comb. of fuel in the working fluid it self. The products of combustion are expanded through the turbine and exhausted into the atm.

② Closed - cycle arrangement :-



In the close cycle, the same working fluid being i.e. air or some other gas, is repeatedly circulated through the system

Advantages :-

① Greater thermal efficiency b/c same max & mini temp.

② Any better working substance like argon, helium etc can be used.

Any lower grade of fuel can be used, because working substance not mixed with fuel.

It can work below atm. pressure.

Disadvantages:-

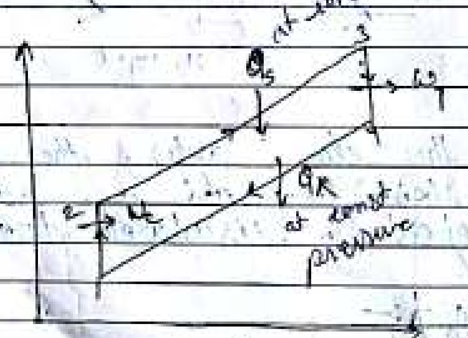
① The cycle becomes complicated and bulky costly.

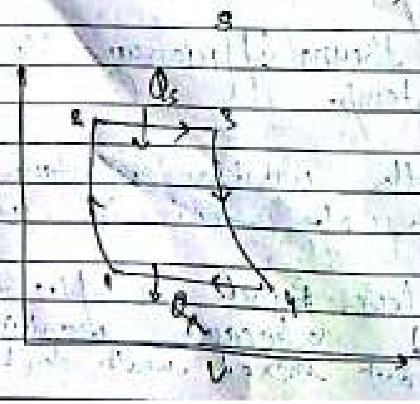
② Because of being very bulky it can't be used for air craft application.

③ Absolute leake proofing of below atmospheric at cycle is very difficult.

* Brayton Cycle :-

Ideal cycle





$Q_S = h_3 - h_2 = c_p(T_3 - T_2)$

$W_C = h_2 - h_1 = c_p(T_2 - T_1)$

$W_T = h_3 - h_4 = c_p(T_3 - T_4)$

$Q_R = h_4 - h_1 = c_p(T_4 - T_1)$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$

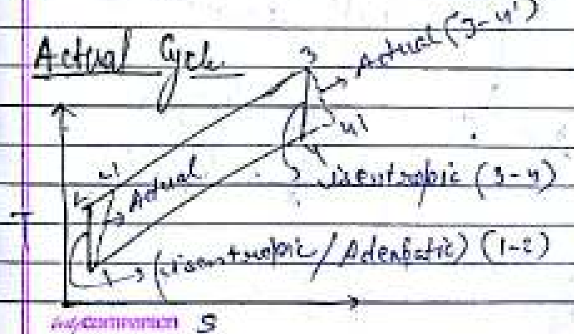
$P_2 = P_3$ & $P_1 = P_4$

$\frac{P_2}{P_1} = \frac{P_3}{P_4} = r_p$ (pressure ratio)

$\eta = \frac{W_{net}}{Q_S} = \frac{W_T - W_C}{Q_S}$

$$\eta = 1 - \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}}$$

Actual Cycle



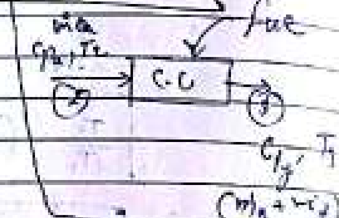
$\eta_c = \frac{\text{Isentropic work}}{\text{Actual work}}$

$\eta_T = \frac{\text{Isentropic work}}{}$

$\eta_T = \dfrac{\text{Actual work}}{\text{Isentropic work}}$

$$\eta_c = \frac{h_2 - h_1}{h_2' - h_1}$$

$$\eta_T = \frac{h_3 - h_4'}{h_3' - h_4}$$



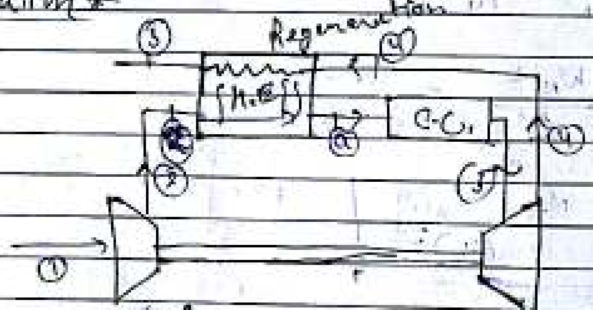
Heat released = Enthalpy rise

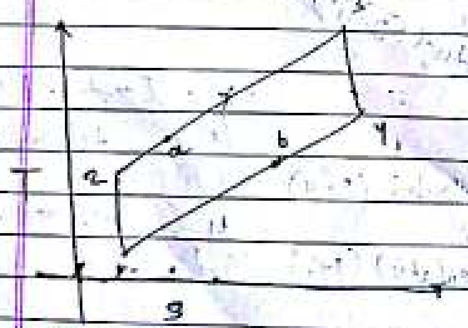
$\Rightarrow \dot{m}_f \times LCV \times \eta_c =$

$[(\dot{m}_a + \dot{m}_f) h_3 - \dot{m}_a h_2]$

$$\left[\dot{m}_f \times LCV \times \eta_c = (\dot{m}_a + \dot{m}_f) C_{p_g} T_3 - \dot{m}_a C_{p_a} T_2\right]$$

* Regeneration *





$Q_s = h_5 - h_a$

$Q_R = h_6 - h_7$

Effectiveness

$$\left[\epsilon = \frac{\text{Actual temp. rise}}{\text{Theoretically/max. temp. rise}} = \frac{T_a - T_2}{T_4 - T_2} \right]$$

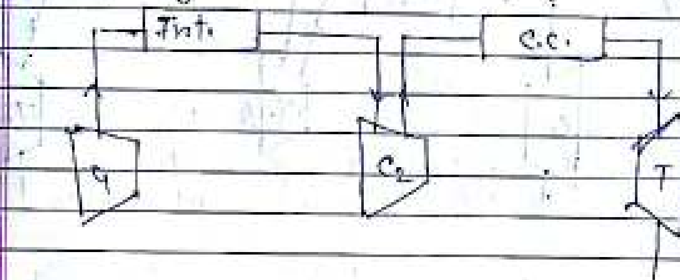
For ideal regenerator ☆

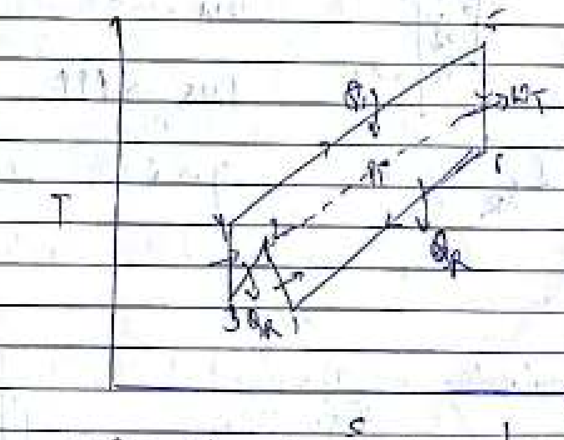
$T_a = T_4$

$T_b = T_2$

$$\eta_{ideal} = 1 - \frac{T_1}{T_3}(r_p)^{\frac{\gamma-1}{\gamma}}$$

* Interpolling :





$T_{m_A} \downarrow \downarrow$

$T_{m_R} \rightarrow \downarrow$

$\eta \downarrow$

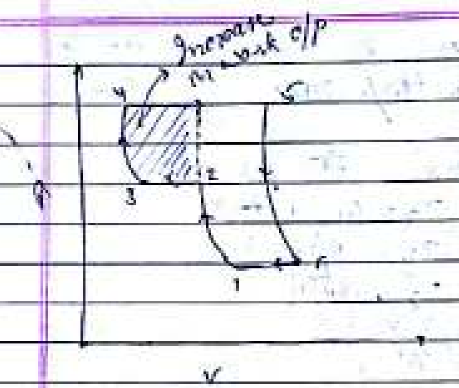
$W_T = c_p(T_5 - T_6) = c_p(h_5 - h_6)$

$Q_s = c_p(h_5 - h_4)$

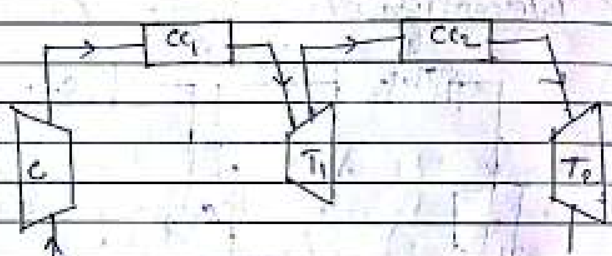
$Q_R = (h_6 - h_1) + (h_2 - h_3)$

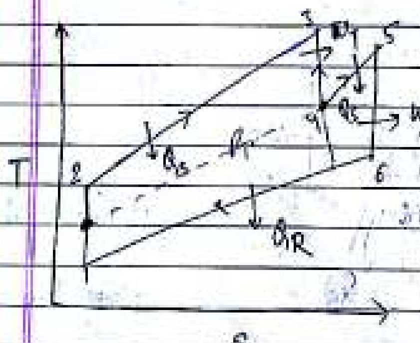
$W_c = (h_2 - h_1) + (h_4 - h_3)$

Perfect Intercooling → $T_1 = T_3$
$W_{c_1} = W_{c_2}$
$P_2 = \sqrt{P_1 P_1}$



* Reheating



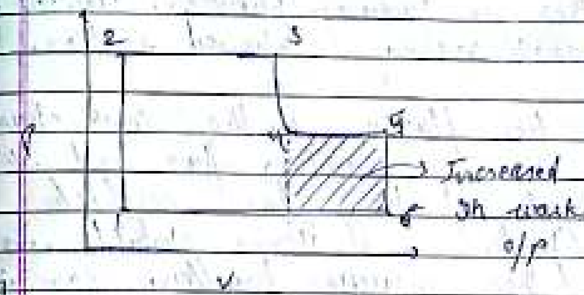


$T_{MA} \rightarrow \uparrow$

$T_{MR} \rightarrow \uparrow\uparrow\uparrow$

$\eta \rightarrow \downarrow$

Perfect reheating → $T_3 = T_5$
$W_{T_1} = W_{T_2}$
$P_i = \sqrt{P_2 P_1}$



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* Combustion System :- The purpose of any combustion system of power generating system is to convert the chemical energy of fuel into the heat energy. The generated heat energy given to the gas, further used to convert into kinetic energy. This kinetic energy is converted into the work pushing through the prime move of the system in gas turbine.

* Basic requirements of gas turbine comb. system :-

① It must be high comb. efficiency for generating the power at lower cost

② The total pressure loss in the comb. chamber (friction and turbine loss and combustion pressure loss) should be as minimum as possible. This factor is very imp. as 1% pressure of loss causes 5% reduction in the plant efficiency. In addition to this, the max. pressure ratio

~~in out~~ of the gas turbine plant is limited to 10 for the reason mentioned earlier.

(4) There must be flame in the comb. chamber always as it is continuous flow and it must propagate properly for complete comb. of fuel. Flame stability is one of the measure problem as it is to be stabilized in a high vel. flow. Flame velocity being considerably low (20 m/sec), some artificial method should be developed as the flow velocity is 10-15 time high than the flame vel.

(5) The comb. should be stable & smooth over the full operational range & provide uniform pressure) gases ~~at~~ going to turbine.

(5) The size and weight of the comb. system should be as small as possible. This is very imp. parameter when the plant is used for aeroplane. Because this requires power to lift the weight during flight. The size should be as compact as possible because space available is small.

(6) As comb. chamber is subjected to high temp. (2000°C) and that also continuously, it is essential to cool the comb. chamber walls to extend the life of the comb. chamber.

(7) The carbon deposit should ~~t~~ not be forming in the surface of the comb. chamber. This is because, it upsets the designed flow ~~pattern~~ pattern and increase the pressure loss due to blockage. If the smoke is formed as carriage with the gases it will start depositing on the blade and disturbe the ~~pr~~ blade profile which is very sensitive for developing the power. Therefore the longer life of comb. chamber as efficient operation of the turbine, formation of carbon ~~deposit~~ deposits and smoke and there their depositing in comb. chamber & turbine blades are high objectionable.

* Factors affecting the performance of the C.C. :-

① Pressure loss :-
The total pressure loss in the comb. chamber is friction pressure loss and comb. pressure loss. The designed is such that the ~~pr~~ pressure loss is should be min. as possible ~~the~~ for better performance of the comb. chamber.

~~If~~ If the fuel turbulence is increased for better evaporation and higher comb. efficiency, the pressure loss increases. As the comb. intensity is increased for small comb. chamber, the comb. pressure loss increases.

This indicates that all the parameters are inter related effect so it is necessary to optimize for better effect.

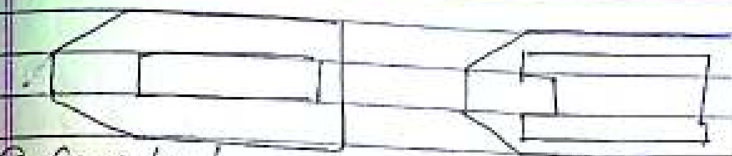
② Comb. intensity & efficiency:-

As mentioned above, both the higher values are essential but the parameters affecting both the properties adversely affect the pressure loss, therefore, a compromise is to be made for the best result among all the parameters in design.

① Comb. chamber configuration:-

Once the volume required for the comb. chamber is fixed considering the parameters mentioned, then the next state is to decide the shape of the comb. chamber.

Reduced length is desirable as it makes the comb. chamber more compact but the min. length should be enough to complete the comb. before entering the turbine otherwise comb. efficiency will be reduced very much. Two arrangements of the comb. chamber are shown below whose total vol. is same but the selection on the basis of optimum effect of pressure loss and comb. efficiency.



(a) Conventional arrangement

(b) Bottle-bank Double-bank arrangement

③ Temp. Distribution of the gas stream before entering the turbine:-

As we know longer life of turbine is possible with uniform temp. of the gas flame. Non-uniform temp. stream generates hot-spots on the turbine blade and reduces its life. In addition to this, non uniform stream of the gas causes un-evenly expansion and high localized stress sets up. This might result in warping and even trapping of the blades.