Elements of Mechanical Engineering [18ME15/25]

Revised: 2020-21

Student Hand Notes

A T M E
College of Engineering

Vision of the Institute

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

Mission of the Institute

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torch bearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence.

COURSE MODULE

Course Coordinator: **Prof. Thejkumar J**				Academic Year:**2020-21**			
Department: **Mechanical Engineering**							
Course Code	Course Title	Core/Elective	Prerequisite	Contact Hours			Total Hrs/ Sessions
				L	T	P	
18ME15/25	**Elements of Mechanical Engineering**	**Core**	**BASIC SCIENCE**	**4**	**-**	**-**	**50**

Course objectives: This course (18ME15/25) will enable students to:
CLO1: Learn the fundamental concepts of energy, its sources and conversion.
CLO2: Comprehend the basic concepts of thermodynamics.
CLO3: Understand the concepts of boilers, turbines, pumps, internal combustion engines and refrigeration.
CLO4: To understand the properties of various engineering material and their applications.
CLO5: Distinguish different metal joining techniques and understand the concepts of power transmission elements.
CLO6: Enumerate the knowledge of working with conventional machine tools, their specifications

Topics Covered as per Syllabus

MODULE-I

Sources of Energy: Introduction and application of energy sources like fossil fuels, Hydel, Solar, Wind, Nuclear fuels and Bio-fuels. Environmental issues like Global Warming and Ozone Depletion

Basic Concepts of Thermodynamics: Introduction, States, Concepts of work, Heat, Temperature, Zeroth law, 1st Law, 2nd Law and 3rd Laws of thermodynamics. Concept of Internal energy, Enthalpy and entropy (Simple Numericals)

Steam: Formation of Steam and Thermodynamic properties of steam (Simple Numericals)

(RBT: L1, L2 and L3)

MODULE-2

Boilers: Introduction to Boilers, Classification, Lancashire boiler, Babcock and Wilcox Boiler, Introduction to Boiler mounting and accessories (No sketches).

Turbines: Hydraulic Turbines- Classification and specification, Principles and operation of Pelton Wheel Turbine, Francis Turbine and Kaplan Turbine (Elementary Treatment only)

Hydraulic Pumps: Pumps, Introduction, Classification and specification of Pumps, Reciprocating pump and Centrifugal Pump, Concept of Cavitation and Priming.

(RBT: L1, L2)

MODULE - 3

Internal Combustion Engines

Classification, IC engines parts, 2 and 4 stroke petrol and 4 stroke diesel engines. P-V diagrams of Otto and Diesel cycles. Simple problems on indicated power, brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and specific fuel consumption.

Refrigeration and Air conditioning

Refrigeration – Definitions – Refrigerating effect, Ton of Refrigeration, Ice making capacity, COP, relative COP and Unit of refrigeration. Refrigerants, Properties of refrigerants, List of commonly used refrigerants, Principle and working of vapor compression refrigeration and vapor absorption refrigeration. Domestic refrigerator, Principles and applications of air conditioners, window and split air conditioners.

(RBT: L1, L2 and L3)

MODULE-4

PROPERTIES, COMPOSITION AND INDUSTRAIL APPLICATIONS OF ENGINEERING MATERIALS:

Metals- Ferrous: Cast Iron, Tool steels and stainless steels. **Non-Ferrous**: Aluminum, brass, bronze, **Polymers**: Thermoplastics and thermo setting polymers. **Ceramics**: Glass, optical fiber glass, cements, **Composites**- Fiber reinforced composites, Metal Matrix composites. **Smart Materials**: Piezoelectric materials, Shape memory alloys, Semiconductors and insulators.

JOINING PROCESSES: SOLDERING, BRAZING AND WELDING

Definitions, Classification and Methods of soldering, Brazing and welding, Brief description of arc welding, Oxy-acetylene welding, TIG welding and MIG welding

BELT DRIVES

Open & crossed belt drives, Definitions- slip, creep, velocity ratio, derivations for length of belt in open and crossed belt drive, ratio of tension in flat belt drives, advantages and disadvantages of V belts and timing belts, simple numerical problems.

GEAR DRIVES:

Types- Spur, helical, bevel, worm and rack and pinion, Velocity ratio, advantages and disadvantages over belt drives, simple numerical problems on velocity ratio

(RBT: L1, L2 and L3)

MODULE-5

Lathe: Principle of Working of a Center Lathe, Parts of a Lathe. Operations on Lathe- Turning, Facing, Knurling, Thread Cutting, Drilling, Taper Turning by Tailstock Offset Method and Compound Slide Swiveling Method. Specification of Lathe

Milling Machine: Principle of Milling, Types of Milling Machines, Working Of Horizontal and Vertical Milling Machines. Milling Processes -P lane Milling, End Milling, Slot Milling, Angular Milling, Form Milling, Straddle Milling, and Gang Milling

(Layout of sketches of the above machines needs to be dealt. Sketches need to be used only for explaining the operations performed on the machines)

Introduction to Advanced Manufacturing Systems

Computer Numerical Control (CNC): Introduction, Components of CNC, Open Loop and Closed Loop Systems, advantages of CNC, CNC Machining centers and Turning Centers.

Robots: Robot Anatomy, Joints and Links, Common Robot Configurations, Applications of Robots in material handling, Processing and assembly and inspection.

(RBT: L1, L2)

List of Text Books

1. **Elements of Mechanical Engineering**, K R Gopal Krishna, Subhash Publication, Bangalore 2008
2. **Work Shop Technology, Vol1 & 2,** Hajara Chowdary, Media Promoters, New Delhi 2001
3. **A Text Book of Elements of Mechanical Engineering**, S.TrymbakaMurthy, 3rd revised edition 2006, I. K International Publishing House Pvt Ltd , New Delhi

List of Reference Books

1. **Elements of Mechanical Engineering**, R K Rajput, Firewall media, 2005
2. **Elements of Mechanical Engineering**, A S Ravindra, Best Publications, 7th edition 2009
3. **CAD/CAM/CIM**, Dr. P Radhakrishnan, 3rd edition, New age International Publisher, New Delhi
4. **Introduction to Robotics: Mechanics & Control**, Craig J J, 2nd edition, Addison-Wesley publishing company, 1989
5. **Introduction to engineering Materials**, B K Agarwal, Tata McGraw Hill Publication, New Delhi.
6. **Thermal Science and Engineering**, Dr. D S kumar, S K Kataria & Sons Publications, New Delhi

List of URLs, Text Books, Notes, Multimedia Content, etc

Video Demonstration of Different types of automation and Mechanisms:

https://web.microsoftstream.com/channel/eb803232-ea0b-44c6-9d3b-2b16a67d1046 (Tech Videos)

https://web.microsoftstream.com/channel/39a40d8b-3f4b-41f3-a027-a9002be969b3 (Lecture Videos)

Copy of Notes (Soft Copy): Available

Course Outcomes: Students will be able to

CO1: Identify different sources of energy, their conversion process and also describe the basic concepts thermodynamics and solving simple numerical problems on steam.	**L3**
CO2: Explain the working principle of boilers, Turbines, Pumps, IC Engines and Refrigeration.	**L2**
CO3: Demonstrate the working principles of an I.C Engine, Refrigeration, air conditioning and also calculate the performance parameters of an I. C engine.	**L3**
CO4: Recognize & Classify the various engineering materials, metal joining processes and power transmission elements. Also solve simple numerical on power transmission elements.	**L3**
CO5: Describe the working of conventional machine Tools, Machining processes and the advanced manufacturing system.	**L2**

Internal Assessment Marks: 40 (30 Marks three Session tests are conducted during the semester and marks allotted based on the average of three performances and additional 10 Marks for Assignments /Unit tests/ written quizzes).

The Correlation of Course Outcomes (CO's) and Program Outcomes (PO's)

Subject Code: 18ME15/25				TITLE: Elements of Mechanical Engineering						Faculty: Thejkumar J		
List of Course Outcomes	**Program Outcomes**											
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO 10**	**PO 11**	**PO 12**
CO-1	2	-	-	-	-	-	2	-	-	-	-	2
CO-2	3	2	-	-	-	-	-	-	-	-	-	-
CO-3	3	2	-	-	-	-	-	-	-	-	-	-
CO-4	2	-	-	-	-	-	-	-	-	-	-	-
CO-5	2	-	-	-	3	-	-	-	-	-	-	2

Note: 3 = Strong Contribution 2 = Average Contribution 1 = Weak Contribution - = No Contribution

MODULE-4

PROPERTIES, COMPOSITION AND INDUSTRAIL APPLICATIONS OF ENGINEERING MATERIALS:

Metals- Ferrous: Cast Iron, Tool steels and stainless steels.
Non-Ferrous: Aluminum, brass, bronze
Polymers: Thermoplastics and thermo setting polymers.
Ceramics: Glass, optical fiber glass, cements
Composites- Fiber reinforced composites, Metal Matrix composites.
Smart Materials: Piezoelectric materials, Shape memory alloys, Semiconductors and insulators.

JOINING PROCESSES: SOLDERING, BRAZING AND WELDING

Definitions, Classification and Methods of soldering, Brazing and welding Brief description of arc welding, Oxy-acetylene welding, TIG welding and MIG welding

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Open & crossed belt drives, Definitions- slip, creep, velocity ratio, derivations for length of belt in open and crossed belt drive, ratio of tension in flat belt drives, advantages and disadvantages of V belts and timing belts, simple numerical problems.

GEAR DRIVES:

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Velocity ratio, advantages and disadvantages over belt drives, simple numerical problems on velocity ratio

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4 PROPERTIES COMPOSITION AND INDUSTRIAL APPLICATIONS OF ENGINEERING MATERIALS

4.1 INTRODUCTION:

In the materials world we are living in, when making a new device/component, most often we come across a very familiar problem. This is nothing but select the right material. Selection of material can play very important role preventing failures. Selection of material for a specific purpose depends on many factors. Some of the important ones are: strength, ease of forming, resistance to environmental degradation, etc. Another dimension an engineer should be aware of it is how to tailor the required properties of materials. Materials can be are broadly classified as metals, ceramics and plastics. This chapter introduces different classes of metallic materials, common fabrication methods, and means to alter their properties on purpose.

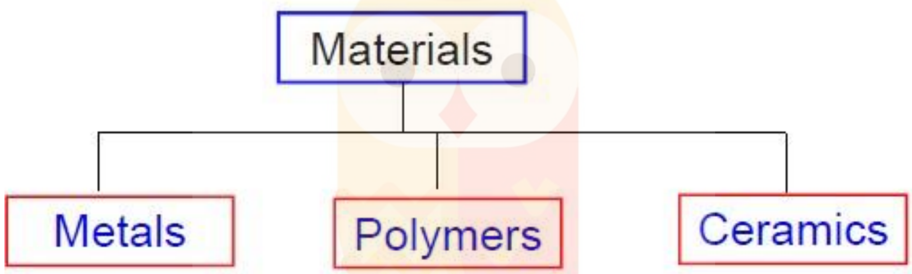


Figure-4.1: Classification of engineering materials

4.2 METALS

Metallic materials are broadly of two kinds - *ferrous* and *non-ferrous* materials. This classification is primarily based on tonnage of materials used all around the world. Ferrous materials are those in which iron (***Fe***) is the principle constituent. All other materials are categorized as non-ferrous materials.

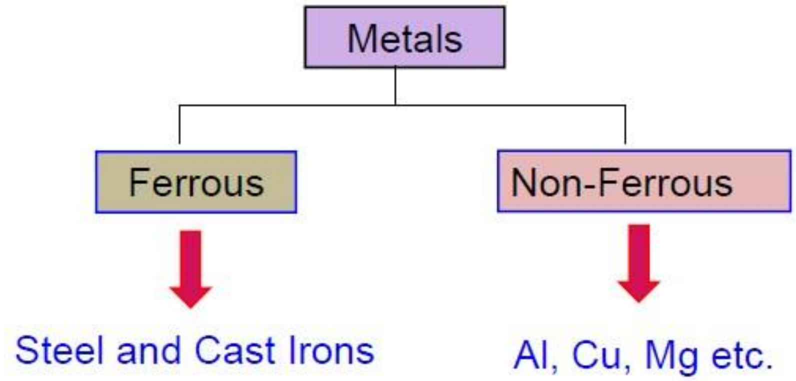


Figure-4.2.1: Classification of Metals

4.2.1 FERROUS METALS

Ferrous materials are produced in larger quantities than any other metallic material. Three factors account for it: (a) availability of abundant raw materials combined with economical extraction, (b) ease of forming and (c) their versatile mechanical and physical properties. One main drawback of ferrous alloys is their environmental degradation i.e. poor corrosion resistance. Other disadvantages include: relatively high density and comparatively low electrical and thermal conductivities. In ferrous materials the main alloying element is carbon (***C***). Depending on the amount of carbon present, these alloys will have different properties, especially when the carbon content is either less/higher than 2.14%. This amount of carbon is specific as below this amount of carbon, material undergoes eutectoid transformation, while above that limit ferrous materials undergo eutectic transformation. Thus the ferrous alloys with less than 2.14% C are termed as steels and the ferrous alloys with higher than 2.14% C are termed as cast irons.

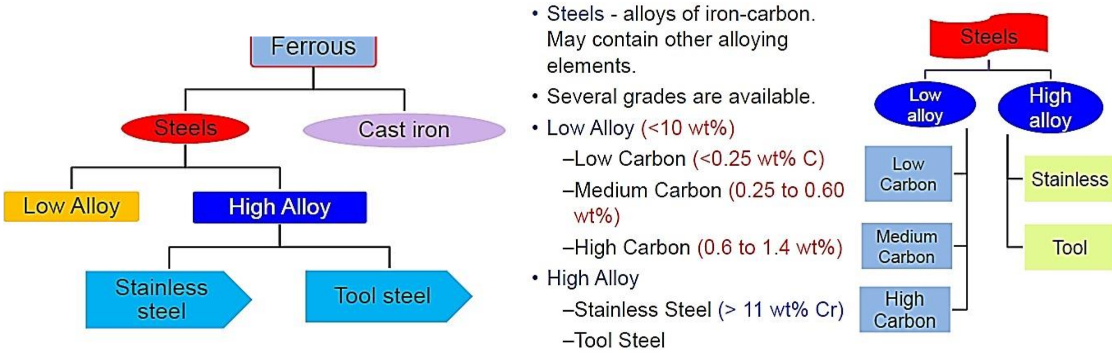


Figure-4.2.1: Classification of ferrous Materials

a) **Mild Steel** – Carbon content of 0.1 to 0.3% and Iron content of 99.7 – 99.9%. Used for engineering purposes and in general, none specialized metal products.

b) **Carbon steel** – Carbon content of 0.6 to 1.4% and Iron content of 98.6 to 99.4 %. Used to make cutting tools such as drill bits.

c) **Stainless Steel** – The name comes from their high resistance to corrosion i.e. they are rust-less (stain-less). Steels are made highly corrosion resistant by addition of special alloying elements, especially a minimum of 12% Cr along with Ni and Mo. Stainless steels are mainly three kinds: ferritic & hardenable Cr steels, austenitic and precipitation hardenable (martensitic, semi-austenitic) steels. This classification is based on prominent constituent of the microstructure. Typical applications include cutlery, razor blades, surgical knives, etc.

d) **Tool steel or High carbon steels**-These are strongest and hardest of carbon steels, and of course their ductility is very limited. These are heat treatable, and mostly used in hardened and tempered conditions. They possess very high wear resistance, and capable of holding sharp edges. Thus these are used for tool application such as knives, razors, hacksaw blades, etc. With addition of alloying element like Cr, V, Mo, W which forms hard carbides by reacting with carbon present, wear resistance of high carbon steels can be improved considerably.

e) **Cast iron-** Though ferrous alloys with more than 2.14 wt.% C are designated as cast irons, commercially cast irons contain about 3.0-4.5% C along with some alloying additions. Alloys with this carbon content melt at lower temperatures than steels i.e. they are responsive to casting. Hence casting is the most used fabrication technique for these alloys.

f) Hard and brittle constituent presented in these alloys, cementite is a meta-stable phase, and can readily decompose to form α-ferrite and graphite. In this way disadvantages of brittle phase can easily be overcome. Tendency of cast irons to form graphite is usually controlled by their composition and cooling rate. Based on the form of carbon present, cast irons are categorized as gray, white, nodular and malleable cast irons.

4.2.2 NON-FERROUS MATERIALS

Non-ferrous materials have specific advantages over ferrous materials. They can be fabricated with ease, high relatively low density, and high electrical and thermal conductivities. However different materials have distinct characteristics, and are used for specific purposes. This section introduces some typical non-ferrous metals and their alloys of commercial importance.

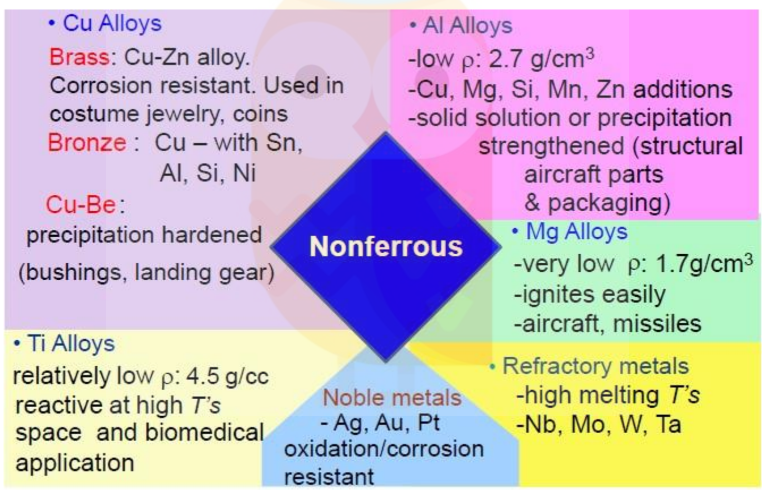


Figure-4.2a: Classification of ferrous Materials

a) Aluminum alloys: These are characterized by low density, high thermal & electrical conductivities, and good corrosion resistant characteristics. As Al has FCC crystal structure, these alloys are ductile even at low temperatures and can be formed easily. However, the great limitation of these alloys is their low melting point (660°C), which restricts their use at elevated temperatures. Strength of these alloys can be increased by both cold and heat treatment – based on these alloys are designated in to two groups, cast and wrought. Chief alloying elements include: Cu, Si, Mn, Mg, Zn. Recently, alloys of Al and other low-density metals like Li, Mg, Ti gained much attention as there is much concern about vehicle weight reduction. Al-Li alloys enjoy much more attention especially as they are very useful in aircraft and aerospace industries. Common applications of Al alloys include: beverage cans, automotive parts, bus bodies, aircraft structures, etc. Some of the Al alloys are capable of strengthening by precipitation, while others have to be strengthened by cold work or solid solution methods

b) **Copper alloys (Brass Bronze):** As history goes by, bronze has been used for thousands of years. It is actually an alloy of Cu and Sn. Unalloyed Cu is soft, ductile thus hard to machine, and has virtually unlimited capacity for cold work. One special feature of most of these alloys is their corrosion resistant in diverse atmospheres. Most of these alloys are strengthened by either cold work or solid solution method. Common most Cu alloys: Brass, alloys of Cu and Zn where Zn is substitutional addition (e.g.: yellow brass, catridge brass, muntz metal, gilding metal); Bronze, alloys of Cu and other alloying additions like Sn, Al, Si and Ni. Bronzes are stronger and more corrosion resistant than brasses.

Figure 4.2b :Bronze Bearings\Copper coins

4.3 POLYMERS

A polymer is a macromolecule, made up of many smaller repeating units called monomer. Polymers have high molecular weight in the range of several thousand or even higher. The first synthetic organic polymer polyvinylchloride was synthesized in 1838 by accidentally. Later, polystyrene was discovered in 1839.

Polymers can be classified into a number of ways which are described below (Figure4.4).

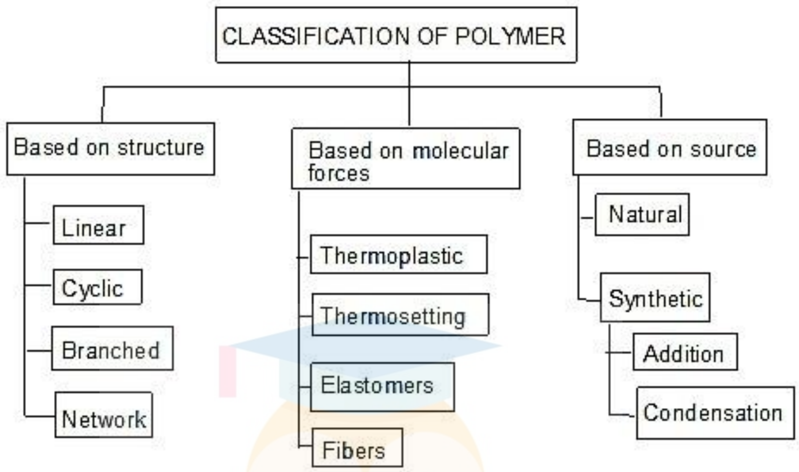


Figure-4.3: Classification of Polymers

4.3.1 Thermoplastic Polymers*:* The individual chains of thermoplastic polymer are held together by van der Waals forces. They are strong if the polymer chains are lined up in an ordered, closely packed array. This region is called crystallites and the other where polymer chains are oriented randomly is called amorphous. Thermoplastic polymers have both ordered crystalline regions and amorphous non crystalline regions. Thermoplastic polymers are hard at room temperature, but become soft when heated, because on heating individual polymer chains slip from one another. Polyethylene, polystyrene, polypropene and teflon are some examples for thermoplastic polymer.

4.3.1 Thermosetting Polymers*:* The greater the degree of cross-linking makes the polymer more rigid. Such cross-linked polymers are called thermosetting polymers.
Thermosetting polymers are generally stronger than thermoplastic polymers due to strong covalent linkage (cross-linking) between polymer chains not by weak intermolecular van der Waals forces. They are more brittle in nature and their shape is permanent. Once it is hardened they cannot be recycled. Melmac, a highly

crosslinked thermosetting polymer of melamine and formaldehyde, used to make lightweight dishes. Bakelite and polyurethanes are examples for thermosetting polymers.

4.4 CERAMICS

Ceramics which were traditionally being used for pottery and clay products only, these days are finding application in electronics, aerospace, bio-applications etc. The application spectrum of ceramics has increased because ceramics possesses specific properties such as corrosion resistance, wear resistance, high hardness, low density etc. The classification of ceramics based on the application is as follows:

(i) Glasses: Glasses are based on Silicate (SiO2) along with other additives to shrink the melting point and to impart special characteristic properties. Glasses are mainly used in the manufacturing of the following products;

(a) Containers (b) households (c) optical glasses etc.

(ii) Optical fibre glasses: Since optical fibers were introduced in 1960s, they have subsequently attracted much attention for a range of applications such as fiber amplifiers and fiber lasers. A glass-ceramic optical fiber containing Ba2TiSi2O8 Nano crystals fabricated using a novel combination of the melt-in-tube method and successive heat treatment is reported for the first time.

(iii)Cements: cement, plaster of paris and lime come under this group of ceramics. The characteristic property of these materials is that when they are mixed with water, they form slurry which sets subsequently and hardens finally. Thus it is possible to form virtually any shape. They are also used as bonding phase, for example between construction bricks.

4.5 COMPOSITES

There is an unabated quest for new materials which will satisfy the specific requirements for various applications like structural, medical, house-hold, industrial, construction, transportation, electrical; electronics, etc. Metals are the most commonly used materials in these applications. In the yore of time, there have been specific requirements on the properties of these materials. It is impossible of any material to fulfill all these properties. Hence, newer materials are developed. In the course, we are going to learn more about composite materials. First, we will deal with primary understanding of these materials and then we will learn the mechanics of these materials.

A composite material is defined as a material which is composed of two or more materials at a microscopic scale and has chemically distinct phases. Thus, a composite material is heterogeneous at a microscopic scale but statistically homogeneous at macroscopic scale. The materials which form the composite are also called as constituents or constituent materials. The constituent materials of a composite have significantly different properties.
Further, it should be noted that the properties of the composite formed may not be obtained from these constituents. However, a combination of two or more materials with significant properties will not suffice to be called as a composite material.

Figure-4.5: Building blocks of composite

4.5.1 Classification of composites:

Composites may be classified either on the type of matrix material incorporated or geometry of reinforcement used in the fabrication of composites. According to the type of matrix material used, there are three types of composites:

1. Metal matrix composites (MMCs) 2. Ceramic matrix composites (CMCs) 3. Polymer matrix composites (PMCs)

1. **Fibre Reinforced Composites**: are the most common and widely used composites. In PMCs, polymers are used as matrix material. PMCs consist of

glass, carbon, or other high strength fibers as reinforcement in a thermoset or thermoplastic matrix. The resulting materials are strong, stiff, and corrosion resistant. Polymer matrix composites offer several advantages over traditional metals and alloys such as flexibility in design, easy processing and ability to produce near net shape products.

2. **Metal matrix composites (MMC)**: In metal matrix composites, metals like Aluminium (Al), Magnesium (Mg) and Copper (Cu) are used as matrix materials. Widely used reinforcements in MMCs are silicon carbide (SiC), Alumina (Al2O3) and Tungsten (W). Metals have much higher strength and stiffness in comparison to polymeric materials like Epoxy which is used as matrix in polymeric material. he application of MMCs are currently restricted to the following fields: Aerospace applications - like helicopter transmission system, Acid Battery, Super alloys for high speed Turbine blades

4.6 SMART MATERIALS

Smart Materials are being developed since last decade in the laboratories all around the world. These are materials which are capable of generating controllable response to the environment. As actuators, they can produce controllable force to modify the response of a system.

As sensors, the same material could be used to monitor the response of the system. Smart materials are being traditionally used in aerospace applications since last decade. Using smart actuators one can modify the flexible modes of a system such that the control effort would not interfere with the vibrating frequencies of the structure.

Active vibration controllers are developed for Helicopters and Large space structures using this principle. Tailoring the gamut of smart materials towards diverse applications is still a major challenge to the researchers and engineers involved in these fields.

4.6.1 Piezoelectric materials

Piezoelectric materials are very common example of such materials where they produce a voltage when stress is applied. Since this effect also applies in the reverse manner, a voltage across the sample will produce stress within the sample. Suitably designed structures made from these materials can therefore be made that bend, expand or contract when a voltage is applied. They can also be used in opticaltracking devices, magnetic heads, dot-matrix printers, computer keyboards, highfrequency stereo speakers, accelerometers, micro-phones, pressure sensors, transducers and igniters for gas grills.

4.6.2 Shape Memory Alloys (SMA) either thermo-responsive materials, or shape memory polymers, are materials that can hold different shapes at various temperatures. They can be deformed and returned to their original shape by heating. In the process, they generate an actuating force. Shape memory alloy, such as nitinol, an alloy of nickel and titanium, which has a corrosion resistance similar to stainless steel, making it particularly useful for biomechanical applications. Such types of materials can be used in coffee-pot thermostat, super elastic spectacle frames, stents for veins, whereas shape memory polymer has the ability to regain its original shape when heated. These are generally used in biodegradable surgical sutures that will automatically tighten to the correct tension and also in self repairing car bodies that will recover shape on gentle heating after a dent.

4.6.3 Semiconductor, any of a class of crystalline solids intermediate in electrical conductivity between a conductor and an insulator. Semiconductors are employed in the manufacture of various kinds of electronic devices, including diodes, transistors, and integrated circuits. Such devices have found wide application because of their compactness, reliability, power efficiency, and low cost. As discrete components, they have found use in power devices, optical sensors, and light emitters, including solid-state lasers. They have a wide range of current- and voltage-handling capabilities and, more important, lend themselves to integration into complex but readily manufacturable microelectronic circuits. They are, and will be in the foreseeable future, the key elements for the majority of electronic systems, serving communications, signal processing, computing, and control applications in both the consumer and industrial markets.

4.6.4 Insulator, any of various substances that block or retard the flow of electrical or thermal currents. Although an electrical insulator is ordinarily thought of as a no conducting material, it is in fact better described as a poor conductor or a substance of high resistance to the flow of electric current. Different insulating and conducting materials are compared with each other in this regard by means of a material constant known as resistivity Electrical insulators are used to hold conductors in position, separating them from one another and from surrounding structures. They form a barrier between energized parts of an electric circuit and confine the flow of current to wires or other conducting paths as desired. The insulation of electrical circuits is a necessary requirement for the successful operation of all electrical and electronic apparatus. Various types of materials are used as electrical insulators, the selection being made primarily on the basis of the specific requirements of each application.

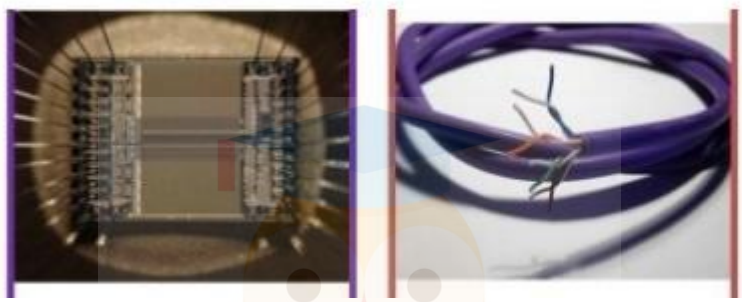


Figure 4.6.4: Semiconductor and Insulator

4.7 Joining Processes: Soldering, Brazing, Welding Process

Joining process is where two or more pieces of parts are joined together to produce a single product of required shape and size. The parts required for joining are produced by any other manufacturing technique. There are different methods used to join the parts. The joining process can be classified as

a) Permanent joining process

b) Semi – permanent or temporary joining process

Permanent joining process is done by fusing the metal together. In this process the metal is heated to its melting state and then it is fused to become one. Some of the examples for permanent joining process are welding soldering and brazing

Temporary joining process is where the metal is not heated. The joining process is carried out at room temperature. Temporary joining process can be done using nuts, bolts, screws and adhesives.

4.7.1 SOLDERING

It is defined as "a joining process wherein coalescence is produced by heating to a suitable temperature and by using a filler metal having a melting point not exceeding 427^{o}C and below the solidification temperature of the base metals". The filler metal fills in the gap of the joint by capillary action. Soldering uses fusible alloys to join metals know as solder. Ordinary gas flames or electric soldering iron is used to supply the heat to melt the solder. Fluxes are used with solder in soldering process.

Fluxes are defined as any solid, liquid or gaseous material when heated accelerates the wetting of metal with the solder. Due to wetting molten solder flow into the joint and fills the space between the two pieces to be soldered. At elevated temperature flux is highly reducing in nature preventing the formation of metal oxides. Fluxes that are generally used in soldering are Rosin, Zinc Chloride and Aluminum Chloride.

The kind of solder used depends on the metals to be joined. There are two different types of solders:

a) **Hard solders** are called spelter and hard soldering process is called silver solder brazing. The hard solder has lead and silver as it constituents. The melting point of the hard solder is in the range of 350^{0}C and above. This process gives greater strength and will stand more heat than soft solder.
b) **Soft solder** is used for joining most common metals with an alloy that melts at a temperature below that of the base metal, and always below 427^{0}C. The melting range of soft solder is 150^{0}C to 200^{0}C. The solder contains tin and lead as it constituents.

➢ **Advantages**

1. The process is done at low temperatures hence, no metallurgical damage to the base metal.
2. The soldering joint can be dismantled by simple heating of the solder.

3. It is cost effective

- **Disadvantages**

1. The strength of the joint is not good compared to welding.
2. Flux material has to be cleaned after soldering, as most of the fluxes are corrosive in nature.

4.7.2 BRAZING

Brazing is a joining process, which produces coalescence of materials by heating to a suitable temperature and using a filler metal having a melting temperature above 427°C and below the solidification temperature of the base metals being joined. The filler metal is distributed between the closely fitted surfaces of the joint by capillary attraction. Brazing is distinguished from soldering in that soldering employs a filler metal having a melting point below 427°C.

- **Brazing procedure:** The metal to be joined is cleaned for oxides, dust and oil. Fluxes are applied on the entire surface where the brazing is carried out. The parts are aligned in position for brazing. The joint is heated using a gas torch with a Carburizing flame. Filler metal is added into the space where the metal is to be joined. Due to the wetting action of the flux, the molten filler metal fills the space by capillary action. The joint is allowed to cool and then the fluxes are cleaned from the surface.

The fluxes used in brazing are borax, boric acid, borates, chlorides and fluorides. Some of the filler metal alloys used for brazing are Aluminum – Silicon, magnesium, copper and copper zinc etc.

- **Advantages**

1. It can be used to join dissimilar metals.
2. It provides good pressure tight joints.
3. Different cross sectional thickness material can be brazed.
4. Brazing avoids metallurgical damage to the metal.

- **Disadvantages**

1. Size limitations of the parts to be brazed. As the outer area has to be elevated to the higher temperature, in large sections increasing the temperature is difficult.
2. Tight mating parts are necessary for capillary action.

3. Flux are corrosive in nature, they have to be cleaned properly after brazing.

4. 8 WELDING PROCESS

At one time, the simple definition of welding was "joining metals through heating them to a molten state and fusing them together." As technical progress in welding processes has advanced, the definition has had to change.

Welding is defined as **"**a localized coalescence of metals, wherein coalescence is obtained by heating to suitable temperature, with or without the application of pressure and with or without the use of filler material. This filler material has the melting point same as the base material**."** It is also know as a *metallurgical joining process* of two metal pieces, to produce a single piece of product. .

For today's definition of welding to be all encompassing, it would have to read, **"**The joining of metals and plastics without the use of fasteners**."**

- **Welding Process**

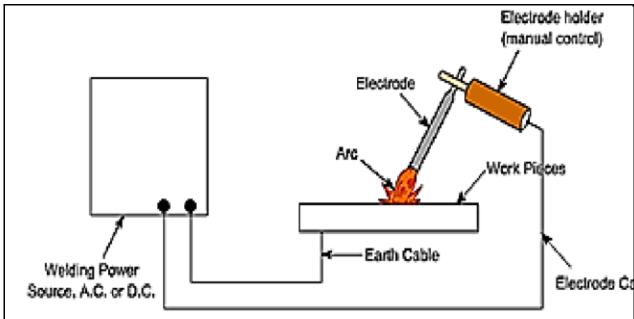
At one time, the simple definition of welding was "joining metals through heating them to a molten state and fusing them together." As technical progress in welding processes has advanced, the definition has had to change.

Welding is defined as **"**a localized coalescence of metals, wherein coalescence is obtained by heating to suitable temperature, with or without the application of pressure and with or without the use of filler material. This filler material has the melting point same as the base material**."** It is also know as a *metallurgical joining process* of two metal pieces, to produce a single piece of product. .

For today's definition of welding to be all encompassing, it would have to read, **"**The joining of metals and plastics without the use of fasteners**."**

4.8.1 ARC WELDING

Arc welding or shielded metal arc welding (SMAW) is the oldest and most widely used process being used for fabrication. The arc is struck between a flux covered stick electrode and the work pieces. The work pieces are made part of an electric circuit, known as welding circuit. It includes welding power source, welding cables, electrode holder, earth clamp and the consumable coated electrode. The details of welding circuit is as follows,



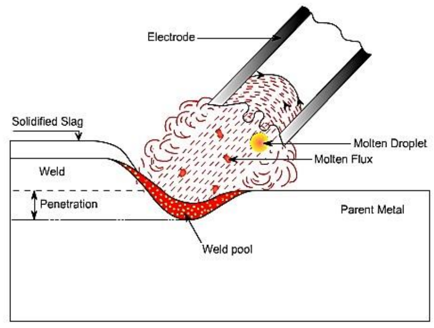


Figure 4.8.1: Arc Welding Circuit	Figure 4.8.1: Molten Metal and Flux Transfer to Weld Pool

Figure **4.8.1** (b) shows the fine molten droplets of metal and molten flux coming from the tip of the coated electrode. The flux melts along with the metallic core wire and goes to weld pool where it reacts with molten metal forming slag which floats on the top of molten weld pool and solidifies after solidification of molten metal and can be removed by chipping and brushing.

Welding power sources used may be transformer or rectifier for AC or DC supply. The requirement depends on the type of electrode coating and sometimes on the material to be welded.

The constant-current or drooping type of power source is preferred for manual metal arc welding since it is difficult to hold a constant arc length. The changing arc length causes arc voltage to increase or decrease, which in turn produces a change in welding current. The steeper the slope of the volt-ampere curve within the welding ranges, the smaller the current change for a given change in arc voltage. This results into stable arc, uniform penetration and better weld seam in spite of fluctuations of arc length.

The welding voltages range from 20 to 30 V depending upon welding current i.e. higher the current, higher the voltage. Welding current depends on the size of the electrode i.e. core diameter. The approximate average welding current for structural steel electrodes is 35.d (where d is electrode diameter in mm) with some variations with the type of coating of electrode.

4.8.2 Oxy- acetylene Gas welding

Gas welding is a most important type of welding process (Figure **4.8.2**). It is done by burning of fuel gases with the help of oxygen which forms a concentrated flame of high temperature. This flame directly strikes the weld area and melts the weld surface and filler material. The melted part of welding plates diffused in one another and creates a weld joint after cooling. This welding method can be used to join most of common metals used in daily life. Acetylene is the fuel gas used. Acetylene produces high heat content in the range of 32000 C than other fuel gases. Acetylene gas has more available carbon (92.3 %) and hydrogen (7.7 %) by weight. The heat is released when the carbon breaks away from hydrogen to combine with O_2 and burn.

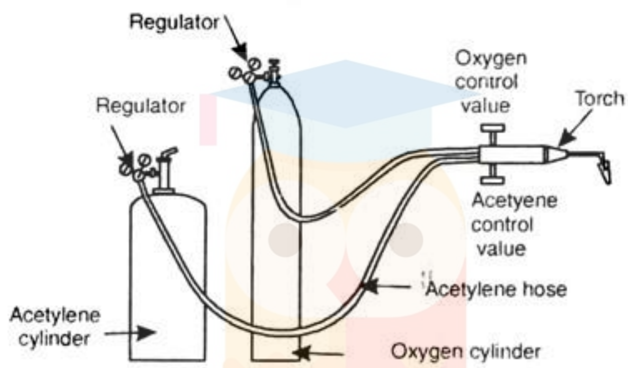


Figure 4.8.2: Oxy- acetylene Gas welding

Gas welding process is quite simpler compare to arc welding. In this process all the equipment are connected carefully. The gas cylinder and oxygen cylinder connected to the welding torch through pressure regulators. Now the regulate pressure of gas and oxygen supplied to the torch where they properly mixed. The flame is ignited by a striker. Take care the tip of torch is pointing downward. Now the flame is controlled through valves situated in welding torch. The flame is set at natural flame or carburizing flame or oxidizing flame according to the welding condition. Now the welding torch moved along the line where joint to be created. This will melt the interface part and join them permanently.

4.9 TYPES OF FLAME

4.9.1 Natural Flame

As the name implies, this flame has equal amount of oxygen and gases fuel by the volume. This flame burns fuel completely and does not produce any chemical effect on metal to be welded. It is mostly used for welding mild steal, stainless steel, cast iron etc. It produces little smoke. This flame has two zones. The inner zone has white in color and has temperature about 3100 degree centigrade and outer zone has blue color and have temperature about 1275 degree centigrade

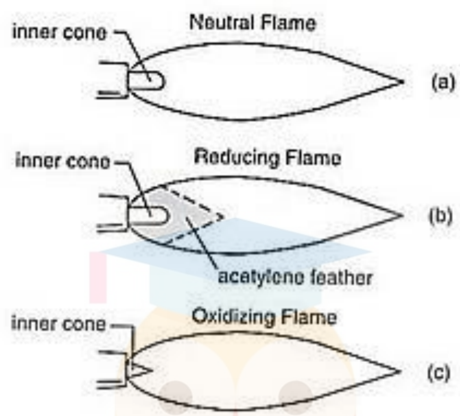


Figure 4.9.1 Types of Flames

4.9.2 Carburizing Flame:

This flame has excess of fuel gas. This flame chemically reacts with metal and form metal carbide. Due to this reason, this flame does not used with metal which absorb carbon. It is smoky and quiet flame. This flame has three regions. The inner zone has white color, the intermediate zone which is red in color and outer cone has blue color. The inner cone temperature is about 2900 degree centigrade. This flame is used to weld medium carbon steel, nickel etc.

4.9.3 Oxidizing Flame:

When the amount of acetylene reduces from natural flame or amount of oxygen increases, the inner cone tend to disappear and the flame obtain is known as oxidizing flame. It is hotter than natural flame and has clearly defined two zones. The inner zone has very bright white color and has temperature of about 3300 degree centigrade. The outer flame has blue in color. This flame is used to weld oxygen free copper alloy like brass, bronze etc

4.9.4 TIG Welding

Tungsten Inert Gas (TIG) or Gas Tungsten Arc (GTA) welding is the arc welding process in which arc is generated between non consumable tungsten electrode and work piece. The tungsten electrode and the weld pool are shielded by an inert gas normally argon and helium. Figure 4.10.4 shows the principle of tungsten inert gas welding process.

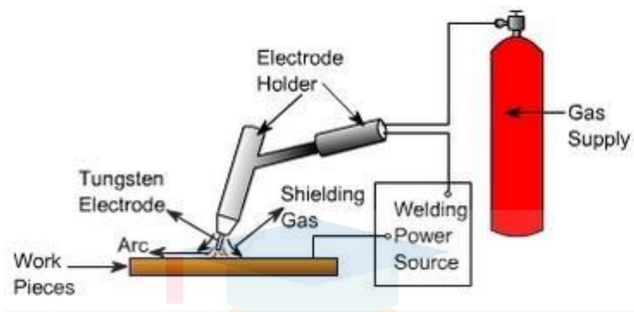


Figure 4.9.4: Schematic Diagram of TIG Welding System

The tungsten arc process is being employed widely for the precision joining of critical components which require controlled heat input. The small intense heat source provided by the tungsten arc is ideally suited to the controlled melting of the material. Since the electrode is not consumed during the process, as with the MIG or MMA welding processes, welding without filler material can be done without the need for continual compromise between the heat input from the arc and the melting of the filler metal. As the filler metal, when required, can be added directly to the weld pool from a separate wire feed system or manually, all aspects of the process can be precisely and independently controlled i.e. the degree of melting of the parent metal is determined by the welding current with respect to the welding speed, whilst the degree of weld bead reinforcement is determined by the rate at which the filler wire is added to the weld pool.

4.9.5 Gas Metal Arc Welding (MIG welding) Gas metal arc welding (GMAW) is the process in which arc is struck between bare wire electrode and work piece as shown in the figure 4.10.5. The arc is shielded by a shielding gas and if this is inert gas such as argon or helium then it is termed as metal inert gas (MIG) and if shielding gas is active gas such as CO_2 or mixture of inert and active gases then process is termed as metal active gas (MAG) welding. Figure illustrates the process of GMA welding.

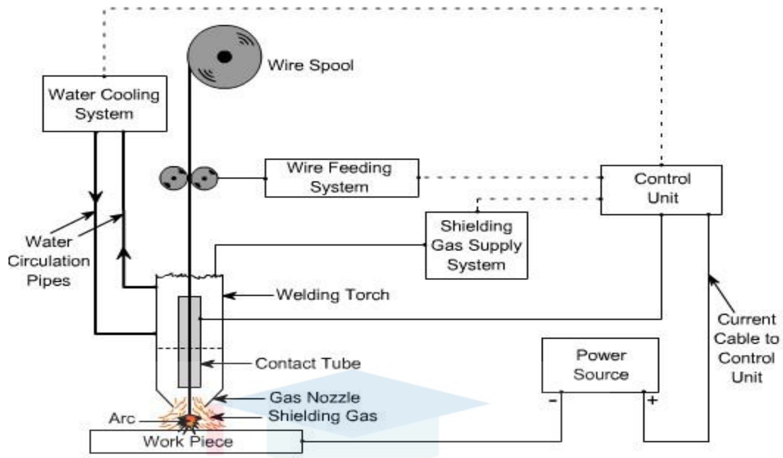


Figure 4.9.5 Schematic Diagram of MIG Welding

Direct current flat characteristic power source is the requirement of GMAW process. The electrode wire passing through the contact tube is to be connected to positive terminal of power source so that stable arc is achieved. If the electrode wire is connected to negative terminal then it shall result into unstable spattery arc leading to poor weld bead. Flat characteristic leads to self-adjusting or self-regulating arc leading to constant arc length due to relatively thinner electrode wires.

GMA welding requires consumables such as filler wire electrode and shielding gas. Solid filler electrode wires are normally employed and are available in sizes 0.8, 1.0, 1.2 and 1.6 mm diameter. Similar to submerged arc welding electrode wires of mild steel and low alloyed steel, are coated with copper to avoid atmospheric corrosion, increase current carrying capacity and for smooth movement through contact tube.

The process is extremely versatile over a wide range of thicknesses and all welding positions for both ferrous and nonferrous metals, provided suitable welding parameters and shielding gases are selected. High quality welds are produced without the problem of slag removal. The process can be easily mechanized / automated as continuous welding is possible.

However, process is costly and less portable than manual metal arc welding. Further, arc shall be disturbed and poor quality of weld shall be produced if air draught exists in working area.

GMA welding has high deposition rate and is indispensable for welding of ferrous and specially for nonferrous metals like aluminum and copper based alloys in shipbuilding, chemical plants, automobile and electrical industries. It is also used for building structures.

4.10 BELT DRIVES

A belt is a looped strip of flexible material used to mechanically link two or more rotating shafts. A belt drive offers smooth transmission of power between shafts at a considerable distance. **Belt drives** are used as the source of motion to transfer to efficiently transmit power or to track relative movement.

4.10.1 POWER TRANSMISSION

Belts are the cheapest utility for power transmission between shafts that may not be parallel. Power transmission is achieved by specially designed belts and pulleys. The demands on a belt drive transmission system are large and this has led to many variations on the theme. They run smoothly and with little noise, and cushion motor and bearings against load changes, albeit with less strength than gears or chains. However, improvements in belt engineering allow use of belts in systems that only formerly allowed chains or gears.

4.10.2 TYPES OF BELT DRIVES:

In a two pulley system, depending upon the direction the belt drives the pulley, the belt drives are divided into two types. They are open belt drive and crossed belt drive. The two types of belt drives are discussed below in brief.

4.10.3OPEN BELT DRIVES

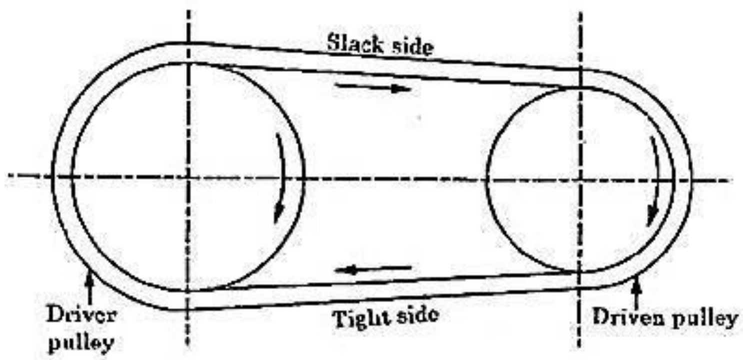


Figure 4.10.3: Open belt drive

An open belt drive is used to rotate the driven pulley in the same direction of driving pulley. In the motion of belt drive, power transmission results make one side of pulley more tightened compared to the other side. In horizontal drives, tightened side is always kept on the lower side of two pulleys because the sag of the upper side slightly increases the angle of folding of the belt on the two pulleys.

4.10.4 Crossed belt drives

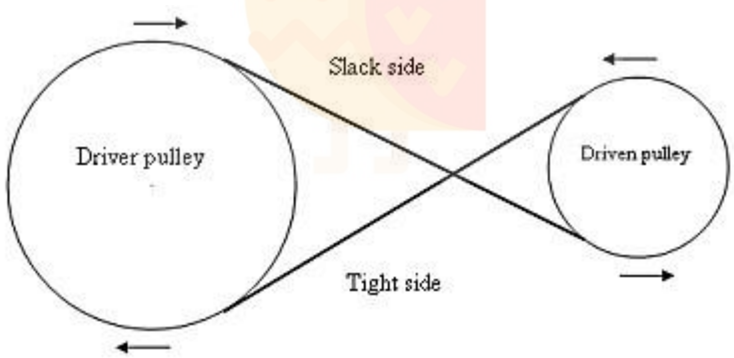


Figure 4.10.4: Crossed belt drive

A crossed belt drive is used to rotate driven pulley in the opposite direction of driving pulley. Higher the value of wrap enables more power can be transmitted than an open belt drive. However, bending and wear of the belt are important concerns.

➢ Advantages of belt drives

a) Belt drives are simple are economical.
b) They don’t need parallel shafts.
c) Belts drives are provided with overload and jam protection.
d) Noise and vibration are damped out. Machinery life is increased because load fluctuations are shock-absorbed.
e) They are lubrication-free. They require less maintenance cost.
f) Belt drives are highly efficient in use (up to 98%, usually 95%).
g) They are very economical when the distance between shafts is very large.

➢ Disadvantages of belt drives

a) In Belt drives, angular velocity ratio is not necessarily constant or equal to the ratio of pulley diameters, because of slipping and stretching.
b) Heat buildup occurs. Speed is limited to usually 35 meters per second.
c) Power transmission is limited to 370 kilowatts.
d) Operating temperatures are usually restricted to –35 to 85°C.
e) Some adjustment of center distance or use of an idler pulley is necessary for wearing and stretching of belt drive compensation.

4.11DEFINITIONS

4.11.1 SLIP OF THE BELT:

The power transmission in belt drive is caused by friction between belt and pulleys. However, some relative movement will always exist at driver-belt interface and belt-driven pulley interface due to ineffective friction. This phenomenon is called as slip the belt. Slip is expressed in percentage. Due to slip, the belt speed will be less than the peripheral speed of the driving wheel and slightly more than peripheral speed of the driven wheel.

4.11.2 Creep:

Presence of friction between pulley and belt causes differential tension in the belt. This differential tension causes the belt to elongate or contract and create a relative motion between the belt and the pulley surface. This relative motion between the belt and the pulley surface is created due to the phenomena known as elastic creep.

4.11.3 Velocity Ratio

Velocity ratio of belt drive Velocity ratio of belt drive is defined as,

$$\frac{N_L}{N_s} = \frac{d_s + t}{d_L + t}(1 - s)$$

Where, N_L and N_s are the rotational speeds of the large and the small pulley respectively, s is the belt slip and t is the belt thickness.

4.11.4 Length of belt in open belt:

Consider an open belt drive as shown in figure,

Let,

D = Diameter of larger pulley. d = Diameter of smaller pulley. x = Distance between centers of pulley. L = Length of belt.

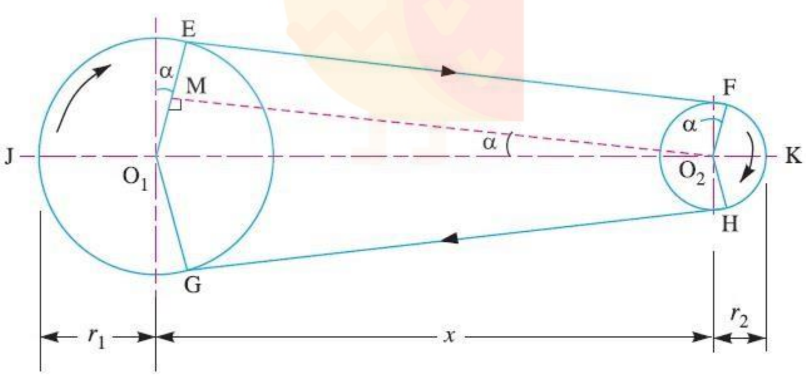


Figure 4.11.4: Open Belt Drive

Length of open belt

Arc GJ + Arc JE[1] + E[1]D + Arc FK + Arc KH + GH

$$L = \sqrt{4C^2 - (D-d)^2} + \frac{1}{2}(D\theta_L + d\theta_s)$$

4.11.5 Length of belt in cross belt

Consider a cross belt drive as shown in figure,

Let,

D = Diameter of larger pulley. d
= Diameter of smaller pulley.
L = Length of belt.

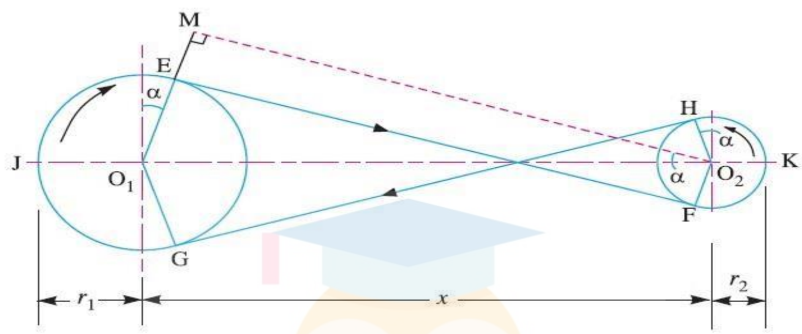


Figure 4.11.5: Crossed belt drive

Length of cross belt

Arc GJ + Arc JE^1 + E^{1}D + Arc FK + Arc KH + GH

$$L = \sqrt{4x^2 - (D+d)^2} + \frac{\pi}{2}(D+d)$$

4.11.3 FLAT BELTS

Figure 4.11.3a: Belts on a Yamaha R 2GM20 marine diesel engine.

The application of a flat belt drive power is transmitted from motor to engine flywheel. Flat belts were used early in line shafting to transmit power in factories. It is a simple system of power transmission that was well suited to its day. It delivered high power for high speeds (500 hp for 10,000 ft. /min), in cases of wide belts and large pulleys. These drives are bulky, requiring high tension leading to high loads, so vee belts have mainly replaced the flat-belts (except when high speed is needed over power.

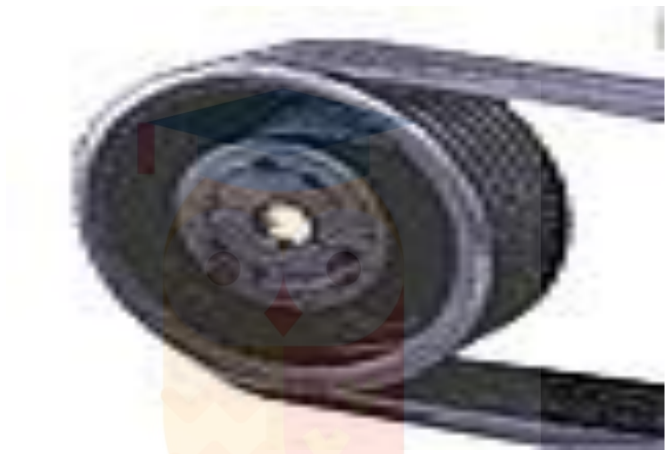


Figure 4.11.3b: Flat belt

Flat belt pulleys shown in figure 4.11.3 need to be carefully aligned to prevent the belt from slipping off. Because flat belts tend to slip towards the higher side of the pulley, pulleys were made with a slightly convex or "crowned" surface (rather than flat) to keep the belts centered. The flat belt also tends to slip on the pulley face when heavy loads are applied. Many proprietary dressings were available that could be applied to the belts to increase friction, and so power transmission. Grip was better if the belt was assembled with the hair (i.e. outer) side of the leather against the pulley although belts were also often given a half-twist before joining the ends so that wear was evenly distributed on both sides of the belt (DB). Belts were joined by lacing the ends together with leather thonging, or later by patent steel comb fasteners. A good modern use for a flat belt is with smaller pulleys and large central distances. They can connect inside and outside pulleys, and can come in both endless and jointed construction.

4.11.4 Ratio of tension in flat belt drives

Consider a driven pulley rotating in the clockwise direction as shown in figure

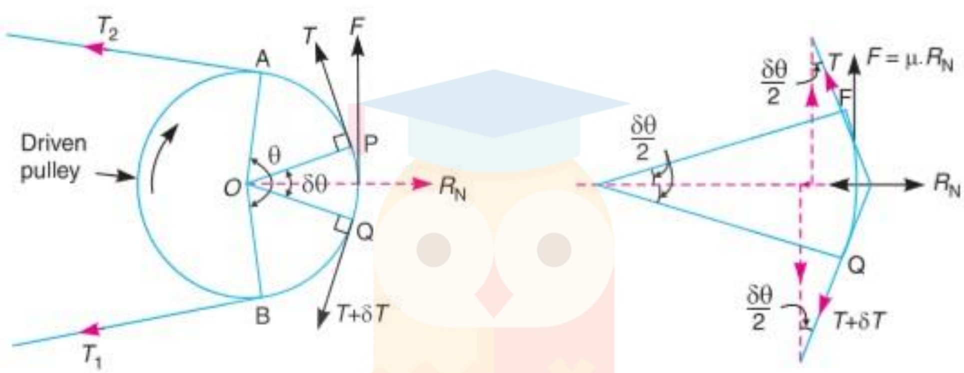


Figure 4.11.4: Tension in belts

Let,

T_1 = Tension in the belt on the tight side.
T_2 = Tension in the belt on slack side.
Θ = Angle of contact in radians.

Now consider a small portion of the belt PQ, an angle $\delta\Theta$ at the center of the pulley as shown in figure.

The belt PQ is in equilibrium under the following forces,

- Tension T in the belt at P
- Tension $(T+\delta T)$ in the belt at Q ➢ Normal reaction R_N
- Frictional force $F= \mu \times R_N$

Where µ is the co-efficient of friction between the belt and pulley Resolving all the forces horizontally, we have

R_N □ TSin __□□ □ □□(T T)Sin __□□

.... **(1)**

2 2

Since the angle δϴ is very small,

Sin □□ = □□

2 2

Substitute in equation 1 we have,

R_N □ T __□□ □ □□(T T) __□□

2 2

R_N □ T □□□T □□□□T □□

2 2 2

Neglecting, T□ __□□,

2

T □□□T □□□ □□T

2 2

R_N □ □□T

Resolving all the forces vertically we have,

F (T□ □□T)Cos__□□ □TCos__□□

2 2

F□□R_N

□R_N □ □□(T T)Cos —— □□ □TCos —— □□

.... **(2)**

2 2

Since the angle δϴ is very small

Put Cos —— □□ =1 in equation 2.

2

□ □ □□ □R_N (TT) T

□ □□R_N T

R_N □——□ T

□

Equating values of R_N

□T

Tδϴ=—— .... **(3)**

□

Rearranging equation 3

□T

——□□□□

T

Integrating above equation between the limits T_1 & T_2 from 0 to ϴ, we have

T

1 □T □

□ □

T 2 ——T □□ □□ 0

T 1 1 □

□
T ₂T□ □□ □□T

□
0 log

T e 1 □log T e 2 □□□

T1) □□□
log (e
T2

T1 □e□□
T2

The above expression gives the relation between the tight side and slack side tensions, in terms of co-efficient of friction and angle of contact.

4.11.5 V Belts

The V belts are the probably the most common means of transmitting power between fractional horse power motors to machines. Mostly, the driver and driven pulleys lie in the same vertical plane. There is an upper limit on the center distance or belt length. Long center distances are not recommended, because the excessive vibration of slack side flutters and shorten the belt life. In general the center distance should not be greater than 3 times the sum of diameters of input and output pulleys. Since the V belt is short, it is subjected to the action of load and fatigue a greater number of times. Further, its ability in absorbing the shocks is poor.

Figure 4.11.5: V Belts

The V belts work better in the speed range 300 to 1500 m/min. V-belts are widely used in variable speed drives using adjustable sheaves. By moving the sheaves axially the pitch diameters of the driving and driven pulleys could be varied to get variable output speed. This type of drive is common on ring spinning and rotor spinning machines. Quarter-turn drives are used to transmit motion between horizontal and vertical shafts using deep groove pulleys and relatively long center distances.

➢ **Advantages**

a) High power transmission capacity because v groves provide excellent grip.
b) The functioning of the belt and the pulley is smooth and quiet.
c) The V belt drives provides compactness due to the small distance between the small distances of pulleys.
d) Slip between belt and pulley are negligible.
e) The axis can be horizontal, vertical or inclined
f) They can be damped vibration.

➢ **Disadvantages**

a) It cannot be used in large center distances.
b) In V belts constructions of pulleys is not simple.
c) V belts cannot be used for long distances due to greater weight per unit length.
d) Cost is high.
e) It may not be applicable for synchronous machines because they are not free from creep.

- **Applications**

  Main drives (drive from motor) in all spinning, yarn preparatory, texturing machines, looms, warping and winding machines and compressors.

4.11.6 Timing Belts

Figure 4.11.6: Timing belt

Timing belts, shown in figure 4.12.6 (also known as Toothed, Notch or Cog) are *positive* transfer belt and can track relative movement. These belts have teeth that fit into a matching toothed pulley. When correctly tensioned, they have no slippage, run at constant speed, and are often used to transfer direct motion for indexing or timing purposes (hence their name). They are often used in lieu of chains or gears, so there is less noise and a lubrication bath is not necessary. Camshafts of automobiles, miniature timing systems, and stepper motors often utilize these belts. Timing belts need the least tension of all belts, and are among the most efficient. They can bear up to 200 hp (150 kW) at speeds of 16,000 ft/min.

Timing belts with a helical offset tooth design are available. The helical offset tooth design forms a chevron pattern and causes the teeth to engage progressively. The chevron pattern design is self-aligning. The chevron pattern design does not make the noise that some timing belts make at idiosyncratic speeds, and is more efficient at transferring power (up to 98%).

Disadvantages:

a) High cost.

b) Need for toothed pulleys.
c) Less protection from overload and jam.
d) No clutch action.

4.12 SAMPLE PROBLEMS

1. An engine running at 200 rpm drives a line shaft, by means of a belt drive. The engine pulley is 750 mm in diameter, and the pulley on the shaft is 450 mm in diameter. Determine the speed of the line shaft. Assume no slip.

Solution:

N_1 = 200 rpm
D_1=750 rpm
D_2=450 rpm
$N_2 = N_1 * (D_1/D_2)$
= 200(750/450) =
333.34rpm.

2. Following are the details of a crossed belt drive

Diameter of the driver	:	200 mm
Diameter of the follower	:	400 mm
Center distance of the drive	:	2m
Speed of the drive	:	400 rpm
Angle of contact	:	197.3 □

Determine the length of the belt required.

Solution:

D_1 = 200 mm
D_2= 400 mm
C = 2m
N_1 = 400 rpm
Length of the belt = $L = 2C + \Pi / 2\ (D_{1+} D_2) + (D_{1+} D_2) / 4C$

= (2x2) + Π / 2 (0.2+ 0.4) + (0.2+ 0.4) / 4x2

= 4.99 m

3. For the above drive if tension on tight side is 1.3 kN, and the coefficient of friction between the belt and pulley is 0.25, find the power capacity of the drive.

Solution:

T_1 = 1.3 kN

□ = 197.3 x (Π /180) radians

V = Π D_1 N_1/60

= (Π x 0.2) (400/60)

= 4.2 m/s T_1

/ T_2 = $e^{□□}$

1.2 x 10^3 / T_2 = $e^{(0.25 \times 197.3 \times \Pi /180)}$

T_2 = 506.33 N

Power transmitted, P = (T_1 - T_2) V

(1200-506.33) x 4.2

= 2.9 kW

4.13 GEAR DRIVES

Gears are defined as toothed wheels, which transmit power and motion from one shaft to another by means of successive engagement of teeth

- **a)** The center distance between the shafts is relatively small.
- **b)** It can transmit very large power
- **c)** It is a positive, and the velocity ratio remains constant.
- **d)** It can transmit motion at a very low velocity.

4.13.1 NOMEN CLATURE

Spur gears are used to transmit rotary motion between parallel shafts. They are usually cylindrical is shape and the teeth are straight and parallel to the axis of rotation.

In a pair of gears, the larger is often called the GEAR and, the smaller one is called the PINION

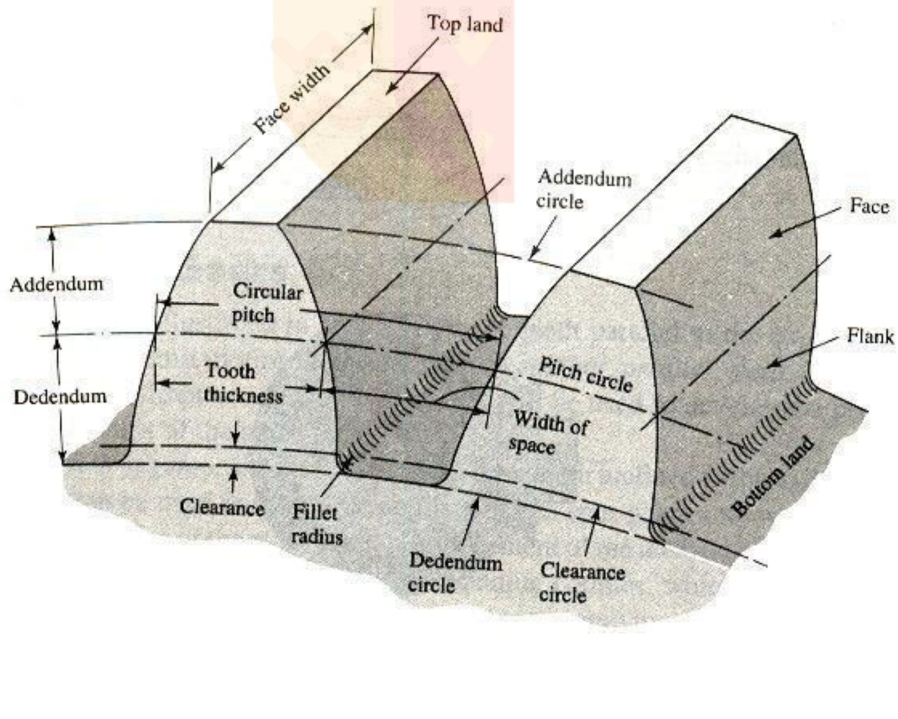


Figure 4.13.1: Nomenclature of Spur Gear

1. **Pitch Surface:** The pitch surfaces of the gears are imaginary planes, cylinders or cones that roll together without slipping.
2. **Pitch circle:** It is a theoretical circle upon which all calculations are usually based. It is an imaginary circle that rolls without slipping with the pitch circle of a mating gear. Further, pitch circles of mating gears are tangent to each other.
3. **Pitch circle diameter:** The pitch circle diameter is the diameter of pitch circle. Normally, the size of the gear is usually specified by pitch circle diameter. This is denoted by “d”
4. **Top land:** The top land is the surface of the top of the gear tooth
5. **Base circle:** The base circle is an imaginary circle from which the involute curve of the tooth profile is generated (the base circles of two mating gears are tangent to the pressure line)
6. **Addendum**: The Addendum is the radial distance between the pitch and addendum circles. Addendum indicates the height of tooth above the pitch circle.
7. **Dedendum**: The dedendum is the radial distance between pitch and the dedendum circles. Dedendum indicates the depth of the tooth below the pitch circle.
8. **Whole Depth**: The whole depth is the total depth of the tooth space that is the sum of addendum and Dedendum.
9. **Working depth:** The working depth is the depth of engagement of two gear teeth that is the sum of their addendums
10. **Clearance:** The clearance is the amount by which the Dedendum of a given gear exceeds the addendum of it’s mating tooth.
11. **Face:** The surface of the gear tooth between the pitch cylinder and the addendum cylinder is called face of the tooth.
12. **Flank:** The surface of the gear tooth between the pitch cylinder and the root cylinder is called flank of the tooth.
13. **Face Width:** is the width of the tooth measured parallel to the axis.
14. **Fillet radius:** The radius that connects the root circle to the profile of the tooth is called fillet radius.
15. **Circular pitch:** is the distance measured on the pitch circle, from a point on one tooth to a corresponding point on an adjacent tooth.

16. **Circular tooth thickness:** The length of the arc on pitch circle subtending a single gear tooth is called circular tooth thickness. Theoretically circular tooth thickness is half of circular pitch.
17. **Width of space:** (tooth space) The width of the space between two adjacent teeth measured along the pitch circle. Theoretically, tooth space is equal to circular tooth thickness or half of circular pitch
18. **Working depth:** The working depth is the depth of engagement of two gear teeth, that is the sum of their addendums
19. **Whole depth:** The whole depth is the total depth of the tooth space, that is the sum of addendum and dedendum and (this is also equal to whole depth + clearance)
20. **Centre distance:** it is the distance between centres of pitch circles of mating gears. (it is also equal to the distance between centers of base circles of mating gears)
21. **Line of action:** The line of action is the common tangent to the base circles of mating gears. The contact between the involute surfaces of mating teeth must be on this line to give smooth operation. The force is transmitted from the driving gear to the driven gear on this line.
22. **Pressure angle:** It is the angle that the line of action makes with the common tangent to the pitch circles.
23. **Arc of contact:** Is the arc of the pitch circle through which a tooth moves from the beginning to the end of contact with mating tooth.
24. **Arc of approach:** it is the arc of the pitch circle through which a tooth moves from its beginning of contact until the point of contact arrives at the pitch point.
25. **Arc of recess:** It is the arc of the pitch circle through witch a tooth moves from the contact at the pitch point until the contact ends.
26. **Velocity Ratio**: Is the ratio of angular velocity of the driving gear to the angular velocity of driven gear. It is also called the speed ratio

4.14 CLASSIFICATION OF GEARS:

a)Spur Gears
b) Helical gears
c) Bevel gears
d) Worm Gear
e) Rack and pinion

a) Spur Gear

Gears have specially constructed toothed profile and are extensively used to transmit power in machines. Gears can be classified into spur gears, helical gears, bevel and worm gears. Within these gears there are sub-classification based on designs. Gears are made of ferrous (steel, cast iron), non-ferrous metals (bronze based) and non-metallic materials (Nylon, fibre reinforced in phenolic resin etc.). Steel is the most widely used material for gears. Spur gears are the simplest gears, having the maximum precision and high power transmission efficiency compared to any other gears. Hence, they are preferred as the first choice in industrial machines, except high speed and high load applications. In spur gears, two meshing gears are mounted on parallel shafts. The teeth are cut parallel to the axis of gear. In a normal or external spur gear, the teeth are cut on the outside of the rim of gear.

Figure 4.14a: Spur Gear

Generally, the input gear is smaller in size and the output gear is larger in size to get speed reduction. The driver and the driven gears are called ‘pinion’, and ‘gear’, respectively.

b) Helical Gears:

In helical gears, the two meshing gears may be mounted on parallel or intersecting shafts. The teeth on helical gear are cut at an angle (helix angle) to the gear axis as shown below. The helix angle usually ranges between 15º and 20º.
Helical gears are classified into: 'Parallel helical gears', 'Crossed helical gears' and 'Herringbone or Honeycomb gears'. All the helical gears generate thrust loads on the shafts because of inclined teeth; hence, these must be taken care while designing the machines.

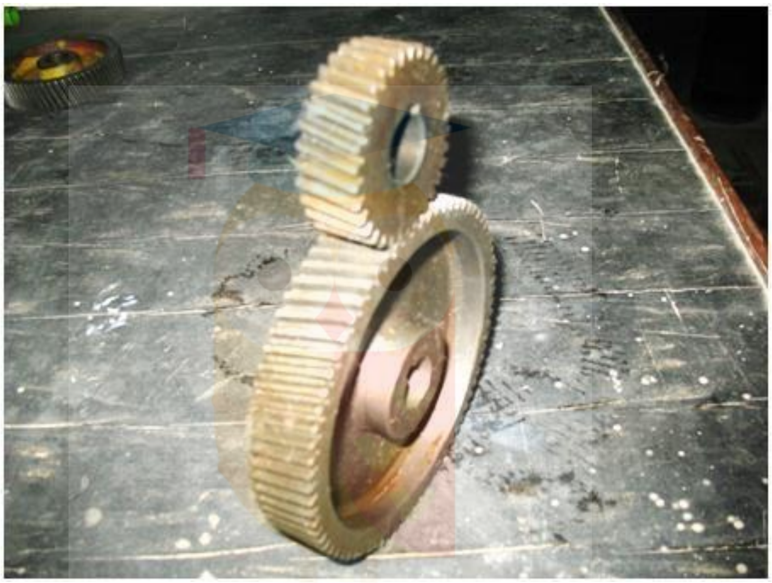


Figure 4.14b: Helical Gear

Since the helix (or teeth) can slope either in upward or downward direction, the term 'right hand' and 'left-hand' helical gears are used to distinguish them. When a helical gear is viewed in a plane parallel to the axis of gear and if the right side of the teeth is nearer to the observer, then it is a right hand gear. The rule is similar to determine whether a screw is right or left-handed. In the above figure, a 'right hand' gear at the top is meshing with a 'left hand' gear at the bottom.

c) Bevel gears:

Since the helix (or teeth) can slope either in upward or downward direction, the term ‘right hand’ and ‘left-hand’ helical gears are used to distinguish them. When a helical gear is viewed in a plane parallel to the axis of gear and if the right side of the teeth is nearer to the observer, then it is a right hand gear. The rule is similar to determine whether a screw is right or left-handed. In the above figure, a ‘right hand’ gear at the top is meshing with a ‘left hand’ gear at the bottom.

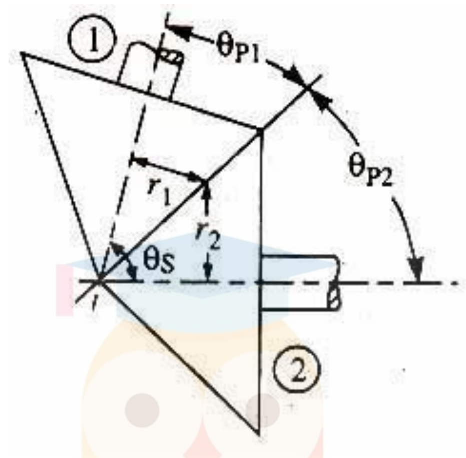


Figure 4.14c: Bevel gear specification

d) Worm Gear

Worm gears are used to transmit power between two nonintersecting shafts, which are right angles to each other. Crossed helical gears are also used for applications involving nonparallel, non-intersecting shafts; but they are limited in their load transmission capacity. Worm gear drives are used for large speed reduction ratio of 100:1 or more in a single stage. This large amount of speed reduction is not possible with any other gears in a single stage. They are very compact compared to other gears. Worm gear drives consists of a worm and a worm gear or wheel which is a helical gear. The worm is similar to a screw. The threads of the worm have an involute helicoid profile. The pair of teeth on meshing worm and worm gear must have the same hand. The teeth on the worm wheel envelop the threads on the worm giving either a line or an area of contact between meshing parts.

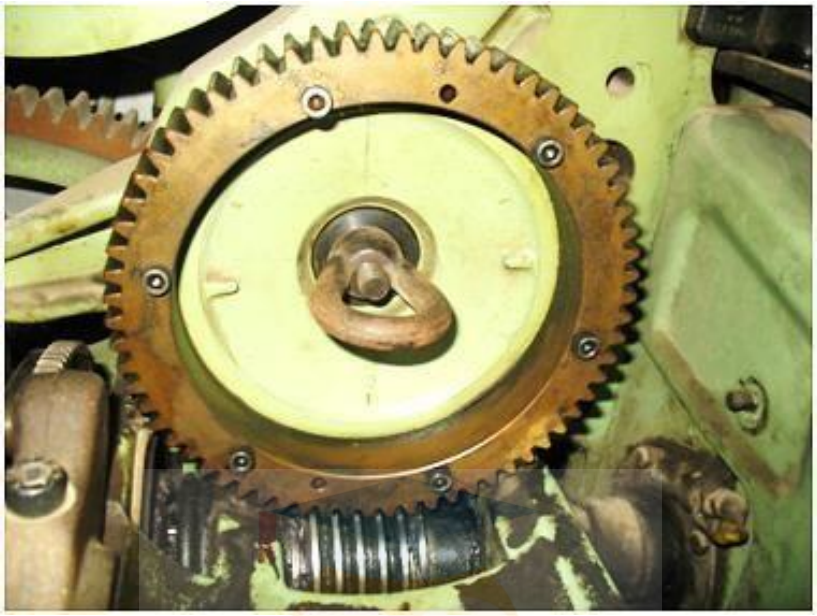


Figure 4.14d: Worm Gear

One of the advantages associated with the use of worm gears is that the tooth engagement occurs without shock prevalent in other gear types. The meshing of teeth occurs with a sliding action resulting in very quiet operation. The sliding friction may produce overheating, which must be dissipated to the surroundings by lubrication. The power transmission efficiency of worm gears is lower compared to spur gears, parallel helical gears, and bevel gears; but higher than that of crossed helical gears. Worm and worm gears produce thrust load on shaft bearings. The power transmission capacity is low and limited to 100kW.

Worm gears are very compact compared to other gears for the same speed reduction. Provision can be made for self-locking operation, where the motion is transmitted only from the worm to the worm wheel. This is advantageous in lifting devices. The worm wheel in general made from phosphor-bronze alloy, which is costly. The worm is usually made of hardened alloy steel. The worm is usually cut on a lath, whereas the gear is hobbed. All the worm gears must be carefully mounted to ensure proper operation.

e) Rack and pinion

Rack and pinion is used to convert a rotary motion to translating motion or vice versa (either the pinion drives the rack or the rack drives the pinion). A rack in mesh with a pinion. The rack and pinion is used in consolidating the lap in sketcher of conventional blow rooms (rack drives the pinion) and to drive the bobbin carriage of roving machines (pinion drives the rack). Rack can be imagined as a spur gear having an infinitely large diameter. Therefore the rack has an infinite number of teeth and a base circle which is infinite distance from the pitch point. With infinite diameter of base circle, the involute outline of teeth on rack becomes straight lines.

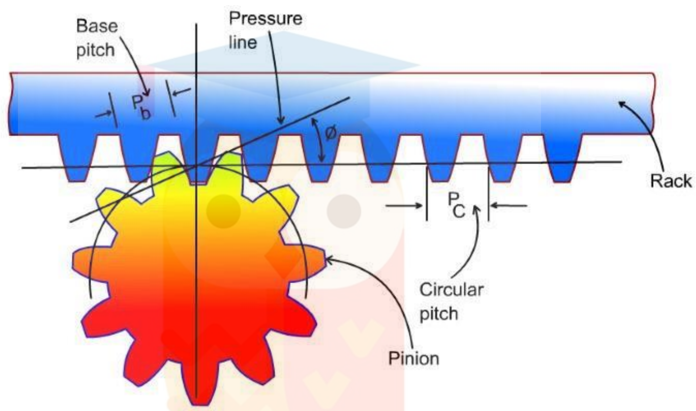


Figure 4.14e: Rack and Pinion