NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

DEPARTMENT OF MECHATRONICS ENGINEERING

COURSE MATERIALS

BE 101-02 INTRODUCTION TO MECHANICAL ENGINEERING

VISION OF THE INSTITUTION
To mould true citizens who are millennium leaders and catalysts of change through excellence in education.
MISSION OF THE INSTITUTION
NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values. We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2013
- Course offered: B.Tech Mechatronics Engineering
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of Dr. A P J Abdul Kalam Technological University.

DEPARTMENT VISION

To develop professionally ethical and socially responsible Mechatronics engineers to serve the humanity through quality professional education.

DEPARTMENT MISSION

1) The department is committed to impart the right blend of knowledge and quality education to create professionally ethical and socially responsible graduates.

2) The department is committed to impart the awareness to meet the current challenges in technology.

3) Establish state-of-the-art laboratories to promote practical knowledge of mechatronics to meet the needs of the society

PROGRAMME EDUCATIONAL OBJECTIVES

I. Graduates shall have the ability to work in multidisciplinary environment with good professional and commitment.

II. Graduates shall have the ability to solve the complex engineering problems by applying electrical, mechanical, electronics and computer knowledge and engage in lifelong learning in their profession.

III. Graduates shall have the ability to lead and contribute in a team with entrepreneur skills, professional, social and ethical responsibilities.

IV. Graduates shall have ability to acquire scientific and engineering fundamentals necessary for higher studies and research.

PROGRAM OUTCOME (PO'S)

Engineering Graduates will be able to:

PO 1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3. Design/development of solutions: Design solutions for complex 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.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. 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.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. 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.

PO 11. 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.

PO 12. 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.

PROGRAM SPECIFIC OUTCOME(PSO'S)

PSO 1: Design and develop Mechatronics systems to solve the complex engineering problem by integrating electronics, mechanical and control systems.

PSO 2: Apply the engineering knowledge to conduct investigations of complex engineering problem related to instrumentation, control, automation, robotics and provide solutions.

COURSE OUTCOMES

CO1	Understand the basic concept of thermodynamics
CO2	Describe about basic principles of engines, turbines and compressors
CO3	Differentiate refrigeration and air conditioning
CO4	Understand the main components of automobile
CO5	List the different types of engineering material
CO6	Describe the different methods of manufacturing

MAPPING OF COURSE OUTCOMES WITH PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	-	-	-	2	2	-	-	-	-	3	2	-
CO2	3	3	-	-	-	2	2	-	-	-	-	3	2	-
CO3	3	3	-	-	-	2	2	-	-	-	-	3	2	-
CO4	3	2	-	-	-	2	2	-	-	-	-	3	2	-
CO5	3	1	-	-	-	2	2	-	-	-	-	3	2	-
CO6	3	-	-	-	-	2	2	-	-	-	-	3	2	-

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

SYLLABUS

Course No.	Course Name	L-T-P-Credits	Year of Introduction
BE 101-02	**INTRODUCTION TO MECHANICAL ENGINEERING**	**2-1-0-3**	**2015**

Course Objectives

To expose the students to the thrust areas in Mechanical Engineering and their relevance by covering the fundamental concepts.

Syllabus

Thermodynamics, laws of thermodynamics, implications, cycles, energy conversion devices, steam and water machines, engines, turbo machines, refrigeration and air conditioning, power transmission devices in automobiles, latest trends, engineering materials and manufacturing processes, types of materials, alloys, shape forming methods, machine tools.

Expected outcome

The student will be able to understand the inter dependence of the thrust areas in Mechanical Engineering and their significance leading to the development of products, processes and systems.

References Books:

- Balachandran, Basic Mechanical Engineering, Owl Books
- Benjamin, J., Basic Mechanical Engineering, Pentex Books
- Clifford, M., Simmons, K. and Shipway, P., An Introduction to Mechanical Engineering Part I - CRC Press
- Crouse, Automobile Engineering, Tata Mc-Graw-Hill, New Delhi
- Gill, Smith and Zuirys, Fundamentals of IC Engines, Oxford and IBH publishing company Pvt. Ltd. New Delhi. Crouse, Automobile Engineering, Tata Mc-Graw-Hill, New Delhi.
- Nag, P. K., Basic and Applied Thermodynamics, Tata McGraw-Hill
- Pravin Kumar, Basic Mechanical Engineering
- Roy and Choudhary, Elements of Mechanical Engineering, Media Promoters & Publishers Pvt. Ltd., Mumbai.
- Sawhney, G. S., Fundamentals of Mechanical Engineering, PHI

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Thermodynamics: Laws of Thermodynamics, significance and applications of laws of thermodynamics; entropy, available energy; Clausius inequality; principle of increase of entropy; Ideal and real gas equations; Analysis of Carnot cycle, Otto cycle , Diesel cycle and Brayton cycle; Efficiency of these cycles.	7	15%
II	Energy conversion devices: Boilers, Steam turbines, Gas turbines and Hydraulic turbines; Working principle of two stroke and four stroke I.C.	7	15%

	Engines (Diesel and Petrol), Reciprocating and centrifugal pumps, rotary pumps, reciprocating and centrifugal compressors, fans, blowers, rotary compressors; Air motor.		
FIRST INTERNAL EXAM			
III	Refrigeration and Air Conditioning: Vapour compression and absorption refrigeration systems, COP, Study of household refrigerator, Energy Efficiency Rating, Psychrometry, Psychrometric processes, window air conditioner, split air conditioner. Ratings and selection criteria of above devices. Refrigerants and their impact on environment.	7	15%
IV	Engines and Power Transmission Devices in Automobiles, Different types of engines used in automobiles, types of automobiles; major components and their functions (Description only); Fuels; Recent developments: CRDI, MPFI, Hybrid engines. Belts and belt drives; Chain drive; Rope drive; Gears and gear trains; friction clutch (cone and single plate), brakes (types and applications only); Applications of these devices.	7	15%
SECOND INTERNAL EXAM			
V	Materials and manufacturing processes: Engineering materials, Classification, properties, Alloys and their Applications; Casting, Sheet metal forming, Sheet metal cutting, Forging, Rolling, Extrusion, Metal joining processes - Powder metallurgy.	7	20%
VI	Machine Tools (Basic elements, Working principle and types of operations) Lathe – Centre Lathe, Drilling Machine – Study of Pillar drilling machine, Shaper, planer, slotter, Milling Machine, Grinding machine, Power saw; Introduction to NC and CNC machines.	7	20%
END SEMESTER EXAM			

QUESTION BANK

MODULE I			
Q:NO:	**QUESTIONS**	**CO**	**KL**
1	Derive the expression to find out the efficiency of Diesel cycle with P-V and T-S diagram.	CO1	K5
2	Briefly explain about Principle of Increase in Entropy.	CO1	K2
3	State Zeroth law and First law of Thermodynamics.	CO1	K2
4	With the help of proper thermodynamic diagrams derive the expression for air standard efficiency of an otto cycle.	CO1	K5
5	Draw the P-V and T-S diagram of a Carnot cycle and explain the process.	CO1	K5
6	State first law thermodynamics for a process and cycle, bring out the limitations.	CO1	K2
7	Distinguish between open and closed systems. Quote one example for each of them.	CO1	K2
8	Analyze various laws of thermodynamics in detail?	CO1	K4
9	Analyze Carnot cycle and derive relationship for thermal efficiency.	CO1	K4
MODULE II			
1	Explain the working of a 4 stroke SI engine with sketches.	CO2	K2
2	Make a comparative study in the working of centrifugal and reciprocating pumps.	CO2	K4
3	Sketch and explain the working of a reaction turbine.	CO2	K2
4	What are the major differences between MPFI and CRDI engines?	CO2	K2
5	Compare the working of two stroke and four stroke internal combustion engines.	CO2	K2
6	Differentiate between impulse and reaction turbines.	CO2	K2
7	Differentiate Fire tube Boiler and Water tube Boiler.	CO2	K2
8	Write short notes on Reciprocating pump.	CO2	K1
9	Analyze the working of four stroke Petrol engine with	CO2	K4

	neat diagrams.		
1	Explain about Vapour Absorption Refrigeration System with a neat sketch.	CO3	K2
2	Descibe the working of Vapour Compression Refrigeration System with its P-H and T-S diagrams.	CO3	K4
3	Descibe in detail various Psychrometric processes.	CO3	K2
4	Explain the working of Window Air Conditioner with a neat sketch.	CO3	K1
5	Explain the working of Split Air Conditioner with a neat sketch.	CO3	K2
6	Describe about the ratings and selection criteria for Split Air conditioner and Window Air conditioner.	CO3	K2
7	Give note on Refrigerants and their impact on environment.	CO3	K2
8	Compare COP and TR.	CO3	K4
MODULE IV			
1	Give account on Gears and Gear trains.	CO4	K2
2	Explain in detail the types of Drives with its advantages, disadvantages and applications.	CO4	K1
3	Give note on Hybrid Engines.	CO4	K2
4	Analyze the working of MPFI system.	CO4	K4
5	Identify and explain the working of CRDI system.	CO4	K4
6	Draw the layout of an Automobile and explain its components and their functions.	CO4	K2
7	Describe the types and applications of Brakes in detail.	CO4	K1
8	Describe about the working of Friction clutch.	CO4	K2
MODULE V			

1	With neat sketches explain Extrusion process.	CO5	K4
2	Explain sand casting with proper sketches.	CO5	K2
3	What is meant by powder metallurgy, write short notes on it.	CO5	K3
4	Explain various sheet metal cutting operations.	CO5	K2
5	Briefly explain various welding processes.	CO5	K3
6	Write short notes on the classification of engineering materials.	CO5	K2
7	What is meant by alloys also mention its applications.	CO5	K2
8	Explain various sheet metal cutting operations.	CO5	K3
MODULE VI			
1	With neat sketch explain lathe machine.	CO5	K2
2	Differentiate shaper and slotter.	CO5	K2
3	Differentiate planer and slotter.	CO5	K2
4	With neat sketch explain grinding machine.	CO5	K2 K2
5	Explain drilling machine with neat sketches.	CO5	
6	With neat sketches explain shaper machine.	CO5	K2
7	What are the operations performed in a milling machine.	CO5	K2
8	Differentiate up milling and down milling.	CO5	K2

APPENDIX 1	
CONTENT BEYOND THE SYLLABUS	
S:NO;	WEB SOURCE REFERENCES
1	https://www.wileymetal.com/6-advanced-welding-processes-and-their-applications-explained/
2	https://www.ndt.net/article/panndt2007/papers/143.pdf
3	https://www.forgingmagazine.com/issues-and-ideas/article/21923033/new-developments-in-forging-technology
4	https://www.forging.org/producers-and-suppliers/technology/vision-of-the-future

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MODULE-1

System:

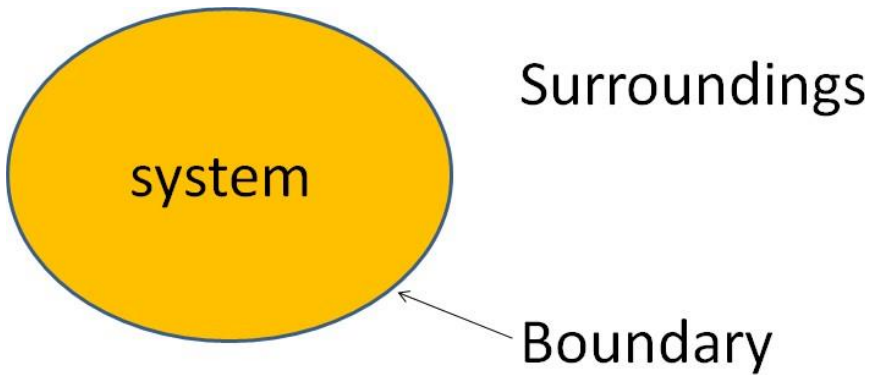
A thermodynamic system is defined as a quantity of matter or a region in space which is selected for the study.

Surroundings:

The mass or region outside the system is called surroundings.

Boundary:

The real or imaginary surfaces which separates the system and surroundings is called boundary. The real or imaginary surfaces which separates the system and surroundings is called boundary.



Types of thermodynamic system

On the basis of mass and energy transfer the thermodynamic system is divided into three types.

1. Closed system
2. Open system
3. Isolated system

Closed system: A system in which the transfer of energy but not mass can takes place across the boundary is called closed system. The mass inside the closed system remains constant.

For example: Boiling of water in a closed vessel. Since the water is boiled in closed vessel so the mass of water cannot escapes out of the boundary of the system but heat energy continuously entering and leaving the boundary of the vessel. It is an example of closed system.

Open system: A system in which the transfer of both mass and energy takes place is called an open system. This system is also known as control volume.

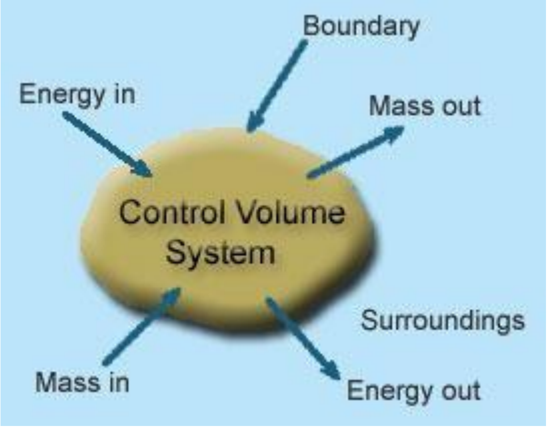
For example: Boiling of water in an open vessel is an example of open system because the water and heat energy both enters and leaves the boundary of the vessel.

Isolated system: A system in which the transfer of mass and energy cannot takes place is called an isolated system.

For example: Tea present in a thermos flask. In this the heat and the mass of the tea cannot cross the boundary of the thermos flask. Hence the thermos flak is an isolated system.

Control Volume:

- Its a system of fixed volume.
- This type of system is usually referred to as "open system" or a "control volume"
- Mass transfer can take place across a control volume.
- Energy transfer may also occur into or out of the system.
- Control Surface- Its the boundary of a control volume across which the transfer of both mass and energy takes place.
- The mass of a control volume (open system) may or may not be fixed.
- When the net influx of mass across the control surface equals zero then the mass of the system is fixed and vice-versa.
- The identity of mass in a control volume always changes unlike the case for a control mass system (closed system).
- Most of the engineering devices, in general, represent an open system or control
- volume.



Example:
Heat exchanger - Fluid enters and leaves the system continuously with the transfer of heat across the system boundary.
Pump - A continuous flow of fluid takes place through the system with a transfer of mechanical energy from the surroundings to the system

Microscopic Approach:

The approach considers that the system is made up of a very large number of discrete particles known as molecules. These molecules have different velocities are energies. The values of these energies are constantly changing with time. This approach to thermodynamics, which is concerned directly with the structure of the matter, is known as statistical thermodynamics.

The behavior of the system is found by using statistical methods, as the number of molecules is very large. So advanced statistical and mathematical methods are needed to explain the changes in the system.

The properties like velocity, momentum, impulse, kinetic energy and instruments cannot easily measure force of impact etc. that describe the molecule.

Large numbers of variables are needed to describe a system. So the approach is complicated.

Macroscopic Approach:

In this approach a certain quantity of matter is considered without taking into account the events occurring at molecular level. In other words this approach to thermodynamics is concerned with gross or overall behavior. This is known as classical thermodynamics.

The analysis of macroscopic system requires simple mathematical formula.

The value of the properties of the system are their average values. For examples consider a sample of gas in a closed container. The pressure of the gas is the average value of the pressure exerted by millions of individual molecules.

In order to describe a system only a few properties are needed.

S.No	**Macroscopic Approach**	**Microscopic Approach**
1	In this approach a certain quantity of matter is considered without taking into account the events occurring at molecular level.	The matter is considered to be comprised of a large number of tiny particles known as molecules, which moves randomly in chaotic fashion. The effect of molecular motion is considered.
2	Analysis is concerned with overall behavior of the system.	The Knowledge of the structure of matter is essential in analyzing the behavior of the system.
3	This approach is used in the study of classical thermodynamics.	This approach is used in the study of statistical thermodynamics.
4	A few properties are required to describe the system.	Large numbers of variables are required to describe the system.

5	The properties like pressure, temperature, etc. needed to describe the system, can be easily measured.	The properties like velocity, momentum, kinetic energy, etc. needed to describe the system, cannot be measured easily.
6	The properties of the system are their average values.	The properties are defined for each molecule individually.
7	This approach requires simple mathematical formulas for analyzing the system.	No. of molecules are very large so it requires advanced statistical and mathematical method to explain any change in the system.

Thermodynamic Equilibrium:

A thermodynamic system is said to exist in a state of thermodynamic equilibrium when no change in any macroscopic property is registered if the system is isolated from its surroundings.
An isolated system always reaches in the course of time a state of thermodynamic equilibrium and can never depart from it spontaneously.
Therefore, there can be no spontaneous change in any macroscopic property if the system exists in an equilibrium state. A thermodynamic system will be in a state of thermodynamic equilibrium if the system is the state of Mechanical equilibrium, Chemical equilibrium and Thermal equilibrium.
Mechanical equilibrium: The criteria for Mechanical equilibrium are the equality of pressures.
Chemical equilibrium: The criteria for Chemical equilibrium are the equality of chemical potentials.
Thermal equilibrium: The criterion for Thermal equilibrium is the equality of temperatures.

State:

The thermodynamic state of a system is defined by specifying values of a set of measurable properties sufficient to determine all other properties. For fluid systems, typical properties are pressure, volume and temperature. More complex systems may require the specification of more unusual properties. As an example, the state of an electric battery requires the specification of the amount of electric charge it contains.

Property:

Properties may be extensive or intensive.
Intensive properties: The properties which are independent of the mass of the system.
For example: Temperature, pressure and density are the intensive properties.
Extensive properties: The properties which depend on the size or extent of the system are called extensive properties.
For example: Total mass, total volume and total momentum.

Process:

When the system undergoes change from one thermodynamic state to final state due change in properties like temperature, pressure, volume etc, the system is said to have undergone thermodynamic process.
Various types of thermodynamic processes are: isothermal process, adiabatic process, isochoric process, isobaric process and reversible process

Cycle:

Thermodynamic cycle refers to any closed system that undergoes various changes due to temperature, pressure, and volume, however, its final and initial state are equal. This cycle is important as it allows for the continuous process of a moving piston seen in heat engines and the expansion/compression of the working fluid in refrigerators, for example. Without the cyclical process, a car wouldn't be able to continuously move when fuel is added, or a refrigerator would not be able to stay cold.
Visually, any thermodynamic cycle will appear as a closed loop on a pressure volume diagram.
Examples: Otto cycle, Diesel Cycle, Brayton Cycle etc.

Reversibility:

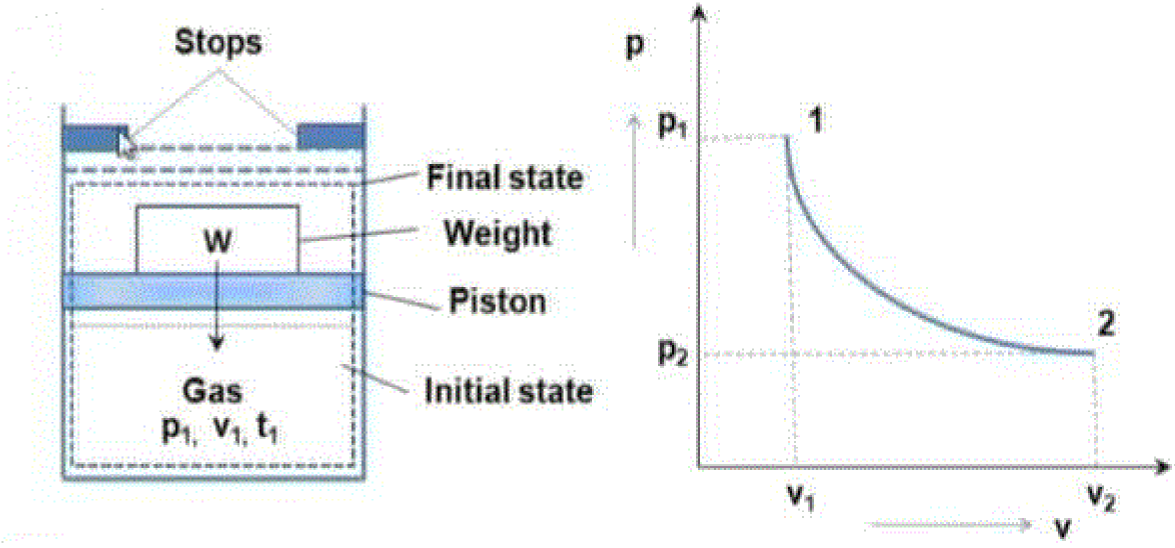
Reversibility, in thermodynamics, a characteristic of certain processes (changes of a system from an initial state to a final state spontaneously or as a result of interactions with other systems) that can be reversed, and the system restored to its initial state, without leaving net effects in any of the systems involved.

An example of a reversible process would be a single swing of a frictionless pendulum from one of its extreme positions to the other. The swing of a real pendulum is irreversible because a small amount of the mechanical energy of the pendulum would be expended in performing work against frictional forces, and restoration of the pendulum to its exact starting position would require the supply of an equivalent amount of energy from a second system, such as a compressed spring in which an irreversible change of state would occur.

Quasi static process:

When a process is processing in such a way that system will be remained infinitesimally close with equilibrium state at each time, such process will be termed as quasi static process or quasi equilibrium process.

In simple words, we can say that if system is going under a thermodynamic process through succession of thermodynamic states and each state is equilibrium state then the process will be termed as quasi static process.



There will see one example for understanding the quasi static process, but let us consider one simple example for better understanding of quasi static process. If a person is coming down from roof to ground floor with the help of ladder steps then it could be considered as quasi static process. But if he jumps from roof to ground floor then it will not be a quasi static process.

Weight placed over the piston is just balancing the force which is exerted in upward direction by gas. If we remove the weight from the piston, system will have unbalanced force and piston will move in upward direction due to force acting over the piston in upward direction by the gas.

Air Standard Cycles:

- An idealized cycle in which air is taken as the working fluid.
- These cycles are used for the analysis of internal combustion engines (eg: engines used in automobiles).
- Actual combustion process in IC engines are replaced by a heat transfer process & Actual exhaust process is replaced by a heat rejection process
- All process are assumed to be reversible
- Work done by air = Difference b/w Heat transferred & Heat rejected.
- If there is no mechanical loss; then,

Workdone during a cycle } = Heat Supplied − Heat Rejected

- Thermal efficiency of a cycle = Ratio of Work done to the heat Supplied during the cycle

& the thermal efficiency of a cycle using air as a working medium is known as

Air Standard Efficiency = Work done / Heat Supplied

$$= \frac{\text{Heat Supplied} - \text{Heat Rejected}}{\text{Heat Supplied}}$$

$$= 1 - \frac{\text{Heat Rejected}}{\text{Heat Supplied}}$$

Mean Effective Pressure: (MEP)

i) Indicator diagram :- Closed contour obtained by drawing the variations of pressure versus volume inside the cylinder of a reciprocating engine.

ii) Work done : Area ~~amount~~ enclosed by the contour.

iii) MEP : Constant pressure acting on the piston which will produce the same amount of work as done by actual varying pressure acting on the piston during a cycle.

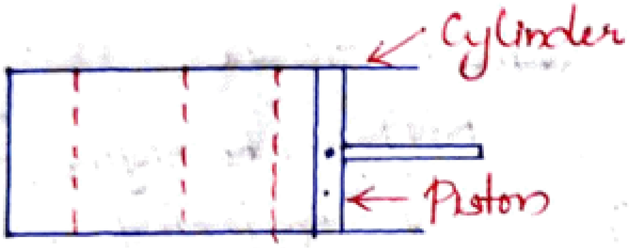
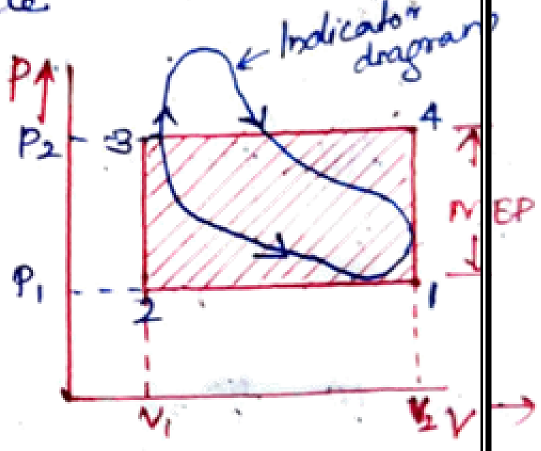


fig. Piston - Cylinder Arrangement



The height of rectangle 1-2-3-4 in fig. is the MEP when the area of indicator diagram is equal to the area of rectangle.

Area of the Indicator diagram = Work done / cycle

$$\Rightarrow MEP \times V_2 - V_1 = W/cycle$$

$$\Rightarrow MEP = \frac{W/cycle}{V_2 - V_1}$$

where $V_2 - V$ is known as Swept Volume

iv) Unit of MEP = N/m^2

v) MEP is used as a parameter to compare the performance of reciprocating engines of same size.

Air Standard Carnot Cycle

* Theoretical ideal thermodynamic cycle proposed by ~~French~~ French physicist Sadi Carnot in 1824.
* This cycle is a reversible cycle.
* Theor. heat engine that operates on the Carnot cycle is called a Carnot Heat Engine.
* Heat engines are used to convert thermal energy to work.
* Ideal cycles which are internally reversible have lesser thermal efficiency than a Carnot cycle which is externally reversible operating within the same temperature limits.
* The Carnot's theorem states that:

<u>Statement a:</u> "All irreversible engines operating b/w two different temperatures (T_1 & $T_2 < T_1$) will have an efficiency less than a Carnot Engine operating ~~&~~ b/w the same temperatures."

<u>Statement b:</u> "All reversible engines operating b/w 2 different temperatures (T_1 & $T_2 < T_1$) will have an efficiency equal to that of a Carnot engine operating ~~&~~ b/w the same temperatures."

* Thermal efficiency is given as

$$\eta_{th} = \frac{\text{Workdone}}{\text{Heat Supplied}} = \frac{W_{net}}{q_s}$$

Processes in a Carnot Cycle: Consists of 4 processes

Process 1-2 (i) Heat is supplied Isothermally - Isothermal heat supply (Isothermal expansion)

Process 2-3 (ii) Adiabatic Expansion or - Isentropic expansion

Process 3-4 (iii) Isothermal heat rejection, or Isothermal compression

Process 4-1 (iv) Adiabatic Compression or Isentropic Compression

- Consider a given mass of air in the cylinder inside which a frictionless piston slides. (assumption for an ideal cycle)
- At State 1: pressure → P_1
  Volume → V_1
  Temperature → T_1

Process 1-2

- Heat is supplied to this air Isothermally from an external hot body. Air expands at Constant temperature T_1 till it reaches the state 2.
- Curve 1-2 in P-V diagram, & horizontal line 1-2 in T-S diagram represents change of state from 1-2.
- Heat is absorbed from the hot body & an equal amount of work is done by the air.

Process 2-3:

- At State 2, source of heat is removed & the air is allowed to expand adiabatically till state 3.
- Represented by curve 2-3 in P-V diagrams & vertical line 2-3 in T-S diagram.
- At State 3: pressure → P_3, Volume → V_3 & Temperature → T_3.
- Work is done during this process by air utilising

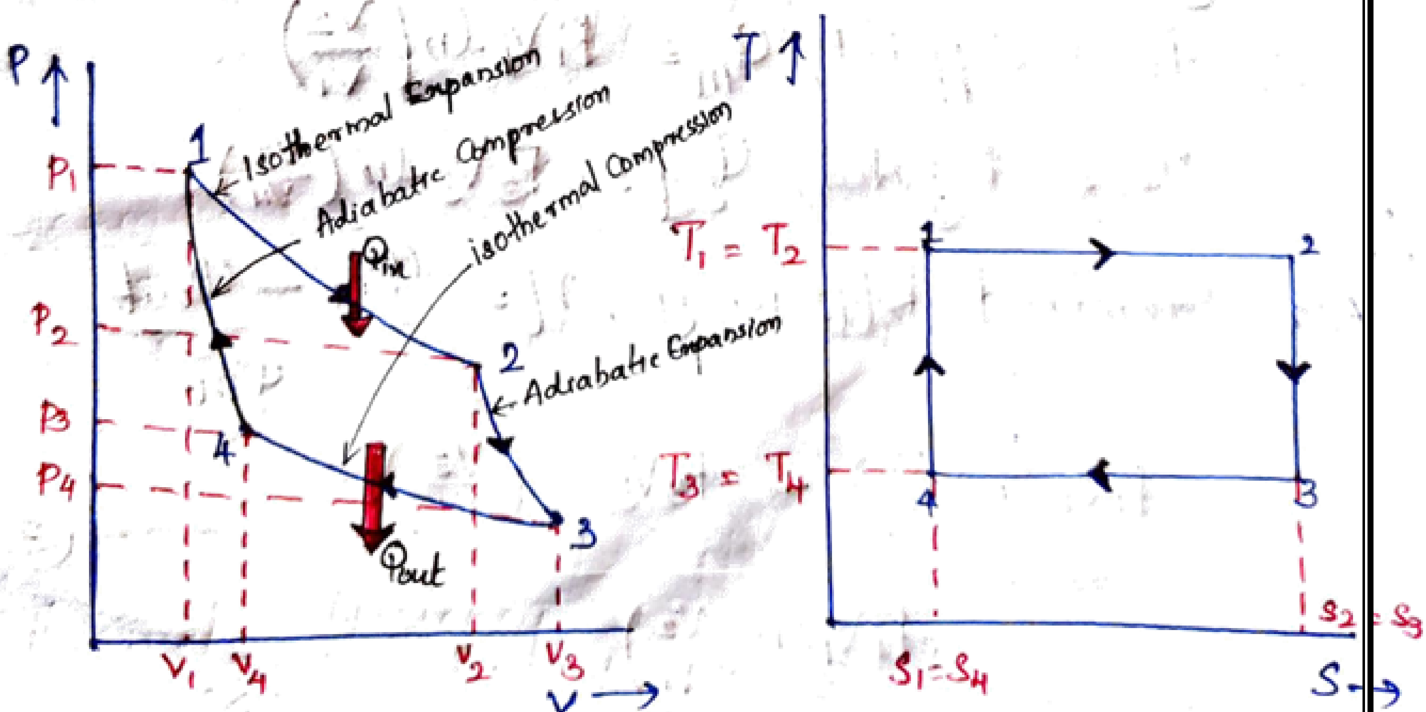
its internal energy.

Process 3-4:

- At state 3 an external cold body is made to contact with cylinder.
- Isothermal heat rejection takes place to the cold body at temperature T_3.
- This isothermal compression is represented using curve 3-4 in P-V diagram & horizontal line in 3-4 in T-S diagram.
- During this process work is done on the air & an equal amount of heat is rejected.

Process 4-1:

- At state 4: the cold body is removed & the air is compressed adiabatically (isentropically) & the air reaches to initial state 1.
- Curve 4-1 represents the process in P-V diagram & vertical line 4-1 represents the process in T-S diagram.
- During this process, work is done on air to bring it to its initial state.



For the adiabatic expansion process 2-3;

$$\frac{V_3}{V_2} = \left(\frac{T_2}{T_3}\right)^{\frac{1}{\gamma-1}} \quad \text{—— ①}$$

For adiabatic compression process 4-1;

$$\frac{V_4}{V_1} = \left(\frac{T_1}{T_4}\right)^{\frac{1}{\gamma-1}}$$

Since $T_1 = T_2$; $T_3 = T_4$; $\frac{V_4}{V_1} = \left(\frac{T_2}{T_3}\right)^{1/\gamma-1}$ ⟵ ②

$\Rightarrow$ $\frac{V_3}{V_2} = \frac{V_4}{V_1}$ (from ① & ②)

i.e., Adiabatic Expansion Ratio = Adiabatic Compression Ratio

& $\frac{V_2}{V_1} = \frac{V_3}{V_4}$

During the entire cycle the heat is supplied during 1-2 & rejected during 3-4.

$\therefore$ Heat Supplied, $Q_{in} = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$

Heat Rejected, $Q_{out} = P_3 V_3 \ln\left(\frac{V_3}{V_4}\right)$

Air Standard Efficiency, $\eta = \frac{Q_{in} - Q_{out}}{Q_{in}}$

$$= \frac{P_1 V_1 \ln\left(\frac{V_2}{V_1}\right) - P_3 V_3 \ln\left(\frac{V_3}{V_4}\right)}{P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)} \quad \text{—— ③}$$

Substituting $PV = mRT$ in ③

$$\Rightarrow \eta = \frac{mR T_1 \ln\left(\frac{V_2}{V_1}\right) - mR T_3 \ln\left(\frac{V_3}{V_4}\right)}{mR T_1 \ln\left(\frac{V_2}{V_1}\right)}$$

$$= 1 - \frac{mR T_3 \ln\left(\frac{V_3}{V_4}\right)}{mR T_1 \ln\left(\frac{V_2}{V_1}\right)} = 1 - \frac{T_3}{T_1} \quad \left(\because \frac{V_3}{V_4} = \frac{V_2}{V_1}\right)$$

$$\Rightarrow \eta = 1 - \frac{T_3}{T_1} = \frac{T_1 - T_3}{T_1}$$

or

$$\boxed{\eta = 1 - \frac{T_2}{T_1}}$$

(generally $T_2 \rightarrow$ temp. of cold body
$T_1 \rightarrow$ temp. of hot body)

(Alternate Sol^n)

from T-S diagram;

$$Q_{in} = T_1 (S_2 - S_1)$$

$$Q_{out} = T_3 (S_3 - S_4)$$

$$\therefore \eta = \frac{T_1 (S_2 - S_1) - T_3 (S_3 - S_4)}{T_1 (S_2 - S_1)}$$

$$= 1 - \frac{T_3}{T_1}\left(\frac{S_3 - S_4}{S_2 - S_1}\right) = 1 - \frac{T_3}{T_1} \quad \left(\because S_2 = S_3;\ S_1 = S_4\right)$$

& replacing $T_3 = T_2 \Rightarrow$

$$\boxed{\eta = 1 - \frac{T_2}{T_1}}$$

(X.)

Problems on Carnot Cycle

1. During a carnot cycle the working fluid receives heat at a temp. of 317°c & rejects heat at a temperature of 22°c. Find the theoritical efficiency of the cycle.

Solution: Given: Temp. at which Heat added to fluid, $T_1 = 317°c = 317+273 = 590k$

Temp at which Heat rejected by fluid, $T_2 = 22°c = 22+273 = 295k$

Theoritical efficiency, $\eta = 1 - \frac{T_2}{T_1}$

ie; $\eta = 1 - \frac{295}{590} = 0.5 = \underline{50\%}$

2. A carnot cycle works with adiabatic compression ratio of 5 & isothermal expansion ratio = 2; volume of air at the beginning of isothermal expansion is $0.3m^3$. If the max temperature & pressure is limited to 550k & 21 bar, determine, if

i) Minimum temperature in the cycle

ii) Thermal efficiency of the cycle

iii) Pressure at all salient points

iv) Work done per cycle.

Take $\gamma = 1.4$.

Solution: (Refer fig.)

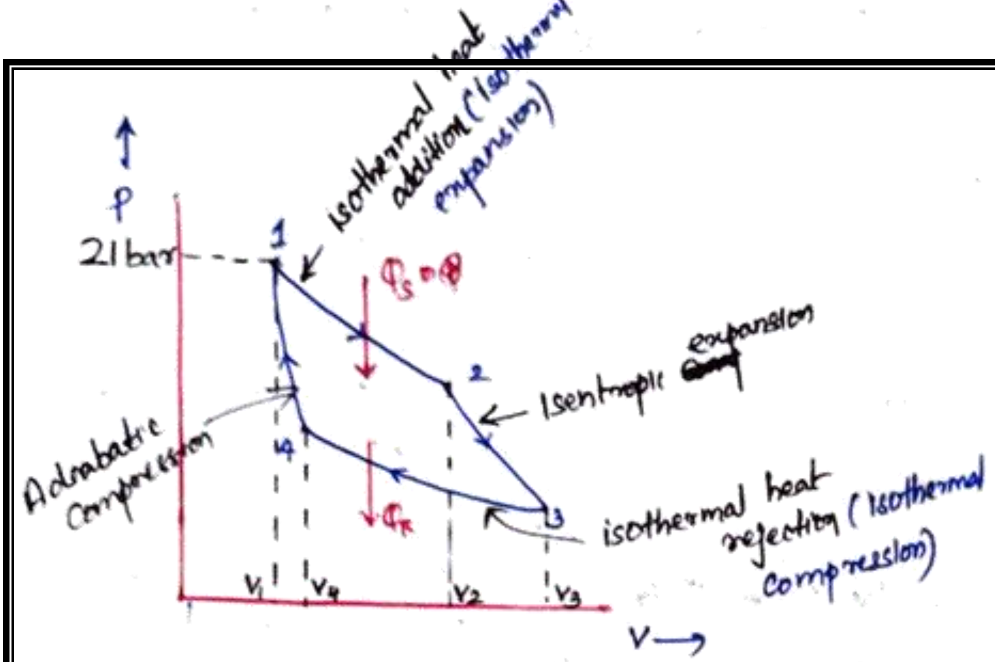
Given data: → Adiabatic compression ratio, $\frac{V_4}{V_1} = 5$.

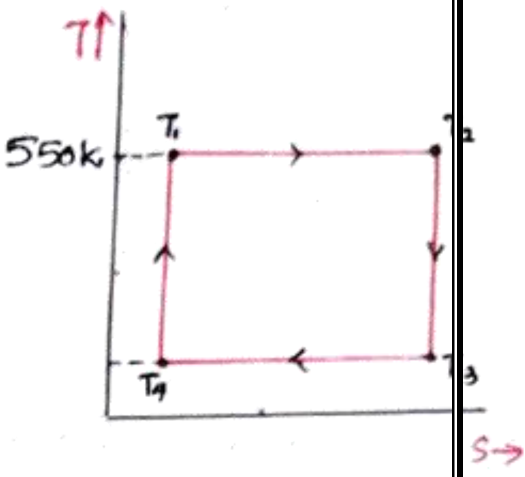
→ Isothermal Expansion ratio, $\frac{V_2}{V_1} = 2$

→ Vol. at the beginning of iso-thermal expansion, $V_1 = 0.3m^3$

$\Rightarrow V_2 = 2 \times V_1 = 2 \times 0.3 = \underline{0.6m^3}$

→ Max. temperature, $T_1 = T_2 = \underline{550K}$





Max. pressure, $P_1 = 21$ bar $= 21 \times 10^5 \ N/m^2$.

To find: i) Min. temp; $T_4 = T_3$

ii) Thermal efficiency of cycle; η

iii) Pressure at all salient points; P_2, P_3, P_4

iv) Work done per cycle; W.

Steps:

1) To find min. temp, $T_4 = T_3$.

For the adiabatic compression process 4-1:

$$\frac{T_4}{T_1} = \left\{\frac{V_1}{V_4}\right\}^{\gamma-1} \quad ; \quad \left(\text{w.k.T} \ \frac{V_4}{V_1} = 5 \right)$$

ie $\therefore \dfrac{T_4}{550} = \left\{\dfrac{1}{5}\right\}^{1.4-1} = 288.92 \text{ K} = T_3.$

ii) Thermal efficiency, η

For a Carnot cycle,

$$\eta = 1 - \frac{T_3}{T_1} \quad ; \quad \text{ie } \eta = 1 - \frac{288.92}{550}$$

$\therefore \eta = 0.474\% = 47.4\%$

iii) Pressure at all salient points, P_2, P_3, P_4:

for isothermal process, 1−2;

$$P_1V_1 = P_2V_2$$

$$\Rightarrow P_2 = \frac{P_1V_1}{V_2} = P_1 \times \left(\frac{1}{2}\right) \quad \left(\because \frac{V_2}{V_1} = 2 \text{ given}\right)$$

$$\therefore P_2 = \frac{21\times10^5}{2} = 10.5\times10^5 \text{ N/m}^2$$

$$\therefore P_2 = 10.5 \text{ bar}$$

For adiabatic process, 2−3;

$$\frac{P_3}{P_2} = \left(\frac{T_3}{T_2}\right)^{\gamma/\gamma-1}$$

$$\Rightarrow P_3 = P_2\left(\frac{T_3}{T_2}\right)^{\gamma/\gamma-1}$$

$$= 10.5 \times \left(\frac{288.92}{500}\right)^{1.4/1.4-1}$$

$$\therefore P_3 = 1.10 \text{ bar}$$

for adiabatic process 4−1:

$$\frac{P_4}{P_1} = \left(\frac{T_4}{T_1}\right)^{\frac{\gamma}{\gamma-1}}$$

$$\Rightarrow P_4 = P_1\left(\frac{T_4}{T_1}\right)^{\gamma/\gamma-1} = 21\times\left(\frac{288.92}{550}\right)^{\frac{1.4}{1.4-1}}$$

$$\therefore P_4 = 2.2 \text{ bar}$$

iv) Workdone, W

For Isothermal process 1-2;

Heat supplied, $Q_s = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$

$\Rightarrow Q_s = 21 \times 10^5 \times 0.3 \times \ln(2)$

$Q_s = 437 \text{ KJ}$

Workdone = Efficiency × Q_s

$= 0.4747 \times 437$

$\therefore W = 208 \text{ KJ}$

(X) **Air Standard Otto Cycle**: Also known as Constant volume cycle. Heat addition & rejection takes place in constant volume.

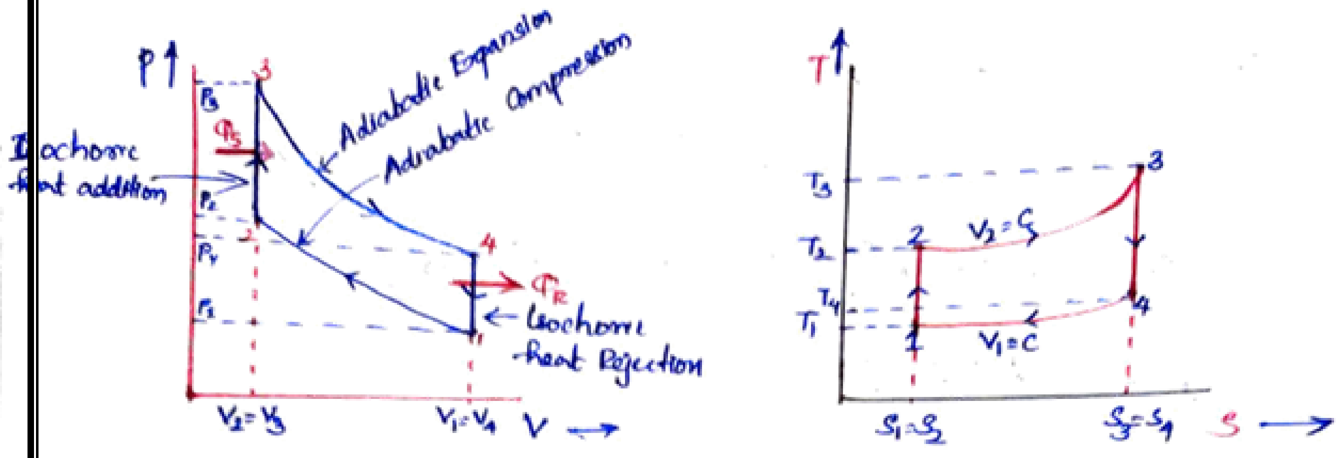
- Theoretical cycle of Spark Ignition Engine.
- Processes: Consists of 4 Reversible Processes.

1-2 : Adiabatic Compression
2-3 : Isochoric Heat Addition
3-4 : Adiabatic Expansion
4-1 : Isochoric Heat Rejection

Consider a cylinder containing 'm' kg of air

At State 1: Pressure - P_1, Volume - V_1, Temperature inside the cylinder - T_1.

(Refer Figure). Curve 1-2 - Adiabatic Compression of air from State 1 to State 2 in PV diagram & Line 1-2 in T-S diagram.



x) Heat is supplied to this compressed air at constant volume from an external body till state 3 is attained

i.e; process 2-3 — Isochoric heat addition.

) At state 3 Adiabatic expansion takes place to reach state 4.

i.e; process 3-4 — Adiabatic expansion.

) From state 3, the body rejects heat at a constant volume to an external cold body till the body attains state 1.

i.e process 4-1 — Isochoric heat addition.

Thus,

Heat supplied during 2-3, $Q_S = mC_v(T_3 - T_2)$

Heat Rejected during 4-1, $Q_R = mC_v(T_4 - T_1)$

∴ Air standard Efficiency of an Otto Cycle $= \eta_{otto} = 1 - \frac{Q_R}{Q_S}$

$$= 1 - \frac{mC_v(T_4 - T_1)}{mC_v(T_3 - T_2)}$$

(X) $$\boxed{\eta_{otto} = 1 - \frac{T_4 - T_1}{T_3 - T_2}}$$ eqn (1)

W.K.T, for the adiabatic process 1-2,

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r)^{\gamma-1}$$ where r is the Compression ratio, $\frac{V_1}{V_2}$.

$\therefore$ $T_2 = T_1 \times r^{\gamma-1}$ ——— eqn (2)

for the adiabatic process 3-4;

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = (r)^{\gamma-1} \left(\because V_1 = V_4 \ \& \ V_2 = V_3\right)$$

$\therefore$ $T_3 = T_4 \times (r^{\gamma-1})$ ——— eqn (3)

$$\therefore \eta_{otto} = 1 - \frac{(T_4 - T_1)}{(T_4 r^{\gamma-1} - T_1 r^{\gamma-1})}$$

$$= 1 - \frac{T_4 - T_1}{(T_4 - T_1) r^{\gamma-1}}.$$

$\therefore$ Air standard Efficiency of an Otto cycle, η_{otto} $= 1 - \frac{1}{r^{\gamma-1}}$

where r = Compression ratio = $\frac{\text{Total Volume}}{\text{Clearance Volume}}$

Problems on Otto Cycle:

1. The efficiency of an otto cycle is 45% & $\gamma = 1.5$. Find its compression ratio.

Solution: Given: $\eta_{otto} = 0.45$

$\gamma = 1.5$

To find: r ?

Steps: For an otto cycle:

$$\eta_{otto} = 1 - \frac{1}{r^{\gamma-1}}$$

$$\therefore 0.45 = 1 - \frac{1}{(r)^{1.5-1}}$$

$$\Rightarrow \underline{\underline{r = 3.31}}$$

2. In an otto cycle, condition of air is 27°C & 1 bar at the start of compression. If the clearance volume is 20% of the swept vol estimate:

i) Temperature at the end of compression

ii) Air standard efficiency of the cycle.

Sol^n: Given: $T_1 = 27°C$,

$P_1 = 1\,bar = 1\times10^5\,N/m^2$

~~$V_2 = 20\%$ of V_1~~

$\Rightarrow$ ~~V_2~~

Clearance vol is 20% of swept volume

$\Rightarrow \quad V_2 = 0.20\% \,(V_1 - V_2)$

ie $\quad V_2 = 0.2V_1 - 0.2V_2.$

or $\quad 1.2V_2 = 0.2V_1$

$$\Rightarrow \frac{V_1}{V_2} = \frac{1.2}{0.2} = 6$$

$\therefore$ Compression ratio, $r = 6.$ $\left(\because \frac{V_1}{V_2} = r\right).$

For an adiabatic compression;

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \quad \text{where } \gamma = 1.4 \text{ (Standard)}$$

$$\Rightarrow T_2 = T_1 (r)^{\gamma-1} = (27+273)(6)^{1.4-1}$$

$$\therefore \boxed{T_2 = 614.30K = 341.3^\circ C}$$

ii) Air Standard Efficiency:

$$\eta_{otto} = 1 - \frac{1}{(r)^{\gamma-1}} = 1 - \frac{1}{(6)^{0.4}} = 0.5116$$

Result:

i) Temperature, $T_2 = 341.3^\circ C$

ii) $\eta_{otto} = 0.5116 = 51.16\%$

3. Calculate the air standard thermal efficiency based on otto cycle for a petrol engine with a cylinder bore of 50mm & stroke of 75mm & a clearance volume of $21.3 cm^3$.

Sol^n: Given: Bore, $D = 50mm = 5cm$; $V_2 = 21.3 cm^3$,

$L = 75mm = 7.5cm$

To find: η

Solution: Total Vol, V_1 = Clearance Vol + Swept Vol.

ie $V_1 = V_2 + \pi r^2 l = V_2 + 3.14 \times \left(\frac{5}{2}\right)^2 \times 7.5$

$\therefore V_1 = \underline{168.56 cm^3}$.

$\therefore$ Compression ratio, $r = \frac{V_1}{V_2} = \frac{168.56}{21.3} = \underline{7.91}$

$\therefore$ Air standard thermal Efficiency, η_{otto} $\Big\} = 1 - \frac{1}{(7.91)^{1.4-1}}$

$= 0.5628 = \underline{56.28\%}$

4. An engine working on the Otto Cycle has an air standard efficiency of 56%. It rejects heat at the rate of 544 kJ/kg of air. The pressure & temperature of air at the beginning of compression are 0.1 MPa & 60°C respectively. Compute,

i) The compression ratio of the engine

ii) Work done per kg of air.

iii) Pressure & temperature at the end of compression &

iv) Maximum pressure in the cycle.

Assume suitable values for C_p & C_v

Given: $\eta_{otto} = 0.56$

$Q_R = 544\ kJ/kg$

$P_1 = 0.1\ MPa$, $T_1 = 60°C = 333\ K$.

To find:

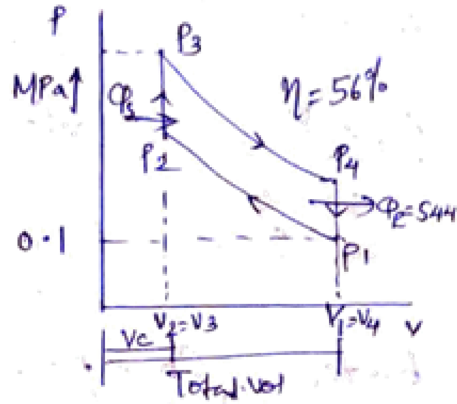
i) r

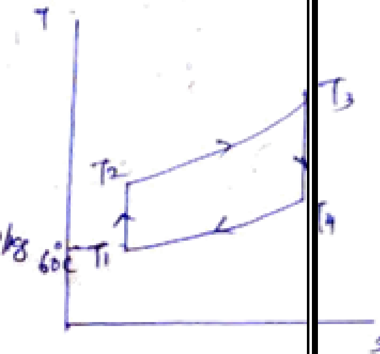
ii) W

iii) P_2

iv) T_2

v) P_3





Steps: i) r

W.K.T;

$$\eta_{otto} = 1 - \frac{1}{(r)^{1.4-1}} \Rightarrow 0.56 = 1 - \frac{1}{(r)^{0.4}}$$

$$\Rightarrow r^{0.4} = 2.27 \Rightarrow \underline{r = 7.76}$$

ii) Workdone, W:

W.K.T.

$$\eta_{otto} = 1 - \frac{\text{Heat } \sout{\text{Supplied}} \text{ Rejected}}{\text{Heat } \sout{\text{Rejected}} \text{ Supplied}} = 1 - \frac{Q_R}{Q_S}$$

$$\therefore \quad 0.56 = 1 - \frac{544}{Q_S}$$

$$\Rightarrow Q_S = 1236.36\ kJ/kg$$

$\therefore$ Work done = Heat Supplied − Heat Rejected

$$\Rightarrow W = 1236.36 - 544\ kJ/kg$$

$$\therefore \underline{W = 692.36\ kJ/kg}$$

iii) Pressure P_2 & Temp, T_2 :

W.K.T, for an adiabatic compression;

$$\left(\frac{P_2}{P_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma} = (r)^{\gamma}$$

$$\Rightarrow P_2 = P_1 r^{\gamma} = 0.1 \times (7.76)^{1.4} \text{ MPa}$$

$$\therefore P_2 = 1.76 \text{ MPa.}$$

for an adiabatic compression;

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

$$\therefore T_2 = T_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{1.4-1}{1.4}}$$

$$\Rightarrow T_2 = 333 \times \left(\frac{1.76}{0.1}\right)^{\frac{0.4}{1.4}}$$

$$\therefore T_2 = 755.6 \text{ K.}$$

or

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = r^{\gamma-1}$$

$$\Rightarrow T_2 = T_1 \times r^{\gamma-1}$$

$$= 333 \times (7.76)^{0.4}$$

$$= 755.6 \text{ K}$$

iv) Max. pressure in the cycle, P_3.

To find P_3 we need to find T_3 initially.

W.K.T. Heat supplied during process 2-3 is

$$Q_s = m C_v (T_3 - T_2)$$

[C_v ∵ Constant Vol process & $m = 1$ ∵ Q_s given/kg]

$$\Rightarrow Q_s = C_v (T_3 - T_2)$$

$$\Rightarrow 1236.36 = 0.718 (T_3 - 755.6)$$

($C_v = 0.718$ kJ/kgK for air)

$\therefore \; T_3 = 2477.86\,K$

Now for constant volume process, 2-3.

$$\frac{P_2}{P_3} = \frac{T_2}{T_3}$$

$$\Rightarrow \quad P_3 = \frac{P_2 T_3}{T_2} = 1.76 \times \frac{2477.86}{755.6} \text{ MPa}$$

$$\therefore P_3 = 5.7 \text{ MPa}$$

Result:

i) $r = 7.76$

ii) $W = 692.36$ kJ/kg

iii) $T_2 = 755.6$ K, $P_2 = 1.76$ MPa

iv) $P_3 = 5.7$ MPa.

3. In an air standard otto cycle the compression ratio is 7 & compression begins at 35°c, 0.1 MPa. The max temperature of the cycle is 1100°c. Find;

i) Heat supplied per kg. of air
ii) Work done per kg of air
iii) The cycle efficiency &
iv) The mean effective pressure.

Take $C_p = 1.005$ kJ/kg k, $C_v = 0.718$ kJ/kgk

Solution: Given: $r = 7$ ie $\frac{V_1}{V_2} = 7$.

$T_1 = 35°c = 308k$, $T_3 = 1100°c = 1373\,K$

$P_1 = 0.1$ MPa $= 0.1 \times 10^6$ N/m²

To find:

i) Heat supplied per kg of air, Q_S
ii) Work done per kg of air, W
iii) Cycle efficiency, η_{otto}
iv) Mean Effective Pressure, M.E.P

Sol^n:

i) Heat supplied $Q_S = mC_v(T_3 - T_2)$

To find T_2; for adiabatic process 1-2

$$\cancel{\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}} \qquad \left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\Rightarrow \quad T_2 = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \times T_1 = 308 \times 7^{0.4} = 670.8K$$

$$\therefore \quad Q_S = 0.718 \times (1373 - 670.8)$$

$$Q_S = 504.18 \text{ KJ/kg}$$

ii) Work done per kg of air, $W = Q_S - Q_R$

where;

$$Q_R = mC_v(T_4 - T_1)$$

To find T_4; for adiabatic process 3-4;

$$\left(\frac{T_3}{T_4}\right) = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \quad \left(\because \begin{array}{l} V_4 = V_1 \\ V_3 = V_2 \end{array}\right)$$

$$\therefore \quad T_4 = T_3 \times \frac{1}{2.18} = \frac{1373}{2.18} = 629.82K$$

$$\therefore \quad Q_R = 0.718(629.8 - 308) = 231.07 \text{ kJ/kg}$$

$\therefore$ Workdone, $W = Q_S - Q_R = 504.18 - 231.07$

$\therefore$ $W = 273.11$ kJ/kg

ii) Cycle efficiency, η_{otto}

$$\eta_{otto} = 1 - \frac{Q_R}{Q_S} = 1 - \frac{231.07}{504.18} = 0.5417$$

$\therefore$ $\eta_{otto} = 54.17\%$

iii) Mean Effective Pressure, $MEP = \frac{\text{Workdone / cycle}}{\text{Swept Volume}}$

where, Swept Volume $= V_S = V_1 - V_2$

W.K.T;

$$P_1 V_1 = m R T_1$$

i.e; $V_1 = \frac{R T_1}{P_1}$ ($\because$ m = 1 kg & R = 0.287 kJ/kgK)

$$\therefore V_1 = \frac{1 \times 287 \times 308}{0.1 \times 10^6} = 0.884\ m^3$$

$\frac{kg \times J/kg\,K \times K}{N/m^2}$ $\therefore m^3$

$$\therefore V_2 = \frac{V_1}{\gamma} = \frac{0.884}{7} = 0.126\ m^3$$

hence; $V_S = 0.758\ m^3$

& $MEP = \frac{273.11}{0.758} = 360.3\ N/m^2$

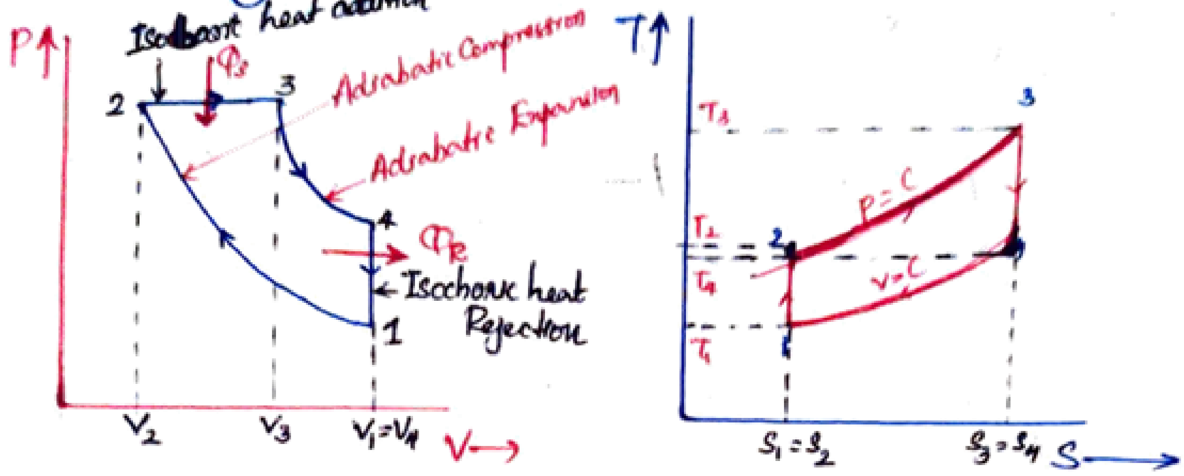
Result:

1) $Q_S = 504.18$ kJ/kg 2) $W = 273.11$ kJ/kg

3) $\eta_{otto} = 54.17\%$ 4) $MEP = 360.3\ N/m^2$

Air Standard Diesel Cycle

- Diesel engine works on a diesel cycle.
- Consists of 4 reversible processes.



Processes:

Consider a cylinder containing 'm' kg of air.

At State 1: Pressure – P_1, Volume – V_1, Temp – T_1

Process 1-2: Adiabatic Compression – represented by curve 1-2 in P-V diagram & line 1-2 in T-S diagram.

Process 2-3: Isobaric Heat Addition – Q_s

Heat is added at a constant pressure

ie;

$$Q = m \cdot C_p (T_3 - T_2) \quad \text{— (1)}$$

Process 3-4: Adiabatic Expansion – Heat supply is stopped & air is made to expand adiabatically, doing external work. Represented by curve 3-4 in P-V & line 3-4 in T-S diagram.

Process 4-1: Isochoric Heat Rejection Q_R –

Heat is rejected in a constant volume process;

$$Q_R = m \cdot C_v (T_4 - T_1) \quad \text{— (2)}$$

Now,

Efficiency of a Diesel Cycle,

$$\eta_{Diesel} = 1 - \frac{Q_R}{Q_S}$$

$$= 1 - \frac{m C_v (T_4 - T_1)}{m C_p (T_3 - T_2)}$$

$$= 1 - \frac{1}{\gamma}\left(\frac{T_4 - T_1}{T_3 - T_2}\right) \quad \left(\because \frac{C_p}{C_v} = \gamma \Rightarrow \frac{C_v}{C_p} = \frac{1}{\gamma}\right)$$

$$\therefore \eta_{Diesel} = 1 - \frac{1}{\gamma}\left(\frac{T_4 - T_1}{T_3 - T_2}\right)$$

Let $\frac{V_3}{V_2}$ – Cut-off Ratio, ρ;

$\frac{V_4}{V_3}$ = Expansion ratio, r_1

$\frac{V_1}{V_2}$ = Compression ratio, r

We have; $\frac{V_4}{V_3} = \frac{V_4}{V_2} \times \frac{V_2}{V_3}$, Since $V_4 = V_1$

$$\frac{V_4}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_3}$$

ie $$r_1 = r \times \frac{1}{\rho}$$

$$\Rightarrow \boxed{r_1 = \frac{r}{\rho}} \quad \text{—— (3)}$$

For the adiabatic process 1–2:

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\Rightarrow \boxed{T_2 = T_1 \times r^{\gamma-1}} \quad \text{—— (4)}$$

For isobaric process 2-3,

$$\frac{T_3}{T_2} = \frac{V_3}{V_2}$$

$$\Rightarrow \boxed{T_3 = T_2 \times \rho = T_1 \times r^{\gamma-1} \times \rho} \quad \text{—— (5)}$$

from adiabatic process 3-4

$$\left(\frac{T_4}{T_3}\right) = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$\left(\frac{T_3}{T_4}\right) = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = r_1^{\gamma-1}$$

$$\Rightarrow T_4 = \frac{T_3}{r_1^{\gamma-1}} = \frac{T_1 \times r^{\gamma-1} \times \rho \times \rho^{\gamma-1}}{r^{\gamma-1}} \quad \left[\because r_1 = \frac{r}{\rho} \text{ from (2)}\right]$$

$$\Rightarrow \boxed{T_4 = T_1 \times \rho^{\gamma}} \quad \text{— (6)}$$

Now Substituting — (4), (5) & (6) in eqn for η_{Diesel};

$$\eta_{Diesel} = 1 - \frac{1}{\gamma}\left(\frac{T_1\rho^{\gamma} - T_1}{T_1 r^{\gamma-1} \times \rho - T_1 r^{\gamma-1}}\right)$$

$$= 1 - \frac{1}{\gamma} \times \frac{T_1(\rho - 1)}{T_1(\rho - 1) r^{\gamma-1}}$$

$$\eta_{Diesel} = 1 -$$

$$\therefore \eta_{Diesel} = 1 - \frac{1}{\gamma} \times \frac{T_1 \times (\rho^{\gamma} - 1)}{T_1 \times r^{\gamma-1} (\rho - 1)}$$

Hence ;

$$\eta_{Diesel} = 1 - \frac{1}{r^{\gamma-1}} \times \frac{1}{\gamma} \left[\frac{\rho^{\gamma} - 1}{\rho - 1} \right]$$

MODULE-2

Hydraulic turbines

Hydraulic turbines are the machines which use the energy of water and convert it into mechanical energy. The mechanical energy developed by a turbine is used in running an an electric generator which couple to the turbine.

According to the type of energy at the inlet or action of water flowing through the turbine runners, turbines classified as

1. Impulse turbine
2. Reaction turbine

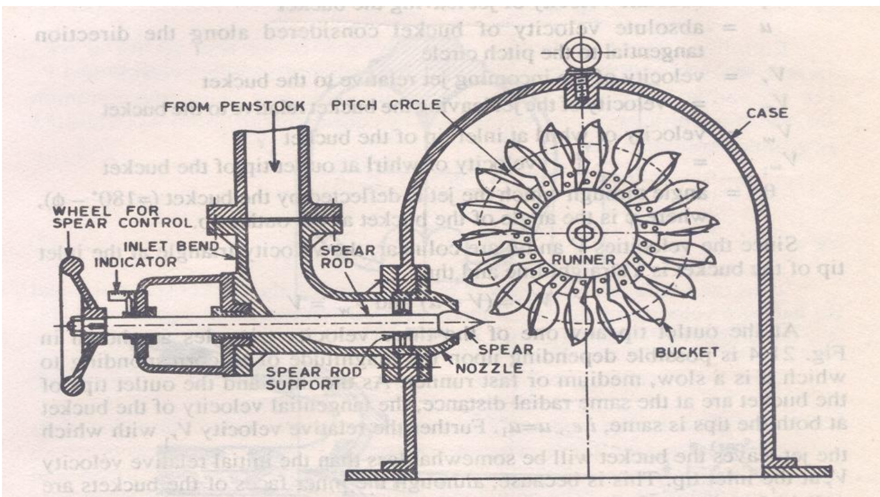
Also turbines are classified according to the direction of fluid flow or flow path

1. Radial flow turbine
2. Axial flow turbine
3. Mixed flow turbine

Impulse turbine

In the turbine all the available energy of water is converted into kinetic energy or velocity head by passing it through a converging nozzle provided at the end of penstock. Penstock is the pipe which carries water from the dam to power station.

The water coming out of the nozzle is forced into a free jet which impinges on a series of buckets of the runner, thus causing it to revolve. The runner is a circular frame with series of buckets. These buckets are shaped like a double hemispherical cup. The buckets are made up of cast iron , steel or bronze. The term *impulse* means that the force that turns the turbine comes from the impact of the jet on the blades.



Working

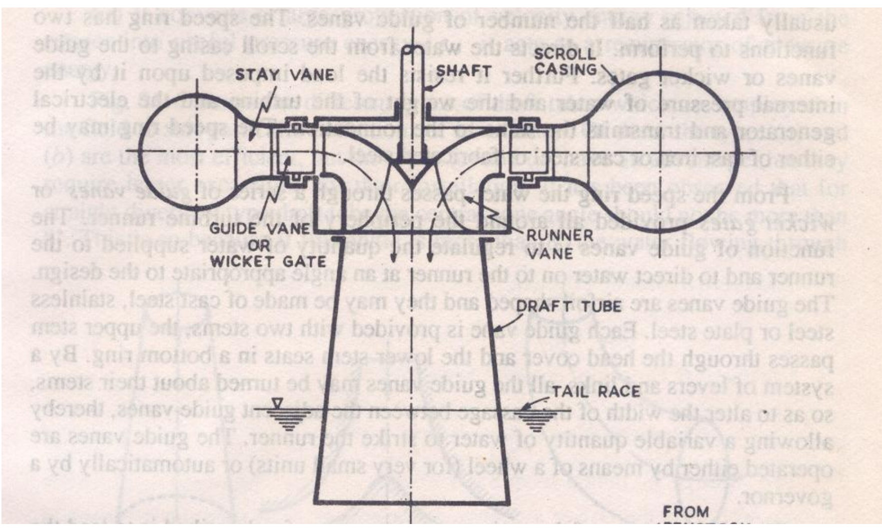
The water from the reservoir enters the nozzle through penstock. Nozzle converts its pressure energy into Kinetic energy. Water leaves the nozzle in the form of jet and impinges the buckets of runner, thus causing it to revolve. Eg: **Pelton turbine**

Reaction turbine

In reaction turbine at the entrance to the runner, only a part of the available energy of water is converted into kinetic energy and substantial part of pressure energy remains. As the water flows through the runner the change from pressure energy to K.E. takes place gradually.

Francis Turbine is an Inward Flow Reaction Turbine having Radial Discharge at Outlet. . Modern Francis Turbine is a mixed flow type turbine (i.e. Water enters the runner of the turbine in the radial direction and leaves the runner in the axial direction).

Radial Flow Turbines are those turbines in which the water flows in the Radial Direction. In Francis Turbine the water flows from outwards to inwards through the runner (Inward Flow Radial Turbine). Reaction Turbine means that the water at the inlet of the Turbine possesses Kinetic Energy as well as Pressure Energy.



CONSTRUCTION: -

The main parts of Francis Turbine are:

CASING

The runner is completely enclosed in an air-tight spiral casing. The casing and runner are always full of water.

GUIDE MECHANISM/GUIDE VANE

It consists of a circular wheel all round the runner of the turbine. The stationary guide vanes are fixed on the guide wheel. The guide vanes allow the water to strike the vanes fixed on the runner without shock at inlet. Also width between the two adjacent vanes can be altered so that amount of water striking the runner can be varied.

RUNNER

It is a circular wheel on which a series of Radial Curved Vanes are fixed. The vanes are so shaped that the water enters and leaves the runner without shock.

DRAFT TUBE

The pressure at the exit of the runner of Reaction Turbine is generally less than atmospheric pressure. The water at exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of turbine to the tail race. This tube of increasing area is called Draft Tube. One end of the tube is connected to the outlet of runner while the other end is sub-merged below the level of water in the tail-race.

Radial flow turbines

In this turbine water flows along the radial direction and remins mainly in the plane normal to the axis of rotation, as it passes through the runner. A radial flow turbine may be either inward radial flow or outward radial flow type. Old francis turbine is an example for the inward radial flow turbine

Axial flow turbine

In this flow of water through the runner is wholly and mainly along the direction parallel to the axis of rotation. Eg: propeller turbine, Kaplan Turbine

Mixed flow turbine

Water enters the runner at the outer periphery in radial direction and leaves the turbine at the centre in the direction parallel to the axis of rotation. Eg: modern Francis turbine

Pumps

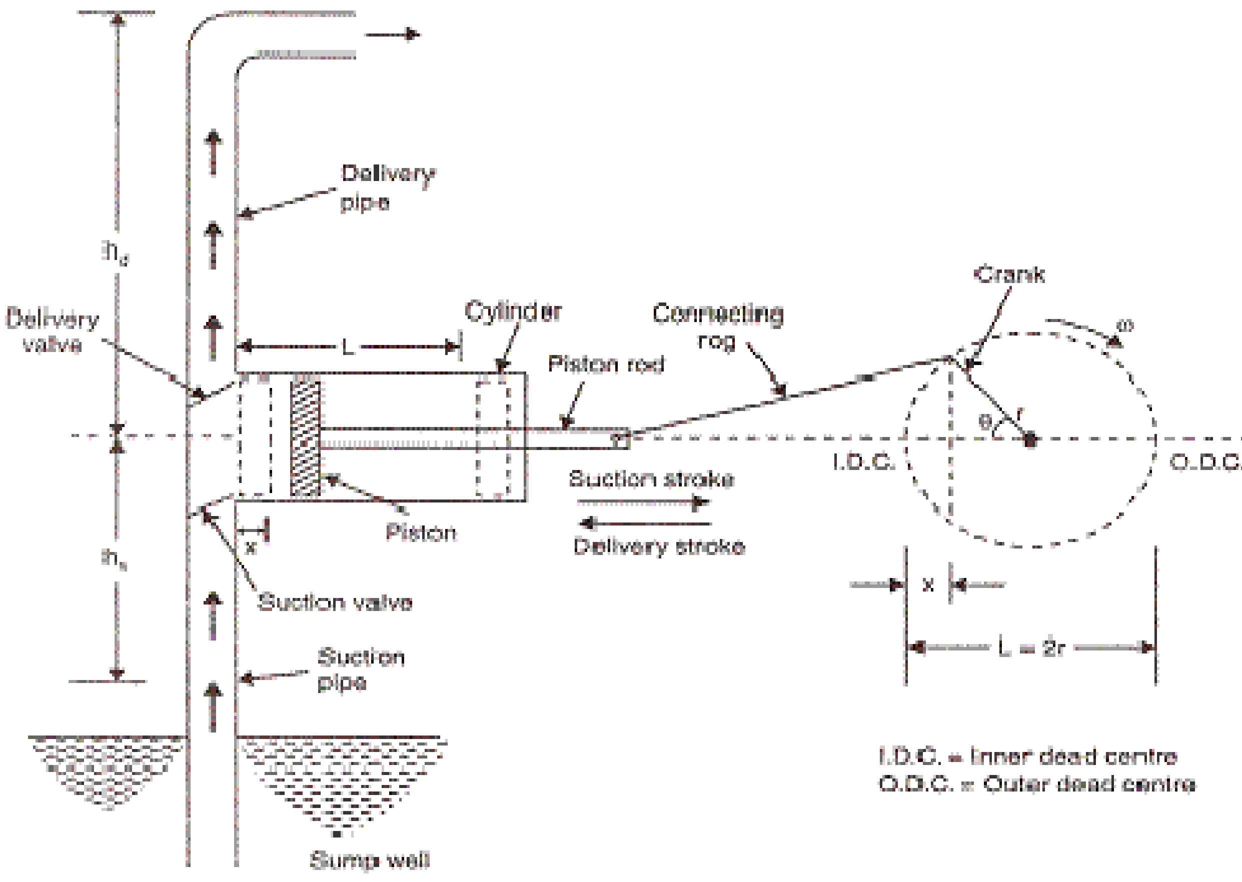
In general pumps may be defined as a mechanical device which when connected in a pipeline, converts the mechanical energy supplied to it from some external sources(normally electric motor) into hydraulic energy and transfer the same to the liquid through the pipeline. Thereby increasing the energy of flowing fluid. Normally pumps are used to transfer liquid from one place to another as well as lower level to higher level. Pumps broadly classified into two

1. Positive displacement pumps
2. Rotodynamic pumps

Positive displacement pumps are those pumps in which liquid is sucked and then it is pushed or displaced due to the thrust exerted on it, by a moving member. Most common example is **reciprocating pumps**

The rotodynamic pumps have a rotating element, called impeller through which liquid passes. During this motion its angular momentum changes, due to which the pre. Energy of liquid is increased . here pump does not push the liquid as in the case of positive displacement pump. Eg: **centrifugal pump**

Reciprocating pump



A reciprocating pump essentially consist of a piston or plunger which moves to and fro inside a cylinder. The cylinder is connected to suction and delivery tube each of which provide with a non return valve called suction valve and delivery valve. The piston connected to the crank by means of a connecting rod. Crank rotated by an engine or motor. When the crank rotates θ=0˚ to θ=180˚ piston moves from extreme left position to extreme right position

Working

During the motion of piston from left to right(refer fig.) a partial vacuum created inside the cylinder. Because of this low pressure water will rise from well through suction tube and fill the cylinder by forcing to open the suction valve. This operation is known as suction stroke.(motion of piston from left to right). In this stroke crank rotates θ=0˚ to θ=180˚. Also delivery valve will be closed and suction valve will be open during this stroke.

When the crank rotates from θ=180˚ to θ=360˚ piston moves inwardly from position right to left. Now piston exerts pressure on the liquid and due to which suction valve closes and delivery valve opens.the liquid is then foced up through delivery pipe. This stroke is known as delivery stroke. Now the pump has completed one cycle. The same cycle repeated as the crank rotates.

Work done by reciprocating pump

The volume of liquid pumped is known as discharge. Here discharge in one cycle equals the volume of cylinder.

$$so\ Qth = \frac{ALN}{60}$$

A= area of cross section of piston

L= stroke length (distance between P1 and P2)

N=no of revolutions per minute

Normally actual discharge found to be less than theoretical discharge.

Theoretical work done= $w.Q_{th}.(H_s + H_d)$

w =specific weight=ρ.g

Hs=suction head, Hd= delivery head

$$Power\ P = \frac{w(ALN)(H_s + H_d)}{60}$$

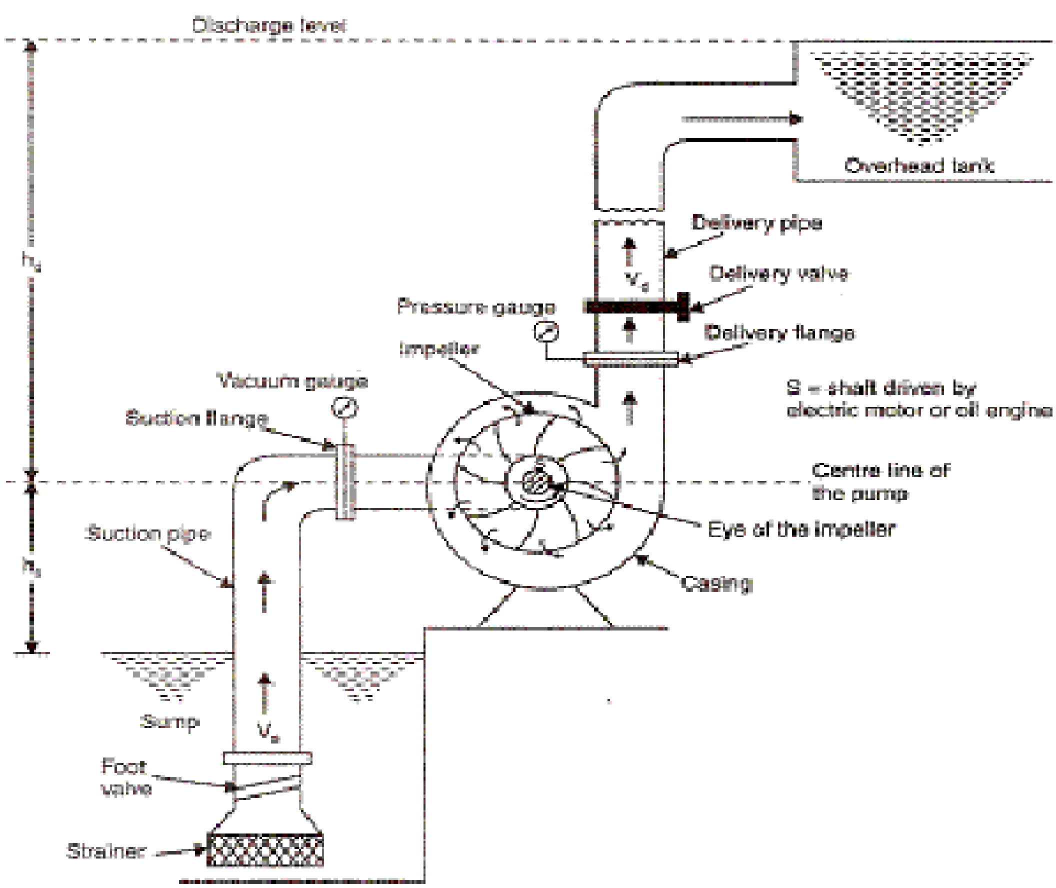
$$\text{Coefficient of discharge} = \frac{Actual\ discharge}{theoretical\ dischrge} = \frac{Qa}{Qt}$$

Centrifugal pumps

The basic principle on which a centrifugal pump work is that when a certain mass of liquid is made to rotate by an external force. It is thrown away from the central axis of rotation and a centrifugal head is developed which enables it to rise to higher levels may be ensured. Since in these pumps the lifting of the liquid is due to the centrifugal action, these pumps are called centrifugal pumps. In addition to centrifugal action, liquid passes through revolving impeller, its angular momentum changes which also results in increasing the pressure of the liquid

Components and construction

Impeller: it is a wheel or rotor which is provided with a series of backward curved blades or vanes. it is mounted on a shaft which is coupled to an external source of energy(electric motor)



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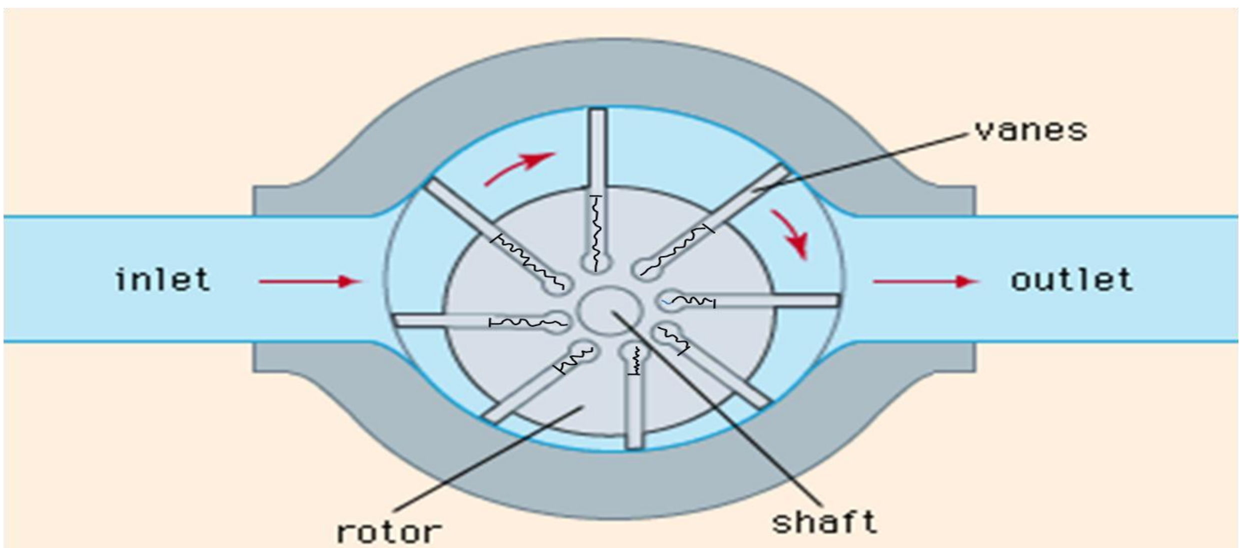
Working

The first step is priming. It is the operation in which suction pipe, casing of pump and portion of delivery tube are completely filled with the liquid which is to be pumped, so that all the air from this portion of the sump is driven out and no air pocket is left. If there is any air pocket, it result in no delivery of liquid from pump. The necessity of priming a centrifugal pump is due to the fact that the pressure generated in a centrifugal pump impeller is directly proportional to the density of fluid.

After the pump is primed, electric motor started to rotate the impeller. Due to rotation impeller rotation, produces a vortex which imparts a centrifugal head to liquid. Then the liquid starts to flow in an outward radial direction therby leaving the vanes of impeller.

Vane pump



A **rotary vane pump** is a positive-displacement pump that consists of vanes mounted on

a rotor that rotates inside of a cavity. In vane pump, the vanes slide in and out of the rotor during the operation of the device. This combination of actions creates a seal on the interior of the cavity, and effectively forms a series of small chambers within the larger chamber. Liquid is captured in each of these chambers and is forced through the system by the resulting pressure of the rotation. Essentially, there is atmospheric pressure on the intake side of the pump that helps to suck in the liquid, while the pressure created by the rotating action help to move and discharge the collected liquid from the outtake or discharge side of the pump. The rotor helps to keep the flow of the liquid uniform throughout the process.

Advantages

- Handles thin liquids at relatively higher pressures
- Compensates for wear through vane extension
- Sometimes preferred for solvents, LPG
- Can run dry for short periods
- Can have one seal or stuffing box
- Develops good vacuum

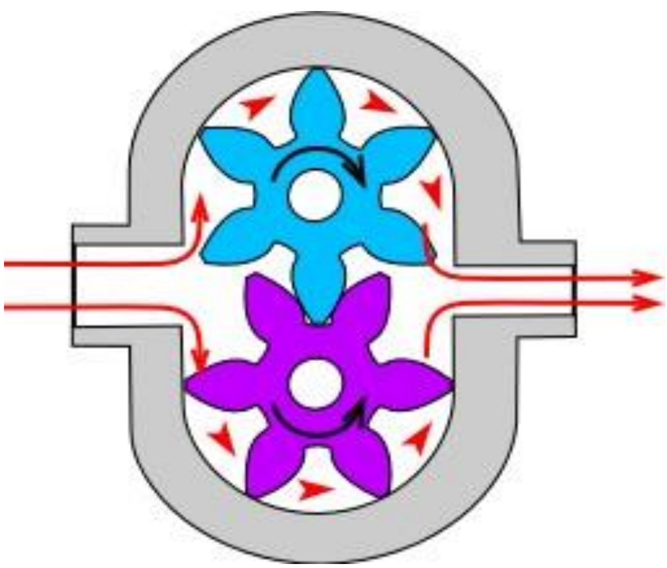
Disadvantages

- Can have two stuffing boxes
- Complex housing and many parts
- Not suitable for high pressures
- Not suitable for high viscosity
- Not good with abrasives

Applications

- Aviation Service - Fuel Transfer
- Auto Industry – pumping of Fuels, Lubes, Refrigeration Coolants
- Bulk Transfer of LPG and NH_3
- LPG Cylinder Filling
- Refrigeration – pumping of Freons, Ammonia
- In distilleries and chemical industries

Gear pump



External gear pumps are similar in pumping action to internal gear pumps in that two gears come into and out of mesh to produce flow. However, the external gear pump uses two identical gears rotating against each other -- one gear is driven by a motor and it in turn drives the other gear. Each gear is supported by a shaft with bearings on both sides of the gear.

1. As the gears come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the gear teeth as they rotate.

2. Liquid travels around the interior of the casing in the pockets between the teeth and the casing -- it does not pass between the gears.

3. Finally, the meshing of the gears forces liquid through the outlet port under pressure.

Because the gears are supported on both sides, external gear pumps are quiet-running and are routinely used for high-pressure applications such as hydraulic applications. With no overhung bearing loads, the rotor shaft can't deflect and cause premature wear.

Advantages

- High speed
- High pressure
- No overhung bearing loads
- Relatively quiet operation
- Design accommodates wide variety of materials

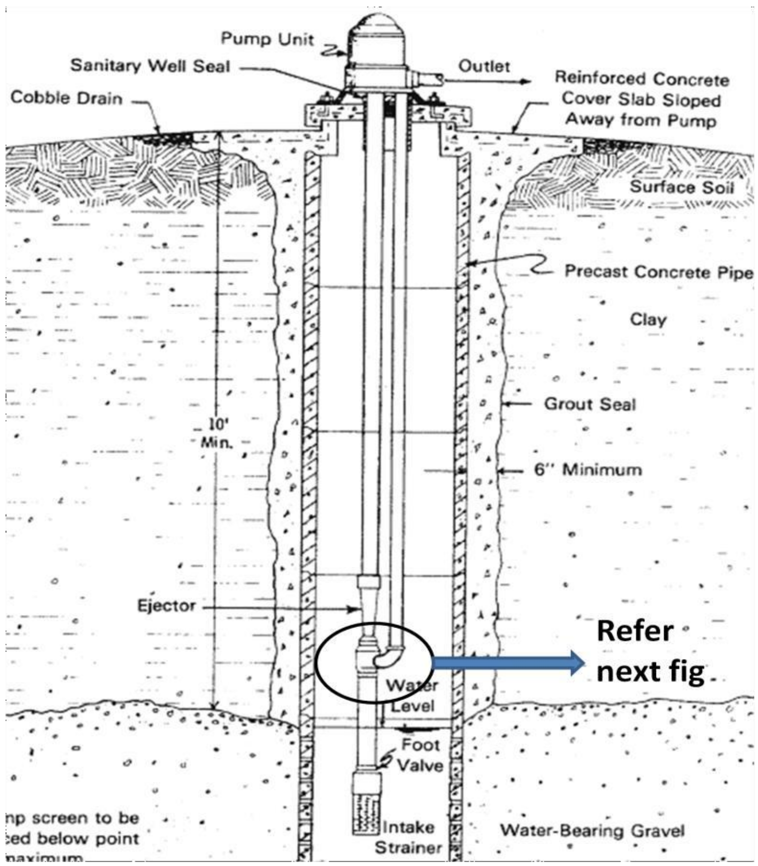
Disadvantages

- Four bushings in liquid area
- No solids allowed
- Fixed End Clearances

Applications

- Pumping of various fuel oils, kerosene and lube oils
- Pumping of Chemicals and polymers
- For Chemical mixing and blending
- Industrial and mobile hydraulic applications
- Pumping Acids and paints etc
- For Low volume transfer

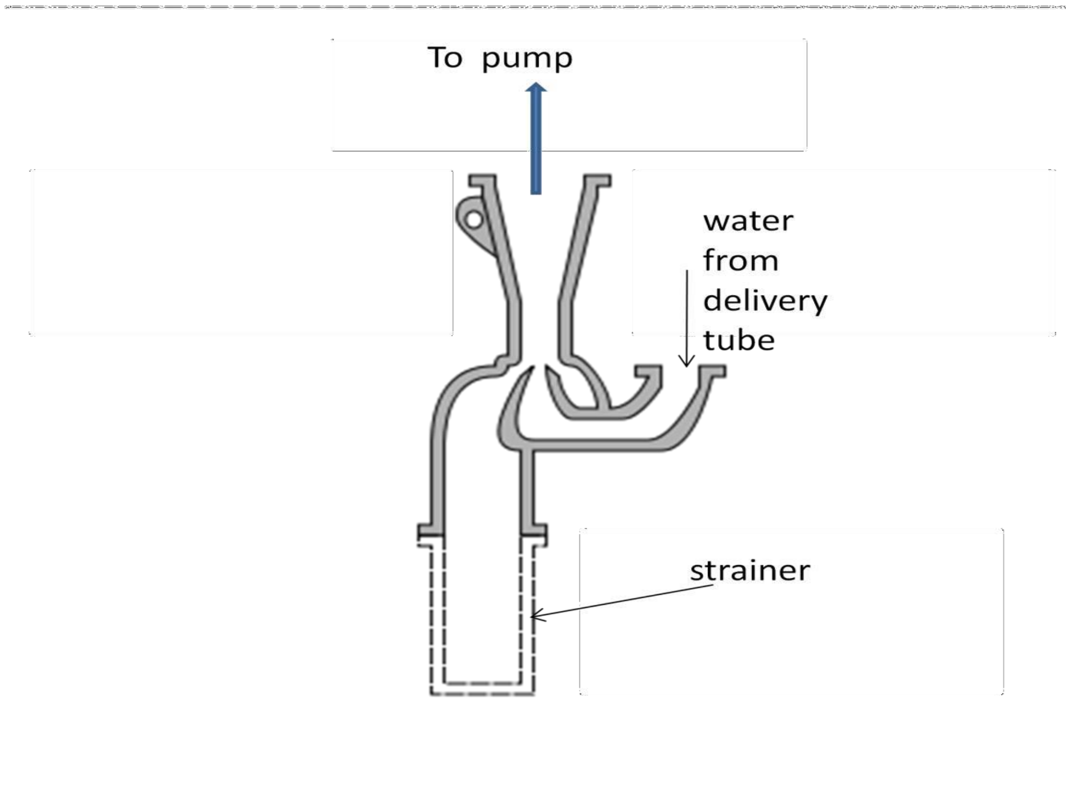
Jet pump



A jet pump is a device that uses the venturi effect of a converging-diverging nozzle to convert the pressure energy of a fluid to velocity energy which creates a low pressure zone that draws in and entrains a suction fluid.

In a jet pump, pumping action is created as a fluid (water, steam, or air) passes at a high pressure and velocity through a nozzle and into a chamber that has an inlet and outlet opening.

The operating principle of a jet pump is as follows: Upon starting up, the fluid is entering through the suction tube and delivered through the delivery pipe. But part of fluid is pumped back to the suction pipe from delivery pipe through another pipe. Refer fig. at the end of this pipe a nozzle is connected where fluid pressure is decreased due to high velocity jet. Due to this low pressure more fluid will enter to the suction pipe.



Application

- In thermal power stations, they are used for the removal of the boiler bottom ash, the removal of fly ash the boiler flue gas, and for creating a vacuum pressure in steam turbine exhaust condensers.
- For use in producing a vacuum pressure in steam jet cooling systems.
- For the bulk handling of grains or other granular or powdered materials.
- The construction industry uses them for pumping turbid water and slurries.

MODULE-3

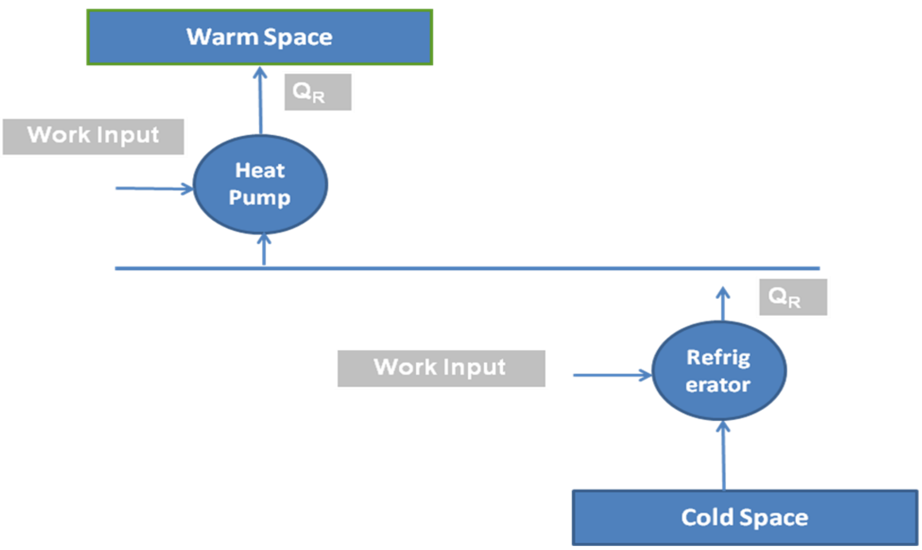
REFRIGERATION AND AIRCONDITIONING

Refrigeration:

- It is defined as the process of providing and maintaining a temperature well below that of surrounding atmosphere.
- In other words refrigeration is the process of cooling substance.

Refrigerators and heat pumps:

- If the main purpose of the machine is to cool some object, the machine is named as refrigerator.
- If the main purpose of machine is to heat a medium warmer than the surroundings, the machine is termed as heat pump.



Terminologies of Refrigeration:

Refrigerating Effect (N): It is defined as the quantity of heat extracted from a cold body or space to be cooled in a given time.

$$N = \frac{\text{Heat extracted from the cold space}}{\text{Time taken}}$$

Specific Heat of water and ice : It is the quantity of heat required to raise or lower the temperature of one kg of water (or ice), through one kelvin or (1^0 c) in one second.

Specific heat of water, $C_{pw} = 4.19$ *kJ/kg K Specific heat of ice,* C_{pice} *= 2.1 kJ/kgK.*

Capacity of a Refrigeration Unit :

- Capacity of a refrigerating machines are expressed by their cooling capacity.
- The standard unit used for expressing the capacity of refrigerating machine is ton of refrigeration.
- One ton of refrigeration is defined as, "the quantity of heat abstracted (refrigerating effect) to freeze one ton of water into one ton of ice in a duration of 24 hours at 0^o c". Heat extracted from at o^o c = latent heat of ice

Latent heat of ice = 336 kJ/kg

i.e., 336 kJ of heat should be extracted one kg of water at 0^o C to convert it into ice.

One ton of refrigeration = 336x1000 kJ/24 hrs.

$$= \frac{336 \times 1000}{24 \times 60} \text{ kJ/min}$$

One ton of refrigeration = 233.333 kJ/min

= 3.8889 kJ/sec

Co efficient of Performance: It is defined as the ratio of heat extracted in a given time (refrigerating effect) to the work input.

Co efficient of performance = Heat extracted in evaporator
Work Input

Co efficient of performance = **Refrigerating Effect**

Wo
rk Input Co efficient of performance =
N

W

The COP is always greater than 1 and known as theoretical coefficient of performance.

Applications of Refrigeration:

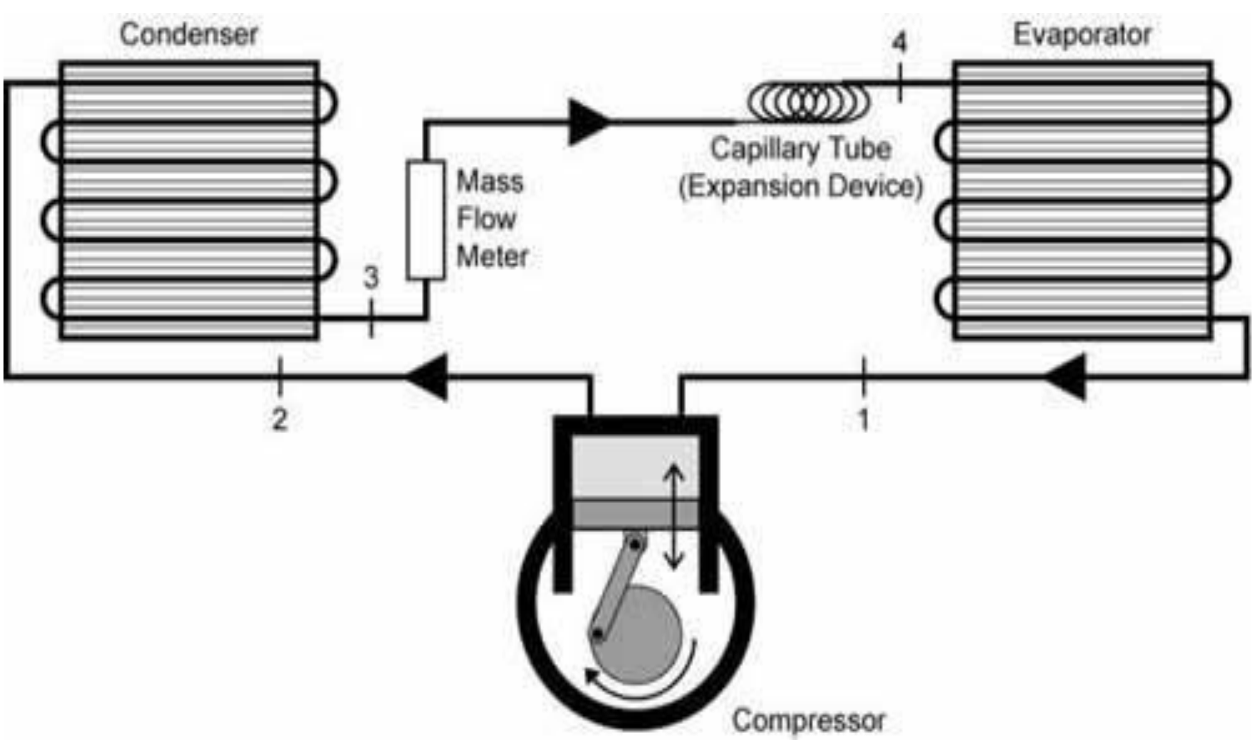
- In chemical industries, for separating and liquefying the gases.
- In manufacturing and storing ice.
- For the preservation of perishable food items in cold storages.
- For cooling water.
- For controlling humidity of air manufacture and heat treatment of steels.
- For chilling the oil to remove wax in oil refineries.
- For the preservation of tablets and medicines in pharmaceutical industries.

- For the preservation of blood tissues etc.,
- For comfort air conditioning the hospitals, theatres, etc.,

Properties of Refrigeration:

- A good refrigerant should have high latent heat of vapourisation.
- It should have low boiling and low freezing point.
- It should be non toxic and should non corrosiveness
- It should be non flammable and non explosive.
- It should have high thermal conductivity
- It should be easy to handle
- It should have low specific volume of vapour.
- It should have high co efficient of performance

Vapour Compression Refrigeration System:



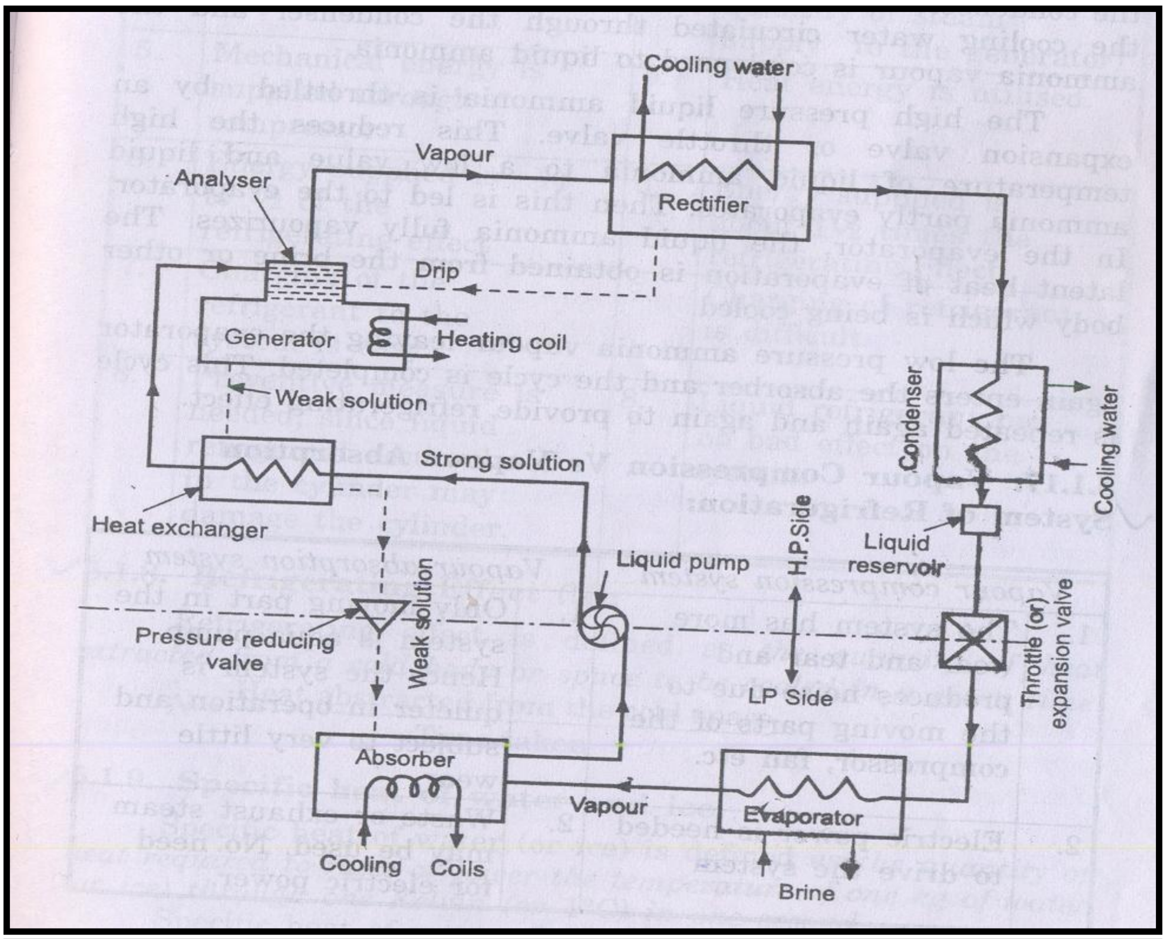
Construction:

- This system consists of a compressor, condenser, a receiver tank, an expansion valve and an evaporator.
- **Compressor :** Reciprocating compressors generally used. For very big plants centrifugal compressors directly coupled with high speed rotating engines (gas turbine) are used.
- For very big plantsCentrifugal compressors directly coupled with high speed rotating engines (gas turbine) are used
- **Condenser :** It is a coil of tubes made of copper.
- **Receiver tank:** It is the reservoir of liquid refrigerant.
- **Expansion Valve:** This is a throttle valve. High pressure refrigerant is made to

flow at a controlled rate through this valve.

- **Evaporator :** It is the actual cooler and kept in the space to be cooled. The evaporator is a coil of tubes made of copper

Vapour Absorption Refrigeration system:



Construction:

- The vapour absorption system consists of a condenser, an expansion valve and an evaporator.
- They perform the same as they do in vapour compression method.

- In addition to these, this system has an absorber, a heat exchanger, an analyser anda rectifier.

Working:

1. Dry ammonia vapour at low pressure passes in to the absorber from the evaporator.
2. In the absorber the dry ammonia vapour is dissolved in cold water and strong solution of ammonia is formed.
3. Heat evolved during the absorption of ammonia is removed by circulating cold water through the coils kept in the absorber.
4. The highly concentrated ammonia (known as Aqua Ammonia) is then pumped by a pump to generator through a heat exchanger.
5. In the heat exchanger the strong ammonia solution is heated by the hot weak solution returning from the generator to the absorber.
6. In the generator the warm solution is further heated by steam coils, gas or electricity and the ammonia vapour is driven out of solution.
7. The boiling point of ammonia is less than that of water.
8. Hence the vapours leaving the generator are mainly of ammonia.
9. The weak ammonia solution is left in the generator is called weak aqua.
10. This weak solution is returned to the absorber through the heat exchanger.
11. Ammonia vapours leaving the generator may contain some water vapour.
12. If this water vapour is allowed to the condenser and expansion valve, it may freeze resulting in chocked flow.
13. Analyser and rectifiers are incorporated in the system before condenser.
14. The ammonia vapour from the generator passes through a series of trays in the analyser and ammonia is separated from water vapour.
15. The separated water vapour returned to generator.
16. Then the ammonia vapour passes through a rectifier.
17. The rectifier resembles a condenser and water vapour still present in ammonia vapour condenses and the condensate is returned to analyser.
18. The virtually pure ammonia vapour then passes through the condenser.
19. The latent heat of ammonia vapour is rejected to the cooling water circulated through the condenser and the ammonia vapour is condensed to liquid ammonia.
20. The high pressure liquid ammonia is throttled by an expansion valve or throttle valve.
21. This reduces the high temperature of the liquid ammonia to a low value and liquid ammonia partly evaporates.
22. Then this is led to the evaporator.
23. In the evaporator the liquid fully vaporizes.
24. The latent heat of evaporation is obtained from the brine or other body which is being cooled.
25. The low pressure ammonia vapour leaving the evaporator again enters the absorber and the cycle is completed.
26. This cycle is repeated again to provide the refrigerating effect.

Applications of refrigeration system:

- Preservation of food items like vegetables, milk and eggs.
- Preservation of medicines.
- Preservation of blood, tissues, etc.,
- Preservation and cooling of cool drinks.
- Preservation of chemicals (Chemical industries)
- Cooling of water.
- Industrial and comfort airconditioning.
- Processing of dairy products.

Comparison between Vapour compression & Vapour Absorption refrigeration systems:

S.No.	Vapour Compression System	Vapour Absorption System
1	This system has more wear and tear and produces more noise	Only moving part in this system is an aqua pump. Hence the quieter in
	due to the moving parts of the compressor.	operation and less wear and tear
2.	Electric power is needed to drive the system	Waste of exhaust steam may be used. No need of electric power
3.	Capacity of the system drops rapidly with lowered evaporator pressure	Capacity of the system decreases with the lowered evaporative pressure, by increasing the steam pressure in generator.
4.	At partial loads performance is poor.	At partial loads performance is not affected.
5.	Mechanical energy is supplied through compressor	Heat energy is utilised
6.	Energy supplied is ¼ to ½ of the refrigerating effect	Energy supplied is about one and half times the refrigerating effect
7.	Charging of the refrigerating to the system is easy	Charging of refrigerant is difficult

8.	Preventive measure is needed, since liquid refrigerant accumulated in the cylinder may damage to the cylinder	Liquid refrigerant has no bad effect on the system.

AIR CONDITIONING:

Air Conditioning is the process of conditioning the air according to the human comfort, irrespective of external conditions.

Applications of Air Conditioning

- Used in offices, hotels, buses, cars.,etc
- Used in industries having tool room machines.
- Used in textile industries to control moisture.
- Used in printing press.
- Used in Food industries, Chemical plants.

CLASSIFICATION OF AIR CONDITIONING:

Air conditioning systems are classified as

1) *According to the purpose*

a) Comfort Air conditioning.

b) Industrial Air conditioning.

2) *According to Season of the year*

a) Summer Air conditioning.

b) Winter Air conditioning.

c) Year round Air conditioning.

Types of Air conditioners

a) Room Air conditioners

b) Winter Air conditioners

c) Central Air conditioners

Functions of Air conditioners

a) Cleaning air.

b) Controlling the temp of air.

c) Controlling the moisture content.

d) Circulating the air.

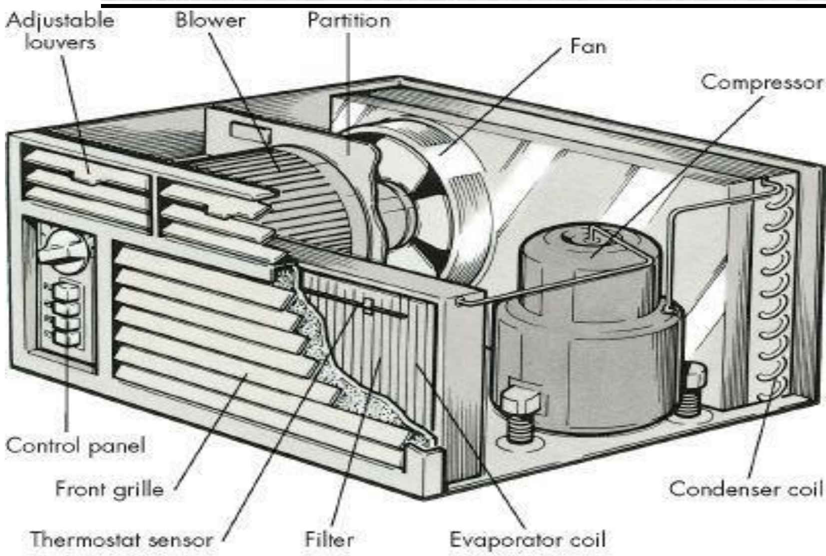
BASIC CONCEPTS:

1) Dry air: The atmospheric air which no water vapour is called dry air.
2) Psychometry: Psychometry is the study of the properties of atmospheric air.
3) Temperature: The degree of hotness (or) Coldness is called the temperature.
4) Moisture: Moisture is the water vapour present in the air.
5) Relative humidity: Relative humidity is the ratio of actual mass of water vapour in a given volume to the mass of water vapour.

6) Dry bulb temperature: The temperature of air measured by the ordinary thermometer is called dry bulb temperature:
7) Wet bulb Temperature: The temperature of air measured by the thermometer when it is covered by the wet cloth is known as wet bulb Temperature.
8) Dew point Temperature: The temperature at which the water vapour starts condensing is called dew point Temperature

Window Type Air Conditioner:

Fig.1 Window room air conditioner



Construction:

- This is also called room air conditioner.
- This unit consists of the following.

1. A cooling system to cool and dehumidify the air involves a condenser, a compressor and a refrigerant coil.
2. A filter to any impurities in the air. The filter is made of mesh, glass wool or fibre.
3. A fan and adjustable grills to circulate the air.
4. Controls to regulate the equipment operation.
5. The low pressure refrigerant vapour is drawn from the evaporator to the hermetic compressor through suction pipe.
6. It is compressed from low pressure to the high pressure and supplied to the condenser.
7. It is condensed in the condenser by passing the outdoor air over the condenser coil by a fan.
8. The liquid refrigerant is passed through the capillary into the evaporator.
9. . In the evaporator the liquid refrigerant picks up the heat from the refrigerator surface and gets vaporized.
10. A motor driven fan draws air from the room through the air filter and this air is cooled by losing its heat to the low temperature refrigerant and cold air is circulated back into the room.
11. The vapour refrigerant from the evaporator goes to the compressor from evaporator and the cycle is repeated.
12. Thus the room is air conditioned
13. . The quantity of air circulated can be controlled by the dampers.
14. The moisture in the air passing over the evaporator coil is dehumidified and drips into the trays.
15. This water evaporator to certain extent and thus helps in cooling the compressor and condenser.
16. The unit automatically stops when the required temperature is reached in the room. This is accomplished by the thermostat and control panel.

Merits and Demerits of Window type air conditioner:

Merits :

- A separate temperature control is provided in each room.
- Ducts are not required for distribution.
- Cost is less.
- Skilled technician is required for installation.

Demerits:

- It makes noise.
- Large hole is made in the external wall or a large opening to be created in the window panel. This leads to insecurity to inmates.

Split Type Air Conditioner - Layout:

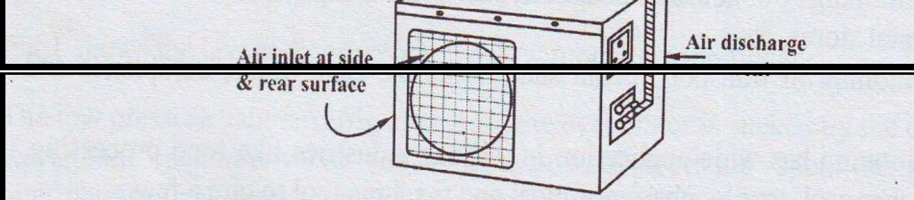


Fig.1 Split type room air conditioner

Fig.1 shows the layout diagram of a split type room air conditioner.

- In split air type air conditioner noise making components like compressor and condenser are mounted outside or away from room.
- Split type air conditioning system has two main components.
  (i) Outdoor Unit (ii) Indoor unit.
- The outdoor unit consists of compressor and condenser.
- The indoor unit consists of power cables, refrigerant tube and an evaporator mounted inside the room.

Working:

- Compressor is used to compress the refrigerant.
- The refrigerant moves between the evaporator and condenser through the circuit of tubing and fins in the coils.
- The evaporator and condenser are usually made of coil of copper tubes and surrounded by aluminium fins.
- The liquid refrigerant coming from the condenser evaporates in the indoor evaporator coil.

- During this process the heat is removed from the indoor unit air and thus, the room is cooled.
- Air return grid takes in the indoor air.
- Water is dehumidified out of air is drained through the drain pipe.
- The hot refrigerant vapour is passed to the compressor and then to the condenser where it becomes liquid.
- Thus the cycle is repeated.
- A thermostat is used to keep the room at a constant, comfortable temperature avoiding the frequent turning on off.

Merits and Demerits of Split type air conditioner:

Merits :

- It is compact
- Upto four indoor AHU's may be connected to one outdoor unit.
- It is energy and money saving.
- Duct is not used.
- Easier to install.
- It is noiseless, because rotary air compressor used is, kept outside.
- It is more efficient and powerful.
- It has the flexibility for zoning.

DeMerits :

- Initial cost is higher than window air conditioner
- Skilled technician is required for installation.
- Each zone or room requires thermostat to control the air cooling.

Applications of air conditioning:

- Used in houses, hospitals, offices, computer centres, theatres, departmental stores etc.,
- Air-conditioning of transport media such as buses, cars trains, aeroplanes and ships.
- Wide application in food processing, printing, chemical, pharmaceutical and machine tool, etc.,

MODULE-4

Power transmission systems

In mechanical industries, power from the engines or electric motor are transmitted to the machines using the following drives

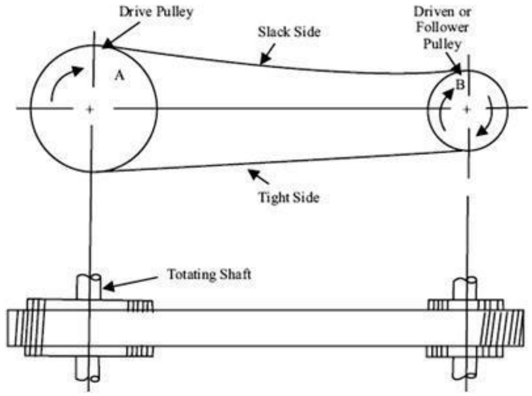
1.belt drive

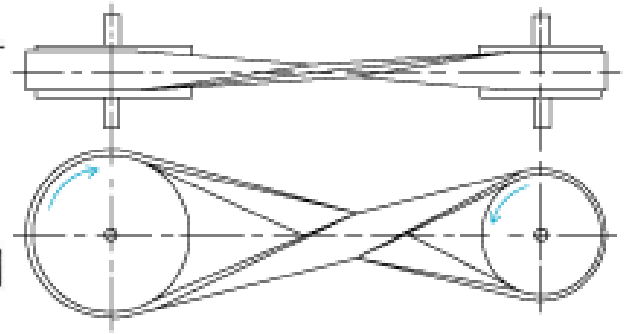
2. chain drive

3. gear drive

Belt drives

A belt is a loop of flexible material used to link two or more rotating shafts mechanically. Belts are looped over pulleys. In a two pulley system, the belt can either drive the pulleys in the same direction, or the belt may be crossed, so that the direction of the shafts is opposite. The shaft from which power is transmitted is called driver shaft and the shaft to which power is transmitted is called driven shaft.





Types of belts

Based on arrangement of shafts and belt

Open belt drive: in this the direction of rotation is same for both driver and driven shaft. See the fig. Above. The driver pulley pulls the belt from one side and delivers the same belt to the other side . hence the tension on the former side will be greater than the later side. The side where tension is more is called tight side and the other side is called slack side.

Cross belt drive: in this driver and driven pulley have different direction of rotation. At the point where belt crosses, it rubs against itself and wears. In order to reduce this shaft should be placed at a minimum distance of 20 d, where ‘d’ is the width of belt.

Based on shape of cross section

Flat belt- it used to transmit moderate amount of power for a long distane between shafts(upto 10m). Flat belts are again classifie as open belt drive and cross belt drive

Vee/ V- belt- these are used to transmit large amout of power between two shafts for a short distance

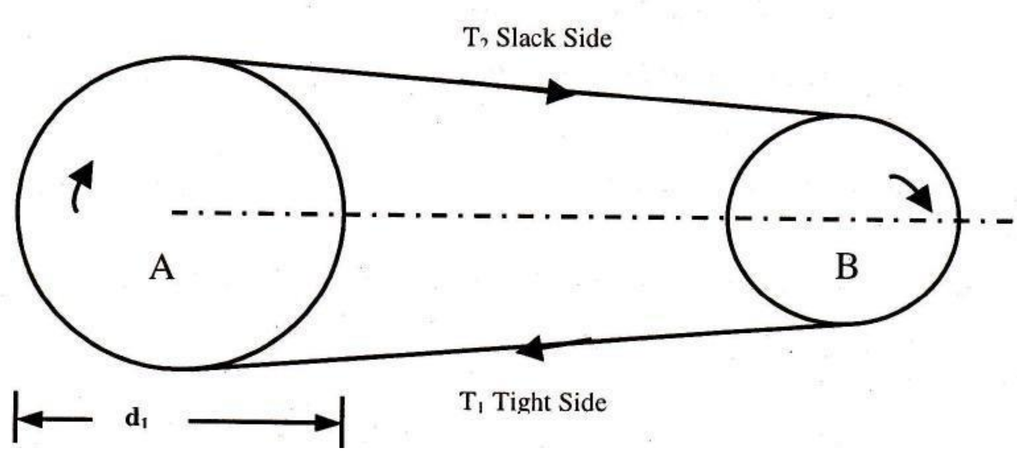
Circular belt/rope- these belts are used to transmit large amount of power for large distance(>8m)

Flat-belt drives are simple and convenient. They permit the use of ordinary pulleys with smooth surfaces, and they can be operated at speeds as high as 40–50 m/sec and more. However, they are bulky in design and low in strength. V-belt drives provide improved attachment of the belt to the pulleys, permit shortening of the centre distances, and allow a decrease in the size of the drive. Round-belt drives are now rare and are used only in mechanisms of low power, such as those in sewing machines.

The advantages of belt drives are their simplicity of design, relative low cost, capacity to transmit power over significant distances (up to 10 m and more), and smooth and noiseless operation. It can be used with very high speed drives. In addition, the elastic properties of the belt and its ability to slip on the pulleys help prevent overload. The disadvantages include the short lifetime of the belts, relatively large size, heavy stress on the shafts and bearings, and variation in the tension ratio caused by the inevitable slipping of the belt.

Belts made of highly elastic, strong synthetic materials like leather, cotton and rubber. Belt drives are widely used in agricultural machines, electric generators, certain machine tools, and textile machines. They are ordinarily used for transmitting power up to 30–50 kilowatts.

Power transmitted by belt drive



Here the driving pulley pulls the belt from the lower side to the upper side. Thus the tension in the lower side will be greater than the tension in the upper side. The upper side is called the slack side and lower side is the tight side.

T_1 - tension in the tight side of the belt is Newton

T_2 – Tension in the slack side of the belt is Newton

d_1 – diameter of the driving pulley

d_2 – diameter of the follower

v = linear velocity of the belt in m/sec

The driven pulley rotates because of the difference in tensions in the tight and slack side of the belt. Therefore the force causing the rotation is the difference between the two tensions the belt exerts a force on the pulley.

Let F is the net force acting on the belt

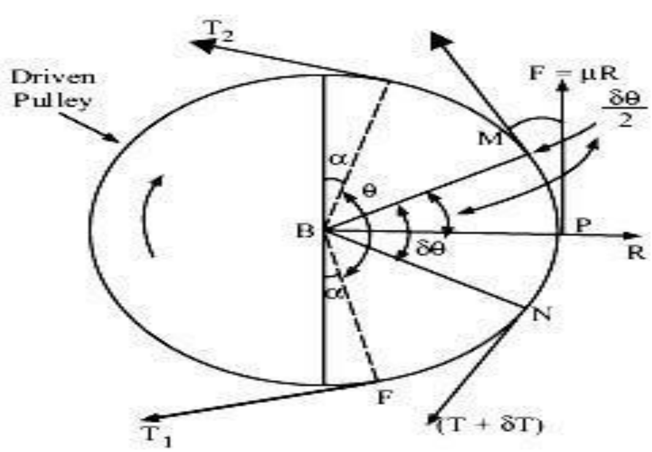
So $F = (T_1-T_2)$

$$power\ transmitted = \frac{work}{time} = forceXdisplacement\ time = forceXvelocity$$

$P = F \ X \ V= (T_1-T_2) \ X \ V$

$P = (T_1-T_2) \ X \ rw=(T_1-T_2) \ XrX2.\pi.N/60.$

Relation between belt tension and friction



In the picture angle of contact between belt and pulley is θ. Let the tight side tension be T1 and slack side tension T2. Consider a short length MN of belt, which subtends an angle δθ at pulley centre. Let T be tension at M and (T + δT) be the tension at N. The frictional force depends normal reaction R. Suppose the belt is in equilibrium. Then ∑X=0 and ∑Y=0. Here x direction is horizontal(radial direction) and y direction is tangential at point P.

$(T + \delta T) \cos (\delta\theta / 2) - T \cos (\delta\theta / 2) - \mu R$

=0 Since δθ is very small,

$\cos (\delta\theta /2) = 1$

$(T + \delta T) + T - \mu R = 0$

$\mu R = \delta T$..(1)

and resolving the force is radial reaction.

$T \sin (\delta\theta / 2) + (T + \delta T) \sin (\delta\theta/2) - R = 0$

Since, δθ is very small, $\sin (\delta\theta/2) = (\delta\theta/2)$

$T\ \delta\theta/2 + (T + \delta T)\ \delta\theta/2\ R = 0$ ($\delta T . \delta\theta / 2$ is

neglected) $T\ \delta\theta = R$ ....(2)

From equations (1) and (2)

$\mu(T\ \delta\theta) = \delta T$

$\delta T / T = \mu\ \delta\theta$

On integration, we get

$\int_{T1}^{T}{}_{2} \delta T/T = \int_{0}^{\theta} \mu d\theta$

$\log T_1 / T_2 = \mu\theta$

$T_1 / T_2 = (e)^{\mu\theta}$

Gears and gear train

Toothed wheels are known as gears. A gear is a rotating machine part having cut *teeth*, which *mesh* with another toothed part in order to transmit torque. Gears having high efficiency and high accuracy. It is having less maintenance cost.

There are different types of gears. Gears may be classified according to the relative position of the axis of revolution. The axis may be

1. spur,
2. helical
3. bevel gear
4. worm and worm wheel
5. Rack and pinion.

Spur Gears

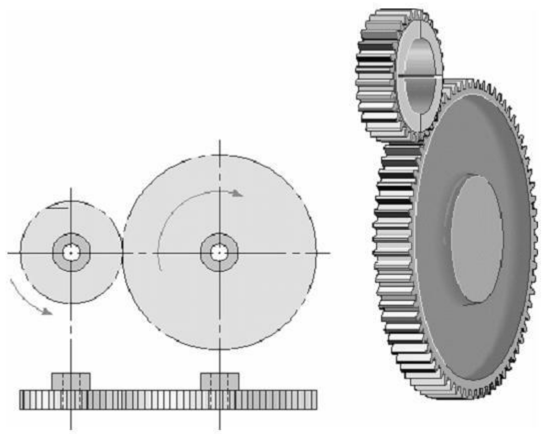
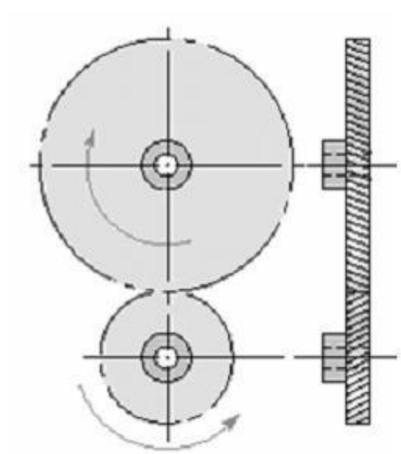


Figure 1: Spur Gear

Spur gears are the most commonly used gear type. They are characterized by teeth which are perpendicular to the face of the gear or teeth are parallel to the axis of rotation. Spur gears are by far the most commonly available, and are generally the least expensive. The basic descriptive geometry for a spur gear is shown in the figure.

Limitations: Spur gears generally cannot be used when a direction change between the two shafts is required. Advantages: Spur gears are easy to find, inexpensive, and efficient.

Helical Gears



Helical gears are similar to the spur gear except that the teeth are at an angle to the shaft/axis of rotation. The resulting teeth are longer than the teeth on a spur gear of equivalent pitch diameter. The longer teeth cause helical gears to have the following differences from spur gears of the same size :

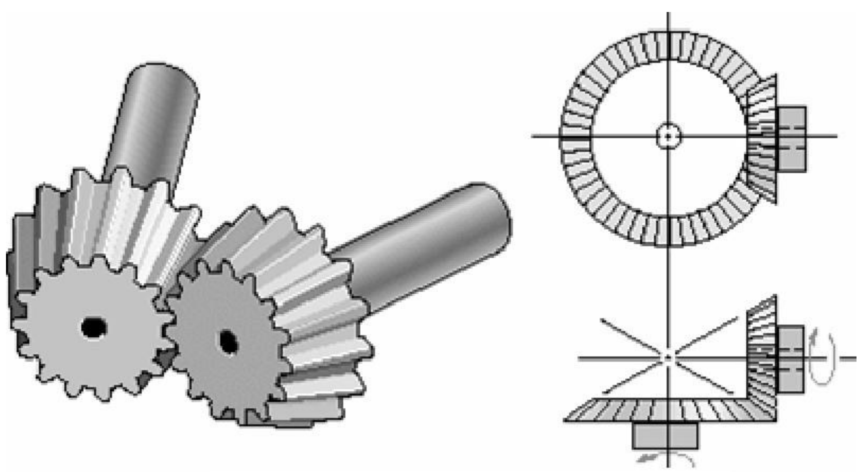
1. Tooth strength is greater because the teeth are longer,
2. Greater surface contact on the teeth allows a helical gear to carry more load than a spur gear
3. The longer surface of contact reduces the efficiency of a helical gear relative to a spur gear

Helical gears may be used to mesh two shafts that are parallel.the angle between tooth and axis of rotation is called helix angle.

Limitations: Helical gears have the major disadvantage that they are expensive . Helical gears are also slightly less efficient than a spur gear of the same size

Advantages: Helical gears can be used on non parallel and even perpendicular shafts, and can carry higher loads than spur gears.

Bevel Gears



Bevel gears are primarily used to transfer power between intersecting shafts. The teeth of these gears are formed on a conical surface. Standard bevel gears have teeth which are cut straight and are all parallel to the line pointing the apex of the cone on which the teeth are based. One of the most common applications of bevel gears is the automobile differential system,

Limitations: Limited availability. Cannot be used for parallel shafts. Can become noisy at high speeds.

Advantages: Excellent choice for intersecting shaft systems.

Worm Gears

Worm gears are special gears that resemble screws, and can be used to drive spur gears or helical gears. Worm gears, like helical gears, allow two non-intersecting , non parallel shafts to mesh. Normally, the two shafts are at right angles to each other. A worm gear is equivalent to a V-type screw thread. Another way of looking at a worm gear is that it is a helical gear with a very high helix angle. Worm gears are normally used when a high gear ratio is desired, or again when the shafts are perpendicular to each other. One very important feature of worm gear meshes that is often of use is their irreversibility: when a worm gear is turned, the meshing spur gear will turn, but turning the spur gear will not turn the worm gear. The resulting mesh is 'self locking', and is useful in ratcheting mechanisms.

Limitations: Low efficiency. The worm drives the drive gear primarily with slipping motion, thus there are high friction losses.

Advantages: Will tolerate large loads and high speed ratios. Meshes are self locking (which can be either an advantage or a disadvantage).

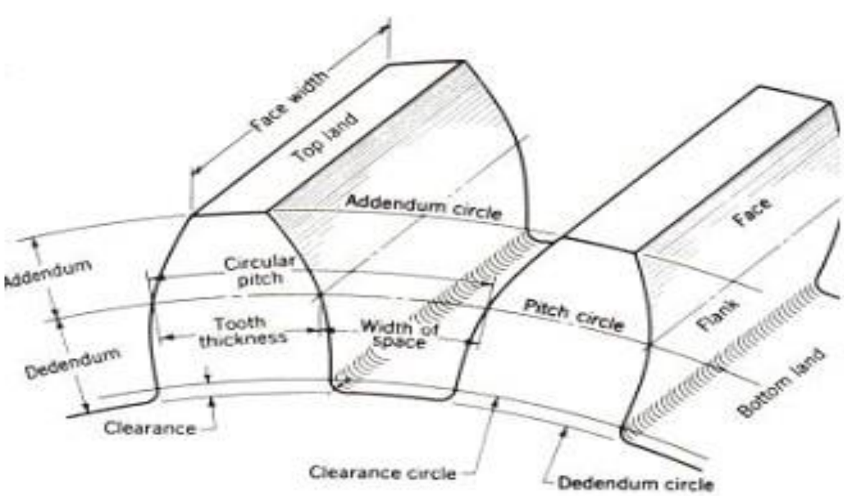
Racks (straight gears)

Racks are straight gears that are used to convert rotational motion to translational motion by means of a gear mesh. (They are in theory a gear with an infinite pitch diameter). In theory, the torque and angular velocity of the pinion gear are related to the Force and the velocity of the rack by the radius of the pinion gear, as is shown below:

Perhaps the most well-known application of a rack is the rack and pinion steering system used on many cars in the past.

Limitations: Limited usefulness. Difficult to find.

Advantages: The only gearing component that converts rotational motion to translational motion. Efficiently transmits power. Generally offers better precision than other conversion methods.



Gear terminology:

- **Pitch circle**: it is an imaginary circle which by pure rolling action, would give the same motion as the actual gear
- **Addendum circle**: A circle drawn through the top of the teeth and is concentric with pitch circle.
- **Root (or dedendum) circle**: The circle drawn through the bottom of the teeth.
- **Addendum**: The radial distance between the pitch circle and the addendum circle.
- **Dedendum**: The radial distance between the pitch circle and the dedendum circle.
- **Clearance**: The difference between the dedendum of one gear and the addendum of the mating gear.
- **Face of a tooth**: That part of the tooth surface lying outside the pitch surface.
- **Flank of a tooth**: The part of the tooth surface lying inside the pitch surface.
- **Circular thickness** (also called the **tooth thickness**) : The thickness of the tooth measured on the pitch circle. It is the length of an arc and not the length of a straight line.
- **Tooth space**: The distance between adjacent teeth measured on the pitch circle.
- **Backlash**: The difference between the circle thickness of one gear and the tooth space of the mating gear.
- **Circular pitch** p: The width of a tooth and a space, measured on the pitch circle.

$$Pc = \frac{\pi D}{T}$$

- **Diametral pitch** P: The number of teeth of a gear per inch of its pitch diameter. A toothed gear must have an integral number of teeth. The *circular pitch*, therefore, equals the pitch circumference divided by the number of teeth. The *diametral pitch* is, by definition, the number of teeth divided by the *pitch diameter*. That is,

$$P_d = \frac{T}{D}$$

- **Module** m: Pitch diameter divided by number of teeth. The pitch diameter is usually specified in inches or millimeters; in the former case the module is the inverse of diametral pitch. $m = \frac{D}{T}$

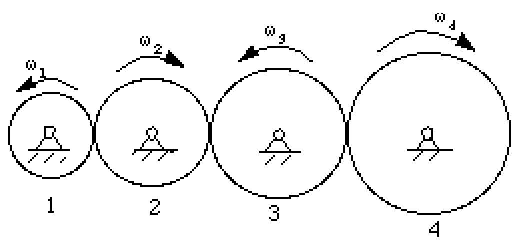
- **Fillet** : The small radius that connects the profile of a tooth to the root circle. **Velocity**
- **ratio**: The ratio of the number of revolutions of the driving (or input) gear to the number of revolutions of the driven (or output) gear, in a unit of time.
- **Pitch point**: The point of tangency of the pitch circles of a pair of mating gears.
- **Line of action**: A line normal to a pair of mating tooth profiles at their point of contact.
- **Path of contact**: The path traced by the contact point of a pair of tooth profiles.
- **Pressure angle** α: The angle between the common normal at the point of tooth contact and the common tangent to the pitch circles. It is also the angle between the line of

action and the common tangent.

- **Base circle** :An imaginary circle used in involute gearing to generate the involutes that form the tooth profiles.

Gear Trains

Gear trains consist of two or more gears for the purpose of transmitting motion and power from one shaft to another. **Figure a** shows a simple ordinary gear train in which there is only one gear for each axis. In **Figure b** a compound gear train is, in which two or more gears may rotate about a single axis



a

$$speed\ ratio\ of\ ordinary\ gear\ train = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

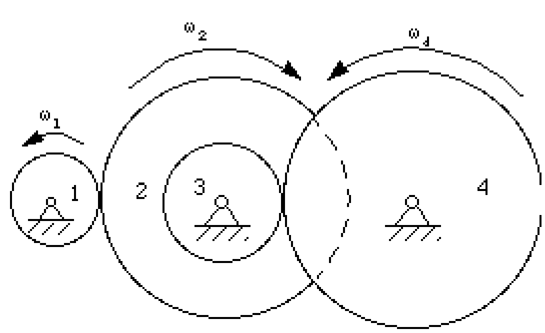
$$\frac{N_1}{N_2} x \frac{N_2}{N_3} = \frac{T_2}{T_1} x \frac{T_3}{T_2}$$

$$\frac{N_1}{N_3} = \frac{T_3}{T_1}$$

$$N = no\ of\ revolution$$

$$T = no\ of\ teeth$$

Compound gear train

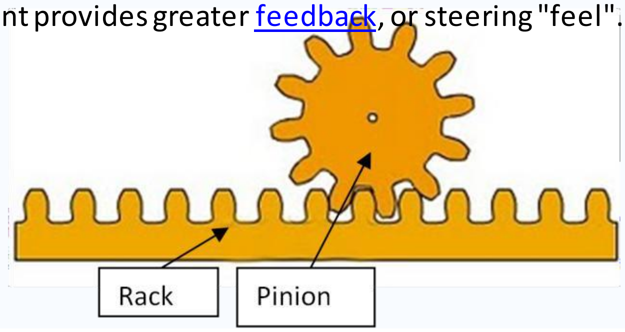


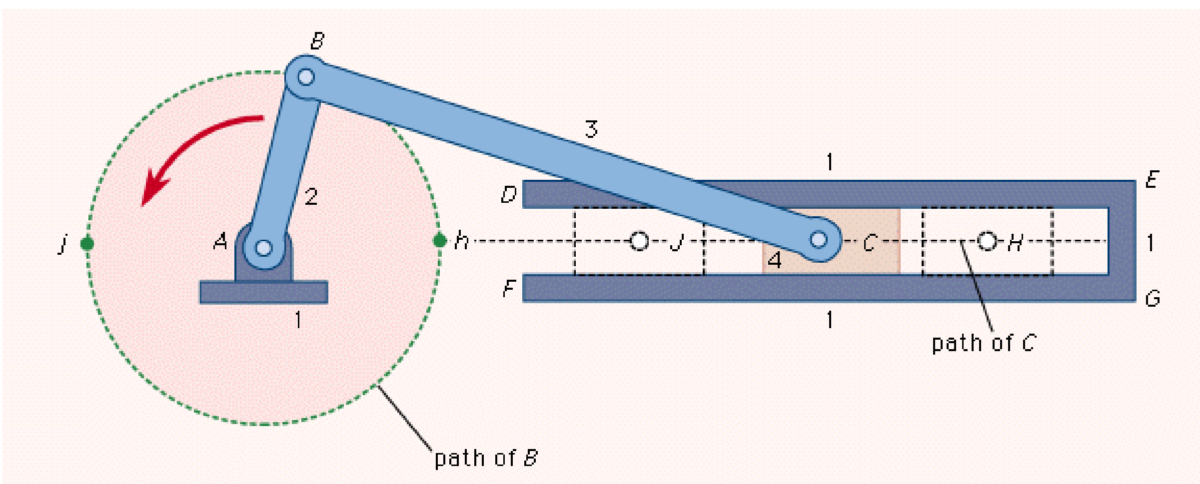
b

Rack and pinion

A **rack and pinion** is a pair of gears which convert rotational motion into linear motion. The circular *pinion* engages teeth on a flat bar (the *rack)*. Rotational motion applied to the pinion will cause the rack to move to the side, up to the limit of its travel.

The rack and pinion arrangement is commonly found in the steering mechanism of cars or other wheeled, steered vehicles. This arrangement provides greater feedback, or steering "feel".



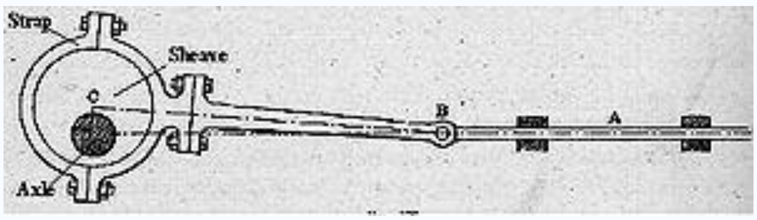


Slider crank mechanism

A slider crank mechanism(see fig.) is most widely used to convert reciprocating to rotary motion (as in an engine) or to convert rotary to reciprocating motion (as in pumps), but it has numerous other applications. Positions at which slider motion reverses are called dead centers. (here Position H and J)When crank and connecting rod are extended in a straight line and the slider is at its maximum distance from the axis of the crankshaft, the position is top dead center (TDC)(position H); when the slider is at its minimum distance from the axis of the crankshaft, the position is bottom dead center (BDC)(position J).

The conventional internal combustion engine employs a piston arrangement in which the piston becomes the slider of the slider-crank mechanism.. Another use of the slider crank is in toggle mechanisms, also called knuckle joints. The driving force is applied at the crankpin so that, at TDC, a much larger force is developed at the slider.

Eccentric mechanism



Eccentric sheave, with strap and eccentric rod fitted.

In mechanical engineering, an **eccentric** is a circular disk (*eccentric sheave*) solidly fixed to a rotating axle with its centre offset from that of the axle/shaft (hence the word "eccentric", out

Internal combustion engines

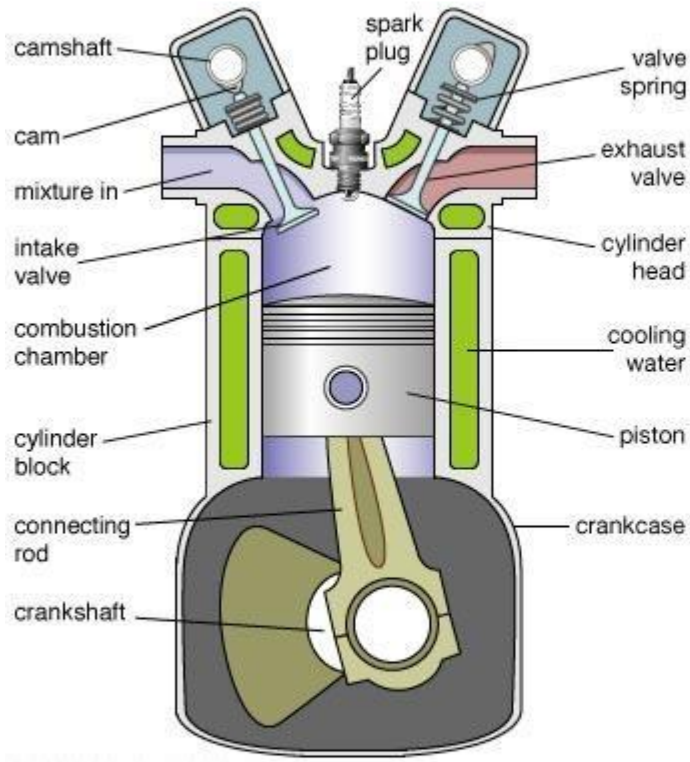
Introduction

A device which transforms one form of energy into another form is called an engine. An engine which converts thermal energy into mechanical energy is called heat engine. Heat engines can be broadly classified into two categories

(i)External combustion engines (EC engines)eg: steam engine

(ii)Internal combustion engines (IC engines)eg: petrol and diesel engine

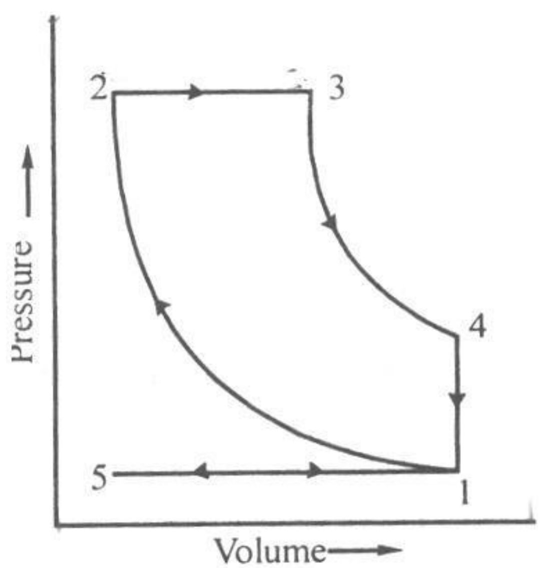
The **internal combustion engine** is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber inside the engine.



Working principle of Diesel engines (Compression Ignition engines)

Diesel engine is based on the work of Rudolph Diesel. It operates based on the theoretical air cycle known as diesel cycle. These engines operate on four stroke or two stroke cycle.

Diesel cycle (Constant pressure cycle)

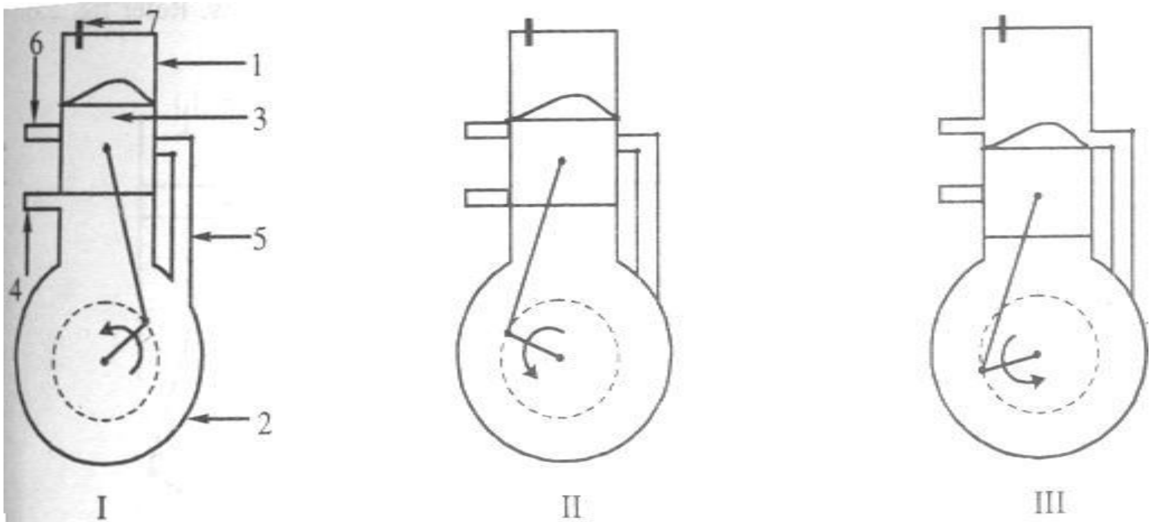


Atmospheric air is drawn into the engine cylinder during the suction stroke and is compressed by the piston during the compression stroke to high pressure and temperature. The temperature of compressed air will be above the ignition temperature of fuel. Just before the end of the compression stroke a metered quantity of fuel under pressure is injected in the form of fine spray by means of a fuel injector. Due to very high pressure and temperature of the air the fuel ignites and the gases expand displacing the piston. After doing work on the piston the burnt gases escape from the engine cylinder

Two stroke diesel engine

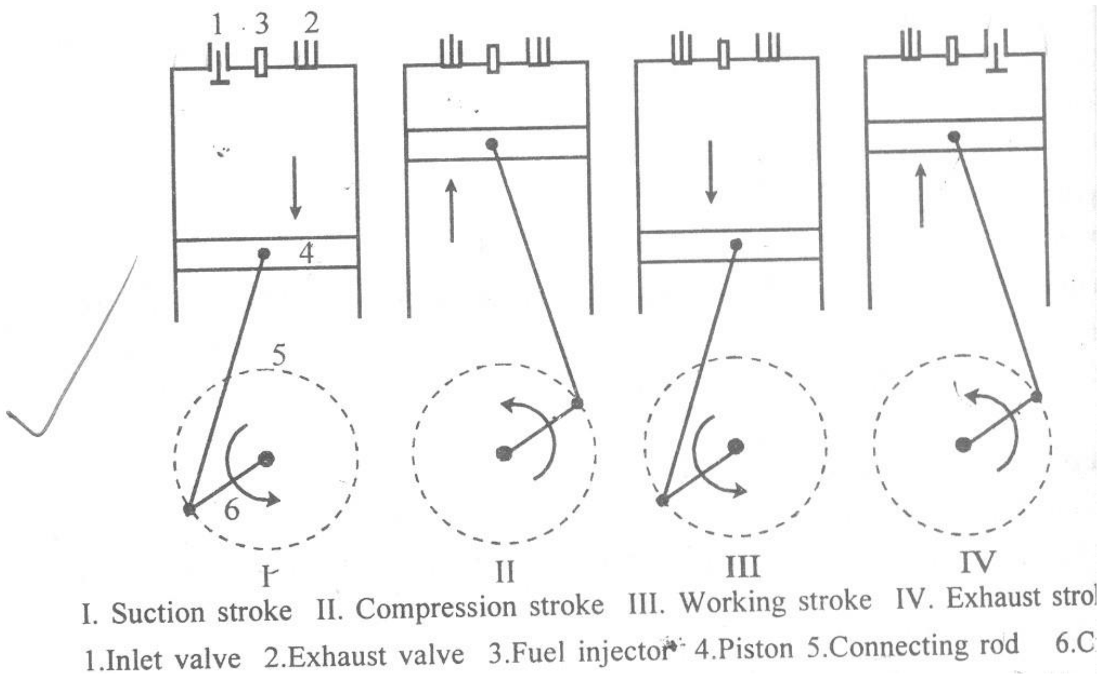
In two stroke diesel engine, one cycle of operation is completed in two strokes of the piston, (in one revolution of the crank shaft) by eliminating separate suction and exhaust strokes. Here ports are provided in place of valves.

Fig. shows the working of a two stroke diesel engine. The cylinder is connected to a closed crankcase. During the upward stroke of the piston, the air in the cylinder is compressed. At the same time fresh air enters the crankcase through the air inlet port. Fig. (I)



1. Cylinder 2. Crank case 3. Piston 4. Air inlet port 5. Transfer port
6. Exhaust port 7. Fuel injector

Four stroke diesel engine



In four stroke cycle engine one cycle of operation is completed in four strokes of the piston (i.e., two revolutions of crank shaft).The various strokes of a four stroke diesel engine are detailed below. Refer PV diagram.

1. Suction stroke

   During this stroke the piston moves from top dead centre (TDC) to bottom dead centre (BDE).The inlet valve opens and air at atmospheric pressure is drawn into the engine cylinder. The exhaust valve remains closed. This operation is represented by the line 5-1 in PV diagram.

2. Compression stroke

   In this stroke the piston moves towards TDC and compresses the enclosed air to high temperature and pressure. This operation is represented by line 1-2 in PV diagram. Both the inlet and exhaust valves remain closed during this stroke.

3. Expansion or working stroke

   Towards the end of compression stroke a metered quantity of fuel is injected into the hot compressed air in the form of fine spray by means of a fuel injector. The fuel starts burning, theoretically, at constant pressure and pushes the piston from TDC. This is shown by line 2-3 in PV diagram. At point 3, fuel supply is cut off. The high pressure gas in the cylinder expand up to point 4, doing work on the piston. The inlet and exhaust valves remain closed during this stroke. At the end of this stroke the exhaust valve opens.

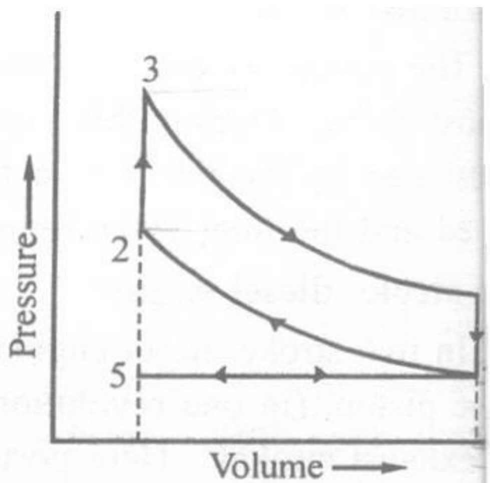
4. Exhaust stroke

The piston moves from BDC to TDC and the burnt gases escape through the exhaust valve. During this stroke the inlet valve remains closed. This stroke is represented by the line 1-5 in PV diagram. During this stroke the exhaust valve remains opened and the inlet valve remains closed. By this one cycle is completed.

2.5 Working principle of petrol engines (Spark Ignition Engines)

Petrol engines operate on the so called Otto cycle. These engines work based on either four stroke or two stroke cycle.

Otto cycle (Constant volume cycle)

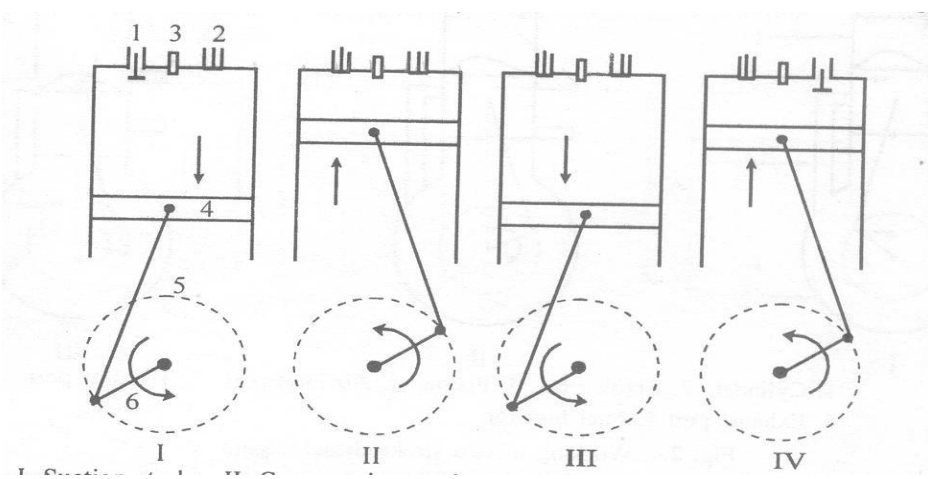


In this cycle, heat is supplied at constant volume. A homogeneous mixture of air and petrol is supplied to the engine cylinder during the suction stroke. A carburettor provides a mixture of petrol and air in the required proportion.

The fuel air mixture (charge) gets compressed during the compression stroke At the end of this stroke, fuel is ignited and combustion occurs at constant volume .The gas expands and moves the piston downwards, during work.

Four stroke petrol engines

The various strokes of a four stroke petrol engine are detailed below. Refer PV diagram



I Suction stroke II Compression stroke III Working stroke IV Exhaust stroke

1 Inlet valve 2 Exhaust valve 3 Fuel injector 4 Piston 5 connecting rod 6 Crank

Fig: Working of four stroke petrol engine

1) Suction stroke

During this stroke the piston moves from top dead centre (TDC) to bottom dead centre (BDC). The inlet valve opens and the fuel air mixture is sucked into the engine cylinder. The exhaust valve remains closed throughout this stroke. This is represented by the line 5-1 in PV diagram.

2) Compression Stroke

The air fuel mixture is compressed as the piston moves from BDC to TDC. Just before the end of this stroke, the spark plug initiates a spark which ignites the mixture and combustion takes place at constant volume (line 2-3 in fig PV diagram). Both the inlet and exhaust valves remain closed throughout this stroke.

3) Expansion or working stroke

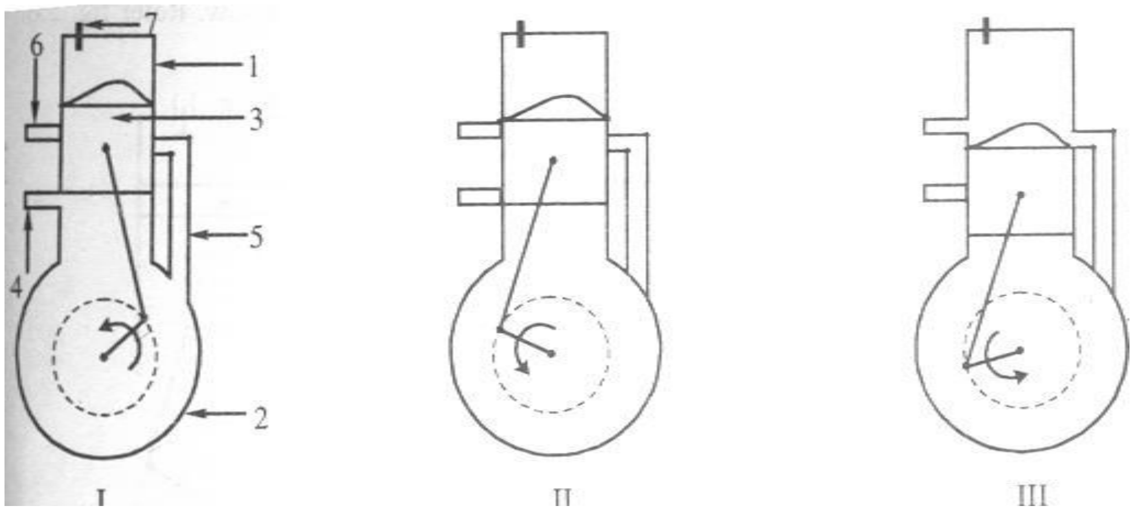
As the fuel air mixture burns, hot gases are produced which drive the piston towards BDC and thus work is done. This expansion process is shown by the line 3-4 in PV diagram. Both the valves remain closed during this stroke.

4) Exhaust stroke

The removal of the burnt gases is accomplished during this stroke. The piston moves from BDC to TDC and the exhaust gases are driven out of the engine cylinder .This operation is represented by the line 1-5 in PV diagram. During this stroke the exhaust valve remains opened and the inlet valve remains closed. By this one cycle is completed.

Two stroke petrol engine

In two stroke petrol engine, one cycle of operation is completed in two strokes of the piston, (in one revolution of the crankshaft) by eliminating separate suction and exhaust strokes. Here ports are provided in place of valves



1 Cylinder 2 Crank case 3 Piston 4 Air inlet port 5 Transfer port 6 Exhaust port 7 Spark plug

Fig 2. Working principle of two stroke petrol engine

Fig 2.shows the working of a two stroke petrol engine. The cylinder is connected to a closed crankcase. During the upward stroke of the piston, the air fuel mixture in the cylinder is compressed. At the same time fresh air fuel mixture enters the crankcase through the inlet port. (Fig. 2 I) Towards the end of this stroke, the air fuel mixture is ignited using an electric spark from the spark plug.

The piston then travels downwards due to the expansion of the gases (fig. 2 II) and near the end of this stroke the piston uncovers the exhaust port and the burnt gases escape through this port. The transfer port is then uncovered (fig 2 III) and the compressed air fuel mixture from the crankcase flow into the cylinder.

The incoming fresh air fuel mixture helps to move the burnt gases from the engine cylinder. Refer fig. 6. In a two stroke petrol engine the operations are the same as that for a two stroke diesel engine with some difference. In this engine, fuel air mixture is admitted into the crank case and compressed. A carburettor is used for mixing the fuel and air in the correct proportion. For the ignition of the fuel air mixture at the end of compression in the engine cylinder, a spark plug is provided. In this case, combustion process is assumed to take place at constant volume.

Comparison of SI and CI engines

1. **Working cycle:** The SI engine, in general, works based on Otto cycle, while the CI engine, in general, works based on diesel cycle.
2. **Fuel:** A highly volatile fuel such as petrol is used in SI engine while non-volatile fuel such as diesel is used in CI engines.
3. **Method of fuel ignition:** In most of SI engines, the fuel and air are introduced into the engine cylinder as a gaseous mixture while in CI engines, the fuel is directly introduced into the cylinder in the form of fine spray. Mixing of fuel and air takes place inside the cylinder.
4. **Method of fuel ignition**: The SI engine requires a spark to initiate combustion while CI engine utilises the condition of high temperature and pressure, produced by the compression of air in the cylinder, to initiate combustion when fuel is injected.
5. **Fuel economy:** CI engines have better fuel economy at all operating conditions.
6. **Compression ratio:** Compression ratio of SI engines range from 6 to 10, where as that of CI engines range from 16 to 20. The higher compression ratio of CI engines result in higher thermal efficiency and hence a greater power output for the same amount of fuel consumed.
7. **Weight:** Because of the higher compression ratio and higher pressure, CI engines require stronger engine parts and hence are heavier
8. **Initial cost:** Initial cost of a SI engine is less than a comparable CI machine.
9. **Maintenance costs:** The maintenance costs of the two types of engines are generally about the same, with CI engine costs slightly higher.

Comparison of two stroke and four stroke cycle engines

1) In a two stroke engine, there is one working stroke for every revolution of the crank shaft whereas in a four stroke engine there is only one power stroke for two revolutions of the crank shaft. Hence, theoretically, the power developed in two stroke engine will be double that of a four stroke engine of the same dimensions However in practice, only about 30 percent extra power is developed .That is, in order to produce the same of power, a two stroke cycle engine will be of less weight and occupies less space.

2) As there is one working stroke in every revolution of the crank shaft, the turning moment of a two stroke engine will be more uniform.

3) As there is no valves in a two stroke engine the construction will be simple and hence low initial cost. The maintenance of the engine will also be easy. The mechanical efficiency will be higher.

4) As there is no separate exhaust stroke in a two stroke engine the scavenging will be poor. Due to this, the fresh charge gets diluted with exhaust gases and the thermal efficiency decreases. Also there is possibility of the fresh charge escaping with the exhaust. This will increase the fuel consumption.

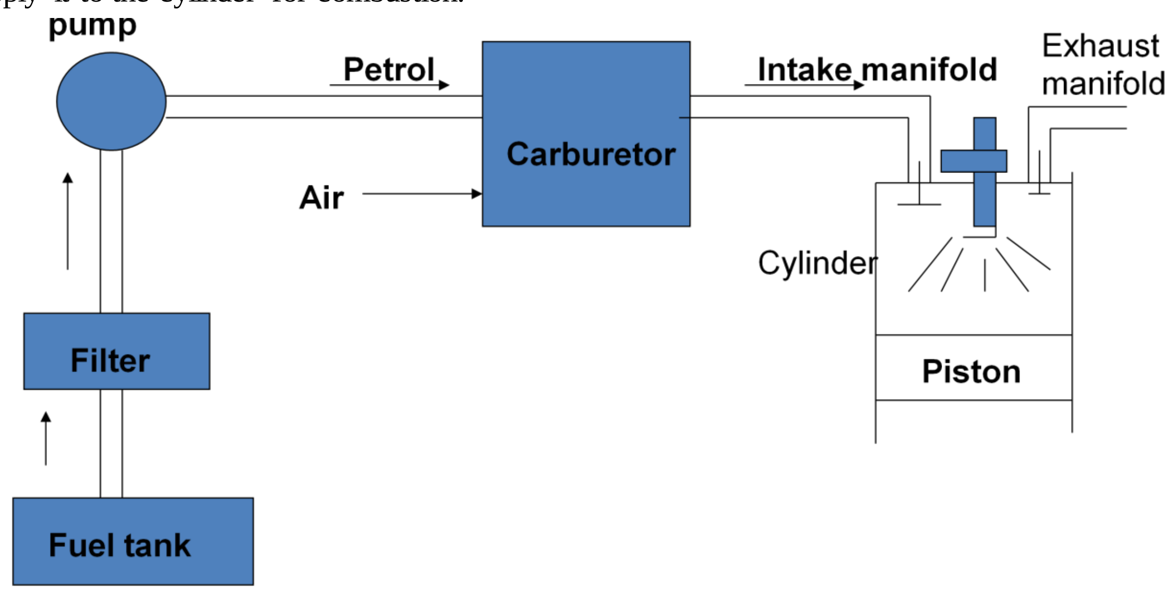
5) The separate exhaust and intake strokes of the four stroke cycle provide greater opportunity for the dissipation of heat from critical parts like piston, and essentially permit the four stroke cycle engine to run at higher speed than two stroke cycle engine.

6) In two stroke engine the power needed to operate suction and exhaust valves is saved.

7) The construction of combustion chamber is simple in a two stroke engine compared to four stroke engine.

Carburation

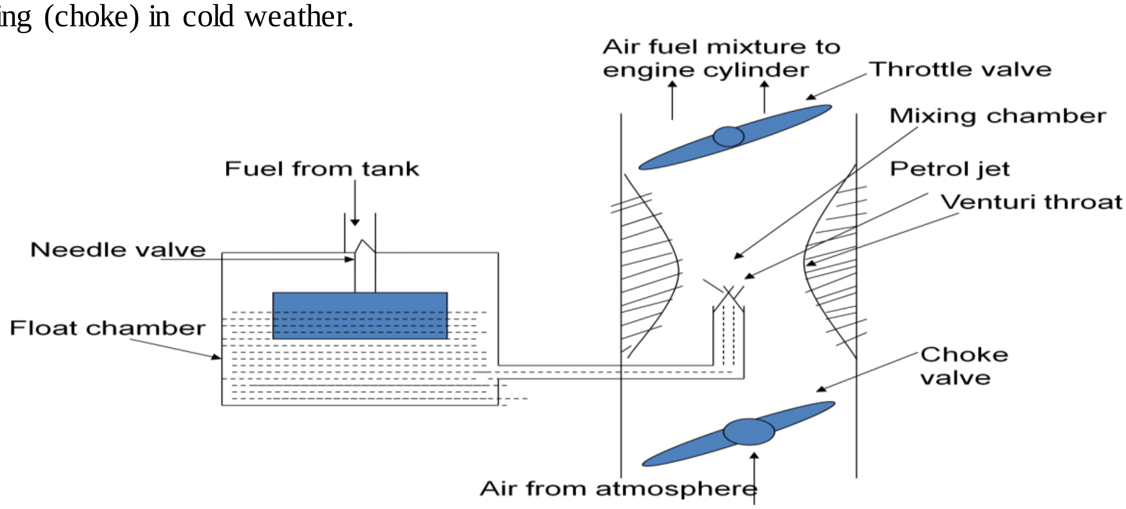
Function of the fuel supply system is to store the fuel required for the engine in a tank and to supply it to the cylinder for combustion.



Carburetor is considered as the *heart of the petrol engine*. It is a device for atomizing and vapourizing the volatile liquid fuel (petrol) and mixing it with air. It is attached to the intake manifold connected with the engine cylinder. In the S.I. engine, combustible petrol – air mixture is prepared outside the engine cylinder. The process of vapourizing the fuel (petrol) and mixing it with air outside the cylinder in the S.I. engine is known as carburetion.

With less air, some portion of the fuel will remain unburnt due to the insufficient supply of oxygen while with excess air, the rate of burning will be slower.

For running at higher speeds and for starting the engine, we need rich air – fuel mixture. For this, the carburetor regulates the throttle valve using accelerator. Provision is made for easy starting (choke) in cold weather.



Carburetor is one chamber where petrol and air was mixed in a fixed ratio and then sent to cylinders to burn it to produce power. This system is purely a mechanical machine with little or no intelligence. It was not very efficient in burning petrol, it will burn more petrol than needed at times and will produce more pollution.

CRDI Engine

CRDI Engine stands for Common Rail Direct Injection (CRDI) engine. It is the latest state-of-the- art technology for diesel engines and suits passenger cars as well as commercial vehicles. One of the main reasons for the increasing popularity of CRDI is its performance and fuel economy. A CRDI engine is based on direct injection technology and has common rails i.e. tubes which inject pressurised fuel directly into the engine. The common rail connects all the injectors and supply fuel at a constant high pressure. The high pressure in the common rail ensures that upon injection, the fuel atomises and mixes consistently with the air, thereby leaving minimal unburnt fuel.

In a CRDI engine, fuel quantity, engine pressure and timing of fuel injection are controlled electronically. The onboard computer makes sure that the fuel is injected at the precise moment. This significantly improves engine efficiency and reduces noise and vibrations as compared to the conventional diesel engines.

Common rail direct fuel injection is a modern variant of direct fuel injection system for petrol and diesel engines. On diesel engines, it features a high-pressure (over 1,000 bar)

Fuel injection is a system for mixing fuel with air in an internal combustion engine. Carburetors were the predominant method used to mix fuel in petrol engines before the widespread use of fuel injection.

The primary difference between carburetors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburetor relies on low pressure created by intake air rushing through it to add the fuel to the airstream.

Multi-point fuel injection(MPFI)

Multi-point fuel injection injects fuel into the intake port just before the cylinder's intake valve, in each cylinder, rather than a common point as in carburator. A Petrol car's engine usually has four or more cylinders. So in case of an MPFI engine, there is one fuel –injector installed near each cylinder, that is why they call it Multi-point (more than one points) Fuel Injection.

MPFI emerged an Intelligent way to do what the Carburetor does. In MPFI system, each cylinder has one injector (which makes it multi-point). Each of these Injectors are controlled by one central **computer**. This computer is a small micro-processor, which keeps telling each Injector about how much petrol and at what time it needs to inject near the cylinder so that only the required amount of petrol goes into the cylinder at the right moment.

So the working of MPFI is similar to Carburetor, but in an improved way, because now each cylinder is treated independently unlike Carburetor. But one major Key difference is that MPFI is an intelligent system and Carburetor is not. MPFI systems are controlled by a computer which does lots of calculations before deciding what amount of petrol will go into what cylinder at a particular point in time. It makes that decision based on the inputs it reads.

For the Inputs, the microprocessor (or car's computer) reads a number of sensors. Through these sensors, the microprocessor knows the temperature of the Engine, the Speed of the Engine, it knows the load on the Engine, it knows how hard you have pressed the accelerator, it knows whether the Engine is idling at a traffic signal or it is actually running the car, it knows the air-pressure near the cylinders, it knows the amount of oxygen coming out of the exhaust pipe.

Based on all these inputs from the sensors, the computer in the MPFI system decides what amount of fuel to inject. Thus it makes it fuel efficient as it knows what amount of petrol should go in. To make things more interesting, the system also learns from the drivers driving habits. Modern car's computers have memory, which will remember your driving style and will behave in a way so that you get the desired power output from engine based on your driving style

MODULE-5

Metal casting

Manufacturing of a machine part by melting (heating a metal or alloy above its melting point) and pouring the liquid metal/alloy in a cavity approximately of same shape and size as the machine part is called **casting process**. After the liquid metal cools and solidifies, it acquires the shape and size of the cavity and resembles the required finished product. The place, where castings are made is called foundry.

The casting procedure:

(a) Preparation of a pattern,
(b) Preparation of a mould with the help of the pattern,
(c) Melting of metal or alloy in a furnace,
(d) Pouring of molten metal into mould cavity,
(e) Breaking the mould to retrieve the casting,
(f) Cleaning the casting and cutting off risers, runners etc., (this operation is called 'fettling'),
(g) Inspection of casting.

MOULDING SAND AND ITS PROPERTIES

In foundries, river sand is used for making moulds. Sand is chemically $SiO2$ (silicon dioxide) in granular form. Ordinary river sand contains some percentage of clay, moisture, non-metallic impurities and traces of magnesium and calcium salts besides silica grains. This sand, after suitable treatment, is used for mould making.

Good, well prepared moulding sand should have the following properties:

(i) **Refractoriness** *:* it should be able to with stand high temperatures.
(ii) **Permeability** *:* ability to allow gases, water vapour and air to pass through it.
(iii) **Green sand strength** *:* when a mould is made with moist sand, it should have sufficient strength, otherwise mould will break.
(iv) **Good flowability** *:* when it is packed around a pattern in a moulding box, it should be able to fill all nooks and corners, otherwise the impression of pattern in mould would not be sharp and clear.
(v) **Good collapsibility** *:* it should collapse easily after the casting has cooled down and has been extracted after breaking the mould. It is particularly important in case of core making.
(vi) **Cohesiveness** *:* ability of sand grains to stick together. Without cohesiveness, the moulds will lack strength.
(vii) **Adhesiveness** *:* ability of sand to stick to other bodies. If the moulding sand does not stick to the walls of moulding box, the whole mould will slip through the box.

Properties like permeability, cohesiveness and green strength are dependent upon size and shape of sand grains, as also upon the binding material and moisture content present in sand. Clay is a natural binder. Chemical binders like bentonite are sometimes added if clay content in natural sand is not enough.

Generally fresh moulding sand prepared in the foundry has the following composition:
Silica 75% (approx.), Clay 10–15%, Bentonite 2–5% (as required), Coal dust 5–10% and

Moisture 6–8%

CORE

Whenever a hole, recess or internal cavity is required in a casting, a core, which is usually made up of a refractory material like sand is inserted at the required location in the mould cavity before finally closing the mould. A core, being surrounded on all sides by molten metal, should be able to withstand high temperature. It should also be adequately supported otherwise due to buoyancy of molten metal, it will get displaced.

Cores are made with the help of core boxes. Core boxes are made of wood and have a cavity cut in them, which is the shape and size of the core. The sand is mixed and filled in the core boxes. It is then rammed. A core box is made in two halves, each half contains half impression of core. Sometimes a core may need reinforcements to hold it together. The reinforcements are in the shape of wire or nails, which can be extracted from the hole in the casting along with core sand.

CASTING DEFECTS

Some of the common defects in the castings are described below:

1. **Blow-holes:** They appear as small holes in the casting. They may be open to surface or they may be below the surface of the casting. They are caused due to entrapped bubbles of gases. They may be caused by excessively hard ramming, improper venting, excessive moisture or lack of permeability in the sand.
2. **Shrinkage cavity:** Sometimes due to faulty design of casting consisting of very thick and thin sections, a shrinkage cavity may be caused at the junction of such sections. Shrinkage cavity is totally internal.
It is caused due to shrinkage of molten metal. Remedy is to use either a chill or relocation of risers.
3. **Misrun:** This denotes incomplete filling of mould cavity. It may be caused by bleeding of molten metal at the parting of cope and drag, inadequate metal supply or improper design of gating.
4. **Cold shut:** A cold shut is formed within a casting, when molten metal from two different streams meets without complete fusion. Low pouring temperature may be the primary cause of this defect.
5. **Mismatch:** This defect takes place when the mould impression in the cope and drag do not sit exactly on one another but are shifted a little bit. This happens due to mismatch of the split pattern (dowel pin may have become loose) or due to defective clamping of cope and drag boxes.
6. **Drop:** This happens when a portion of the mould sand falls into the molten metal. Loose sand inadequately rammed or lack of binder may cause this defect.
7. **Scab:** This defect occurs when a portion of the face of a mould lifts or breaks down and the recess is filled up by molten metal.
8. **Hot tear:** These cracks are caused in thin long sections of the casting, if the part of the casting cannot shrink freely on cooling due to intervening sand being too tightly packed, offers resistance to such shrinking. The tear or crack usually takes place when the part is red hot and has not developed full strength, hence the defect is called “hot tear”. Reason may be excessively tight ramming of sand.

9. **Other defects** include scars, blisters, sponginess (due to a mass of pin holes at one location) and slag inclusions etc.

Advantages of casting

1. Parts of complex shape can be made easily.
2. Extremely large as well as extremely small objects can be made.
3. The only way to making parts from cast iron is casting
4. Casting parts having high strength to compressive forces.

Disadvantages

1. Melting of metal is required high energy.
2. Labour- intensive process
3. Time taking process. After finishing each step only we can start next step.(without pattern mould cannot be made.)

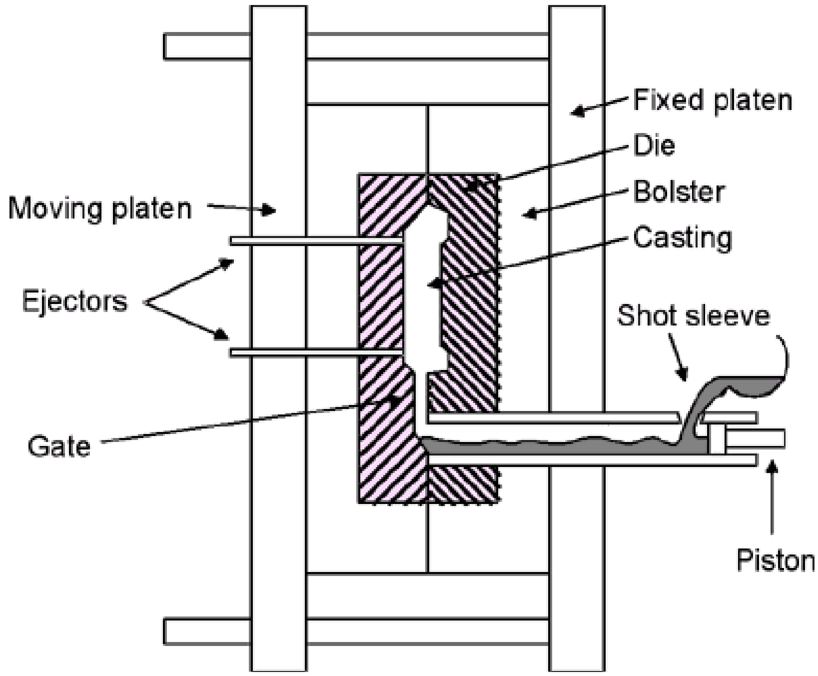
DIE CASTING

A sand mould is usable for production of only one casting. Die is essentially a metal mould and can be used repeatedly. A die is usually made in two portions. One portion is fixed and the other is movable. Together, they contain the mould cavity in all its details. After clamping or locking the two halves of the dies together molten metal is introduced into the dies. If the molten metal is fed by gravity into the dies, the process is known as **gravity die casting** process. On the other hand, if the metal is forced into the dies under pressure (*e.g.*, a piston in a cylinder pushes the material through cylinder nozzle), the process is called "**pressure die casting**". The material of which the dies are made, should have a melting point much higher than the melting point of casting material. A great number of die castings are made of alloys of zinc, tin and lead, and of alloys of aluminium, magnesium and copper. Hence dies are made out of low alloy steels. The dies are usually water or air cooled.

Since most materials contract on cooling, extraction of castings from dies becomes important otherwise they will get entangled in the die as they cool. Therefore, in the design of dies, some arrangement for extraction of casting is incorporated.

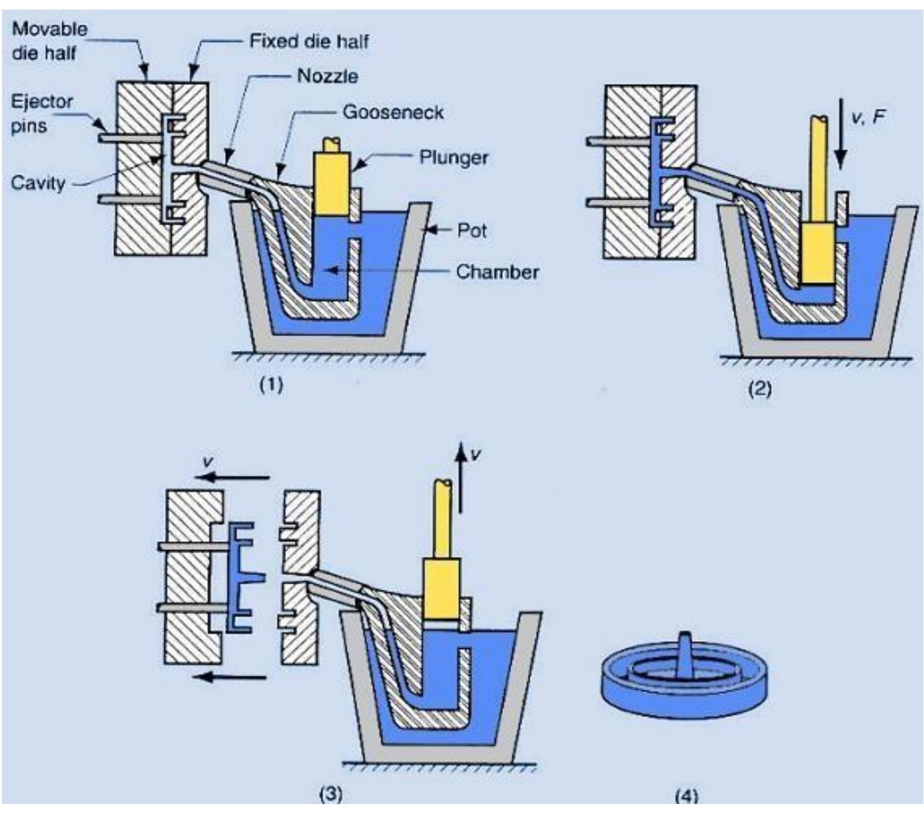
STEPS IN DIE CASTING

1. Close and lock the two halves of a die after coating the mould cavity surfaces with a mould wash, if specified:
2. Inject the molten metal under pressure into the die.
3. Maintain the pressure until metal solidifies.
4. Open die halves.
5. Eject the casting along with runner, riser etc.
6. The above cycle is repeated.

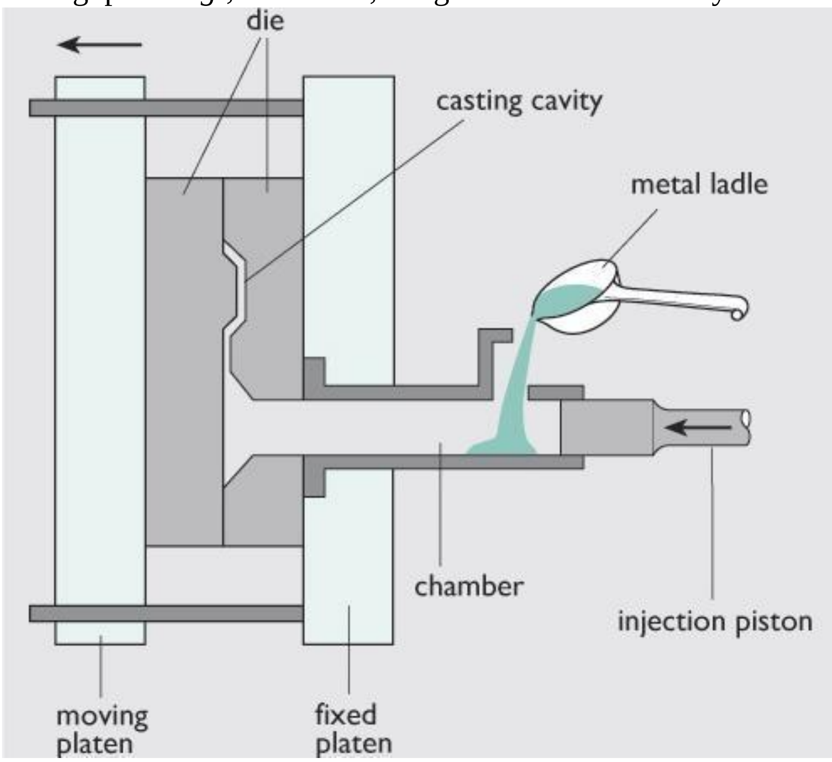


Types of pressure die casting methods:

1. **Hot chamber process:** This uses pressures up to 35 MPa and is used for zinc, tin, lead, and their alloys. In this process the chamber, in which molten metal is stored before being pressure injected into the die, is kept heated.



2. **Cold chamber process:** In this process, pressures as high as 150 MPa are used. The storing chamber is not heated. This process is used mainly for metals and alloys having relatively higher melting point *e.g.*, aluminium, magnesium and their alloys.



Advantages and disadvantages of die casting:

1. It is used for mass production of castings of small and medium size. *e.g.*, pistons of motorcycle and scooter engines, valve bodies, carburetor housings etc.
2. The initial cost of manufacturing a die is very high. It is a disadvantage.
3. This process produces high quality, defect free castings.
4. The castings produced by this process are of good surface finish and have good dimensional control and may not require much machining. All castings produced are identical.
5. Large size castings cannot be produced by this process. It is a disadvantage.
6. Castings with very complex shape or with many cores are difficult to produce by die casting.
7. In case of mass production, castings can be produced cheaply.
8. The process does not require use of sand and requires much less space as compared to a conventional foundry using sand moulds.

Forging

Forging is the process in which, metal and alloys are deformed to the specified shapes by application of repeated compressive force from a hammer. It is usually done hot (hot forging); although sometimes forging is done at room temperature (cold forging). The raw material is usually a piece of a round or square cross-section slightly larger in volume than the volume of the finished component.

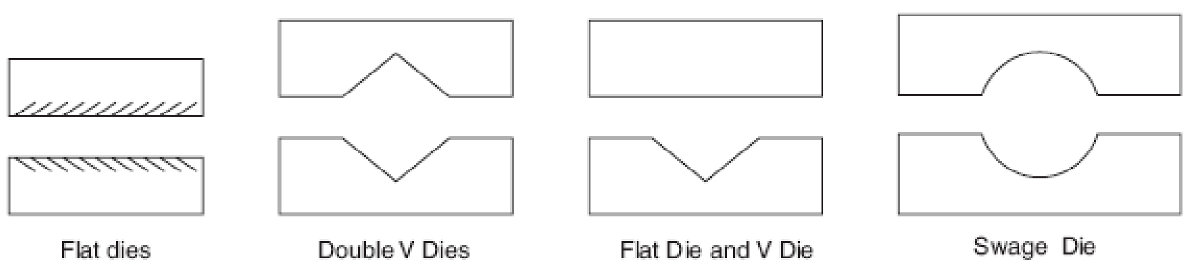
Components produced by forging are bolts, spanners, crane hooks, crankshaft etc

Open-die forging

Open-die forging is also known as ***smith forging***. In open-die forging, a hammer strikes and deforms the work piece, which is placed on a stationary anvil.

Open-die forging gets its name from the fact that the dies do not enclose the work piece, allowing it to flow except where contacted by the dies. Therefore the operator needs to orient and position the work piece to get the desired shape.

The dies are usually flat in shape, but some have a specially shaped surface for specialized operations. For example, a die may have a round, concave, or convex surface or be a tool to form holes or be a cut-off tool.

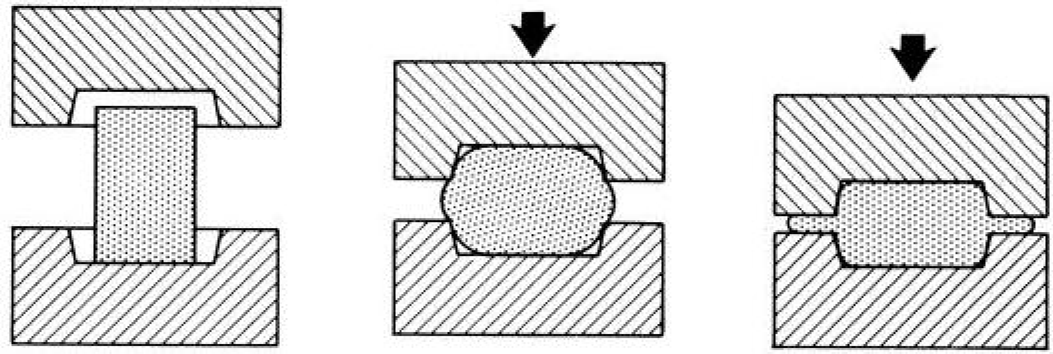


Closed die forging

In closed-die forging metal is placed in a die resembling a mold, which is attached to the anvil. Usually the hammer die is shaped as well. The hammer is then dropped on the work piece, causing the metal to flow and fill the die cavities.

Depending on the size and complexity of the part the hammer may be dropped multiple times in quick succession. Excess metal is squeezed out of the die cavities, forming what is referred to as *flash*.

The flash cools more rapidly than the rest of the material; this cool metal is stronger than the metal in the die so it helps prevent more flash from forming. This also forces the metal to completely fill the die cavity. After forging the flash is removed



Net-shape forging

This process is also known as *precision forging*. This process was developed to minimize cost and waste associated with post forging operations. Therefore, the final product from a precision forging not needed final machining.

Cost savings are gained from the use of less material, and thus less scrap, the overall decrease in energy used, and the reduction or elimination of machining. The downside of this process is its cost; therefore it is only implemented if significant cost reduction can be achieved

Rolling

In this process, metals and alloys are plastically deformed into semi finished or finished products by being pressed between two rolls which are rotating.

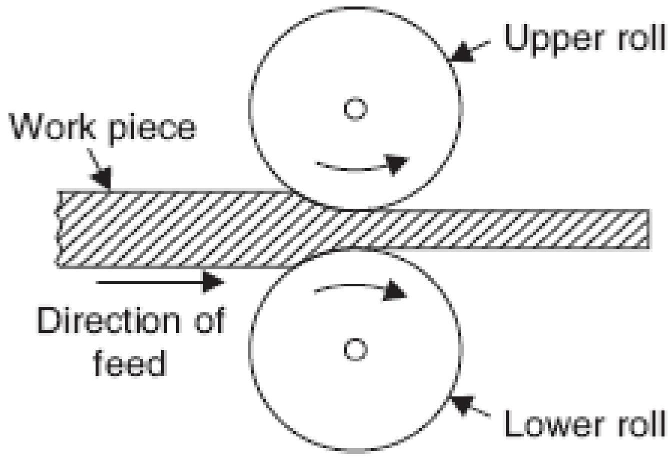
The metal is initially pushed into the space between two rolls, thereafter once the roll grips the edge of the material, the material gets pulled in by the friction between the surfaces of the rolls and the material.

The material is subjected to high compressive force as it is squeezed (and pulled along) by the rolls. This is a process to deal with material in bulk in which the cross-section of material is reduced and its length increased

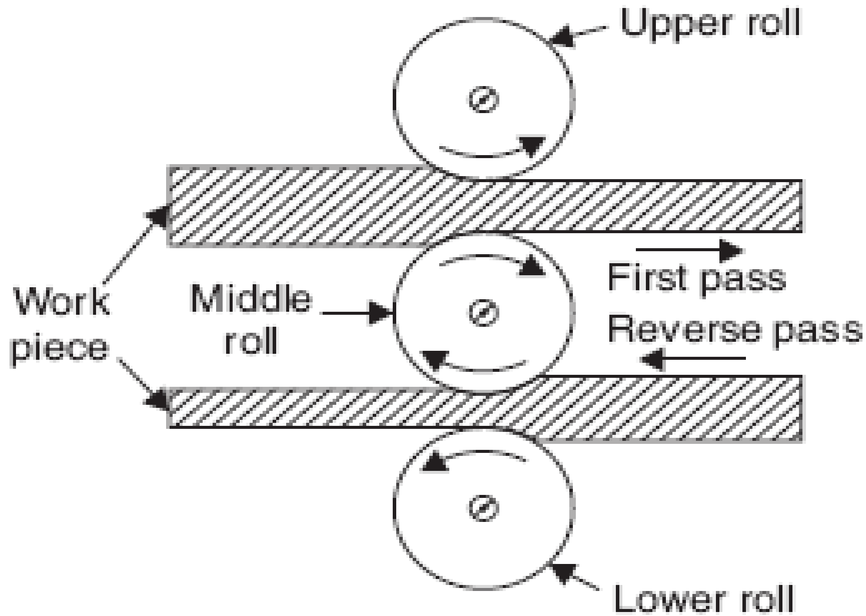
TWO ROLL PROCESS:

It comprises of two heavy rolls placed one over the other. The vertical gap between the rolls is adjustable. The rolls rotate in opposite directions and are driven by powerful electrical motors. Usually the direction of rotation of rolls cannot be altered, thus the work has to be fed into rolls from one direction only.

Since transporting material (which is in red hot condition) from one side to another is difficult and time consuming (material may cool in the meantime), a ‘‘two high reversing mill’’ has been developed in which the direction of rotation of rolls can be changed.



Three high mills:



Extrusion

Extrusion is a process in which the metal is subjected to plastic flow by enclosing the metal in a closed chamber in which the only opening provided is through a die. The material is usually treated so that it can undergo plastic deformation at a sufficiently rapid rate and may be squeezed out of the hole in the die. In the process the metal comes out as a long strip with the same cross-section as the die-opening. The process of extrusion is most commonly used for the manufacture of solid and hollow sections of nonferrous metals (Mg,Al,Cu,Ni etc)and polymers etc . However, some steel products are also made by extrusion.

Extrusion processes can be classified as followed:

(A)Hot Extrusion

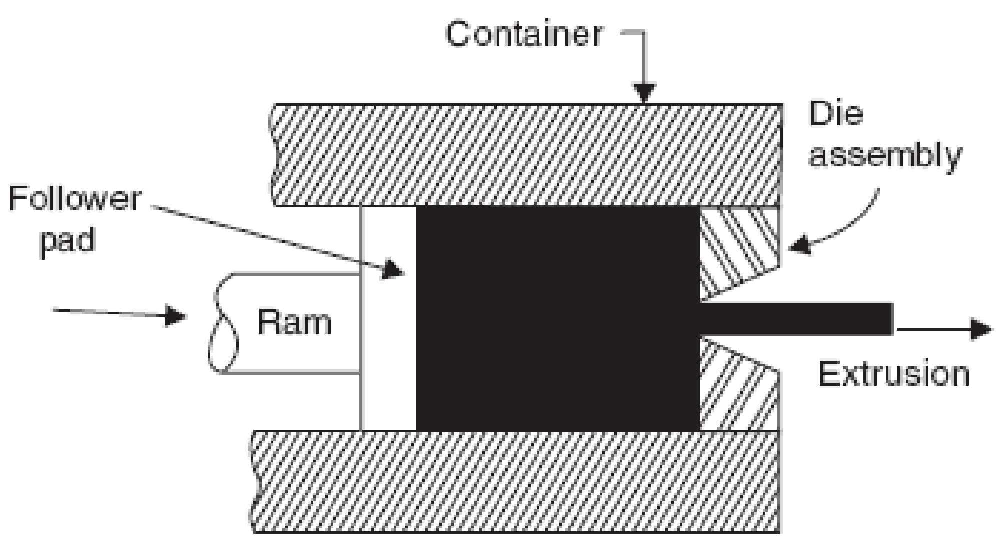
(i) Forward or Direct extrusion.
(ii) Backward or Indirect extrusion.

(B) Cold Extrusion

(i) Hooker extrusion.
(ii) Hydrostatic extrusion.
(iii) Impact extrusion.
(iv) Cold extrusion forging.

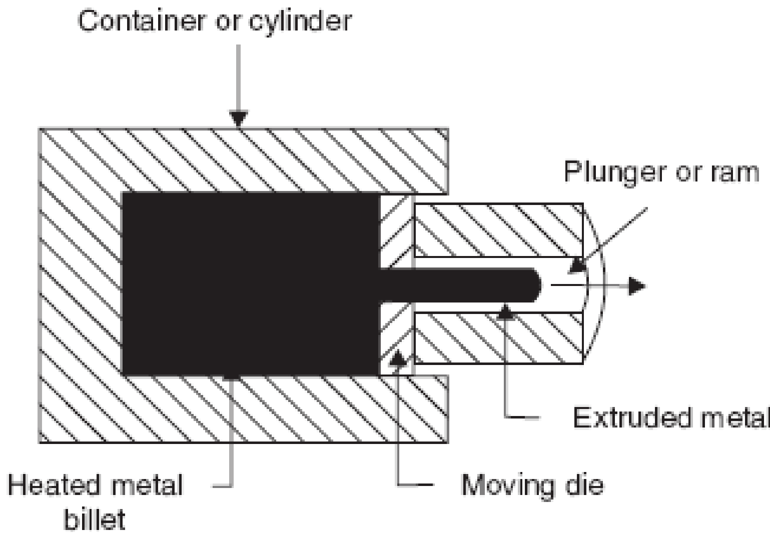
Forward or direct extrusion process:

The material to be extruded is in the form of a block. It is heated to requisite temperature and then transferred to a chamber. This block kept between the ram and die. In the front portion of the chamber, a die with an opening in the shape of the cross-section of the extruded product, is fitted. The block of material is pressed from behind by means of a ram and a follower pad. As the ram moves forward, pressure develops and metal plastically deforms. Since the chamber is closed on all sides, the heated material is forced to squeeze through the die-opening in the form of a long strip of the required cross-section.



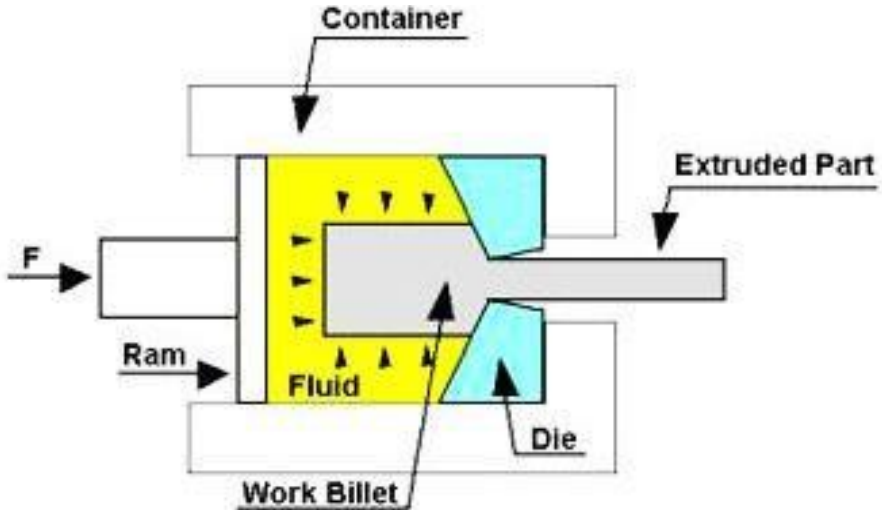
Backward or indirect extrusion:

The block of heated metal is inserted into the container/chamber. It is confined on all sides by the container walls except in front, where a ram with the die presses upon the material. As the ram presses backwards, the material has to flow forwards through the opening in the die. The ram is made hollow so that the bar of extruded metal may pass through it unhindered. This process is called backward extrusion process as the flow of material is in a direction opposite to the movement of the ram. In the forward extrusion process the flow of material and ram movement were both in the same direction.



Hydrostatic extrusion:

It is a type of cold extrusion process. In the hydrostatic extrusion process the billet is completely surrounded by a pressurized liquid, except where the billet contacts the die. The fluids commonly used are glycerin, ethyl glycol, mineral oils, castor oil mixed with alcohol etc. these fluids are helpful in reducing the friction between metal block and chamber surface. This is a direct extrusion process. Pressure is applied to the metal blank on all sides through the fluid medium.



The advantages of Hydrostatic extrusion process include:

- No friction between the container and the billet reduces force requirements. This ultimately allows for faster speeds, higher reduction ratios, and lower billet temperatures.
- Usually the ductility of the material increases when high pressures are applied.
- An even flow of material.
- Large billets and large cross-sections can be extruded.
- No billet residue is left on the container walls.

The disadvantages are

- The billets must be prepared by tapering one end to match the die entry angle. This is needed to form a seal at the beginning of the cycle.
- Handling the fluid under high pressures can be difficult.

Welding

Welding means the process of joining two metal parts together to give strong joint . The welding process is subdivided into two main classes.

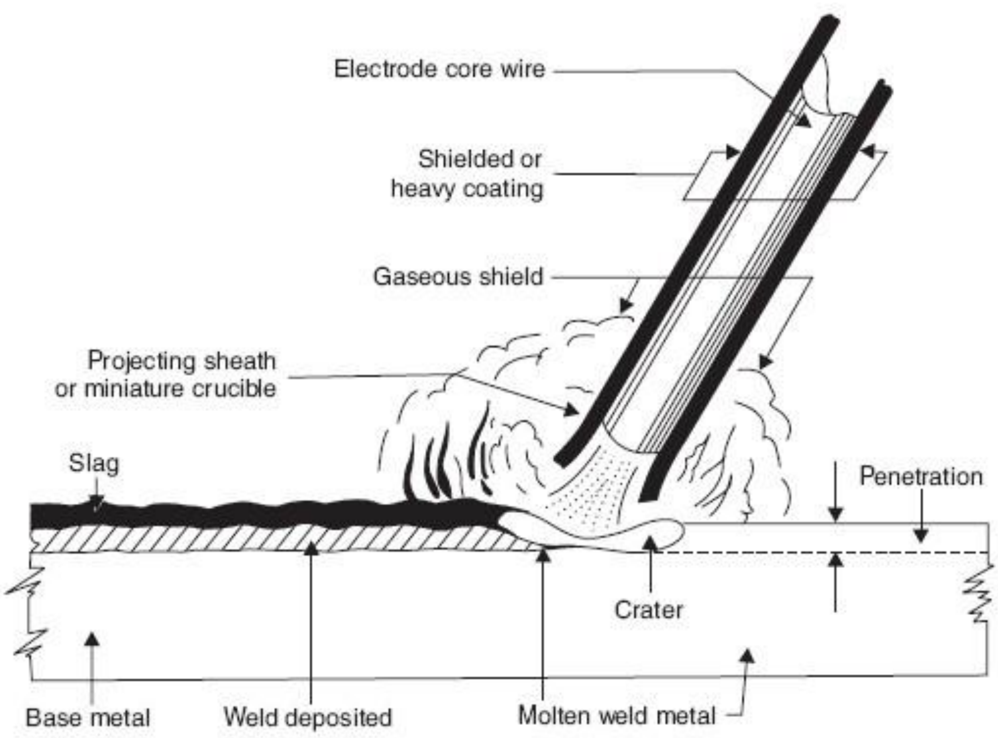
2. **Fusion welding:** which involves heating the ends of metal pieces to be joined to a temperature high enough to cause them to melt or fuse and then allowing the joint to cool. The joint, after the fused metal has solidified will result in a strong joint.

3. **Pressure welding:** which involves heating the ends of metal pieces to be joined to a high temperature, but lower than their melting point and then keeping the metal pieces joined together under pressure for some time. This results in the pieces welding together to produce a strong joint

Based on the sources of heat, fusion welding is again classified to different type

- Electric arc welding: electric arc is the source of heat
- Gas welding: A burning gas is producing the heat. Normally acetylene is used.
- Electric resistance welding: heat produced from the electric resistance of material
- Thermite welding: chemical reaction is the source of heat. Etc
- Laser welding: heat produced using Laser.

SMAW (shielded metal arc welding)



it is a

An electric current, welding power supply is used to form an electric arc between the electrode and the metal to be joined. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination

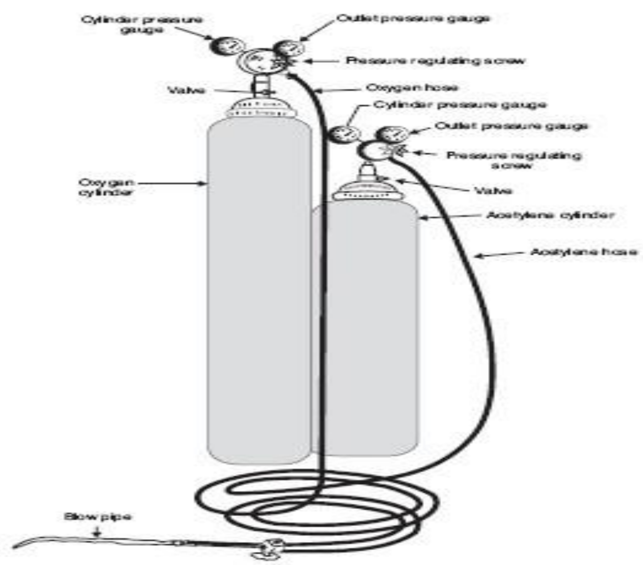
Oxy fuel welding

It is a welding process in which required heat is obtained by a combustion of a fuel gas. The heat used to melt the ends of work pieces to be joined an also to melt the filler metal rod(welding rod). Several gas mixtures are using but mainly acetylene is mostly used for welding as it produces high temp. of order of 3200°c. Acetylene gas is obtained by mixing calcium carbide with water

$CaC_2+2H_2O=Ca(OH)_2+C_2H_2$

$C_2H_2+O_2=4CO+H_2$

$4CO+ 2H_2+3\ O_2=4CO_2+2H_2O$



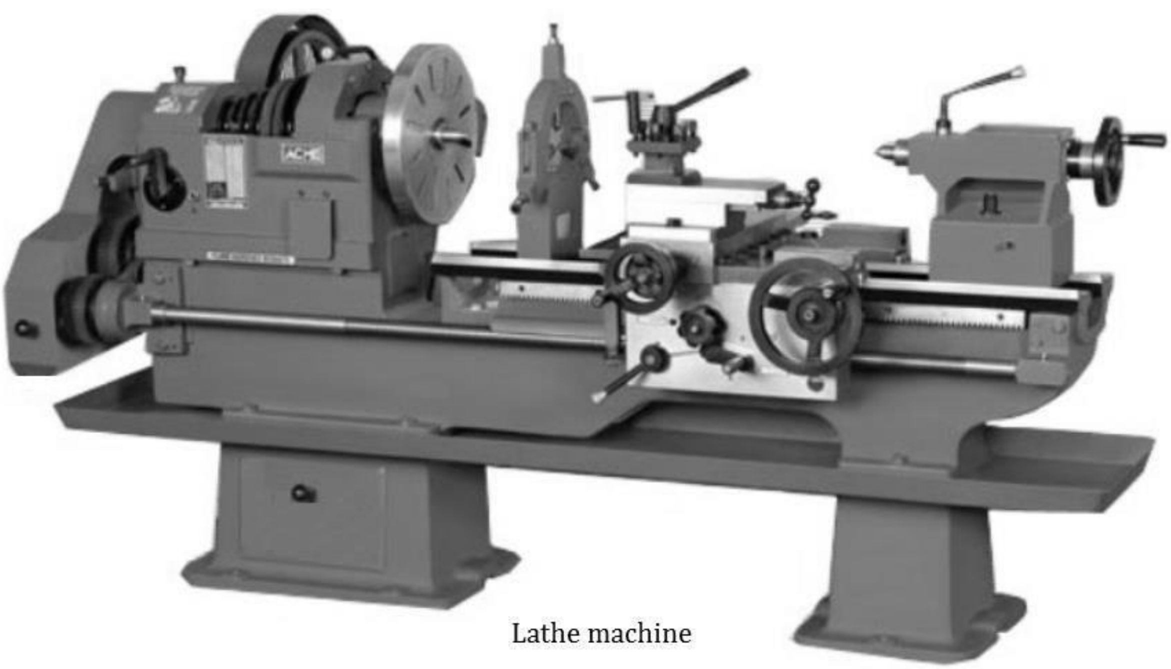
Acetylene and oxygen are stored separately in different cylinders as shown in fig. and these gases are mixed in the welding torch /blow pipe as shown below. Tube from oxygen cylinder and acetylene cylinder are connected to respective valves. These gases are mixed in the mixing chamber and mixture is sent out through the tip of head tube.

MODULE-6

LATHE

Introduction

The lathe is a machine tool, which holds the work piece between two rigid and strong supports called centers or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post, which is held against the revolving work. The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work.



Lathe machine

Common types of lathes

1. Speed lathe
    a. Woodworking lathe
    b. Centering lathe
    c. Polishing lathe
    d. Metal spinning lathe
2. Engine lathe
    a. Belt driven lathe
    b. Individual motor driven lathe
    c. Gear head lathe

3. Bench lathe

4. Tool room lathe

5. Semi-automatic lathe

    a. Capstan lathe

    b. Turret lathe

6. Automatic lathe

7. Special purpose lathe

    a. Wheel lathe

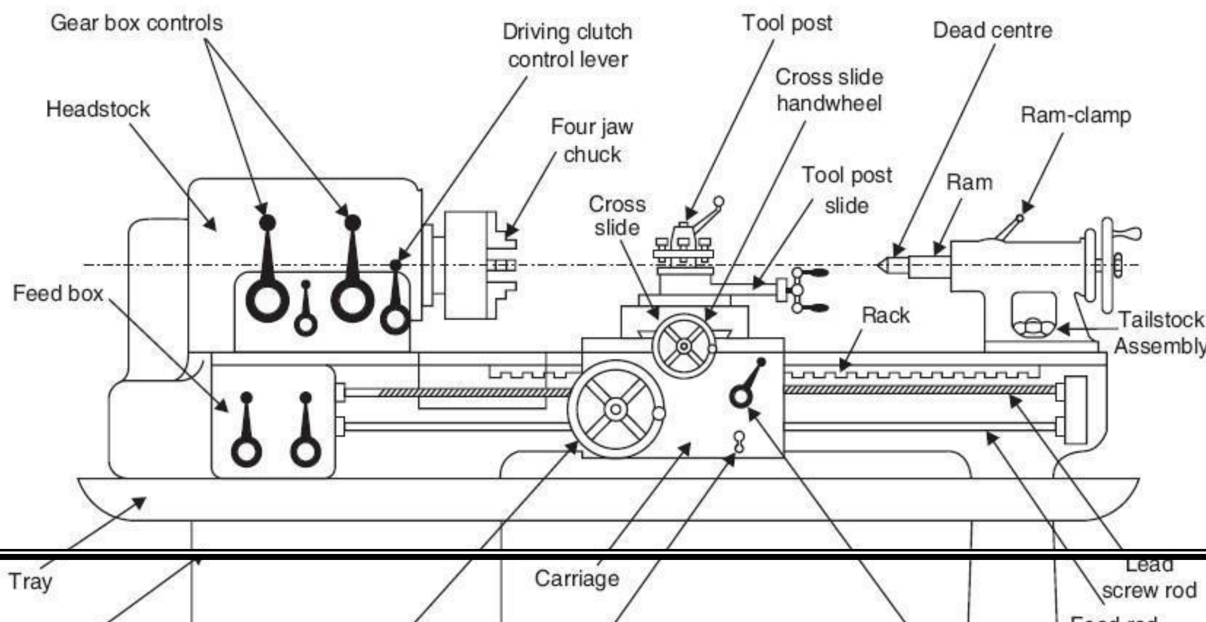
    b. Gap bed lathe

    c. ‘T’ lathe

    d. Duplicating lathe

8. Computer Numeric Control lathe (CNC lathe)

Principal parts of an engine lathe



1. **Bed:** The bed is a heavy, rugged casting and it carries the headstock and tailstock for supporting the work piece and provides a base for the movement of carriage assembly, which carries the tool.

2. **Headstock**: The headstock is provided in the left hand side of the bed and it serves as housing for the driving pulleys, back gears, headstock spindle, live centre and the feed reverse gear. The headstock spindle is a hollow cylindrical shaft that provides a drive from the motor to work holding devices.

3. **Gear Box**: The quick-change gearbox is placed below the headstock and contains a number of different sized gears.

4. **Carriage**: The carriage is located between the headstock and tailstock and serves the purpose of supporting, guiding and feeding the tool against the job during operation. The main parts of carriage are:

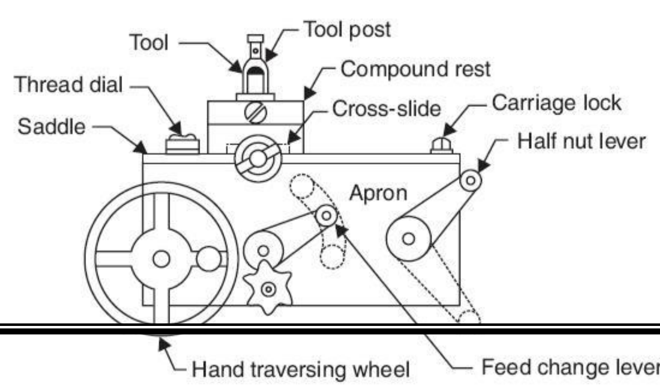
a) **The saddle** is an H-shaped casting mounted on the top of lathe ways. It provides support to the cross-slide, compound rest and tool post.

b) **The cross slide** is mounted on the top of saddle, and it provides a mounted or automatic cross movement for the cutting tool.

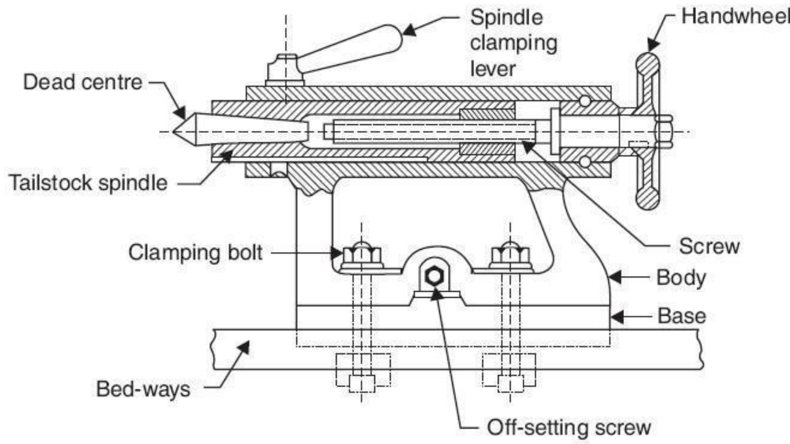
c) **The compound rest** is fitted on the top of cross slide and is used to support the tool post and the cutting tool.

d) **The tool post** is mounted on the compound rest, and it rigidly clamps the cutting tool or tool holder at the proper height relative to the work centre line.

e) **The apron** is fastened to the saddle and it houses the gears, clutches and levers required to move the carriage or cross slide. The engagement of split nut lever and the automatic feed lever at the same time is prevented she carriage along the lathe bed.



5. **Tailstock**: The tailstock is a movable casting located opposite the headstock on the ways of the bed. The tailstock can slide along the bed to accommodate different lengths of work piece between the centers. A tailstock clamp is provided to lock the tailstock at any desired position.



Tailstock

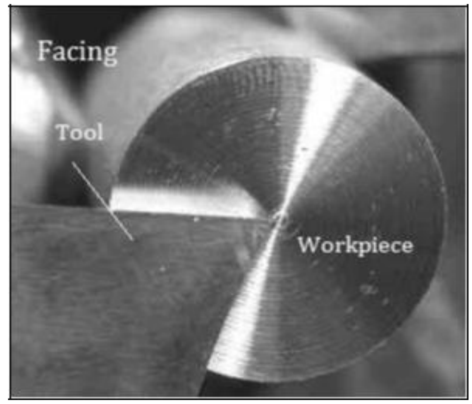
6. **Lead screw:** A lead screw also known as a power screw is a screw, moves the carriage by a precise increment for every rotation of the screw. The lead screw is made with square, acme, or buttress type threads.

Lathe operations

The engine lathe is an accurate and versatile machine, on which many operations can be done on this machine. These operations are:

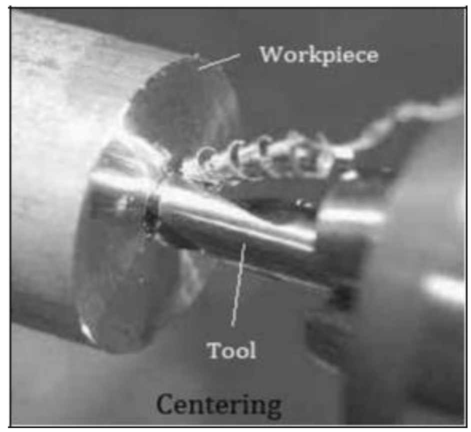
1. Facing
2. Centering
3. Turning
4. Parting
5. Drilling
6. Boring
7. Reaming
8. Knurling
9. Forming
10. Chamfering
11. Thread cutting

Facing



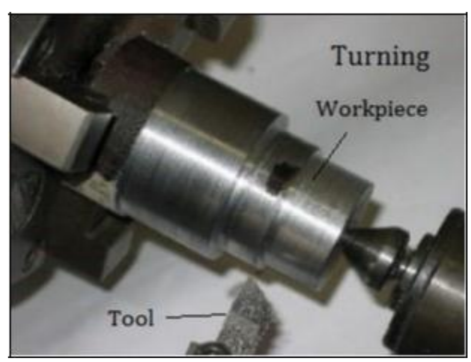
Facing is the process of removing metal from the end of a work piece by using a single point cutting tool, to produce a flat surface. Figure shows the details of facing operation.

Centering



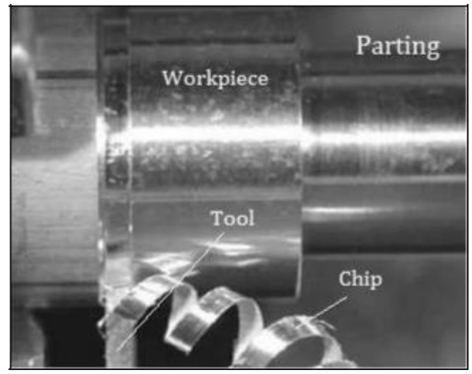
Centering is the process of providing a small tapered hole at end of a work piece by using centering tool, which can helpful to accommodate and support a running centre in the tailstock. Figure shows the details of centering operation.

Turning



Turning is the process of removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal.

Parting



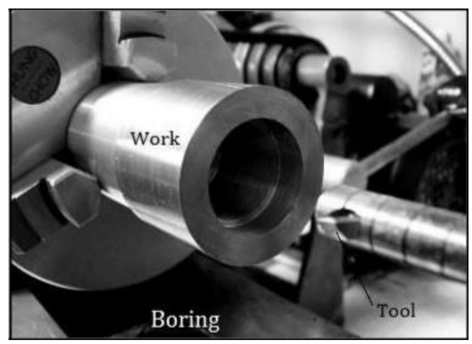
Parting is the process of cut off the work piece at a specific length by using a blade-like cutting tool. It is normally used to remove the finished end of a work piece from the bar stock that is clamped in the chuck.

Drilling

Drilling is the process of making holes at the end face of the work piece by using a drill bit, fixed with drill chuck, clamped at tailstock.

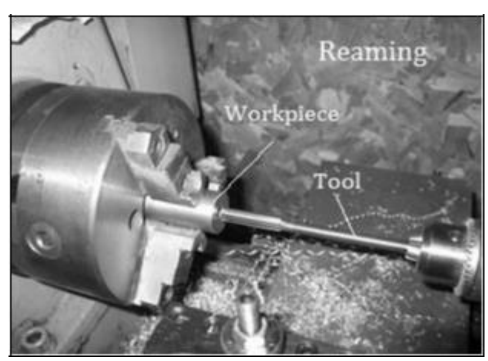
Boring

Boring is the process of enlarging a hole that has already been drilled or cast, by using a single point cutting tool or boring head containing several such tools.



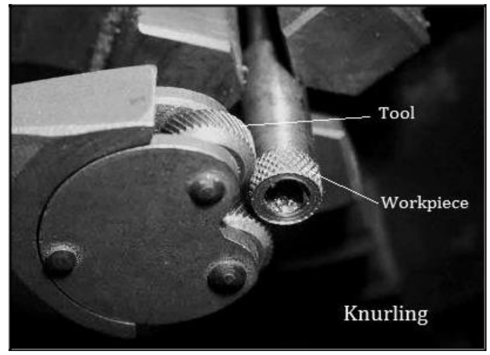
Reaming

Reaming is the process of finishing a drilled or bored hole with great degree of accuracy. The drilled or bored hole not always is straight or accurate.

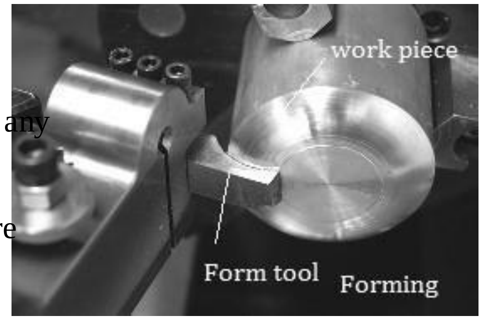


Knurling

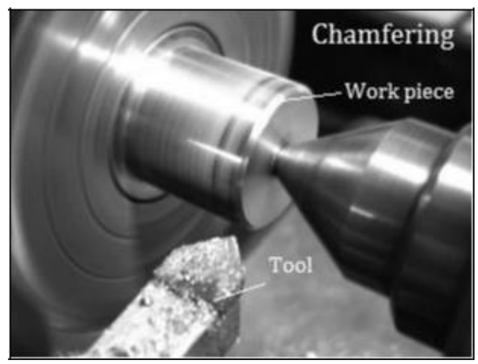
Knurling is a process of making easy-to-grip geometric pattern on a finished outer surface of work pieces like handles, knobs, rollers, etc. to hold them firmly. Figure shows the details and geometric pattern of knurled grips.



Forming



Forming is a process of produces a convex, concave or any irregular profile on the work piece by using a form tool. Figure shows the details of forming operation.



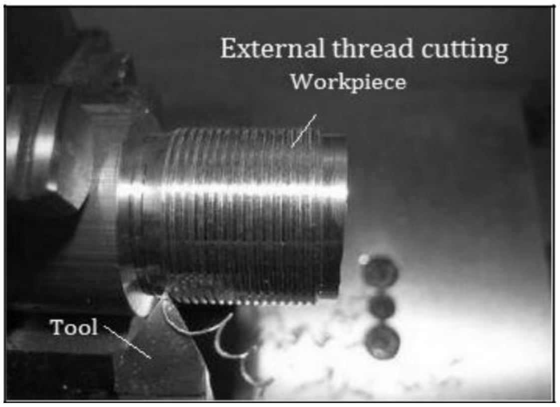
Chamfering

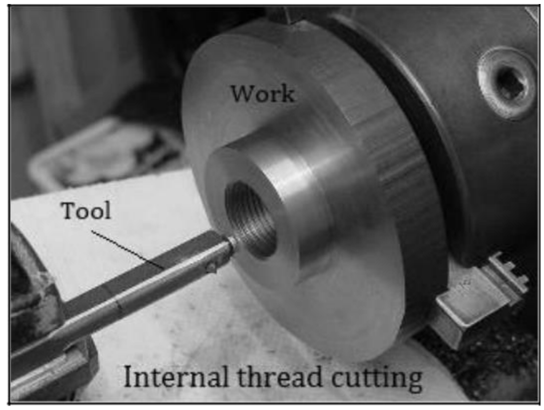
Chamfering is a process of bevelling the extreme end of a work piece. This is done to remove the burrs and sharp edges from the extreme end of the work piece.

Thread cutting

Thread cutting is a process of cutting very accurate screw threads by using a single point cutting tool, which is the process of guiding the linear motion of the tool bit in a precisely known ratio to the rotating

motion of the work piece.



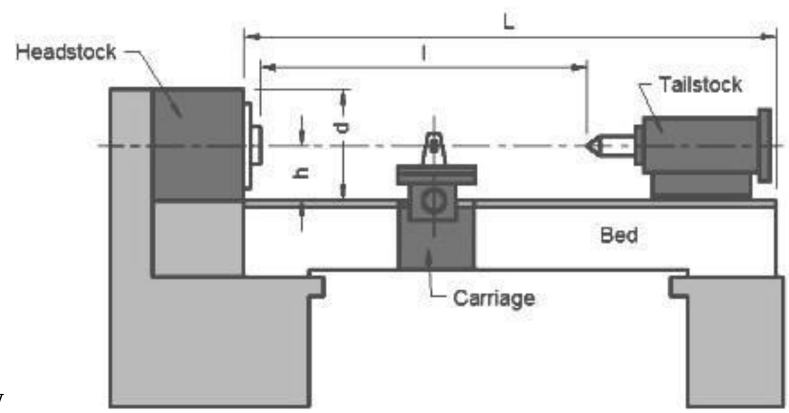


Lathe specifications

In order to identify or to purchase a lathe machine, certain standard of specification must be considered.

Following are some of the important required specifications.

1. Length of bed
2. Length between centres
3. Centre height
4. Swing diameter over bed
5. Horse power of the motor
6. Number of spindle speeds
7. Number of feeds
8. Bore diameter of the spindle
9. Width of the bed
10. Type of the bed
11. Pitch value of the lead screw
12. Spindle nose diameter
13. Floor space required
14. Type of the machine



Specification of a lathe

L - Length of bed
l - Length between lathe centres
h - Centre height
d - Swing diameter over bed

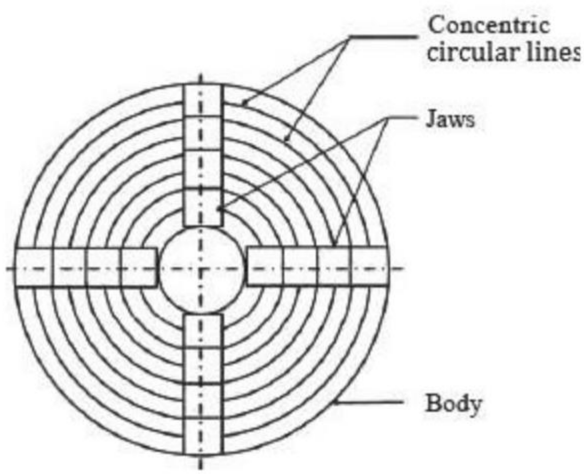
Work holding devices

Work holding devices are used to hold and rotate the work pieces along with the spindle. Following are the different types of work holding devices used in a lathe shop:

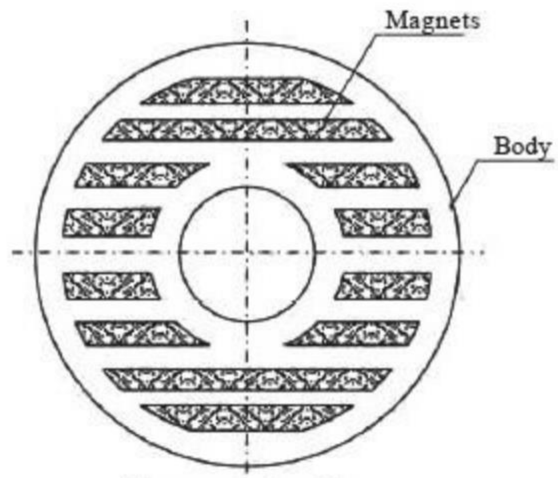
1. Chucks
2. Face plate
3. Driving plate
4. Catch plate
5. Carriers
6. Mandrels
7. Centres
8. Rests

Chucks

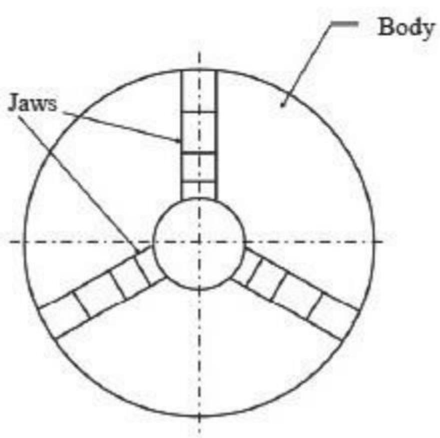
Work pieces of short length, large diameter and irregular shapes, which cannot mounted directly between centres, held quickly and rigidly in chuck. Different types of chucks are, three jaws universal chuck, four jaw independent chuck, magnetic chuck, collet chuck and combination chuck.



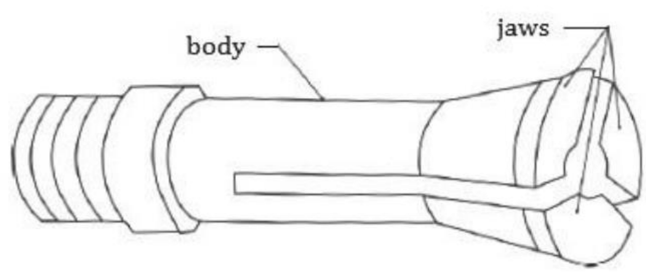
Four jaw chuck



Magnetic chuck



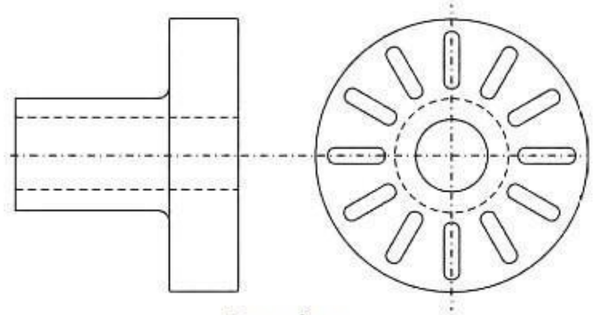
Three jaw chuck



Collet chuck

Face plate

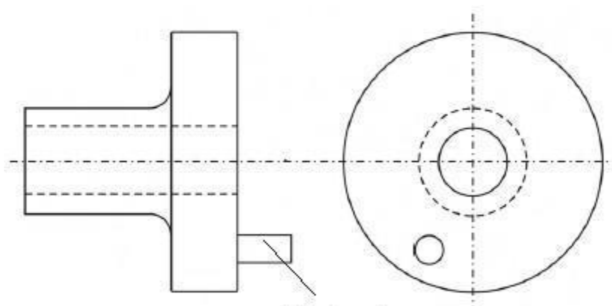
Faceplate is used to hold large, heavy and irregular shaped work pieces, which cannot be conveniently held between centres. It is a circular disc bored out and threaded to fit to the nose of the lathe spindle. It provided with radial plain and 'T' slots for holding the work by bolts and clamps.



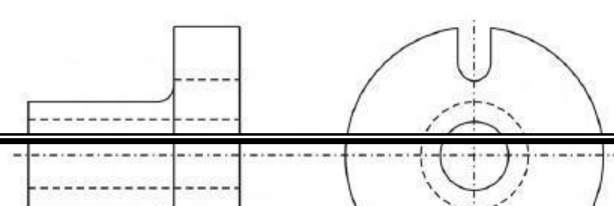
Face plate

Driving plate

The driving plate is used to drive a work piece when it is held between centres. It is a circular disc screwed to the nose of the lathe spindle. It is provided with small bolts or pins on its face.



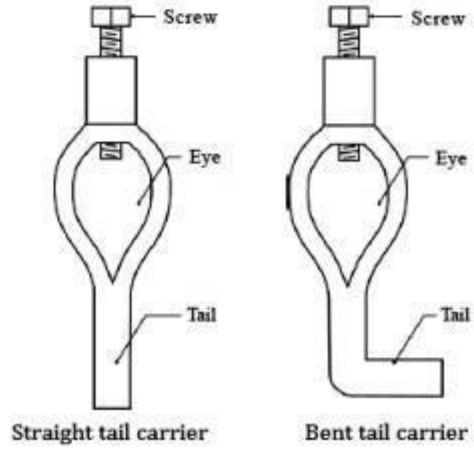
Catch plate



When a work piece is held between centres, the catch plate is used to drive it. It is a circular disc bored and threaded at the centre. Catch plates are designed with ‘U’ – slots or elliptical slots to receive the bent tail of the carrier.

Carriers

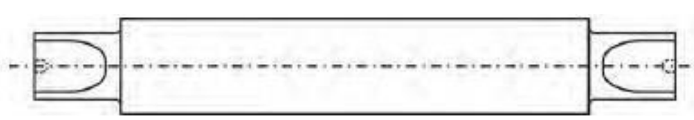
When a work piece is held and machined between centres, carriers are useful in transmitting the driving force of the spindle to the work by means of driving plates and catch plates. The work is held inside the eye of the carrier and tightened by a screw. Carriers are of two types and they are: Straight tail carrier and Bent tail carrier. Straight tail carrier is used to drive the work by means of the pin provided in the driving plate. The tail of the bent tail carrier fits into the slot of the catch plate to drive the work.



Carriers

Mandrels

A previously drilled or bored work piece is held on a mandrel to be driven in a lathe and machined. There are centre holes provided on both faces of the mandrel. The


Plain mandrel

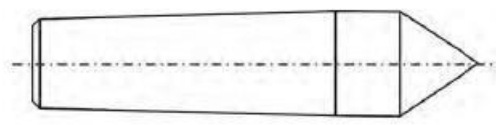
live centre and the dead centre fit into the centre holes. A carrier is attached at the left side of the mandrel. The mandrel gets the drive either through a catch plate or a driving plate. The work piece rotates along with the mandrel. There are several types of mandrels and they are:

7. Plain mandrel 2. Step mandrel 3. Gang mandrel 4. Screwed mandrel 5. Collar mandrel

6. Cone mandrel 7. Expansion mandrel

1.5.6.7 Centres

Centres are useful in holding the work in a lathe. The shank of a centre has Morse taper on it and the face is conical in shape. There are two types of centres, namely



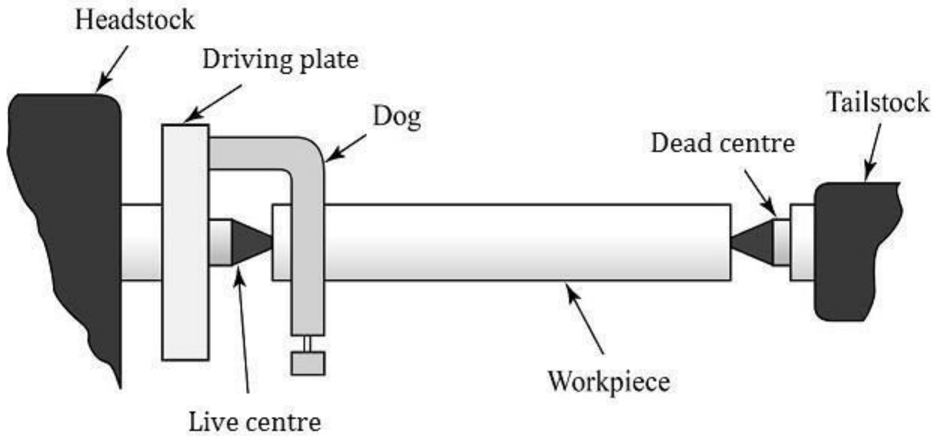
Centre

1. Live centre
2. Dead centre

The live centre is fitted on the headstock spindle and rotates with the work. The centre fitted on the tailstock spindle is called dead centre. Centres are made of high carbon steel and hardened and then tempered. So the tips of the centres are wear resistant. Different types of centres are available according to the shape of the work and the operation to be performed. They are

1. Ordinary centre
2. Ball centre
3. Half centre
4. Tipped centre
5. Pipe centre
6. Revolving centre
7. Inserted type centre

Figure below shows different work holding devices



Holding workpiece between centres

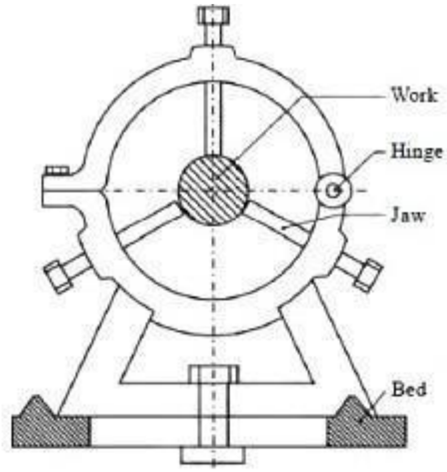
Rests

A rest is a mechanical device to support a long slender work piece when it is turned between centres or by a chuck. It is placed at some intermediate point to prevent the work piece from bending due to its own weight and vibrations setup due to the cutting force. There are two different types of rests.

1. Steady rest
2. Follower rest

Steady rest

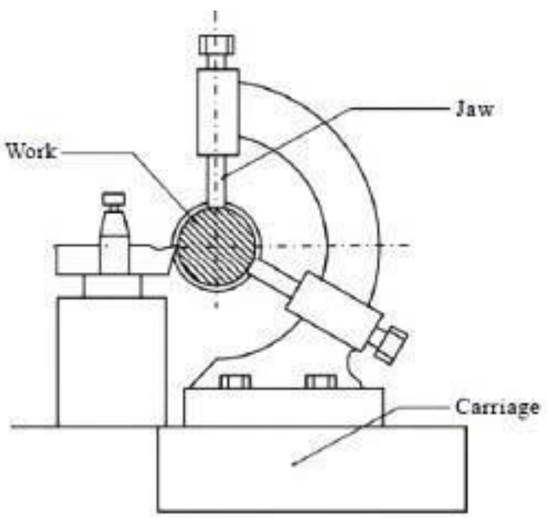
Steady rest is made of cast iron. It may be made to slide on the lathe bed ways and clamped at any desired position where the work piece needs support. It has three jaws. These jaws can be adjusted according to the diameter of the work. Machining is done upon the distance starting from the headstock to the point of support of the rest. One or more steady rests may be used to support the free end of a long work.



Steady rest

Follower rest

A follower rest consists of a "C" like casting having two adjustable jaws which support the work. The rest is bolted to the back end of the carriage and moves with it. Before setting the follower rest, the end of the work piece is machined slightly wider than the jaws to provide the true bearing surface. The tool is slightly in advance position than the jaws, and the tool is fed longitudinally to the carriage, the jaws always follow the tool giving continuous support to the work piece. The follower rest prevents the job from springing away when the cut is made and is used in finish turning operation. The follow rest is normally used with small diameter stock to prevent the work piece from "springing" under pressure from the turning tool.



Follower rest

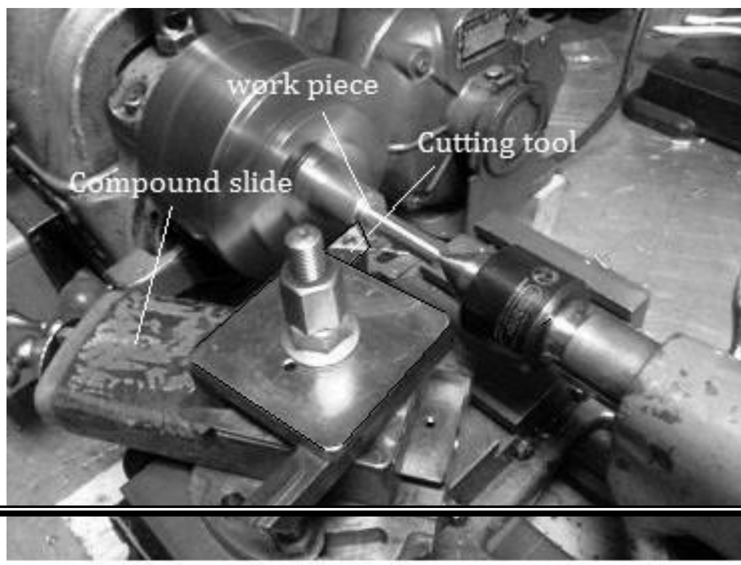
Taper turning

Taper turning is an operation performed on a lathe that feeds a tool at an angle to the length of the work piece in order to create a conical shape. There are different taper turning methods, which are:

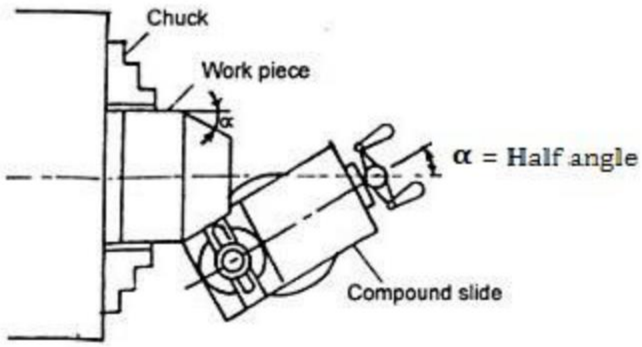
1. Swivelling the compound rest method
2. Form tool method
3. Tailstock set over method
4. Taper turning attachment method
5. Combined feed method

Taper turning by swivelling the compound rest

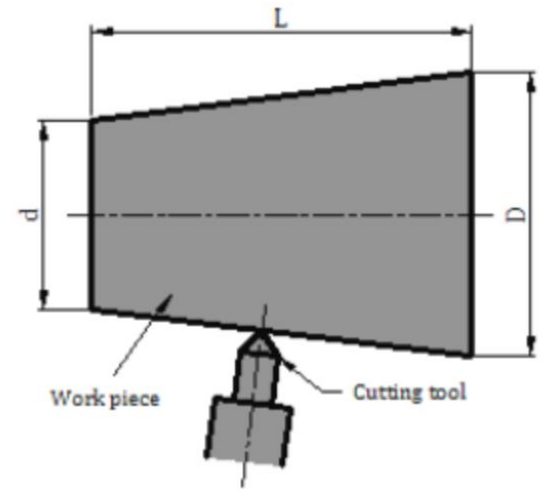
This method employs the principle of turning taper by rotating the work piece on the lathe axis and feeding the tool at an angle to the axis of rotation of the work piece. The tool mounted on the compound rest is attached to a



circular base, graduated in degree, which may be swiveled and clamped at any desired angle. Once the compound rest is set at the desired half taper angle, rotation of the compound slide screw will cause the tool to be fed at that angle and generate a corresponding taper. This method is limited to turning a short taper owing to the limited movement of the cross slide.



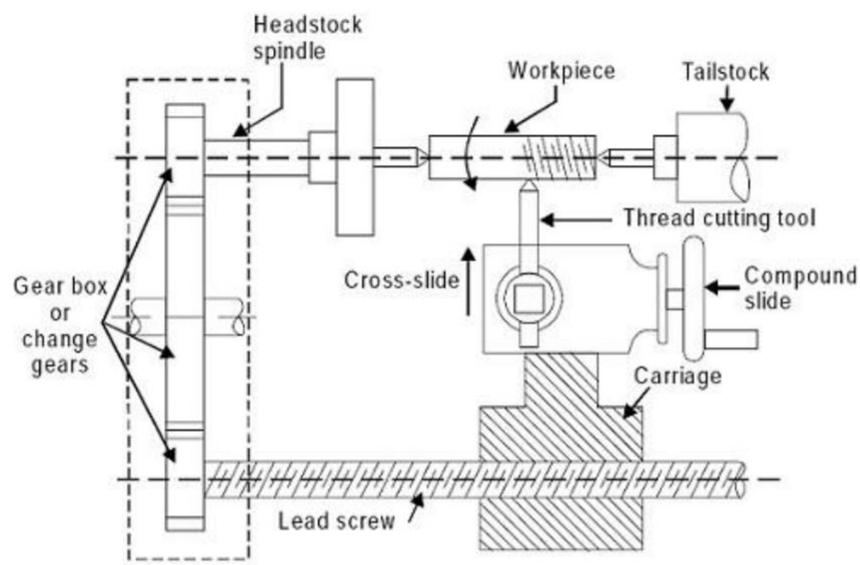
Taper turning by swiveling the compound rest



Taper angle, $\tan \alpha = \frac{D-d}{2L}$

D = Major diameter
d = Minor diameter
L = Length of slope

$$\alpha = \tan^{-1}\left(\frac{D-d}{2L}\right)$$



Thread cutting

Thread cutting

Thread cutting is an operation of producing helical grooves on round shaped work pieces such as V, square or power threads on a cylindrical surface. Following are the various steps for the threading process.

- In thread cutting operation the first step is to remove the excess material from the work piece to make its diameter equal to the major diameter of the thread to be cut.

- The shape or form of the thread depends on the shape of the cutting tool to be used. The tool point must be ground so that it has the same angle as the thread to be cut. In a metric thread the included angle of the cutting edge should be ground exactly 60°. Typical angles are 60° for ‘V’ threads, and 29° for ACME threads.
- The top of the nose of the tool should be set at the same height as the centre of the work piece.

- The correct gear ratio is required between the machine spindle and the lead screw. This can be determined in the following manner:

DRILLING MACHINE

Drilling machine is a machine tool designed for drilling holes in metallic and non metallic materials. The cutting tool is a multi-point cutting tool, known as drill.

PRINCIPAL PARTS OF THE DRILLING MACHINE

1. **Head**: Head contains the electric motor, v pulleys and v belt which transmit rotary motion to the drill spindle at a no. of speeds.

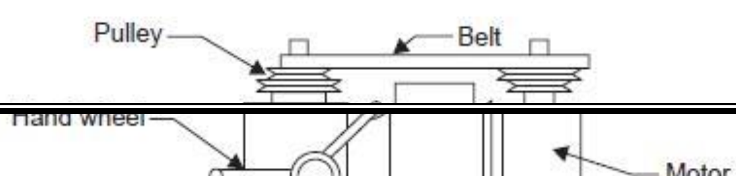
Spindle: spindle is made up of alloy steel. It rotates as well as moves up and down in a sleeve.

Drill chuck: It is held at the end of the drill spindle and in turn it holds the drill bit.

1. **Adjustable table**: It is supported on the column of the drilling machine and can be moved vertically and horizontally. It also carries slots for bolts clamping.

Base: It supports the column, which, in turn, supports the table, head etc.

1. **Column**: It is a vertical round or box section, which rests on the base and supports the head and the table



DRILLING MACHINE OPERATIONS

The following are the most common operations performed on the drilling machine

Drilling: it is an operation of producing a circular hole in a work piece by forcing a drill in the work piece.

1. **Boring**: it is an operation of enlarging a hole that has already been drilled. Single point cutting tool is used in boring.

2. **Reaming**: Reaming is done with reamers. It is done to generate the hole of proper size and finish after drilling

Tapping: It is an operating of producing internal threads in a hole by means of a tap.

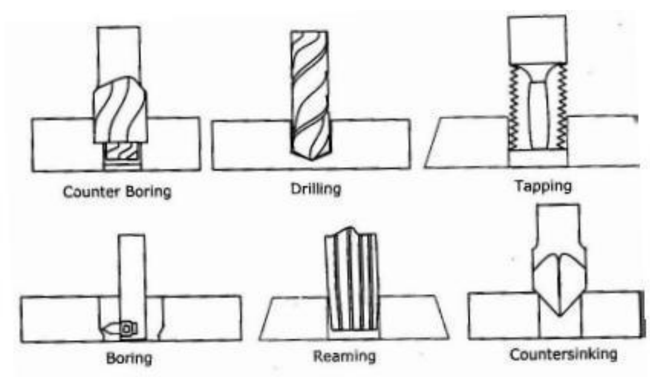
1. **Counter Boring:** It is an operation of enlarging the entry of a drilled hole to accommodate the bolt head etc. Counter boring tool does it.

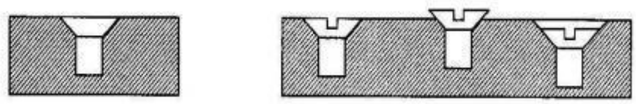
Spot Facing: It is an operation done on the drilled hole to provide smooth seat for bolt head.

1. **Counter Sinking:** It is an operation to bevel the top of a drilled hole for making a conical seat. A counter sunk drill is used in this operation.

8.Trepanning

Trepanning is the operation of producing a hole in sheet metal by removing metal along the circumference of a hollow cutting tool. Trepanning operation is performed for producing large holes





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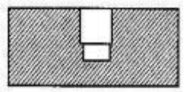
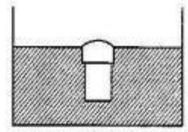
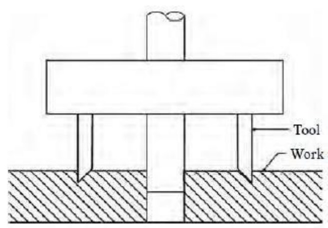
Countersunk hole



Counterbored hole



Spot faced hole



TYPES OF DRILLING MACHINE.

1. Portable drilling machine

2. Sensitive drilling machine

   Bench mounting and floor mounting

3. Upright drilling machine(Round column and box column section)

4. Radial drilling machine
   5. Plain, semi universal and universal

6. Gang drilling machine

7. Multiple spindle drilling machines.

8. Automatic drilling machine

9. Deep hole drilling machine(vertical and horizontal)

Portable drilling machine

1. Can be operated with ease anywhere in the workshop and is used for drilling holes in the work piece in any position which cannot be drilled in a standard drilling machine.

2. Most of the portable drilling machines are driven by motor.

Bench drilling machine

1. These are light duty machines used in small workshops. Also called Sensitive drilling machines, because of its accurate and well balanced spindle.

2. Used for drilling small holes at high speed in light jobs

3. Holes of diameter 1 mm to 15 mm can be drilled.

4. There is no arrangement for any automatic feed of the drill spindle. Feed is purely by hand control.

5. As the operator senses the cutting action, at any instant it is called sensitive drilling machine.

Upright drilling machine

1. These are designed for handling medium sized work pieces.

2. In construction it is similar to sensitive drilling machine but it is heavier than sensitive drilling machine.

3. In this large number of spindle speeds and feeds are available.

4. But it is heavier than sensitive drilling machine

Radial drilling machine

- These are heavy duty and versatile drilling machine used to perform drilling operate on large and heavy work piece. Holes up to 7.5 cm.

- Work piece is marked for exact location and mounted on the work table. Drill bit is then located by moving the radial arm and drill to the marked location. By starting drill spindle motor holes are drilled.

Gang drilling machine

- When a number of single spindle drilling machine columns are placed side by side on a common base and a common work table , the machine is known as gang drilling machine.

- In a gang drilling machine 4 to 6 spindles may be mounted side by side.

- The speed and feed of the spindles are controlled independently.

- Each spindle may be set up properly with different tools for different operations.

- A series of operations may be performed on the work by simply shifting the work from one position to the other on the work table.

Multiple spindle drilling machines

- Used to drill a number of holes in a piece of work simultaneously and to reproduce the same pattern of holes in a number of identical pieces in a mass production work.
- In this several spindles are driven by a single motor and all the spindles holding drills are fed into the work simultaneously.
- Feed may be obtained by raising the table or lowering the drill head.

Deep hole drilling machine

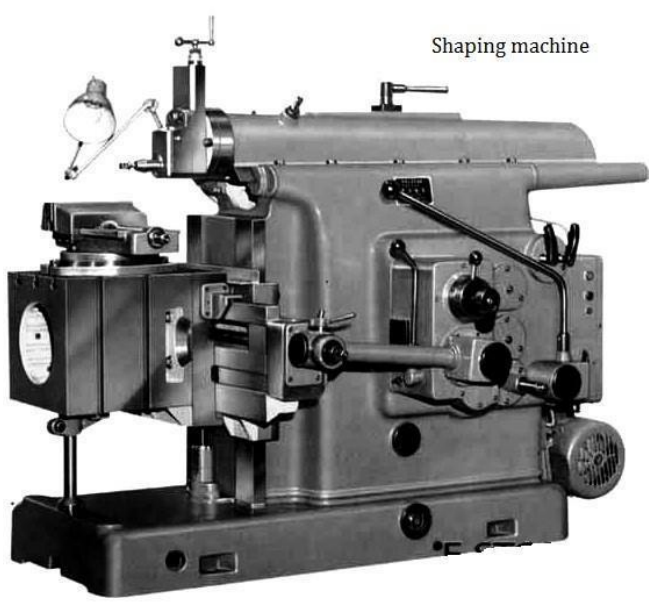
Special machines and drills are required for drilling deep holes in long shaft, crank shaft, rifle barrels

This machine is operated at high speed and low feed.

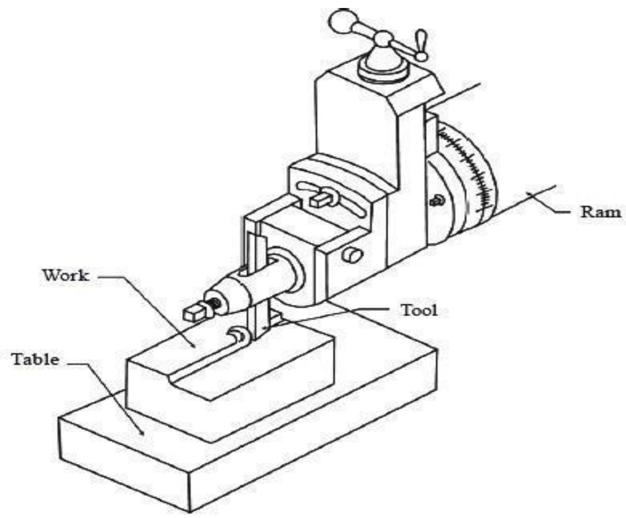
SHAPER

Introduction

Shaping is a process of machining a flat surface which may be horizontal, vertical, inclined, concave or convex using a reciprocating single point tool. A shaping machine is a reciprocating type of machine tool.



The work is held firmly on the table and the ram is allowed to reciprocate over it. A single point cutting tool is attached to the ram. When the ram moves horizontally in the forward direction, the tool removes metal from the work. On the return stroke, metal is not removed. The ram moves at a slow speed during forward stroke. But during return stroke, the ram moves at a faster speed. Though the distances of ram movement during the forward and return stroke remain the same, the time taken by the



Shaper operations

return stroke is less as it is faster. It is possible by 'Quick return mechanism'. In a shaping machine, a flat horizontal surface is machined by moving the work mounted on the table in a cross direction to the tool

movement. When vertical surfaces are machined, the feed is given to the tool. When an inclined surface is machined, the vertical slide of the tool head is swivelled to the required angle and the feed is given to the tool by rotating the down feed hand wheel.

Common types of shaper

Shapers are classified in many ways, i.e. According to the length of the stroke, type of driving mechanism, direction of travel of the ram, the type of work they do, the types and design of table etc. The different types of shapers are,

1. Crank shaper
2. Hydraulic shaper
3. Universal shaper
4. Standard shaper
5. Draw-cut shaper
6. Horizontal shaper
7. Vertical shaper
8. Geared Shaper
9. Contour shaper
10. Travelling head shaper

Crank shaper

Crank and slotted link mechanism of a crank type shaper converts the rotation of an electric motor into reciprocating movement of the ram. Though the lengths of both the forward and return strokes are equal, the ram travels at a faster speed during return stroke. This quick return is incorporated in almost all types of shaper.

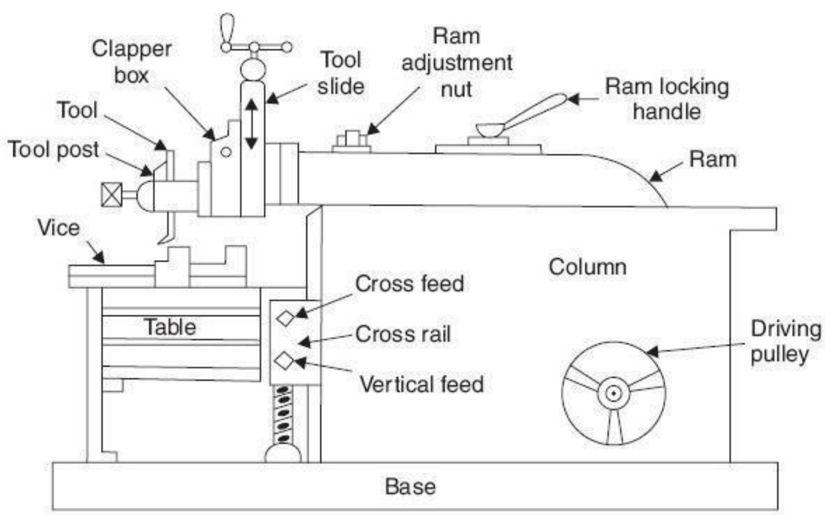
Hydraulic shaper

The ram of a hydraulic shaper is connected to a piston. Oil at high pressure is pumped to the cylinder of the hydraulic system. As the oil pushes the piston, the ram reciprocates. Hydraulic shapers are high power machines and are used for heavy duty work.

Universal shaper

The universal shaper has a special type of table which can be swiveled and positioned at any angle about a horizontal axis. Apart from the cross and vertical travel, the table of a universal shaper can be swiveled to any angle to machine inclined surfaces. In the process, the position of the work in the table need not be changed. These machines are utilised in precision workshops.

Principal parts of a shaper



Principal parts of a shaper

Base

The base is hollow and is made of cast iron. It provides the necessary support for all the other parts of the machine. It is rigidly bolted to the floor of the workshop.

Column

It is a box like casting mounted vertically on top of the base. Two accurate guide ways are machined on the top of the column. The ram reciprocates on these guide ways. The front face of the column is provided with two vertical guide ways. They act as guide ways for the cross rail. Cross rail moves vertically along these guide ways. The column encloses the ram reciprocating mechanism and the mechanism for stroke length adjustment.

Cross rail

It is mounted on the front vertical guide ways of the column. The table may be raised or lowered by adjusting the cross rail vertically. A horizontal cross feed screw is fitted within the cross rail.

Table

It is an important part useful in holding the work firmly on it. It is mounted on the saddle which is located above the cross rail. The top and sides of the table are accurately machined and have T-slots. Work pieces are held on the table with the help of shaper vise, clamps and straps.

Ram

Ram supports the tool head on its front. It reciprocates on the accurately machined guide ways on the top of the column. It is connected to the reciprocating mechanism placed inside the column. The position of ram reciprocation may be adjusted according to the location of the work on the table.

Tool head

The tool head is fitted on the face of the ram and holds the tool rigidly. It provides vertical and angular feed movement of the tool. The swivel tool head can be positioned at any required angle and the vertical slide can be moved vertically or at any desired angle to machine vertical or inclined surfaces.

Shaper operations

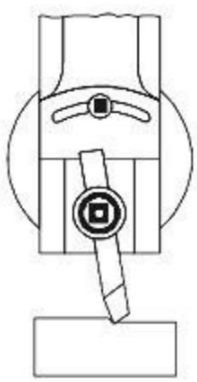
A shaper is a machine tool primarily designed to generate a flat surface by a single point cutting tool. Besides this, it may also be used to perform many other operations. The different operations, which a shaper can perform, are as follows:

1. Machining horizontal surface
2. Machining vertical surface
3. Machining inclined surface
4. Slot cutting

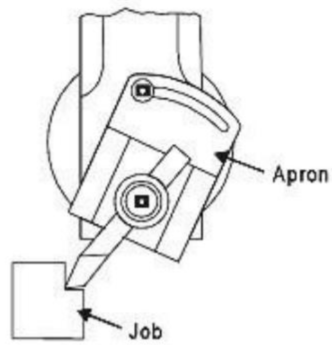
5. Key ways cutting

6. Machining irregular surface

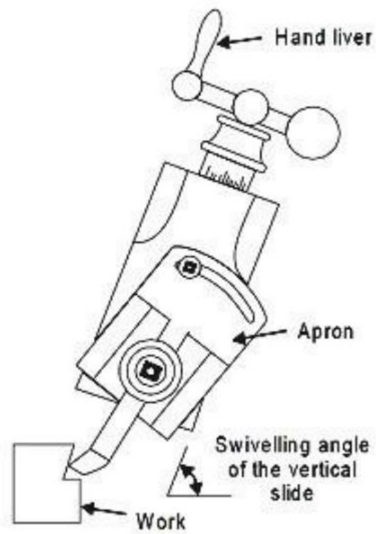
7. Machining splines and cutting gears



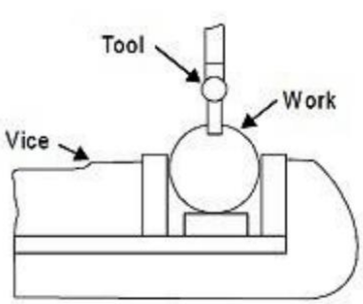
Machining horizontal surface



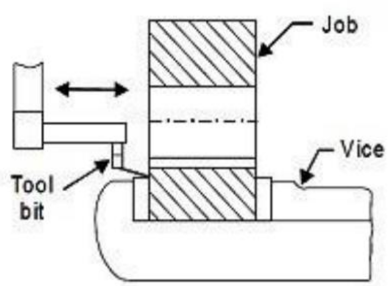
Machining vertical surface



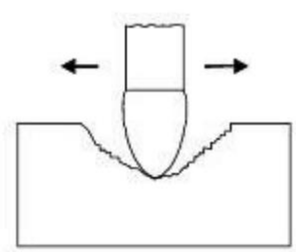
Machining inclined surface



Slot cutting

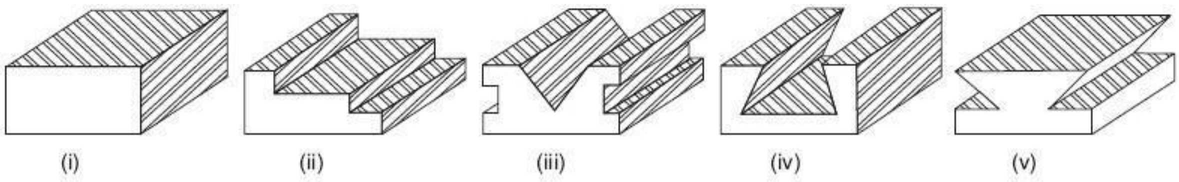


Keyway cutting



Irregular machining

Components manufactured by shaper operations



Components manufactured by shaping processes

SLOTTING MACHINE

Slotting machine

SLOTTER

Introduction

The slotter or slotting machine is also a reciprocating type of machine tool similar to a shaper. It may be considered as a vertical shaper. The machine operates in a manner similar to the shaper, however, the tool moves vertically rather than in a horizontal direction. The job is held stationary. The slotter has a vertical ram and a hand or power operated rotary table.

Common types of slotting machine

2. Puncher slotting machine
3. General production slotting machine
4. Precision tool room slotting machine
5. Keyseater slotting machine

Principal parts of a Slotting machine

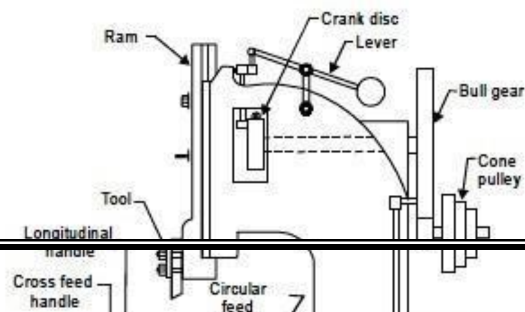


Figure shows a slotter and its various parts. The main parts of a slotter are discussed as under:

2. **Bed or Base**

   It is made up of cast iron. It supports column, tables, ram, driving mechanism, etc. The top of the bed carries horizontal ways along which the work table can traverse.

3. **Table**

It holds the work piece and is adjustable in longitudinal and cross-wise directions. The table can be rotated about its centre.

4. **Hand wheels**

They are provided for rotating the table and for longitudinal and cross traverse. Column is the vertical member. They are made up of cast iron and it houses the driving mechanism. The vertical front face of the column is accurately finished for providing ways along which the ram moves up and down.

5. **Ram**

It is provided to reciprocate vertically up and down. At its bottom, it carries the cutting tool. It is similar to the ram of a shaper; but it is more massive and moves vertically, at right angle to the worktable, instead of having the horizontal motion of a shaper.

6. **Cross-slide**

It can be moved parallel to the face of the column. The circular work-table is mounted on the top of the cross-slide.

Uses of slotting machines

2. It is used for machining vertical surfaces
3. It is used angular or inclined surfaces
4. It is used It is used to cut slots, splines, keyways for both internal and external jobs such as machining internal and external gears
5. It is used for works as machining concave, circular, semi-circular and convex surfaces
6. It is used for shaping internal and external forms or profiles
7. It is used for machining of shapes which are difficult to produce on shaper
8. It is used for internal machining of blind holes
9. It is used for machining dies and punches

Slotting machine operations

Operations which can be performed on the slotting machine are, cutting of:

3. Internal grooves or key ways
4. Internal gears
5. Recesses
6. Concave, circular and convex surfaces etc

Types of slotter tools

A typical set of slotter cutting tools includes the following:

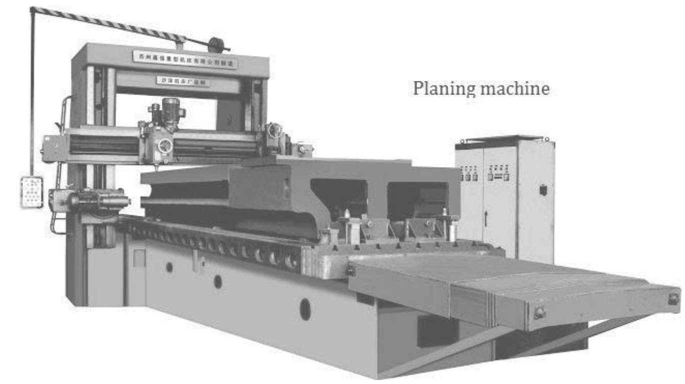
2. Roughing
3. Finishing
4. Right hand
5. Left hand
6. Keyway
7. Scriber

Slotting cutter

PLANAR

Introduction

Planer is used primarily to produce horizontal, vertical or inclined flat surfaces by a single point cutting tool. But it is used for machining large and heavy work pieces that cannot be accommodated on the table of a shaper. In addition to machining large work, the planer is frequently used to machine multiple small parts held in line on the platen. Planer is mainly of two kinds namely open housing planer and double housing planer. Figure below shows an image of a double housing planer.



Common types of planers

Following are the common types of planers:

6. Double housing planer

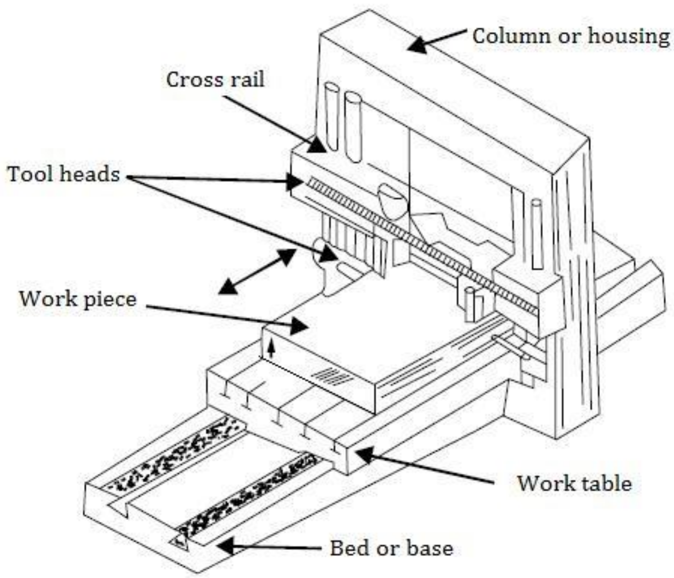
7. Open side planer

8. Pit planer

9. Edge or plate type planer

10. Divided table planer

Principal parts of planer



Principal parts of planer

Following are the mail parts of the double housing planer machine

1. Bed and table
2. Housings
3. Cross rail
4. Tool heads
5. Driving and feed mechanism

Bed and table

The bed is a long heavy base and table made of cast iron. Its top surface is flat and machined accurately. The flat top surface has slots in which the work piece can be securely clamped. The work piece needs rigid fixing so that it does not shift out of its position. The standard clamping devices used on planer machine are: Heavy duty vice, T-holders and clamps, angle plate, planer jack, step blocks and stop. The table movement may be actuated by a variable speed drive through a rack and pinion arrangement, or a hydraulic system.

Housings

The housings are the rigid and upright column like castings. These are located near the centre on each side of the base.

Cross rail

The cross rail is a horizontal member supported on the machined ways of the upright columns. Guide ways are provided on vertical face of each column and that enables up and vertical movement of the cross rail. The vertical movement of the cross rail allows to accommodate work piece of different heights. Since the cross rail is supported at both the ends, this type of planer machine is rigid in construction.

Tool heads

Generally two tool heads are mounted in the horizontal cross rail and one on each of the vertical housing.

Tool heads may be swiveled so that angular cuts can be made.

Driving and feed mechanism

The tool heads may be fed either by hand or by power in crosswise or vertical direction. The motor drive is usually at one side of the planer near the centre and drive mechanism is located under the table.

Planing machine operations

Operations which can be performed on the Planing machine are,

3. Planing flat horizontal
4. Planing vertical surfaces
5. Planing curved surfaces
6. Planing at an angle and machining dovetails.
7. Planing slots and grooves

MILLING MACHINE

Introduction


Universal milling machine

A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter. The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. One or more number of cutters can be mounted simultaneously on the arbor of milling machine. This is the reason that a milling machine finds wide application in production work. Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and helical surfaces of various cross- sections.

Common types of milling machines

Milling machine rotates the cutter mounted on the arbor of the machine and at the same time automatically feed the work in the required direction. The milling machine may be classified in several forms, but the

choice of any particular machine is determined primarily by the size of the work piece to be undertaken

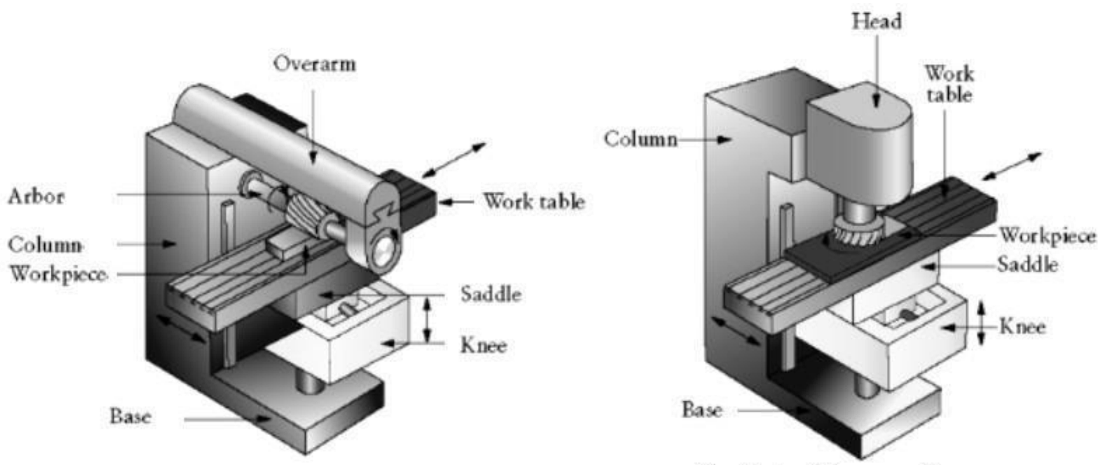
and operations to be performed. According to general design, the distinctive types of milling machines are:

1. Column and knee type milling machines
   a) Hand milling machine
   b) Horizontal milling machine
   c) Universal milling machine
   d) Vertical milling machine
2. Planer milling machine
3. Fixed-bed type milling machine
   a) Simplex milling machine.
   b) Duplex milling machine.
   c) Triplex milling machine.
4. Machining center machines
5. Special types of milling machines
   a) Rotary table milling machine.
   b) Planetary milling machine.
   c) Profiling machine.
   d) Duplicating machine.
   e) Pantograph milling machine.
   f) Continuous milling machine.
   g) Drum milling machine
   h) Profiling and tracer controlled milling machine

Principles of milling

In milling machine, the metal is cut by means of a rotating cutter having multiple cutting edges. For cutting operation, the work piece is fed against the rotary cutter. As the work piece moves against the cutting edges of milling cutter, metal is removed in form chips of trochoid shape. Machined surface is formed in one or more passes of the work. The work to be machined is held in a vice, a rotary table, a three jaw chuck, an index head, between centers, in a special fixture or bolted to machine table. The rotatory speed of the cutting tool and the feed rate of the work piece depend upon the type of material being machined.

Principal parts of a milling machine



Universal milling machine

Vertical milling machine

Principal parts of milling machines

1. Base

It is a foundation member and it carries the column at its one end. In some machines, the base is hollow and serves as a reservoir for cutting fluid.

2. Column

The column is the main supporting member mounted vertically on the base. It is box shaped, heavily ribbed inside and houses all the driving mechanism for the spindle and table feed. The front vertical face of the column is accurately machined and is provided with dovetail guide way for supporting the knee.

3. Knee

The knee is a rigid grey iron casting which slides up and down on the vertical ways of the column face. An elevating screw mounted on the base is used to adjust the height of the knee and it also supports the knee.

4. Saddle

The saddle is placed on the top of the knee and it slides on guide ways set exactly at 90° to the column face. The top of the saddle provides guide-ways for the table.

5. Table

The table rests on ways on the saddle and travels longitudinally. A lead screw under the table engages a nut on the saddle to move the table horizontally by hand or power. In universal machines, the table may also be swiveled horizontally. For this purpose the table is mounted on a circular base. The top of the table is accurately finished and T -slots are provided for clamping the work and other fixtures on it

6. Overhanging arm

It is mounted on the top of the column, which extends beyond the column face and serves as a bearing support for the other end of the arbor.

7. Front brace

It is an extra support, which is fitted between the knee and the over-arm to ensure further rigidity to the arbor and the knee.

8. Spindle

It is situated in the upper part of the column and receives power from the motor through belts, gears and clutches and transmit it to the arbor.

9. Arbor

It is like an extension of the machine spindle on which milling cutters are securely mounted and rotated. The arbors are made with taper shanks for proper alignment with the machine spindles having taper holes at their nose. The arbor assembly consists of the following components.

1. Arbor	2. Spindle	3. Spacing collars	4. Bearing bush	5. Cutter
6. Draw bolt	7. Lock nut	8. Key block	9. Set screw	

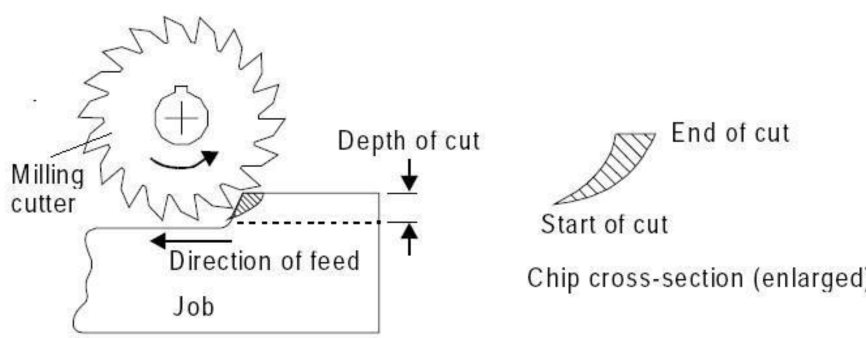
Milling methods

There are two distinct methods of milling classified as follows:

1. Up-milling or conventional milling
2. Down milling or climb milling.

Up-milling or conventional milling

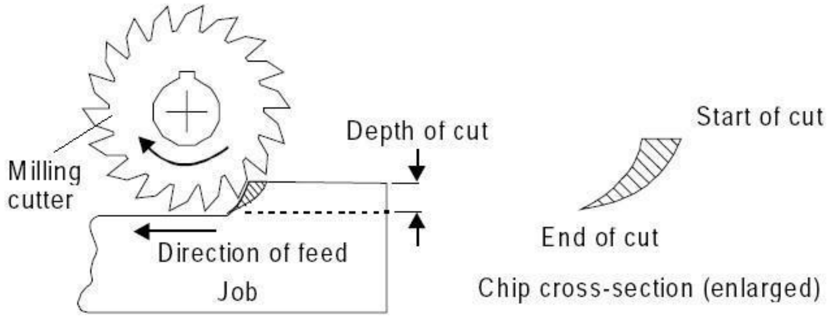
In the up-milling or conventional milling, the metal is removed in form of small chips by a cutter rotating against the direction of travel of the work piece. In this type of milling, the chip thickness is minimum at the start of the cut and maximum at the end of cut. As a result the cutting force also varies from zero to the maximum value per tooth movement of the milling cutter. The major disadvantages of up-milling process are the tendency of cutting force to lift the work from the fixtures and poor surface finish obtained. But being a safer process, it is commonly used method of milling.



Up milling process

Down-milling or climb milling

In this method, the metal is removed by a cutter rotating in the same direction of feed of the work piece. Chip thickness is maximum at the start of the cut and minimum in the end. In this method, there is less friction involved and consequently less heat is generated on the contact surface of the cutter and work piece. Climb milling can be used advantageously on many kinds of work to increase the number of pieces per sharpening and to produce a better finish. With climb milling, saws cut long thin slots more satisfactorily than with standard milling. Another advantage is that slightly lower power consumption is obtainable by climb milling, since there is no need to drive the table against the cutter.



Down milling process

Various milling machine operations

Following different operations can be performed on a milling machine:

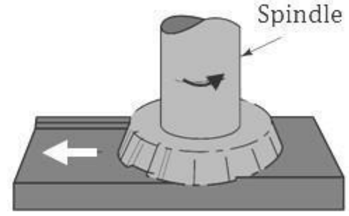
1. Plain milling operation
2. Face milling operation
3. Side milling operation
4. Straddle milling operation
5. Angular milling operation
6. Gang milling operation
7. Form milling operation

8. Profile milling operation
9. End milling operation
10. Saw milling operation
11. Slot milling operation
12. Gear cutting operation
13. Helical milling operation
14. Cam milling operation
15. Thread milling operation

Plain Milling Operation

This is also called slab milling. This operation produces flat surfaces on the work piece. Feed and depth of cut are selected, rotating milling cutter is moved from one end of the work piece to other end to complete the one pairs of plain milling operation.

Face Milling



Face milling

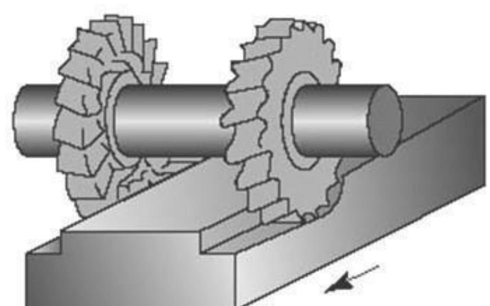
This operation produces flat surface at the face on the work piece. This surface is perpendicular to the surface prepared in plain milling operation. This operation is performed by face milling cutter mounted on stub arbor of milling machine. Depth of cut is set according to the need and cross feed is given to the work table.

Side Milling Operation

This operation produces flat and vertical surfaces at the sides of the work piece. In this operation depth of cut is adjusted by adjusting vertical feed screw of the work piece.

Straddle Milling Operation

This is similar to the side milling operation. Two side milling cutters are mounted on the same arbor. Distance between them is so adjusted that both sides of the work piece can be milled simultaneously. Hexagonal bolt can be produced by this operation by rotating the work piece only two times as this operation produces two parallel faces of bolt simultaneously.


Straddle milling

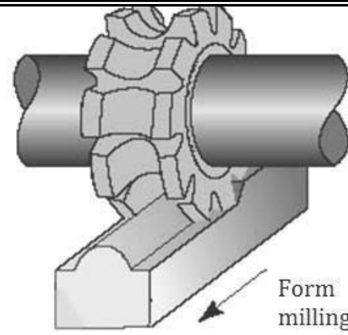
Angular Milling Operation

Angular milling operation is used to produce angular surface on the work piece. The produced surface makes an angle with the axis of spindle which is not right angle. Production of 'V" shaped groove is the example of angular milling operation.

Gang Milling Operation

As the name indicates, this operation produces several surfaces of a work piece simultaneously using a gang of milling cutters. During this operation, the work piece mounted on the table is fed against the revolving milling cutters.

Form Milling

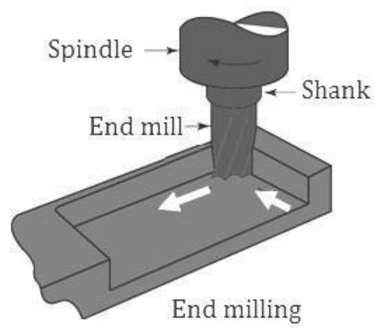


This operation produces irregular contours on the work surface. These irregular contours may be convex, concave, or of any other shape. This operation is done comparatively at very low cutter speed than plain milling operation.

Profile Milling

In this operation a template of complex shape or master die is used. A tracer and milling cutter are synchronized together with respect to their movements. Tracer reads the template or master die and milling cutter generates the same shape on the work piece. Profile milling is an operation used to generate shape of a template or die.

End Milling



End milling operation produces flat vertical surfaces, flat horizontal surfaces and other flat surfaces making an angle from table surface using milling cutter named as end mill. This operation is preferably carried out on vertical milling machine.

Saw Milling

Saw milling operation produces narrow slots or grooves into the work piece using saw milling cutter. This operation is also used to cut the work piece into two equal or unequal pieces which cut is also known as "parting off".

Slot Milling Operation

The operation of producing keyways, grooves, slots of varying shapes and sizes is called slot milling operation. Slot milling operation can use any type of milling cutter like plain milling cutter, metal slitting saw or side milling cutter. Selection of a cutter depends upon type and size of slot or groove to be produced.

Gear Cutting Operation

The operation of gear cutting is cutting of equally spaced, identical gear teeth on a gear blank by handling it on a universal dividing head and then indexing it. The cutter used for this operation is cylindrical type or end mill type. The cutter selection also depends upon tooth profile and their spacing.

Helical Milling Operation

Helical milling produces helical flutes or grooves on the periphery of a cylindrical or conical work piece. This is performed by swiveling the table to the required helix angle, then rotating and feeding the work piece against revolving cutting edges of milling cutter. Helical gears and drills and reamers are made by this operation.

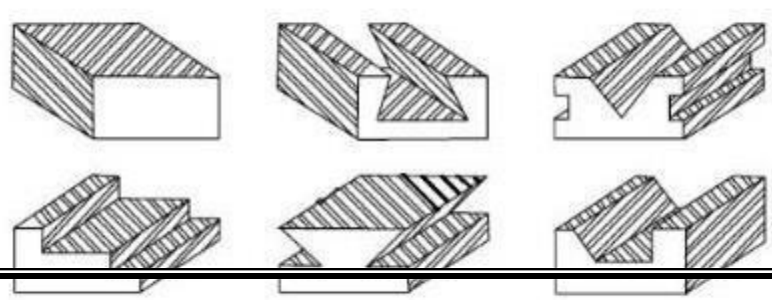
Cam Milling Operation

The operation cam milling is used to produce the cam on milling machine. In this operation cam blank is mounted at the end of the dividing head spindle and the end mill is held in the vertical milling attachment.

Thread Milling Operation

The operation thread milling produces threads using thread milling centres. This operation needs three simultaneous movements revolving movement of cutter, simultaneous longitudinal movement of cutter, feed movement to the work piece through table. For each thread, the revolving cutter is fed longitudinal by a distance equal to pitch of the thread. Depth of cut is normally adjusted equal to the full depth of threads.

Surfaces generated by milling machine



Types of milling cutters

Milling cutters are made in various forms to perform certain classes of work, and they may be classified as:

1. Plain milling cutter
2. Side milling cutter
3. Face milling cutter
4. Angle milling cutter
5. End milling cutter
6. Fly cutter
7. T-slot milling cutter
8. Formed cutter
9. Metal slitting saw

Plain milling cutter

Plain milling cutter

These cutters are cylindrical in shape having teeth on their circumference. These are used to produce flat surfaces parallel to axis of rotation. Depending upon the size and applications plain milling cutters are categorized as light duty, heavy duty and helical plain milling cutters.

Side milling cutter

Side milling cutters are used to remove metals from the side of work piece. These cutters have teeth on the periphery and on its sides. These are further categorized as plain side milling cutters having straight circumferential teeth. Staggered teeth side milling cutters having alternate teeth with opposite helix angle providing more chip space. Half side milling cutters have straight or helical teeth on its circumference and on its one side only. Circumferential teeth do the actual cutting of metal while side teeth do the finishing work.

Side milling cutter

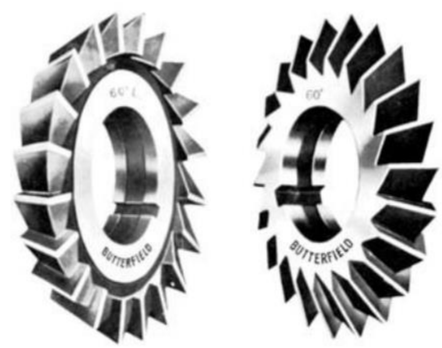
Face milling cutter

Face milling cutter

A face mill is an end mill optimised for facing cuts, whose teeth are arranged in periphery. Some face mills are solid in construction, but many others feature indexable teeth, with the cutter body designed to hold multiple disposable carbide or ceramic tips or inserts, often golden in color. When the tips are blunt, they may be removed, rotated (indexed) and replaced to present a fresh, sharp face to the work piece. This increases the life of the tip and thus its economical cutting life.

Angular milling cutter

These cutters have conical surfaces with cutting edges over them. These are used to machine angles other than 90°. Two types of angle milling cutters are available single angle milling cutter and double angle milling cutter.



Single angle Double angle

Angular milling cutter

End milling cutter

End mills are used for cutting slots, small holes and light milling operations. These cutters have teeth on their end as well as on periphery. The cutting teeth may be straight or helical. Depending upon the shape of their shank, these are categorized as discussed below.

End mill cutter

1. **Taper Shank Mill**

Taper shank mill have tapered shank.

2. **Straight Shank Mill**

Straight shank mill having straight shank.

3. **Shell End Mills**

These are normally used for face milling operation. Cutters of different sizes can be accommodated on a single common shank.

Fly cutter

Fly cutters are the simplest form of cutters used to make contoured surfaces. These cutters are the Single-pointed cutting tool with cutting end ground to desired shape. These are mounted in special adapter or arbor. Used in experimental work instead of a specially shaped cutter

T slot cutter

T Slot cutter

These are the special form of milling cutters used to produce 'T' shaped slots in the work piece. It consists of small side milling cutter with teeth on both sides and integral shank for mounting.

Formed cutters

Formed cutters may have different types of profile on their cutting edges which can generate different types of profile on the work pieces. Depending upon tooth profile and their capabilities, formed cutters are categorized as given below.

1. **Convex Milling Cutters**

   These cutters have profile outwards at their circumference and used to generate concave semicircular surface on the work piece.

2. Concave Milling Cutters

These milling cutters have teeth profile curve in words on their circumference. These are used to generate convex semicircular surfaces.

3. Corner Rounding Milling Cutters

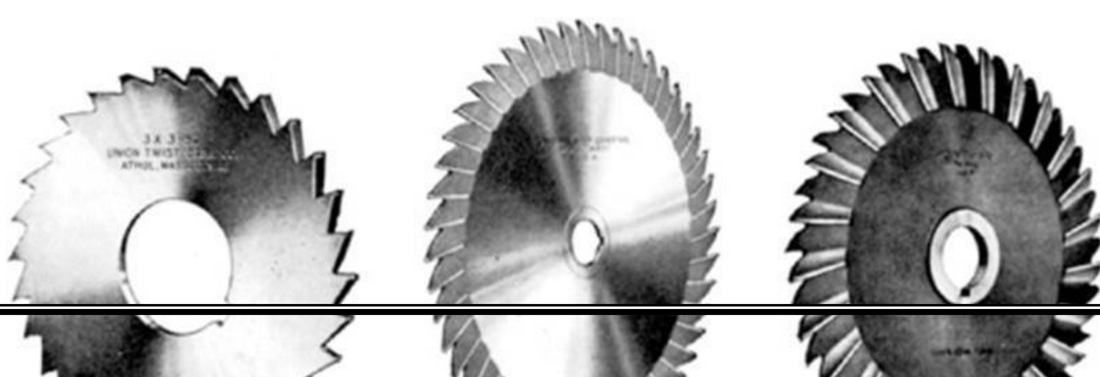
These cutters have teeth curved inwards. These milling cutters are used to form contours of quarter circle. These are main used in making round corners and round edges of the work piece.

Concave Convex Gear tooth

Formed cutters

Metal slitting saw

These cutters are like plain or side milling cutters having very small width. These are used for parting off operations. It is of two types. If teeth of this saw resembles with plain milling cutter, it is called plain milling slitting saw. If its teeth matches with staggered teeth side milling cutter, it is called staggered teeth slitting saw.



GRINDING

Introduction

Grinding is a metal cutting operation performed by means of abrasive particles rigidly mounted on a rotating wheel. Each of the abrasive particles act as a single point cutting tool and grinding wheel acts as a multipoint cutting tool. The grinding operation is used to finish the work pieces with extremely high quality of surface finish and accuracy of shape and dimension. Grinding is one of the widely accepted finishing operations because it removes material in very small size of (micro-chips) chips 0.25 to 0.50 mm. It provides accuracy of the order of 0.000025mm. Grinding of very hard material is also possible.

Advantages of grinding

1. Investment is less and design is simple
2. Surface finishing will be approximate 10 times better as compared to milling and turning process of machining.
3. Dimensional accuracy will be quite good
4. Grinding process could be performed on hardened and unhardened work piece like metals, alloys, carbides, ceramics, composites materials.

Applications of grinding

1. Surface finishing
2. Slitting and parting
3. De-scaling and deburring
4. Grinding of tools and cutters and re-sharpening
5. Internal hole finishing
6. Form finishing

Classification of grinding machines

According to the accuracy of the work to be done on a grinding machine, they are classified as

1. Rough grinding machines
2. Precision grinding machines

Conventional grinding machines can be broadly classified

1. Surface grinding machine
2. Cylindrical grinding machine
3. Internal grinding machine
4. Tool and cutter grinding machine

Surface grinding machines

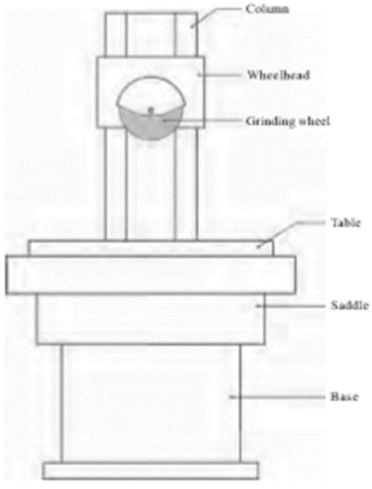
Surface grinding machines are employed to finish plain or flat surfaces horizontally, vertically or at any angle.

There are four different types of surface grinders

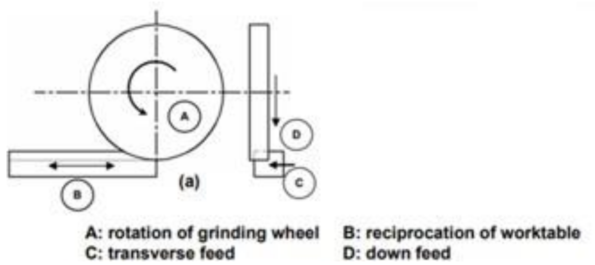
(a) Horizontal spindle and reciprocating table type
(b) Horizontal spindle and rotary table type
(c) Vertical spindle and reciprocating table type
(d) Vertical spindle and rotary table type

Horizontal spindle surface grinding machine

The majority of surface grinders are of horizontal spindle type. The grinding wheel is mounted on a horizontal spindle and the table is reciprocated to perform grinding operation. The periphery of the wheel is used for grinding. The area of contact between the wheel and the work is small, hence the speed is uniform over the grinding surface and the surface finish is good.

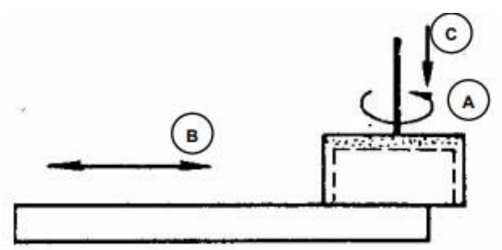


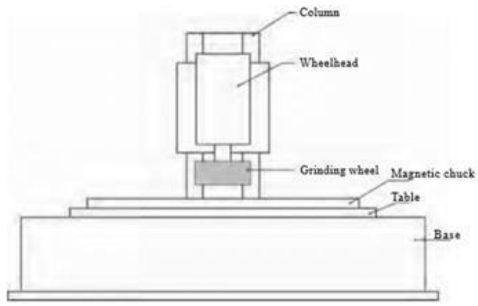
Horizontal spindle surface grinder



Vertical spindle surface grinding machine

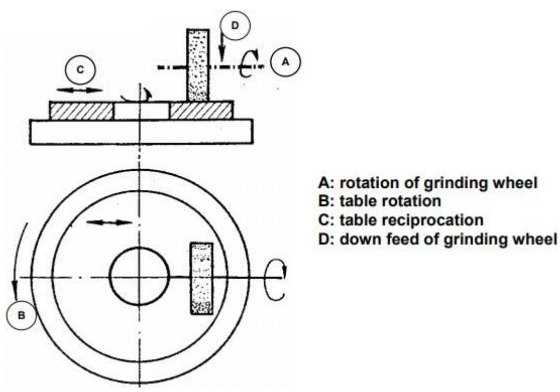
The grinding wheel is mounted on the vertical spindle of the machine which slides vertically on the column. The table is made to reciprocate to perform grinding. The face or sides of the wheel are used for grinding in the vertical type surface grinders. The area of contact is large and stock can be removed quickly but quality is inferior to horizontal grinding.





Horizontal spindle rotary table Surface grinder

The table is moved to perform the grinding operation. This machine has a limitation in accommodation of work piece and therefore does not have wide spread use. By swivelling the worktable, concave or convex or tapered surface can be produced on individual part.



Cylindrical grinding machine

This machine is used to produce external cylindrical surface. Cylindrical grinders are generally used to grind external surfaces like cylinders, taper cylinders, faces and shoulders of work.

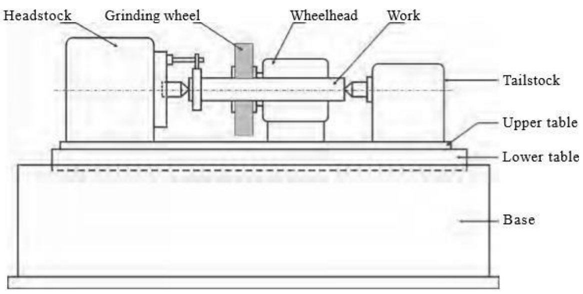
Broadly there are three different types of cylindrical grinding machine as follows:

1. Plain centre type cylindrical grinder
2. Universal cylindrical surface grinder
3. Centre-less cylindrical surface grinder

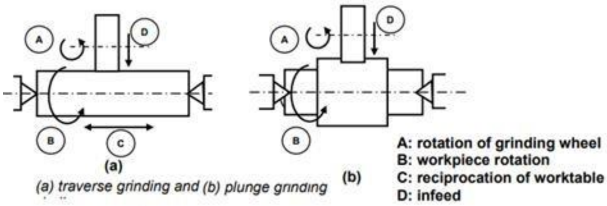
Plain centre type cylindrical grinder/external grinding machine

The work piece is held between head stock and tailstock centres. A disc type grinding wheel performsthegrindingactionwithitsperipheralsurface.Bothtraverseandplungegrindingcan be carried out in this machine as shown. In this grinding wheel is moved into the work. The desired surface is then produced by traversing the work piece across the wheel.

Plunge grinding - The basic movement is of the grinding wheel being fed radially into the work while the later revolves on centres.



Cylindrical grinding machine



(a) traverse grinding and (b) plunge grinding

Universal cylindrical grinding machine

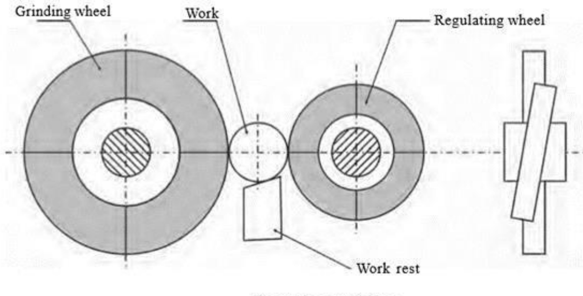
These grinders, in addition to the features offered by plain grinders, are provided with a swiveling headstock and a swiveling wheel head. This permits the grinding of taper of any angle, much greater than is possible in plain grinder.

Universal grinder has the following additional features:

- The centre of the head stock spindle can be used alive or dead.
- The wheel head can be swiveled in a horizontal plane in any angle.
- The headstock can be swiveled to any angle in the horizontal plane.

Centre-less cylindrical grinder

This grinding machine is a production machine in which outside diameter of the workpiece is ground. The workpiece is not held between centres but by a work support blade. It is rotated by means of a regulating wheel and ground by the grinding wheel. Centre-less grinding, the regulating wheel revolving at a much lower surface speed than grinding wheel controls the rotation and longitudinal motion of the workpiece.



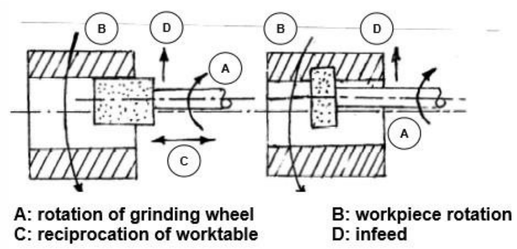
Centreless grinding

Internal grinding machine

This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled.

Broadly there are three different types of internal grinding machine as follows:

1. Chucking type internalgrinder
2. Planetary internalgrinder
3. Centre-less internalgrinder

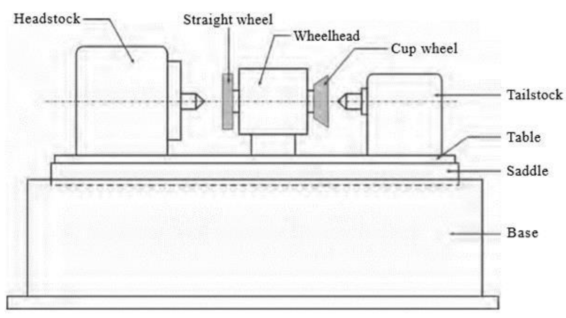


Centre-less internal grinder

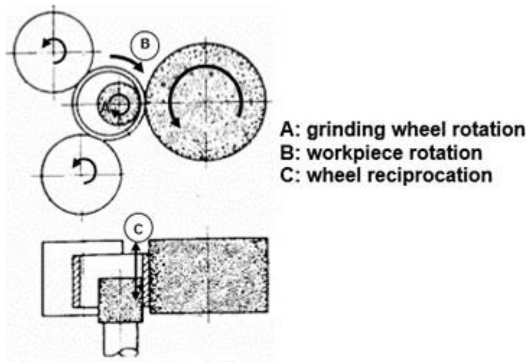
This machine is used for grinding cylindrical and tapered holes in cylindrical parts (e.g. cylindrical liners, various bushings etc). The work piece is rotated between supporting roll, pressure roll and regulating wheel and is ground by the grinding wheel

Tool and cutter grinding machines

Tool and cutter grinders are used mainly to sharpen the cutting edges of various tools and cutters. The can also do surface, cylindrical and internal grinding to finish jigs, fixtures, dies and gauges.



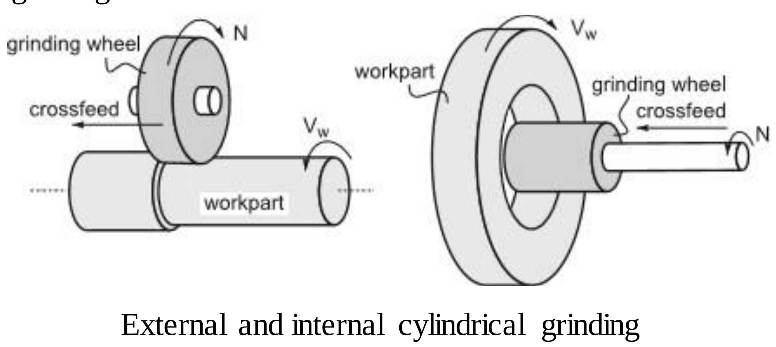
Tool and cutter grinder



Internal centreless grinding

Cylindrical grinding

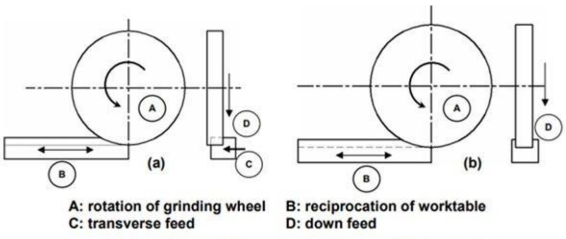
Cylindrical grinding is performed by mounting and rotating the work between centres in a cylindrical grinding machine. The work is fed longitudinally against the rotating grinding wheel to perform grinding.



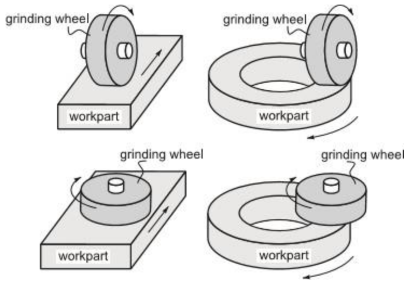
External and internal cylindrical grinding

Surface grinding machines

Surface grinding machines are employed to finish plain or flat surfaces horizontally, vertically. In surface grinding, the spindle position is either horizontal or vertical, and the relative motion of the work piece is achieved either by reciprocating the work piece past the wheel or by rotating it. The possible combinations of spindle orientations and work piece motions yield four types of surface grinding



Surface grinding (a) traverse grinding (b) plunge grinding



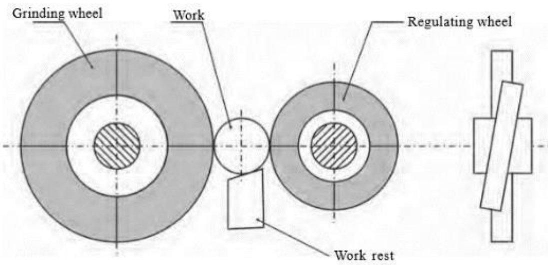
Centre-less grinding

Centre-less grinding is a method of grinding external cylindrical, tapered and formed surfaces on work pieces that are not held and rotated between centres or in chucks. There are two types of centre-less grinding and they are

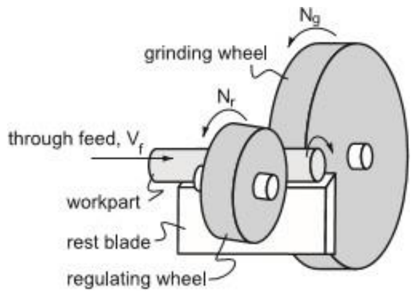
1. External centre-less grinding
2. Internal centre-less grinding

External centre-less grinding

Twowheels-agrindingandaregulatingwheelareusedinexternalcentre-lessgrinding.Both these wheels are rotated in the same direction. The work is placed upon the work rest and rotated between the wheels. The feed movement of the work along its axis past the grinding wheel is obtained by tilting the regulating wheel at a slight angle from the horizontal. An angular adjustment of 0 to 10 degrees is provided in the machine for this purpose.



Centreless grinding



Internal centre-less grinding

The principle of external centre-less grinding is applied to internal centre-less grinding also. Grinding is done on the inner surfaces of the holes. In internal centre-less grinding, the work is supported by three rolls- a regulating roll, a supporting roll and a pressure roll. The grinding wheel contacts the inside surface of the work-piece directly opposite the regulating roll. The distance between the contours of these two wheels is the wall thickness of the work.

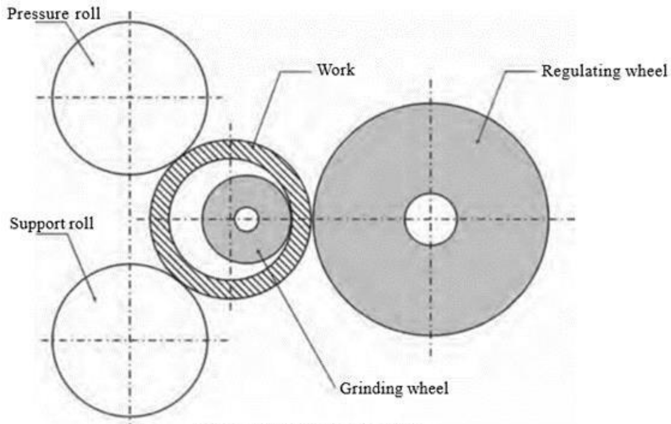
Advantages of centre-less grinding

1. Work piece is supported the entire length, grinding is done very accurately.
2. Small, slender and fragile work pieces can be ground easily.
3. No chucking or other holding devices are required.

4. As the process is continuous, it is best adapted for production work.
5. The size of the work can easily be controlled.
6. Low order of skill is needed in the operation of the machine.

Disadvantages of centre-less grinding

1. In hollow work, there is no certainity that the outer diameter will be concentric with the inside diameter.
2. Works having multiple diameters are not handled easily.



Internal centreless grinding

Universal cylindrical grinding machine

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Grinding machine operations

Grinding processes are generally classified based on the type of surface produced.

1. Cylindrical grinding process.
2. Surface grinding process.
3. Centre less grinding process.