LUKHADHIRJI ENGINEERING COLLEGE - MORBI

MECHANICAL ENGINEERING DEPARTMENT

LAB MANUAL

INTERNAL COMBUSTION ENGINES (3171923)

(Professional Elective V)

NAME:	
EN.NO:	
SEM:	**DIVISION:**
ACADEMIC YEAR:	

LUKHADHIRJI ENGINEERING COLLEGE

MORBI

MECHANICAL DEPARTMENT

CERTIFICATE

This to certify that Mr /Ms. ___________________________________ (Enrolment Number __________________________ from **Mechanical Engineering** course in semester **VII** has satisfactorily completed the course in Academic Year _______________; as a partial fulfilment of subject **(PE-V) Internal Combustion Engine – (3171923)** within the walls of Lukdhirji Engineering College MORBI - 363642

*Date of Submission:*_______________

Staff in-Charge

H.O.D.

Mechanical Department

Vision of the Institute

To provide quality engineering education and transforming students into professionally competent and socially responsible human beings.

Mission of the Institute

- To provide a platform for basic and advanced engineering knowledge to meet global challenges
- To impart state-of-art know- how with managerial and technical skills
- To create a sustainable society through ethical and accountable engineering practices

Vision of the Department

To deliver quality engineering education for Mechanical Engineers with Professional competency, Human values and Acceptability in the society.

Mission of the Department

- To nurture engineers with basic and advance mechanical engineering concepts
- To impart Techno-Managerial skill in students to meet global engineering challenges
- To create ethical engineers who can contribute for sustainable development of society

Program Educational Objectives (PEOs)

Mechanical Engineering graduates will be able to,

1. Apply the knowledge of basic science and engineering to analyze and solve problems related to mechanical engineering.
2. Design and develop the new system/process using advanced tools and technologies.
3. Enhance professional practice to meet global challenges with ethical and social responsibility.

Program Specific Outcomes (PSOs)

1. Students will be able to apply the knowledge of computer aided tools for design and development of products based on engineering principles.
2. Students will be able to manage production of components/systems using conventional and advanced manufacturing methods.

PROGRAM OUTCOMES (PO'S)

PO1 **Engineering knowledge**: Apply the knowledge of mathematics, science, Mechanical engineering fundamentals and specialization to the solution of complex engineering problems.

PO2 **Problem analysis**: Identify, formulate, review research literature, and analyze compl ex mechanicalengineering problems reaching substantiated conclusions using first pr inciples of mathematics, natural sciences, and mechanical engineering.

PO3 **Design/development of solutions**: Design solution for complex mechanical engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4 **Conduct investigations of complex problems**: Use research-based knowledge and researchmethods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5 **Modern tool usage**: Create, select and apply appropriate techniques, resources and modern engineering and IT tools including prediction and modelling the complex mechanical engineering activities with an understanding of the limitations.

PO6 **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess social, health, safety, legal and cultural issues and the cons and the consequent responsibilities relevant to the professional engineering practice.

PO7 **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8 **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9 **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10 **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11 **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12 **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

SYLLABUS

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

COURSE OBJECTIVES & COURSE OUTCOMES

Sr. No.	CO statement	Marks % weightage
CO 1	Describe and explain the major phenomena going on in an internal combustion engine such as gas exchange, combustion and emissions formation/reduction.	40
CO 2	Explain the performance and evaluation of internal combustion engine and to discuss how this is affected.	35
CO 3	Reflect on the role of internal combustion engines for transports in society as well as the emissions issue from both a sustainable and ethical perspective.	10
CO 4	To aware about the alternative fuels and their properties.	10
CO 5	To brief the latest development of unconventional engines.	5

Content

Sr. No.	Course Content	Total Hours
1	**Introduction:** Comparison of SI and CI Engines, Difference in thermodynamic and operatingvariables, comparison of performance characteristics, comparison of initial and maintenancecosts application of SI and CI engine.	4
2	**Fuels and its supply system for SI and CI engine:** Important qualities of IC engine fuels, rating of fuels, Carburetion, mixture requirement for different loads and speeds, simple carburetor and its working, types of carburetors, MPFI, types of injection systems in CI engine, fuel pumps and injectors, types of nozzles, spray formation.	6

3	**Combustion in SI and CI Engines:** Combustion equations, calculations of air requirement in I C Engine, stoichiometric air fuel ratio, proximate and ultimate analysis, enthalpy of formation, adiabatic flame temperature. Stages of combustion in SI engines, abnormal combustion and knocking in SI engines, factors affecting knocking, effects of knocking, control of knocking, combustion chambers for SI engines. Stages of combustion in CI engines, detonation in C.I. engines, factors affecting detonation, controlling detonation, combustion chamber for SI and CI engine.	8
4	**Engine lubrication:** Types of lubricants and their properties, SAE rating of lubricants, Types of lubrication systems Engine Cooling: Necessity of engine cooling, disadvantages of overcooling, **Cooling systems and their comparison:** Air cooling, Liquid cooling Supercharging/Turbo-charging: Objectives, Limitations, Methods and Types, Different arrangements of turbochargers and superchargers	7
5	**Rating, Testing and Performance:** Measurements of speed, air flow, fuel consumption, indicated power brake power, frictional horse power, and smoke, testing of engines as perIndian Standard 10001, performance test for variable speed I C Engines, heat balance sheet,governing test for constant speed IC engines, effect of fuel injection parameters in CI engines and ignition advance of SI engines on performance of engine. Rating of internal combustionengine based on (I) continuous operation of engine (II) Maximum power an engine can develop (III) Power calculated from empirical formula, Trouble Shooting and Overhauling of Engines.	8
6	**Emission of IC engine:** Emission from SI engine, effect of engine maintenance on exhaust emission control of SI engine, diesel emission, diesel smoke and control, diesel and control comparison of gasoline and diesel emission. Measurement and calculation for of emission constituents.	6
7	**Unconventional Engines &Alternative Fuels for IC Engine:** Working principle of stratified charge engines sterling engine, Wankel engine Methanol, Ethanol, vegetable oils, bio gas, bio-fuels, hydrogen and comparison of their properties with Diesel and petrol.	6

Reference Books:

1. I. C. Engines by Heywood.
2. I. C. Engines by Mathur& Sharma, Dhanpatrai
3. I. C. Engines by V.Ganeshan, Tata McGraw Hill
4. I. C. Engines by Domkundwar&Domkundwar, Dhanpatrai
5. I. C. Engines by R.K.Rajput, LaxmiPrakashan

INDEX

Sr No.	Experiment	Course Outcome	Page No.	Date of Experiment	Marks (20)	Sign with Date
1	To study about Classification and different parts of IC Engines.	**CO1**				
2	To Construct the Valve Timing Diagram for a given single cylinder I C Engine.	**CO1**				
3	To study about different carburetion system in SI engine	**CO2**				
4	To Study about Combustion in SI and CI Engine.	**CO3**				
5	To carry out performance test of computerized four stroke single cylinder diesel engine test rig	**CO4**				
6	To draw a Heat Balance sheet for computerized four stroke single cylinder diesel engine test rig	**CO4**				
7	To study about engine emission and it's control	**CO4**				
8	To study of properties of scope of alternative fuel.	**CO5**				
9	To study of latest development of some unconventional engines	**CO5**				

TERM WORK RUBRICS

Name:

Enrolment Number:

Subject:

Academic Year:

	Excellent	Very good	good	Needs Improvement
Regularity				
Involvement in Lab/Assign Work				
Content Accuracy				
Illustration and Diagram				
Overall Organisation				
Overall rating				

Signature of Faculty

Experiment No: 1

AIM: To study about Classification and different parts of IC Engines.

Objective: students should be able to….

1. Classify various types of engines
2. Relate the name and functions of different parts of engine.

Engine Classifications

Internal combustion engines can be classified in a number of different ways:

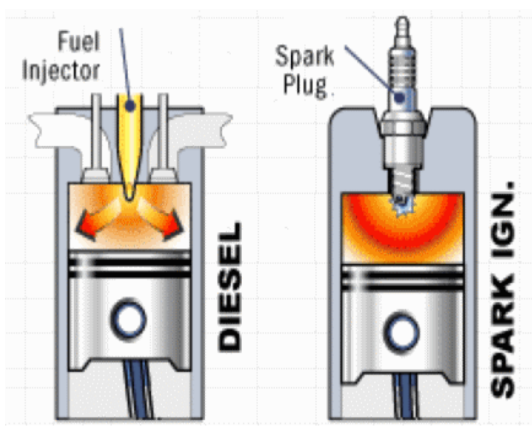
1. Types of ignition

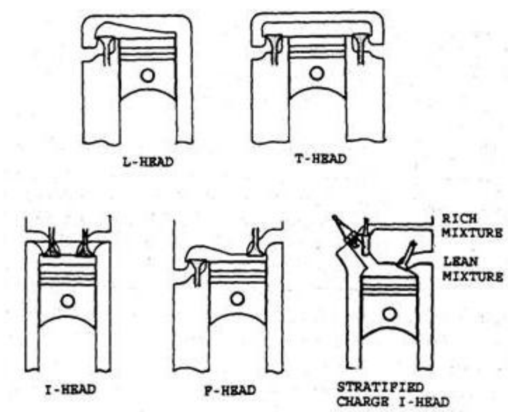
(a) Spark Ignition (SI)

An SI engine starts the combustion process in each cycle by use of a spark plug. The spark plug gives a high voltage electrical discharge between two electrodes, which ignites the air fuel mixture in the combustion chamber surrounding the plug. In early engine development, before the inventor of electric spark plug, many forms of torch holes were used to initiate combustion from an external flame.

(b) Compression Ignition (CI)

The combustion process in a CI engine starts when the air-fuel mixture self-ignites due to high temperature in the combustion chamber caused by high Compression.





CI Engine **SI Engine** **Valve Location**

2. Engine cycle

Four-stroke cycle: A four-stroke cycle has four piston movements over two engine revolutions for each cycle.

Two-stroke cycle: A two-stroke cycle has two piston movements over one revolution for each cycle.

Note: Three stroke cycles and six stroke cycles were also tried in early engine development.

3. Valve location

a. Valves in head (Overhead valve), also called I Head engine.

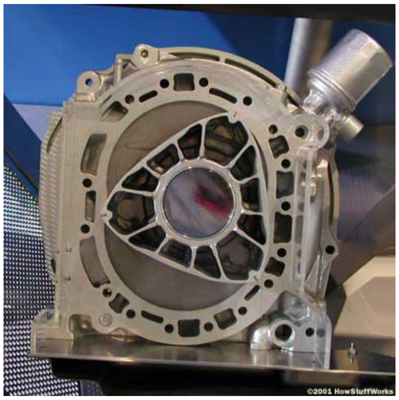
b. Valves in block (flat head), also called L Head engine. Some historic engines with valves in block had the intake valve on one side of the cylinder and the exhaust valve on the other side. These were called T Head engines.

c. One valve in head (usually intake) and one in block, also called F Head Engine; this is much less common.

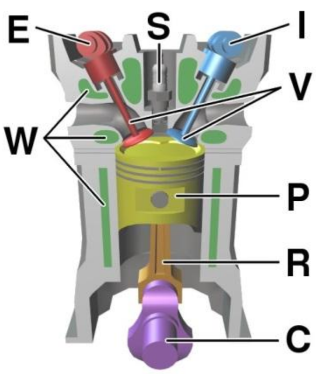
4. Basic Design

a. ***Reciprocating:*** Engine has one or more cylinders in which pistons reciprocate back and forth. The combustion chamber is located in the closed end of each cylinder. Power is delivered to a rotating output crankshaft by mechanical linkage with the pistons.

b. ***Rotary:*** Engine is made of a block (stator) built around a large non-concentric rotor and crankshaft. The combustion chambers are built into the non-rotating block. A number of experimental engines have been tested using this concept, but the only design that has ever become common in an automobile is the Wankel engine in several Mazda models. Mazda builds rotary automobile engines with one, two, and three rotors.



Rotary Engine



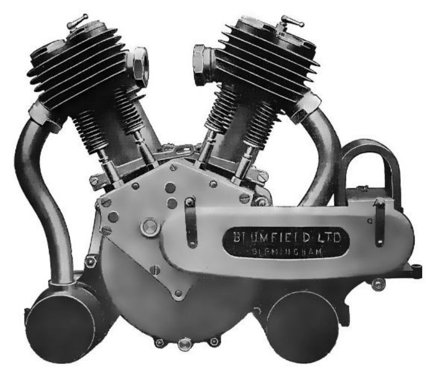
Reciprocating Engine

5. Position and number of cylinders of reciprocating engines

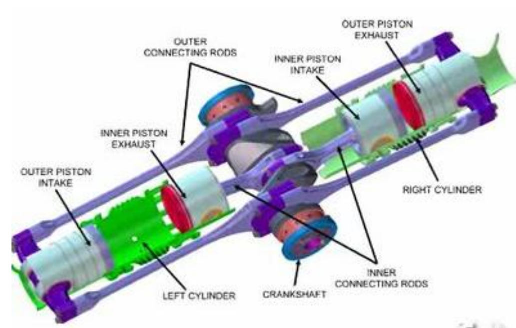
a. ***Single Cylinder:*** Engine has one cylinder and piston connected to the crankshaft.

b. In-Line: Cylinders are positioned in a straight line, one behind the other along the length of the crankshaft. They can consist of 2 to 11 cylinders or possibly more. In-line four-cylinder engines are very common for automobile and other applications. In-line six and eight cylinders are historically common automobile engines In-line engines are sometimes called Straight (e.g., straight six or straight eight).

c. V Engine: Two banks of cylinders at an angle with each other along a single crankshaft, allowing for a shorter engine block. The angle between the banks of cylinders can be anywhere from 15° to 120° with 60°-90°. V engines usually have even numbers of cylinders from 2 to 20 or more. V6s and V8s re common automobile engines, with V12s and V16s (historic) found in some luxury and high performance vehicles. Large ship and stationery engines have anywhere from 8 to 20 cylinders. Volkswagen has a v5 on the market with two cylinders slightly out of line (15deg) with the other three so that the cylinders can be moved closer together to shorten the engine block. Honda makes a true V5 motorcycle engine.



d. Opposed Cylinder Engine: Two banks of cylinders opposite to each other on a single crankshaft (a V engine with 180 deg V). These are common on small aircraft and some automobiles with an even number of cylinders from two to eight or more. These engines are often called flat engines (e.g., flat four).



e. W engine: Engines of two different cylinder arrangements have been classified as W engines in the technical literature. One type is the same as a V engine except with three banks of cylinders on the same crankshaft. They are not common, but some race cars of 1930 s and some luxury cars of the 1990s had such engines either with 12 cylinders or 18 cylinders. Another type of W engine is the modern 16 cylinder engine made for the Bugatti automobile (W16). This engine is essentially two V8 engines connected together on a single crankshaft

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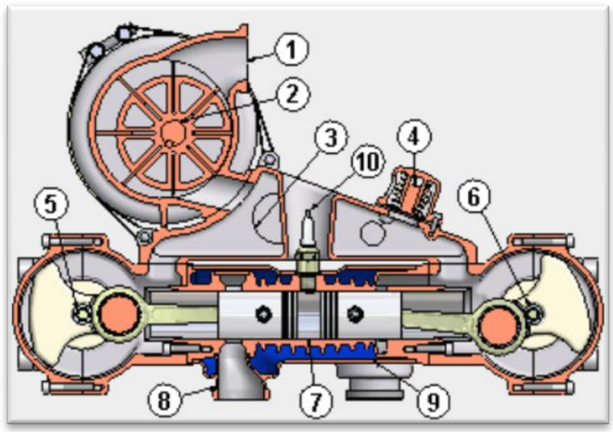
f. Opposed piston engine: Two pistons in each cylinder with the combustion chamber in the center between the pistons. A single combustion process causes two power strokes at the same time, with each piston being pushed away from the center and delivering power to a separate crankshaft at each end of the cylinder. Engine output is either on two rotating crankshafts or on one crankshaft incorporating a complex mechanical linkage. These engines are generally of large displacement, used for power plants, ships, or submarines.



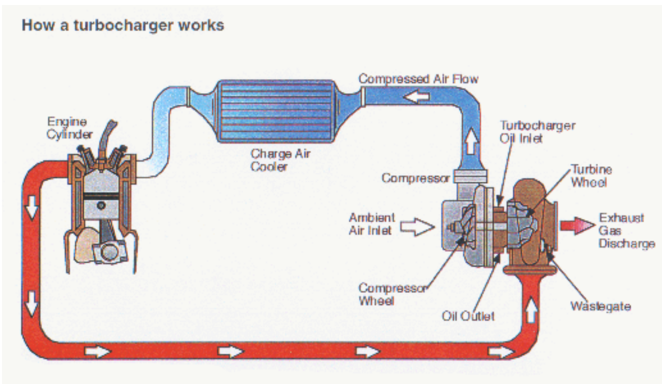
g. Radial engine: Engines with pistons positioned in a circular plane around a circular crankshaft. The connecting rods of the piston are connected to a master rod, which in turn, is connected to the crankshaft. A bank of cylinders on a radial engine almost always has an odd number of cylinders ranging from 3 to 13 or more. Operating on a four-stroke cycle every other cylinder fires and has a power stroke as the crankshaft rotates, giving a smooth operation. Many medium and large size propeller driven aircraft use radial engines. For large aircraft two or more banks of cylinders are mounted together, one behind the other on a single crankshaft, making one powerful smooth engine. Very large ship engines exist with upto 54 cylinders, engines six banks of 9 cylinders each. In the early part of 20th century experimental radial aircraft here were a few experimental radial aircraft engines that had an even number of cylinders (4 to 12). These engines operated on a two-stroke cycle and never became standard.

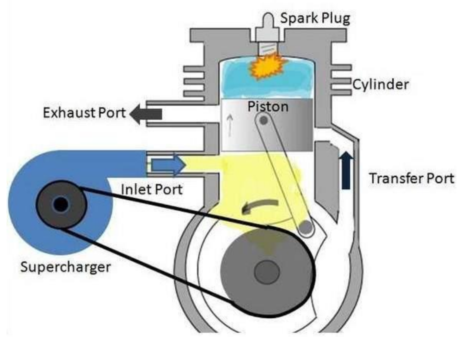
6. Air Intake Process

(a) **Naturally Aspirated**: No intake air pressure boosts system.

(b) **Super charged**: Intake air pressure increased with the compressor driven off of the engine crankshaft.

(c) **Turbo charged**: Intake air pressure increased with the turbine compressor driven by the engine exhaust gases.





Supercharger

Turbocharged Engines

(d) **Crankcase compressed**: Two-stroke cycle engine which uses the crankcase as the intake air compressor. Limited development work has also been done on design and construction of four-stroke cycle engines with crank case compression.

7. Method of fuel input for spark ignition engines

(a) Carbureted: A device for mixing air and fuel to facilitate the combustion process

(b) Multipoint port fuel injection: One or more injectors at each cylinder intake.

(c) Throttle body fuel injection: Injectors upstream in intake manifold.

(d) Gasoline direct injection: Injectors mounted in combustion chambers with injection directly into cylinders.

8. Method of fuel input for compression ignition engines

(a) Direct injection: Fuel injected into main combustion chamber.

(b) Indirect injection: Fuel injected into secondary combustion chamber.

(c) Homogeneous charge compression ignition: Some fuel added during intake stroke.

9. Fuel used

(a) Gasoline
(b) Diesel oil or Fuel oil
(c) Gas, Natural gas, Methane
(d) Alcohol-Ethyl, Methyl
(e) Dual fuel: There are a number of engines that use a combination of two or more fuels. Some, Usually large, CI engines use a combination of natural gas and diesel fuel. These are attractive in developing third world countries because of the high cost of the diesel fuel. Combined gasoline alcohol fuels are becoming more common as an alternative to straight gasoline automobile engine fuel.
(f) Gasohol: Common fuel consisting of 90% gasoline and 10% alcohol.

10. Application

Automobile, Locomotive, Stationery, Marine, Aircraft, Small, Portable, chain saw, model airplane.

11. Type of cooling

(a) Air cooled
(b) Liquid cooled, Water-cooled.

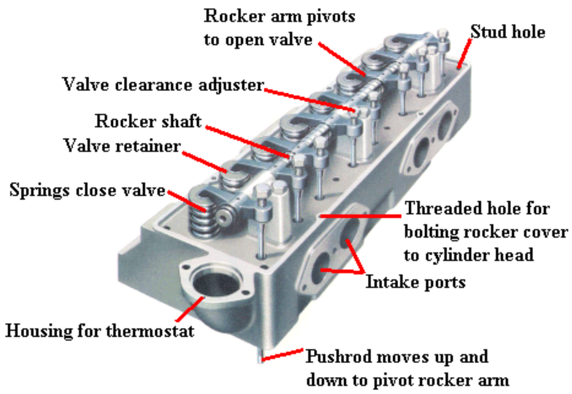
Different Parts of IC Engines:

Different Parts of IC Engines:

1) Cylinder Liners or Sleeve:

- **Function:** i)Guides the piston(Space in which the piston makes a reciprocating motion).
  ii) Contains gas under pressure.
- **Material:** Made of hard grade cast iron (usually, cast in one piece).
- The cylinder is supported in the cylinder block.
- The walls of thecylinder have highly polished hard surfaces.
- The upper end consists of a combustion or clearance space in which ignition and combustion of the charge take place.
- The cylinders need to have low friction coefficient but high stiffness.

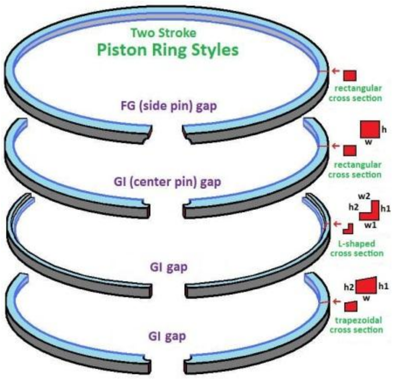
2) Cylinder Head:
   - **Function:** Main function is to seal the working end of the cylinder and not to permit entry and exit of gases on overhead valve engines.
   - **Material:** Cast iron or Aluminum.
   - **Method of Mfg:** Casting or forging.



3) Piston:
   - The cylindrically shaped mass that reciprocates back and forth in the cylinder.
   - **Function:** It acts as a face to receive gas pressure and transmits the thrust to the crank shaft through connecting rod.
   - **Material:** Cast iron or Aluminum alloy or Steel
     - Iron and steel pistons can have sharper corners because of their higher strength. They also have lower thermal expansion which allows for tighter tolerances and less crevice volume.
     - Aluminum pistons are lighter and have lessmass inertia.

   - **Method of Mfg:** Casting or forging.
   - The top of the piston is called crown and the sides are called skirt.
   - The face on the crown makes up one wall of the combustion chamber and may be a flat or highly contoured surface.
   - Some pistons contain an indented bowl in the crown which makes up a large percent of clearance volume.

4) Piston Rings:
   - Metal rings that fit into circumferential groups around the piston and form a sliding surface against the cylinder walls.
   - Near the top of the piston are usually two or more compression rings made with highly polished surfaces.

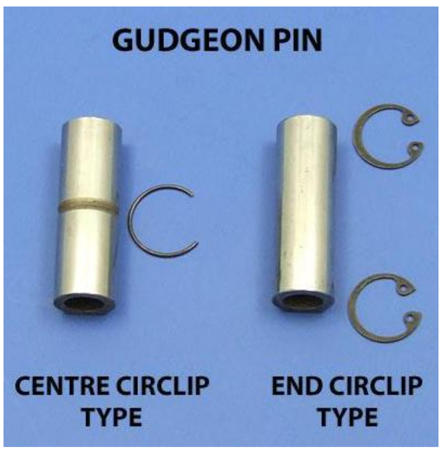


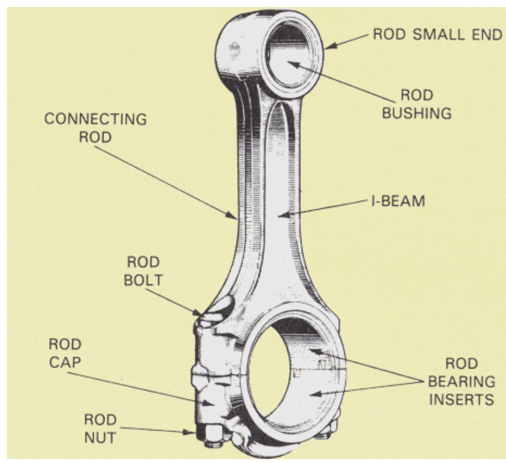
   a) Compression Rings:
      - **Function:** i) The purpose of the rings is to form a seal between the piston and cylinder walls and to restrict the high pressuregases in the combustion chamber from leaking pass the piston into the crank case.
        ii) Transfer of heat from the piston crown to cylinder walls.

b) Oil Control Rings:
- Below the compression rings on the piston is at least one oil ring, which assists in lubricating the cylinder walls
- **Function:** The oil control ring is used to scrape the surplus oil from the cylinder walls to reduce oil consumption.

- **Material:** Cast Iron
- **Method of Mfg.:** Casting

5) Gudgeon Pin (or Piston Pin):
- **Function:**It forms the link between the small end of the connecting rod and the piston, and allows the connecting rod to swivel.
- **Material:** Hardened steel
- **Method of Mfg.:** Forging
- It is made hollow for lightness since it is reciprocating parts.



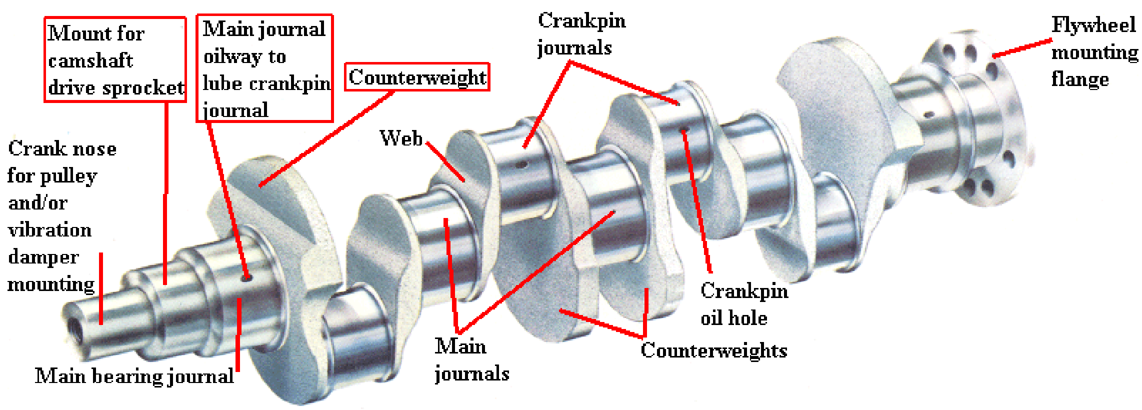


6) Connecting Rod:
- It connects piston and crank shaft
- Small end of C.R. is fitted with piston by piston pin or gudgeon pin.
- The other end is connected to crank shaft by crank pin.

- **Function:** It transmits the piston load to the crank, causing the latter turn, thus converting the reciprocating motion of the piston into rotary motion of the crank shaft.
- **Material:** Alloy steel (Nickel, Chrome and Chrome Vanadium Steel), aluminum for small engine
- **Method of Mfg:** Forging
- I-beam Section : because of this shape C.R. having high weight to strength ratio.

7) Crank Shaft:

- **Function:** It converts the reciprocating motion of the piston into useful rotary motion of the output shaft.



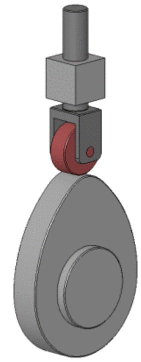
- **Method of Mfg:** High tensile forging.
- **Material:**Cast iron, Steel
- The balance weights are provided for static and dynamic balancing of the rotating system.
- The stroke is twice the crank shaft ‘throw’ (throw-the distance between the big end and main bearing centers.

8) Valve:

- **Function:**Engine valves open and close to control the flow in and out of the combustion chamber.
- Steel
- Most engines have one intake and one exhaust valve per cylinder.
- However, a few high performance engines have four valves or even six valves per cylinder.
- An intake valve controls the flow of air-fuel mixture or just air through the cylinder head intake port. It is large valve.
- An exhaust valve controls the flow of burnt gases out of the combustion chamber. The exhaust valve is smaller.

9) Camshaft:

- **Function:**A camshaft opens the engine valves at the right time during each stroke.
- For a four stroke internal combustion engine the camshaft rotates at one-half the crankshaft speed.
- Most modern automobile engines have one ormore camshafts mounted in the engine head (Overhead cam). Older engines had camshafts in the crank case.



10) Cam (Cam Lobes):
- The cam lobes press-fit on camshaft
- The shape of the cam lobes affects
  - When each valve opens in relation to piston position.
  - How long each valve stays open.
  - How far each valve opens.

11) Cam follower or tappet:
- **Function:** To convert the radial motion of the cams into the reciprocating motion necessary for opening and closing the valves requires the use of cam followers or tappets.

12) Rocker Arm:

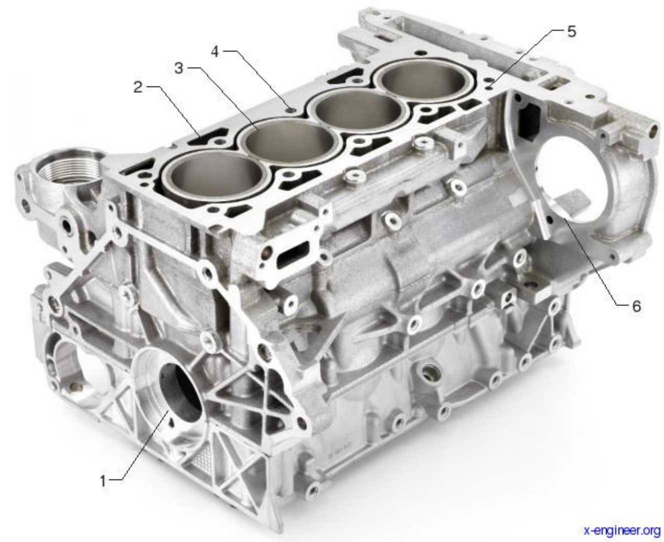
- **Function:** Rocker arms can be used to transfer motion from the push rods to the valves.
- Cast iron or stamped steel.

13) Governor:
- **Function:** to control the fluctuations of engine speed due to changes of load.

14) Crank Case or Engine Block:
- The **engine block** is one of the biggest, heaviest and important component of the internal combustion engine. An engine block is sometimes called a **cylinder block** but it has the same meaning. Depending on the engine, the cylinder block can be a single component or split in two, an upper and a lower block. The main functions of the engine block are:

- contains some of the moving arts of the engine: piston, connecting rod, crankshaft
- contains a part of the cooling circuit
- together with the cylinder head forms the combustion chamber
- it is support for a part of the lubrication circuit: oil pan, oil pump, oil filter
- it is support for auxiliary devices: starter motor, A/C compressor, alternator, intake and exhaust manifolds, etc.
- Lower part of the engine.

1 crankshaft fixing support
2 coolant circuit passage
3 cylinder
4 threaded hole (for cylinder head bolts)
5 lubrication circuit passage
6 auxiliary equipment support



- In many engines the oil pan makes up part of the crankcase housing.
- In some high performance engines the crankcase is designed with windows between the piston bays to allow free airflow between bays. This is to reduce air pressure build up on the backside of the pistons during power and intake strokes.
- The cylinder head is mounted on top of the engine block. Between the cylinder head and engine block there is a cylinder head gasket which helps sealing the combustion chamber and the cooling circuits.
- It has to withstand high amount of mechanical and thermal stress.
- Usually the engine block is manufactured from cast alloyed iron. This is a cost effective solution. The performance engines are manufactured from aluminium alloy, which, compared to iron engine blocks have the following advantages:
  - lower mass
  - higher thermal conductivity
  - better wear resistance
  - are easier to manufacture

The most important disadvantage of the aluminium based engine block is higher cost.

15) Carburetor:

- **Function:** Venturi flow device that meters the proper amount of fuel into the air flow by means of pressure differential.

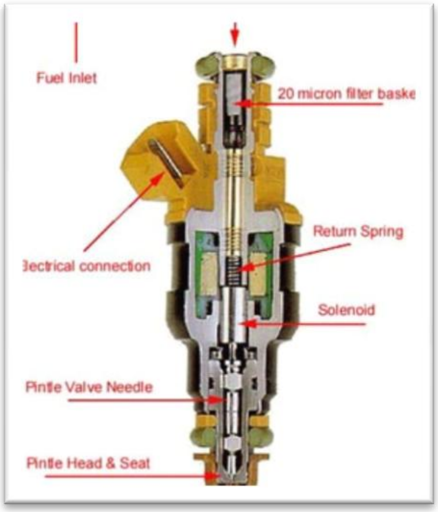
For many decades it was the basic fuel metering system on all automobile (and other) engnes. It is still used on low cost small engines like lawn mowers but is uncommon on new automobiles.

16) Fuel Pump:

- **Function:**Fuel has to be pumped from the fuel tank to the engine and delivered under low pressure to the carburetor or under high pressure to the fuel injection system.
  - Increasing pressure.
  - Controlling the quantity of fuel supplied to the injector.
- Generally, Use in diesel engine.

17) Fuel Injector:

- **Function:**The fuel injector is a small nozzle through which liquid fuel is injected at high pressure into the cylinder at the end of compressor stroke..



Fuel-Injector

Spark-Plug

18) Spark Plug:

- Generally, use in Petrol Engine.
- A spark plug is a device to ignite the compressed fuel/air mixture by an electric spark (High intensity spark),

19) Exhaust Manifold:

- Piping systems that carries exhaust gases away from the engine cylinders, usually made of cast iron.

20) Flywheel:

- Mounted on the crank shaft.
- **Function:** Minimizes cyclic variation in speed by storing energy during power stroke.
- Flywheels are typically made of forged steel, Cat iron andAluminium.Flywheels are made of composites of epoxy resin and carbon fiber. A carbon composite is four times stronger than steel, but only one quarter the weight. High strength, low density material as they are used for energy storage devices.

Experiment No: 2

AIM: To Construct the Valve Timing Diagram for a given single cylinder I C Engine.

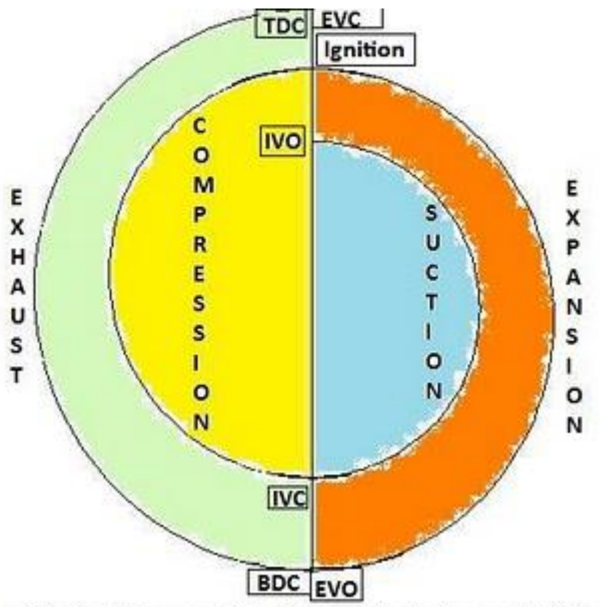
Objectives: Learner will be able to

1. Find the valve timing diagram of given engine.
2. Illustrate the significance of Valve timing Diagram for an engine.

Introduction

Valve timing is crucial to the efficient operation of the 4-stroke petrol or diesel engine. The opening and closing of the inlet and exhaust valves at the correct time in relation to piston position must be precisely controlled, either at a fixed compromise position, or variable within finely controlled limits.

The valves are opened and closed by the camshaft(s) which are driven by chain, toothed belt or gear train from the crankshaft. To understand valve timing diagram first of all one needs to understand different process in a cylinder.



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

Theoretical Valve Timing Diagram

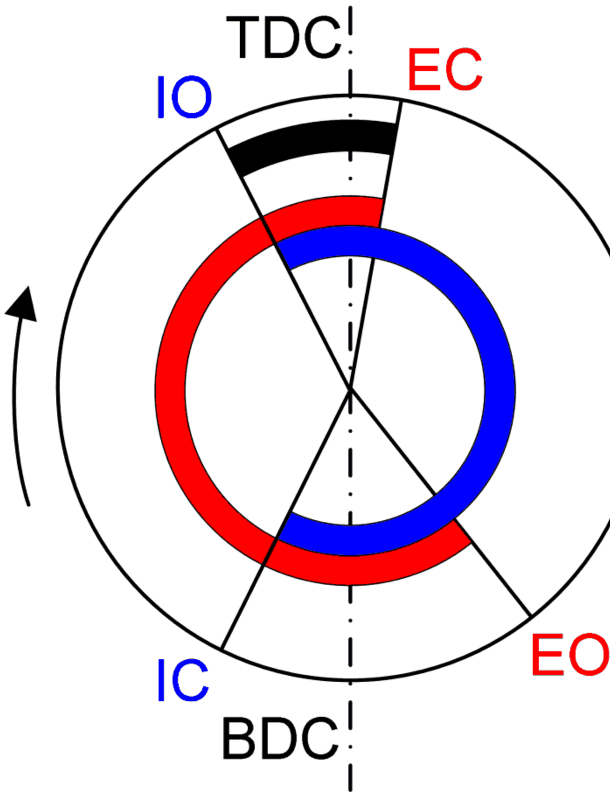
The exact moment at which the inlet and outlet valve opens and closes with reference to the position of piston and crank shown diagrammatically is known as *Valve Timing Diagram.*The timing is expressed in terms of degrees of crank rotation.

Suction Stroke: Inlet valve is open. Piston moves from the Top Dead Centre(TDC) to Bottom Dead Centre(BDC). Air-fuel mix is sucked in by negative pressure in cylinder.

Compression Stroke: Inlet and outlet valves closed. Piston moves upwards from BDC to TDC. Air-fuel mix is compressed.

Expansion/Power Stroke: Inlet and outlet remains closed here also. Piston moves from down from TDC to BDC. This happens as a result of ignition of the mixture inside the cylinder. Ignition is started by spark plug.

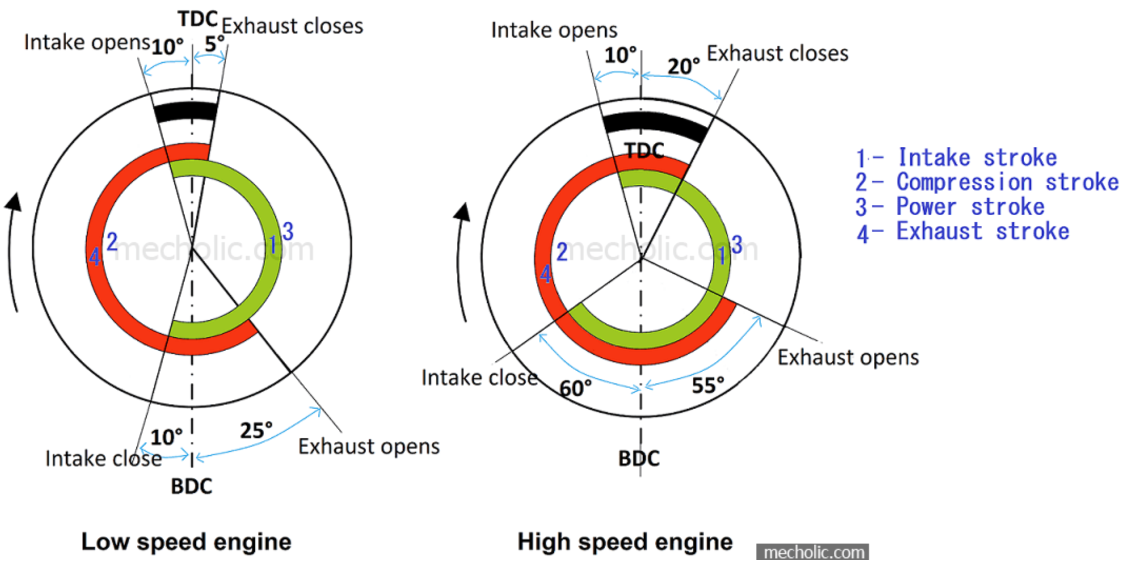
Exhaust Stroke: Exhaust valve opens. Piston moves up from BDC to TDC. Exhaust gases are pushed out of the cylinder.



Actual Valve Timing Diagram

The Actual Valve Timing Diagram has slight variations with respect to the Theoretical Valve Timing Diagram. The variations are made in order to maximize the engine performance.

Refer the figure given and compare it with the Theoretical VTD to the see the difference. The reason for making these deviations from theoretical VTD is explained below.



Opening and closing of Inlet Valve:

The inlet valve is made to open 10degree to 30degree before the piston reaches the Top Dead Center (TDC) during Suction Stroke and is allowed to close only after 30degree to 40degree after the piston reaches and leaves the BDC in the beginning of compression-stroke.

Reason – The reason for doing this is to facilitate silent operation of the engine under high speeds. The inlet valves are made to operate slowly to avoid noise and hence sufficient time should be provided for the air-fuel mix to get into the cylinder. Thus valves are made to open before the actual BDC.

Since the inlet valve is a small opening sufficient mixture doesn't enter the cylinder in such short time, as the piston reaches BDC. Thus the inlet valve is kept open for some time period of time after BDC, to facilitate sufficient flow of charge into the cylinder.

OpeningandclosingofExhaustValve*:*

The exhaust valve is made to open 30degree to 60degree before the TDC in the exhaust stroke and allowed to close only after 80 to 10 in0 the beginning of the suction-stroke.

Reason – The gases inside the cylinder possess a higher pressure even after the expansion stroke. This higher pressure enables it to move out of the cylinder through the exhaust valve reducing the work that needs to be done by the engine piston in pushing out these gases. Thus the exhaust valve is made to open before the piston reaches the BDC thus enabling the gases to escape outside on its own and the remaining gases are pushed out by the upward motion of the piston.

When the piston reaches the TDC, if the exhaust valve is closed like in actual timing diagram, a certain amount of exhaust gases will get compressed and remain inside the cylinder and will be carried to the next cycle also. To prevent this, the exhaust valves are allowed to close only a certain time after the piston reaches the TDC.

Performance:

Safety Precautions:

1. Use this equipment with permission of lab in charge/ subject teacher/ competent authority only.
2. Testing and performance on this test rig must be done under able supervision only.
3. Keep all items taken; to respective place at the end of performance.
4. Without fail make an entry of using this test rig is UTILIZATION REGISTER available with test rig.

Follow the SOP mentioned here to construct the valve timing Diagram for given single cylinder Diesel engine cut section, and draw the result at the place provided:

Operating Procedure (S.O.P.) :

1. Attaché crank angle measurement device to the crank shaft, by keeping angle of crank on the position of end of exhaust stroke and starting of suction stroke. Here the piston will be at TDC of stroke.
2. At this instant both intake valve and exhaust valve will be in open condition.
3. Set the angle measurement device at 0^o position at this instant.
4. Rotate the flywheel by keeping keen eye on the rocker arm corresponding to exhaust valve and identify the event when it starts deflecting for closing condition.

5. Further rotation of the flywheel will show the instant when the rocker arm corresponding to Intake valve starts deflecting for closing condition. When inlet valve is fully closed note the angle rotation on angle measurement device.
6. Further identify when fuel injection starts and note the angle rotation on angle measurement device.
7. Rotating the flywheel further; note the instant when rocker arm corresponding to exhaust valve starts deflecting for opening condition. When Exhaust valve is fully open note the angle rotation on angle measurement device
8. Keep rotating the flywheel and locate the instant when intake valve is start opening, and when it is fully open; note the angle rotation on angle measurement device.
9. By this time crank/flywheel must have gone through 2 full revolutions.
10. Draw a valve timing diagram using angle values noted through this process and discuss about it amongst each other and with your instructor.

Draw Valve Timing Diagram here:

Conclusion:

Experiment No: 3

AIM: To study about different carburetion system in SI engine

Objective: Students will be able to,

1. Illustrate different carburetor and carburetion system.

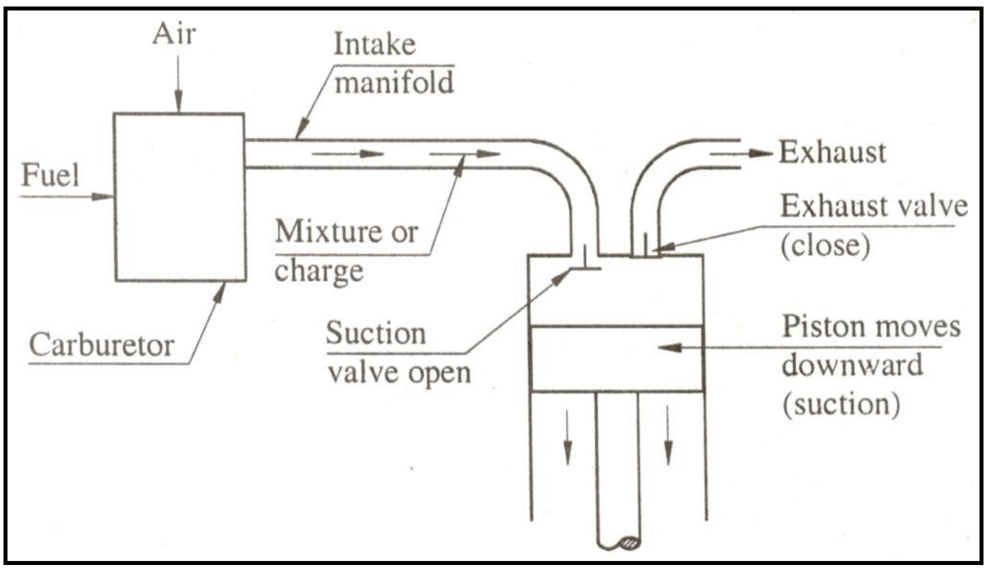
Introduction

In the SI engine a combustible fuel- air mixture is prepared outside the engine cylinder. The process of preparing this mixture is called carburetion. This complicated process is achieved in the induction system. The carburetor, a device that atomizes the fuel and mixes it with air, is the most important part of the induction system. The pipe that carries the prepared mixture to the engine cylinder is called the intake manifold.

During the suction stroke vacuum is crated in the cylinder, which causes the air to flow through the carburetor and the fuel to be sprayed from the fuel jets. Because of the volatility of the fuel, most of the fuel vaporizes and forms a combustible fuel-air mixture. However, some of the larger droplets may reach the cylinder in the liquid form and must be vaporized and mixed with air during the compression stroke before ignition by the electric spark.

Four important factors which significantly affect the process of carburetion are :

1. The time available for the preparation of the mixture.
2. The temperature of the incoming air of the intake manifold.
3. The quality of the fuel supplied.
4. The design of the induction system and combustion chamber.

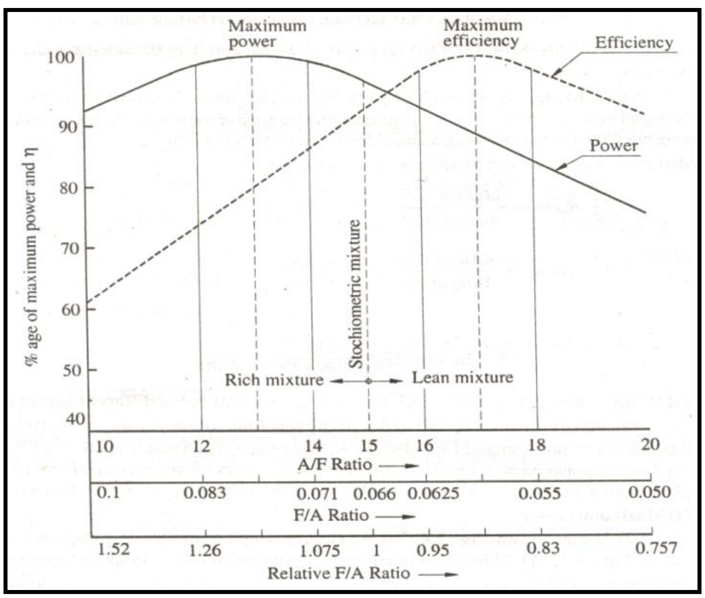


Charge transfer from carburetor to cylinder

Atomization, mixing, and vaporization, are the processes, which require a finite time to occur. In high-speed engines the time available for mixture formation is very small. To complete these processes during such a small period requires great ingenuity in designing the carburetion system. Because of the short time available complete and efficient mixing, vaporization, and distribution is difficult to achieve. Temperature is a factor, which controls the vaporization processor the fuel. A high temperature results in high rate of vaporization. The temperature of the mixture can be increased by, say, heating the induction manifold but this would reduce power due to reduction in mass flow. The volatility of the fuel affects the vaporization and distribution of fuel. The design of the induction manifold, etc. affects the uniform distribution of the mixture among the cylinders and the constancy of its composition under variable operating conditions.

Properties of the Air-Petrol Mixtures:

There is a limited range of air-fuel ratios, in a homogeneous mixture, which can be ignited in a SI engine. These limits are about 7:1 A/F by mass on the rich side, and about 20:1 A/F on the lean side in single cylinder engines. The properties of different air-petrol mixtures in this range .The effect of A/F ratio on power output and specific fuel consumption for a SI engine for full throttle and constant speed condition. A typical fuel consumption loop for various A/F ratios. The most important hint to note from these figures is that the A/F ratio for maximum power is not the same as the A/F ratio for maximum economy. Further, the A/F ratio for maximum power and maximum economy varies with load.



For full throttle and constant speed operation

(a) Mixture requirements for maximum power.

That the maximum power is obtained at about 12.5:1 A/F (0.08:1 F/A). Maximum energy is released when slightly excess fuel is introduced so that all the oxygen present in the cylinder is utilized. More fuel than this does no help. In fact it is disadvantageous because the combustion of a large excess of fuel with the same amount of oxygen results in smaller energy release due to partial combustion, and more carbon monoxide is formed. Mechanical efficiency is maximum at maximum power position.

(b) Mixture Requirements for Minimum Specific Fuel Consumption.

Atfull throttle, maximum efficiency occurs at an A/F ratio of about 17:1 (0.06:1 A/F ratio). Maximum efficiency occurs at a point slightly leaner than the chemically correct A/F ratio because excess air requires complete combustion. Of fuel when mixing is not perfect; and the power maximum temperatures associated with the inlet mixture favourable affect the chemical equilibrium and specific inlet of the gases. However, if the mixture is made too lean, the flame speed is reduced so much that the large time losses overcome the above-mentioned beneficial effects, and the efficiency falls off.

Various investigators have experimentally determined the properties of air-petrol mixtures, which are summarized. For practical purpose the portion of the fuel consumption loop between B and D is important.

1. Idling And Low Load:

The no load running mode of the engine is called idling. During idling, the nearly closed throttle restricts the air supply and the suction pressure is very low. This condition of low pressure gives rise to backflow of exhaust gases and air leakage from the various parts of the engine intake system.

At idling and during part load operation backflow during the valve overlap period occurs since the exhaust pressure is higher than the intake pressure. This increases the amount of residual gases. During the suction process the residual gases expands, thereby, reducing the fresh mixture inhaled. Increase dilution causes the combustion to be erratic or even impossible. Irregular and slow combustion, so, obtained results in poor thermal efficiency and higher exhaust emissions.

The problem of dilution by residual gases becomes more pronounced at low loads and idling because the exhaust temperature reduces with decreasing load, i.e. the density and hence mass of the residual gases increase.

Further dilution of the charge occurs due to air leakage past valves, etc., at low inlet manifold pressures obtained at idling and low loads.

The above two phenomena require that the air-fuel ratios used for idling and low loads, say up to about 20 per cent of full load, should be rich for smooth engine operation. Up to this point the amount of fuel burned is quite small, hence, fuel economy is not important.

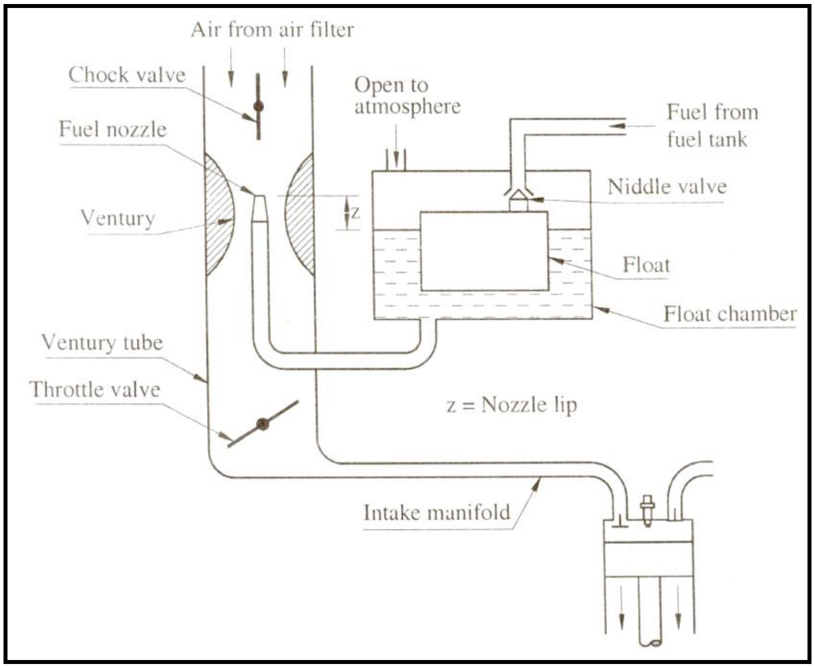
How rich mixture improves combustion needs some explanation. The amount of fresh charge brought in during idling is much less than that during full throttle operation. The presence of exhaust gas tends to obstruct the contact of fuel and air particles-a requirement necessary for satisfactory combustion. The richening of mixture increases the probability of contact between fuel and air particles and thus improves combustion.

2. Normal Power Range or Crushing Range.
As the load is increased above 20% of rated load the dilution by residual gases as well as leakage decrease and therefore in the normal power range the prime consideration is usually the fuel economy. As already started maximum fuel economy occurs at A/F ratio of about 17:1. Practical valves are about 5% higher. Due to manufacturing tolerances provided in the carburetor the air-fuel ratio supplied by it varies during operation. A value of about ±6% is typical of a standard carburetor. A closer control of these tolerances say to a value of about ±3%, would allow leaner mixtures to be used and thereby, improving both the fuel economy as well as the exhaust levels.

2. Maximum Power Range.
As already stated the mixture requirement for maximum power is a rich mixture. Of A/F about 14:1 or (F/A = 0.07). Besides providing maximum power, a rich mixture also prevents overheating of exhaust valve at high load and inhibits detonation. At high load there is greater heat transfer to engine parts. Enriching the mixture reduces the flame temperature and the cylinder temperature, there by reducing the cooling problem and lessening the chances of damaging the exhaust valves. Also reduced temperature tends to reduce detonation. Aircraft engines have elaborate arrangement for enrichment of mixture, as detonation can wreck the engine in a matter of seconds.

A Simple or Elementary Carburetor:

To understand a modern carburetor which is a complicated piece of equipment, it is helpful to first study a simple or elementary carburetor which provides an air-fuel mixture for crushing or normal range at a single speed and then to add it other mechanisms to provide for other duties like starting, idling, variable load and speed operation and acceleration.



Simple Carburetor

A simple carburetor it consists of a float chamber nozzle with metering orifice, venture and throttle valve. The float and a needle valve system maintain a constant height of petrol in the float chamber. If the amount of fuel in the float chamber falls below the designed level, the float lowers, thereby opening the needle of fuel supply valve. When the designed level has been reached, the float closes the needle valve, thus stopping additional fuel flow from the supply system. Float chamber is vented to their atmosphere.

During suction stroke air is drawn through the venture. Venturi is a tube of decreasing cross-sectional which reaches a minimum at the throat. The air passing through the venture increases in velocity and the pressure in the venture throat decrease. From the float chamber, the fuel is fed to a discharge jet, the tip of which is located in the throat of the venturi. Now because the pressure in the float chamber is at atmospheric and that at the discharge jet below atmospheric a pressure differential, called carburetor depression, exits between them. This causes discharge of fuel into the air stream and the rate of flow is controlled or metered by the size of the smallest section in the fuel passage. This is provided by the discharge jet and the size of this jet is chosen empirically to give the required engine performance. The pressure at the throat at the fully open throttle condition lies between 4 and 5 cm. Hg below atmospheric, and seldom exceeds 8 cm Hg below atmospheric. To avoid wastage of fuel, the level of the liquid in the jet is adjusted by the float chamber needle valve to maintain the level a short distance below the tip of the discharge jet.

The petrol engine is quantity governed which means that when less power is required at a particular speed the amount of the change delivered to the cylinder is reduced. This is achieved by means of a throttle valve of the butterfly type, which is situated after venturi tube. As the throttle is closed less air flows through the venturi tube and less is the quantity of air fuel mixture delivered to the cylinders and hence less is the power developed. As the throttle is opened, more air flows through the chock tube, and the power of the engine increase.

A simple carburetor of the type described above suffers from a fundamental fault in that it provides increasing richness as the engine speed and air flow increase with full throttle because the density of the air tends to decrease as the rate of air flow increase. Also, it provides too lean mixtures at low speeds at the rate of air flow increase.

Fundamental Fault of a simple Carburetor: A simple carburetor of the type described above suffers from a fundamental fault in that provides increasing richness as the engine speed and air flow increase with full throttle because the density of the air tends to decrease as the rate of air flow increase. Also, it provides too lean mixtures at low speeds at part open throttle. This phenomenon can be explained as follows: Since the throttle regulates the amount of air flowing up the venturi tube, it also checks the quantity of fuel issuing from the nozzle by regulating the vacuum at the throat. At low engine speeds with part open throttle for the vacuum at the throat is small and hence we get too lean a mixture. At high engine speeds the vacuum at the throat is high and hence we get too rich mixture. The mathematical analysis of air-fuel ratio supplied by an elementary carburetor**.**

Complete Carburetor:

In order to satisfy the demands of an engine under all conditions of operation the following additional systems are added to the simple carburetor:

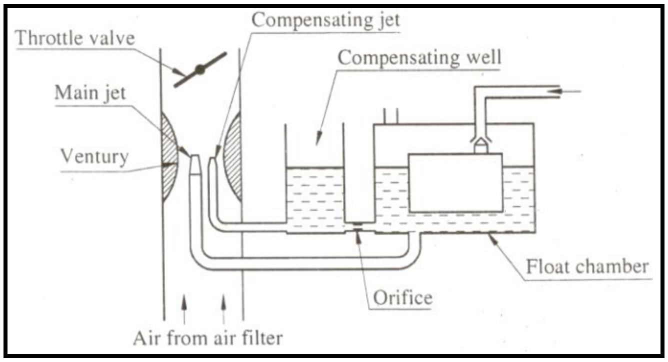
1. Main metering system
2. Idling system
3. Power enrichment by economizer system
4. Acceleration pump system.
5. Choke.

Main Metering system. The main metering system of a carburetor is designed to supply a nearly constant basis fuel – air ratio over a wide range of speeds and loads. This mixture corresponds approximately to best economy at full throttle (A/F ratio = 15.6 or F/A = 0.064). Since a simple or elementary carburetor tends to enrich the mixture at higher speeds automatic compensating device are incorporated in the main metering system to correct this tendency.

These devices are:

1. Use of a compensating jet that allows an increasing flow of air through a fuel passage as the mixture flow increases.
2. Use of emulsion tube for air bleeding. In this device the emphasis is on air bleeding alone.
3. Use of a tapered metering pin that is arranged to be moved in and out of the main or auxiliary fuel orifice either manually or by means of some automatic mechanism changing the quantity of fuel drawn into the air charge.
4. Back-suction control or pressure reduction in the float chamber.
5. Changing the position or jet in the venturi. The suction action is highest at the venture throat, therefore by rising the venturi the nozzle relatively moves to points with smaller suction and the flow of fuel is decreased.
6. Use of an auxiliary air valve or port that automatically admits additional air as mixture flow increases.

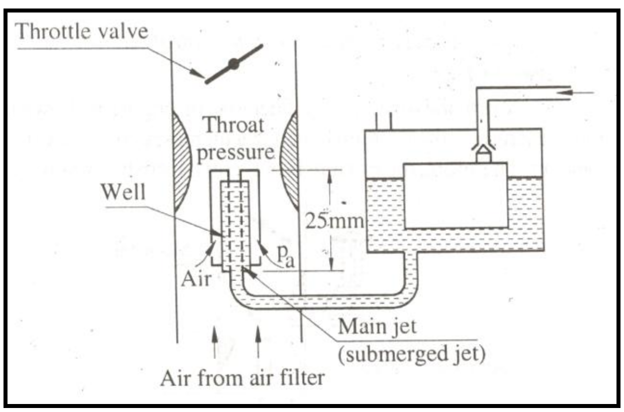
(a) Compensating Jet device.



Compensating Jet Device

This device is shown in fig. In this device in additional to the main jet, a compensating jet is provided which is in communication with a compensating jet is provided which is in communication with a compensating well. The compensating well is open to atmosphere and gets its fuel supply from the float chamber through a restricting orifice. As the air flow increases, the level of fuel in the well decreases, thus reducing the fuel supply through the compensating jet. The compensating jet thus tends towards leanness as the main jet tends towards richness, the sum of the two remaining constant as shown in fig. At even higher rates of air flow, when the compensating jet has been emptied, air is bled through the compensating jet to continue the leanness effect, and incidentally to assist in fuel atomization.

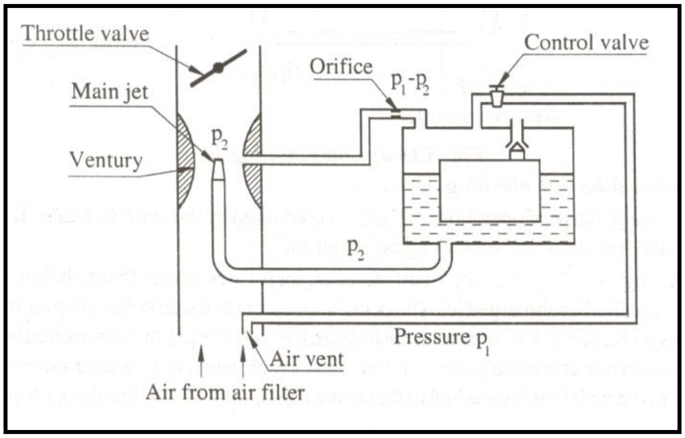
(b) Emulsion tube or air bleeding device.



Emulsion tube

In the modern carburetor the mixture correction is done by air bleeding alone. In this arrangement the main metering jet is fitted about 25 mm below the petrol level and it is called a submerged. The jet is situated at the bottom of a well, the sides of which have holes which are in communication with the atmosphere. Air is drawn through the holes in the column, is not as great that in the simple or elementary carburetor. Initially, the petrol is the well is at a level equal to that in the float chamber. On opening the throttle this petrol, being subject to the low throat pressure, is drawn into the air. This continues with decreasing mixture richness as the holes in the central tube are progressively uncovered. Normal flow the takes place from the main jet.

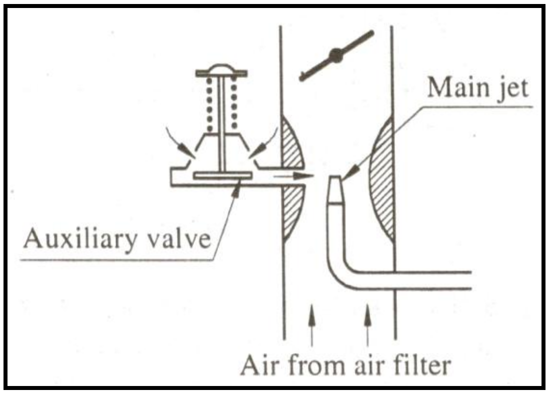
(c) Back – suction control or pressure reduction method.
(d)



Back Suction Control

A common method of changing the air – fuel ratio in large carburetors as the back suction control shown in fig. In this arrangement a relatively large vent line connects the carburetor entrance with the top of the float chamber. Another line, containing a very small orifice line, connects the top of the float chamber with the venturi throat. A control valve is placed in the large vent line. When the valve is wide open, the vent line unrestricted the pressure in the float chamber is equal to P_1, and the pressure difference acting on the fuel orifice is $(P_1 – P_2)$. If the valve is closed, the float chamber communicates only with the venturi throat and the pressure on the fuel surface will be P_2. Then Δp_f will be zero, and no fuel will flow. By adjusting the control valve any pressure between p_1 and p_2 may be obtained in the float chamber, thus changing the quantity of fuel discharged by the nozzle.

(e) Auxiliary valve carburetor.



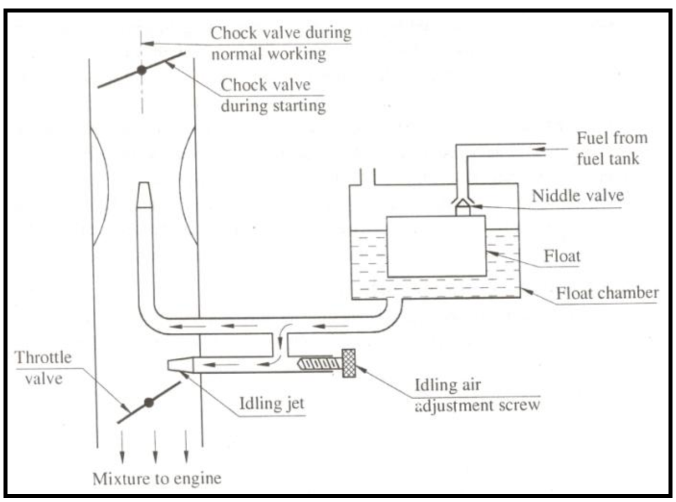
Auxiliary Valve

An auxiliary valve carburetor is illustrated in fig. With an increase of engine load, the vacuum at the venturi throat also increase. This causes the valve spring to lift the valve admitting additional air and the mixture is prevented from the becoming over – rich.

(f) Auxiliary port carburetor.

An auxiliary port carburetor is illustrated in fig. By opening the butterfly valve, additional air is admitted and at the same time the depression at the venturi throat is reduced, decreasing the quantity of fuel drawn in. This method is used in aircraft carburetors for altitude compensation.

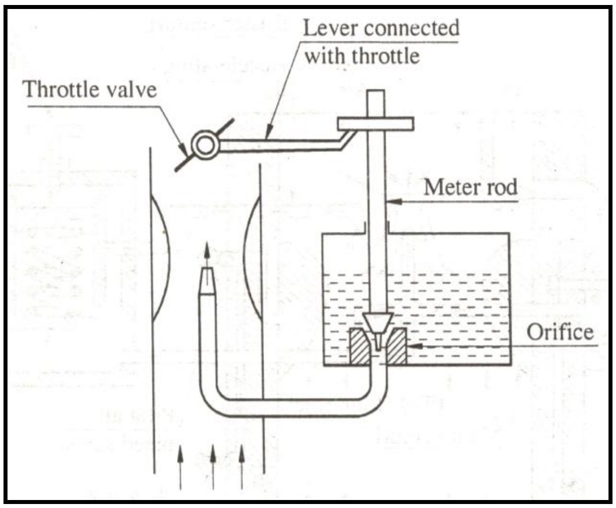
Idling system.



Idling System

It has already been shown that at idling and low load the engine requires a rich mixture (about A/F 12: 1), However, the main metering metering system not only fails to enrich the mixture at low air flows but also supplies no fuel at all at idling. For this reason, a separate idling jet must be added to the basis carburetor. An example of idling jet is shown in fig. In consists of a small fuel line from the float chamber to a point a little on the engine side of the throttle. This line contains a fixed fuel orifice. When the throttle is practically closed, the full manifold suction operators on the outlet to this jet. In addition, the very velocity past the throttle plate increase the suction locally. Fuel can therefore be lifted by the additional height up to the discharge point, but this course only at very low rates of air flow. As the throttle is opened, the main jet gradually takes over while the idle jet becomes ineffective.The desired air-fuel ratio for the idling jet is regulated manually by idle adjust, which is a needle valve controlling the air bleed.

Power Enrichment or Economizer System.



Power Enrichment

As the maximum power range of operation (75% to 100% load) is approached, some device must allow richer mixture (A/F about 13.1,F/A 0.08) to be supplied despite the compensating leanness. Such a device is the meter rod economizer shown in fig. The name economizer is rather misleading. It stems from the fact that such a device provides a rich uneconomical mixture at high load demand without interfering with economical operation in the normal power range. The meter rod economizer shown in fig. simply provides a large orifice opening to the main jet as the throttle is opened beyond a certain point. The rod may be tapered or stepped. Other examples provide for the opening of auxiliary jets through some linkages to the throttle movement or through a spring action when manifold vacuum is lost as the throttle is opened.

Acceleration Pump System.
It has already been shown that when it is desired to accelerate the engine rapidly, a simple carburetor will not provide the required rich mixture. Rapid opening of the throttle will be immediately followed by an increased air flow, but the inertia of the liquid fuel will cause at least a momentarily lean mixture just when richness is desired for power. To overcome this deficiency an acceleration pump is provided, one example of which is shown in fig. The pump consists of a spring loaded plunger. A linkage mechanism is provided so that when the throttle is rapidly opened the plunger moves into the cylinder and forces an additional jet of fuel into the venture. The plunger is raised again against the spring force when the throttle is partly closed. Arrangement is provided so that when the throttle is opened slowly, the fuel in the pump cylinder is not forced into the venture but leaks past plunger or some holes into the float chamber.

Instead of the mechanical linkage shown some carburetors have a pump plunger held up by manifold vacuum. Whenever that vacuum is reduced by the rapid opening of the throttle, a spring forces the plunger down in a pumping action identical to that of the pump illustrated.

Choke.
During cold starting period at low cranking speed and before the engine has warmed up, a mixture much richer than usual mixture (almost 5 to 10 times more fuel) must be supplied simply because a large friction of the fuel will remain liquid even in the cylinder, and only the vapour fraction can provide a combustible mixture with the air. The most common means of obtaining this rich mixture is by the use of a choke, which is a butterfly type of valve placed between the entrance to the carburetor and the venture throat as shown in fig. By partially closing the choke, a large pressure drop can be produced at the venture throat that would normally result from the amount of air following through the venturi. This strong suction at the throat will draw large quantities of fuel from the main nozzle and supply a sufficient rich mixture so that the ratio of evaporated fuel to air in the cylinders is within combustible limits. Choke valves are sometimes made with a spring loaded by-pass so that high pressure drops and excessive choking will not result after the engine has started and has attained a higher speed. Some manufactures make the choke operate automatically by means of a thermostat such that when the engine is cold the choke is closed by a bimetallic elements. After starting and as the engine warm up the bimetallic element gradually opens the choke to its fully open position.

An alternative to the choke is the provision of auxiliary fuel jets that are opened manually or automatically only as required.

Carburetor Types:

There are basically two types of carburetors open chock and constant vacuum type. In the former, the main orifice, known as the choke tube or venture, is of fixed dimensions, and metering so effected by varying the pressure drop across it. In the case of the constant vacuum type the area of the air passage is varied automatically while the pressure drop is kept approximately constant. Almost all carburetors except S.U. Carburetor are of open choke type. The important examples of open choke type are Zenith, Solex, Center and Stromberg carburetors. S.U. carburetor is of constant vacuum type.

Carburetors may be up draught, horizontal or downdraught. The downdraught and horizontal are most widely used. The downdraught has the advantage that the mixture is assisted by gravity in its passage into the engine induction tract, and at the same time the carburetor is usually responsibly accessible. The horizontal version has some advantage where under-bonnet space is limited. The up draught variety is now almost obsolete and is only used where neither of the other types can be accommodated.

Description of Some Important Makes of Carburetors

Solex Carburetors. :

The Solex carburetor is famous for ease of starting, good performance, and reliability. It is made in various models, and is used in fiat and standard cars and Willy's jeep.A schematic arrangement of a Solex carburetor. The unique feather of this carburetor is the Bi-starter for cold starting. The various circuits of the Solex carburetor are described below:

(i) Normal Running:

The Solex carburetor has a conventional float (1) in a float chamber. For normal running, the fuel is provided by the main jet (2) and the air by the choke tube or venturi (3) the fuel from the main jet passes into the well of the air bleed emulsion systems. 4) is the emulsion tube which has lateral holes. The correct balance of air and fuel is automatically ensured by air entering through and being calibrated by the air correction jet. (5) The metered emulsion of fuel and air is discharged through the spraying orifice or nozzles (6) drilled horizontally in the vertical standpipe in the middle of choke tube or venturi. (7) Is the conventional butterfly valve.

(ii) Cold Starting and Warming.

The unique feature of Solex carburetors is the provision of bi-starter or a progressive starter. The starter valve is in the form of a flat disc (8) with holes of different sizes. These holes connect the starter petrol jet (9) and starter air jet sides to the passage, which opens into a hole just below the throttle, valve at (11). Depending upon the opposite the passage. The starter lever (12) either bigger or smaller holes come opposite the passage. The starter lever, which rotates the starter valve, is operated from the dashboard control by mean if a flexible cable. Initially, for starting richer mixture is required and after the engine starts the richness required decreases. So in the start position the starter control pulled out fully bigger holes are the connecting holes. The throttle valve being in the position the whole of the engine suction is applied to starting passage (11), sucking petrol from jet (9) and air from jet (10). The jets and passages are so shaped that the mixture supplied to the carburetor is rich enough for starting.

After the engine has started, the starter, the starter level is brought to the intermediate position, bringing the smaller hole in the starter valve (8) in to circuit, thus reducing the amount of petrol. Also this position, the throttle valve is partly open, so that the petrol is also coming out from the main jet. The reduced mixture supply from the starter system in this situation is however sufficient to keep the engine running, till it reaches the normal running temperatures, when the starter is brought to off position.

(iii) Idling and Slow Running.

From the lower part of the well of the emulsion system a hole leads off to the pilot jet (13). At idling the throttle is almost closed and hence engine suction is applied at the petrol jet. Fuel is drawn there form, and mixed with a small amount of air admitted through the small pilot air bleed orifice (14) and forms an emulsion which is conveyed down the vertical channel and discharged into the throttle body past the idling volume control screw (15). The slow running adjustment screw allows the speed of the engine to be varied. The volume control screw (15), which permits variation of the slow, running jet6s delivery of petrol, allows the richness of the mixture to be corrected with accuracy.

To ensure the smooth transfer from idle and low speed circuit to the main jet circuit without the occurrence of flat spot, bypass orifice (17) is provided on the venture side of the throttle valve. As the throttle is opened wide, the suction at idle port (16) is decreased. But suction is also applied now at the idle port and thus spot is avoided.

(iv) Acceleration.

To avoid flat spot during acceleration a diaphragm type acceleration pump is provided. It delivers spurts of extra fuel needed for acceleration through pump injector (18). Pump lever (19) is connected to the accelerator so that when the pedal is pressed, the lever moves towards left, pressing the membranes towards left-thus forcing the petrol through moves the diaphragm back towards right creating vacuum towards left which opens the pump inlet valve (21) and thus admits the petrol from chamber into the pump.

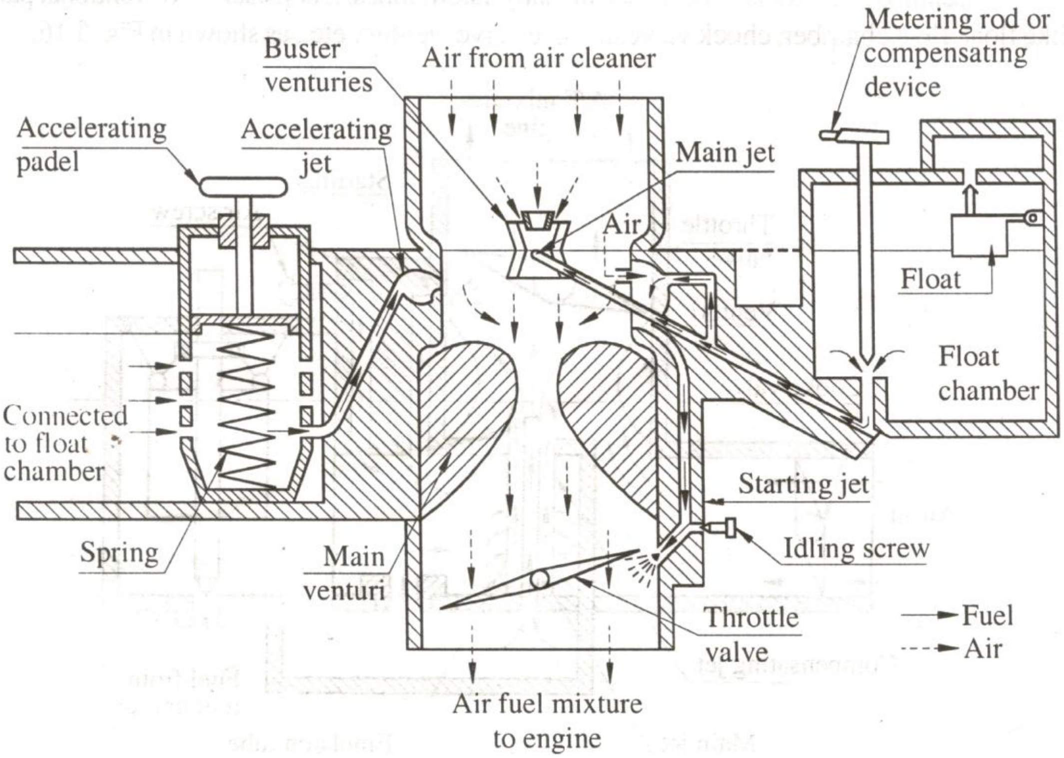
1. Carter Carburetor.

Carter carburetor is an American make carburetor and is used in jeep. A diagrammatic view of a downdraft type carburetor is described below.

The petrol enters the float chamber (1), which is of the conventional type. The air enters the carburetor from the top; a choke valve (2) in the passage remains open during normal running. The carter carburetor has a triple remains open during normal running. The carter carburetor has a triple venture diffusing type of choke, i.e. it has three ventures, and the smallest lies above the level in the float chamber. Other two below the petrol level, one below other. At very low speeds, suction in the primary venture (3) is adequate to draw the petrol. The nozzle (4) enters the primary venture at an angle, delivering the fuel upwards against the air stream securing an even flow of finally divided atomized fuel. The mixture from the primary venture passes centrally through the secondary venture (5) where it is surrounded by a blanket of air stream and finally this leads to the third venture (6), where again the fresh air supply insulates the stream from the second venture. The mixture reaches the engine in atomized form. Multiple ventures result in better formation of the mixture at very low speeds causing steady and smooth operation at very low and also at very high engine speeds.

In the carburetor a mechanical metering is employed in the fuel circuit there is a metering rod (7) actuated by a mechanism connected with the main throttle. The metering rod has two or more steps of diameter. The area of opening between the metering rod and metering rod governs the amount of petrol drawn in to the engine. At top speed the metering rod is lifted, the smallest section of the rod is in the jet and the maximum quantity of petrol flows out to mix with the maximum amount of air corresponding to full throttle opening.

Starting circuit: For starting a choke valve (2) is provided in the air-circuit. The choke valve is butterfly type, one half of which is spring controlled. The valve is hinged at the centre. When the engine is fully choked, the whole of the engine suction is applied at the main nozzle, which then delivers fuel. As the airflow is quit small, the mixture supplied is very rich. Once the engines fires, the spring-controlled half of the choke valve is sucked open to provide correct amount of air during warming up period.



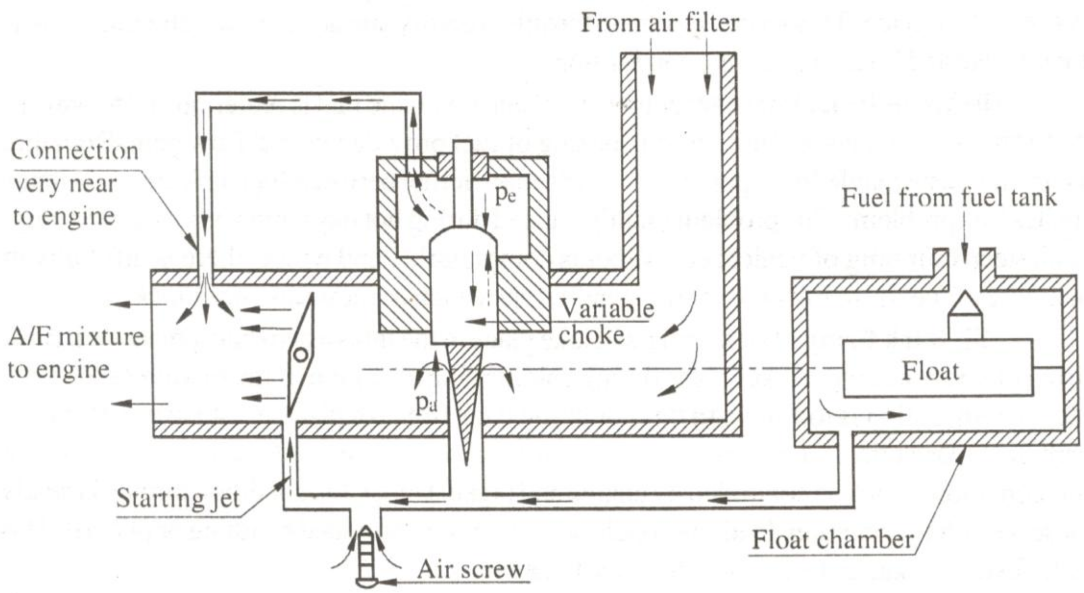
Carter Carburetor.

Idle and low speed circuit: For idling rich mixture is required in small quantity. In idling condition throttle valve (8) is almost closed. The whole of the engine suction is applied at the idle port (9). Consequently the petrol is drawn through the idle feed jet (10) and air through first bypass (11) and a rich idle mixture is supplied. In low speed operation the throttle valve is delivered both by the main venture and low speed port (12) through idle passage.

Acceleration pumps circuit. The acceleration pump is meant to overcome flat spot in acceleration. The pump consists of a plunger (13) working inside a cylinder consisting of inlet check valve (14) and outlet check valve (15). The pump plunger is connected to accelerator pedal by throttle control rod (16). When the throttle is suddenly opened pressing accelerator pedal, pump is actuated and a small quantity of petrol is spurted into the choke type by a jet (17). Leaving the accelerator pedal causes the pump piston to move up, thereby, sucking fuel from the float chamber for next operation. The purpose of acceleration pump is only to provide an extra spurt of fuel during acceleration pump is only to provide an extra spurt of fuel during acceleration to avoid flat spot not to supply fuel continuously for heavy load.

2. S. U. Carburetor:

Carburetor in general is 'constant choke' type. Zenith, Solex and carter carburetors are examples of this type. S.U.carburetor differs completely from them being 'constant vacuum or depression' type with automatically variable choke. The diagrammatic view of the basic components of a horizontal S.U. carburetor. The carburetor has a conventional system of float chamber which feeds fuel into a vertical channel in which is situated the jet sleeve (1). The sleeve bears a number of holes in its side, so that the fuel will enter the sleeve and thus stand the same level as in the float chamber.



S U Carburetor

Into the jet sleeve (1) fits the tapered metering needle (2) which a secured by a grub screw into the choke piston assembly (3). This part of the piston sides up and down in the air passage, one end of which is connected to atmosphere through air cleaner and the other to the engine thought a conventional throttle valve (4). The upper portion of the choke piston if formed into a suction disc. (5). Which is a sliding fit in the suction chamber (6), the whole assembly being located by a hardened hollow steef guide rod (13), which has its bearing in the long boss in the centre of the suction chamber as shown. The upper side of suction disc is connected to the air passage through a suction hole (7) and the lower side to the atmosphere through at atmospheric hole (8).

The working of the carburetor is as follows: By means of the suction hole, engine depression is transmitted to the upper face of the suction piston, while atmospheric air pressure is admitted to the lower chamber through the atmospheric hole. Thus the piston on chock piston any instant depends upon the balance of its own weight and a light spring (9) (down) if provided, against the vacuum force (up). As the weight of the piston is constant, the vacuum also remains constant. Thus, constant vacuum, variable choke is obtained. Due to constant vacuum at approximately constant air velocity is maintained. With the vertical movement of the choke piston the metering needle also moves up and down concentrically in the petrol jet orifice (10), thus varying the effective area of the jet. As the piston rises under increased suction, the tapped needle also moves upwards and increases the effective jet area, allowing a greater amount of petrol to flow into the main air stream and vice versa. Thus approximately constant air-fuel ratio is maintained.

The unique feature of the S.U. carburetor is that it has only one jet. There is no separate idling or acceleration pump. Since a constant high air velocity across the jet is maintained even under idling condition, the necessity for a separate idling jet is obviated.

For cold starting a rich mixture is required. This is provided by an arrangement to lower the jet tube away from the needle by means of the jet lever, thereby enlarging the jet orifice. The lever is operated from the dashboard in the car.

There is also an arrangement providing a slightly rich mixture on acceleration. For this purpose an oil dashpot (12) is provided in the upper part of the hollow piston guide rod (13). In this a small piston (14) is suspended by a rod from the oil cap nut (15). This arrangement also prevents the flutter of choke piston.

In turning the carburetor, vibration in mixture strength is obtained by selecting needles having different tapers, and a wide range of different needles available. The idling speed is adjusted with the help of adjustment nut, which moves the jet sleeve up and down.

The S.U. carburetor is used in many British cars and was used in Hindustan Ambassador car.

Experiment No: 4

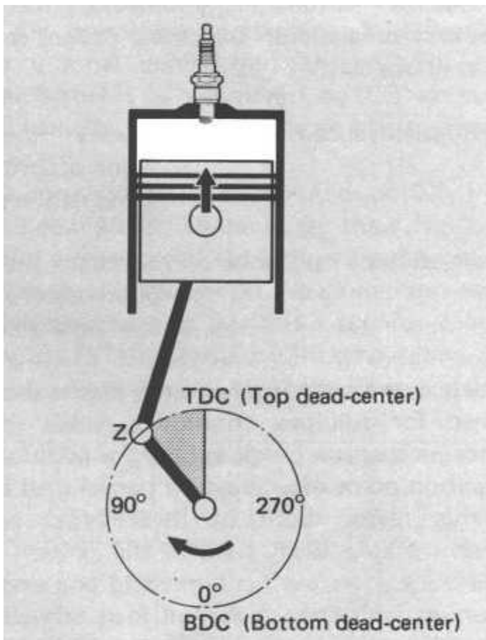
AIM: To Study about Combustion in SI and CI Engine.

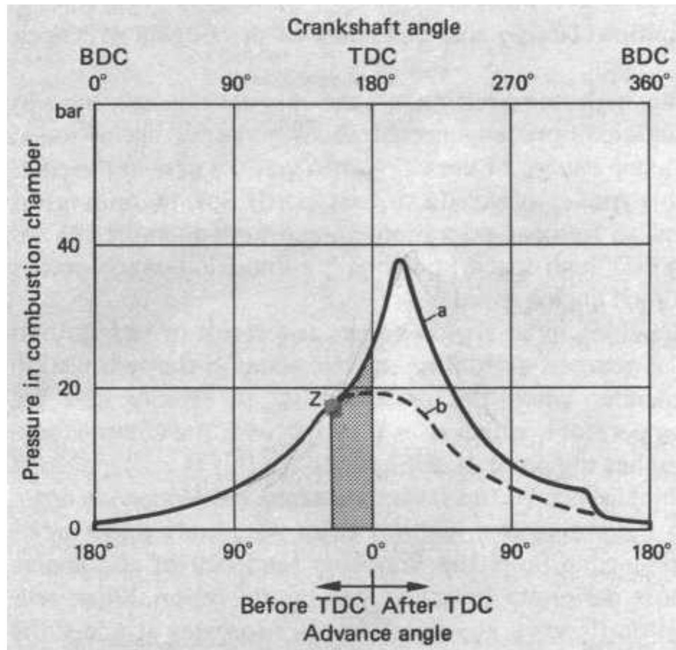
Objective: Students will be able to,

1. Interpreted the phenomenon of combustion in SI and CI engines
2. Infer the occurrence of Knocking in SI and CI engines.

COMBUSTION in SI ENGINES

In a conventional SI engine, fuel and air are mixed together in the intake system, inducted through the intake valve into the cylinder where mixing with residual gas takes place, and then compressed during the compression stroke. Under normal operating conditions, combustion is initiated towards the end of compression stroke at the spark plug by an electric discharge. Following inflammation, a turbulent flame develops, propagates through the premixed air-fuel mixture (and burned gas mixture from the previous cycle) until it reaches combustion chamber walls, then it extinguishes.





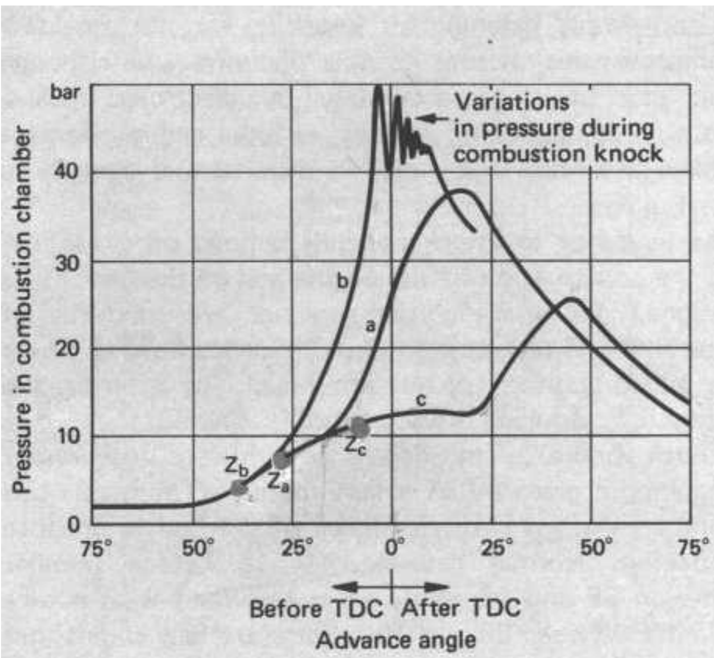
COMBUSTION

Combustion event must be properly located relative to the TDC to obtain max power or torque. Combined duration of the flame development and propagation process is typically between 30 and 90 CA degrees.

If the start of combustion process is progressively advanced before TDC, compression stroke work transfer (from piston to cylinder gases) increases. If the end of combustion process is progressively delayed by retarding the spark timing, peak cylinder pressure occurs later in the expansion stroke and is reduced in magnitude.

These changes reduce the expansion stroke work transfer from cylinder gases to the piston. The optimum timing which gives maximum brake torque (called maximum brake torque or MBT timing) occurs when magnitude of these two opposing trends just offset each other.
Timing which is advanced or retarded from this optimum MBT timing gives lower torque.

Optimum spark setting will depend on the rate of flame development and propagation, length of flame travel path across the combustion chamber, and details of the flame termination process after it reaches the wall - these depend on engine design, operating conditions and properties of the fuel-air and burned gas mixture.



With optimum spark setting, max pressure occurs at about 15 degrees CA after TDC (10 - 15), half the charge is burned at about 10 degrees CA after TDC.

In practice spark is retarded to give a 1 or 2 % reduction in brake torque from max value, to permit a more precise definition of the timing relative to the optimum.

Normal combustion

spark-ignited flame moves steadily across the combustion chamber until the charge is fully consumed.

Abnormal combustion

fuel composition, engine design and operating parameters, combustion chamber deposits may prevent occuring of the normal combustion process. There are two types of abnormal combustion

(i) Knock
(ii) Surface ignition

Piston Damage by Knock

KNOCK

Knock is the autoignition of the portion of fuel, air and residual gas mixture ahead of the advancing flame that produces a noise.
As the flame propagates across combustion chamber, end gas is compressed causing pressure, temperature and density to increase.
Some of the end gas fuel-air mixture may undergo chemical reactions before normal combustion causing autoignition - end gases then burn very rapidly releasing energy at a rate 5 to 25 times in comparison to normal combustion. This causes high frequency pressure oscillations inside the cylinder that produce sharp metallic noise called knock.
Knock will not occur when the flame front consumes the end gas before these reactions have time to cause fuel-air mixture to autoignite. Knock will occur if the precombustion reactions produce autoignition before the flame front arrives.

Surface Ignition

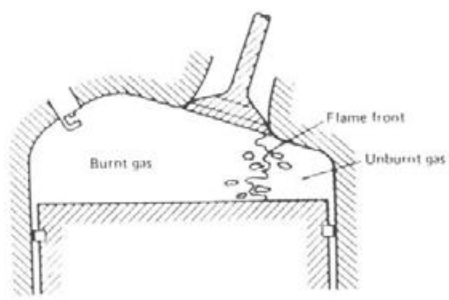
Surface ignition is ignition of the fuel-air charge by overheated valves or spark plugs, by glowing combustion chamber deposits or by any other hot spot in the engine combustion chamber - it is ignition by any source other than the spark plug.
It may occur before the spark plug ignites the charge (preignition) or after normal ignition (postignition). It may produce a single flame or many flames. Surface ignition may result in knock.

Normal Combustion

When piston approaches the end of compression stroke, a spark is discharged between the spark plug electrodes – spark produces a small nucleus of flame that propagates into unburnt gas. There is a delay of approx constant duration until a noticable increase in the cylinder pressure as a result of chemical reactions is recorded in “p ~ α diagram” - called the delay period. This is approx 0.5 ms (for example corresponds to 7.5 OCA at 2500 rpm) and only approx 1 % of the charge is burned during that period.
Delay period depends on temperature, pressure and composition of fuelair mixture, the energy applied at the spark plug, the duration of the spark, volume of the charge which is ignited initially and the gas flow in the cylinder (turbulence level).

Second stage of combustion

After the ignition, cylinder pressure continues to rise while the flame front travels at a certain flame speed and peak pressure is obtained at 5 – 20 OCA ATDC. This is essential for max thermal efficiency. Since combustion takes a finite time, mixture is ignited before TDC, at the end of compression stroke – spark advance The second stage continues until maximum pressure is obtained and lasts about 25 – 30 OCA.



Combustion process takes place in a turbulent flow field.
The structure of the flame and the speed at which it propagates across the combustion chamber depends on charge motion, charge composition and combustion chamber geometry – engine design, operating conditions and mixture properties are important. The volume enflamed behind the flame front continues to grow in roughly spherical manner, except where intersected by the chamber walls. At any flame radius and engine geometry, flame front surface area influences combustion – larger this surface area, the greater the mass of fresh charge that cross this surface and enter the flame zone.

Laminar flame speed is the velocity at which the flame propagates into quiescent premixed unburnt mixture ahead of the flame. Flame is the result of a self sustaining chemical reaction occurring within a region of space called the flame front where unburnt mixture is heated and converted into products. Flame front consists of two regions; a preheat zone (temperature of the unburnt mixture is raised mainly by heat conduction from the reaction zone, no significant reaction takes place) and a reaction zone (upon reaching a critical temperature exothermic chemical reaction begins - the temperature where exothermic reaction begins to the hot boundary at downstream equilibrium burned gas temperature).

Final Stage of Combustion

Final stage covers the period from the max cylinder pressure to the termination of the combustion process. Maximum temperature value is reached during this stage (after max p) Usually 70 – 75% of the total energy is released until max p is obtained, and 85 – 90% of the total energy is released until max T is obtained. For partial load conditions, the flame speed is lower (low T and p), only 50 % of the energy is released until max pressure point.

Factors Influencing Combustion

Engine Speed

Mixture burning rate is strongly influenced by engine speed. The duration of combustion in crank angle degrees only inc slowly with increasing engine speed. Increase of the engine speed, reduces the time available for a complete combustion. Inc in engine speed also increases the mean piston speed and turbulence intensity – increses flame speed. But this does not effect ignition delay period, thus delay period increases in CA degrees. To compansate this, ignition timing should be adjusted – spark advance is increased with increasing engine speed.

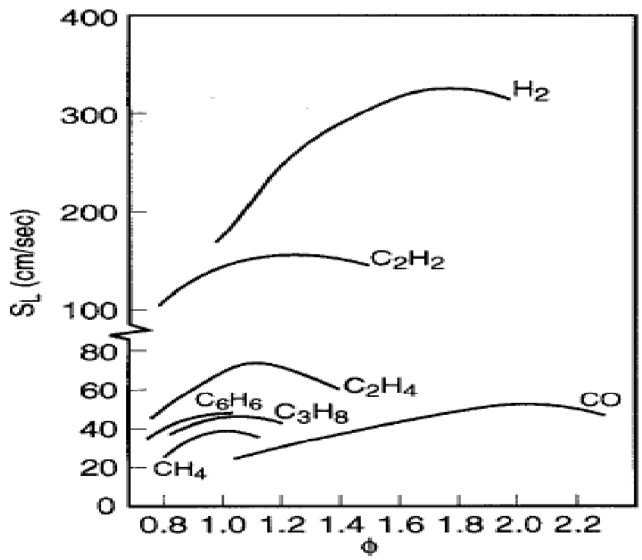
Mixture Properties

The fuel-air equivalence ratio affects the burning rate. Flame development show a minimum and the burning rate show a maximum for slightly rich mixtures ($\varphi \approx 1.2$). Burning rate reduces for richer and leaner mixtures. The burned gas fraction in the unburned mixture, due to the residual gas fraction and any recycled exhaust gases (EGR), slows down both flame development and ropagation. Residual gas fraction increases at part loads in SI-engines (due to closing the throttle), reducing flame propagation. Fuel composition changes can be significant. Faster burning engines (high turbulence) are less sensitive to changes in mixture composition, p and T than slower burning engines.

Induction Pressure

Increase in the induction pressure reduces flame propagation speed, but also increases the temperatures at the end of compression process which effects the flame speed, and reduces combustion duration. Induction pressure is effected at part-loads - partially opened throttle. Flame speed is reduced, to compansate the inc in combustion duration spark advance is increased.

Fuel Properties



Compression Ratio

Increase in CR increases the p and T of the charge at ignition, reduces the mass fraction of the residual gases - more favorable conditions are developed for ignition which reduces the first stage of combustion, and increases flame propagation rate in the main stage. Increasing CR, increases Area/Volume ratio of the cylinder, increasing the cooling effects and the quench layers. Final stage of combustion is increased.

Combustion Chamber Design

Intake manifold design and combustion chamber shape effects the gas flow and turbulence intensity. Turbulence strongly effects burning rate of the fuel.Spark plug location effects distance traveled by the flame and flame front surface area. Number of spark plugs.Pressure gradiant should be controlled for optimum conditions in terms of total efficiency.

Abnormal Combustion

Knock originates in the extremely rapid release of much of the energy contained in the end-gas ahead ofthe propagating turbulent flame, resulting in high local pressures. Non-uniform nature of this pressure distribution causes pressure waves or shock waves to propagate across the chamber, which may cause chamber to resonate at its natural frequency.

Knock Fundamentals

Origin of knock

Autoignition theory holds when fuel-air mixture in the end-gas region is compressed to sufficiently high p and T, the fuel oxidation process - starting with the preflame chemistry and ending with rapid energy release - can occur spontaneously in parts or all of the end-gas region.
Detonation theory postulates that under knocking conditions, advancing flame front accelerates to sonic velocity and consumes the end-gas at a rate much faster than would occur with normal flame speeds.

Autoignition is the term used for a rapid combustion reaction which is not initiated by any external ignition source. Autoignition of gaseous fuel-air mixture occurs when the energy released by the reaction as heat is larger than heat lost to surroundings - as a result T of the mixture increases, rapidly accelerating the rates of reactions involved.

In complex reacting systems, large number of reactions take place - simultaneous, interdependent reactions or chain reactions. There is initiating reaction where highly reactive intermediate species or radicals are produced from stable molecules (fuel and oxygen). This step is followed by propagation reactions - radicals react with reactant molecules to form products and other radicals to continue the chain. Some propagating reactions produce two reactive radical
molecules for each radical consumed - chain branching, extremely fast reaction rates. The process ends with termination reactions - chain propagating
radicals are removed.

Fuel Factors

The knocking tendancy is related to molecular size and structure of the fuel.

Paraffins - inc length of carbon chain inc knocking tendancy, compacting carbon atoms by side chains dectendancy to knock, adding methyl groups (CH3) dec knocking tendancy.

Olefins - introduction of one double bond has little effect on antiknock, two or three bond inc antiknock tendancy

Napthenes and aromatics - N have significantly greater knocking tendancy than corresponding size A, introduction of one double bond has little effect on antiknock, two or three bond reduce knocking tendancy considerably, lengthening side chain attached to basic ring structure inc knocking tendancy, branching of the side chain dec knocking tendancy.

Design Parameters

Compression ratio
increase in CR increases thermal efficiency but also increases the tendancy to knock - limits engine performance.

Combustion chamber size and shape
as combustion chamber volume gets smaller, "surface area-to-volume" ratio increases providing efficient cooling, reduces tendancy to knock. In SI-engines max piston diameter is limited to 150 mm Flame propagation distance (chamber shape and spark plug location, number of spark plugs used) also effects knock

Valve overlap
reduces residual gases, produces cooling effect - reduces knock tendancy

Engine cooling
efficient cooling reduces tendancy to knock - water cooling systems are more effective, in air-cooled engines CR is limited

Operating Parameters

Equivalence ratio
autoignition reactions occur at slightly lean mixtures - flame speed is lower (more time for autoignition to happen), pre-reaction duration is relatively short. Lean and rich mixtures - tendancy to knock is reduced.

Spark advance
increasing spark advance, p and T increases, flame speed also increases reducing the time for pre-reactions, but tendancy to knock increases with increasing spark advance.

Engine speed
turbulence intensity increases - flame propagation increases, volumetric eff is reduced and induction p is reduced, tendency to knock decreases with inc in engine speed (rpm)Induction p and Twith decreasing induction p and T, compression p and T is reduced which reduces the tendency to knock.In turbocharged engines knock tendency is increased.

Oxygen concentration in combustion chamberdecreasing oxygen concentration reduces the tendency to knock humidity of intake air also cools the charge and reduces knocking tendancy.

Cooling water temperature

cooling water T effects mean combustion chamber temperatures - tendancy to knock decreases with decrease in T

Cyclic Variations in Combustion

For successive operating cycles, cylinder pressure versus time (or CA) shows substantial variations - due to variations occuring in combustion process. Each individual cylinder can also have significant differences in the combustion process and pressure development between cylinders in a multicylinder engine.

Cyclic variations are caused by variations in mixture motion within cylinder at the time of spark cycle-by-cycle, variations in the amounts of air and fuel fed to the cylinder each cycle, and variations in the mixing of fresh mixture and residual gases within cylinder (especially in vicinity of spark plug) at each cycle.Same phenomena applies to cylinder-to-cylinder differences.

Cycle-to-cyle variations are important for, optimum spark advance (effects engine power output and efficiency) and extreme cyclic variations limit engine operation.Fastest burning cycles with over-advanced spark timing have highest tendancy to knock - determine fuel octane requirement and limit compression ratio.Slowest burning cycles with retarded spark timing are most likely to burn incompletely - set practical lean operating limits, limit EGR which engine will tolerate.
Variations in cylinder p correlate with variations in brake torque which is directly related to vehicle drivability.

Measures for cycle-to-cycle variations
pressure related parameters - max cylinder p, the crank angle at which max p occurs, max rate of p rise, crank angle at which $(dp/d\theta)$max occurs, indicated mean effective pressure.
burn-rate related parameters - max heat transfer rate, max mass burning rate, flame development angle ($\Delta\theta$d), rapid burning angle ($\Delta\theta$b)flame front position parameters - flame radius, flame front area, enflamed or burnt volume, all at given times, flame arrival at given locations.

The coefficient of variation (COV) in indicated mean effective pressure
standard deviation in indicated mean effective pressure (pime) divided by mean pime expressed in percent (usually), vehicle driveability problems usually result when COVimpe exceeds about 10 percent. COV increases by leaning the mixture.

Combustion in CI Engines

Introduction

The development of the compression- ignition (CI) engine, also known as Diesel engine, was mainly due to the work of Dr. Rudol diesel, which got a patent of his engine in 1982. Today the CI engine is a very important prime mover, being used in buses, trucks, locomotives, tractors, pumping sets and other stationary industrial applications, small and medium electric power generation and marine propulsion. The importance of CI engines is due to

(1) Its higher efficiency than SI engine is due to

(2) CI engine fuels (diesel oils) being less expansive than SI engine fuels (patrol or gas oil). Furthermore, since CI, engine fuels have a higher specific gravity than petrol, and since fuel is sold on the volume basis (liters) and not on mass basis (kg), more kg of fuel per liter are obtained in purchasing CI engine fuel.

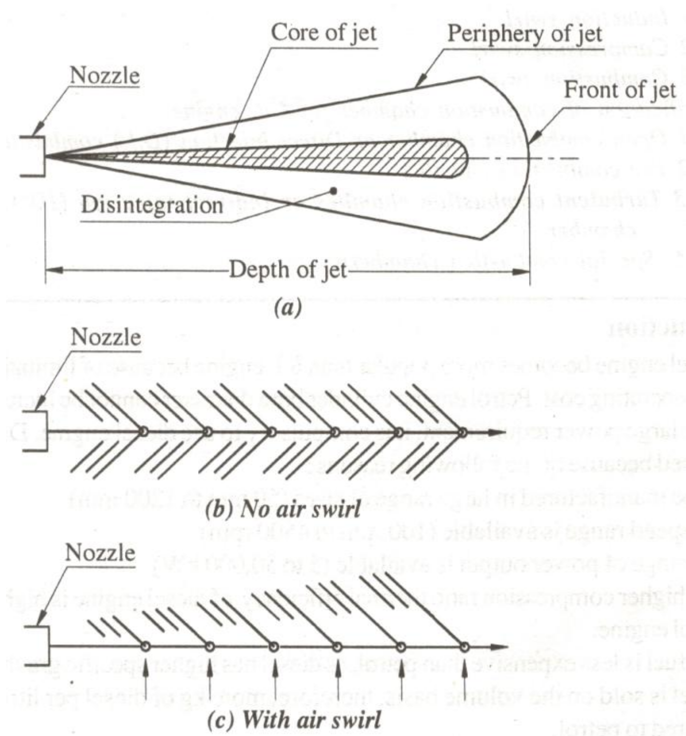
These factors make the running cost of CI engines much less than SI engines and hence make them attractive for all industrial, transport and other applications. However, the passengers cars it has not found much favor because of the main backwards of a CI engine in relation to SI engine – heavier weight, noise and vibration, smoke and odor. Because of the utilization of higher compression ratios (12: 1 to 22: 1 compared to 6: 1 to 11: 1 of SI engines) the forces coming on the various parts of the engine are greater and therefore heavier parts are necessary. Also because of heterogeneous mixture, lean mixture (large air-fuel ratio) is used. Both the factors result in a heavier engine. The smoke and odor are the result of the nature of diesel combustion phenomenon, i.e., incomplete combustion of a heterogeneous mixture, and droplet combustion.

Compression-ignition engines, because of their varied applications, are manufactured in a large of sizes, speeds, and power outputs. The piston diameters vary from about 50 mm to 900 mm, speeds range from 100 to 4400 rpm and power output range from 2 to 4352 b.p.

Combustion in the CI engine:

The process of combustion in the compression- ignition engine is fundamentally different from that in a spark- ignition engine. In the SI engine a homogeneous carbureted mixture of petrol vapour and air, in nearly stoichiometric or chemically correct ratio, is compressed in the compression stock through a small compression ratio (6:1 to 11:1) and the mixture is ignited at one place before the end of the compression stroke by means of an electric spark. After ignition a single definite flame front progresses through the air fuel mixture, and entire mixture being in the combustible range. For a given speed the quantity of charge (both air and fuel) depends on load.

In the CI engine, air along is compressed through a large compression ratio (12:1 to 22:1) during the compression stroke raising highly its temperature and pressure. In this highly compressed and highly heated air in the combustion chamber (well above ignition point of fuel) one or more jets of fuel are injected in the liquid state, compressed to a high pressure of 110 to 200 bar by means of a fuel pump. Each minute droplet as it enters the hot air (temperature 450-5500 C and pressure 30-40 bar) is quickly surrounded by an envelope of its own vapour and this, in turn, and after an appreciable interval, is inflamed at the surface of the envelope.To evaporate the liquid, latent heat is abstracted from the surrounding air, which reduce the temperature of a thin layer of air surrounding the droplet and some time must be elapse before this temperature can be raised again by abstracting heat from the main bulk of air in its vicinity. As soon as this vapour and the air in contact with it reach a certain temperature and the local air0fuel ratio is within combustible range, ignition takes place (through the core is still liquid and relatively cold). Once ignition has taken place and a flame established, the heat required for further evaporation would be supplied from that released by combustion. The vapour would be burning as fast as it can find fresh oxygen.



Schematic representation of disintegration of fuel jet in CI engine

Thus we see that at first there is a delay period before ignition takes place. (The study of delay period phenomenon is very important in the CI engine combustion and is discussed in detail later). The duration of delay period depends, among other factors, on temperature and pressure of the air and the self-ignition temperature of the fuel. The higher the air temperature or the lower self-ignition temperature, the shorter the delay. Higher pressure also results in shorter ignition delay because of increase in the rate of heat transfer and more intimate contact between the hot air and the cold fuel. Once the delay period on the ability of the droplet to find fresh oxygen, i.e. on the rate of which it is moving through the air or the air is moving past it.

In the CI engine the fuel is not injected at once, but is spread over a define period of time corresponding to 20 – 40 degrees of crank travel. The initial fuel droplets meet air whose temperature is only little above their self- ignition temperature and they ignite after the ignition delay. The subsequent fuel droplets find air already heated to a much higher temperature by the burning of initial droplets and, therefore, light up much more quickly, almost as they issue from the injector nozzle, but their subsequent progress is handicapped because of less quantity of oxygen available.

As it is impossible to inject the fuel droplets so that they distribute uniformly thought the combustion chamber is essentially heterogeneous. Under these conditions if the air writhen the cylinder were motionless, only a small proportion of the fuel would find sufficient oxygen and even burning of this fuel would be slow or even cheked as it would be surrounded by its own products of combustion. It is, therefore, essential to impart an orderly and controlled movement to air and fuel so that a continues supply of fresh air is brought to each burning droplet and the products of combustion are swept away. The effect of this air motion, called air swirl, on the fuel jet.

It may be recalled here that in the SI engine combustion also motion of the air essential to speed up the combustion. However, there is a basic difference in the motions required in SI and CI engines. In SI engines we call it turbulence and in CI engines we call it swirl. Turbulence, which is required in SI engines, implies disordered air motion with no general direction of flow, to break up the surface of the flame front and to distribute the shreds of flame thought an externally prepared homogeneous combustive mixture. Swirl which is required in CI engines implies an orderly movement of the whole body of air with a particular direction of flow, to bring a continuous supply of fresh air to each burning droplet and sweep away the products of combustion which otherwise would suffocate it.

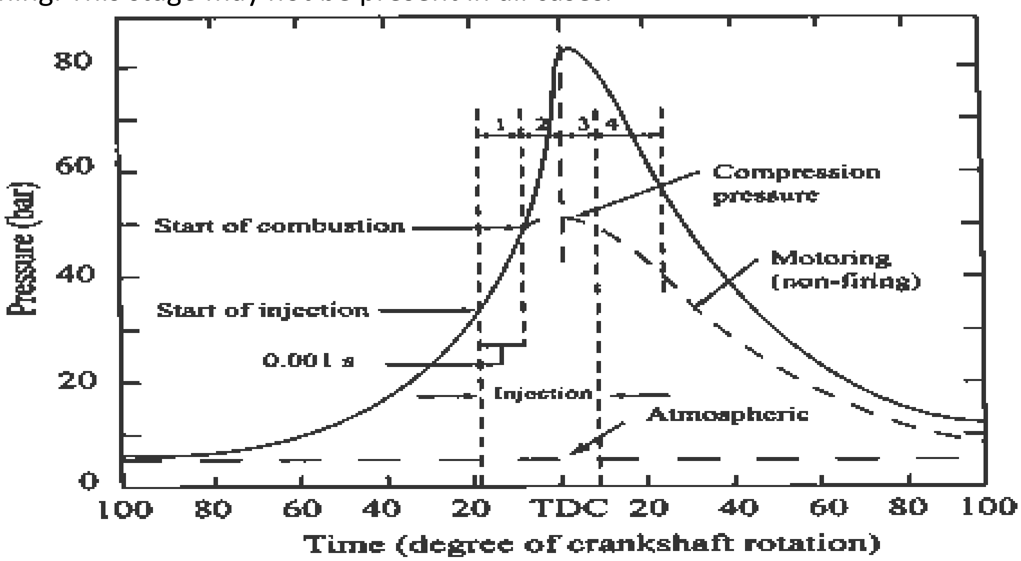
Stages of combustion:

Ricardo considered CI engine combustion as taking place in three distinct stages

1 First stage: Ignition delay period during which some fuel has been admitted has not yet been ignited. The ignition delay is counted from the start of injection to the point where p- θ curve separates from the pure air compression curve. The delay period is a sort of preparatory phase. The ignition delay is discussed in detail later.

2 Second stage: Rapid or uncontrolled combustion following ignition. In this second stage the pressure rise is rapid because during the delay period the fuel droplet have had time to spread themselves over a wide area and they have fresh air all around them. The period of rapid or uncontrolled combustion is counted from the end of delay period to the point of maximum pressure on the indicator diagram. About one-third of the heat is evolved during this period.

3 Third stage: Controlled combustion (probable diffusion flame).The second stage of rapid or uncontrolled combustion is followed by the third stage – the controlled combustion. At the end of second stage the temperature and pressure are so high that the fuel droplets injected during the last stage burn almost as they enter and further pressure rise can be controlled by purely mechanical means, i.e by the injection rate .The period of controlled combustion is assumed to end at maximum cycle temperature. The heat evolved by the end of controlled combustion is about 70 to 80 percent of the total heat of the fuel supplied during the cycle. To these three stages of combustion, first proposed by Ricardo, a fourth stage can be added – late burning or after – burning. This stage may not be present in all cases.



Stages of combustion in the CI engine.

4 Fourth stage: After burning. Theoretically it is expected that combustion process shall end after the third stage. However, because of poor distribution of the fuel particles, combustion continues during part of the reminder of the expansion stroke. This after burning can be called the fourth stage of combustion. The duration of the after- during can be called the fourth stage of combustion. The duration of the after burning phase may correspond to 70-80 degrees of crank travel from tdc and the total heat envied by the end of entire combustion process is 95 to 97% and 3 to 5 % of heat goes as unburnt fuel in exhaust.

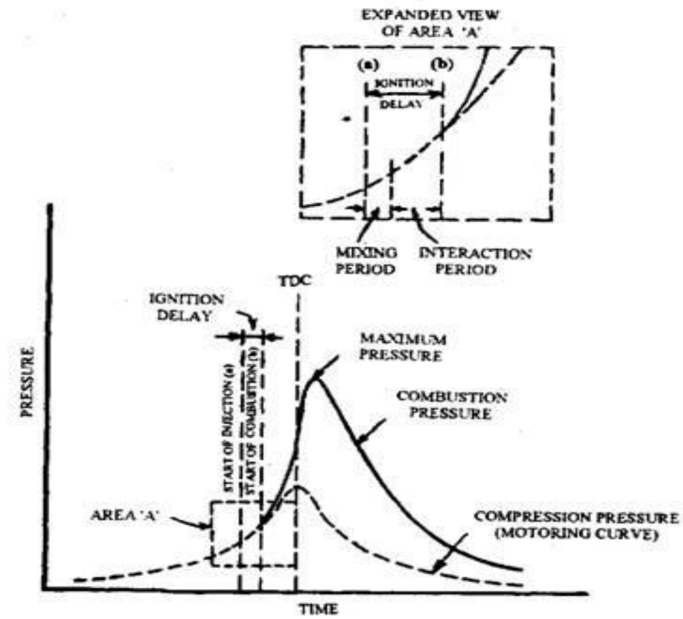
Delay period or Ignition lag:

The first stage of combustion in the CI engine i.e. the delay period exerts a very great influence on both engine design and performance and therefore, needs a detailed study. Pressure crank angle (or time) diagram between points "a" and "b". Points "a" represents the time of injection and point "b" represent the time at which the pressure curve (caused by combustion) first separates from the compression curve (non-firing or motoring) curve. This ignition delay period can be roughly divided in to two parts.

(1) **Physical delay**: The period of physical delay is the time between the beginning of injection and the attainment of chemical reaction conditions. In the physical delay period the fuel is atomized vaporized mixed with air, and raised in temperature.

(2) **Chemically delay**: The second part of the delay is called chemical delay in which pre flame reactions start slowly and then a accelerate until local inflammation or ignition takes place. Generally chemical delay is longer than the physical delay. However, it depends on temperature. At high temperatures chemical reaction is quicker and physical delay is longer than chemical delay. The delay period refers to the sum of physical and chemical delay. In most CI engines the ignition delta is shorter than the duration of injection.

In fact the ignition lag in the SI engine is basically equivalent to the chemical delay in the CI engine. There is no component like physical delay in the SI engine as the charge consists of homogeneous mixture of vaporized fuel and air. The delay period in CI combustion affects rate of pressure rise and, hence, knocking. It also affects engines start ability.



Pressure - time diagram illustrating ignition delay

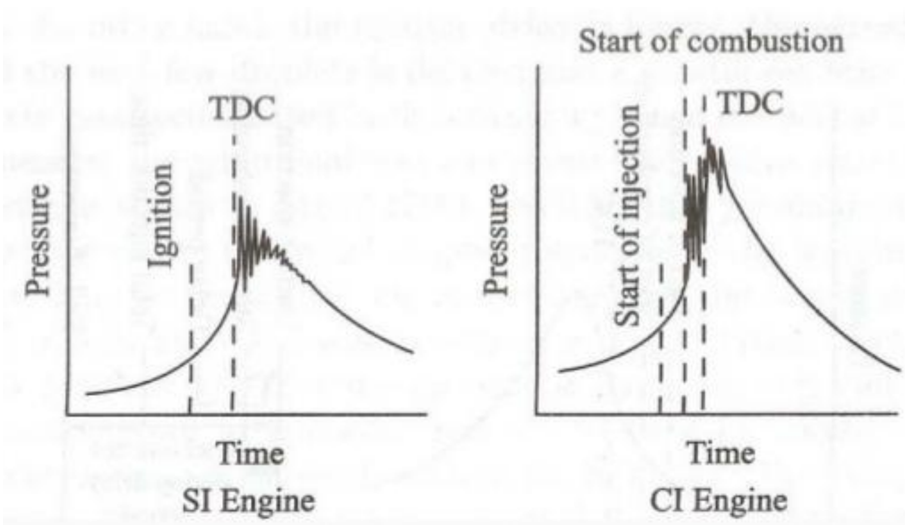
It is clear that the pressure reached during the second stage will depends on the duration of the delay period (the longer the delay period the more rapid and higher is the pressure rise, since more fuel will be present in the cylinder before the rate burning comes under control. This causes rough running and may cause 'diesel knock'. (The diesel knock is discussed in detail later). Therefore the diesel engine designer aims to keep the delay period as short as possible, both for smooth running and to maintain control over the pressure changes. But some delay period is necessary otherwise the droplets would not be dispersed in the air for complete combustion. This will result in high smoke and high fuel consumption. In practice, the delay period is more than required and the designer's efforts are always devoted towards shortening it as much as possible.

Diesel knock:

We have already discussed that if the delay period is a long a large amount of fuel will be injected and accumulated in the chamber. The auto- ignition of this large amount of fuel may cause high rate of pressure rise and high maximum pressure, which may cause knocking in diesel engines. A long delay period not only increase the amount of fuel injected by the moment of ignition, but also improves the homogeneity of the fuel- air mixture and its chemical preparedness for explosion- type self-ignition similar to detonation in SI engines.
It is very instructive to compare the phenomenon of detonation in SI engines with that of knocking in CI engines. There is no doubt that these two phenomena are fundamentally similar. Both are

processes of auto-ignition subject to the ignition time-lag characteristics of the fuel-air mixture. However, differences in the knocking phenomena of the SI engine and the CI engine should also be carefully noted.

(1) In the SI engines, the detonation occurs near the end of combustion whereas in the CI engines detonation occurs near the beginning of combustion.
(2) The detonation in the SI engine is of a homogeneous charge causing very high rate of pressure rise and very high maximum pressure. In the CI engine the fuel and air are imperfectly mixed and hence the rate of pressure rise is normally lower than that in the detonating part of the charge in the SI engine.



Detonation in the SI engine compared with knocking in the CI engine

(3) Since in the CI engine the fuel is injected in to the cylinder only at the end of compression stroke there is no question of ’ pre-ignition’ or ‘ premature ignition’. As in the SI engine.
(4) In the SI engine it is relatively easy to distinguish between knocking and non-knocking operation as the human ear easily finds the distinction. However, in the case of the CI engines have a sufficiently high rate of pressure rise per degree of crank angle to cause audible noise. When such noise becomes excessive or there is excessive vibration in engine structure, in the opinion of the observe, the engine is said to knock. It is clear that personal judgment is involved here. Thus in the CI engine there is no definite distinction between normal and ‘ knocking ‘ combustion. The maximum rate of pressure rise in the CI engine may reach as high as 10 bars per crank degree angle.

It is most important to note that factors that tend to reduce detonation in the SI engine increase knocking in the CI engine and vice verse because of the following reason. The detonation or knocking in the SI engine is due to simultaneous auto-ignition of the last part of the charge. To eliminate detonation in the SI engine we want to prevent altogether the auto-ignition of the last part of the charge and therefore desire a long delay period and high self-ignition temperature of the fuel. To eliminate knock in the CI engine we want to achieve auto-ignition as early as possible and therefore desire a short delay period and low self-ignition temperature of the fuel. The factors, which reduce knocking in the SI and CI engines.

It is also clear from the above table and discussion that & good CI engine fuel is a bad SI engine fuel and a good SI engine fuel is bad CI engine fuel. In other words, diesel oil has low self-ignition temperature and short time lag where as petrol has Hugh self-ignition temperature and long ignition lag. In terms of fuel rating diesel oil has high Cetane number (40-60) and low octane number (about 30) and petrol has high octane number (80-90) and low Cetane number (18).

Sr no.	Factors	SI engine	CI engine
1	Self-ignition temperature of fuel	High	Low
2	Time lag or delay period for fuel	Long	Short
3	Compression ratio	Low	High
4	Inlet temperature	Low	High
5	Inlet pressure	Low	High
6	Combustion chamber wall temperature	Low	High
7	Speed	High	Low
8	Cylinder size	Small	Large

Methods of controlling diesel knock (Reducing delay period):

1. The above discussions of delay period suggest design and operating factors for reducing the delay period.

Reducing the degree of turbulence as it will reduce heat loss can also reduce the delay period. However, it will increase the combustion period and thus reduce torque and thermal efficiency.

2. The delay angle is reduced (i.e. Cetane number is increase) by adding chemical dopes, called ignition accelerators. The two chemical dopes used are ethyl-nitrate and amyl-nitrate in concentrations of 8.8 gm/ liter, respectively.

The chemical dopes increase the pre flame reactions and reduce the flash point. These chemicals increase the Cetane rating of diesel fuel by auto ignition at lower temperatures. Unfortunately, these are expansive and because they contain nitrogen, they increase NO_2 emissions dramatically.

3. There would be high rate of pressure rise and high maximum pressure in the second stage (uncontrolled combustion) if large amount of fuel collects in the delay period. It can be reduce by arranging the injector so that only a small amount of fuel is injected a first. Oxfords achieved this by employing two injectors, slightly ‘out of phase. But a long combustion would reduce the thermal efficiency.

Experiment No: 5

AIM: To carry out performance test of computerized four stroke single cylinder diesel engine test rig

Objective:
1. To conduct a load test on 4stroke, single cylinder diesel engine to study its performance under various loads.
2. To find the result as per calculation and compare these with one which is obtained by computerized test rig.

DETAILED SPECIFICATIONS OF TEST RIG :

Supplier Name : **Technical Teaching (D) Equipments**
No. 73/13, Doddanna Industrial Estate,
19th Cross, Vishwaneedam Post,
Near Peenya 2nd Stage", Bengaluru, Karnataka, 56009

Date of Installation : **23/03/2016**

Total Cost : **₹ 6,25,000**

Parameters measured : 1.Performance test
2. Heat balance test

Standard Accessories:

- Fuel Measurement consumption by volumetric method and also provide fuel measurement by load cell on fuel tank.
- Air intake measurement by using orifice plate U tube manometer of proper height & Air box with size of 300X300X500 mm.
- Digital RPM meter (Except Mechanical loading)
- Digital Electronic torque controller for Eddy current dynamometer
- Digital temperature gauges (Air IN, Exhaust OUT, Cooling Water IN and OUT)
- fuel tank 10 lit capacity,
- Water flow Measurement through Rota meter with 2400 LPH capacity
- Clean and soft water supply tank of capacity 300 lit with ISI certified motor pump set.
- Combustion pressure sensor, crank angle sensor ,
- Exhaust gas calorimeter,
- Engine interfaces, computer system with i3 processor or equivalent AMD processor, window 8 OS and ms office 2014, 1 PCI slot and PC card, data logger with suitable software & LED colour monitor.

Test Rig is capable of find out Different parameters Like:

1. brake power
2. fuel consumption

3. brake thermal efficiency
4. BMEP
5. volumetric efficiency
6. air fuel ratio
7. indicated power
8. friction power
9. IMEP
10. indicated thermal efficiency
11. mech. Efficiency
12. Indicated Torque
13. Diagrams of Combustion pressure versus crank angle, Combustion pressure versus volume, Heat Release Curve.

- **Experiment Manual and spare part Manual is available in soft and hard copy**

Safety Precautions:

1. Use this test rig with permission of lab in charge/ subject teacher/ competent authority only.
2. Testing and performance on this test rig must be done under able supervision only.
3. Before starting engine start cooling water circulation pump without fail. Never run the test rig without cooling water supply, this may damage pressure measuring sensors.
4. Immediately turn OFF the engine if water supply is interrupted, or temperature sensor is showing higher temperature then permissible value.
5. Make sure for proper quantity of fuel and cooling water supply is available in respective tanks for the duration of performance.
6. After starting engine wait of steady state before taking results for batter accuracy of reading.
7. In the computer, save all reading and performance report in a proper directory with proper name to have hassled-free reporting and filing.

8. Do not uses USB drive to take the data / report etc from computer, concern lab in-charge shall provide that.
9. After copulation of performance / testing shut off all equipment and peripherals properly.
10. Without fail make an entry of using this test rig in UTILIZATION REGISTER of test rig.

Operating Procedure (S.O.P.) :

1. Select start – all programs – engine_9ch_new, the main window computerized test bench tester opens.
2. Before starting test set all the engine parameters and initial values through initial settings which are necessary for calculating various engine parameters.
3. To open initial setting window select file DUT info - initial settings.
4. All the channels have to be calibrated before starting the test for the first time.
5. “Load & Heat balance test” window displays load applied on the engine along with torque and speed.
6. Following 4 tab windows : a) observation data, b) load and efficiency, c) heat balance, d) heat balance credit and debit will appear enter data recorded.
7. File path shows where the data are stored when SAVE button is pressed.
8. Time taken for fuel consumption for last test will show in sec taken for the engine to consume the quantity of fuel between high sense and low sense sensors for the last set of readings taken.
9. Clicking on start test button “Datalog10CH” window will appear.
10. Data logger will test the engine automatically and “PV-Pθ Diagram” window will appear.

Observations and Calculations:

Testing Parameters of Engine:

- Note it down from the test data sheet developed from test rig Software

Sr. No.	Particulars	Value as available	Value with Unit conversion (if Required)
1.	Engine Type as per classification:		
2.	Bore Diameter:		
3.	Stroke Length:		
4.	Engine speed(Rated):		
5.	Fuel used:		
6.	C. V. of Fuel used:		

Observations for Efficiency Calculations:

- Note it down from the test data sheet developed from test rig Software

Sr. No	Particulars	Test 1	Test 2	Test 3	Test 4	Test 5
1	Pressure indicated:					
2	Engine Speed:					
3	Rate of Fuel supply:					
4	Load on Dynamometer:					
5	Load Arm Length:					
6	Break Power:					
7	Indicated Power:					
8	Mechanical Efficiency:					
9	Break Thermal Efficiency:					
10	Indicated Thermal Efficiency:					
11	Specific Fuel Consumption:					

Sample Calculations: (For test no. ____)

1) **Indicated Power:**

$$I\,.P. = \frac{P_m \times L \times A \times N}{60 \times 10^3} \quad kW$$

Here ***N*** = the number of working stroke per minuts
= ***Engine Speed/2*** for Four Stroke Engine

2) **Break Power:**

$$B\,.P. = \frac{2 \times \pi \times N \times T}{60 \times 10^3} \quad kW$$

Here ***N*** = the is the speed of Engine in ***r.p.m.***

3) **Mechanical Efficiency:**

$$\eta_{mech} = \frac{I.P.}{B.P.} \times 100 \quad \%$$

4) **Indicated Thermal Efficiency:**

$$i\ \eta_{th} = \frac{I.P}{\dot{m}_f \times C.V.} \times 100 \qquad \%$$

5) **Break Thermal Efficiency:**

$$Break\ \eta_{th} = \frac{B.P.}{\dot{m}_f \times C.V.} \times 100 \qquad \%$$

.

Calculated Result for each Test and % error							
Sr. No	**Particulars**		**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**
1	Break Power:	Result					
		% error					
2	Indicated Power:	Result					
		% error					
3	Mechanical Efficiency:	Result					
		% error					
4	Break Thermal Efficiency:	Result					
		% error					
5	Indicated Thermal Efficiency:	Result					
		% error					

Conclusion:

Experiment No: 6

AIM: To draw a Heat Balance sheet for computerized four stroke single cylinder diesel engine test rig

Objective:
1. To conduct a load test on 4stroke, single cylinder diesel engine to find the heat distribution for engine.
2. To relate the findings with the real world scenario and environment aspects

DETAILED SPECIFICATIONS OF TEST RIG :

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No. 73/13, Doddanna Industrial Estate,
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Date of Installation : **23/03/2016**

Total Cost : **₹ 6,25,000**

Parameters measured : 1.Performance test
2. Heat balance test

Standard Accessories:

- Fuel Measurement consumption by volumetric method and also provide fuel measurement by load cell on fuel tank.
- Air intake measurement by using orifice plate U tube manometer of proper height & Air box with size of 300X300X500 mm.
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13. Diagrams of Combustion pressure versus crank angle, Combustion pressure versus volume, Heat Release Curve.

- **Experiment Manual and spare part Manual is available in soft and hard copy**

Safety Precautions:

1. Use this test rig with permission of lab in charge/ subject teacher/ competent authority only.
2. Testing and performance on this test rig must be done under able supervision only.
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4. Immediately turn OFF the engine if water supply is interrupted, or temperature sensor is showing higher temperature then permissible value.
5. Make sure for proper quantity of fuel and cooling water supply is available in respective tanks for the duration of performance.
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3. To open initial setting window select file DUT info - initial settings.
4. All the channels have to be calibrated before starting the test for the first time.
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Observations and Calculations:

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- Note it down from the test data sheet developed from test rig Software

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2.	Bore Diameter:		
3.	Stroke Length:		
4.	Engine speed(Rated):		
5.	Fuel used:		
6.	C. V. of Fuel used:		

Observations for Efficiency Calculations:

- Note it down from the test data sheet developed from test rig Software

Sr. No	Particulars	Test 1	Test 2	Test 3	Test 4	Test 5
1	Pressure indicated:					
2	Engine Speed:					
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4	Load on Dynamometer:					
5	Load Arm Length:					
6	Break Power:					
7	Indicated Power:					
8	Mechanical Efficiency:					
9	Break Thermal Efficiency:					
10	Indicated Thermal Efficiency:					
11	Specific Fuel Consumption:					

Sample Calculations: (For test no. ____)

1) **Total Heat Supplied**:

$$Q = \dot{m_f} \times C.V. \quad kJ$$

2) **Break Power:**

$$B.P. = \frac{2 \times \pi \times N \times T}{60 \times 10^3} \quad kW$$

Here ***N*** = the is the speed of Engine in ***r.p.m.***

- ***Find the B.P. unit kW equivalent to kJ***

3) Heat carried away by Exhaust Gasses:

$$Q_{Exhust\ Gasses} = m_a\, C_{p_{air}} \left(T_{Exhust\ gasses} - T_{air\ in} \right) \quad kJ$$

4) Heat carried away by Cooling water:

$$Q_{cooling\ \ water} = m_w\, C_{p_{water}} \left(T_{Water\ \ out} - T_{water\ \ in} \right) \quad kJ$$

5) . Unaccounted Heat:

$$Q_{mis} = Q - B.P. - Q_{Exhust\ Gasses} - Q_{Cooling\ Water}$$

.

Heat Balance Sheet based on Heat and Percentage of Heat:

Heat Supplied:			Heat Utilized:			
	kJ	%			kJ	%
1			1	Break Power		
			2	Heat Carried away by Exhaust gas		
			3	Heat Carried Away by Cooling water		
			4	Unaccented Heat		

Conclusion:

Experiment No: 7

AIM: To study about engine emission and it's control

Objective: Students should be able to identify different emission parameter and choose the emission control system.

A major effect of emission:-

1. Global worming
2. Acid rain
3. Malting of polar ice caps
4. The rising of the sea level
5. Respiratory and other health hazard problem

1. Emission and control in Spark Ignition engine

Source of emission: -

1. Evaporation process
2. Crankcase blowby
3. Tail pipe / Exhaust

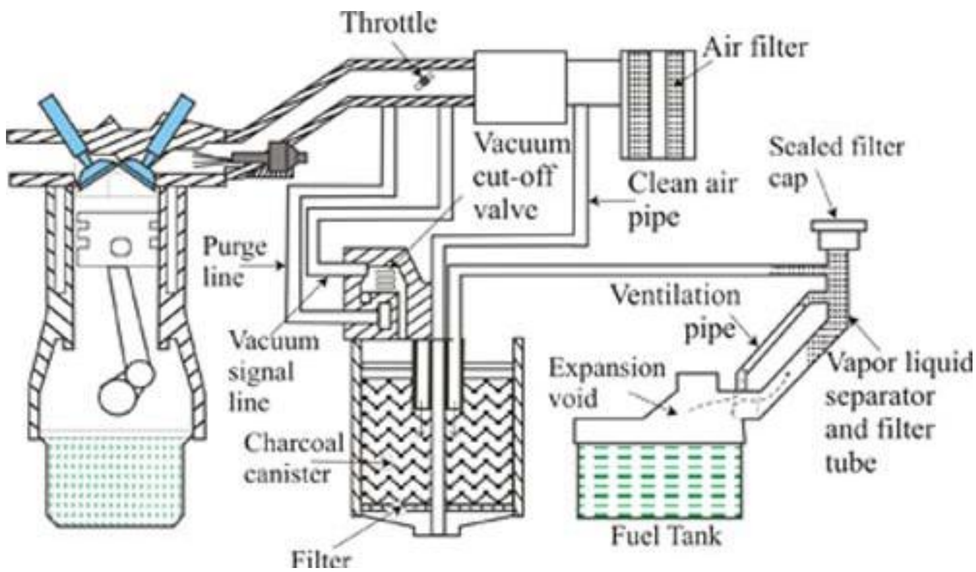
1. Evaporation process:

In the uncontrolled vehicles, fuel vapours from the fuel tank and carburetor were vented into the atmosphere that constituted about 20% of all hydrocarbon emissions from a gasoline passenger car.

- ***Evaporation emission control:***

The evaporative emission control system consists of a device to store fuel vapours produced inthe fuel system due to evaporation. A canister containing activated charcoal is used to store the fuel vapours. The vapours produced in the fuel tank normally collect in the fuel tank itself and are vented to the charcoal canister when fuel vapour pressure becomes excessive. The fuel vapours from thetank and carburetor led to and adsorbed into the charcoal. In the PFI engines only the fuel tank is connected to the canister

When engine is running, the vacuum created in the intake manifold is used to draw fuel vapours from the canister into the engine. Purging air is sucked through the canister which leads the fuel vapours from canister to the engine. An electronically controlled purge valve is used. During engine acceleration additional mixture enrichment can be tolerated and under these operating conditions the stored fuel vapours are usually purged into the intake manifold. This system is a fully closed system. A sealed fuel tank filler cap is used and a stable fuel tank pressure is maintained by the purging process of the canister.



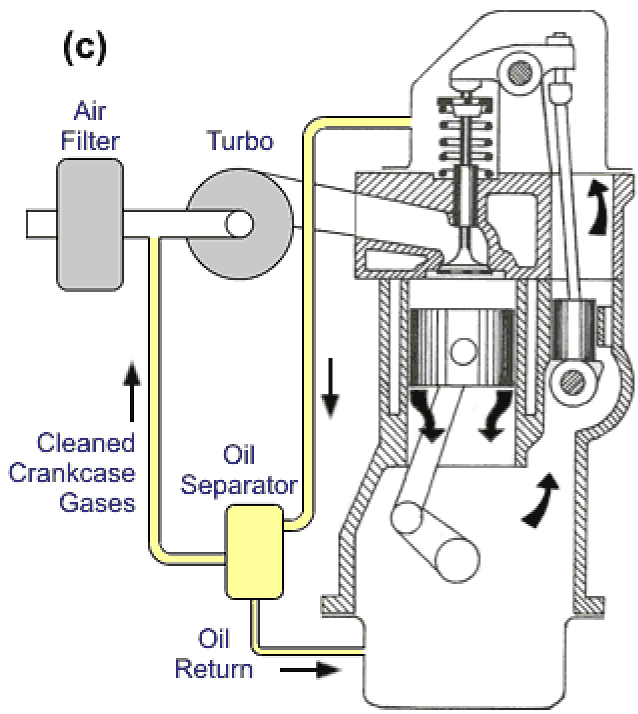
Evaporative emission control system for a MPFIengine

2. Crankcase blowby:

A small amount of charge in the cylinder leaks past piston rings into crankcase of the reciprocating engines. Near top dead center (TDC) when the rings change their position in the grooves at the end of compression stroke, combustion has already begun and the cylinder pressures are high. A significant part of charge stored in the piston- ring-cylinder crevice leaks into the crankcase. These gases are known as 'crankcase blow by' and their flow rate increases as the engine is worn out and the piston - cylinder clearances and ring gaps increase. In the homogeneous charge engines, the crankcase blow by gas is high in HC concentration. Only a small fraction of the gas stored in the ring crevices and hence blow by gases may consist of partially burnt mixture. This source contributes about 20 percent of total hydrocarbons emitted by an uncontrolledcar.

- ***Crankcase emission control:***

The crankcase blowby gases in the uncontrolled engines were ventilated to atmosphere under the effect of pressure difference occurring naturally between the crankcase and atmosphere. For control of cankcase emissions, the blowby gases are recycled back to the engine assisted by a positive pressure drop between the crankcase and intake manifold. When engine is running and intake charge is throttled the intake manifold is at a lower pressure than the crankcase. The blow-by gases mix with the intake charge to be burned inside the engine cylinder to CO_2 and H_2O. A typical PCV system is shown in the bottom fig. A tube connects crankcase or cylinder head cover to the intake manifold below throttle valve, which leads the blowby gases back to the engine. Due to suction effect of intake manifold as the pressure in the crankcase falls, ventilation air from the air cleaner is drawn into the crankcase that continuously purges it. A one-way valve (PCV valve) is used to control the flow of blowby gases PCV valve restricts flow of blowby gases during idling and very light loads which otherwise would cause excessive leaning of the charge by ventilation air.Under normal engine operation, PCV valve is fully open providing free flow of the gases while under high intake manifold vacuum the flow is restricted



PCV System

3. Tail Pipe/ Exhaust:

Into the SI engine most of the pollutant gas is remove from the tail pipe, Most of the 50-60% of unborn HC is escape, and 100% of the CO and NO_xareremoving from the Tail pipe also. The composition of exhaust emissions from gasoline-powered vehicles differs depending on the individual vehicle’s operating characteristics, as well as the type of fuel used. The majority of vehicle exhaust emissions are composed of carbon dioxide, nitrogen, water vapor, and oxygen in unconsumed air.

Major pollutant: CO, HC, NO_x ,Photochemical smog, CO_2

- **CO(**Carbon monoxide)**:**

- The Carbon monoxide emission, CO is intermediate product of combustion remains in exhaust if there is not enough Oxygen to convert to carbon dioxide, known as incomplete combustion
- Maximum CO is generally formed when the mixture is rich. Theoretically, petrol engine exhaust is free of CO if the air fuel ratio is 16:1.
- Testing of CO emission is detected by **NDIR** (Non-Dispersive Infra-Red Analyzer)

Idling: “Idling” refers to running a vehicle’s engine when it’s not moving, such as when you’re at a red light or stuck in traffic. Idling is part of the process of driving a car and is a fairly common occurrence for most drivers. However, idling may not be the best thing for your car, fuel consumption, or the environment. At this situation rich fuel mixture is given because of the exhaust gas dilution. This rich mixture is a major criteria of the CO formation. At this stage Air fuel ratio is 10-12.

Maximum Power: The power band of an internal combustion gasoline automobile engine typically starts at midrange engine speeds (around 4,000 RPM) where maximum torque is produced, and ends close to the redline after reaching maximum power between 5,000 and 6,500 RPM. So into that situation also rich mixture is use so CO is formed. At max power Air fuel ratio is 12-13.

- **HC (Hydrocarbon):** Unburned hydrocarbon (HC) emission results because part of the fuel inducted into the engine escapes combustion. HC emissions is dependent on many mechanisms such as adsorption and desorption of fuel in oil layer, flame quenching, fuel escaping into crevices and accumulation of fuel in engine deposits, etc. Testing of HC, the method is use that called **FID** (Flame Ionization and detection).

- **NO_x (Nitrogen oxide):** Among the air pollutants gasoil emit are oxides of nitrogen **NO** and **NO_2**, generically abbreviated as NO_x. Nitrogen oxides have harmful direct effect on human health, and indirect effect through the damage they do to agricultural crops and ecosystem. Vehicle NO_X emission have been regulated since the 1960s.

- Oxides of the N_2 are formed at higher temperature and when O_2 is available.
- The maximum NO_X formed at 14-16 Air fuel ratios, at a lean mixture.
- In practice, the main methods employed for the measurement of NOx are infrared, chemiluminescence and electrochemical.

- Photochemical smog: NO_X and HC they react in the presents of the sunlight and lower temperature to give a higher undesirable phenomenon known as Photochemical Smog.

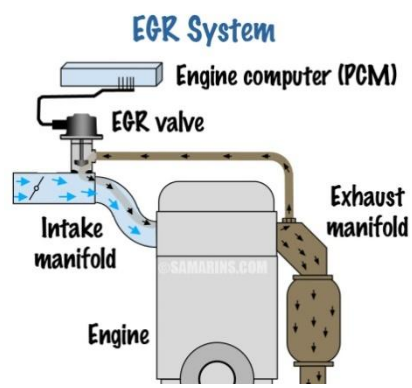
Emission control:

Mostly control by a three main methods: 1. Engine Design Modification
2. Exhaust gas recirculation
3. Exhaust gas oxidation

1. Engine design modification:

- **Lower compression ratio: -**Lower compression ration reduced the quenching effect by reducing the quenching area thus reducing HC. Lower compression ration also reduced NO_X emission due to lower maximum temperature. However reduce thermal efficiency and increases fuel consumption.
- **Ignition timing:** - NOx, HC, and CO emissions decrease with **retarding the ignition timing**, and with adding hydrogen to CNG fuel, NOx emission increases due to the high temperature but CO and HC drop because of complete combustion.
- **Reduce valve overlap: -**Increased overlap allows some fresh charge to escape directly and increase emission level. This can be controlled by reducing valve overlap.
- **Combustion chamber area modification**: - Modification of combustion chamber involves avoiding flame quenching zones where combustion might otherwise be incomplete and resulting in high HC emission. This includes:
    - Reduced surface to volume(S/V) ratio
    - Reduced squish area
    - Reduced space around piston ring
    - Reduced distance of the top piston ring from the top of the piston.

2. Exhaust gas recirculation: Unlike diesel engines, EGR can be actually used in gasoline engines to reduce NO_X emission effectively. Therefore, recirculating exhaust gas on gasoline engines is used primarily to reduce throttling loss at part load range, thus reduce fuel consumption, and secondarily, to reduce NO_X emission levels.



3. Exhaust gas oxidation: The exhaust gas coming out of exhaust manifold is treated to reduce HC and CO emission.

- **After Burner:** An after burner is a burner where air is supplied to the exhaust gases and mixture is burnt with the help of ignition system. The HC and CO which are formed in the engine combustion because of inadequate O_2 and inadequate time to burn are further burnt by providing air separate box, known as after burner. After burnet is located near to the exhaust manifold with an intention is that no fall in the temperature of exhaust. The oxidation of HC in the after burner depends upon the temperature of exhaust.

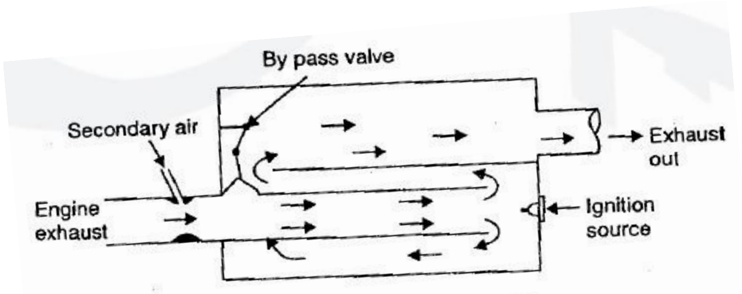


Fig. 18.6. Direct flame after-burner.

- **Exhaust manifold reactor:**It is a further development of after burner where the design is changed so as to minimize the heat loss and to provide sufficient time for mixing of exhaust and secondary air. Since the exhaust gases are at high temperature, the injection air reacts with HC, CO and aldehydes to reduce greatly the concentration of such emissions.

- **Catalytic converter:** A catalytic converter is a device which is placed in the vehicle exhaust system to reduced HC and CO by oxidizing catalyst and NO by reducing catalyst.The basic requirernents of a catalytic converter are:
  1. High surface area of the catalyst for better reactions.
  2. Good chemical stability to prevent any deterioration in performance.
  3. Low volume heat capacity to reach the operating temperatures.
  4. Physical durability with attrition resistance.
  5. Minimum pressure drop during the flow exhaust gases through the catalyst bed, this will not increase back pressure of the engine.

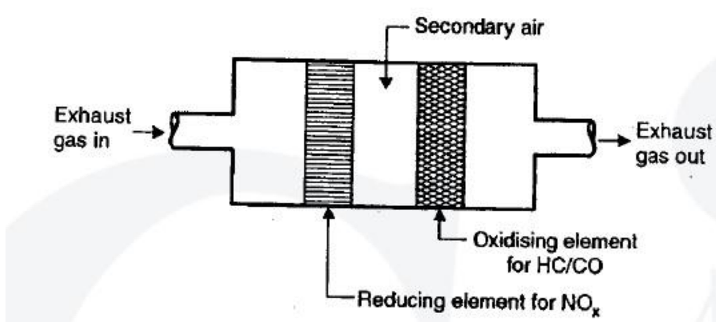


Fig. shows a catalytic converter, developed by the Ford Company. It consists of two separate elements, one for $NO_X$and the other for HC/CO emissions. The secondary air is injected ahead of the first element. The flow in the converter is axial.

- **Oxidation catalytic reactions:** CO, HC and O_2 from air are catalytically converted to CO_2 and H_2O and number of catalysts are known to be effective noble metals like platinum and plutonium, copper, vanadium, iron, cobalt, nickel, chromium etc.
- **Reduction catalytic reaction:** The primary concept is to offer the NO molecule an activation site, say nickel or copper grids in the presence of CO but not O_2 which will cause oxidation, to from N_2 and CO_2. The NO may react with a metal molecule to form an oxide which then in turn, may react with CO to restore the metal molecule.

  Rhodium is best catalyst to control NO_X but A / F ratio must be within a narrow range off 14.6: 1 to 14.7: 1.

Major drawbacks off catalytic converterare as under:

1. Owing to the exothermic reactions in the catalyst bed the exhaust systems are hotter than normal
2. Car equipped with such converter should not use leaded fuel as lead destroys complete catalytic activity.
3. If the fuel contains sulphur (as diesel oil) emission of SO_3 is increased.

Emission and control in Compression ignition engine

Emissions form diesel engines can be classified in the same categories as those for the gasoline engines but the level ofemission in these categories vary considerably. Typical level, ofthe constituents of the exhaust products of combustion in 4-stroke cycle and 2 stork cycles are given in table. At idling. Accelerating, partial load and full load.

Engine exhaust constituents	Concentration as measured in exhaust products			
	Idling	**Acceleration**	**Partial load operation**	**Fuel load operation**
Two-stroke cycle engine				
1. CO%	0.01	0.25	0.01	0.35
2. CO_2%	0.85	5.5	3.8	5.30

3. HC ppm	250	500	350	550
4. NO_X ppm	200	1200	1100	1250
5. RCH ppm	17.4	9.5	1.0	5.5
6. Smoke Hartrige unit	4	44	4	10
Four-stork cycle engine (Un-supercharged)				
1. CO%	0.02	0.06	0.04	0.25
2. CO_2%	2.5	3.5	5.5	6.7
3. HC ppm	180	330	210	150
4. NO_X ppm	330	920	590	780
5. RCH ppm	8.0	7.5	5.0	1.5
6. Smoke Hartrige unit	4	44	4	10

Diesel smoke and control:

- **Exhaust Smoke:** Engine, any volume of the combustion chamber in which the fuel is burnt at a relatively F/A ratio grater then 1.5(F_R>1.5) at the pressure developed in these engines product soot. The quantity if soot formed depends on the following factors:
  I. The local F/A ratios
  II. The type of fuel
  III. The pressure.

If this soot is able to find adequate air (O_2) which on the whole is much in excess of the requirements of perfect combustion, it will burn completely. If it is unable to find air (O_2) in the combustion cycle, it will pass as exhaust, and if the quantity is sufficient, it will be visible and that is called Smoke. The colour of the smoke depends on the size of soot particles.

- Formation of a small is basically a process of conversion of molecules or hydrocarbon fuels into particles of soot. It should be noted that soot is not carbon but simply an aggomeration of very large polybenzenoid free radius, it is also observed at sword formation during the early ugly part of actual combustion process is common toward diesel engines but it not consumed during the later parts of conduction.

- Pyrolysis of fuel molecule himself is all thought to be responsible for shoot formation fuel heated with insufficient O_2 will gives carbonaceous deposits. It is believed that the heavy end of diesel and fuel may pyrolyze to yield the type of smoke that is also from the diesel engine. Believed to be the path of formation of polycyclic aromatic hydrocarbons (benzo-pyrene) found in soot.

The smoke of the diesel engine generally two types,

- **Blue-white smoke:** It is caused by liquid droplets of lubricating oil or fuel oil while starting from cold start. Owing to low lower Surrounding temperatures the combustion products are at a relatively low temperature and intermediate product of combustion do not burn. This results in bluish white smoke when exhausted. This type of smoke is also formed when lubricating oil flows past piston rings.

- **Black smoke**: It consists of carbon particles suspended in the exhaust gas and depends largely upon A, /F ration. It increases rapidly with the increase in load and available air is depleted.

- **Causes of Smoke**:It is known that the cause of smoke is incomplete burning of fuel inside the combustion chamber. The two major reasons for incomplete combustion are:
  1. Incorrect A/Fratio
  2. Improper mixing

1. **Injection system:**The following injection characteristics substantially increase the smoke level..
   - Unsuitable droplet size
   - Inadequate or excess penetration
   - Excessive duration of injection
   - Secondary injection
   - Improper dispersion atomization

2. **Rating**: it has been observed that smoke limited power is reached much before the thermal load limited power and the inevitability of smoke in exhaust is inherent in fewer loads. Thus it seems, smoke is unavoidable in CI engine, and only its level can be kept as low as possible.

3. **Load:** Smoke may be defined as visible products of combustion.Rich mixtures (higher loads) results inhigher smoke because of non-availability of oxygen for combustion.

4. **Fuel:** The white smoke produced in an engine depends upon the quality of fuel. Generally, more volatile fuels give less smoke than heavier fuels of similar certainnumber.The certain number exercises no effect onproductionof blacksmoke.

5. **Fuel-air ratio:** the smog increasing with the increasing fuel air ratio. Please increase in a smoke occurs with as much as 25% as excess air in the cylinder; Clearance indicated that, even in the presence of excess oxygen, diesel engine has a mixing problem.

6. **Engine type and speed:**The smog level at higher load is higher in naturally aspirated engine than turbocharged engine because the letters have adequate oxygen even at a full-load. At low as well as high speed the smoke is worse.

7. **Maintenance:** The smoke levelgreatly depends upon the condition of the engine. Good maintenance

A must for lower smoke levels (the maintenance affect the injection characteristics and the quantity of lubricating oil which passes across the piston rings and thud exercises significant effect on engine tendency to generate smoke).

- **Measurement of smoke:** Two basic type of smoke meter for measurement smoke density are;
  I. Filter darkening type. (Examples: Bosch smoke meter; Vem Brand smoke meter).
  II. Light extinction type. (Examples: Hartridge smoke meter; UTAC smoke meter).

1. **Bosch smoke meter:**
   - It is a filter darkening type of smoke meter.
   - In this meter, a measured volume of exhaust gases drawn through a filter paper which is a blanked to various degrees depending upon the carbon present into exhaust gas. The density of "soot" is measured by timing out amount of light reflected from the sooted paper.
   - The specifically of sample volume, filter papers size etc. are well defined.

2. **Hartridge smoke meter:**
   - It works on the principal of high extinction.
   - In this meter exhaust sample is passed through tubes of about 0.46 m length which has light source at one end and photocell or solar cell at the other end. The amount of light passed through this smoke column is used as indication of level of smoke.
   - This type of meter is useful for continuous testing and can be employed in vehicles.

- **Control of smokes:** There is hardly any successful method to control the soot except the engine has to run at lower load i.e. Derating and Maintain the engine at best possible condition.

The other method to control the smoke.

1. Smoke suppress out additives:

- It has been observed that some barium compounds when added in fuel reduce the temperature of combustion and avoid the soot formation. It is further observed that if the soot is formed, the barium compounds break the min very fine particles and reduce the smoke.
- The use of barium sals, however, enhances the deposit formation tendencies of engine and reduces the life of the fuel filter.

2. Fumigation:

- It is a method of introducing the smell of small amount of fuel with the intake manifold. They initiate pre combustion reaction before and during the compression stroke resulting in reduced chemical delays, because the intermediate products such is the peroxides and aldehydes react more rapidly with oxygen than original hydrocarbons. The shortening in a chemical delay period curves thermal cracking which is responsible for shoot formation.
- Fumigation rate of about 11 to 15% gives the best smoke improvement.

3. Catalytic mufflers:

- The use of catalytic mufflers, unlike petrol engine, is not very effective.
- Much development is needed in such-devices before they can be put to use.

5. Diesel Odour and Control:

It has been observed through some experiments that the products of partial oxidation are the main cause of odour in diesel exhaust. This partial oxidation may be because of either very lean mixture such as during idling or due to quenching effect.

The following factors affect odour production:

1. Fuel-air ratio
2. Engine operation node
3, Engine type
4. Fuel consumption
5. Odour suppressant additives.

Control of odour:

- Server manufacturer's chaim that odour additive compounds can reduce the intensity of odour, but it has been found in practice that these additives hardly have any effect on odour formation etc.
- The control of odours by using catalytic is used to development. It has been found experimental that a few oxidations catalyzed reduced intensity of odour.

Experiment No: 8

AIM: To study of properties of scope of alternative fuel.

Objective: Students should be able to relate different alternative fuels and their properties and there scope.

Introduction:

Alternative fuels are derived from sources other than petroleum. Most are produced domestically, reducing our dependence on imported oil, and some are derived from renewable sources. Often, they produce less pollution than gasoline or diesel.

(a) Alcohols: These include methanol (methyl alcohol), ethanol (ethyl alcohol), propanol (propyl alcohol), butanol (butyl alcohol) as compounds

- The OH group which replaces one of the H atoms in an alkane, gives these compounds their characteristic properties
- Specific heating value is lower than gasoline (42 – 43 MJ/kg) methanol (19.7 MJ/kg) and ethanol (26.8 MJ/kg)
- For air-fuel mixture SHV is comparable with gasoline (MJ/kg-mixture at stoichiometric mixtures)
- Other alcohol groups such as dihydric and trihydric alcohols are not used as a fuel in IC engines

(i) Methanol

- Can be obtained from natural gas
- has near and long-term potential
- Has high octane quality (130 RON, 95 MON)
- Can be used in low-concentration (5-15 %) in gasoline to increase octane number of the mixture Problems;
- Poor solubility in gasoline, toxicity, low energy content (about half of gasoline), high latent heat of vaporization and oxygen content
- Contribute to poor drivability, incompatibility with some metals

❖ **Advantages of methanol fuel:**

- The benefits of using Methanol are that it reduces emissions, which has a significant effect on bettering the environment.
- Methanol blended with gasoline significantly increases the performance. It also has a lower risk of flammability than normal gasoline.
- Another benefit of Methanol is that it is made from domestically renewable sources. Methanol can also be used to make the octane enhancer MTBE.
- Another huge possible benefit of Methanol is that it can be made into hydrogen, which could be used as a link for hydrogen fuel cells.

- **disadvantages of methanol fuel:**
  - Some of the disadvantages of Methanol are that although its emissions are safer than that of gasoline,
  - It has a high amount of formaldehyde emissions.
  - As with Ethanol, it gets less gas mileage, so it would require more frequent fuelling.
  - The cost of Methanol is also slightly higher than that of premium gasoline.
  - Unfortunately, the number of vehicles and vehicle fuelling sites have significantly decreased over the past few years.
  - It is being used even less now because recently MTBE has been found to contaminate ground water.

(ii) Ethanol

- Produced from biomass
- It is made from the sugars found in grains, such as: Corn, Sorghum, and Barley Other sources of sugars to produce ethanol include: Potato skins, Rice, Sugar cane, Sugar beets, Yard clippings, Bark, Switch grass etc. -Has high octane number
- can be used in low–concentrations in gasoline
- Most of the ethanol used in the United States today is distilled from corn
- Scientists are working on cheaper ways to make ethanol by using all parts of plants and trees rather than just the grain.
- About 99% of the ethanol produced in the United States is used to make "E10" or "gasohol," a mixture of 10% ethanol and 90% gasoline.
- Any gasoline powered engine can use E10, but only specially made vehicles can run on E85, a fuel that is 85% ethanol and 15% gasoline

- **Advantages of Ethanol fuel:**

  - The fuel can utilize existing distribution outlets. Other fuel sources such as hydrogen would require the creation of distribution networks and technology with accompanying establishment costs
  - It is a renewable resource and so would reduce the use of non-renewable materials.
  - It could reduce greenhouse gas emissions if solar energy was used to distil it from aqueous solutions.
  - It reduces dependence on imported oil and the influence of the oil cartels that currently control oil production and price. This reduced dependence on imported oil also protects consumers from the economic variations that are caused by the political and social events in oil producing countries

- **disadvantages of Ethanol fuel:**
  - There are claims that the production and distribution of ethanol as an alternative motor vehicle fuel source will in fact increase greenhouse gas emissions over those generated by conventional fuels
  - The disposal of the large amounts of smelly waste fermentation liquors after removal of ethanol would present major environmental problems.
  - There is a cost involved in making ethanol is nearly twice as much as the cost of making gasoline. There is also a cost involved in modifying vehicles to use ethanol or methanol.

(b) Biodiesel:

Biodiesel is a renewable and clean-burning fuel that is made from waste vegetable oils, animal fats, or recycled restaurant grease for use in diesel vehicles. Biodiesel produces less toxic pollutants and greenhouse gases than petroleum diesel.

- It is methyl or ethyl ester of a fatty acid produced from vegetable oil of edible or non-edible types or animal fat or algae, by transesterification process using catalysts.
- Has better lubricating properties and much higher cetane ratings than today's low sulphur diesel fuels.
- Its addition reduces the fuel system wear.
- Can be used in the pure form (B100), or may be blended with petroleum diesel in any concentration in most diesel engines for transportation purpose.
- However, the engine may face problems, such as low temperature operation, less durability and drop in power. New diesel fuel injection systems, such as common rail systems are equipped with materials that are compatible with biodiesel (B100).
- Biodiesel offers a substantial reduction in particulate matter (25%-50%) and a marginal increase of NOx (1%-6% when it is used as an alternative fuel in a CI engine.

- **The major problems associated with biodiesel are**
  a. poor oxidation stability,
  b. higher viscosity and density,
  c. lower calorific value, and
  d. Cold flow property.

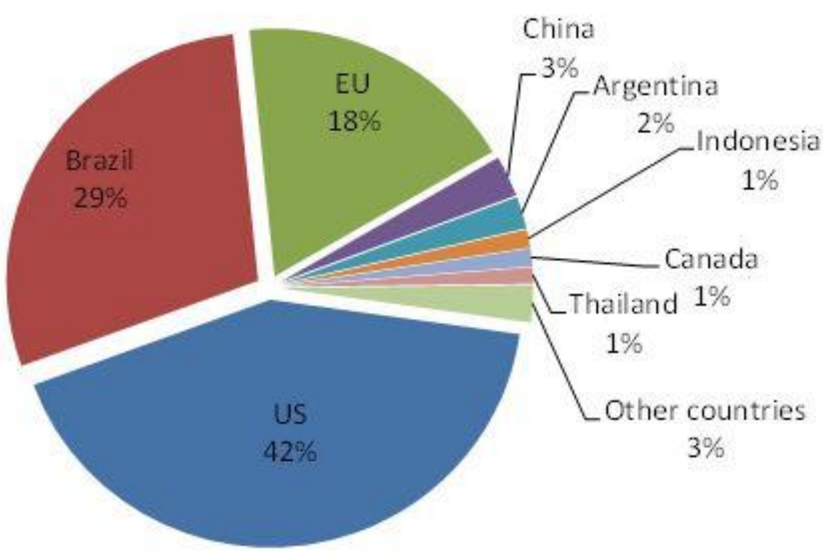
-Blends of 20% and lower biodiesel can be used in diesel engines with no, or only minor modifications.

❖ Advantages of Biodiesel:

- It Produced From Renewable Resources.
- One of the main advantages of using biodiesel is that it can be used in existing diesel engines with little or no modifications at all and can replace fossil fuels to become the most preferred primary transport energy source.
- To protect the environment from further heating up, many people have adopted the use of biofuels.
- Vehicles that run on biodiesel achieve a 30% fuel economy than petroleum-based diesel engines, which means it makes fewer trips to gas stations and runs more miles per gallon.

❖ Disadvantages of Biodiesel:

- Biodiesel is much more expensive than other conventional fuels. Currently, it is almost 1.5 times more expensive than petroleum.
- Since biofuels are made from animal and vegetable fat, more demand for these products may raise prices for these products and create a food crisis in some countries.
- As more crops are grown to produce biofuels, more fertilizer is used, which can have a devastating effect on the environment. The excess use of fertilizers can also result in soil erosion and lead to land pollution.



Bio-diesel production by different countries 2020

(c) Biogas:

Biogas is an energy-rich gas produced by anaerobic decomposition or thermo-chemical conversion of biomass. Biogas is composed mostly of methane (CH4), the same compound in natural gas, and carbon dioxide (CO2).

- Produced by the anaerobic decomposition of organic materials such as cow dung and other waste such as cornhusks, leaves, straw, garbage, flesh of car cusses, poultry droppings, pig dung, human excreta, sewage and the plants specially grown for this purpose like water hyacinth, algae, certain types of grasses. In addition, any cellulosic organic material of animal or plant origin, which is easily biodegradable, is a potential raw material for biogas production.
- Also produced by pyrolysis and hydrogasification methods -Contains a mixture of methane (50-60% vol), CO2 (30-45%), hydrogen (5-10%), nitrogen (0.5-7%) and small traces of other gases such as hydrogen sulphide and oxygen
- It is a clean, but slow burning gas and having value between 5000 to 5500 kcal/kg or 38131 kJ/m3 -The octane rating of biogas is 130 and ignition temperature is 650 °C
- Can be used to operate both compression ignition (diesel) and spark ignition (petrol) engines. CI engines can operate on dual.
- fuel (biogas+diesel) operation and pilot injection operation in which small quantity of diesel is required for igniting the mixture of air and biogas -80% saving of diesel oil can be achieved Drawback of biogas is present of CO2. The engine performance can be improved by reducing the CO2 content in biogas.

❖ **Advantages of Biodiesel:**

- Gas generated through bio digestion is Biogas is a renewable, as well as a clean, source of energy.
- Gas generated through bio digestion is non-polluting; it actually reduces greenhouse emissions (i.e. reduces the greenhouse effect).
- Biogas generation may improve water quality. Moreover, anaerobic digestion deactivates pathogens and parasites.
- The technology used to produce biogas is quite cheap.
- Biogas generators save women and children from the daunting task of firewood collection. As a result, more time is left for cooking and cleaning.

❖ **Disadvantages of Biodiesel:**

- An unfortunate disadvantage of biogas today is that the systems used in the production of biogas are not efficient.
- Another biogas disadvantage is that industrial biogas plants only make sense where raw materials (food waste, manure) are in plentiful supply. For this reason, biogas generation is much more suitable for rural and suburban areas
- After refinement and compression, biogas still contains impurities. If the generated bio-fuel was used to power automobiles it could corrode the metal parts of the engine. This corrosion would lead to increased maintenance costs. The gaseous mix is much more suitable for kitchen stoves, water boilers, and lamps.

(d) Hydrogen:

❖ Clean burning fuel and has the highest energy content per unit mass of any chemical fuels, which can reduce the dependency on hydrocarbon, based fuels Production: Most common method of producing hydrogen involves splitting water (H_2O) into its component parts of hydrogen (H_2) and oxygen (O). There are different methods to produce hydrogen-

1) Steam reformation or partial oxidation of hydrocarbons such as natural gas, naphtha or crude oil. It converts methane into hydrogen and carbon monoxide by reaction with steam over a nickel catalyst.
2) Coal gasification- Hydrogen made from coal can probably be justified as a fuel for special applications where the unique characteristics of hydrogen can be put to advantage such as its weight or its non-polluting characteristics.
3) Electrolysis- it uses electrical current to split water into hydrogen at the cathode (+) and oxygen at anode (-).
4) Thermo chemical method- it utilizes heat to achieve the chemical splitting of water to its elements without the need for intermediate electricity generation and without the need to use the extremity high temperature of 2500 °C or more.
5) Photo-electrolysis- it uses sunlight and catalysts to split water. In this method, a current is generated by exposing on or both electrodes to sunlight. Hydrogen and oxygen gases are liberated at the two electrodes by the decomposition of water. A catalyst may be included to facilitate the electrode process.
6) Biological and photo-biological water splitting use sunlight and biological organisms to split water.
7) Thermal water splitting uses a very high temperature (approximately 1000 °C) to split water.
8) Biomass gasification uses selected microbes to break down a variety of biomass feed stocks into hydrogen.

❖ **Utilization of hydrogen gas:**

Hydrogen can be utilized for the following purpose:

a. Residential use- hydrogen can be used in domestic cooking (stoves), radiant space heaters, electricity for lighting and for operating domestic appliances (e.g. refrigerator) which could be generated by means of fuel cells, with hydrogen gas at one electrode and air at other.
b. Industrial use- hydrogen can be used as a fuel or a chemical reducing (i.e. oxygen removal) agent. It can also be used instead of coal or coal derived gases, to reduce oxide ores (iron ore) to the material (iron).
c. Aircraft application- The earliest application of liquid hydrogen fuel is expected to be in a jet aircraft. Cold liquid hydrogen can be used directly or indirectly to cool the engine and the air frame surfaces of a high speed air craft
d. . iv. Electric power generation- It comprises the production of electricity by using hydrogen in fuel cell system. Hydrogen could also be used as a means for storing and distributing electrical energy. The objective of developing fuel cell power stations is to centralized and local generation of electricity.
e. As an alternative transport fuel- Hydrogen is tried as an alternative fuel in internal combustion engine. The stoichiometric hydrogen air mixture burns seven times as fast as the corresponding gasoline air mixture, which is a great advantage in internal combustion engines, leading to higher engine speeds and greater thermal efficiency. Hydrogen fuel used in IC engines is in automobiles, buses, trucks and farm machinery.

Methods of using Hydrogen as a fuel in CI engines

i. A mixture of fuel gas and air, with an approximately constant fuel to air ratio is introduced into the cylinder intake manifold. The engine power is controlled by varying the quantity of mixture entering the cylinder by means of throttle valve. It is not safe because the mixture is formed in the manifold.
ii. The hydrogen is injected directly into the engine cylinder through a valve under pressure and air is inducted through another intake valve. This method is safer one, since hydrogen and air are supplied separately; an explosive mixture is occurred inside the cylinder only. The engine power output is controlled by varying the pressure of hydrogen gas from about 14 atm at low power to 70 atm at high power.

iii. During the intake stroke, the hydrogen gas at normal or moderate pressure is drawn through the throttle valve into the engine cylinder whereas unthrottled air is drawn in through the intake port. The variation of engine power can be achieved with adjustment of hydrogen inlet throttle. The changes in fuel proportion as well as power is developed due to supply of un throttle air and power variation is possible because of the wide composition range over which hydrogen-air mixture can be ignited

❖ **Advantages of using Hydrogen fuelled engine**

i. It provides high efficiency because it utilizes a higher proportion of the energy in the fuel.
ii. I0i. The amount of carbon monoxide and hydrocarbons in the exhaust is very small since they are originating only from the cylinder lubricating oil.
iii. It can be easily available because it is produced by electrolysis of water.
iv. Fuel leakage to environment is not pollutant.

❖ **Disadvantages of using Hydrogen fuelled engine**

i. Due to high heat release, the combustion temperature may be high and a level of nitrogen oxide is high. It can be reduced by reducing the combustion temperature by injecting water vapour into the cylinder from the exhaust.
ii. It requires heavy, bulky fuel storage both in vehicle and at the service station.
iii. Difficulty in refuelling and possibility of detonation.
iv. Poor engine volumetric efficiency- gaseous fuel will displace some of inlet air and poor volumetric efficiency will result.
v. Fuel cost would be high at present day technology.

(e) Natural Gas:

Natural gas is present in the earth and is often produced in association with the production of crude oil. Processing is required to separate the gas from petroleum liquids and to remove contaminants. First, the gas is separated from free liquids such as crude oil, hydrocarbon condensate, water and entrained solids. The separated gas is further processed to meet certain pipelines quality specifications with respect to water content, hydrocarbon dew point, heating value and hydrogen sulphide content. Generally, a gas sweetening plant removes hydrogen sulphide and other sulphur compounds

Over 70% of the natural gas is formed by methane. It is Colourless, odourless and mostly constitutes methane, which is a relatively unreactive hydrocarbon.

❖ **Properties of natural gas:**

- The state of matter of this gas is gaseous.
- It does not have any colour and is a tasteless gas. It is free of any kind of toxic, there is no smoke on burning and it has high calorific value.
- The gas is odourless. However, a chemical called mercaptan is added to it in small amounts to give it distinctive smell of eggs. This helps to find out any gas leaks. It is a combustible gas and a fossil fuel.
- It's a mixture of simple hydrocarbon compounds.
- It contains primarily methane, along with small amounts of ethane, butane, pentane, and propane.
- The by-products of this gas are water vapour and carbon dioxide. Air is 60% heavier than natural gas.
- It has a low flammability range and a high ignition temperature. Generally, it is transported through pipes

(I) CNG (Compressed Natural Gas)

a) -Natural gas consists of elements of compressor, some sort of compressed gas storage and dispensing unit of CNG into vehicles

b) -Two types of CNG refuelling system- slow fill and fast fill. In slow fill system, several vehicles are connected to the output of the compressor at one time. These vehicles are then refilled over several hours of compressor operation. In fast fill systems, enough CNG is stored so that several vehicles can be refuelled one after the other, just like refuelling from a single gasoline dispenser

c) -The storage system of CNG is arranged as several tanks in cascade form. The CNG pressure in cascade is higher than the maximum storage pressure of the cylinder on the vehicle. The cascade attempts to deliver as much of its CNG to vehicles as possible before the pressure difference decreases to where the flow rate slows dramatically. A dryer should include in most CNG refuelling systems to remove water vapour, impurities and hydrogen sulphide from natural gas before it is compressed. If water vapour is present then it can condense in the vehicle fuel system, causing corrosion especially if hydrogen sulphide is present. CNG driven vehicles with catalytic converter have less CO and HC emission but NOx emission is high.

❖ **Advantages of CNG:**

- Less Harmful than coal or oil and environmentally friendly.
- Easy storage and transport because natural gas stored and transported through pipelines, small storage units, cylinders or tankers on land and sea.

- The vehicles operating on CNG has lower maintenance costs as compared to hydrocarbon fuel-powered vehicles so reduced fuel cost.
- CNG gives a better life to lubricating oils, as it does not contaminate and dilute the crankcase oil.
- It produces less pollution in the form of CO2, CO, NOx and SOx as compared to petrol.
- It is lighter than air and tends to dissipate when there is a leakage unlike Propane, which is heavier than air, collects into explosive pockets.

❖ **Disadvantages of CNG:**

- Reduced power for the same engine capacity.
- CNG filling stations are very limited.
- The performance of the car is reduced significantly. Acceleration is slower so you may have to rev the engine more to get going.
- The burning of natural gas also releases carbon dioxide, carbon monoxide and other carbon components, which are greenhouse gases that cause global warming.
- Provide less mileage than gasoline.

(ii) LPG (Liquefied Petroleum Gas)

a) LPG is available in the market in two forms- one is propane and the other is butane. Propane is popular alternative fuel because of its infrastructure of pipelines, processing facilities and storage for its efficient distribution and also it produces fewer emissions. Propane is produced as a by-product of natural gas processing and crude oil refining

b) Natural gas contains LPG, water vapour and other impurities and about 55% of the LPG is compressed from natural gas purification. LPG is a simple mixture of hydrocarbon mainly propane/propylene (C3S) and butane/ butylene's (C4S)

c) Propane is an odourless, non-poisonousgas, which has lowest flammability range.

Utilization of LPG:

LPG is used as a fuel in heating appliances and vehicles. It is increasingly used as an aerosol propellant and a refrigerant, replacing chlorofluorocarbons in an effort to reduce damage to the ozone layer In Europe, LPG is used as an alternative to electricity and heating oil (kerosene).It can be used as power source for combined heat and power technologies (CHP). CHP is the process of generating both electrical power and useful heat from a single fuel source. This technology has allowed LPG to be used not just as fuel for heating and cooking, but also for de-centralized generation of electricity.

- **The advantages of LPG:**
- It is non-toxic, non- corrosive in nature.
- It burns cleanly and has high octane rating e.g. more than 100 RON (Research Octane Number).
- LPG engines have less knocking/ vibration.
- It does not produce harmful emission like CO, NOx and higher hydrocarbons.
- Particulate emissions are also less. So frequent cleaning of the combustion chamber is not required.

- **The disadvantages of LPG:**
- It causes suffocation, in case of leakage as it heavier than air.
- It is hazardous as it inflammable gas.
- It is consumed more as it has low energy density.
- It does not provide power to the vehicle in mountains or rough terrains.
- It is costlier than CNG. It has to be supplied in a heavy steel cylinder.

(f) Producer Gas:

Producer gas is a product of oxidation-reduction reactions of air with biomass. Biomass is chemically composed of elements C, H, O and some N and hence the oxidation results in products of combustion like CO_2 and H_2O. The molecules of O_2 in the air oxidises C and H to produce these products. The gases which are at high temperature due to partial oxidation pass through a bed of charcoal (which is produced because of oxidation reaction itself) and the reduction reaction of these gases with carbon leads to carbon monoxide and hydrogen

Volumetric composition of producer gas is CO (16-20%), H_2 (16-18%), CO_2 (8-10%) and some traces of higher hydrocarbons. Producer gas has a high percentage of N_2, since air is used. Therefore, it has a low heat value. Density of producer gas is 0.9 to 1.2 kg/m3.

Property:

Producer gas is a renewable fuel that burns efficiently and its utilization in diesel engine on dual fuel mode offers several benefits in terms of liquid fuel saving, besides addressing socioeconomic issues.

(g) Blast Furnace Gas:

It is a by-product of melting iron ore in steel plants. It principally consists of CO and contains low heat value similar to producer gas. It consists of about 60% nitrogen, 18-20% CO_2 and some amount of oxygen, which are not flammable. It may be combined with natural gas or coke oven gas before combustion or a flame support with richer gas or oil is provided to sustain combustion. The auto ignition temperature of blast furnace gas is approximate 630 °C and it has Lower Explosive Limit (LEL) of 27% &Upper Explosive Limit (UEL) of 75% in an air-gas mixture at normal temperature and pressure. The gas is hazardous due to higher concentration of carbon monoxide.It should be cleaned properly because it contains lot of dust particles. Blast furnace gas depends upon types of fuel used and method of operating the blast furnace.

❖ **Blast furnace gas has the following properties:**

- BF gas is almost a colourless gas (mild whitish) and normally it is odourless. However it may have a slight sulphur odour, but this should not be relied upon as a warning of its presence.
- BF gas a lean fuel gas with a calorific value (CV) in the range of 650 to 900 kcal/N cum. CV of the BF gas is very much dependent upon the coke rate in the blast furnace.
- BF gas has a high density. It is around 1.250 kg/cum at the standard temperature and pressure (STP) which is 0 deg C of temperature and 1 atm of pressure. This density is highest amongst all the gaseous fuel. Since the density is higher than the density of air, it settles at the bottom in case of a leakage.
- BF gas has low theoretical flame temperature which is around 1455 deg C. BF gas has a low rate of flame propagation. It is lower than any other common gaseous fuel. BF gas burns with a non-luminous flame. Auto ignition point of BF gas is around 630 deg C.

❖ **Blast Furnace Advantages**:

- Continuous feeding, continuous tapping, suitable for large-scale continuous production;
- Low power requirements;
- The product is further processed (continuous casting and rolling) with good performance.
- Mature technology and low production cost.
- High efficiency.

- **Blast Furnace gas Disadvantages:**
    - Blast furnace ironmaking is inseparable from the coke source, but the coke resources are getting less and less, but the price is getting higher and higher, the cost of iron making will be higher and higher, and it is likely that one day will meet the depletion of coke resources.
    - The blast furnace ironmaking damages the environment very much.
    - The production process of blast furnace ironmaking is long.
    - High-energy consumption rate.

(h) Coke Oven Gas:

1. It is produced during the making of coke. It is also resulting from oxidation-reduction reactions of coal or coke with air and sometimes steams. It depends upon the type of coal used and operation method of oven.
2. The composition of coke oven gas is H_2 (54% vol), CH_4 (24%), CO (8%), CO_2 (6%) and some traces of higher hydrocarbon and nitrogen. With the application of heat, the heavier hydrocarbons are cracked and volatile portion of coal is driven off and results in high composition of $H_2$and CH_4.
3. Its heat value per cubic meter is only about one-half that of natural gas and density is 0.40 kg/m3.

- **Characteristics of coke oven gas:**
- Raw coke oven gas has a yellowish brown colour and an organic odour.
- It is a flammable gas with lower explosive limit of 4 % and upper flammability limit of 75 %.
- Its vapour density is 0.39 (air=1) and relative density is 0.589. Raw coke oven gas is a flammable material with a flash point of less than 60 degree C.

Clean coke oven gas is a colourless gas with odour characteristics of hydrogen sulphide and hydrocarbons. It has a lower explosive limit of 4.4 % and upper explosive limit of 34 %. Its vapour density is 0.36 (air=1).

Experiment No: 9

AIM: To study of latest development of some unconventional engines

Objective: Students should be able to illustrate the construction and working of several unconventional engine's

1. Stratified charge engine

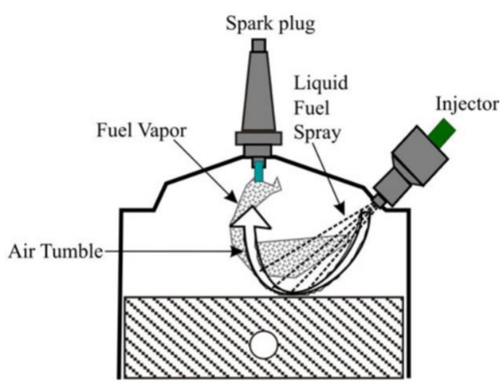
The approach of a stratified charge engine with exhaust gas recirculation (EGR) has been widely introduced in automobile. It is a type of internal-combustion engine, similar in some ways to the Diesel cycle, but running on normal gasoline. The name refers to the layering of fuel/air mixture, the charge inside the cylinder.

In a traditional Otto cycle engine, the fuel and air are mixed outside the cylinder and are drawn into it during the intake stroke. The air/fuel ratio is kept very close to stoichiometric. This mixture is easily ignited and burns smoothly.

The problem with this design is that after the combustion process is complete, the resulting mixture contains considerable amounts of free oxygen and nitrogen atoms. These will readily react with each other, creating NO_x, a pollutant. This is currently addressed with the use of a catalytic converter in the exhaust system, which break the NO_x back into N_2 and O_2.

A Diesel engine, on the other hand, injects the fuel into the cylinder directly. This has the advantage of more fuel-efficient engine, which is why they are commonly found in applications where they are being run for long periods of time, like in trucks. However, the Diesel engine has problems as well. The fuel is sprayed right into the highly compressed air, and never has time to mix properly. This leads to portions of the charge consisting almost entirely of air, and others almost entirely of fuel. The inefficient combustion that results from this poor mixture leads to the presence of other pollutants, notably soot.

The stratified charge design attempts to fix the problems with both engines. It uses a direct-injection system like the Diesel, with its inherent ability to be run at efficient high compressions. However, like the Otto, it relies on gasoline's ability to mix quickly and cleanly in order to avoid the poor combustion found in the Diesel.

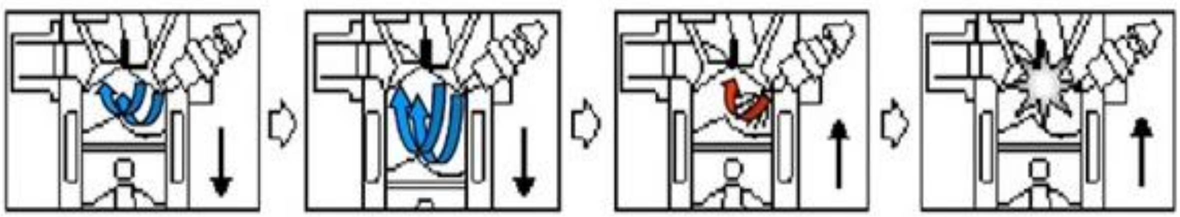


Schematic of a Stratified Engine Combustion System

➢ Working

A stratified charge engine only pulls air through the transfer system. The fuel required for combustion is forced into the cylinder through an injector placed in the top of the cylinder (head). The injector sprays a fuel/air mixture in the form of a fuel cloud into the cylinder. Surrounding this cloud is air supplied by the transfer system. As the cloud is ignited and burns, the surrounding air provides almost complete combustion before the exhaust port opens. For stratified charge engine, it is well know that lean, stratified combustion can reduce fuel consumption and gain some merits in gasoline spark-ignited, direct injection engines for several reasons. Fuel spreads in a thin film over the wall and is evaporated by the air swirling in the chamber to form the stratified charge.

Stratified Charge Engine



In order to realize the stratified combustion, the cylinder mixture formation in time, spatial control is essential. Stratified charge engine could operate unthrottled as does the diesel engine. First, unthrottled operation allows for a significant reduction in pumping loss, especially at low loads. Second, the lean mixture being compressed has a higher ratio of specific heats. This allows for a more efficient compression and expansion process. Third, there are lower wall heat losses in the cylinder because of the centralization of the mixture away from the walls.

A stratified charge engine concentrates a rich mixture near the spark plug (air-fuel ratio is less than 14.7:1) and lean mixture (at air-fuel ratios of 50:1 or greater) throughout into the cylinder.

To do stratification, the fuel injectors are aimed in order to inject the fuel into only one area of the cylinder, often a small "subcylinder" at the top of the main cylinder. This leads to a very rich charge in that area that ignites easily and burns smoothly. As the combustion proceeds, it meets a very lean area (often only air) where it cools rapidly and the harmful NOx never has a chance to form. The additional oxygen in the lean charge also combines with any CO to form CO2, which is less harmful. The much cleaner combustion allows for the elimination of the catalytic converter, as well as allowing the engine to be run at leaner mixtures, using less fuel.

In a stratified charge engine, the fuel is injected into the cylinder just before ignition. This allows for higher compression ratios without "knock," and leaner air/fuel mixtures than in conventional internal combustion engines. All the subtlety of engine operation in stratified mode occurs at level of injection. In this air-fuel ratio is free to range from rich limit of homogeneous to lean limit of stratified combustion and the combustion mode is varies between homogeneous and stratified as per need.

➢ Advantages:

1. The overall air-fuel ration can be very lean reaching 40:1 to 50:1 giving high fuel efficiency.
2. The mixture being rich near spark plug, good ignition characteristics without misfire are obtained.
3. The end gases being very fuel lean, pre-combustion reactions would be very slow leading to reduced knocking tendency. Hence, a higher compression ratio can be used further improving the fuel efficiency.
4. Presence of rich mixture near spark plug keeps the formation of NO_x at low levels. The mixture that burns early is deficient in oxygen although it attains high combustion temperatures.

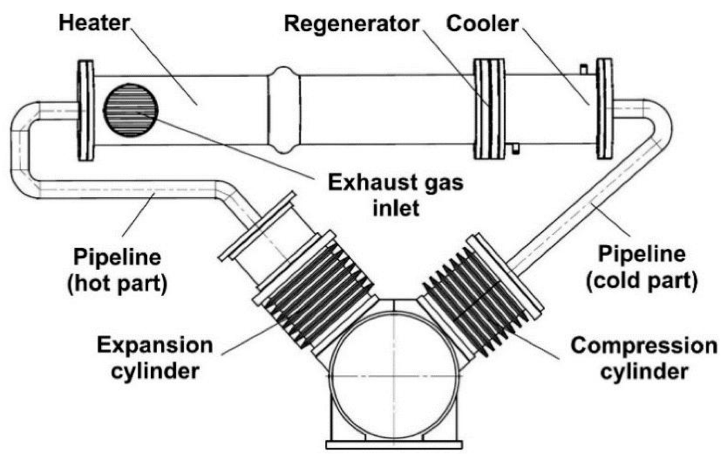
➢ Disadvantages:

1. Injectors add significant cost to the system but fuel efficiency advantages are overcome this.
2. With increasing load, the efficiency matches with that of conventional engines due to stoichiometric mixture.
3. High cyclic variability can disrupt the formation (and location) of the stratified areas, reducing the effect of the spark –if the rich area is not near the spark then combustion either may not occur properly.

2. Stirling Engine

A Stirling engine is a heat engine that is operated by the cyclic compression and expansion of air or other gas (the working fluid) at different temperatures, resulting in a net conversion of heat energy to mechanical work. More specifically, the Stirling engine is a closed-cycle regenerative heat engine with a permanent gaseous working fluid. Closed-cycle, in this context, means a thermodynamic system in which the working fluid is permanently contained within the system, and regenerative describes the use of a specific type of internal heat exchanger and thermal store, known as the regenerator. Strictly speaking, the inclusion of the regenerator is what differentiates a Stirling engine from other closed-cycle hot air engines.

Originally conceived in 1816 by Robert Stirling as an industrial prime mover to rival the steam engine, its practical use was largely confined to low-power domestic applications for over a century. However, contemporary investment in renewable energy, especially solar energy, has increased the efficiency of concentrated solar power.



Sterling Engine

➢ Working

The engine is designed so the working gas is generally compressed in the colder portion of the engine and expanded in the hotter portion resulting in a net conversion of heat into work an internal regenerative heat exchanger increases the Stirling engine's thermal efficiency compared to simpler hot air engines lacking this feature.

The Stirling engine uses the temperature difference between its hot end and cold end to establish a cycle of a fixed mass of gas, heated and expanded, and cooled and compressed, thus converting thermal energy into mechanical energy. The greater the temperature difference between the hot and cold sources, the greater the thermal efficiency. The maximum theoretical efficiency is equivalent to that of the Carnot cycle, but the efficiency of real engines is less than this value because of friction and other losses.

Since the Stirling engine is a closed cycle, it contains a fixed mass of gas called the "working fluid", most commonly air, hydrogen or helium. In normal operation, the engine is sealed and no gas enters or leaves; no valves are required, unlike other types of piston engines. The Stirling engine, like most heat engines, cycles through four main processes: cooling, compression, heating, and expansion. This is accomplished by moving the gas back and forth between hot and cold heat exchangers, often with a regenerator between the heater and cooler. The hot heat exchanger is in thermal contact with an external heat source, such as a fuel burner, and the cold heat exchanger is in thermal contact with an external heat sink, such as air fins. A change in gas temperature causes a corresponding change in gas pressure, while the motion of the piston makes the gas alternately expand and compress.

The gas follows the behaviour described by the gas laws that describe how a gas's pressure, temperature, and volume are related. When the gas is heated, the pressure rises (because it is in a sealed chamber) and this pressure then acts on the power piston to produce a power stroke. When the gas is cooled the pressure drops and this drop means that the piston needs to do less work to compress the gas on the return stroke. The difference in work between the strokes yields a net positive power output.

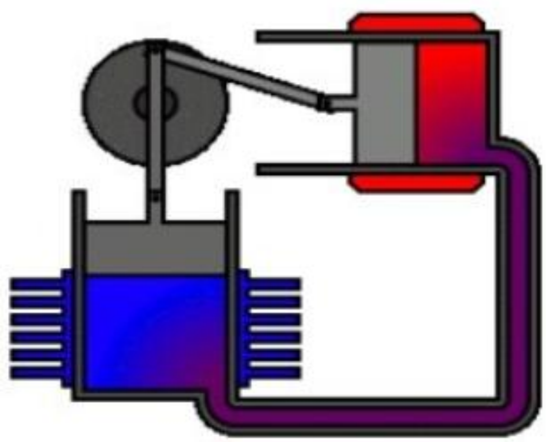
When one side of the piston is open to the atmosphere, the operation is slightly different. As the sealed volume of working gas comes in contact with the hot side, it expands, doing work on both the piston and on the atmosphere. When the working gas contacts the cold side, its pressure drops below atmospheric pressure and the atmosphere pushes on the piston and does work on the gas.

➢ Configurations of Stirling Engines

There are three major types of Stirling Engines, that are distinguished by the way they move the air between the hot and cold areas:

1) The Alpha Configuration

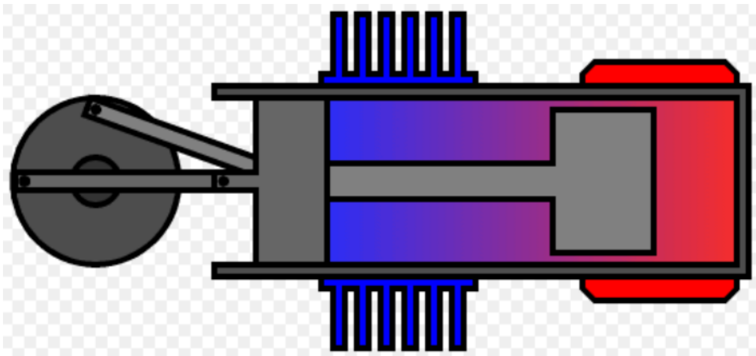
An alpha Stirling contains two power pistons in separate cylinders, one hot and one cold. The hot cylinder is situated inside the high-temperature heat exchanger and the cold cylinder is situated inside the low-temperature heat exchanger. This type of engine has a high power-to-volume ratio but has technical problems because of the usually high temperature of the hot piston and the durability of its seals. In practice, this piston usually carries a large insulating head to move the seals away from the hot zone at the expense of some additional dead space. The crank angle has a major effect on efficiency and the best angle frequently must be found experimentally. An angle of 90° frequently locks.



Alpha Configured Stirling Engine

2) The Beta Configuration

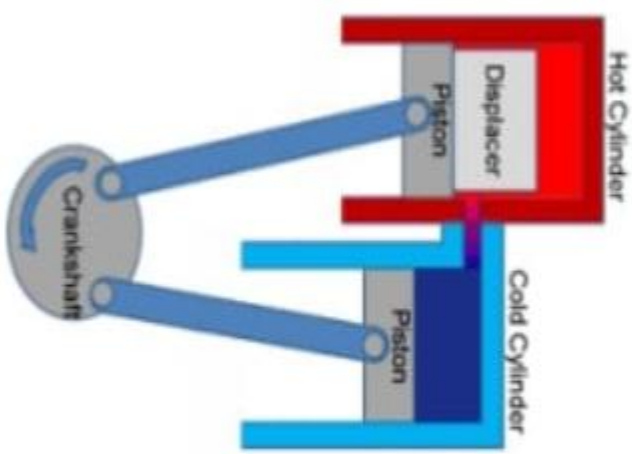
A beta Stirling has a single power piston arranged within the same cylinder on the same shaft as a displacer piston. The displacer piston is a loose fit and does not extract any power from the expanding gas but only serves to shuttle the working gas between the hot and cold heat exchangers. When the working gas is pushed to the hot end of the cylinder it expands and pushes the power piston. When it is pushed to the cold end of the cylinder it contracts and the momentum of the machine, usually enhanced by a flywheel, pushes the power piston the other way to compress the gas. Unlike the alpha type, the beta type avoids the technical problems of hot moving seals, as the power piston is not in contact with the hot gas.



Beta Configured Stirling Engine

3) The Gamma Configuration

A gamma Stirling is simply a beta Stirling with the power piston mounted in a separate cylinder alongside the displacer piston cylinder, but still connected to the same flywheel. The gas in the two cylinders can flow freely between them and remains a single body. This configuration produces a lower compression ratio because of the volume of the connection between the two but is mechanically simpler and often used in multi-cylinder Stirling engines.



Gamma Configured Stirling Engine

➢ Advantages

1. Various heat sources (solar, thermal, nuclear energy, waste heat, biological)
2. Environmentally friendly
3. Heat is external and the burning of a fuel-air mixture can be more accurately controlled.
4. Operates at relatively low pressure and thus are much safer than typical steam turbines.
5. Less manpower needed to operate any type of commercial Stirling engine.

➢ Disadvantages

1. The Stirling cycle is not actually achievable, due to requirement of costly materials to maintain the high temperature differentials.
2. The real cycle in Stirling machines is less efficient than the theoretical Stirling cycle.
3. The efficiency of the Stirling cycle is lower where the ambient temperatures are mild, while it would give its best results in a cool environment.
4. Dissipation of waste heat is especially complicated because the coolant temperature is kept as low as possible to maximize thermal efficiency. This increases the size of the radiators, which can make packaging difficult.

3. Wankel Engine

The Wankel rotary engine is a type of internal combustion engine, invented by German engineer Felix Wankel, which uses a rotor instead of reciprocating pistons. This design promises smooth high-rpm power from a compact, lightweight engine.

The Wankel engine is a type of internal combustion engine using an eccentric rotary design to convert pressure into rotating motion.Compared to the reciprocating piston engine, the Wankel engine has more uniform torque and less vibration and, for a given power, is more compact and weighs less.

The rotor, which creates the turning motion, is similar in shape to a Reuleaux triangle, except the sides have less curvature. Wankel engines deliver three power pulses per revolution of the rotor using the Otto cycle. However, the output shaft uses toothed gearing to turn three times faster giving one power pulse per revolution. This can be seen in the animation below. In one revolution, the rotor experiences power pulses and exhausts gas simultaneously, while the four stages of the Otto cycle occur at separate times. For comparison, in a two-stroke piston engine there is one power pulse for each crankshaft revolution (as with a Wankel engine output shaft) and, in a four-stroke piston engine, one power pulse for every two revolutions.

➢ Working

The Wankel cycle. The "A" marks one of the three apexes of the rotor. The "B" marks the eccentric shaft, turning three times for every revolution of the rotor. In the Wankel engine, the four strokes of a typical Otto cycle engine are arranged sequentially around an oval, unlike the reciprocating motion of a piston engine.

In the basic single rotor Wankel engine, a single oval (technically an epitrochoid) housing surrounds a three-sided rotor (a Reuleaux triangle) which turns and moves within the housing. The sides of the rotor seal against the sides of the housing, and the corners of the rotor seal against the inner periphery of the housing, dividing it into three combustion chambers.

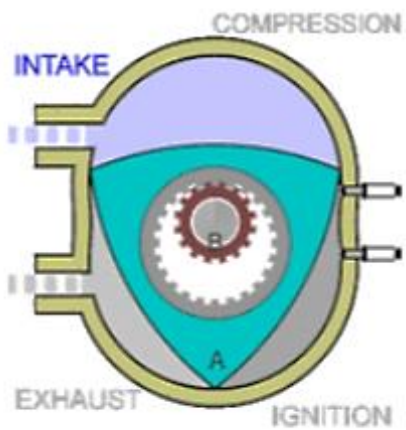


Diagram of Wankel Engine

As the rotor turns, its motion and the shape of the housing cause each side of the rotor to get closer and farther from the wall of the housing, compressing and expanding combustion chamber similarly to the "strokes" in a reciprocating engine. However, whereas a normal Four-stroke cycle engine produces one combustion stroke per cylinder for every two revolutions (that is, one half power stroke per revolution per cylinder) each combustion chamber of each rotor in the Wankel generates one combustion 'stroke' per revolution (that is, three power strokes per rotor revolution). Since the Wankel output shaft is geared to spin at three times the rotor speed, this becomes one combustion 'stroke' per output shaft revolution per rotor, twice as many as the four-stroke piston engine, and similar to the output of a two-stroke cycle engine. Thus, power output of a Wankel engine is generally higher than that of a four-stroke piston engine of similar engine displacement in a similar state of tune, and higher than that of a four-stroke piston engine of similar physical dimensions and weight.

➢ Advantages

1. A far higher power to weight ratio than a piston engine.
2. Approximately one third of the size of a piston engine of equivalent power output. Thus, it is easier to package in small engine spaces than an equivalent piston engine
3. No reciprocating parts results in operation without vibrations.
4. Able to reach higher revolutions per minute than a piston engine.
5. Not prone to engine-knock.
6. Cheaper to mass-produce, because the engine contains fewer parts.
7. Superior breathing, filling the combustion charge in 270 degrees of main shaft rotation rather than 180 degrees in a piston engine.
8. Supplying torque for about two thirds of the combustion cycle rather than one quarter for a piston engine.
9. Wider speed range giving greater adaptability.
10. Can use fuels of wider octane ratings.
11. Does not suffer from "scale effect" to limit its size.
12. Easily adapted and highly suitable to use hydrogen fuel.
13. On some Wankel engines the sump oil remains uncontaminated by the combustion process, so no oil changes are required. The oil in the main shaft is totally sealed from the combustion process. The oil for Apex seals and crankcase lubrication is separate. In piston engines the crankcase oil is contaminated by combustion blow-by through the piston rings.

➢ Disadvantages

1. **Rotor sealing:** This is still a minor problem as the engine housing has vastly different temperatures in each separate chamber section. The different expansion coefficients of the materials lead to imperfect sealing. Additionally, both sides of the seals are exposed to fuel, and the design does not allow for controlling the lubrication of the rotors accurately and precisely.
2. Rotary engines tend to be overlubricated at all engine speeds and loads, and have relatively high oil consumption and other problems resulting from excess oil in the combustion areas of the engine, such as carbon formation and excessive emissions from burning oil.
3. **Apex seal lifting:** Centrifugal force pushes the apex seal onto the housing surface forming a firm seal. Gaps can develop between the apex seal and troichoid housing in light-load operation when imbalances in centrifugal force and gas pressure occur.

4. Fuel combustion is slow using gasoline fuel, because the combustion chamber is long, thin, and moving.
5. Flame travel occurs almost exclusively in the direction of rotor movement, adding to the poor quenching of a gasoline/air mixture of 2mm, being the main source of unburned hydrocarbons at high rpm.
6. Due to the shape of the moving combustion chamber, which results in poor combustion behaviour and mean effective pressure at part load and low rpm. This results in unburnt fuel entering the exhaust stream.
7. Meeting the emissions regulations requirements sometimes mandates a fuel-air ratio using gasoline fuel that is not conducive to good fuel economy.
8. As unburned fuel when using gasoline fuel is in the exhaust stream, emissions requirements are difficult to meet.