II B. Tech IV semester (Autonomous IARE R-16)

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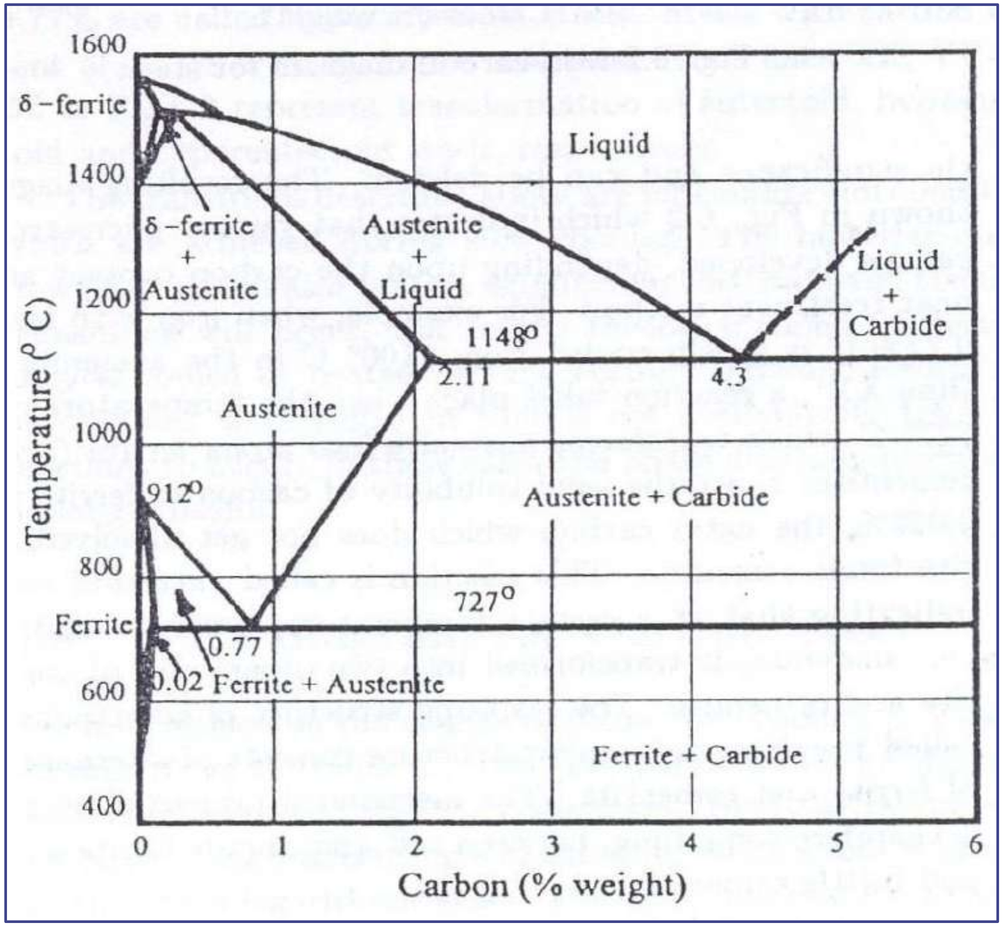
Unit-1

AIRCRAFT ENGINEERING MATERIALS

Introduction

- Metals and alloys may not posses all the desired properties in the finished product. Alloying and heat treatment are two methods which are extensively used for controlling material properties.
- In heat treatment, the microstructures of materials are modified. The resulting phase transformation influences mechanical properties like strength, ductility, toughness, hardness and wear resistance.
- Purpose of heat treatment is to increase service life of a product by increasing its strength of hardness, or prepare the material for improved manufacturability
- The basis of change in properties is phase or equilibrium diagrams

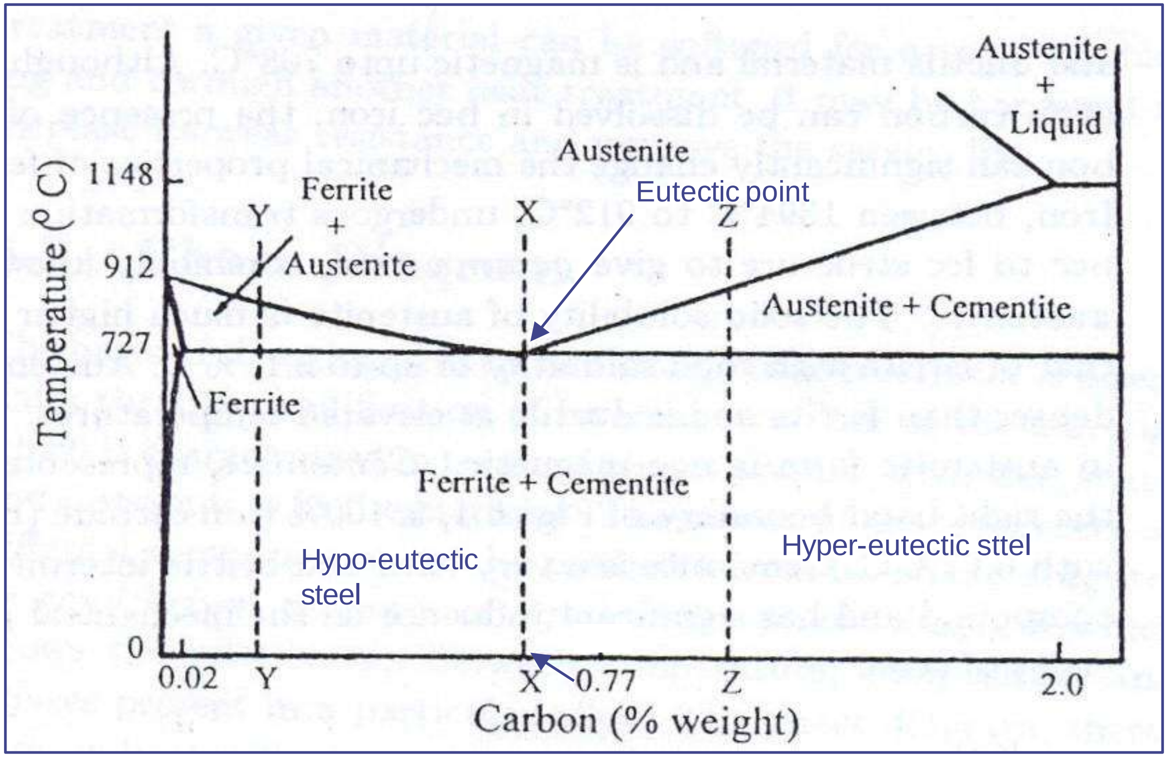
Iron Carbon Phase Diagram



FE-C Phase Diagram

- In the phase diagram Carbon percentage is shown up to 6% only since commercially pure iron contains up to 0.008% C, Steels up to 2.11% C and C.I.s up to 6.67% C.
- Pure iron melts at 1583^{o} C. When it cools first it forms delta ferrite, then austenite and finally alpha ferrite.
- Alpha ferrite or ferrite is a solid solution of BCC iron with a maximum solid solubility of 0.022% C at a temperature of 727^{o}C.
- Delta ferrite has no practical significance as it is stable only at high temperatures.
- Ferrite (derived from Latin word Ferrum) is relatively soft and ductile and is magnetic up to 768^{o}C.
- Iron, between 1394 to 912^{o}C, undergoes transformation form BCC to FCC structure to give Gamma iron, commonly known as Austenite.
- The solid solubility of Austenite is much higher than ferrite and is up to 2.11 % C. Austenite is denser than ferrite and more ductile at higher temperatures.
- Steel in austenitic form is non-magnetic.

Iron Carbon Diagram of Steels



XX: Eutectoid Reaction

Eutectoid Reaction

- When iron containing 0.77% C, is cooled from 1100^{o}C, in the austenitic phase (line XX), a reaction takes place, when the temperature reaches 727^{o}C, which converts it to ferrite (BCC) and cementite.
- This reaction is called Eutectoid Reaction.
- The resultant microstructure of eutectoid steel is called Pearlite which contains alternate layers of ferrite and cementite.
- Mech. Prop. Of Pearlite is therefore in between soft and ductile ferrite and hard and brittle cementite.

Hypo-eutectoid Steel

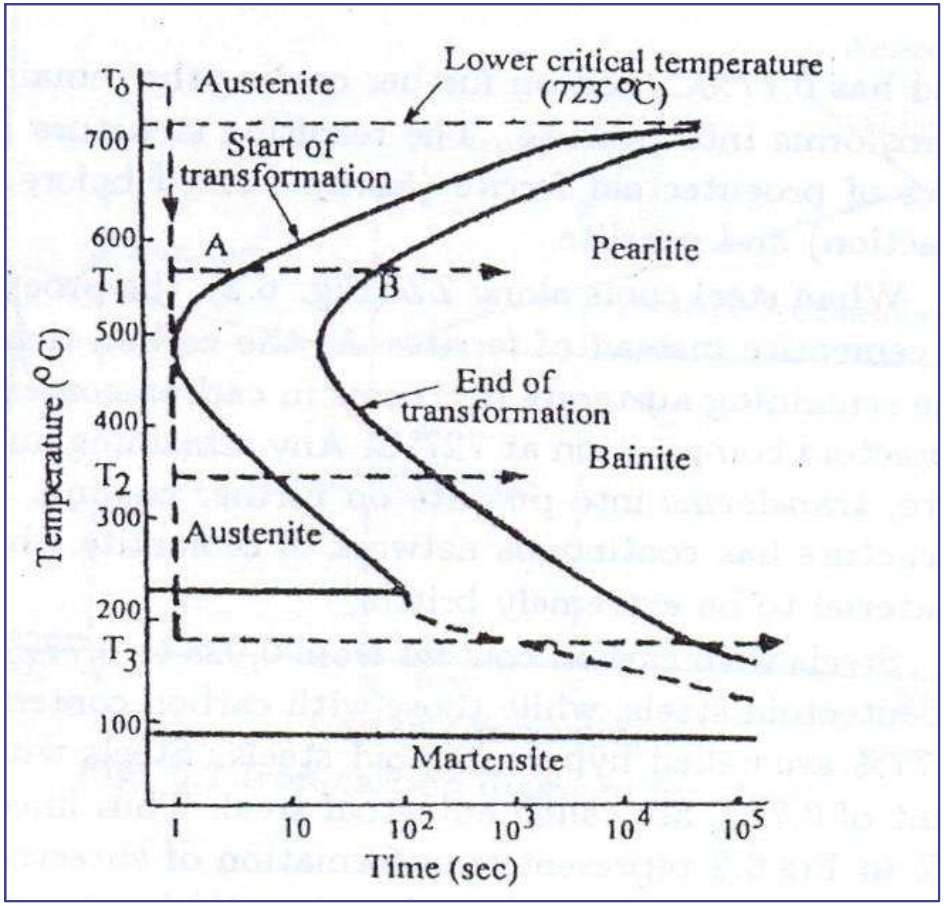
- Similarly when the carbon content is less than 0.77% (line YY) the material is entirely austenitic at higher temperature, but cooling it enters the region of stable ferrite and austenite.
- At 727^{o}C the austenite is of eutectoid composition and has 0.77% C, and on further cooing the remaining austenite transforms into pearlite. The resulting structure is proeutectoid ferrite and pearlite.

Hyper-eutectoid Steel

- When steel cool along line ZZ, the proeutectoid phase is ferrite than austenite. As the carbon-rich phase forms, the remaining austenite decreases in carbon content and reaches eutectoid composition at 727^{o}C.
- Any remaining austenite, transforms into pearlite below 727^{o}C.
- The resulting structure has continuous network of cementite which causes the material to be extremely brittle.
- Point to be noted here that these transformations are obtained during slow cooling, however by rapid cooling entirely different results are obtained since sufficient time is not available for phase reaction to occur.

Time-Temperature-Transformation (TTT) Diagram for Steel

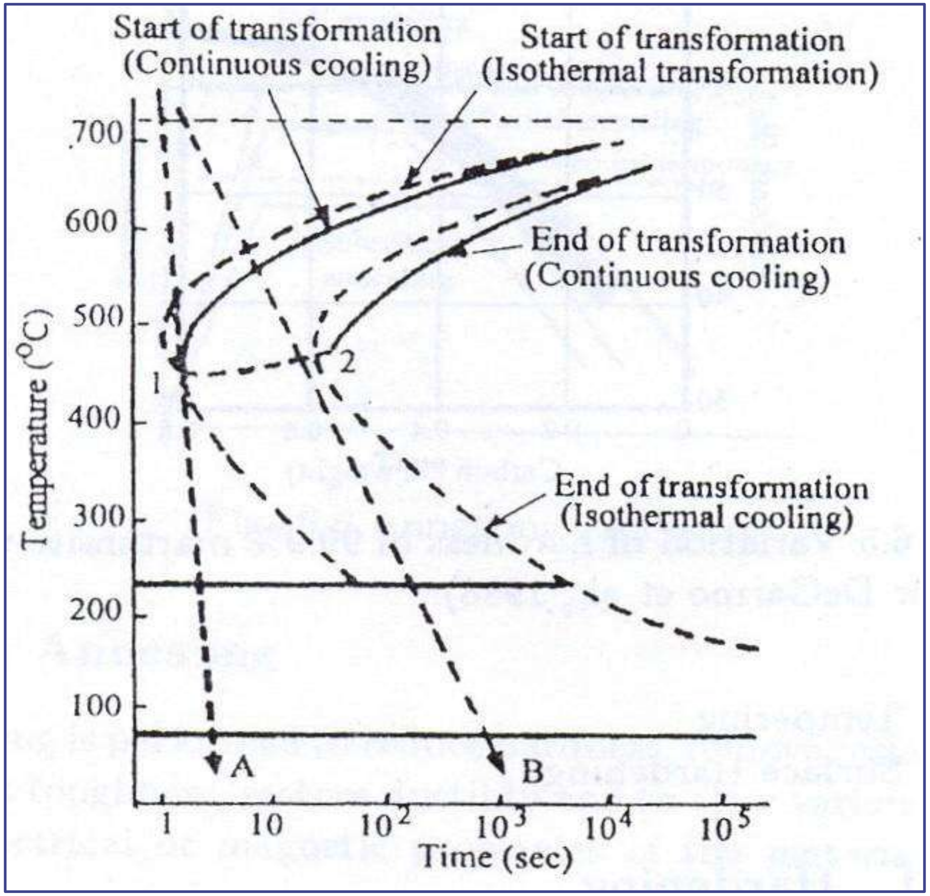
- Pearlite is produced if cooling rate is slow like in air or in a furnace. Fine pearlite is harder and less ductile than coarse pearlite.
- Bainite is a very fine microstructure, consisiting of ferrite and cementite, somewhat like Pearlite but have different morphology.This phase is stronger and more ductile than pearlite.



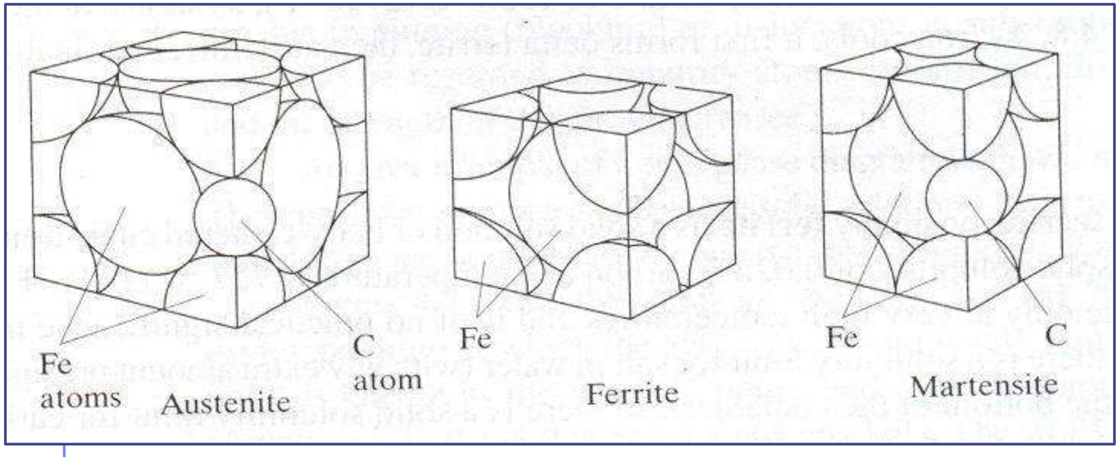
TTT diagram of Eutectic Steel

Modified TTT Diagram

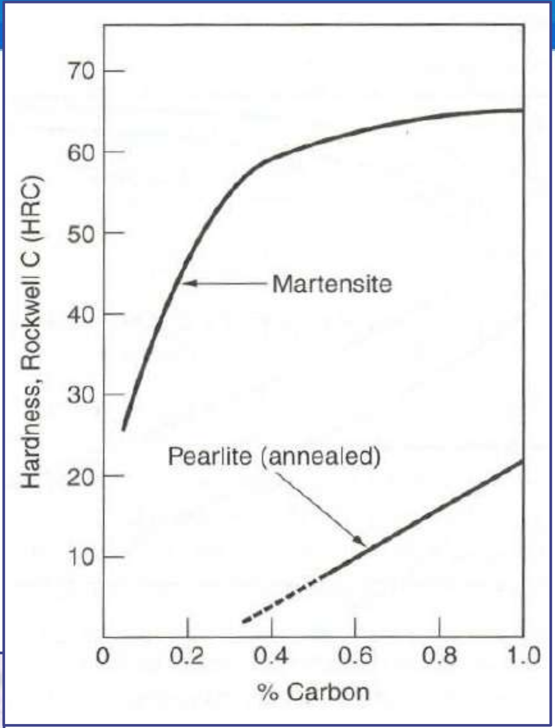
- When austenite is cooled at a very high rate, such as quenching it in water, its FCC structure transforms to Body Centered Tetragonal (BCT) known as Martensite.
- It is a extremely hard and brittle phase which lacks toughness, so limited use.

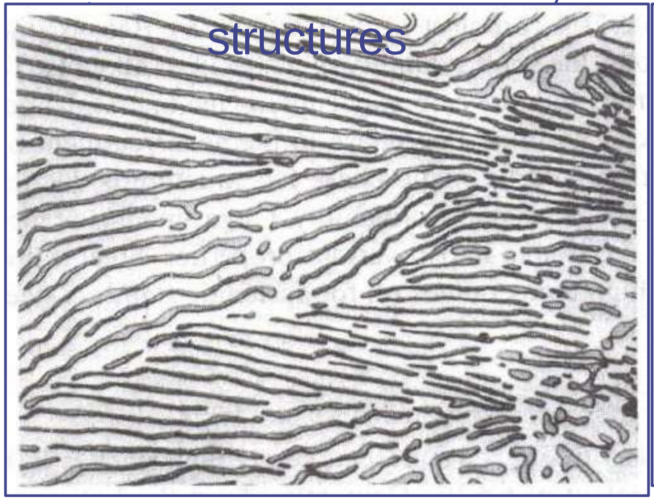


Microstructures



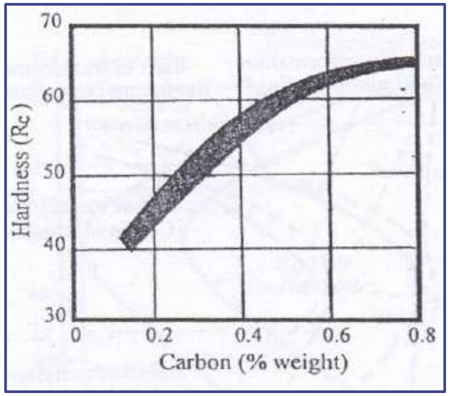
Unit cells of FCC, BCC, BCT structures





Pearlite

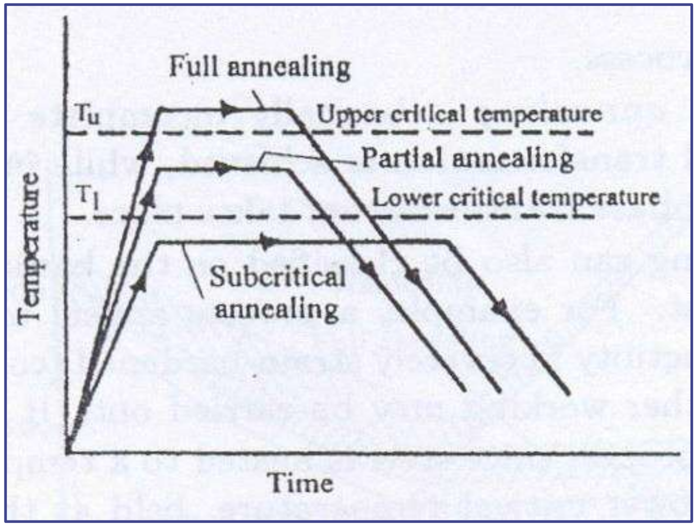
Martensite



99% Matensite

Annealing

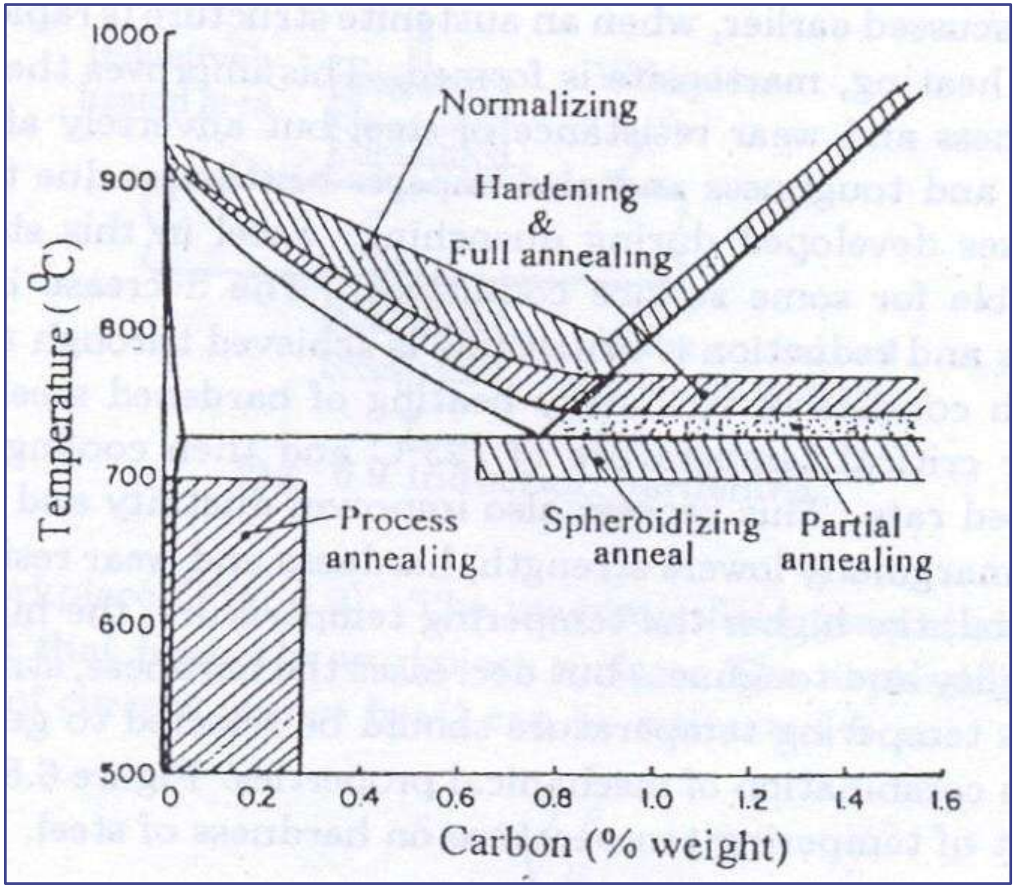
- Annealing is performed to reduce hardness, remove residual stresses, improve toughness, restore ductility, and to alter various mechanical, electrical or magnetic properties of material trough refinement of grains.
- Cooling rate is very slow around 10^{o}C per hour. Process is carried out in a controlled atmosphere of inert gas to avoid oxidation.
- Partial annealing is incomplete annealing and there is partial phase transformation however in sub-critical annealing there is no phase transformation.
- Used to achieve ductility in work hardened steels.



Normalizing

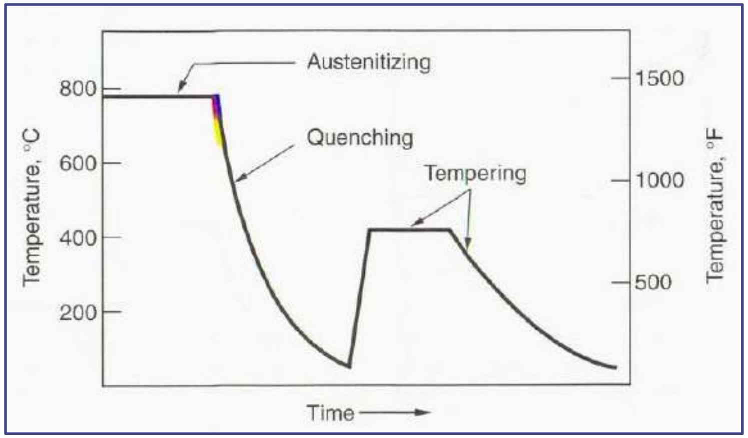
- The process is similar to annealing and is carried out to avoid excessive softness in the material.
- The material is heated above austenitic phase and then cooled in air . This gives relatively faster cooing and hence enhanced hardness and less ductility.
- In this process, austenite is decomposed in ferrite and carbide at relatively lower temperature and fine pearlite is produced.
- Normalizing is less expensive than annealing.
- In normalization variation in properties of different sections of a part is achieved.
- The selection of heat treatment operations is strongly influenced by the carbon content in th esteel.

Heat treatments on phase diagram of steel



Tempering

- Martensite is very hard and brittle.
- Tempering is applied to hardened steel to reduce brittleness, increase ductility, and toughness and relieve stresses in martensite structure.
- In this process, the steel is heated to lower critical temperature keeping it there for about one hour and then cooled slowly at prescribed rate.
- This process increses ductility and toughness but also reduces hardness, strength and wear resistance marginally. Increase in tempering temperature lowers the hardness.



- Heat treatment methods in general change the properties of entire material.
- Hardening improves wear resistance of material but lowers impact resistance and fatigue life. Therefore sometimes there is requirement of surface hardening
- Two methods are used, first is heating and cooing to get required phase, and second is thermo-chemical treatment.

UNIT II
CASTING, WELDING AND INSPECTION TECHNIQUES

1.1 CASTING PROCESS

PATTERN is considered as the model of anything so constructed that it may be used for forming an impression called **MOULD** .

- When the mould is filled with molten and metal is allowed to solidify it forms a reproduction of pattern called **CASTING**.

- **PROCESS**

1. Pattern making
2. Moulding and core making
3. Melting and casting
4. Testing and Inspection

Aircraft components produced by Casting

PATTERN MATERIALS

- **Requirement of the service.**
- **Easily worked , shaped and joined.**
- **Light in weight**
- **Strong hard and durable.**
- **Dimensionally stable in all situations.**
- **Easily available at low costs.**
- **Repairable and reused.**
- **Able to take good surface finish.**

TYPES OF MATERIALS FOR PATTERN MAKING

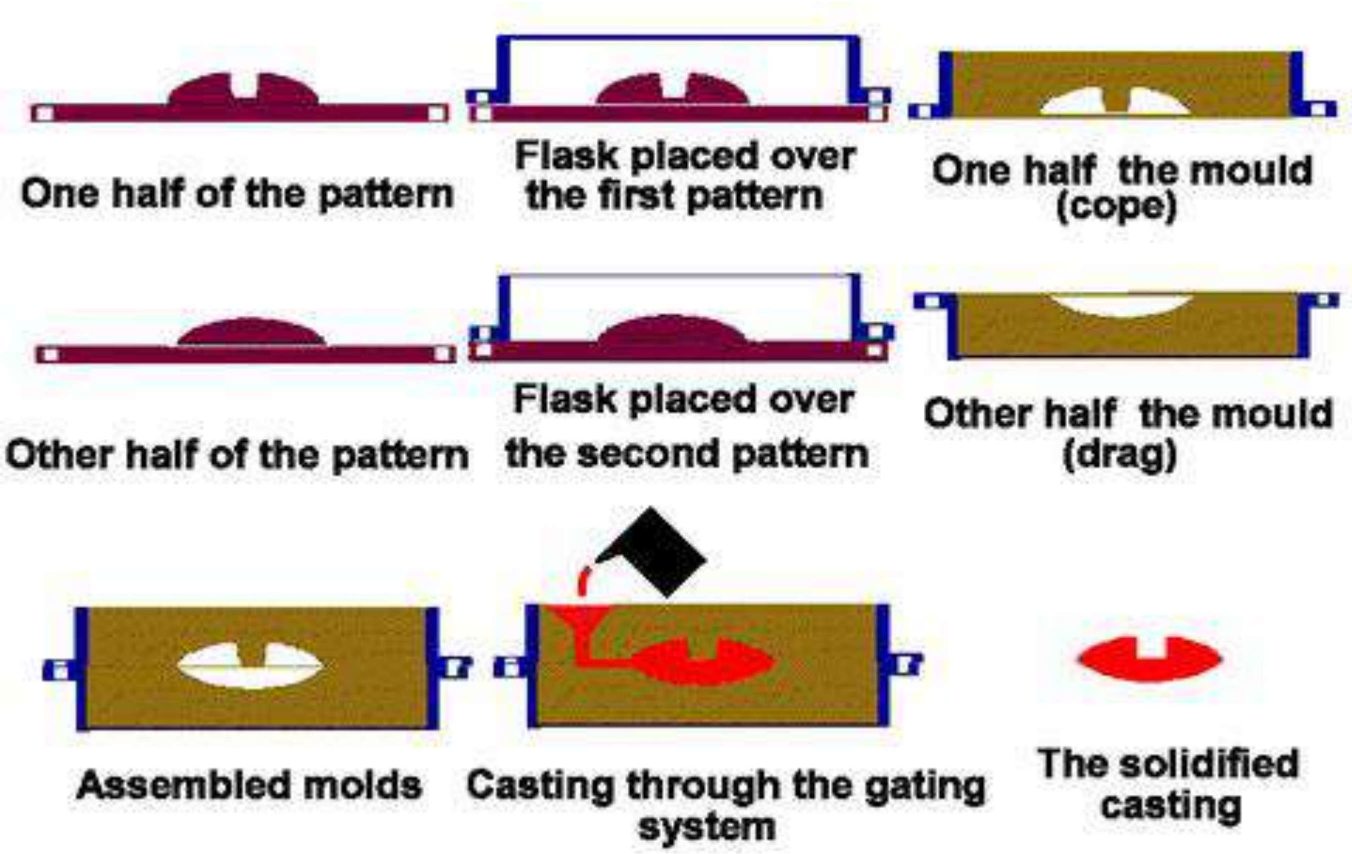
- 1**. Wood**
- ADVANTAGE
  - Most common material used in pattern making as it is easy to work and easily available.
- DISADVANTAGE
  - Effected by the moisture.
  - Poor surface finishing.
- 2.**Metal**
- ADVANTAGE
  - Metal is used when large number of casting are desired from a pattern or when the conditions are severe for the wooden pattern.
  - Don’t change their shape when subjected to the moist conditions.
- Metal patterns are useful in machine moulding because of their accuracy durability and strength.

Plastic Light weight Easy to make Light in weight Smooth glossary surface.

1.1 SAND CASTING

Sand casting, also known as sand molded casting, is a metal casting process characterized by using sand as the mold material.
The term "sand casting" can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories called foundries.
Over 70% of all metal castings are produced via a sand casting process.

- Sand casting is relatively cheap and sufficiently refractory even for steel foundry use.
- In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand.
- The mixture is moistened, typically with water, but sometimes with other substances, to develop strength and plasticity of the clay and to make the aggregate suitable for molding.
- The sand is typically contained in a system of frames or mold boxes known as a flask.
- The mold cavities and gate system are created by compacting the sand around models, or patterns, or carved directly into the sand.

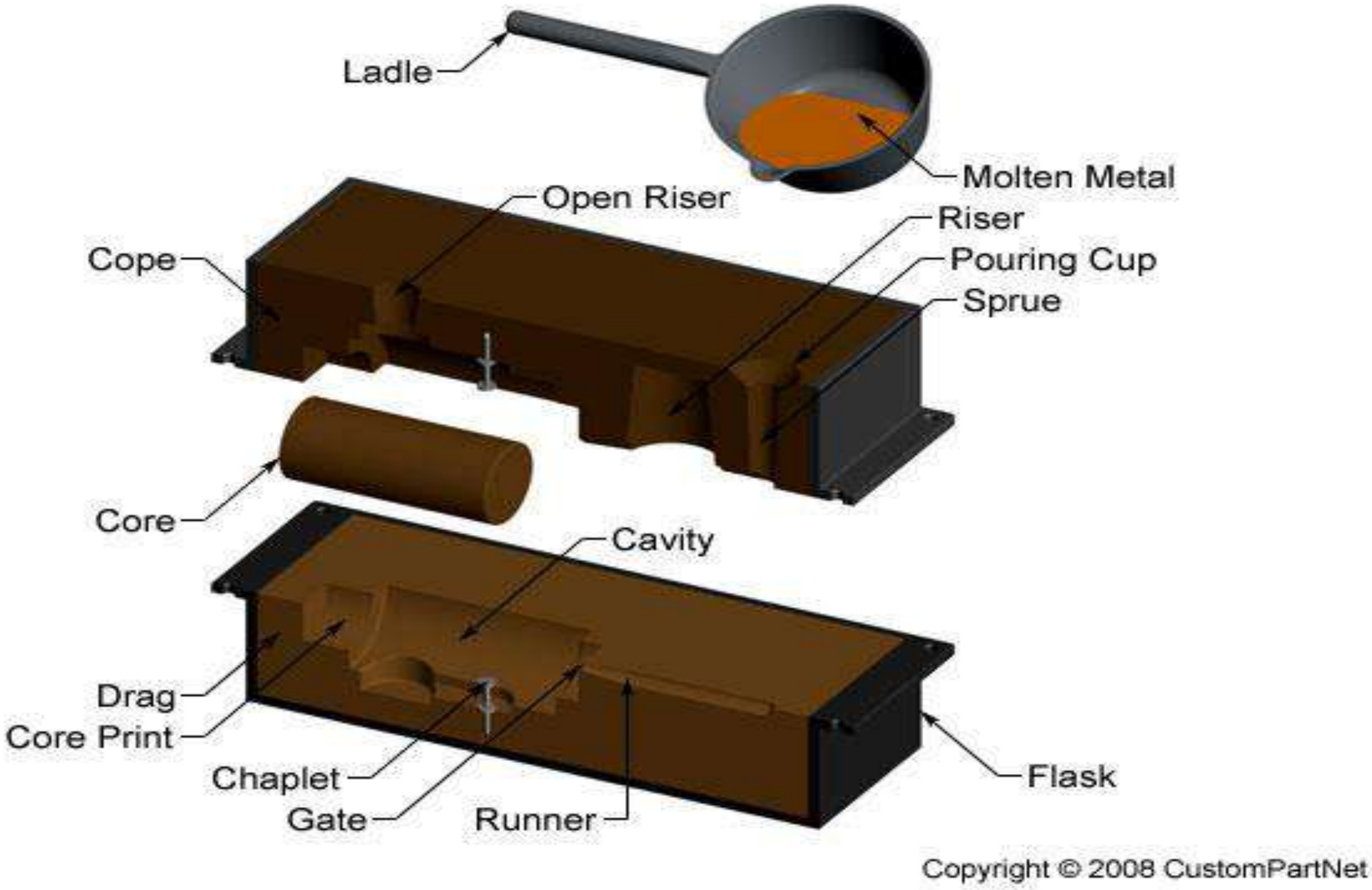

One half of the pattern
Flask placed over the first pattern
One half the mould (cope)
Other half of the pattern
Flask placed over the second pattern
Other half the mould (drag)
Assembled molds
Casting through the gating system
The solidified casting

- The cavity is contained in an aggregate housed in a box called the flask.
- **Core** is a sand shape inserted into the mold to produce the internal features of the part such as holes or internal passages. Cores are placed in the cavity to form holes of the desired shapes. Core print is the region added to the pattern, core, or mold that is used to locate and support the core within the mold.
- **A riser** is an extra void created in the mold to contain excessive molten material. The purpose of this is feed the molten metal to the mold cavity as the molten metal solidifies and shrinks, and thereby prevents voids in the main casting.
- In a two-part mold, which is typical of sand castings, the upper half, including the top half of the pattern, flask, and core is called **cope** and the lower half is called **drag**.
- The **parting line** or the parting surface is line or surface that separates the cope and drag.
- The drag is first filled partially with sand, and the core print, the cores, and the gating system are placed near the parting line.
- The cope is then assembled to the drag, and the sand is poured on the cope half, covering the pattern, core and the **gating system**. The sand is compacted by vibration and mechanical means. Next, the cope is removed from the drag, and the pattern is carefully removed.
- The object is to remove the pattern without breaking the mold cavity. This is facilitated by designing a draft, a slight angular offset from the vertical to the vertical surfaces of the pattern. This is usually a minimum of 1° or 1.5 mm (0.060 in), whichever is greater. The rougher the surface of the pattern, the more the draft to be provided.

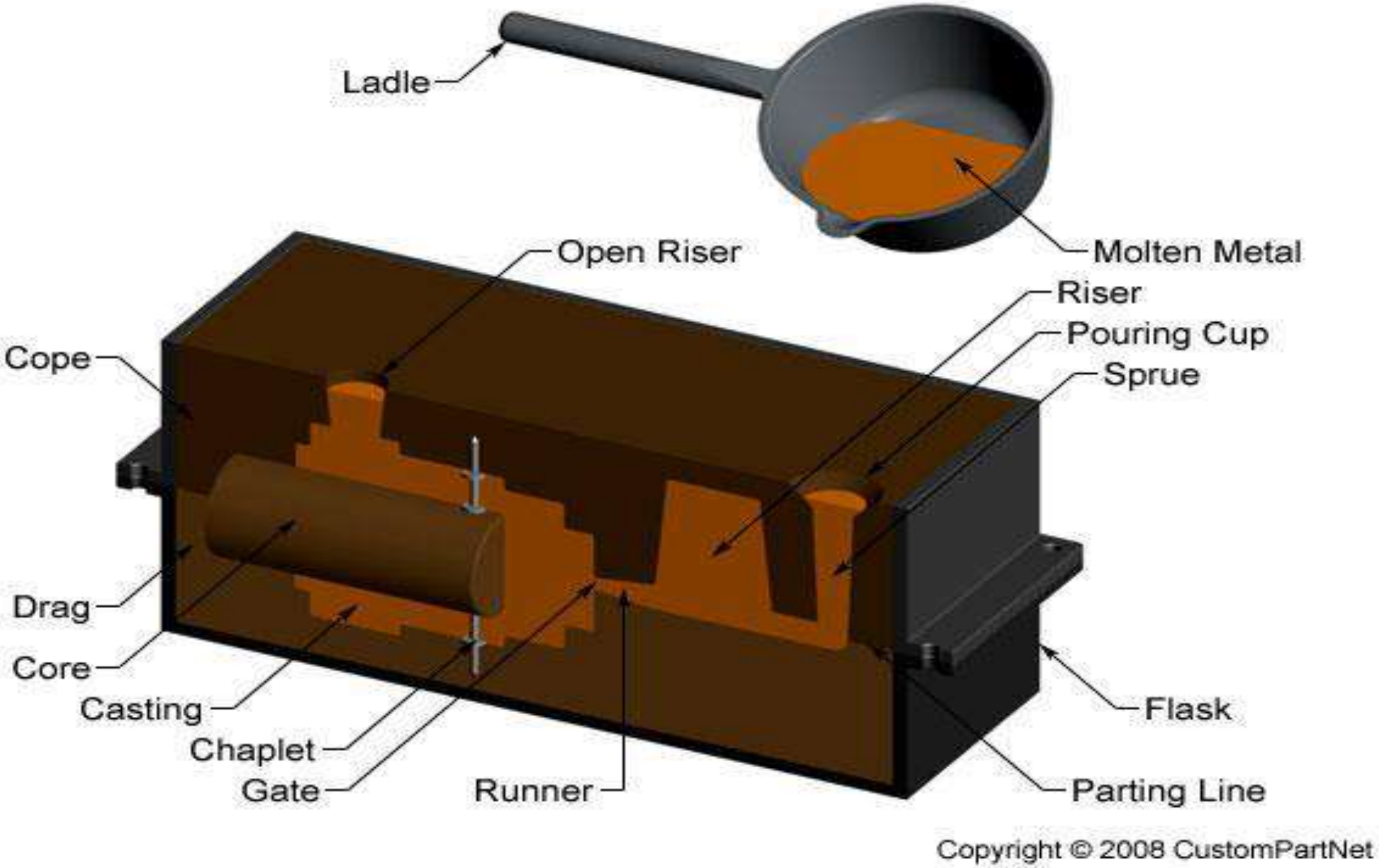
Sprues and Runners

The molten material is poured in the pouring cup, which is part of the gating system that supplies the molten material to the mold cavity. The vertical part of the gating system connected to the pouring cup is the **sprue**, and the horizontal portion is called the **runners** and finally to the multiple points where it is introduced to the mold cavity called the **gates**. Additionally there are extensions to the gating system called vents that provide the path for the built up gases and the displaced air to vent to the atmosphere.

The cavity is usually made oversize to allow for the metal contraction as it cools down to room temperature. This is achieved by making the pattern oversize. To account for shrinking, the pattern must be made oversize by these factors, on the average. These are linear factors and apply in each direction. These shrinkage allowance are only approximate, because the exact allowance is determined the shape and size of the casting.



Dissembled view of casting



Assembled view of casting

Casting products

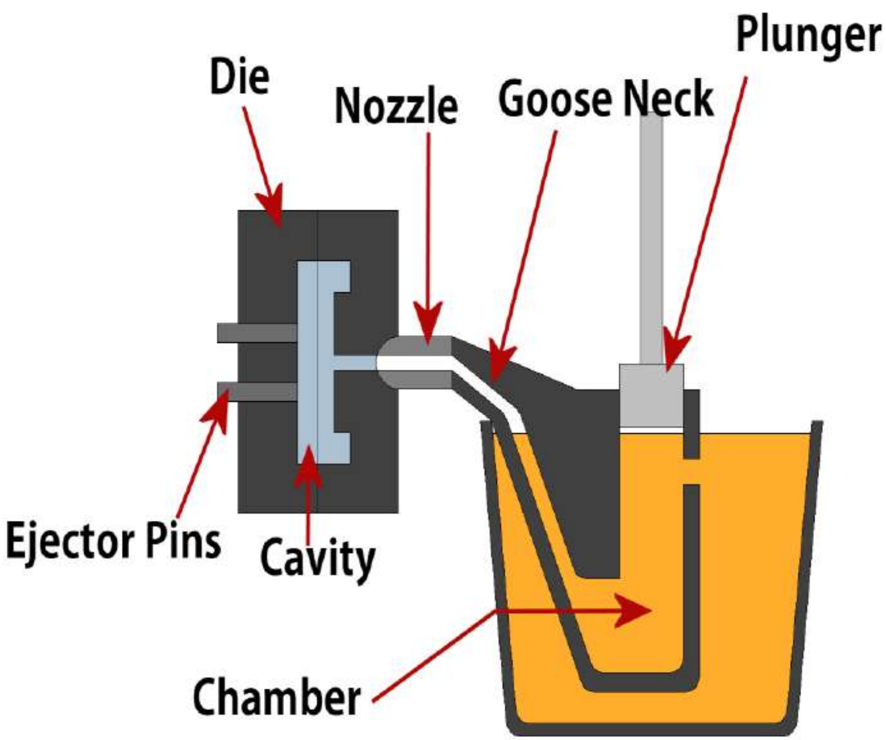
PERMANENT MOULD CASTING

The moulds are reused repeatedly in permanent mould casting.

1.2 DIE CASTING

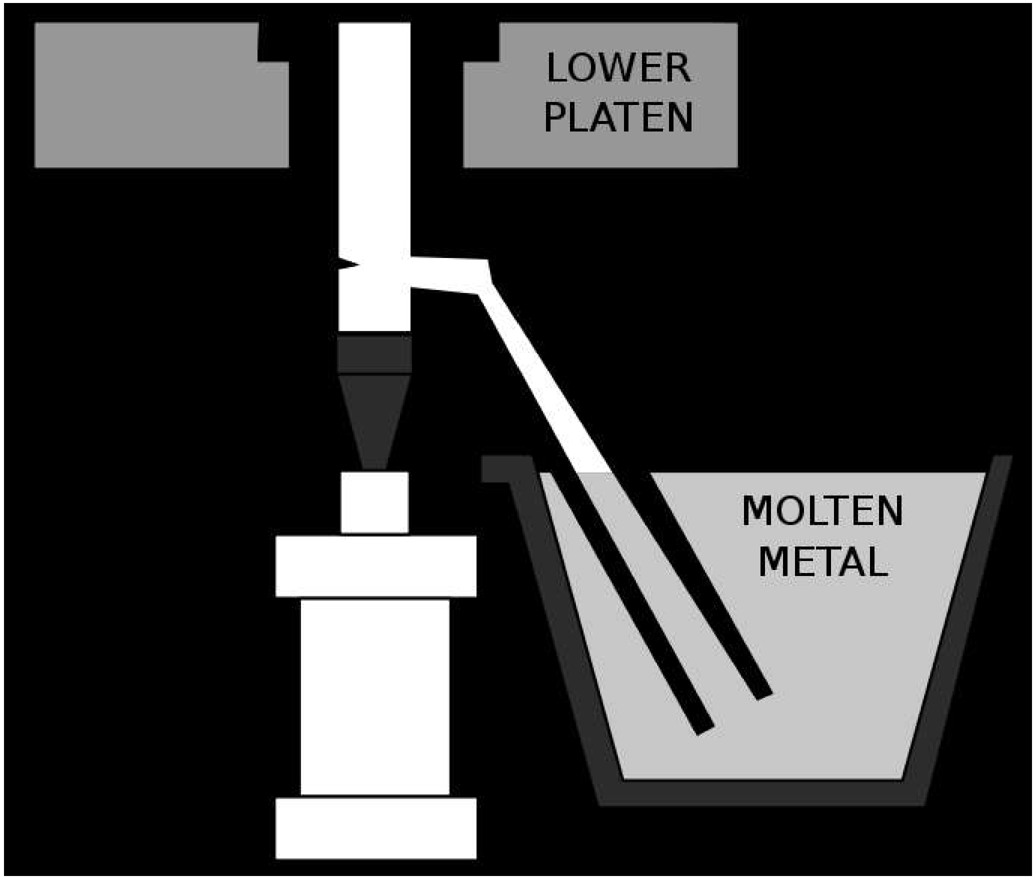
- Die casting is art of rapidly producing accurately dimensioned parts by forcing molten metal under pressure into split metal dies which resemble a common type of permanent mould.
- Within a fraction of seconds the molten metal fills the entire die including all the minute details.
- This process is particularly suitable for lead, magnesium, tin and zinc alloys.

HOT-CHAMBER DIE CASTING



- Hot-chamber die casting, also known as gooseneck machines, rely upon a pool of molten metal to feed the die.
- At the beginning of the cycle the piston of the machine is retracted, which allows the molten metal to fill the "gooseneck".
- The pneumatic or hydraulic powered piston then forces this metal out of the gooseneck into the die.
- The advantages of this system include fast cycle times (approximately 15 cycles a minute) and the convenience of melting the metal in the casting machine.
- The disadvantages of this system are that it is limited to use with low-melting point metals and that aluminum cannot be used because it picks up some of the iron while in the molten pool.
- Therefore, hot-chamber machines are primarily used with zinc, tin, and lead based alloys

COLD CHAMBER MACHINE



- These are used when the casting alloy cannot be used in hot-chamber machines; these include aluminum, zinc alloys with a large composition of aluminum, magnesium and copper.
- The process for these machines start with melting the metal in a separate furnace.
- Then a precise amount of molten metal is transported to the cold-chamber machine where it is fed into an unheated shot chamber (or injection cylinder).
- This shot is then driven into the die by a hydraulic or mechanical piston.
- The biggest disadvantage of this system is the slower cycle time due to the need to transfer the molten metal from the furnace to the cold-chamber machine

ADVANTAGES OF DIE CASTING

1. Very high rate of production is achieved.
2. Close dimensional tolerances.
3. Surface finish of 0.8 microns.
4. Fine details can be produced.
5. Longer die life is obtained.

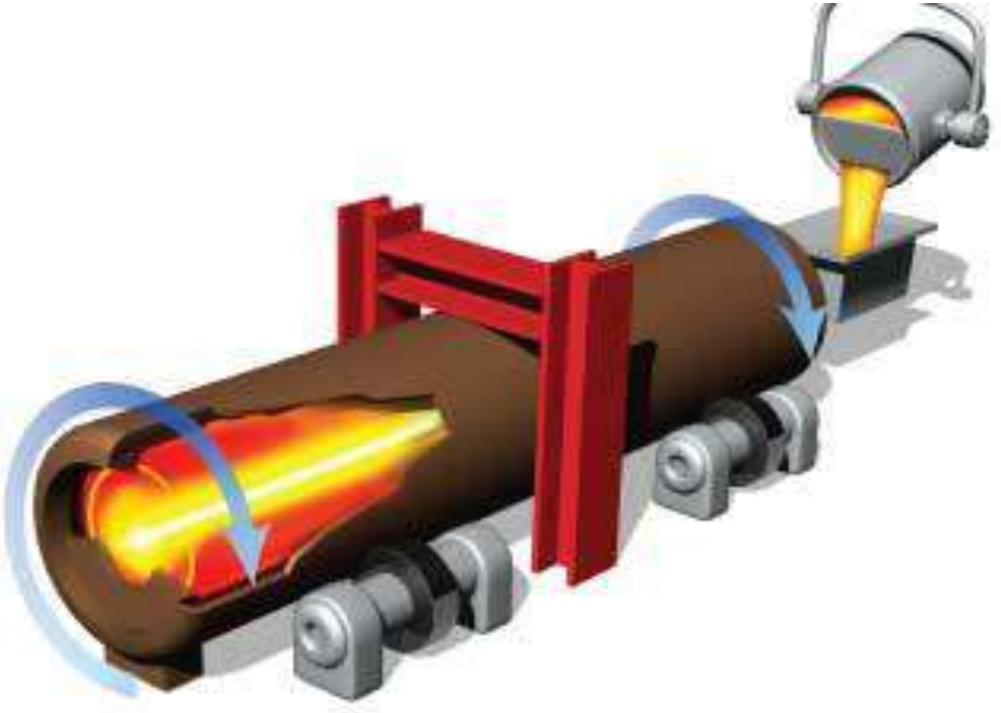
DISADVANTAGES

1. Not economical for small runs.
2. Only economical for nonferrous alloys.
3. Heavy casting cannot be cast.
4. Cost of die and die casting equipment is high.

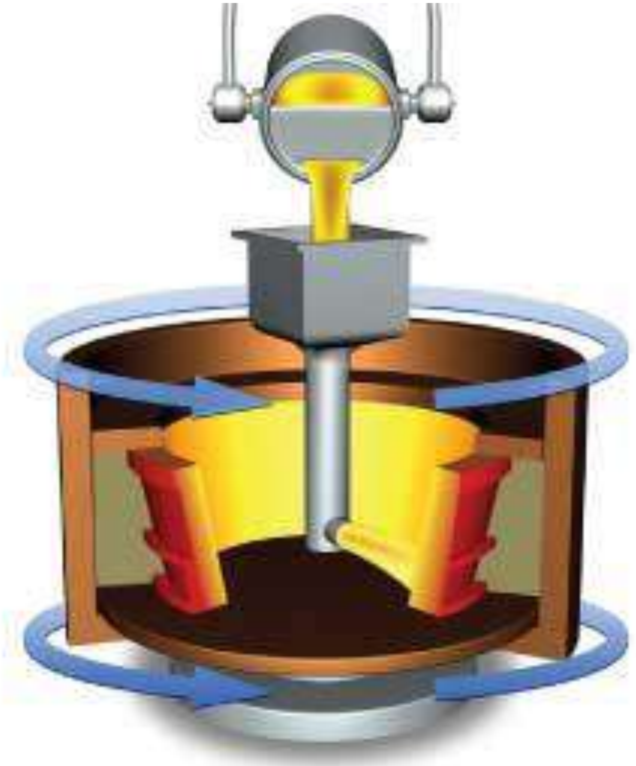
Casting products

CENTRIFUGAL CASTING

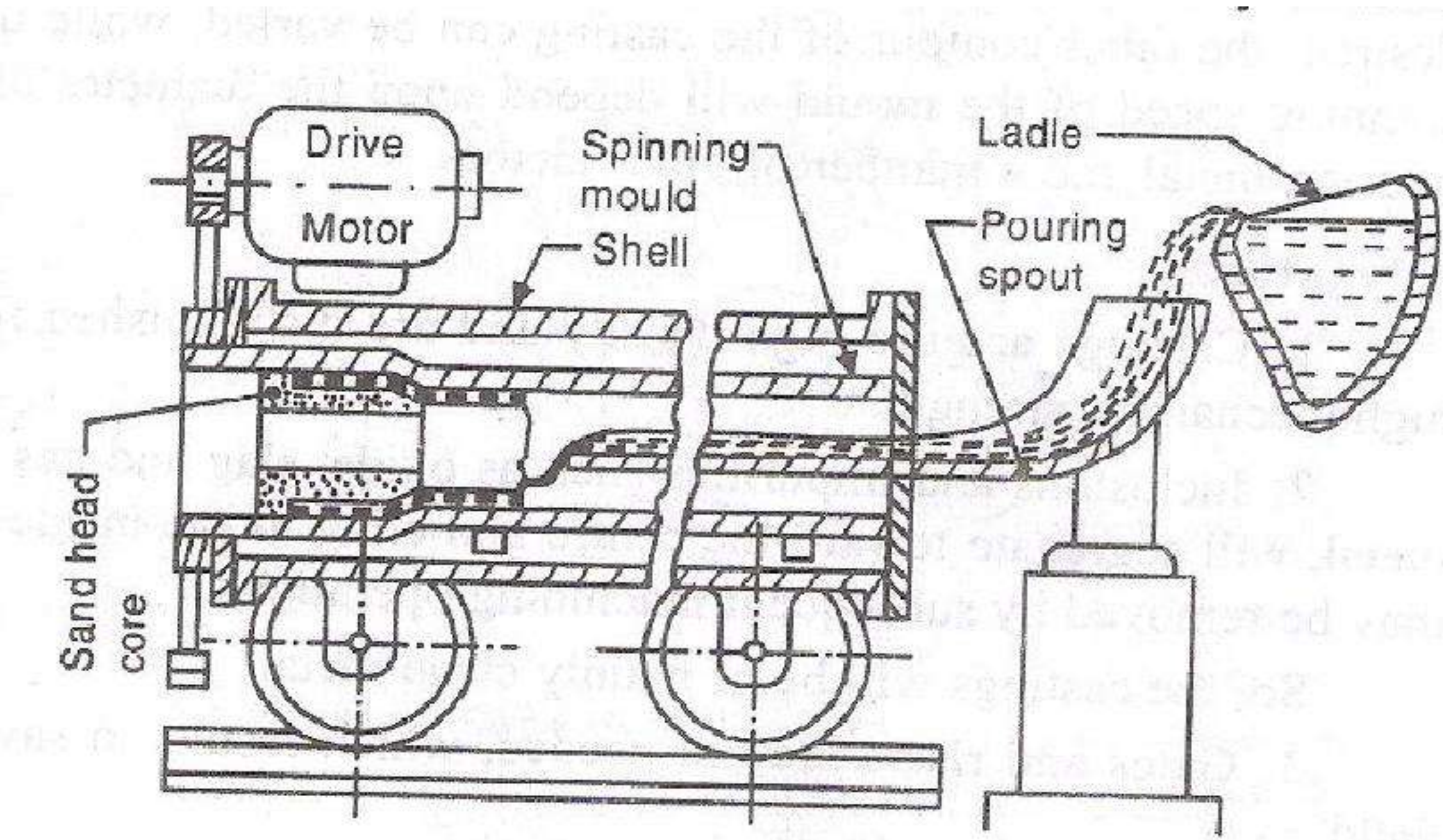
- In centrifugal casting, a permanent mold is rotated continuously about its axis at high speeds (300 to 3000 rpm) as the molten metal is poured.
- The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling.
- The casting is usually a fine-grained casting with a very fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusions are thrown to the surface of the inside diameter, which can be machined away.
- Casting machines may be either horizontal or vertical-axis.
- Horizontal axis machines are preferred for long, thin cylinders, vertical machines for rings.
- Most castings are solidified from the outside first. This may be used to encourage directional solidification of the casting, and thus give useful metallurgical properties to it. Often the inner and outer layers are discarded and only the intermediary columnar zone is used.

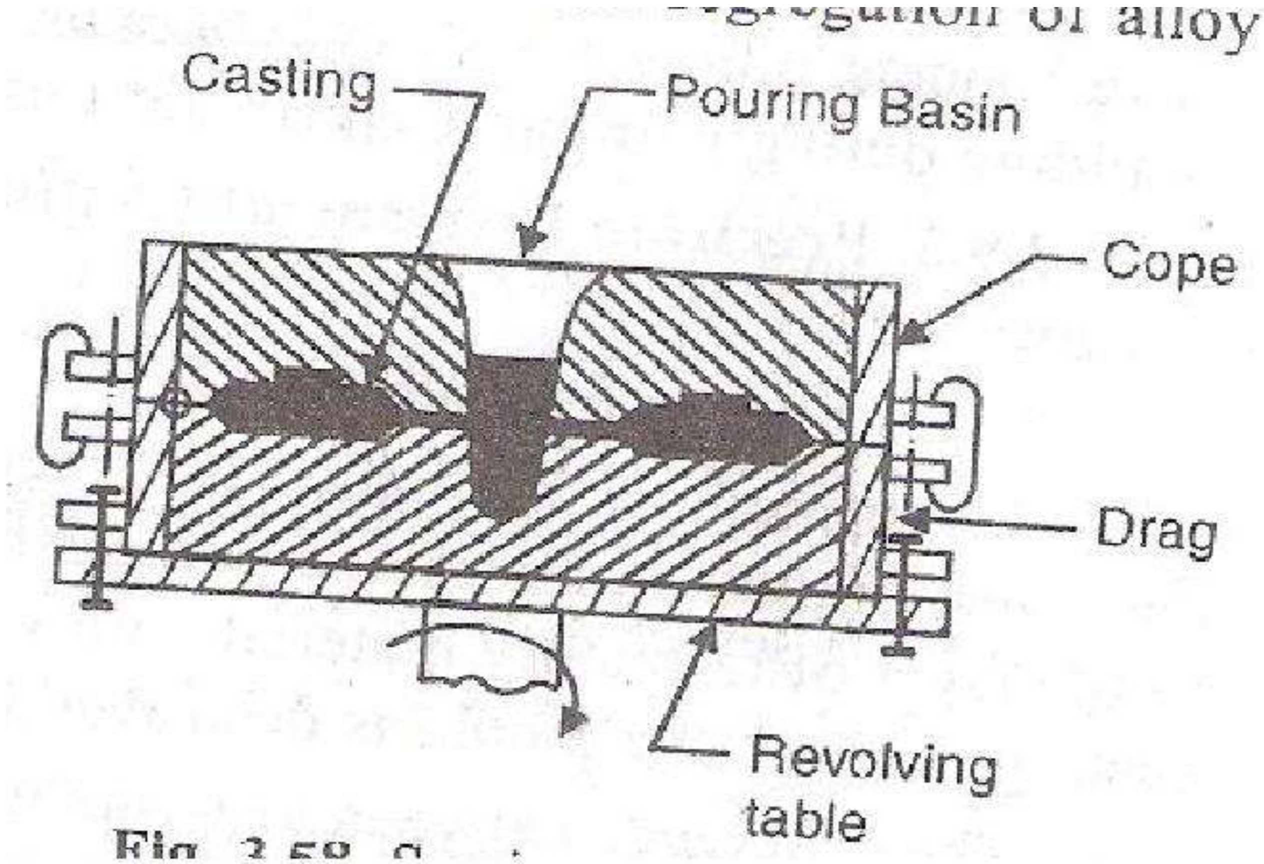


HORIZANTAL CENTRIFUGAL CASTING



VERTICAL CENTRIFUGAL CASTING


Drive
Motor
Spinning mould
Shell
Ladle
Pouring spout
Sand head core


Casting
Pouring Basin
Cope
Drag
Revolving
table

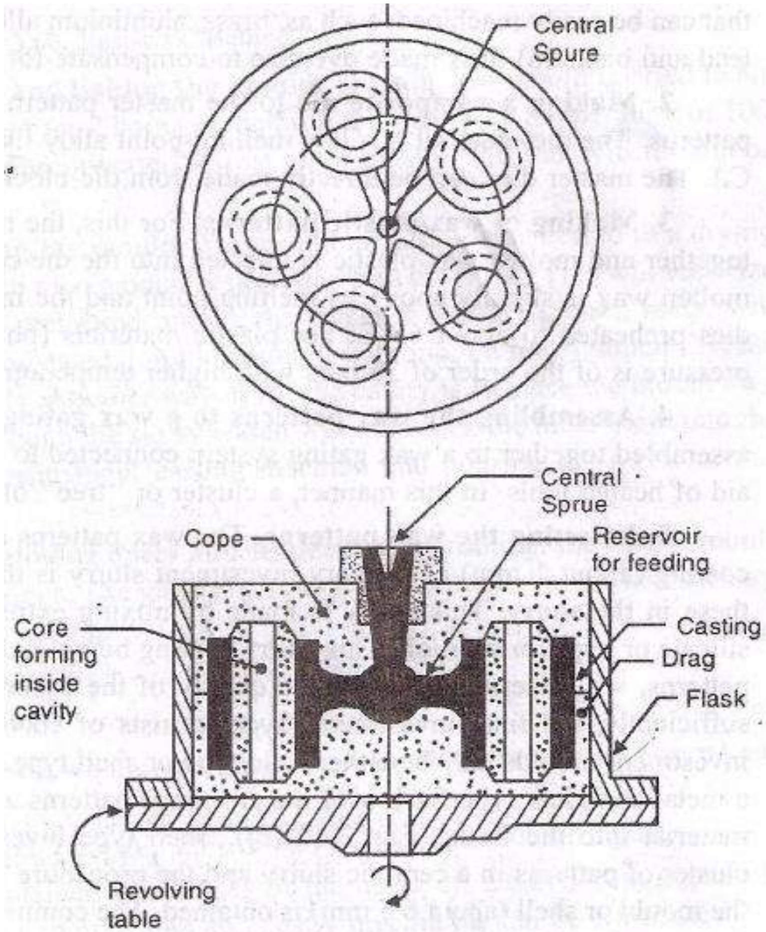


Fig. 3.59. Centrifuge Casting.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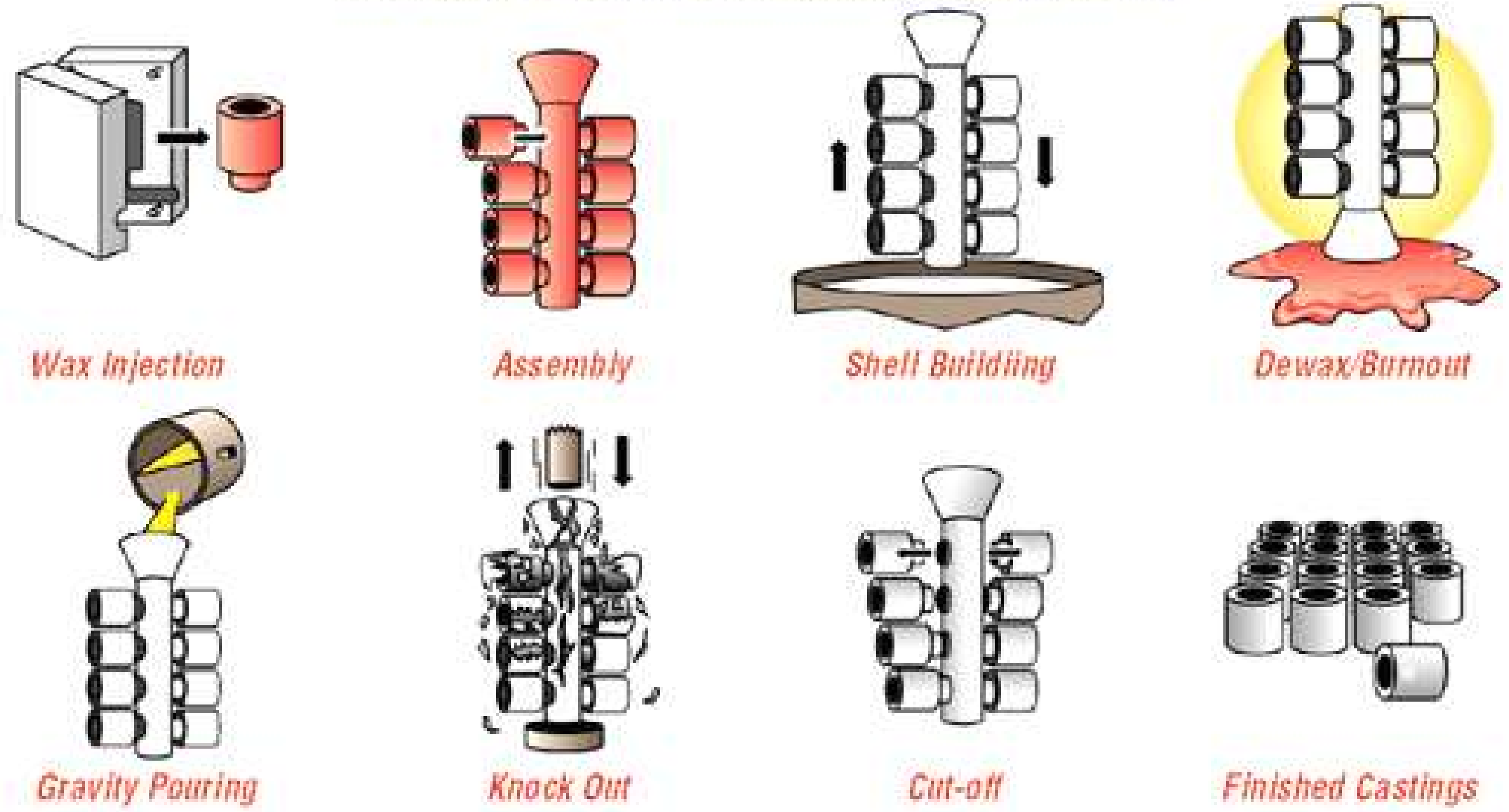
The Basic Steps in the Investment Casting Process



Advantages of Investment casting

- Many Intricate forms with undercuts can be cast.
- A very smooth surface is obtained with no parting line.
- Dimensional accuracy is good.
- Certain un Machin able parts can be cast to preplanned shape.
- It may be used to replace die-casting where short runs are involved.

Disadvantages of Investment casting

- This process is expensive, is usually limited to small casting, and presents some difficulties where cores are involved.
- Holes cannot be smaller than 1/16 in. (1.6mm) and should be no deeper than about 1.5 times the diameter.
- Investment castings require very long production-cycle times versus other casting processes.
- This process is practically infeasible for high-volume manufacturing, due to its high cost and long cycle times.
- Many of the advantages of the investment casting process can be achieved through other casting techniques if principles of thermal design and control are applied appropriately to existing processes that do not involve the shortcomings of investment castings

ALLOWANCS IN CASTING PROCESS

Patterns are not made the exact same size as desired casting for several reasons. Such patterns would produce castings which are under size . That is why allowance should be present in pattern.

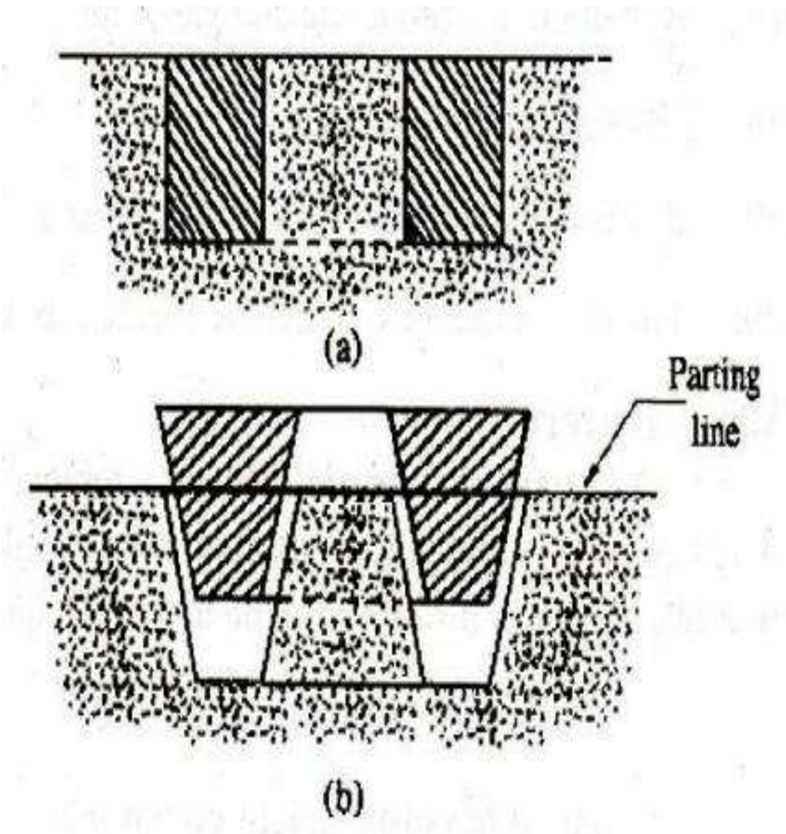
1. Shrinkage allowance

When a metal solidifies and cools it shrinks and contracts in size.
To compensate for this the pattern is made larger than the desired casting size to get exact required size of the casting after shrinking.
The pattern maker lays the measurement of the pattern using the shrink contraction rule , which is slightly longer than the ordinary rule of the same length.
For example to make a pattern for cast iron the pattern maker uses a shrink rule measuring about 10 mm /m
Since cast iron shrinks at 10 mm/m.

2. Machining allowance

The extra amount of the metal provided on the surfaces to be machined is called machine finish allowance.
The amount that is to be added depends on

- Kind of the metal to be used
- Shape and size of the casting
- Method of the moulding



3. Draft allowance

When a pattern is drawn from the mould there is always some possibility of injuring the edges of the mould. This danger is greatly decreased when the vertical surfaces of the pattern are tapered inward slightly. This taper inward in the vertical surface is called Draft.

Draft may be also expressed in millimeters / meter or in degrees.

The draft depends on

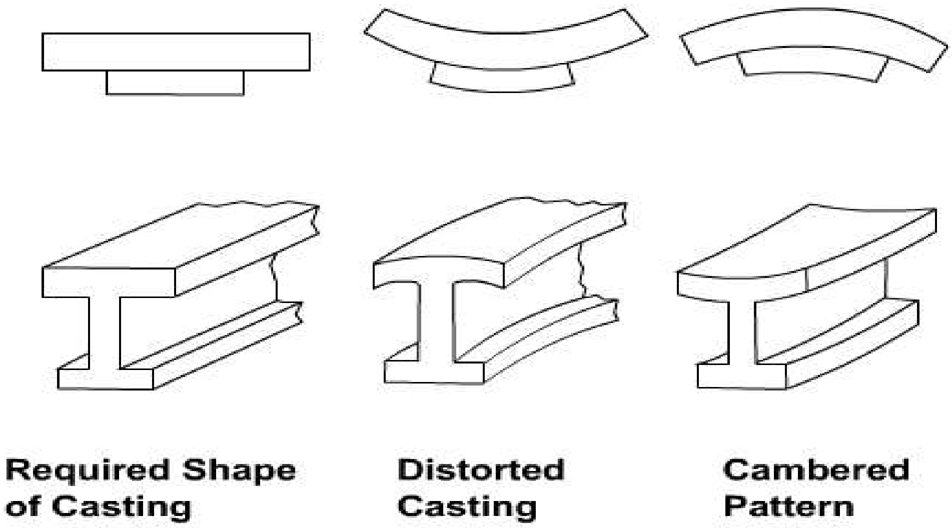
- Type of moulding process
- Length of the vertical side
- 10-20 mm/m on exterior surfaces and 40-60 mm/m on the interior surfaces.

4. Distortion allowance

Some castings because of their size shape and type of metal used tend to wrap or distort during the cooling period.

This is a result of uneven shrinkage or due to uneven metal thickness or one surface being more exposed than another causing it to cool more rapidly.

The shape of the pattern is bent slightly in the opposite direction to overcome this distortion. This feature is called distortion or chamber allowance.



5. Rapping allowance

When a pattern is rapped in the mould before it is withdrawn the cavity in the mould is slightly increased . In every case where casting must be uniform and true to pattern rapping or shake allowance is provided to make pattern slightly smaller than the actual size to compensate the rapping of the mould.

PROPERTIES OF THE MOULDING SAND

1.Porosity

Molten metal always contains a certain amount of the dissolved gases which are evolved outside when the metal freezes. Also the molten metal coming in contact to the moist sand generates steam or water vapor. If these gases and water vapor do not find opportunity to escape from the mould they will form gas holes and pores in the casting. Therefore the sand must be porous to allow these gases to escape outside. This property is called porosity.

2. Flowability

Ability to behave like a fluid is called flowability. When rammed it will flow to all the portions of a mould and pack all round the pattern to take the desired shape.

3. Collapse ability

After the molten metal gets solidified the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing and cracking of the metal.

4. Adhesiveness

The sand particles must be capable of adhering to the another body i.e. they should cling to the sides of the moulding boxes. It is due to this property the sand mass can be successfully held in the moulding box and it does not fall out of the box when it is removed.

5.Cohesiveness

The ability of the sand particles to stick together .

Welding is a process of joining similar metals by application of heat with or without application of pressure and addition of the filler material.

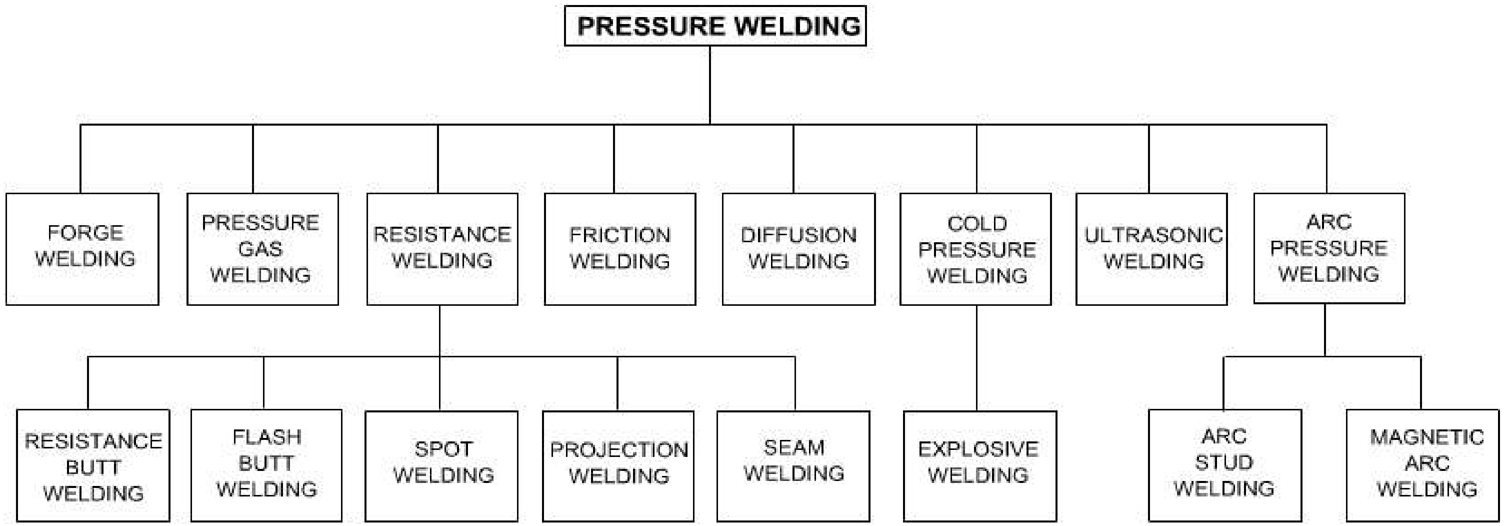
Weld ability is the capacity to be welded into inseparable joints and having specified properties such as definite weld strength , proper structure etc.

1. Thermal expansion
2. Thermal conductivity
3. Melting point
4. Surface condition
5. Change in micro structure

Plastic welding or Pressure welding

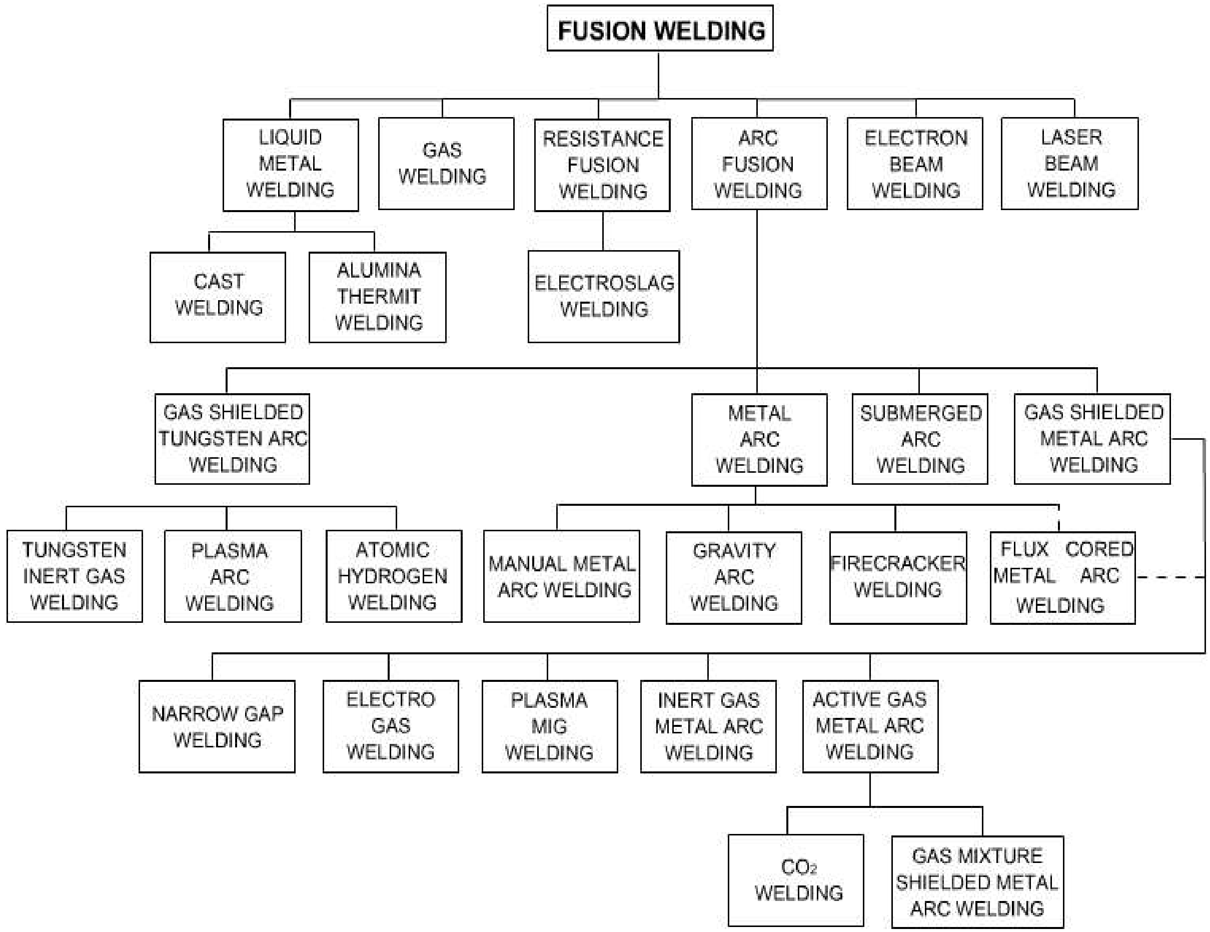
The metal pieces which are to be joined are heated to plastic state and forced together by using external pressure.

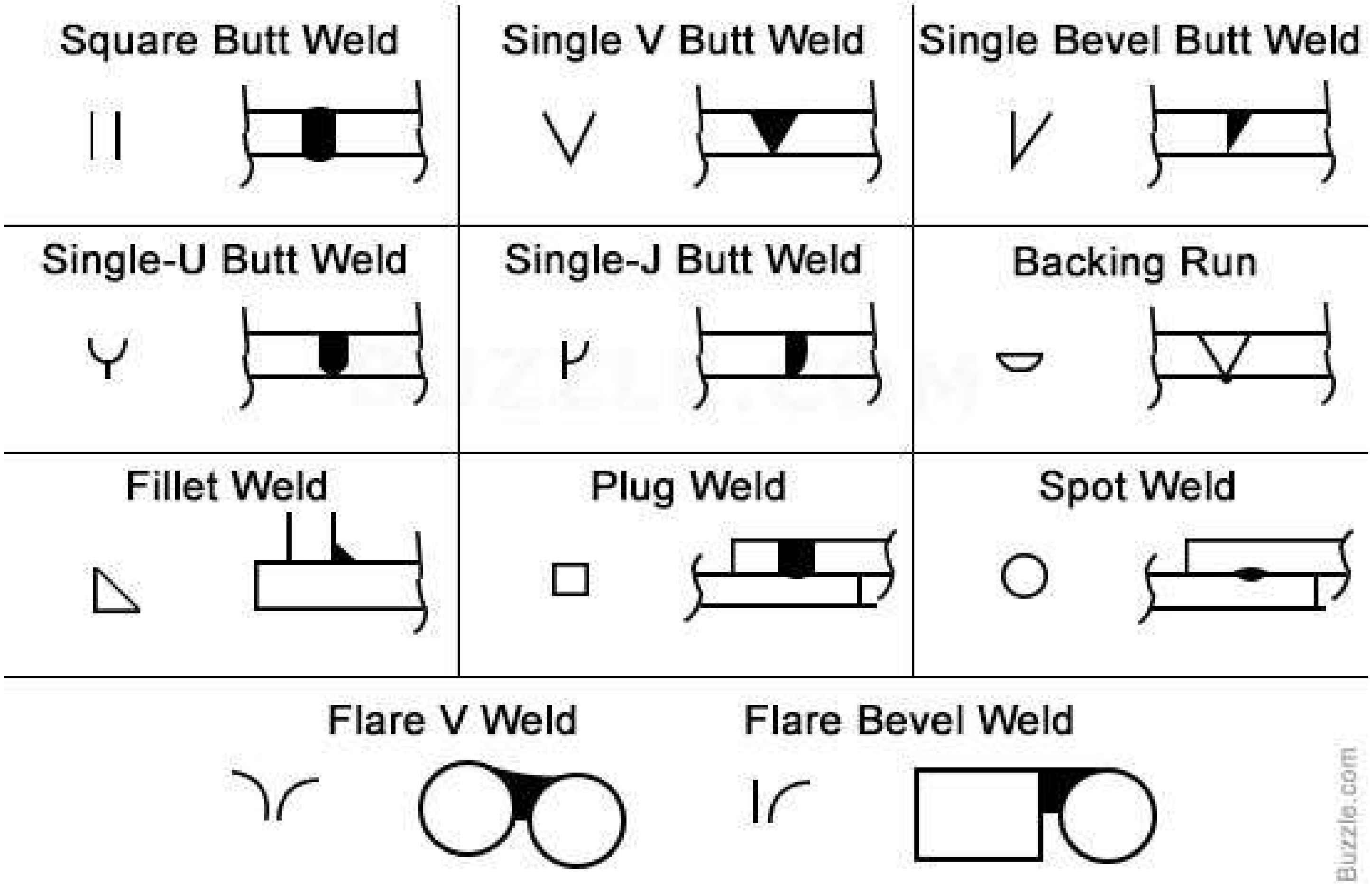
1. Forge welding
2. Thermit welding
3. Resistance welding
4. Gas welding



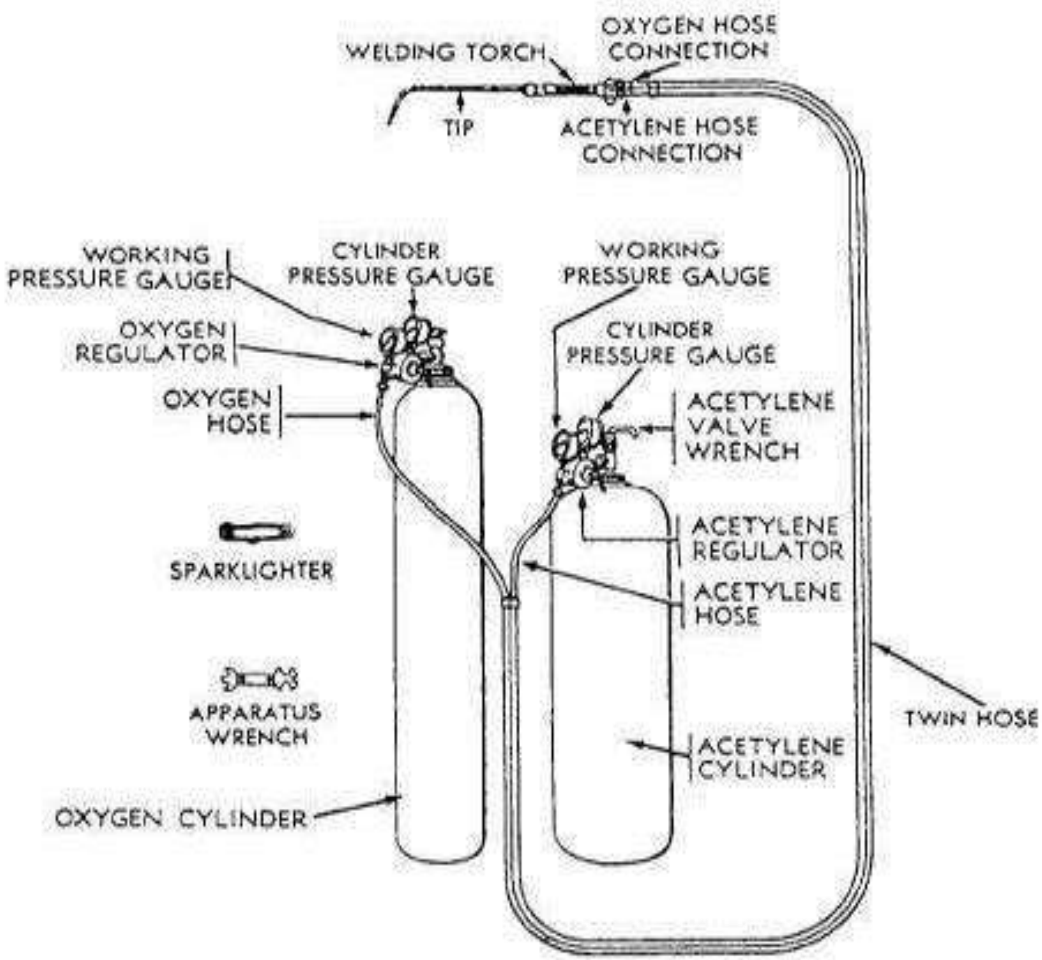
Fusion welding or non pressure welding the material at the joint is heated to the molten state and allowed to be solidified.

1. Arc welding
2. Thermit welding




Square Butt Weld
Single V Butt Weld
Single Bevel Butt Weld
Single-U Butt Weld
Single-J Butt Weld
Backing Run
Fillet Weld
Plug Weld
Spot Weld
Flare V Weld
Flare Bevel Weld
Buzzle.com

OXY ACETLYNE GAS WELDING



This type of welding is used to join metal sheets and plates having thickness of 2 to 50 mm.

With metal thicker than 15 mm filler metal is used. The composition of the **filler rod** is almost same as the part being welded .

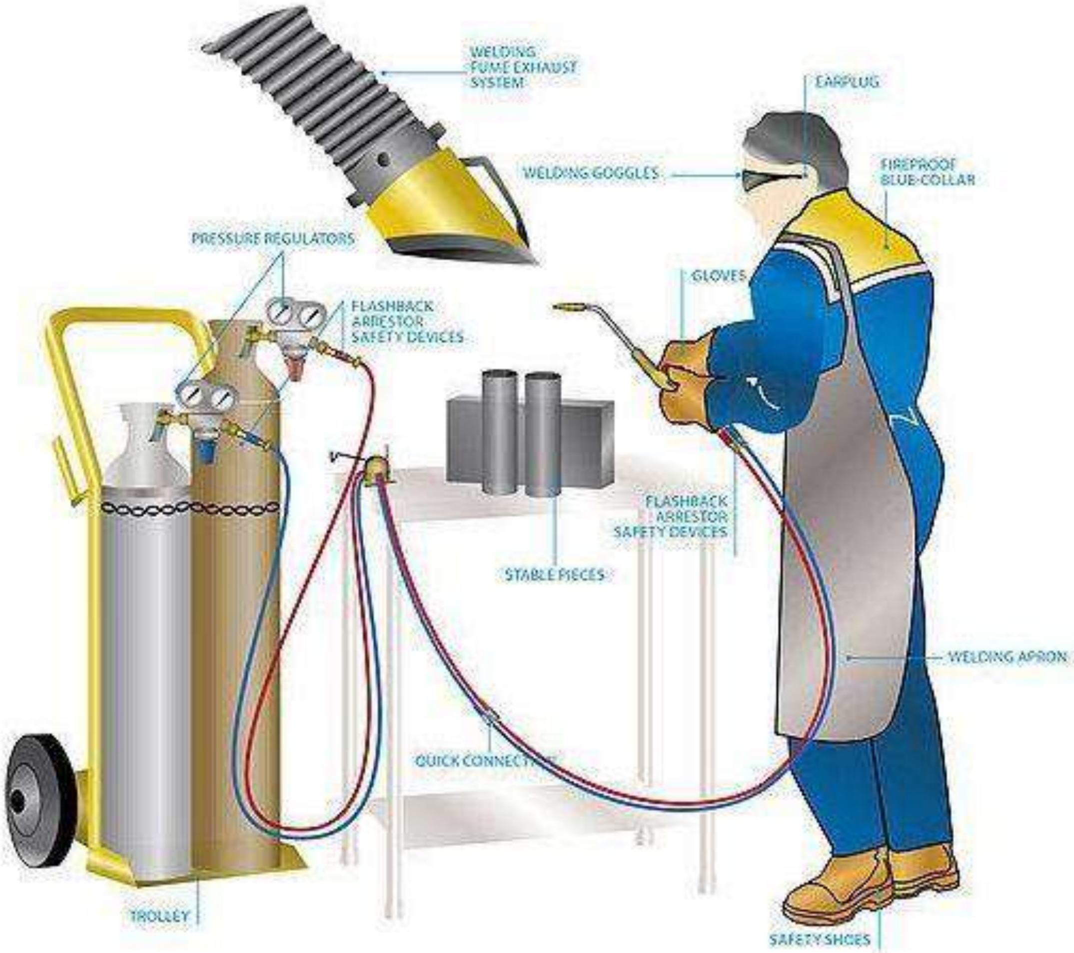
To remove the oxides and impurities present on the surfaces of the metal and to obtain satisfactory bonding **FLUX** is employed during the welding .

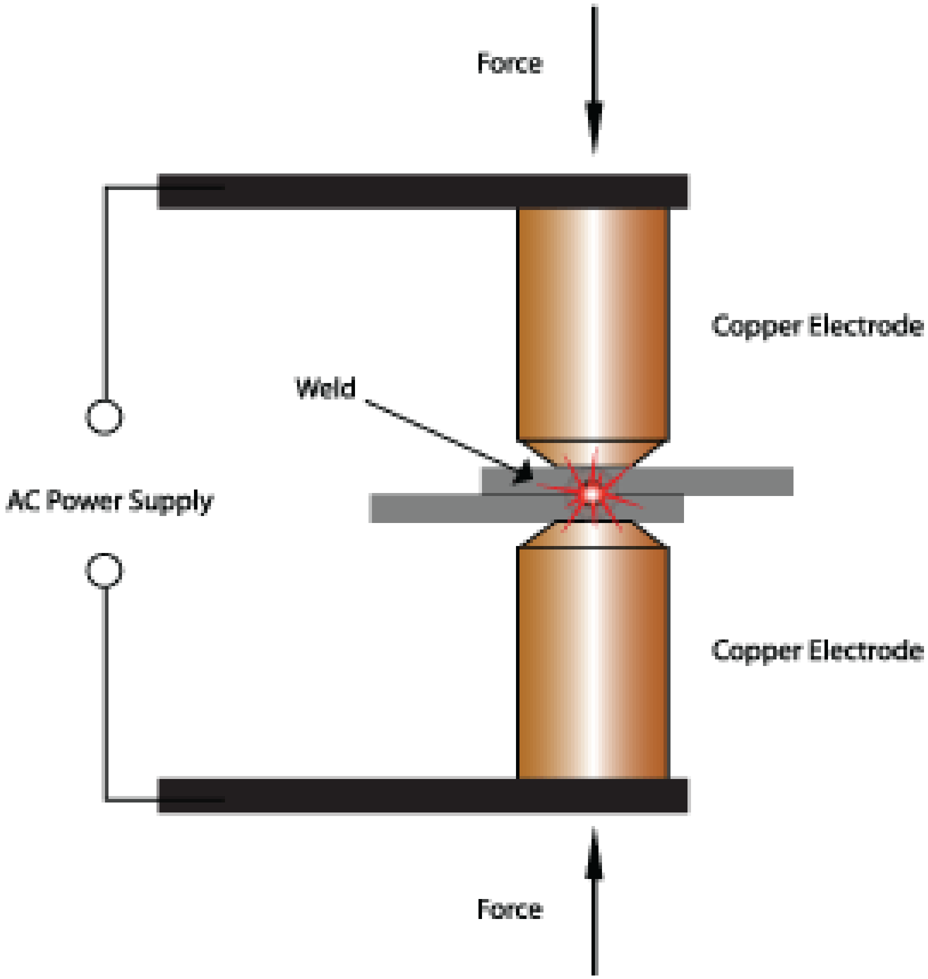
Exception for mild steel which has manganese and silicon which acts as oxidizing agents.

The temperature of Oxygen and acetylene flame at hottest region is 3200 degrees.

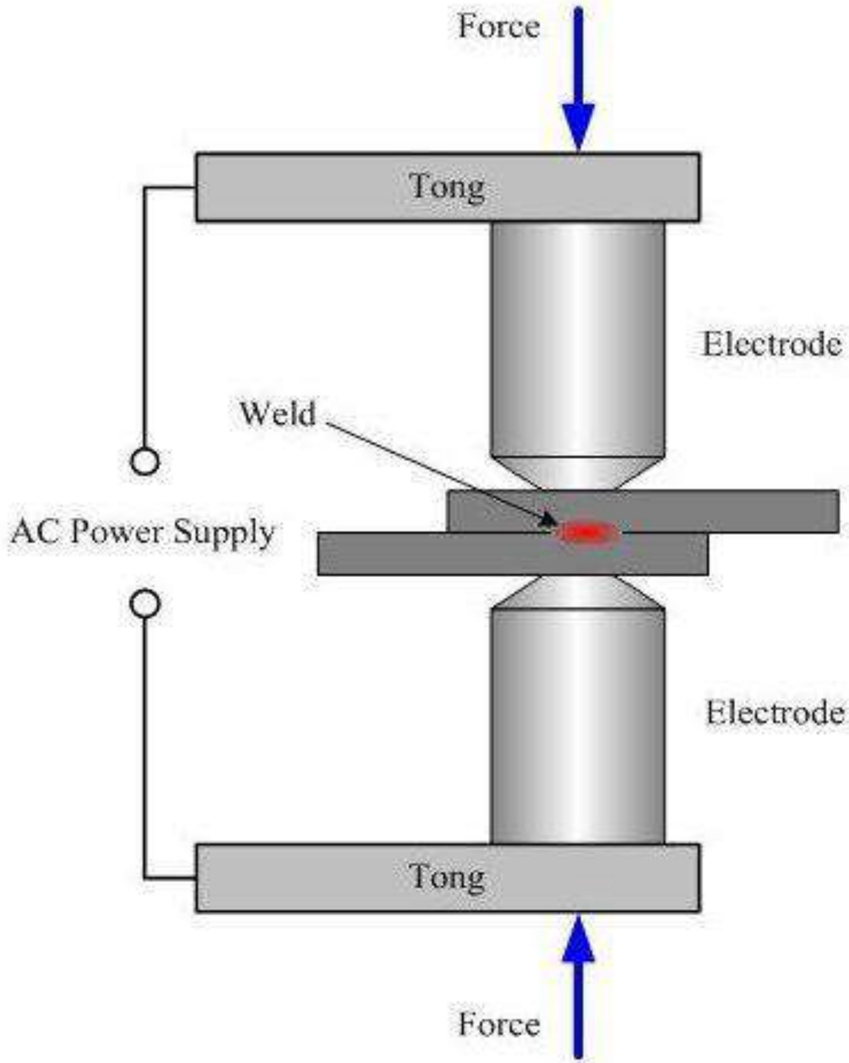
OXY-HYDROGEN WELDING

Weld low temperature metals like aluminum lead and magnesium.

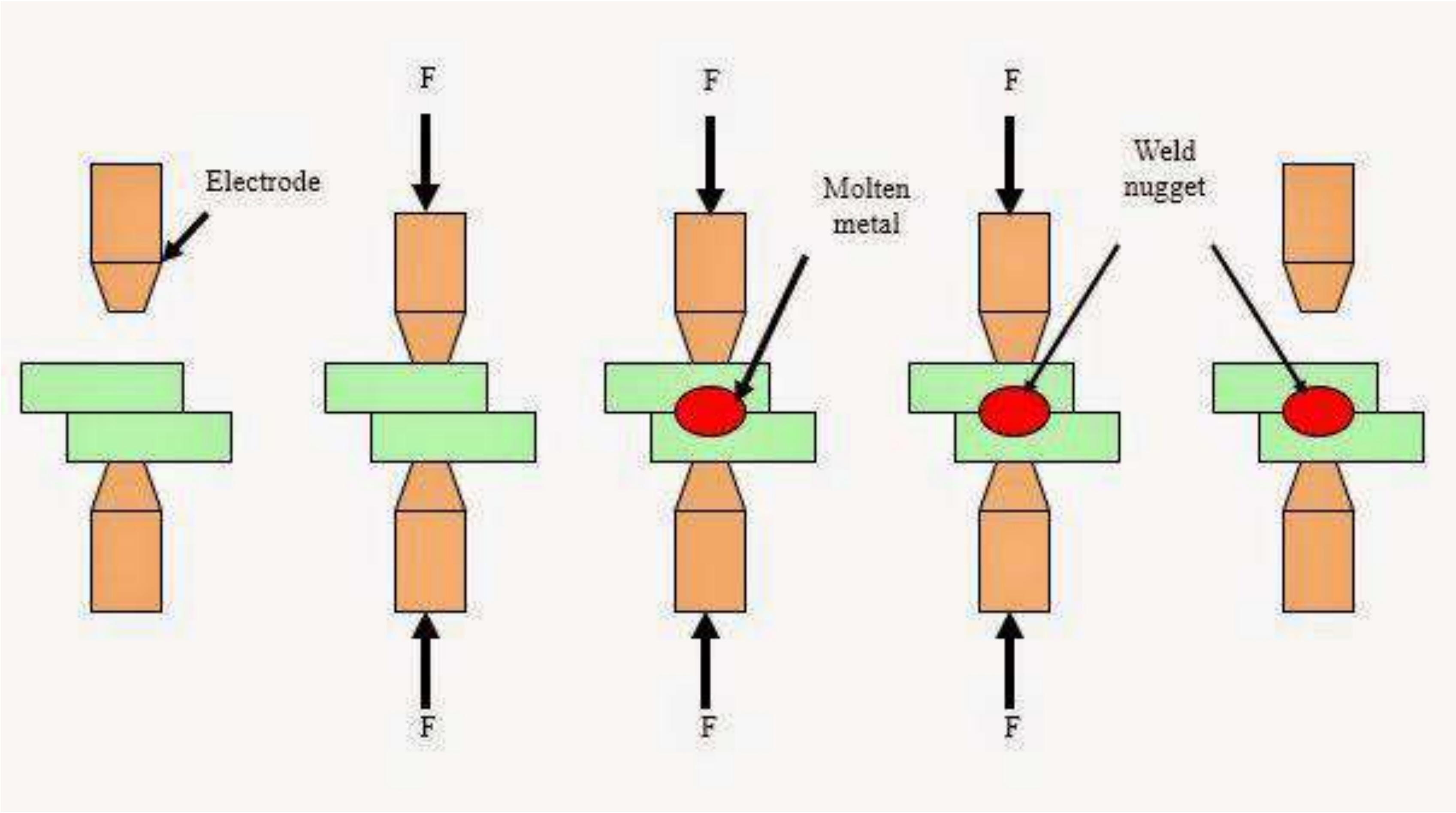

WELDING FUME EXHAUST SYSTEM
EARPLUG
WELDING GOGGLES
FIREPROOF BLUE-COLLAR
PRESSURE REGULATORS
GLOVES
FLASHBACK ARRESTOR SAFETY DEVICES
FLASHBACK ARRESTOR SAFETY DEVICES
STABLE PIECES
WELDING APRON
QUICK CONNECTOR
TROLLEY
SAFETY SHOES



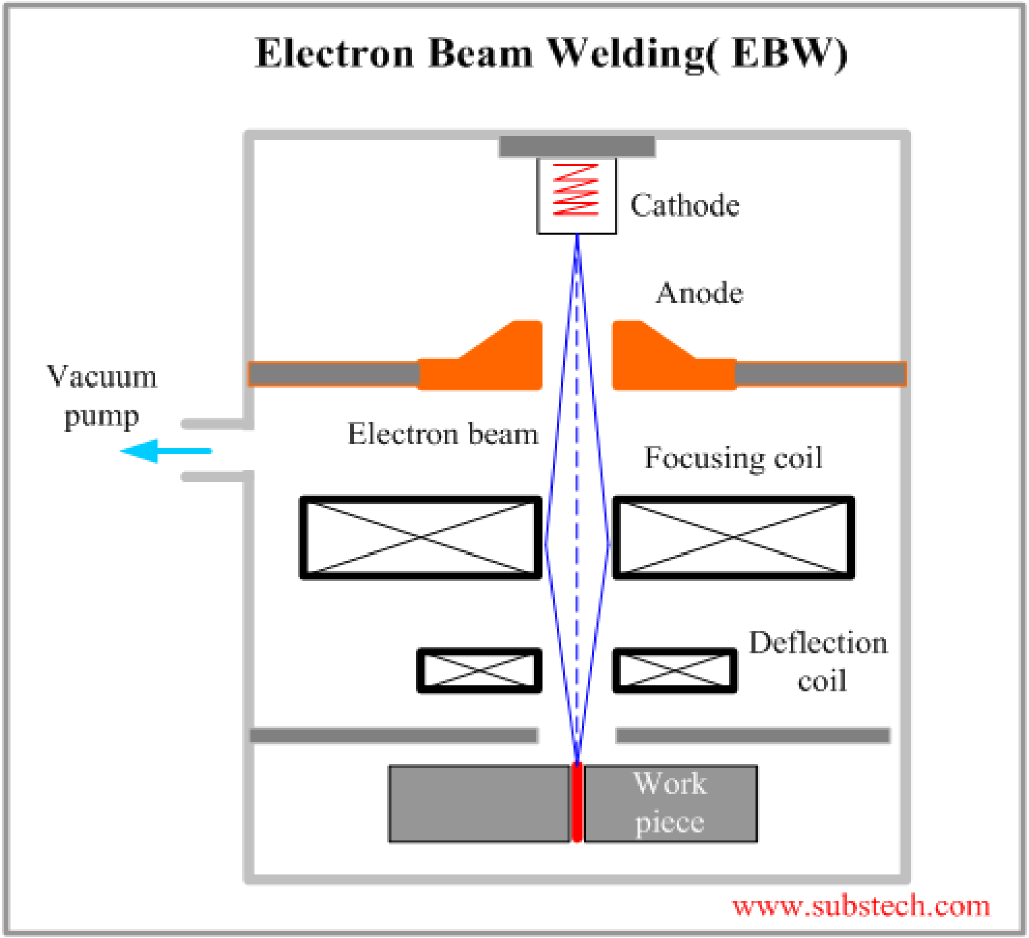
RESISTANCE WELDING

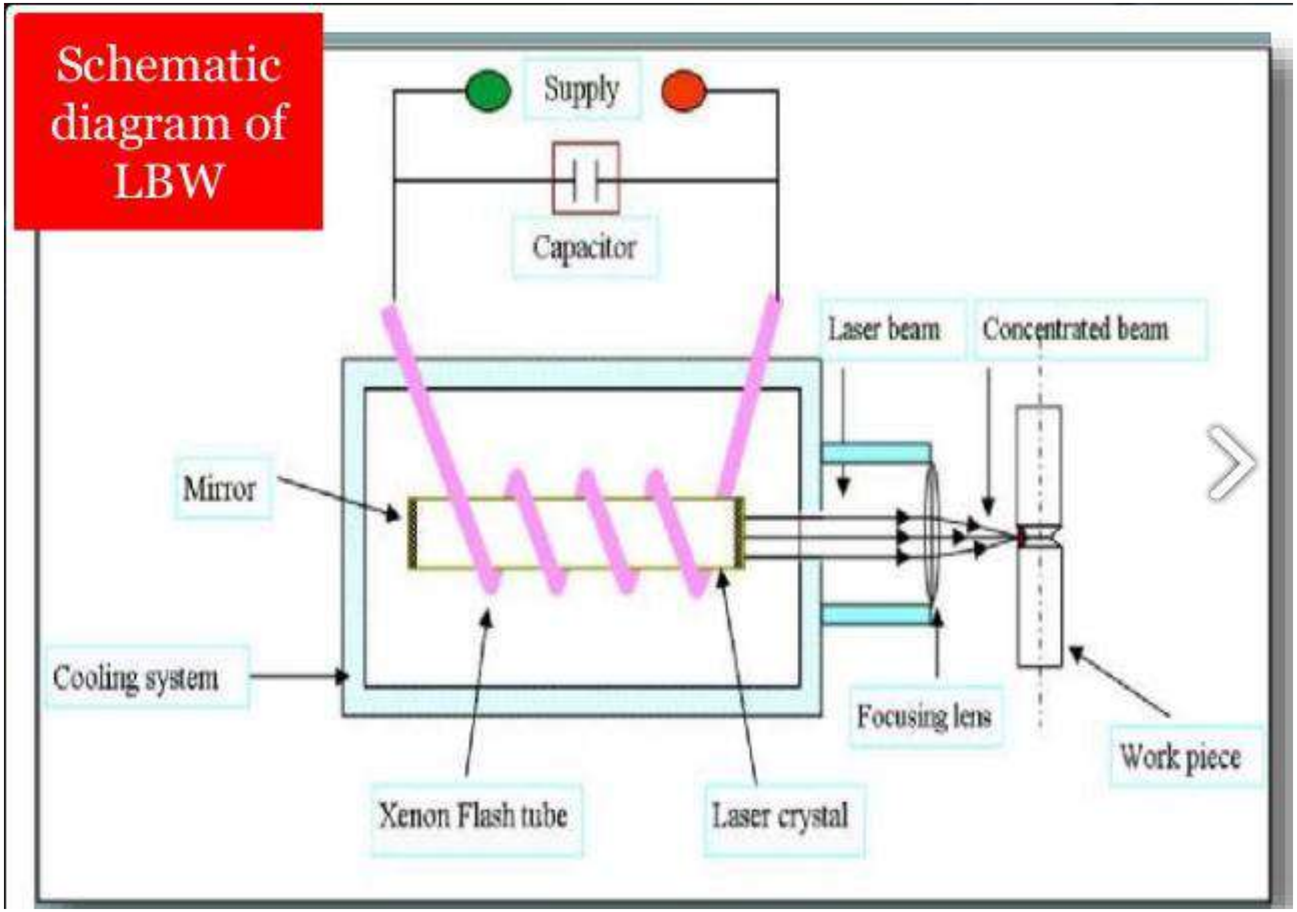


Resistance welding is one of the oldest of electric welding process in use by industry today. The weld is made by a combination of heat, pressure and time. As the name resistance welding imlies, it is the resistance of the material to be welded to causes current to flow and localized heating in the part. The pressure exerted by the tongs and electrode tips, through which the current flows, hold the parts to be welded in intimate contact before, during and after the welding current time cycle. The required amount of time to current to flow in the joint is determined by material thikness and type, the amount of current flowing and the cross-section area of the welding tip contact surfaces.



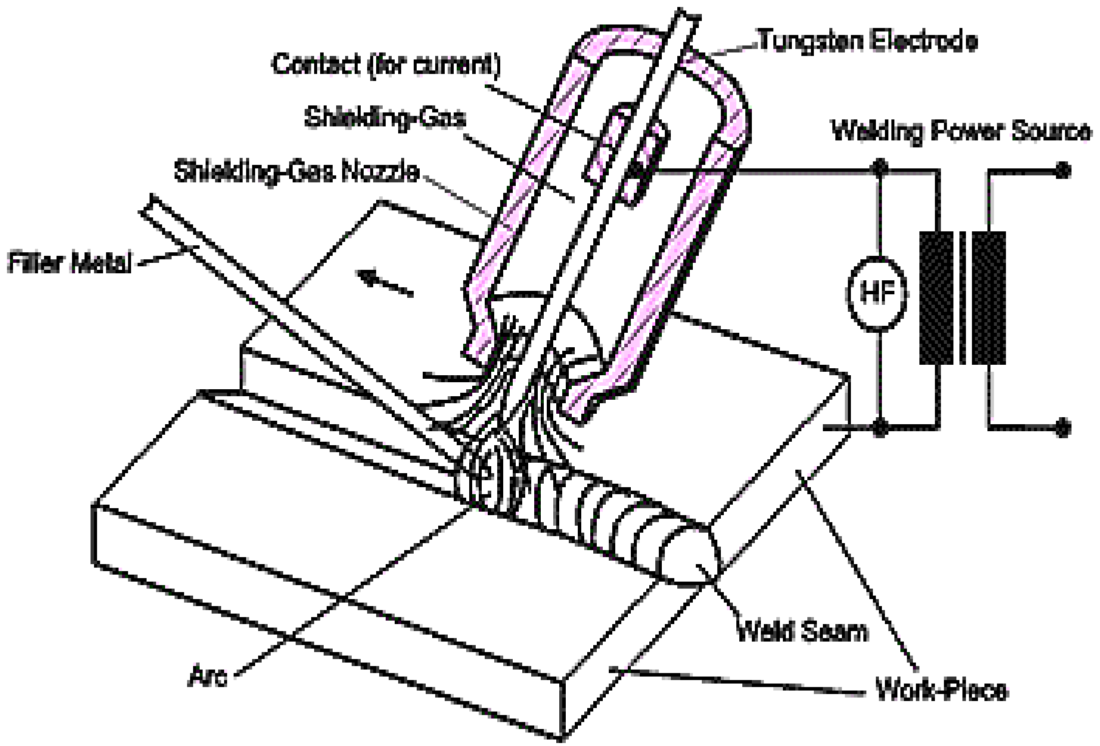
Spot welding

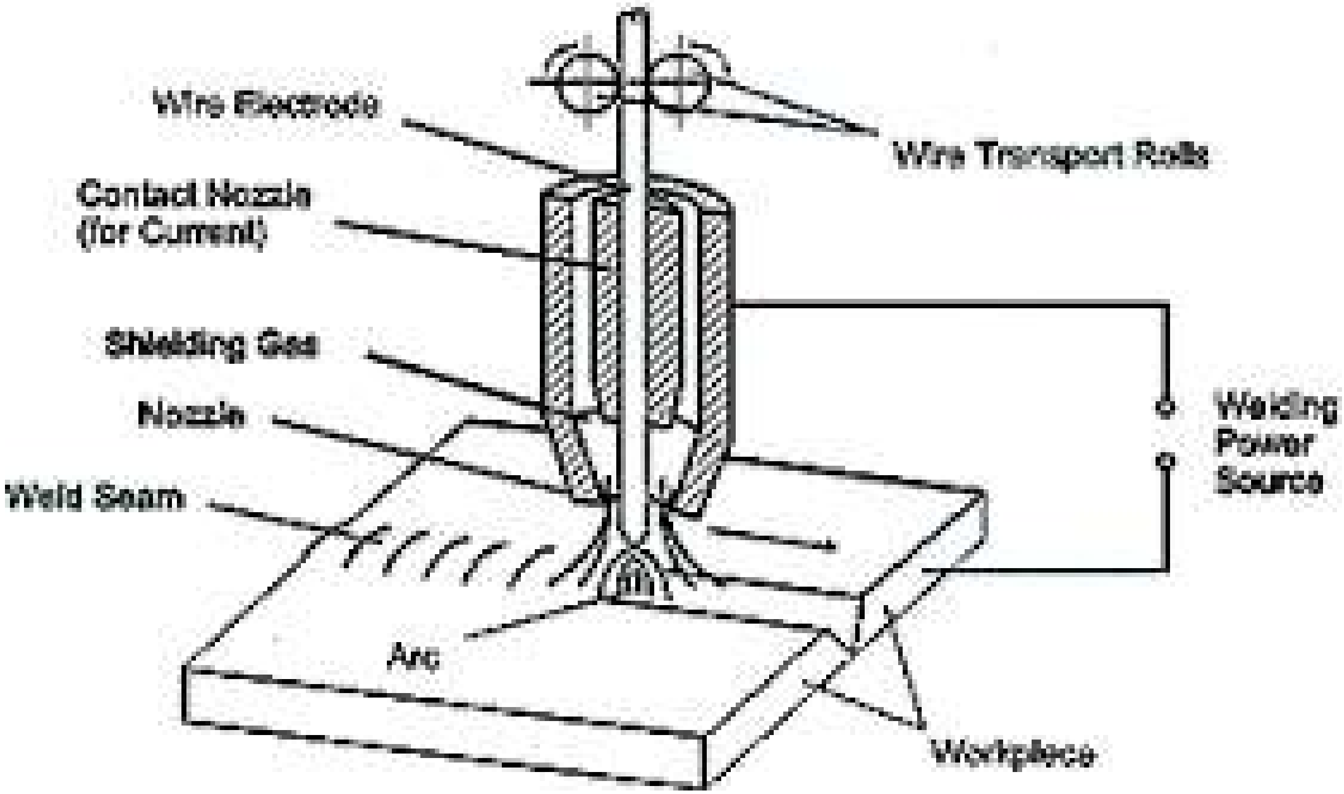

Electron Beam Welding(EBW)
Cathode
Anode
Vacuum
pump
Electron beam
Focusing coil
Deflection
coil
Work
piece
www.substech.com



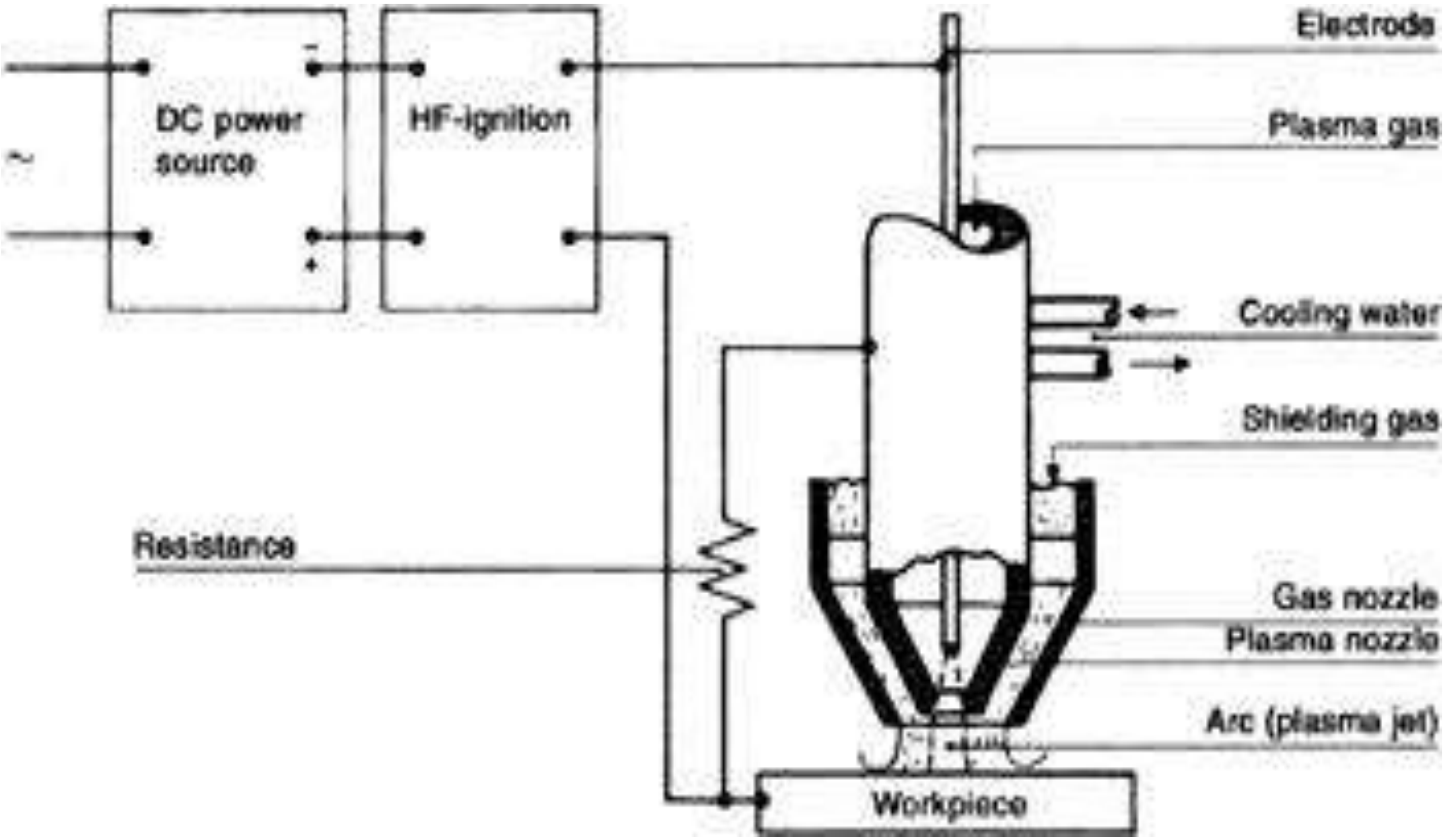
Schematic diagram of LBW
Supply
Capacitor
Laser beam
Concentrated beam
Mirror
Cooling system
Focusing lens
Work piece
Xenon Flash tube
Laser crystal

Principle of TIG Welding

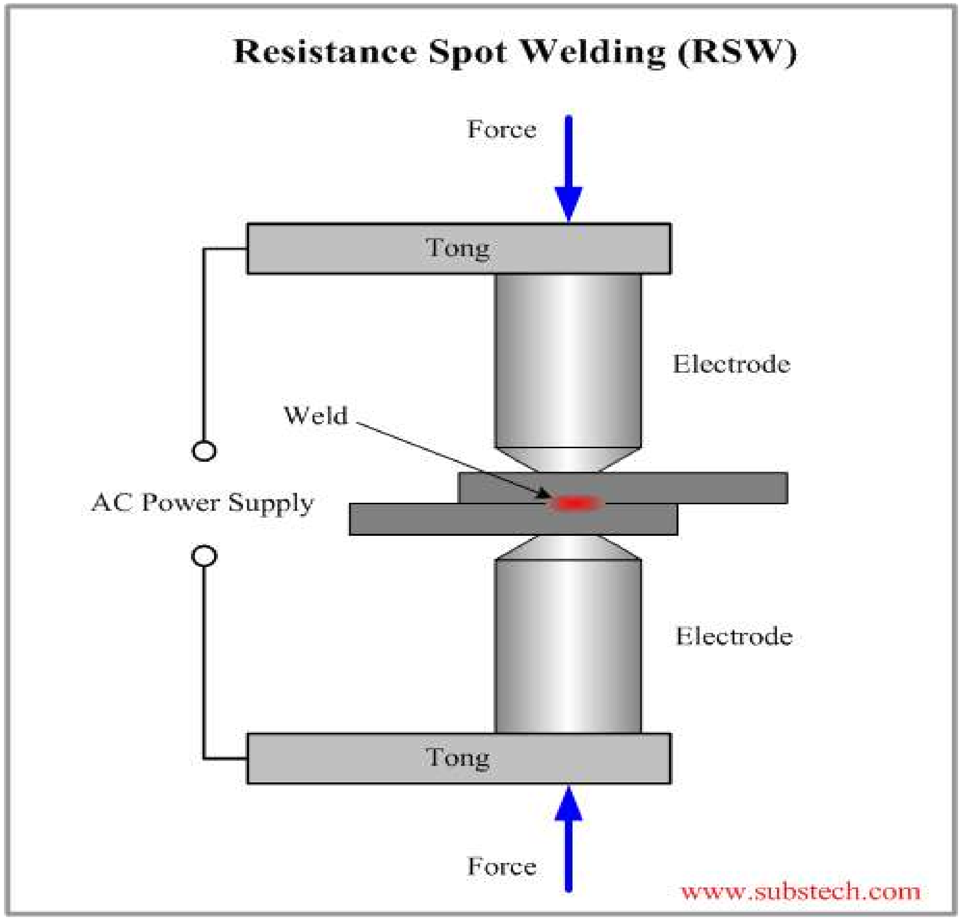


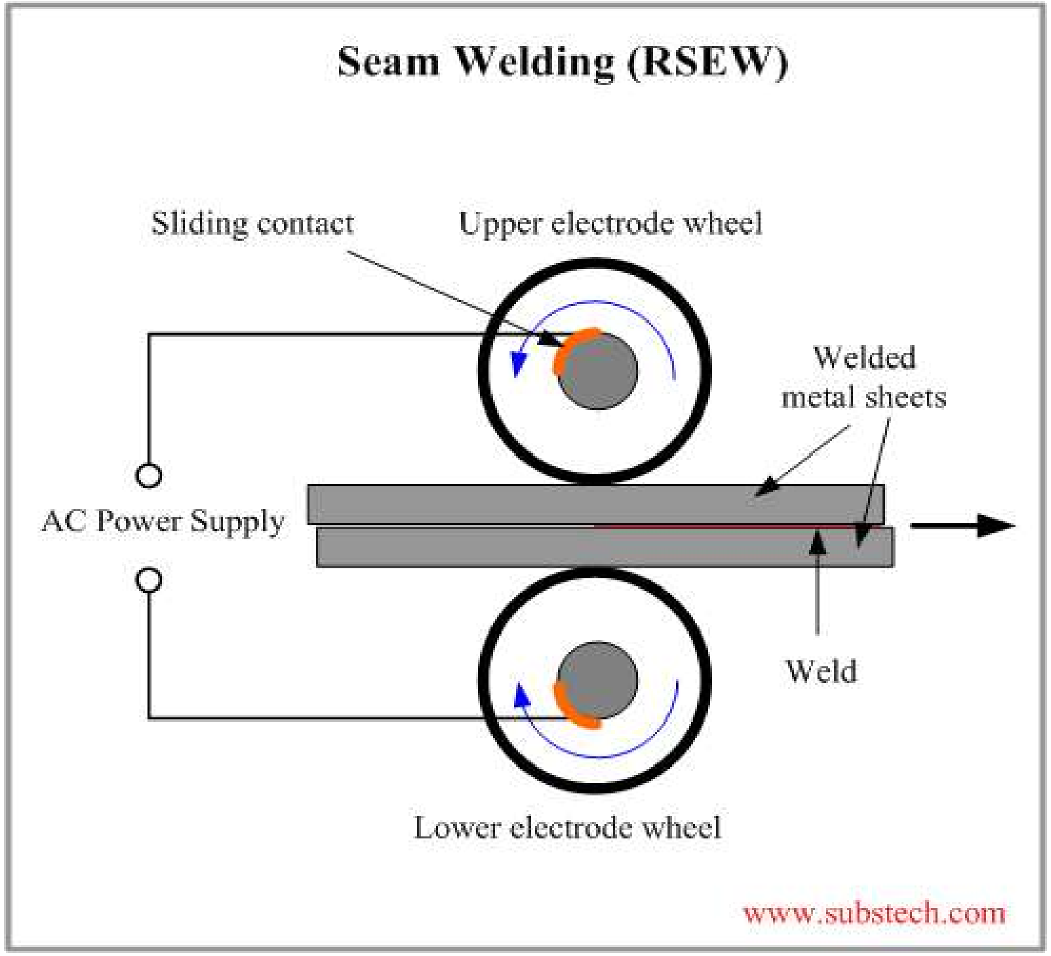

Wire Electrode
Wire Transport Rolls
Contact Nozzle
(for Current)
Shielding Gas
Nozzle
Weld Seam
Welding
Power
Source
Arc
Workpiece

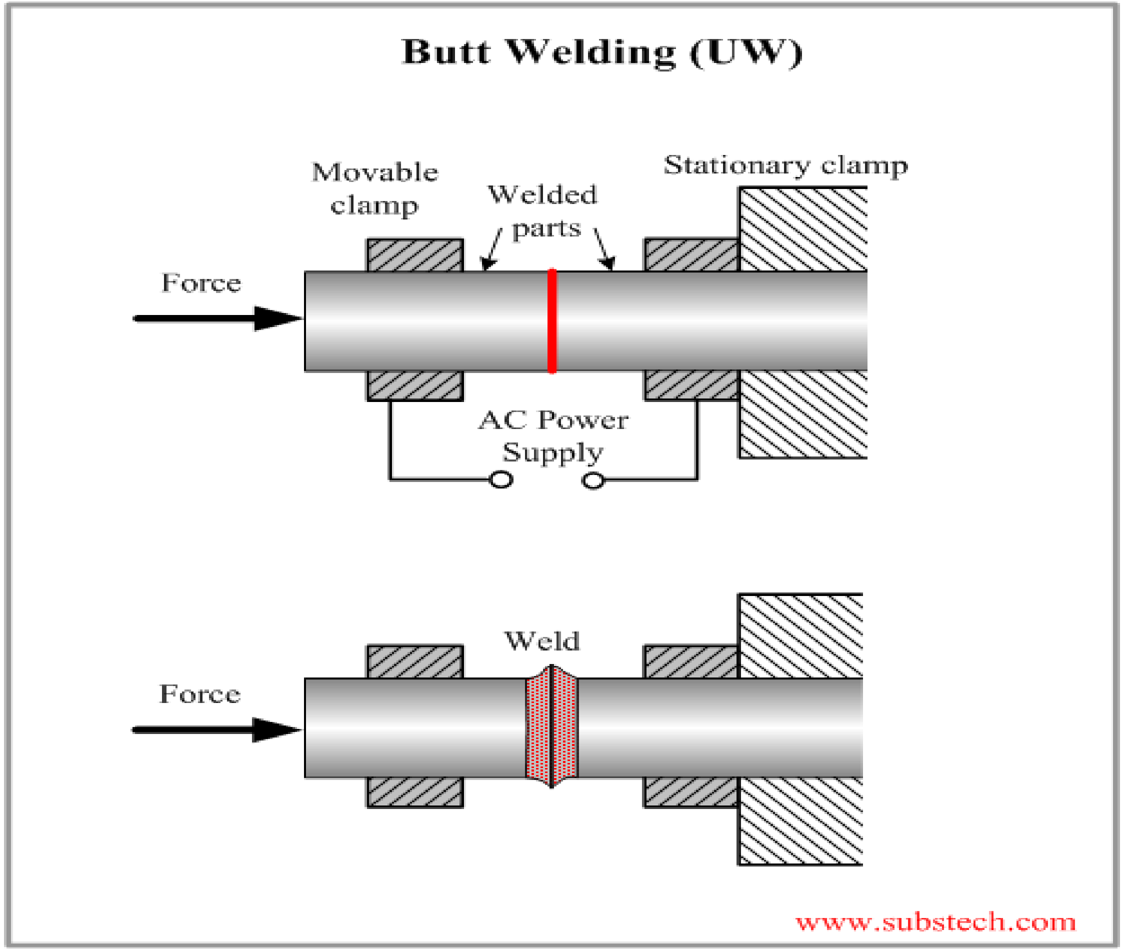
MIG Welding



PLASMA ARC WELDING


Resistance Spot Welding (RSW)
Force
Tong
Electrode
Weld
AC Power Supply
Electrode
Tong
Force
www.substech.com


Seam Welding (RSEW)
Sliding contact
Upper electrode wheel
Welded
metal sheets
AC Power Supply
Weld
Lower electrode wheel
www.substech.com


Butt Welding (UW)
Movable clamp
Welded parts
Stationary clamp
Force
AC Power Supply
Weld
Force
www.substech.com

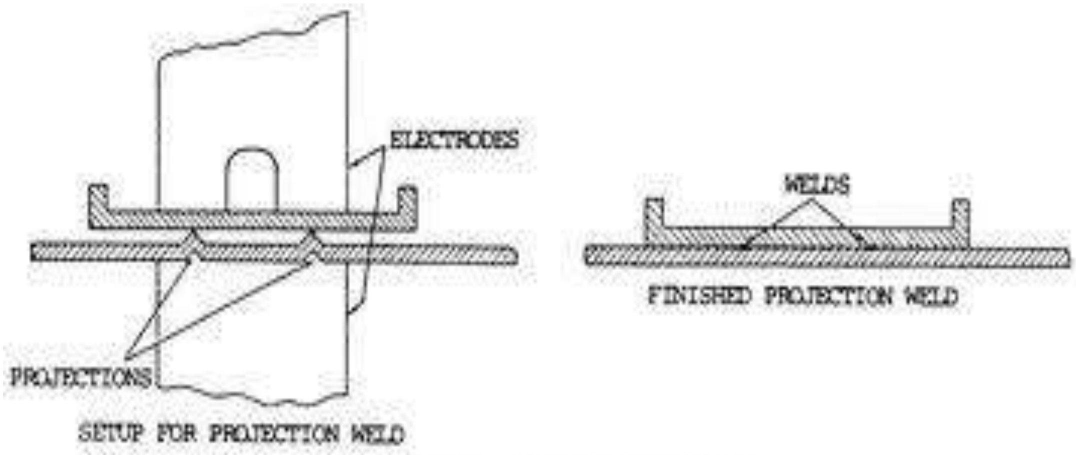
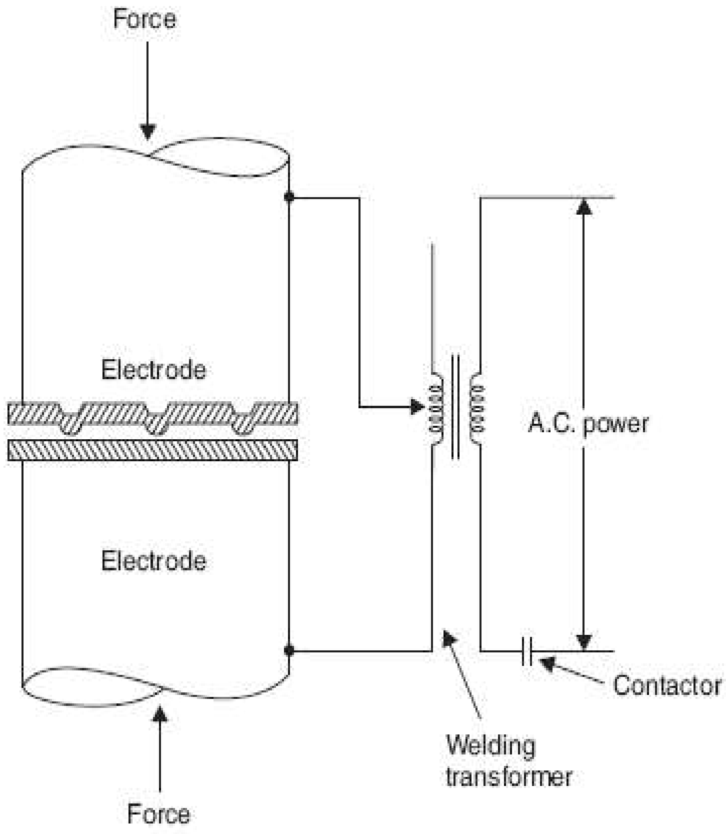


Figure 5-40. Projection welding.



PROJECTION WELDING

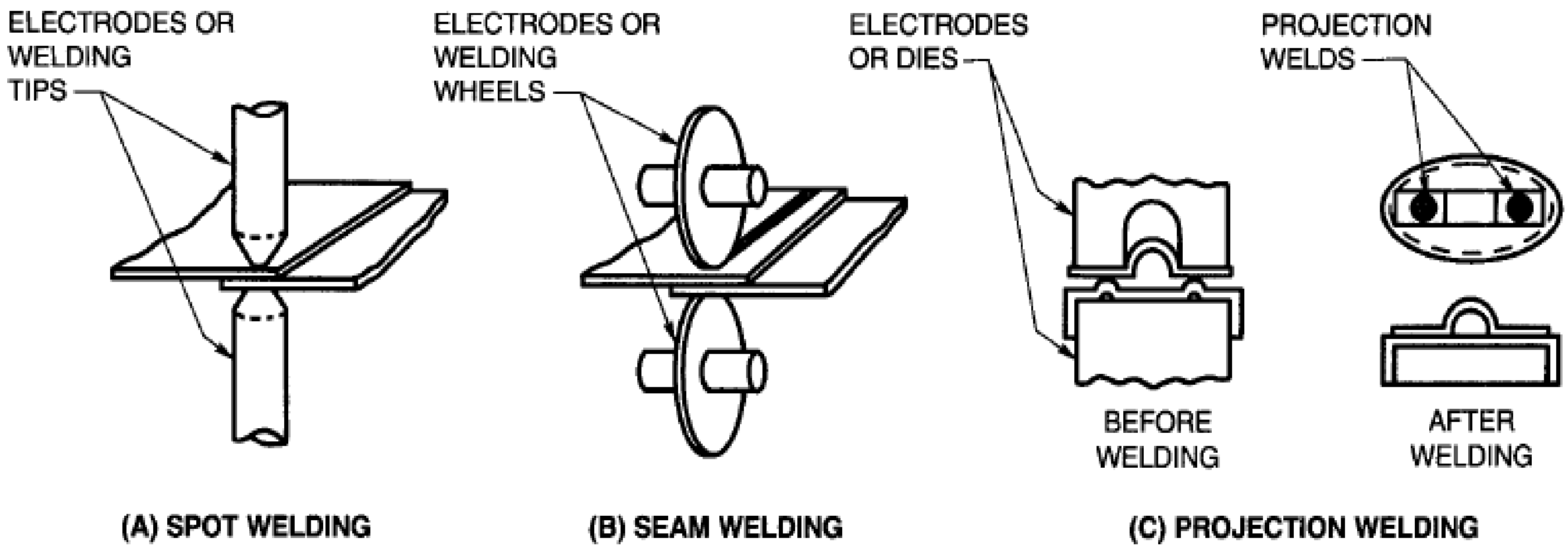


Figure R-7—Simplified Diagrams Showing the Basic Processes of Spot, Seam, and Projection Welding

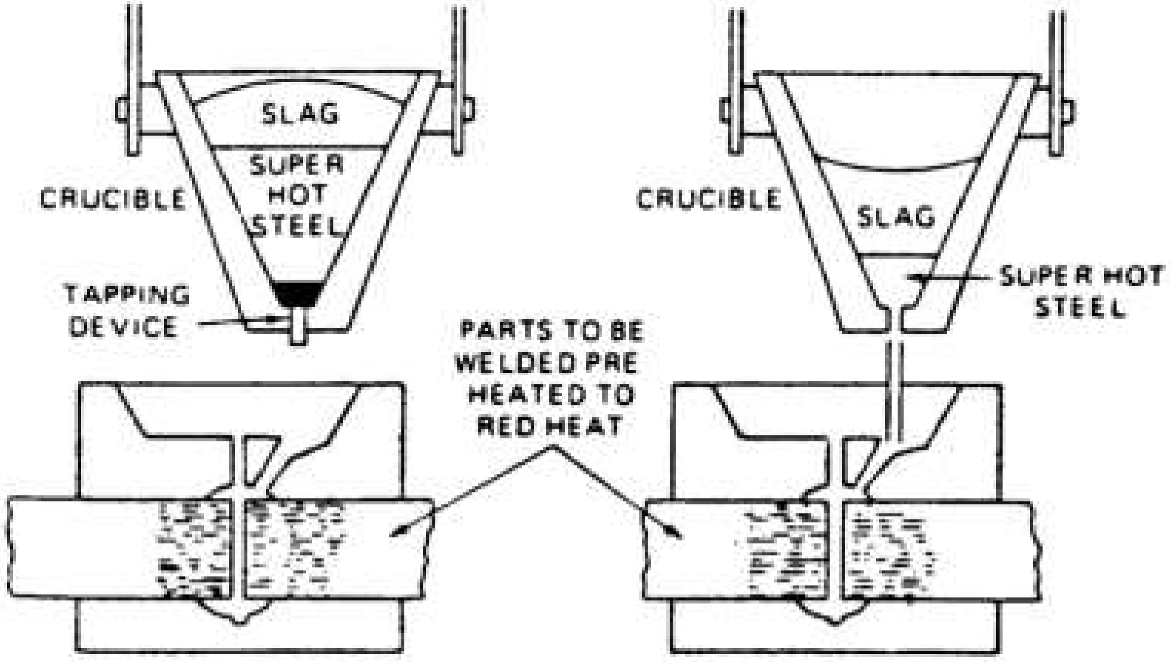
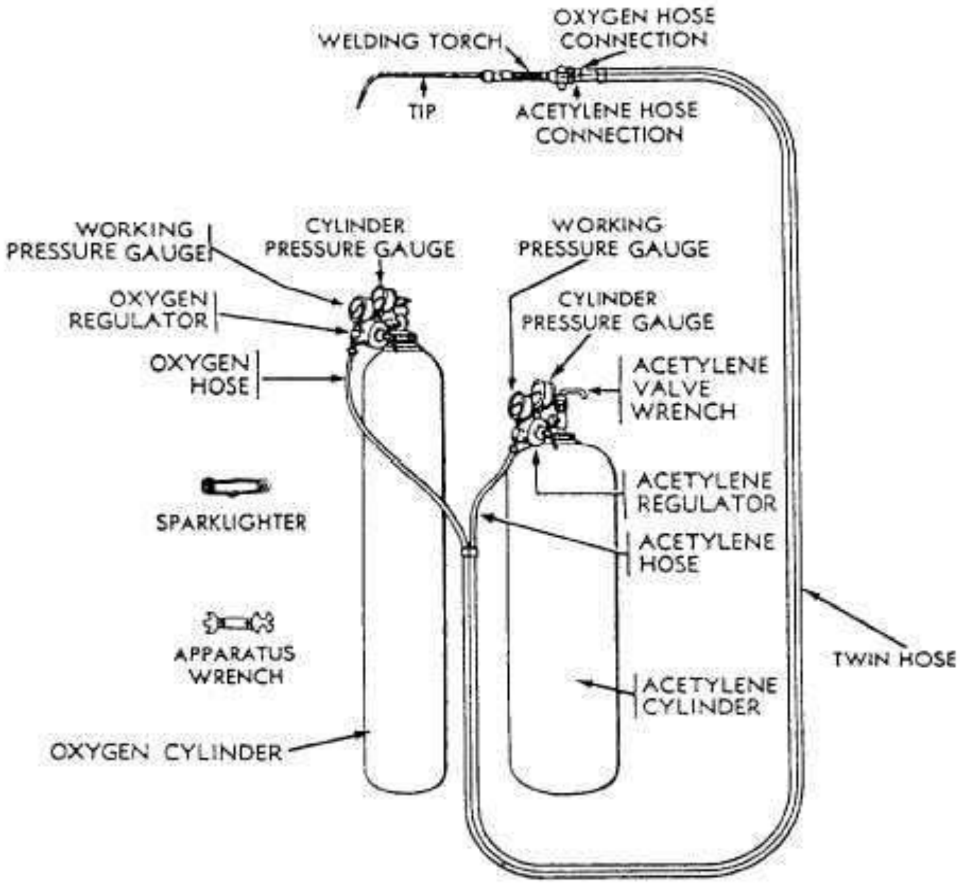


Figure 6-12. Steps in making a thermit weld.

THERMIT WELDING



OXY ACETLYNE GAS WELDING

Introduction to Nondestructive Testing

Outline

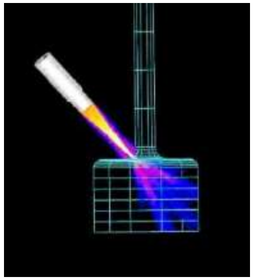
- Introduction to NDT
- Overview of Six Most Common NDT Methods
- Selected Applications

Definition of NDT

The use of noninvasive techniques to determine the integrity of a material, component or structure

or

quantitatively measure some characteristic of an object.



i.e. Inspect or measure without doing harm.

Methods of NDT

Visual

Microwave

Thermography

Tap Testing

Magnetic Particle

Acoustic Microscopy

X-ray

Acoustic Emission

Magnetic Measurements

Liquid Penetrant

Ultrasonic

Replication

Laser Interferometry

Eddy Current

Flux Leakage

What are Some Uses of NDE Methods?

- Flaw Detection and Evaluation
- Leak Detection
- Location Determination
- Dimensional Measurements
- Structure and Microstructure Characterization
- Estimation of Mechanical and Physical Properties
- Stress (Strain) and Dynamic Response Measurements
- Material Sorting and Chemical Composition Determination

When are NDE Methods Used?

- To assist in product development
- To screen or sort incoming materials
- To monitor, improve or control manufacturing processes
- To verify proper processing such as heat treating
- To verify proper assembly
- To inspect for in-service damage

Six Most Common NDT Methods

- Visual
- Liquid Penetrant
- Magnetic
- Ultrasonic
- Eddy Current
- X-ray

Visual Inspection

Most basic and common inspection method.

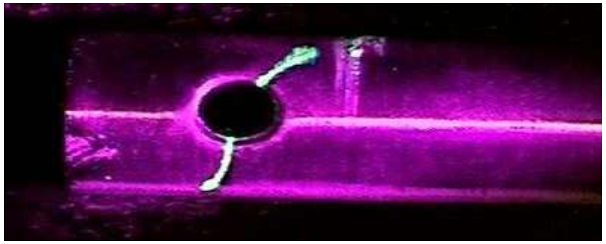
Tools include fiberscopes, borescopes, magnifying glasses and mirrors.

Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines.

Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines.

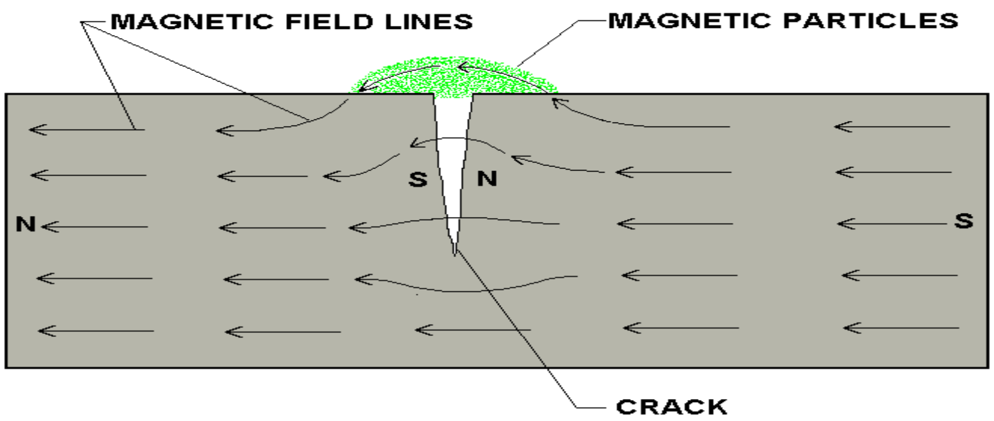
Liquid Penetrant Inspection

- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen.
- Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.

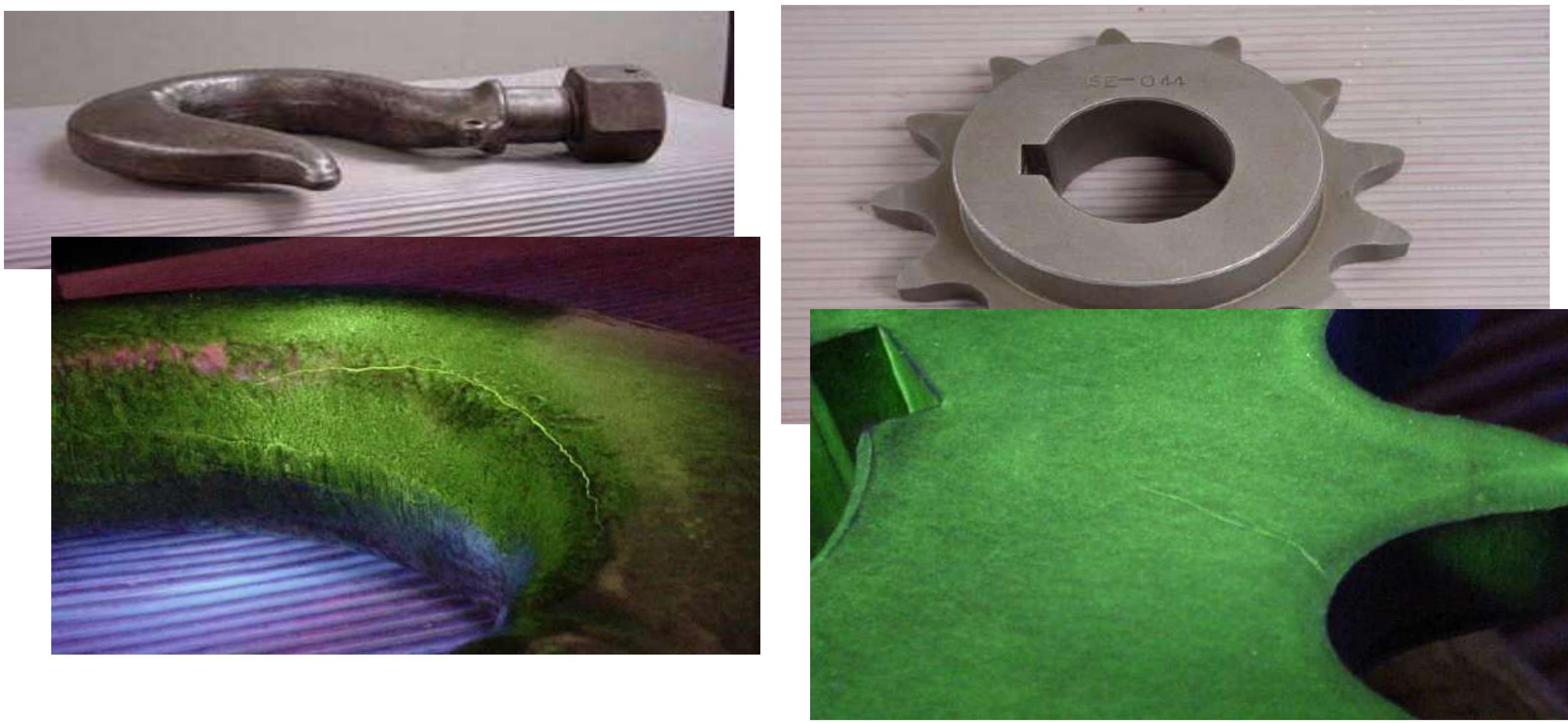


Magnetic Particle Inspection

- The part is magnetized. Finely milled iron particles coated with … hen applied to the specimen. These particles are attracted to magnetic flux leakag… er to form an indication directly over the discontinuity. This indication can b… der proper lighting conditions.

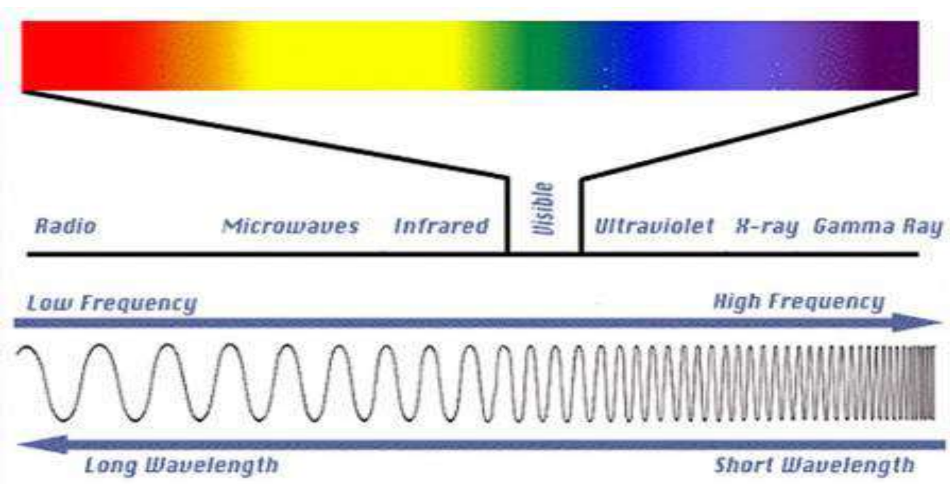


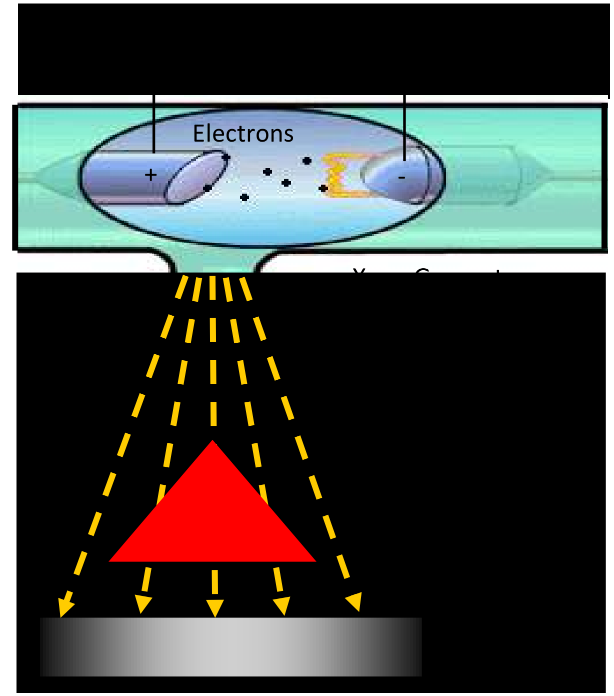
Magnetic Particle Crack Indications



Radiography

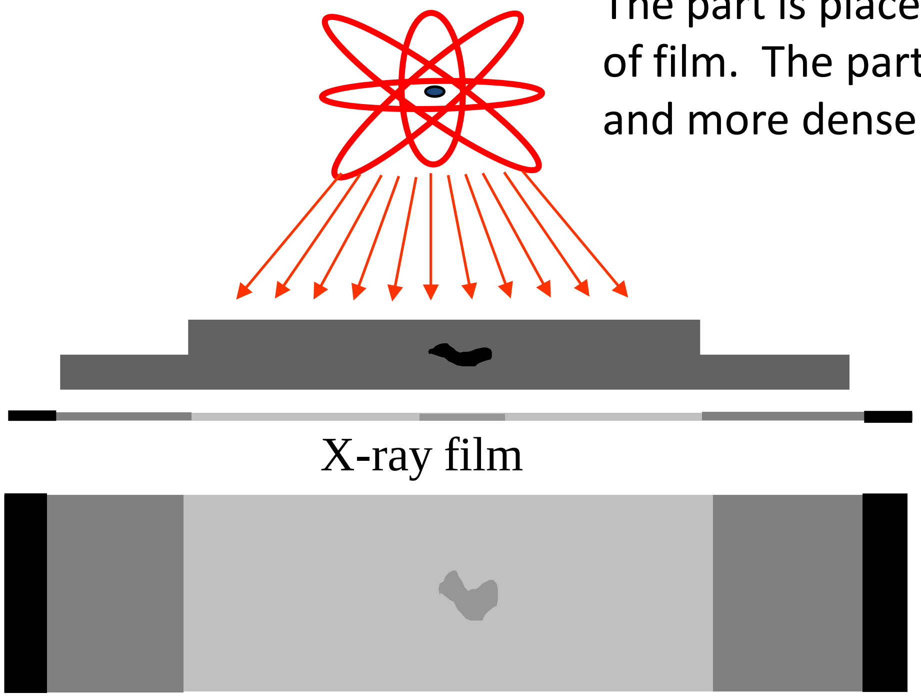
The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we
see as visible light. The radiation can come from an X-ray generator or a radioactive source.





Film Radiography

The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.



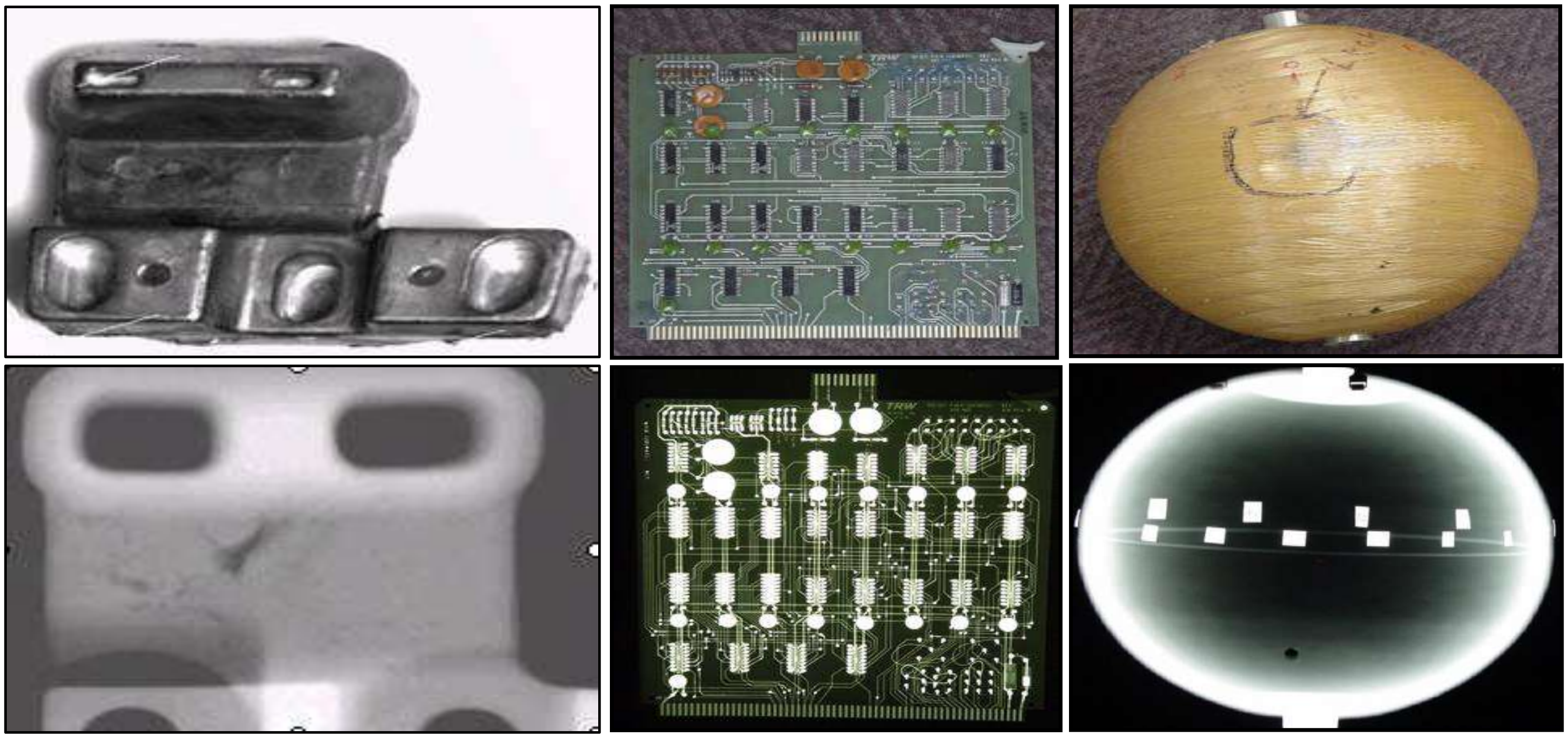
Top view of developed film

The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

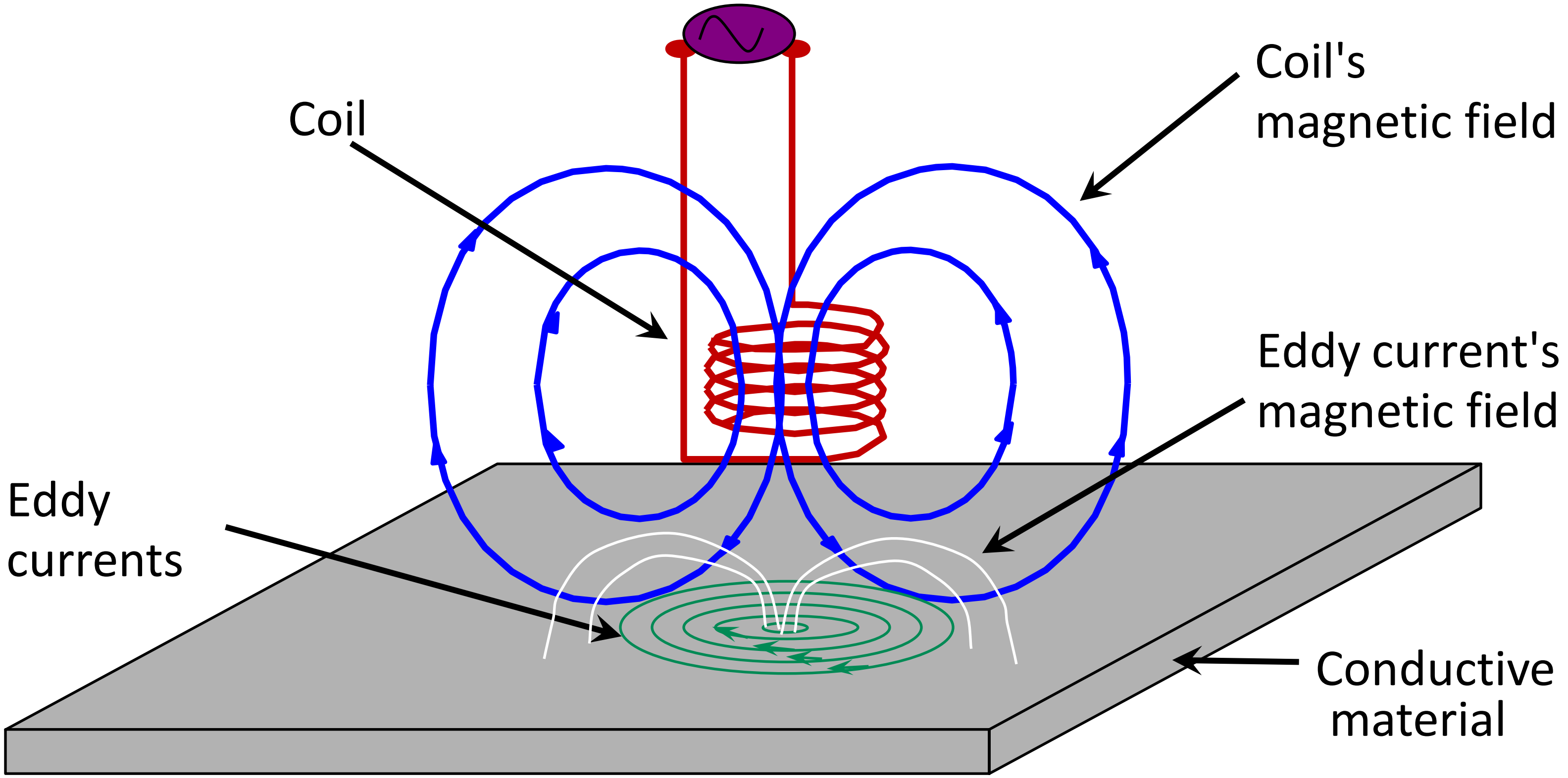
= less exposure

= more exposure

Radiographic Images



Eddy Current Testing

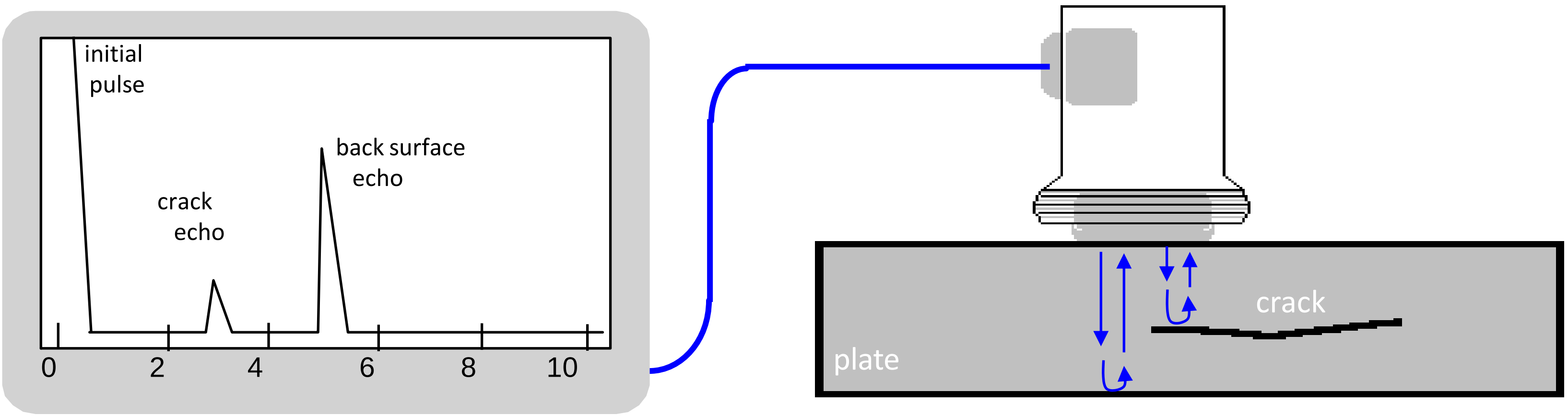


Eddy Current Testing

Ultrasonic Inspection (Pulse-Echo)

High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws.

Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound.



Oscilloscope, or flaw detector screen

Ultrasonic Imaging

High resolution images can be produced by plotting signal strength or time-of-flight using a computer-controlled scanning system.

Gray scale image produced using the sound reflected from the front surface of the coin

Gra[redacted]

Common Application of NDT

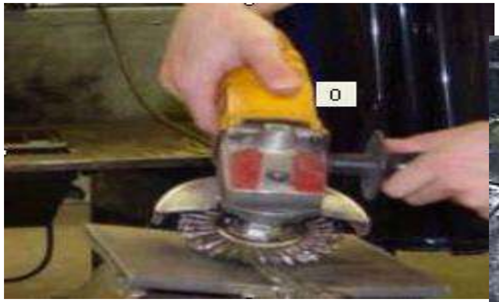
- Inspection of Raw Products
- Inspection Following Secondary Processing
- In-Services Damage Inspection

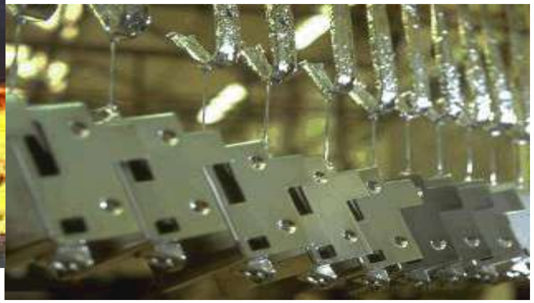
Inspection of Raw Products

- Forgings,
- Castings,
- Extrusions,
- etc.

Inspection Following Secondary Processing

- Machining
- Welding
- Grinding
- Heat treating
- Plating
- etc.



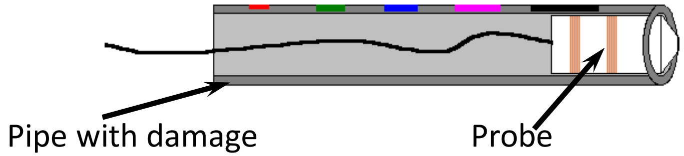


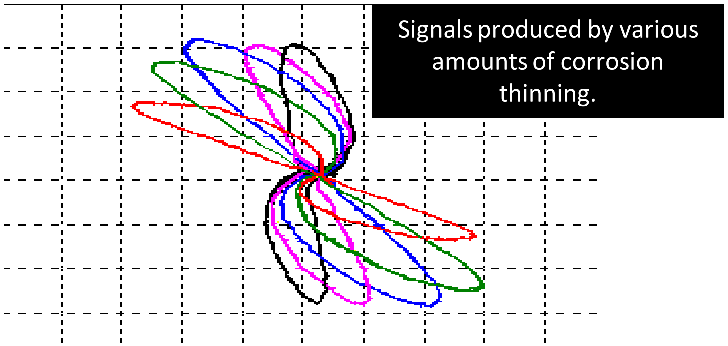
Inspection For In-Service Damage

- Cracking
- Corrosion
- Erosion/Wear
- Heat Damage
- etc.

Power Plant Inspection

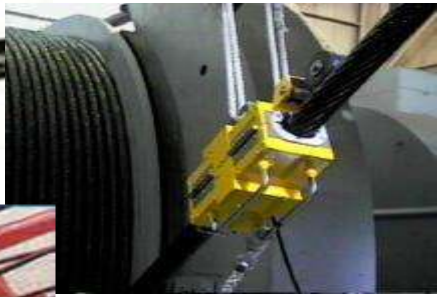
Periodically, power plants are shutdown for inspection.
Inspectors feed eddy current probes into heat exchanger tubes to check for corrosion damage.





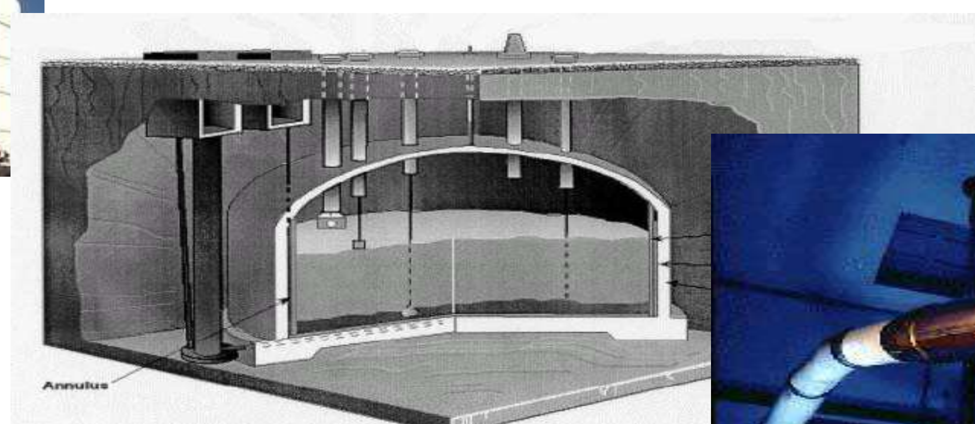
Wire Rope Inspection

Electromagnetic devices and visual inspections are used to find broken wires and other damage to the wire rope that is used in chairlifts, cranes and other lifting devices.



Storage Tank Inspection

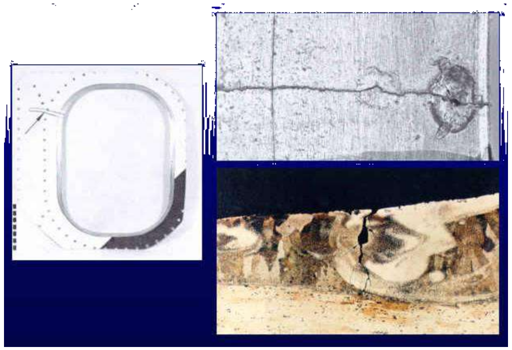
Robotic crawlers use ultrasound to inspect the walls of large above ground tanks for signs of thinning due to corrosion.



Cameras on long articulating arms are used to inspect underground storage tanks for damage.

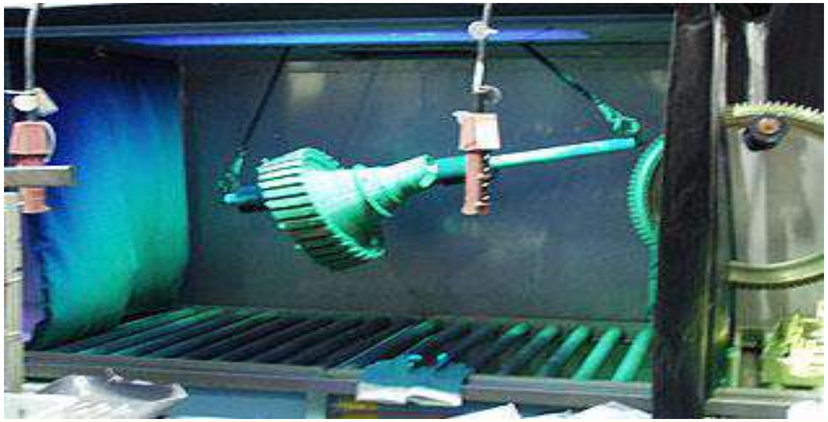
Aircraft Inspection

- Nondestructive testing is used extensively during the manufacturing of aircraft.
- NDT is also used to find cracks and corrosion damage during operation of the aircraft.
- A fatigue crack that started at the site of a lightning strike is shown below.



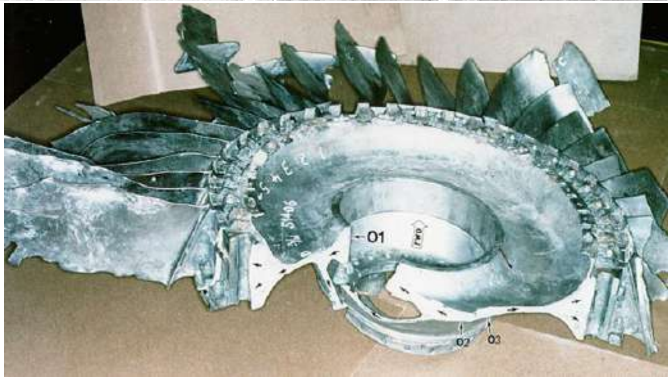
Jet Engine Inspection

- Aircraft engines are overhauled after being in service for a period of time.
- They are completely disassembled, cleaned, inspected and then reassembled.
- Fluorescent penetrant inspection is used to check many of the parts for cracking.



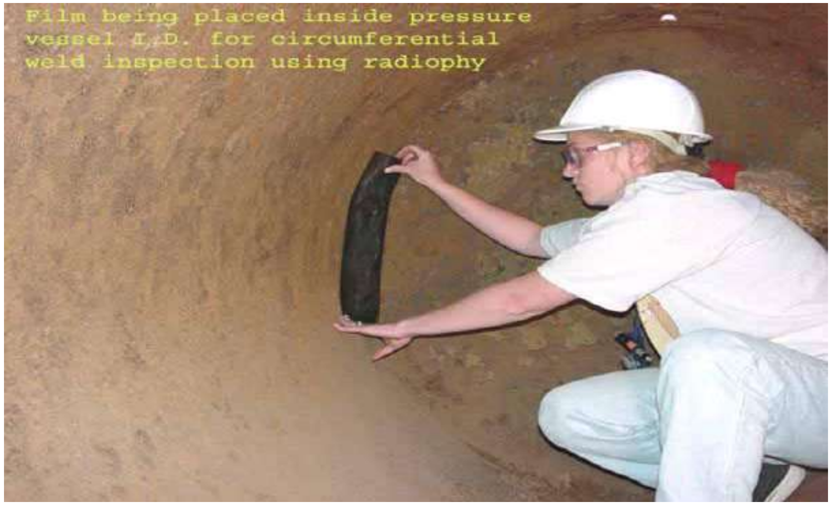
Crash of United Flight 232

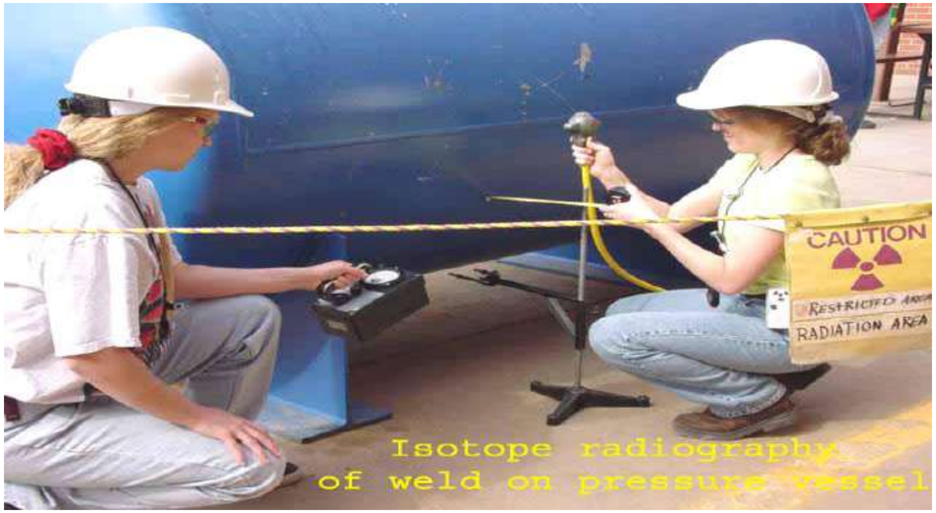
A defect that went undetected in an engine disk was responsible for the crash of United Flight 232.



Pressure Vessel Inspection

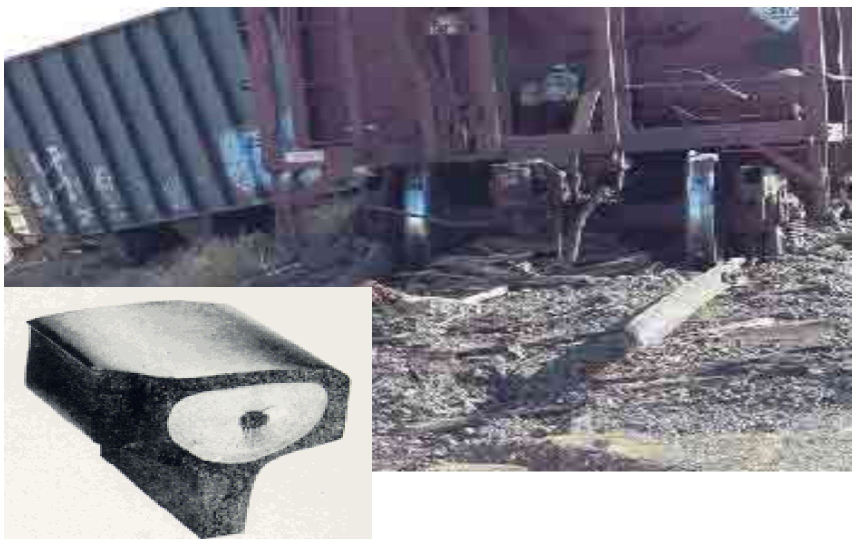
The failure of a pressure vessel can result in the rapid release of a large amount of energy. To protect against this dangerous event, the tanks are inspected using radiography and ultrasonic testing.

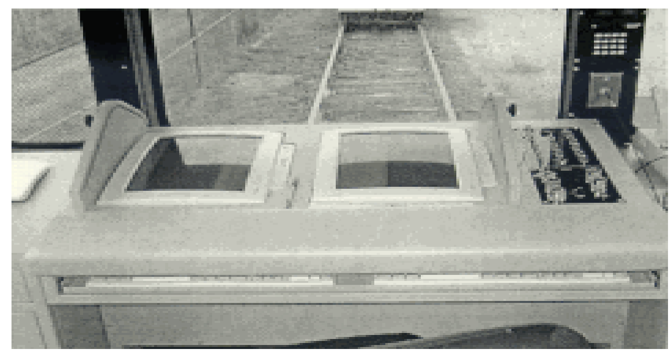




Rail Inspection

Special cars are used to inspect thousands of miles of rail to find cracks that could lead to a derailment.





Bridge Inspection

- The US has 578,000 highway bridges.
- Corrosion, cracking and other damage can all affect a bridge's performance.
- The collapse of the Silver Bridge in 1967 resulted in loss of 47 lives.
- Bridges get a visual inspection about every 2 years.
- Some bridges are fitted with acoustic emission sensors that "listen" for sounds of cracks growing.

Pipeline Inspection

NDT is used to inspect pipelines to prevent leaks that could damage the environment. Visual inspection, radiography and electromagnetic testing are some of the NDT methods used.

Special Measurements

- Boeing employees in Philadelphia were given the privilege of evaluating the Liberty Bell for damage using NDT techniques. Eddy current methods were used to measure the electrical conductivity of the Bell's bronze casing at various points to evaluate its uniformity.

For More Information on NDT

The Collaboration for NDT Education

www.ndt-ed.org

The American Society for Nondestructive Testing

www.asnt.org

Unit-III

SHEET METAL PROCESSES IN AIRCRAFT INDUSTRY

Introduction

- Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes.
- Countless everyday objects are constructed of the material.
- Thicknesses can vary significantly, although extremely thin thicknesses are considered foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate.

Sheet metal processing

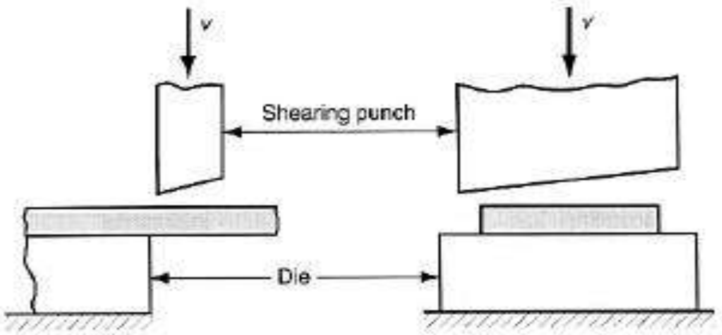
- The raw material for sheet metal manufacturing processes is the output of the rolling process. Typically, sheets of metal are sold as flat, rectangular sheets of standard size.
- If the sheets are thin and very long, they may be in the form of rolls. Therefore the first step in any sheet metal process is to cut the correct shape and sized ‘blank’ from larger sheet.

- **Sheet Metal Forming processes**

Introduction

1. Sheet metal processes involve plane stress loadings and lower forces than bulk forming
2. Almost all sheet metal forming is considered to be secondary processing
3. The main categories of sheet metal forming are
   - Shearing
   - Bending
   - Drawing

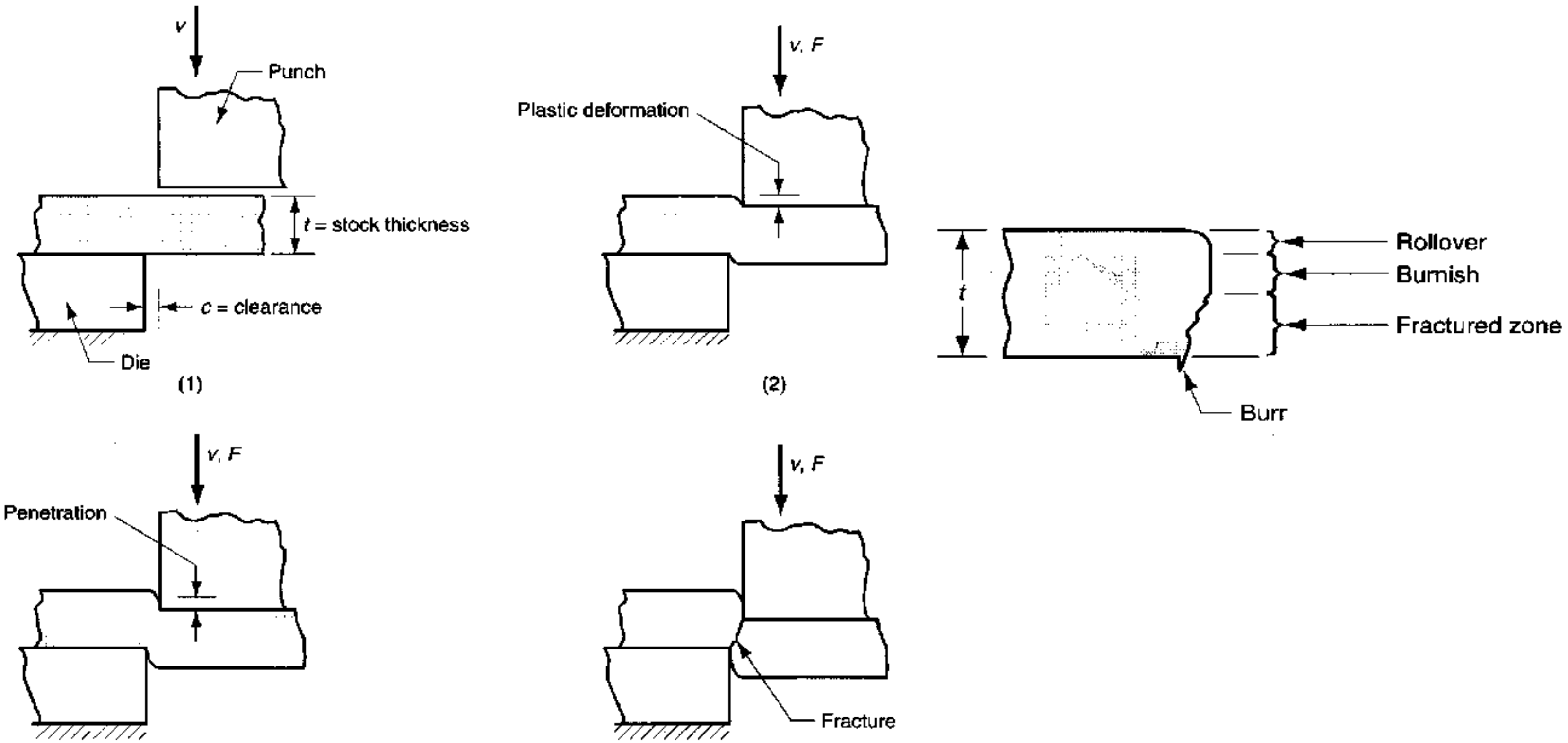
- Shearing
- Shearing is a sheet metal cutting operation along a straight line between two cut-ting edges by means of a power shear.



Shearing operation

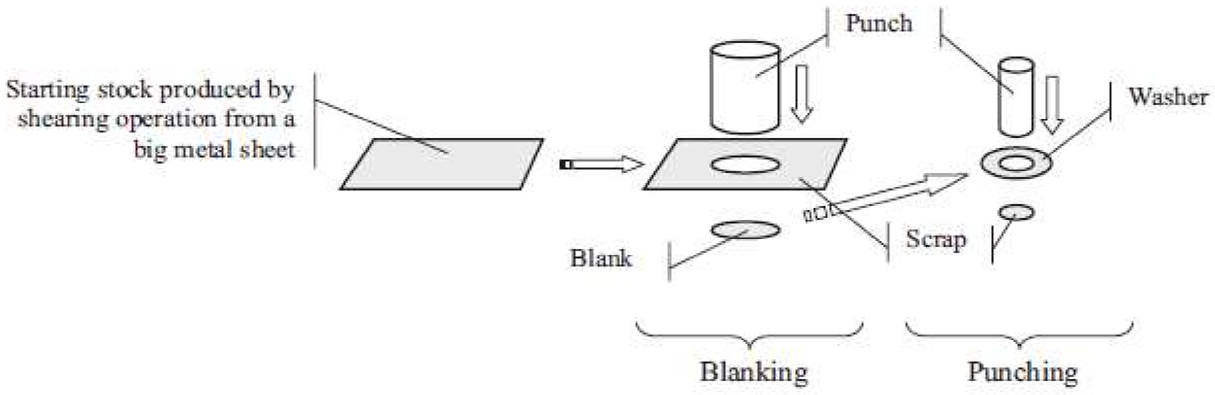
Shearing by two sharp cutting edges.

Plastic deformation to penetration to fracture



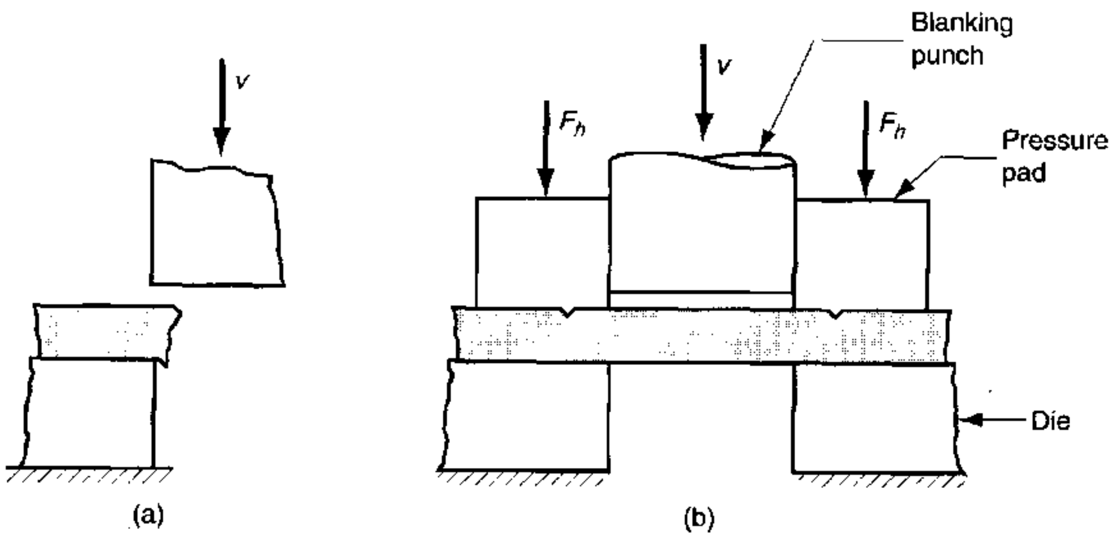
• Blanking and punching

- Blanking and punching are similar sheet metal cutting operations that involve cutting the sheet metal along a closed outline. If the part that is cut out is the desired product, the operation is called ***blanking*** and the product is called *blank. If the remaining stock is the desired part, the operation is called* ***punching.*** *Both operations are illustrated on the example of producing a washer*



Steps in production of washer

Sheet-metal Cutting Operations



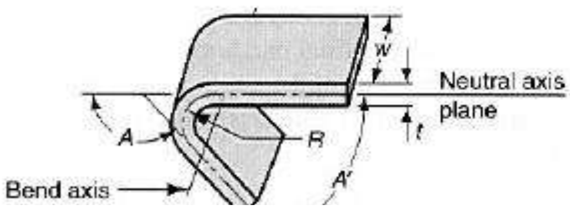
Fine blanking - close tolerances and smooth edges in one step.

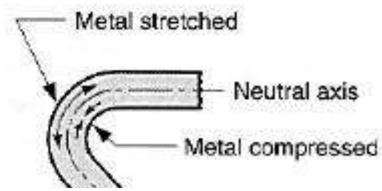
Trimming - Cutting operation to remove excess metal

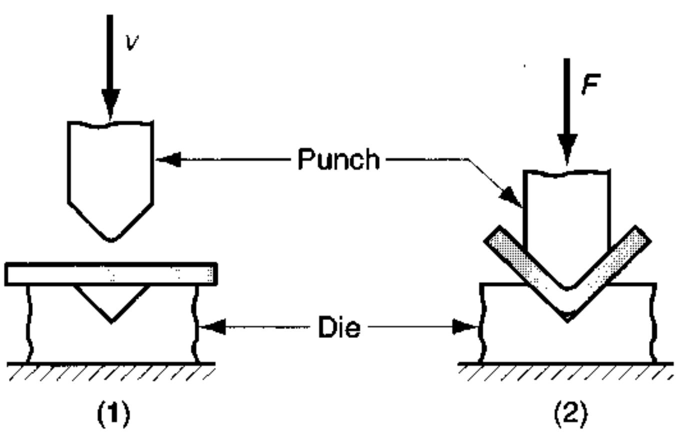
Shaving - Shearing with very small clearance to obtain accurate dimensions., secondary or finishing operation.

Bending

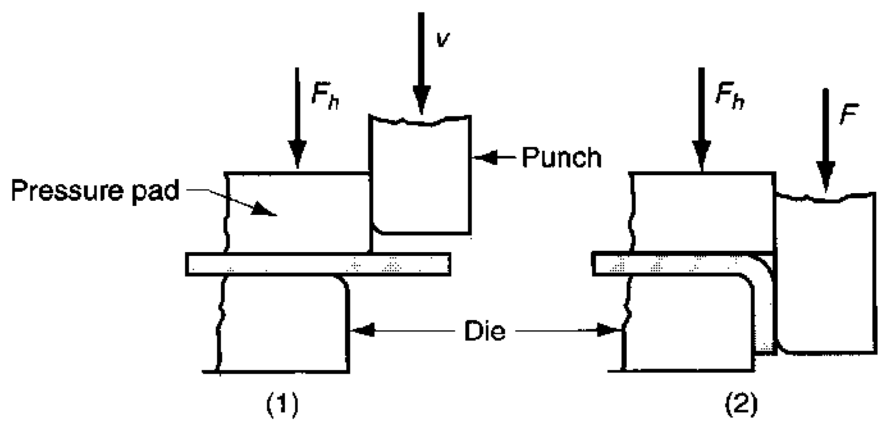
Bending is defined as the straining of the sheet metal around a straight edge







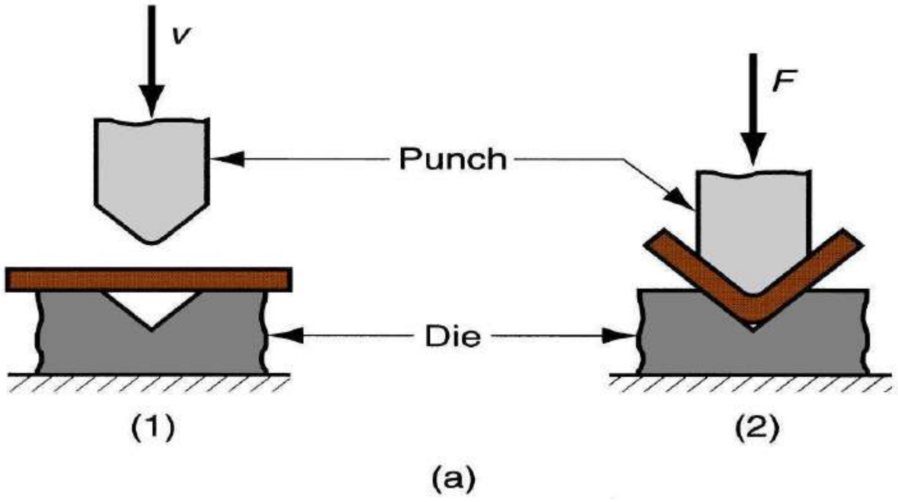
V- bending



Edge - bending

V-Bending

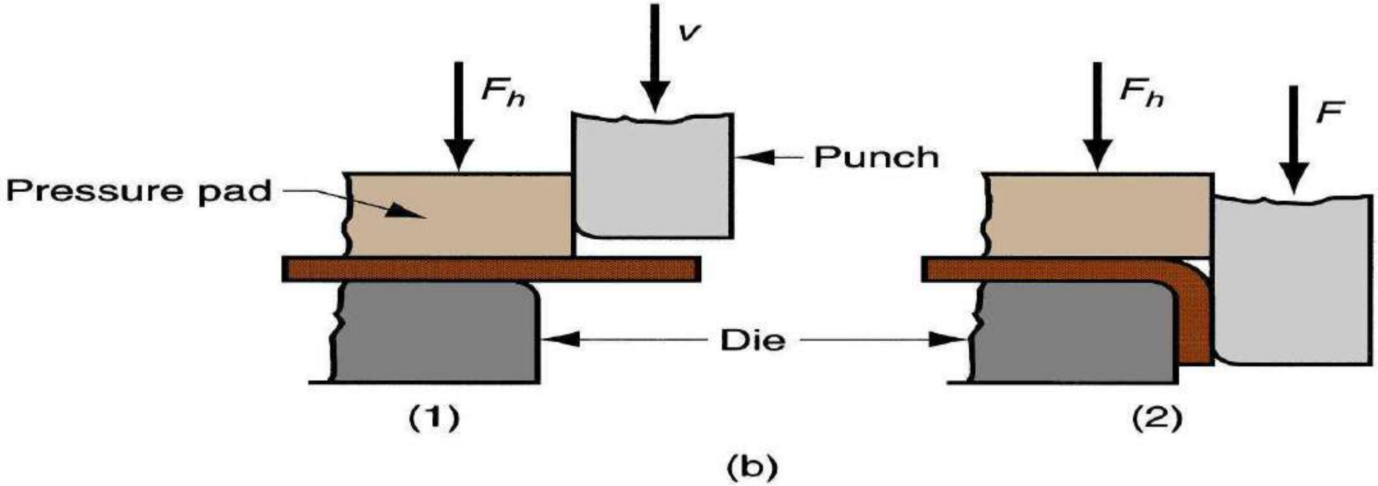
- For low production
- Performed on a *press brake*
- V-dies are simple and inexpensive



(a) V-bending;

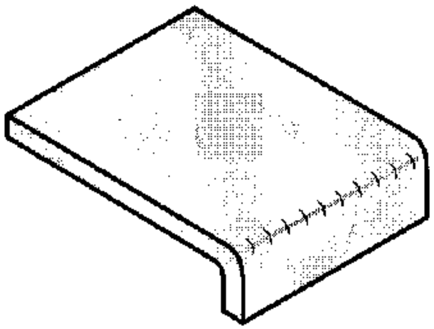
Edge Bending

- For high production
- Pressure pad required
- Dies are more complicated and costly

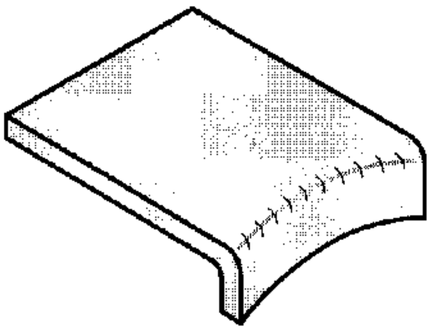


(b) edge bending.

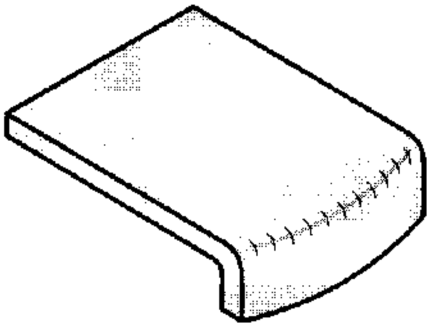
Bending Operations



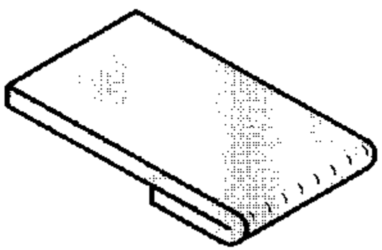
Straight flanging



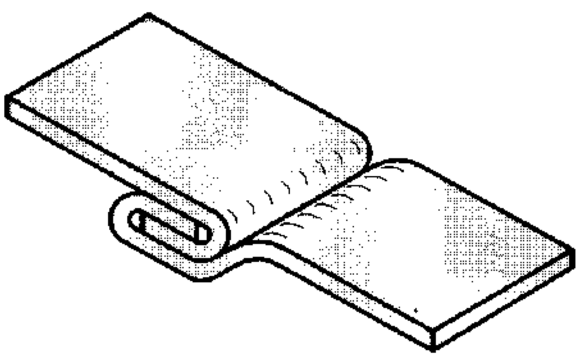
Stretch flanging



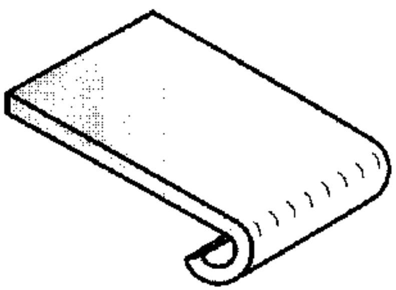
Shrink flanging



Hemming



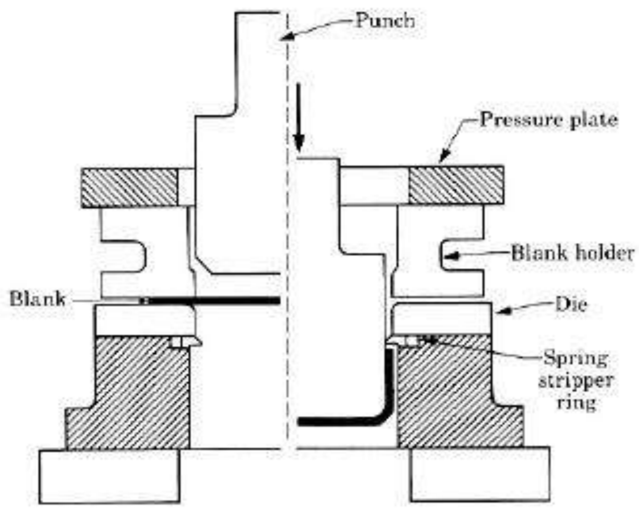
Seaming



Curling

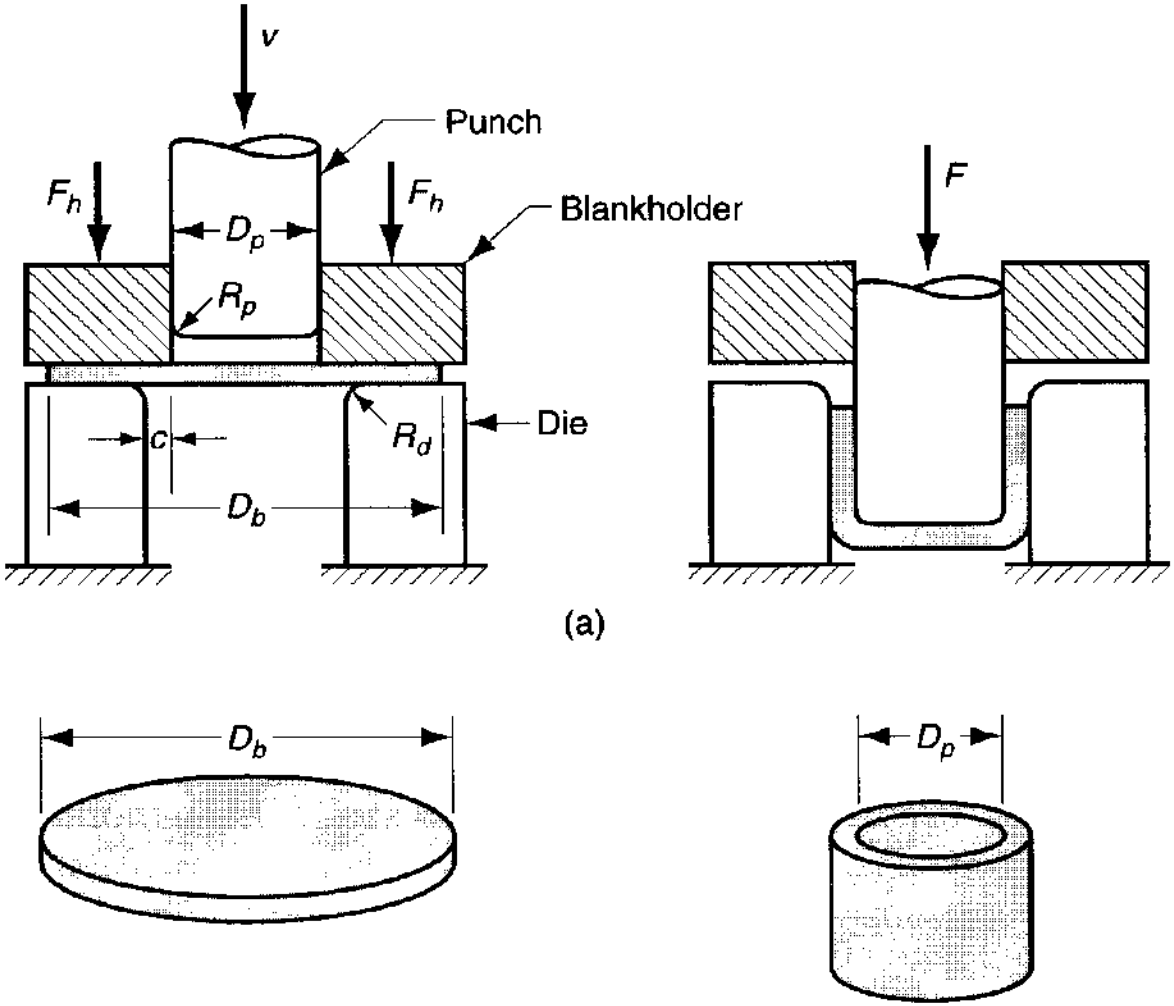
Drawing

Drawing is a sheet-metal operation to make hollow-shaped parts from a sheet blank



Deep drawing of a cup-shaped part:
(*Left*) start of the operation before punch contacts blank, and (*Right*) end of stroke

Drawing



c = Clearance

D_b = blank diameter

D_p = Punch diameter

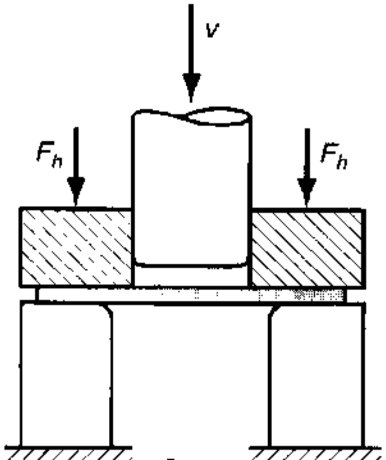
R_d = die corner radius

R_p = Punch corner radius

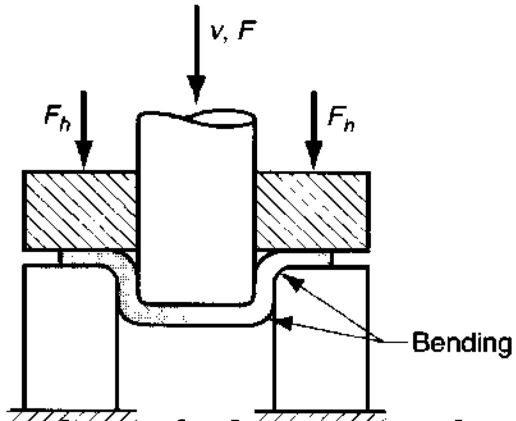
F = drawing force

F_h = holding force

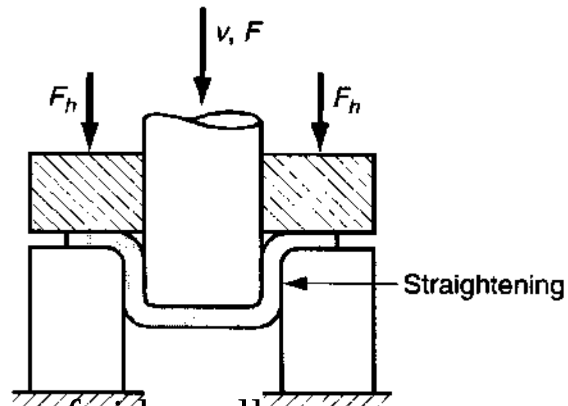
Deep Drawing



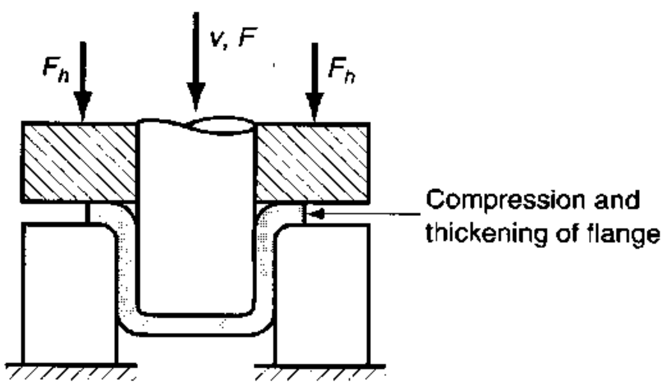
Initial step



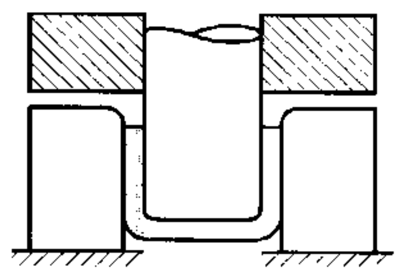
bending of edge



straightening of side wall

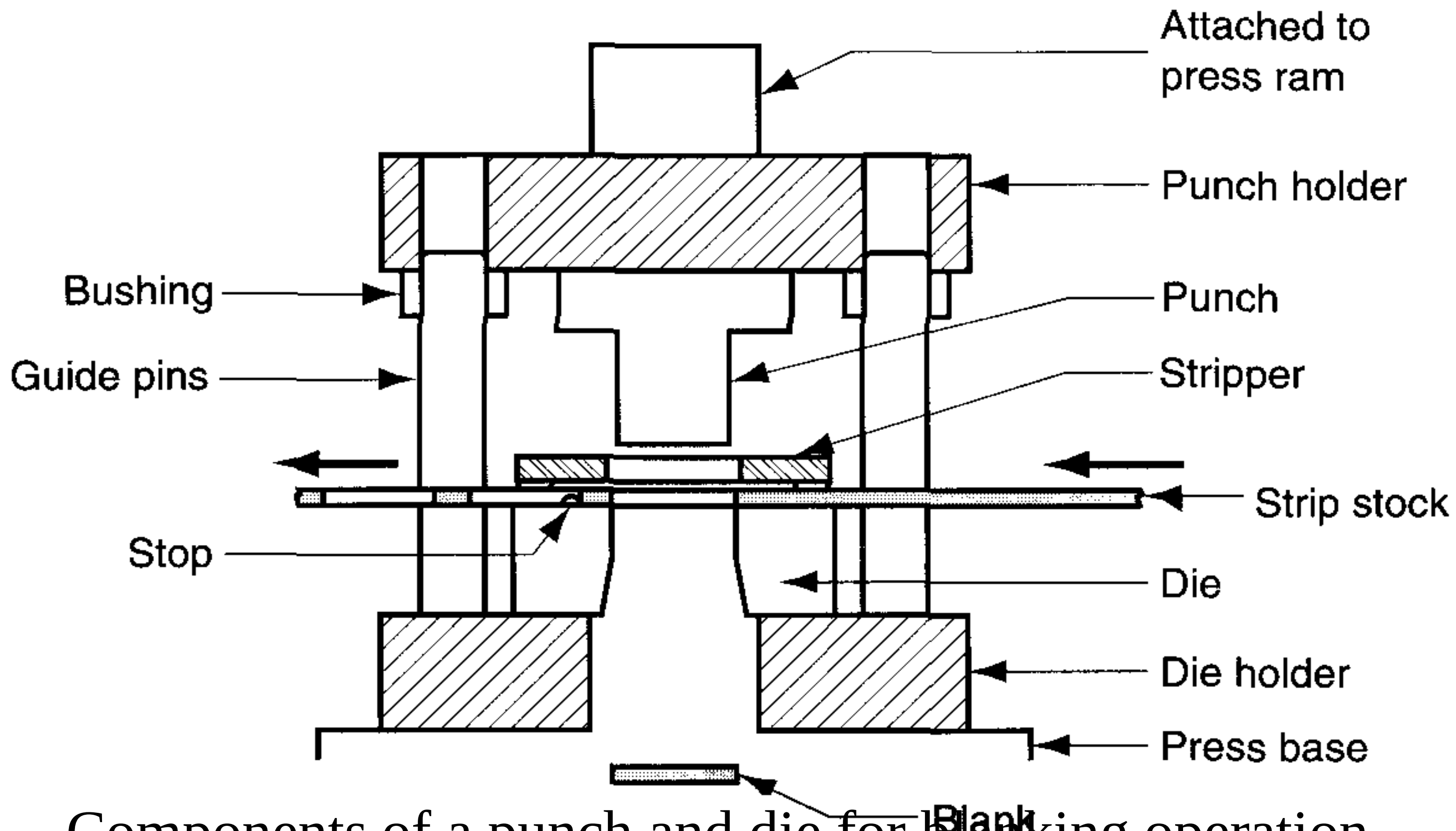


Thinning and drawing



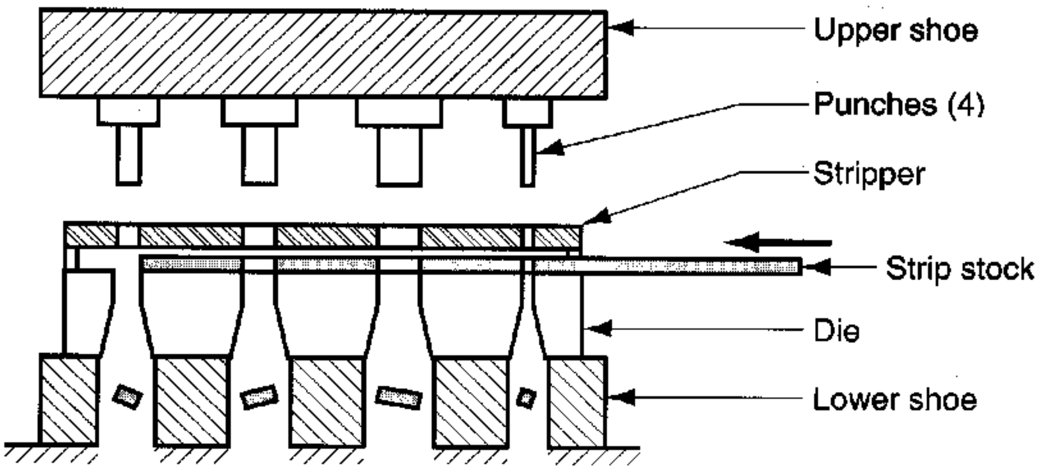
final cup shape

Dies

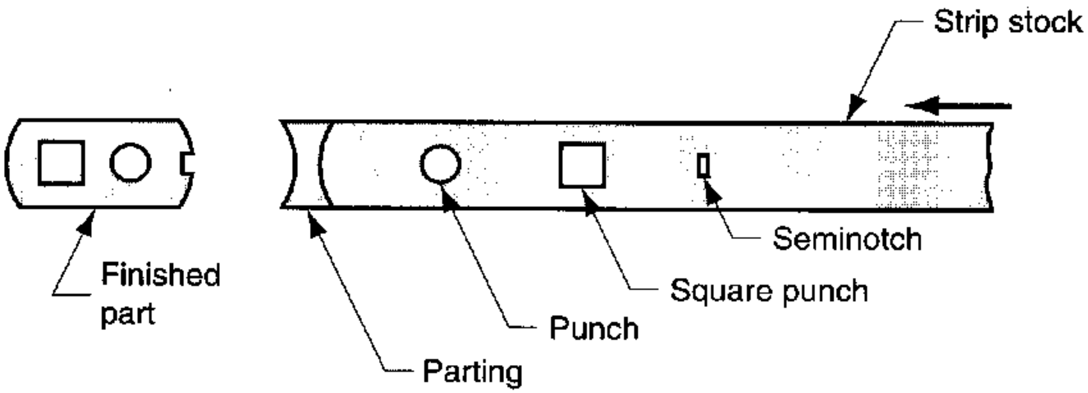


Components of a punch and die for blanking operation

Dies



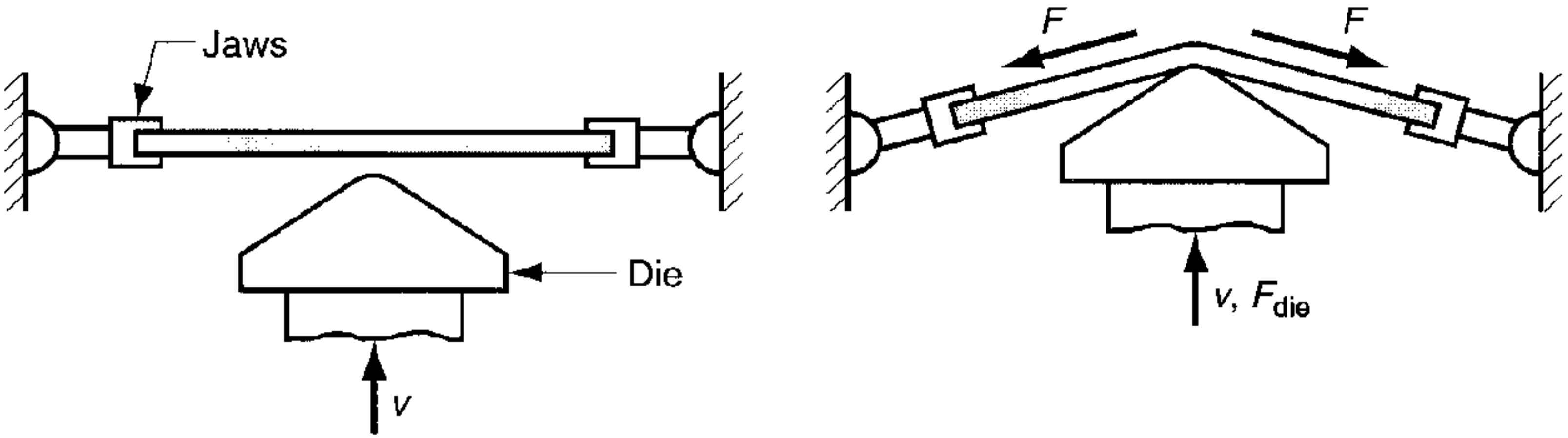
(a)



(b)

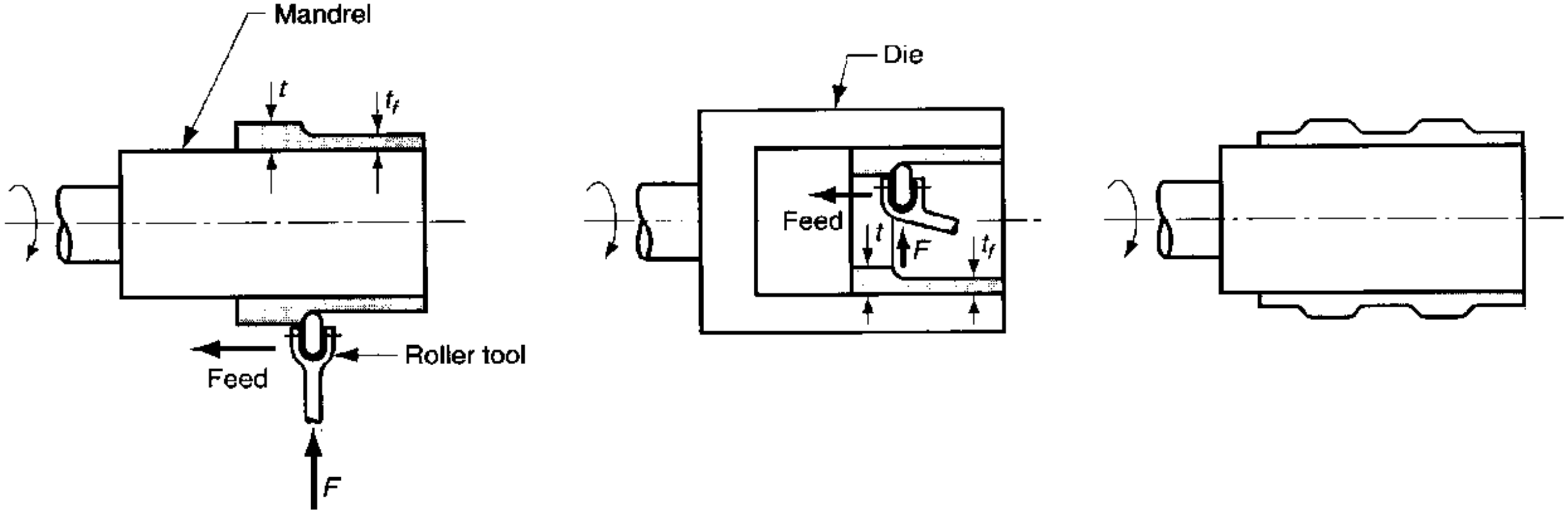
Progressive dies and final part

Stretch Forming



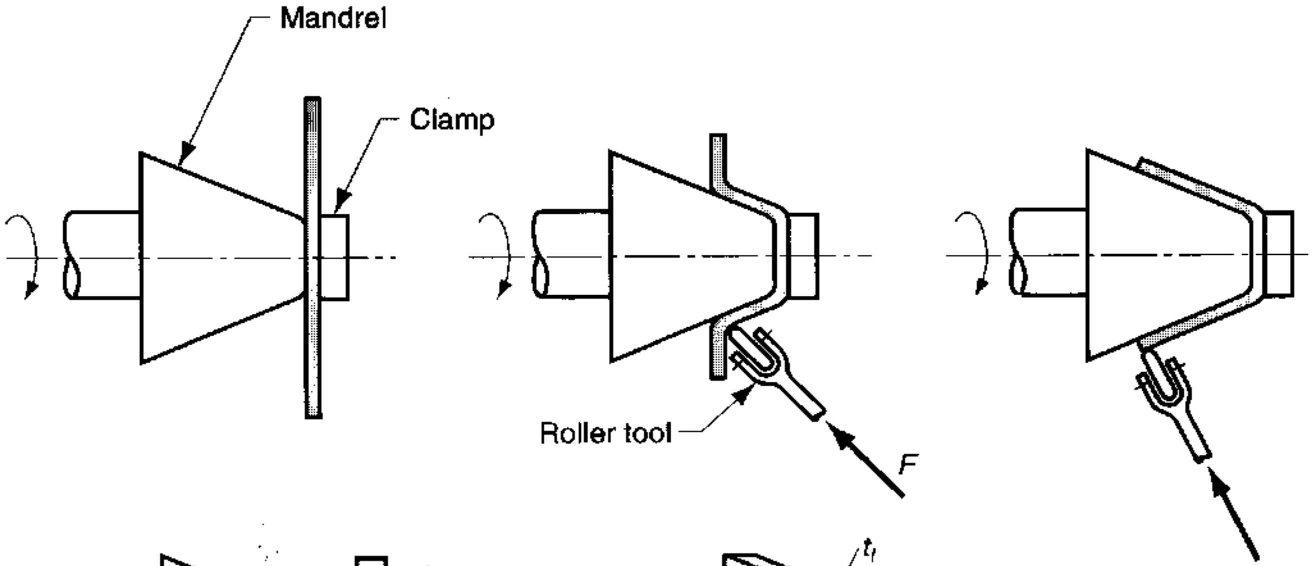
Stretching and forming with a die at the same time.

Spinning

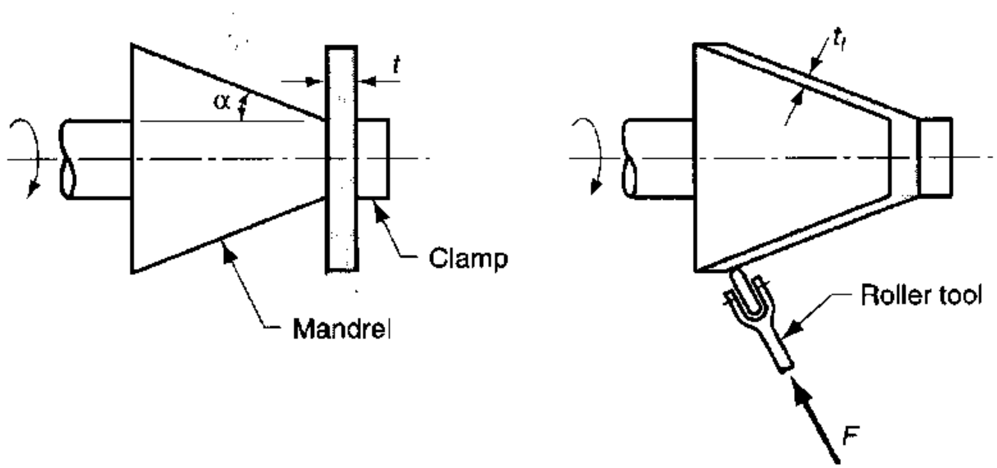


Tube spinning - similar to shear spinning but working on a tube.

Spinning



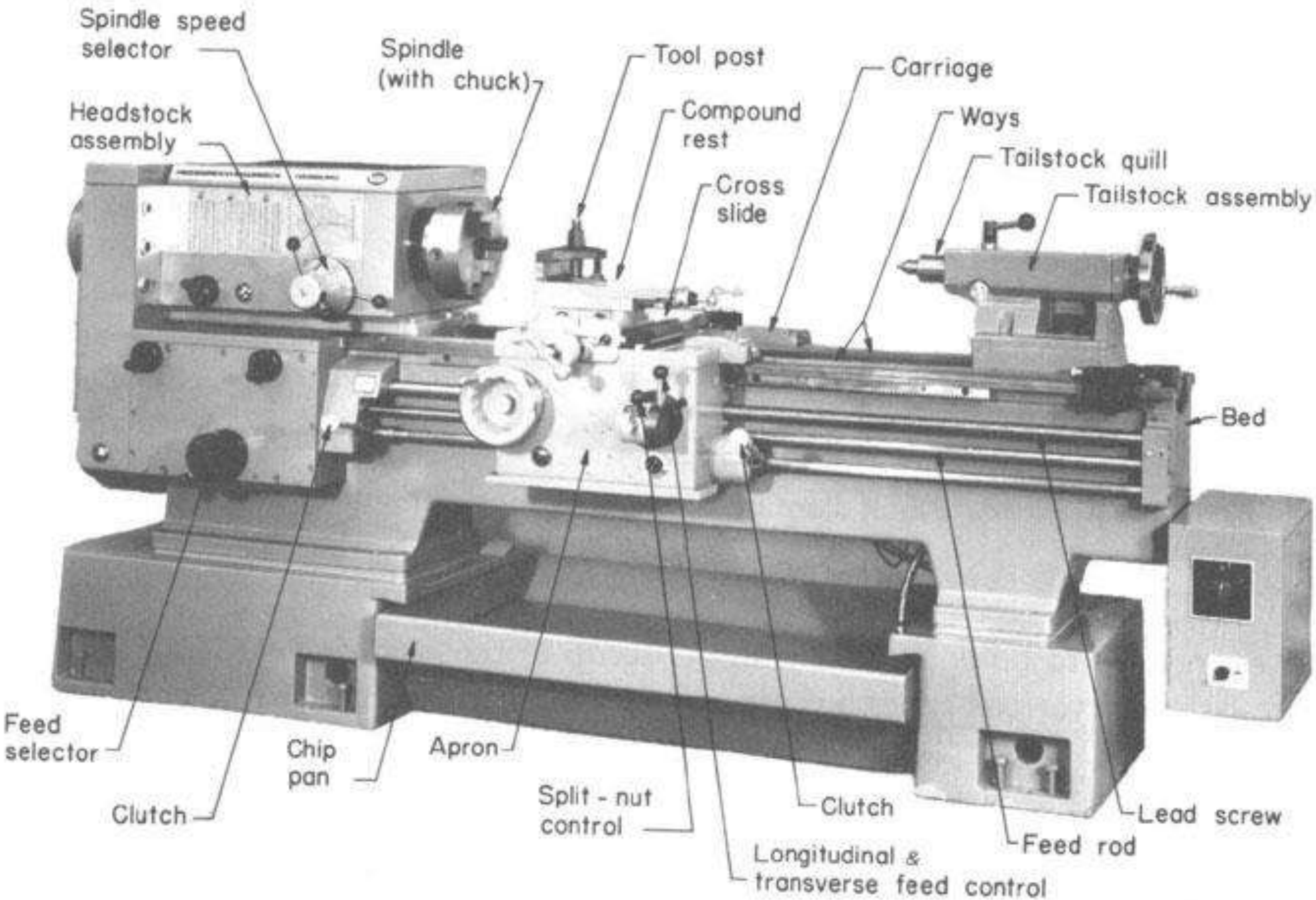
Conventional spinning



Shear spinning - thinning and bending occur at the same time.

Unit-IV

CONVENTIONAL AND UNCONVENTIONAL MACHINING PROCESSES


Spindle speed selector
Spindle (with chuck)
Tool post
Carriage
Headstock assembly
Compound rest
Ways
Tailstock quill
Cross slide
Tailstock assembly
Bed
Feed selector
Chip pan
Apron
Clutch
Split - nut control
Clutch
Lead screw
Feed rod
Longitudinal & transverse feed control

- **Bed:** Usually made of cast iron. Provides a heavy rigid frame on which all the main components are mounted.
- **Ways**: Inner and outer guide rails that are precision machined parallel to assure accuracy of movement.
- **Headstock:** mounted in a fixed position on the inner ways, usually at the left end. Using a chuck, it rotates the work.
- **Gearbox:** inside the headstock, providing multiple speeds with a geometric ratio by moving levers.
- **Spindle**: Hole through the headstock to which bar stock can be fed, which allows shafts that are up to 2 times the length between lathe centers to be worked on one end at a time.
- **Chuck**: 3-jaw (self centering) or 4-jaw (independent) to clamp part being machined.
- Chuck: allows the mounting of difficult work pieces that are not round, square or triangular.
- **Tailstock**: Fits on the inner ways of the bed and can slide towards any position the headstock to fit the length of the work piece. An optional taper turning attachment would be mounted to it.
- **Tailstock Quill**: Has a Morse taper to hold a lathe center, drill bit or other tool.
- **Carriage**: Moves on the outer ways. Used for mounting and moving most the cutting tools.
- **Cross Slide**: Mounted on the traverse slide of the carriage, and uses a hand wheel to feed tools into the work piece.

- **Compound Rest**: Mounted to the cross slide, it pivots around the tool post.
- Tool Post: To mount tool holders in which the cutting bits are clamped.
- **Apron**: Attached to the front of the carriage, it has the mechanism and controls for moving the carriage and cross slide.
- **Feed Rod:** Has a keyway, with two reversing pinion gears, either of which can be meshed with the mating bevel gear to forward or reverse the carriage using a clutch.
- **Lead Screw**: For cutting threads.
- **Split Nut**: When closed around the lead screw, the carriage is driven along by direct drive without using a clutch.
- **Quick Change Gearbox:** Controls the movement of the carriage using levers.
- **Steady Rest**: Clamped to the lathe ways, it uses adjustable fingers to contact the work piece and align it. Can be used in place of tailstock or in the middle to support long or unstable parts being machined.
- **Follow Rest**: Bolted to the lathe carriage, it uses adjustable fingers to bear against the work piece opposite the cutting tool to prevent deflection.

SPEED LATHE


BENCH LATHE

TURRET LATHE

WHEEL LATHE SPECIAL PURPOSE LATHE


T LATHE

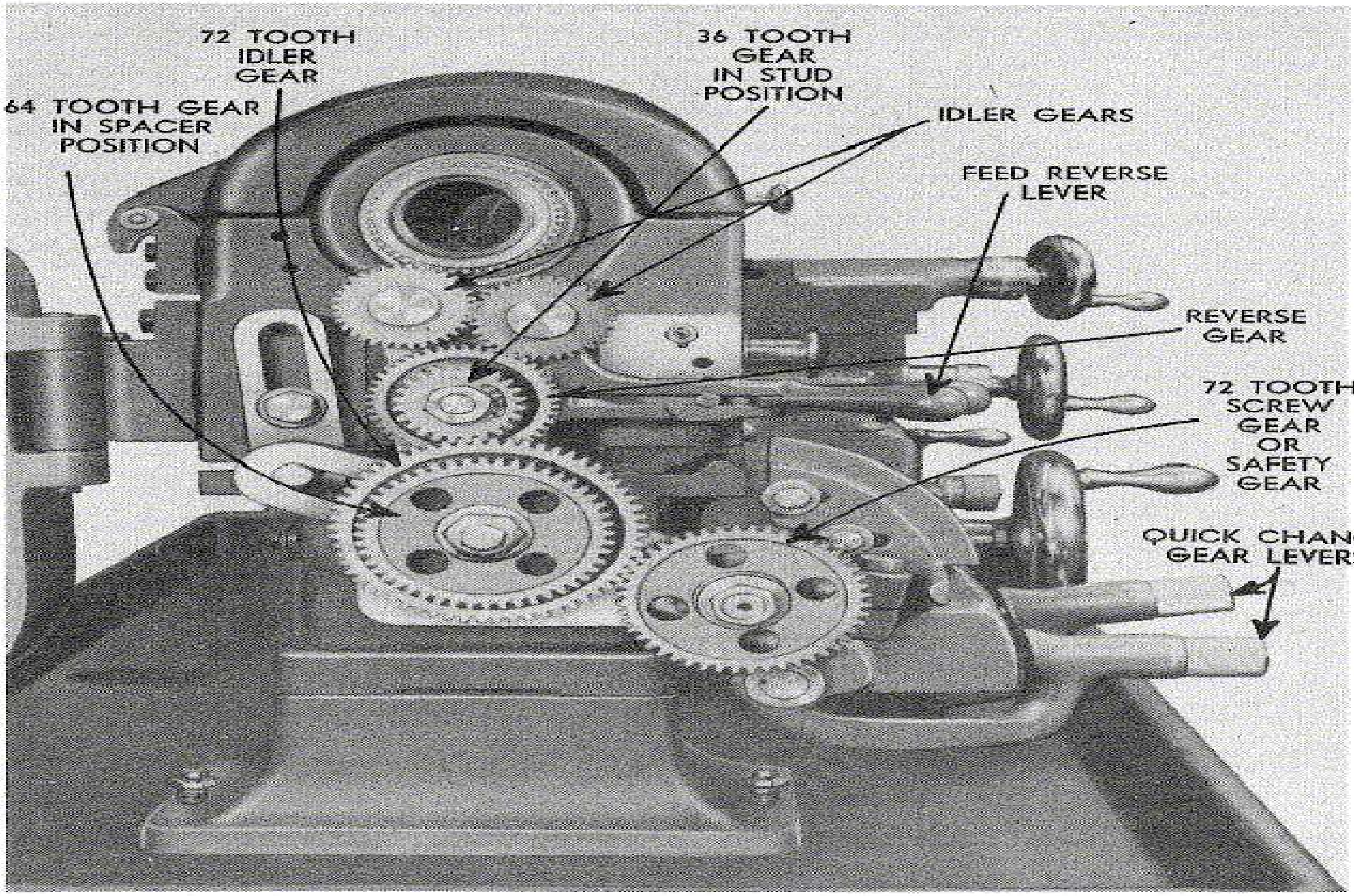
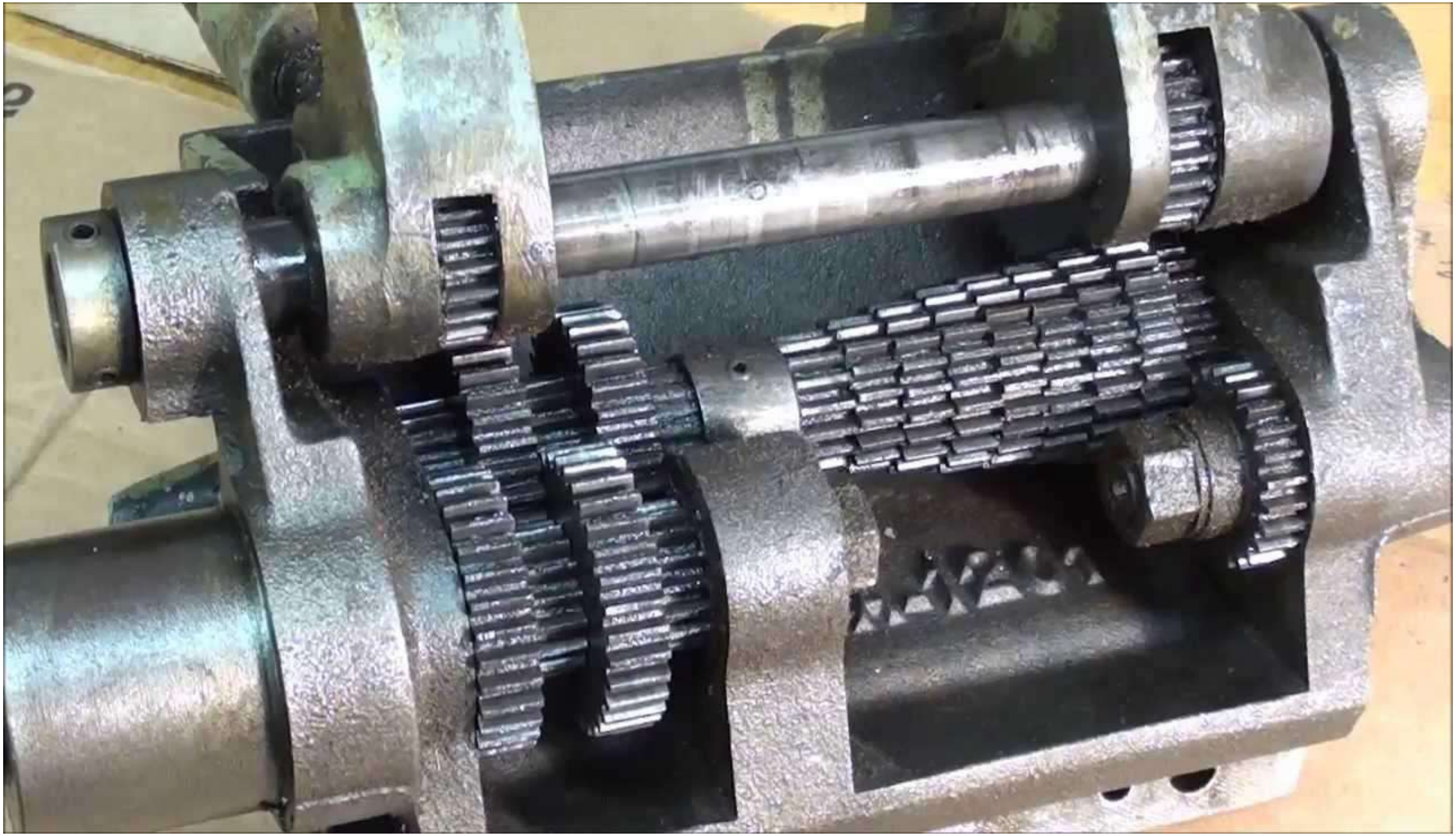
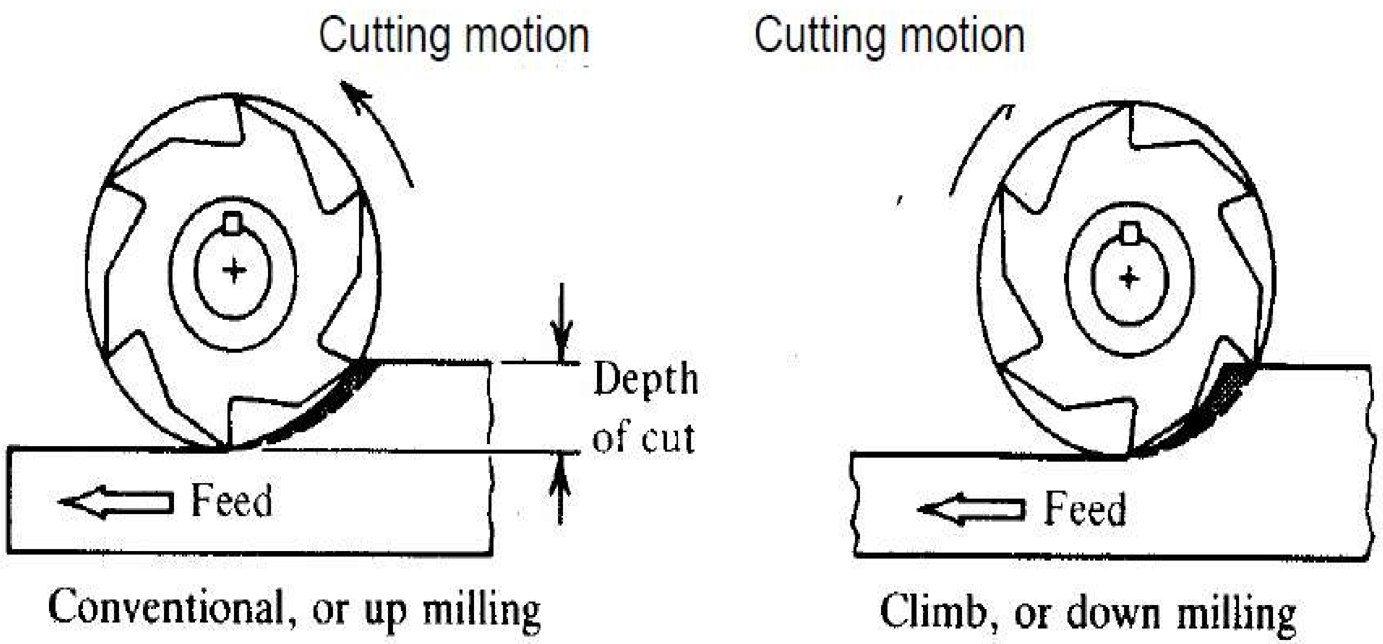
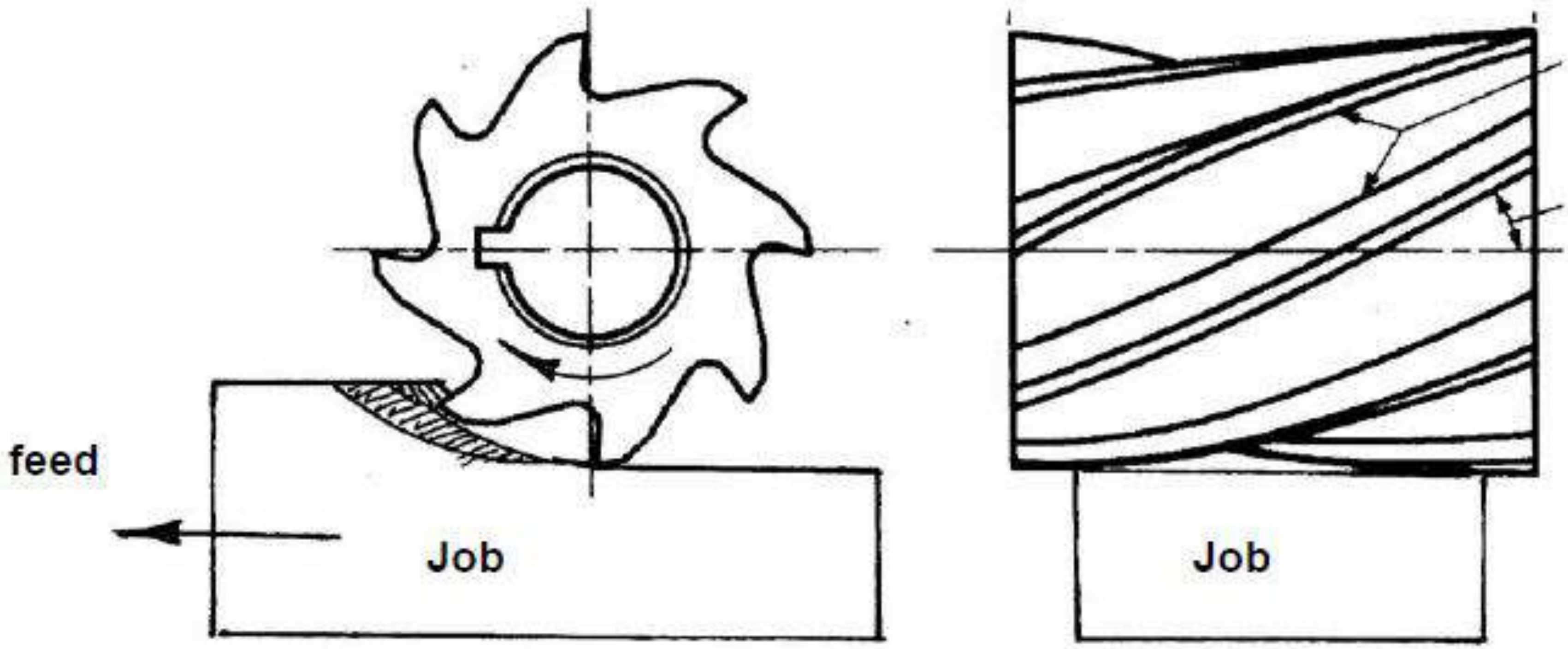


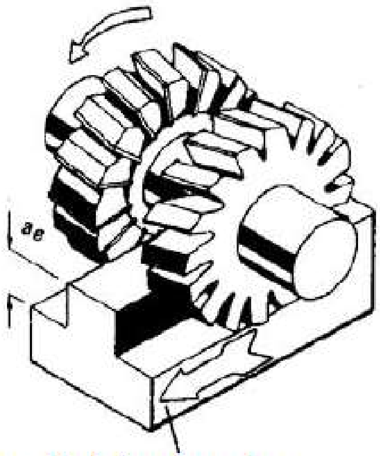
FIGURE 8—CHANGE GEAR TRAIN ON LOGAN QUICK CHANGE GEAR LATHE



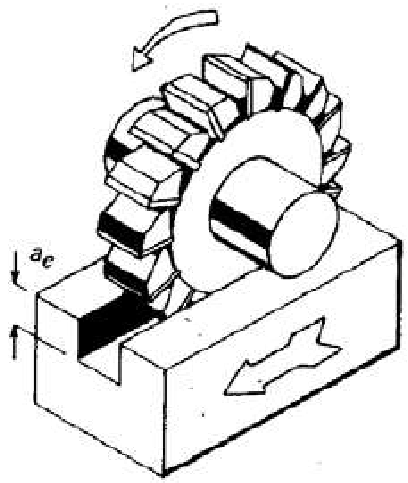
The basic function of milling machines is to produce flat surfaces in any orientation as well as surfaces of revolution, helical surfaces and contoured surfaces of various configurations. Such functions are accomplished by slowly feeding the work piece into the equispaced multi edge circular cutting tool rotating at moderately high speed


Cutting motion
Cutting motion
Depth
of cut
Feed
Feed
Conventional, or up milling
Climb, or down milling

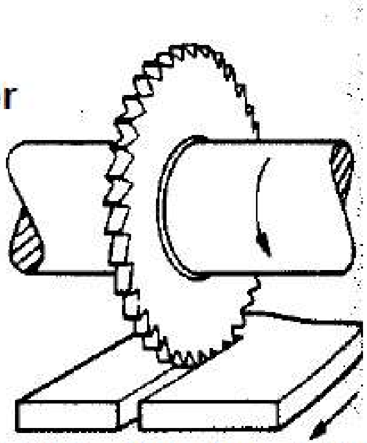

feed
Job
Job



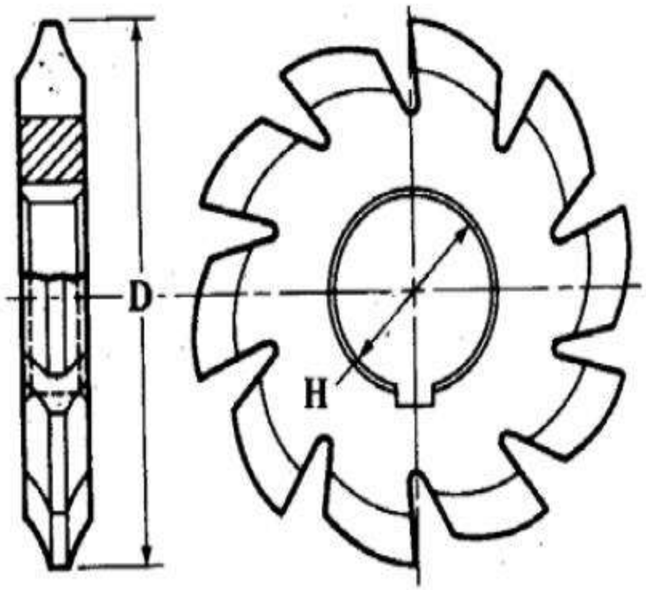
(a) parallel facing by
two side (single) cutter

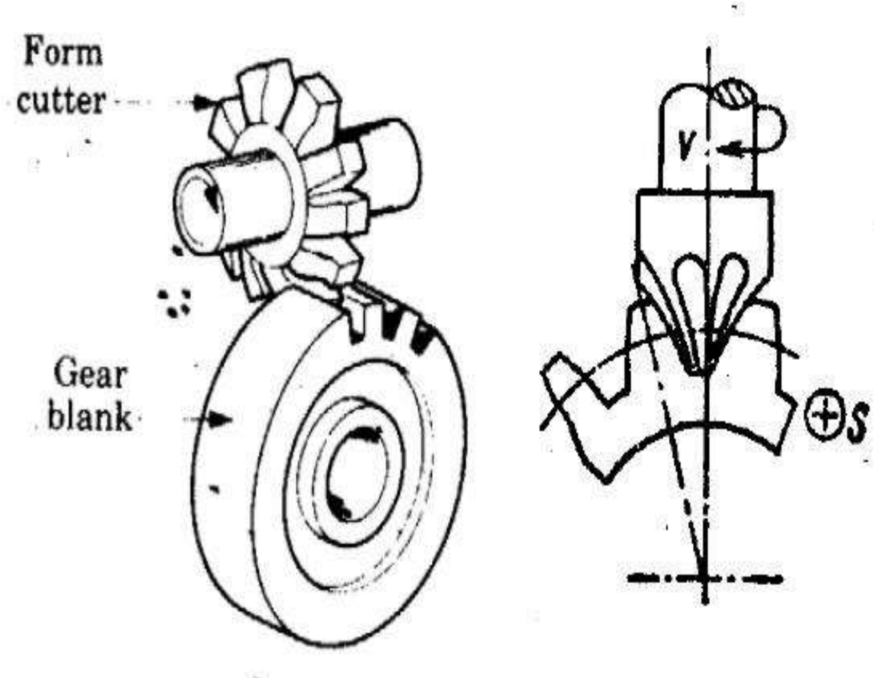


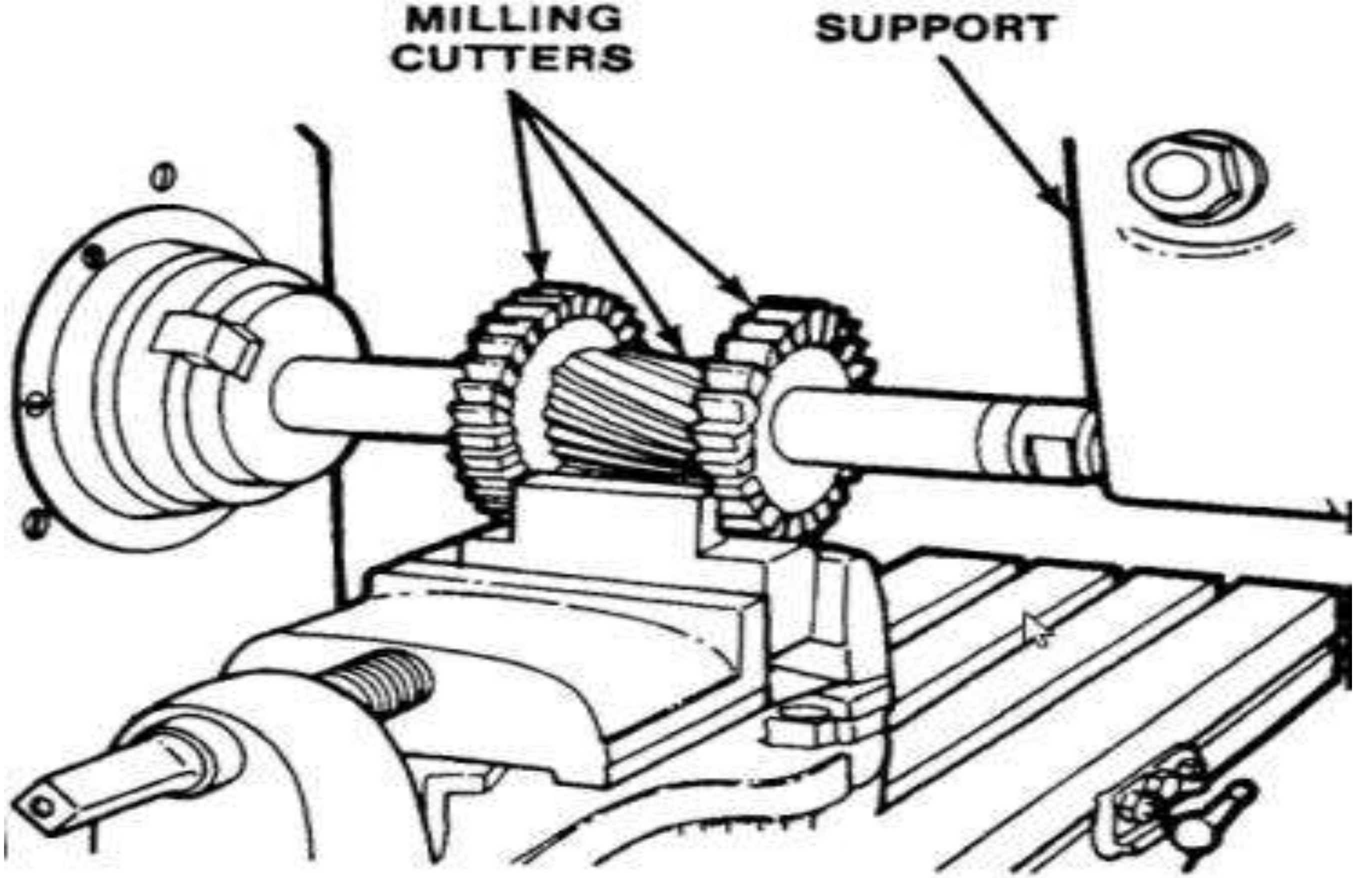
(b) slotting by side (double sided)
milling cutter

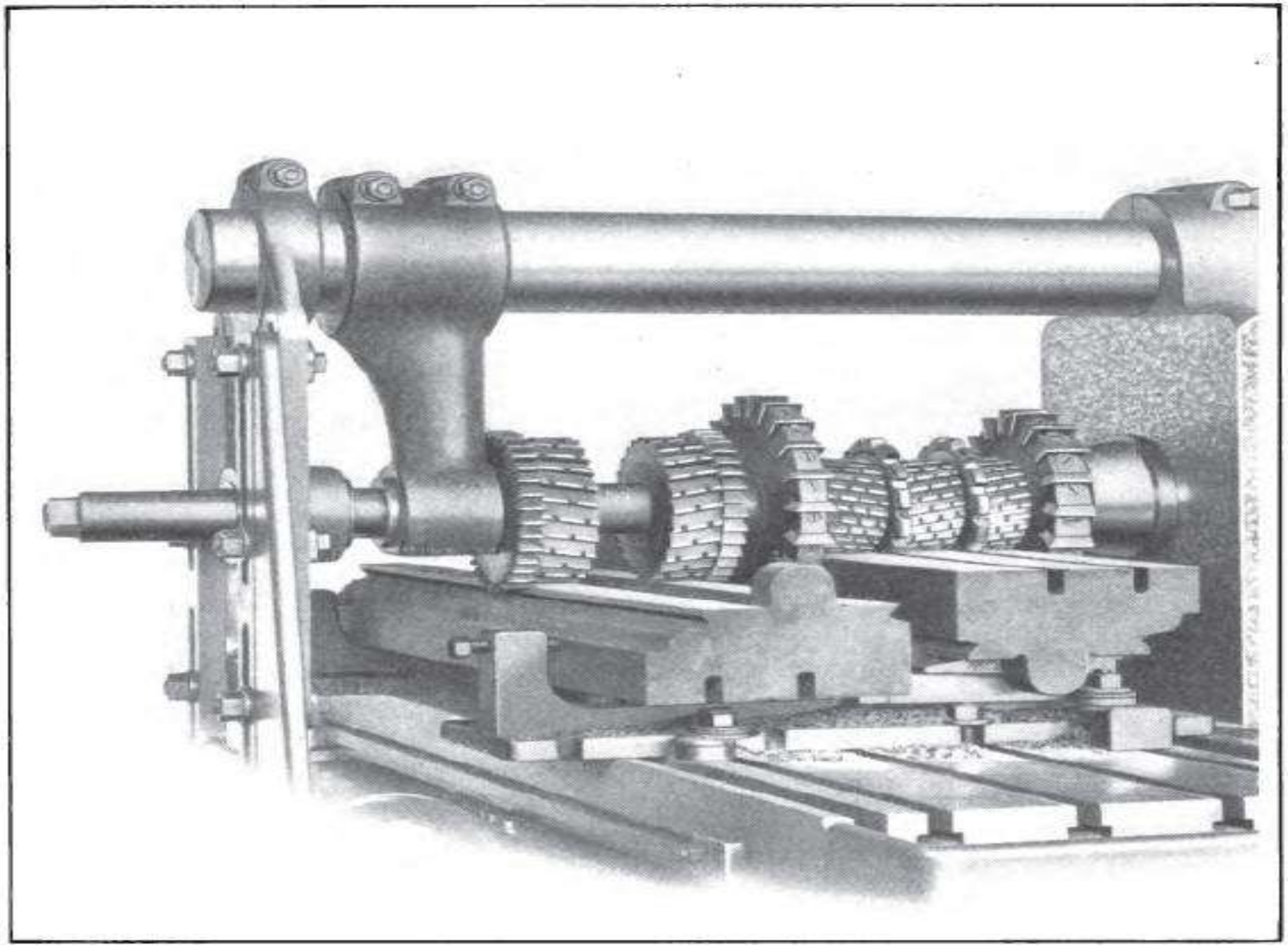


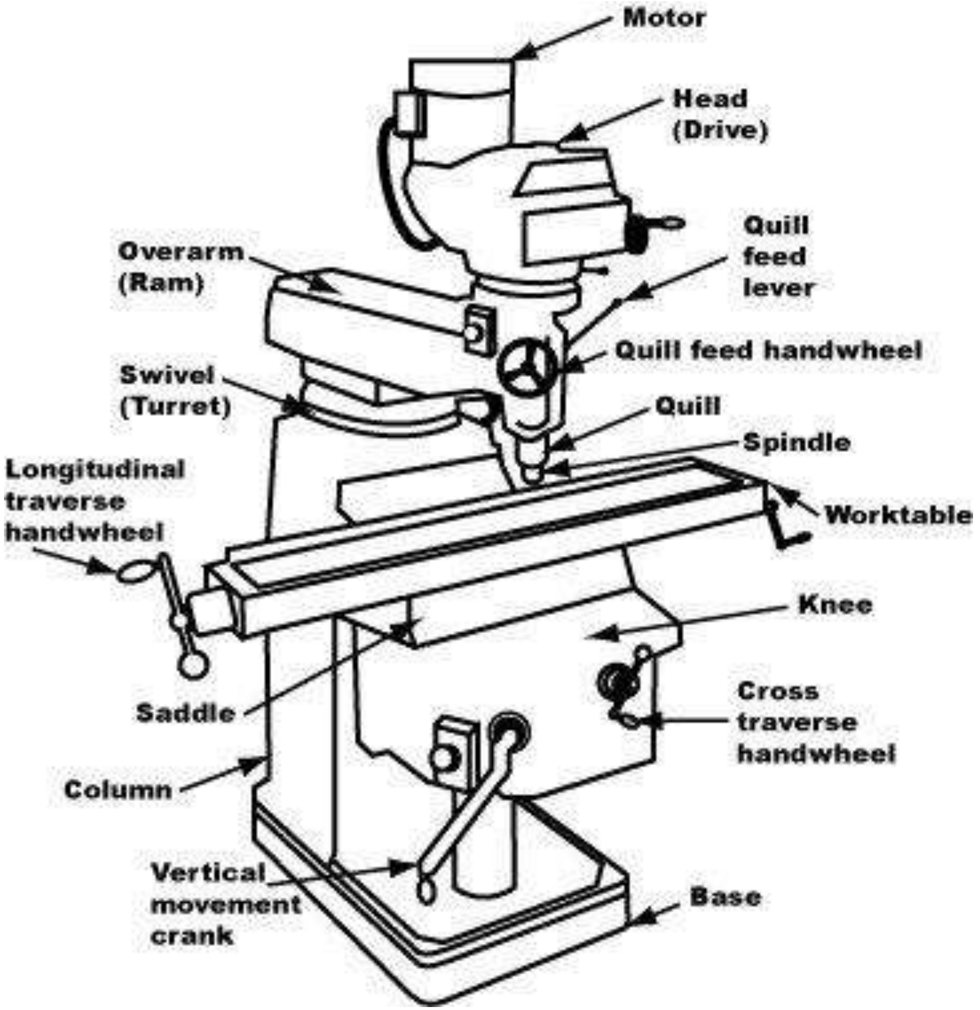
(c) Parting by slitting saw


D
H


Form
cutter
Gear
blank
V
S


MILLING
CUTTERS
SUPPORT




Motor
Head
(Drive)
Quill
feed
lever
Overarm
(Ram)
Quill feed handwheel
Swivel
(Turret)
Quill
Spindle
Longitudinal
traverse
handwheel
Worktable
Knee
Cross
traverse
handwheel
Saddle
Column
Vertical
movement
crank
Base

Sheet metal forming processes

Sheet metal processes can be broken down into two major classifications and one minor classification

•**Shearing processes**

processes which apply shearing forces to cut, fracture, or separate the material.

•**Forming processes**

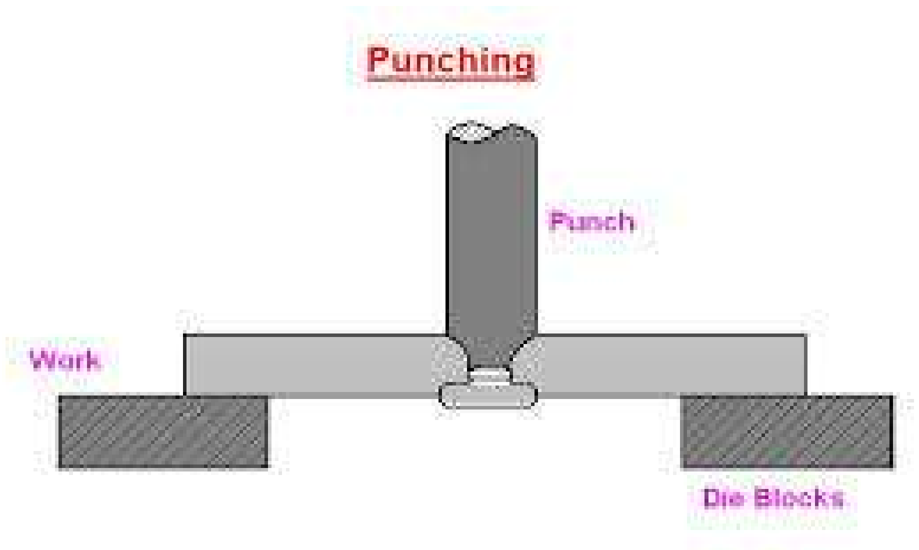
processes which cause the metal to undergo desired shape changes without failure, excessive thinning, or cracking. This includes bending and stretching.

•**Finishing processes**

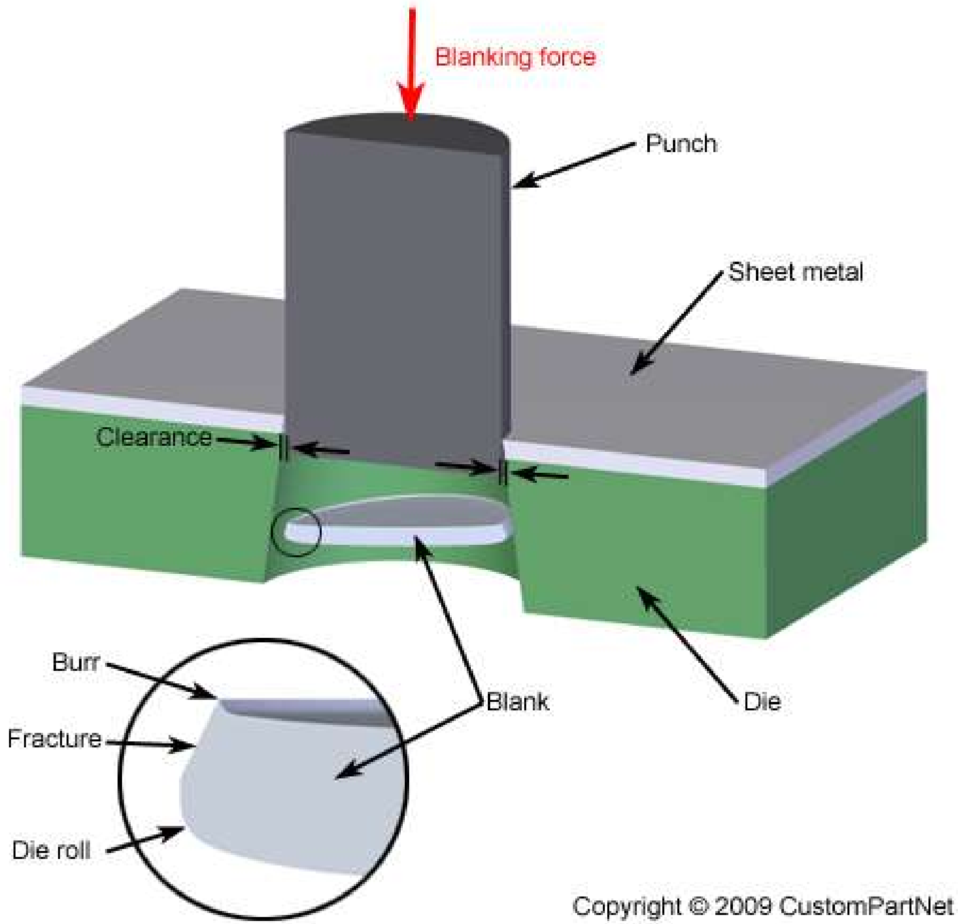
processes which are used to improve the final surface characteristics.

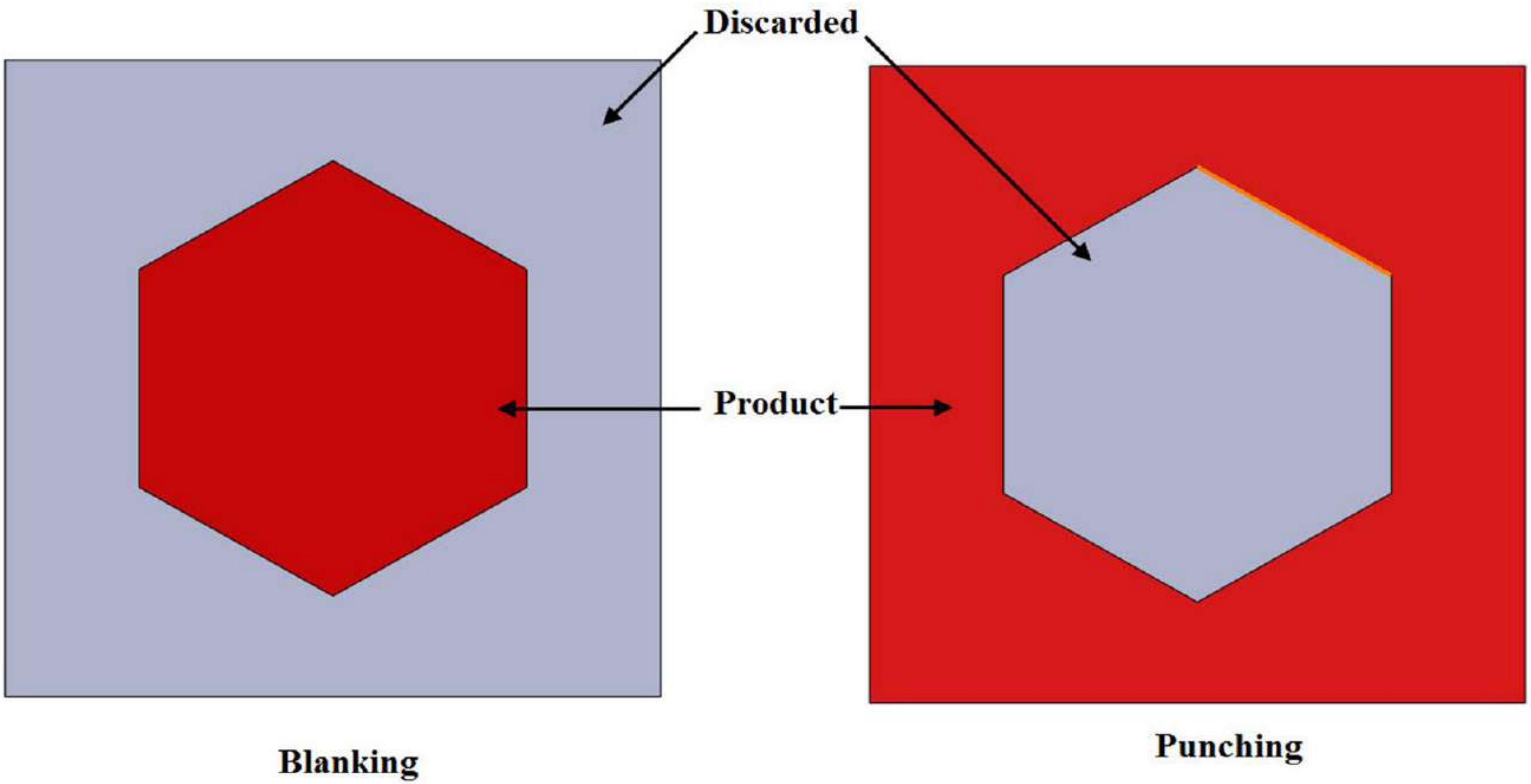
Shearing Process

1. Punching: shearing process using a die and punch where the interior portion of the sheared sheet is to be discarded.

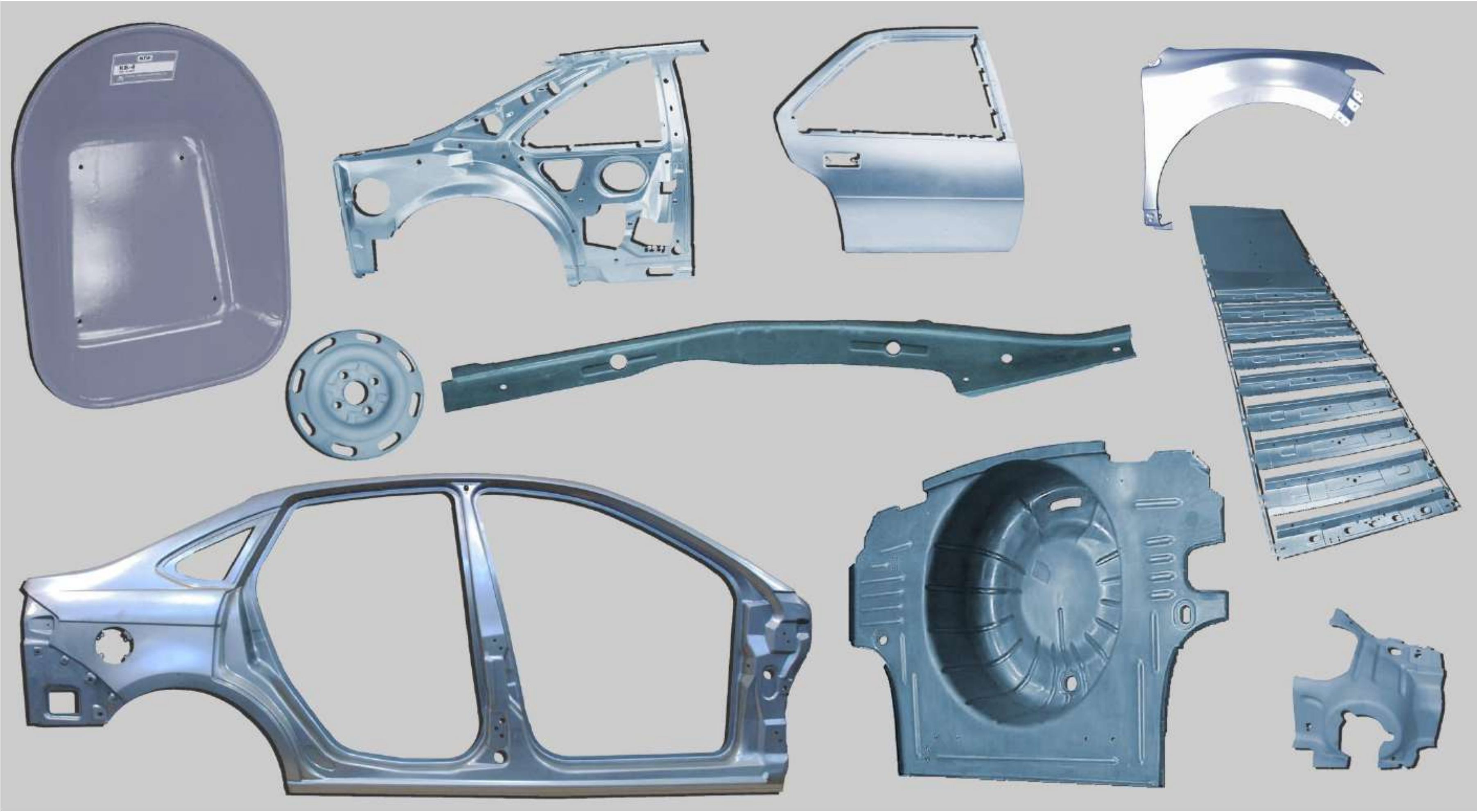


Blanking:
shearing process using a die and punch where the exterior portion of the shearing operation is to be discarded


Blanking force
Punch
Sheet metal
Clearance
Burr
Fracture
Die roll
Blank
Die
Copyright © 2009 CustomPartNet

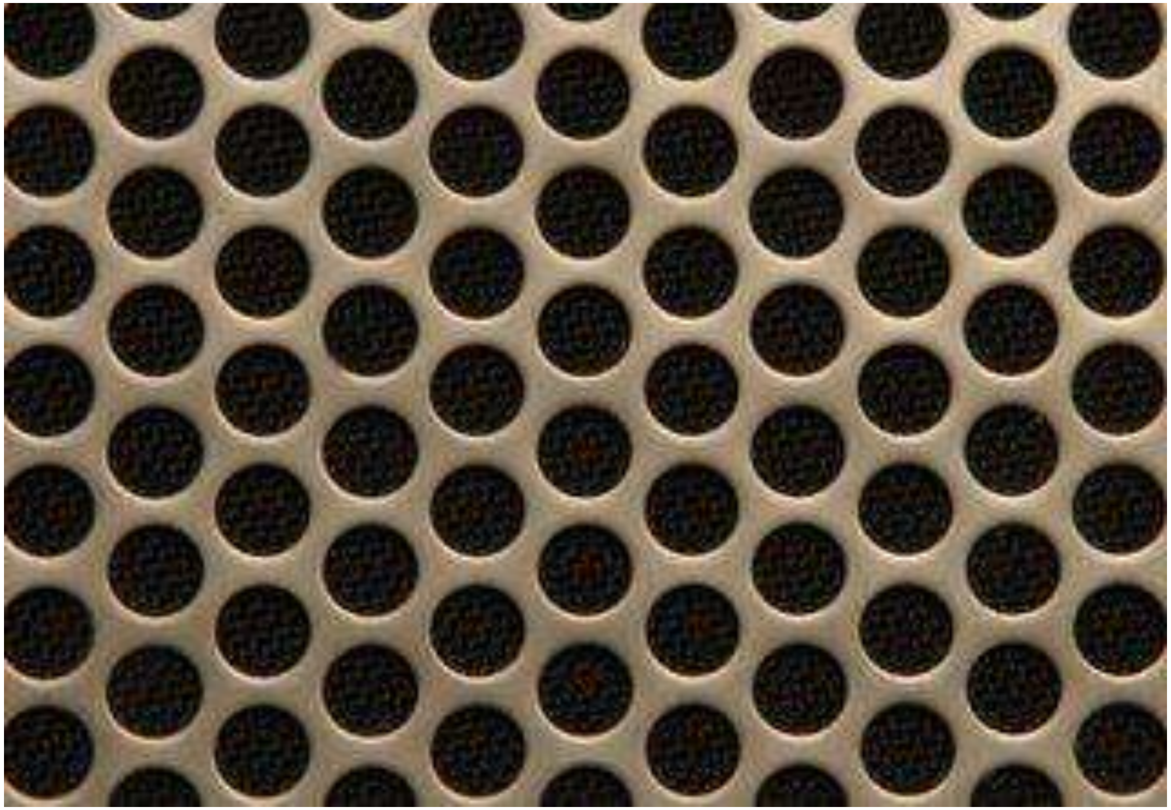


Discarded
Product
Blanking
Punching



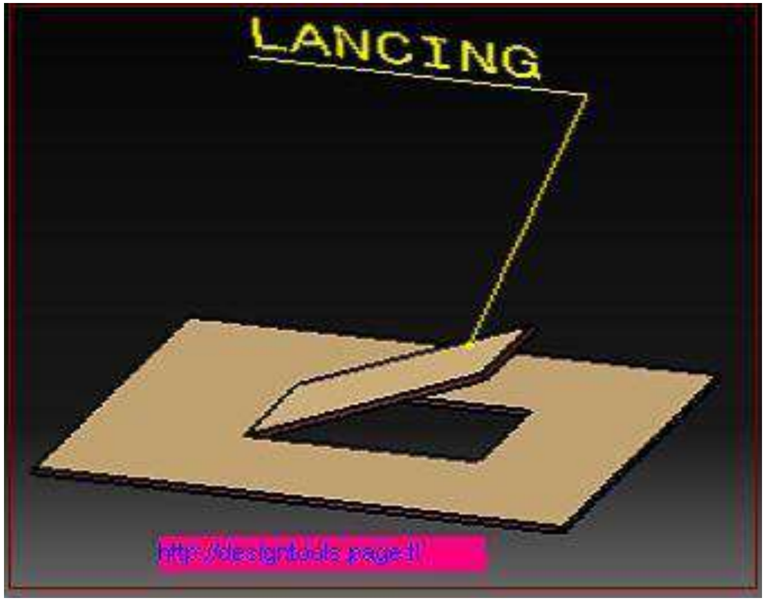
Components made with blanking and punching

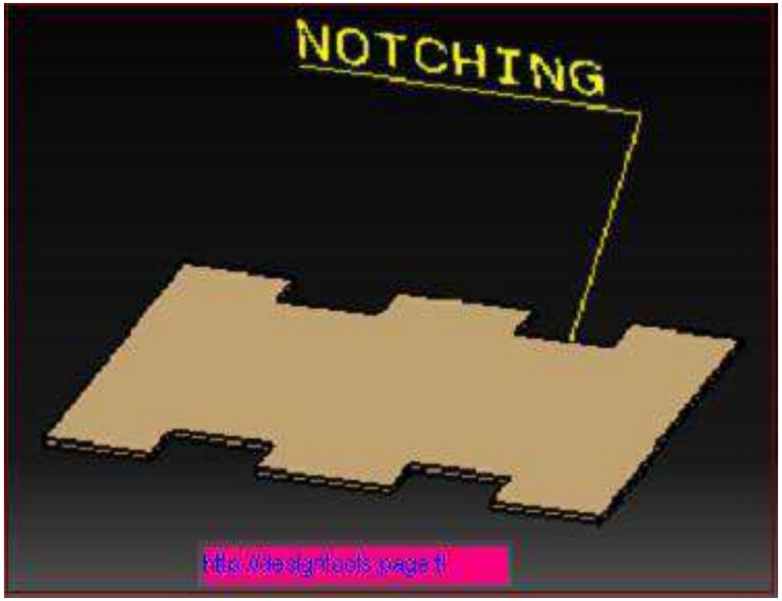
Perforating:
punching a number of holes in a sheet



Parting: shearing the sheet into two or more pieces

Notching: removing pieces from the edges
Lancing : leaving a tab without removing any material

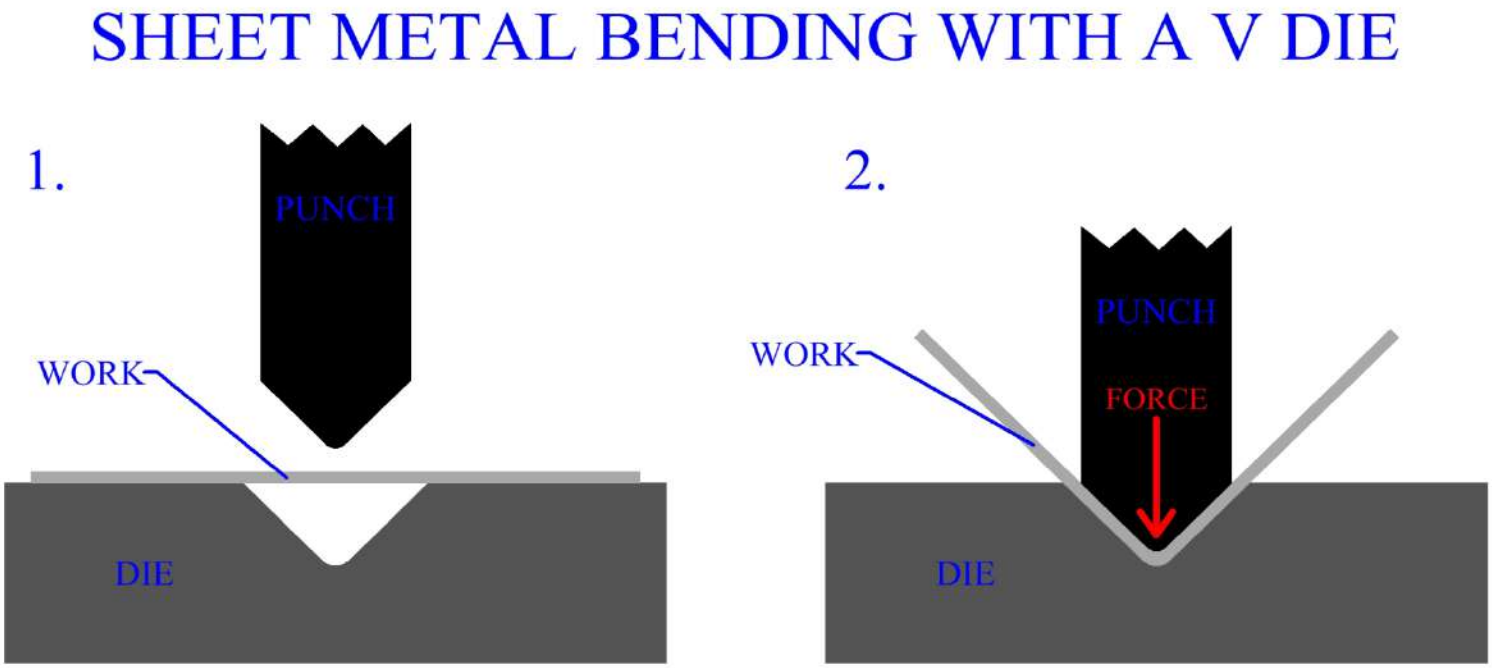




Forming Processes

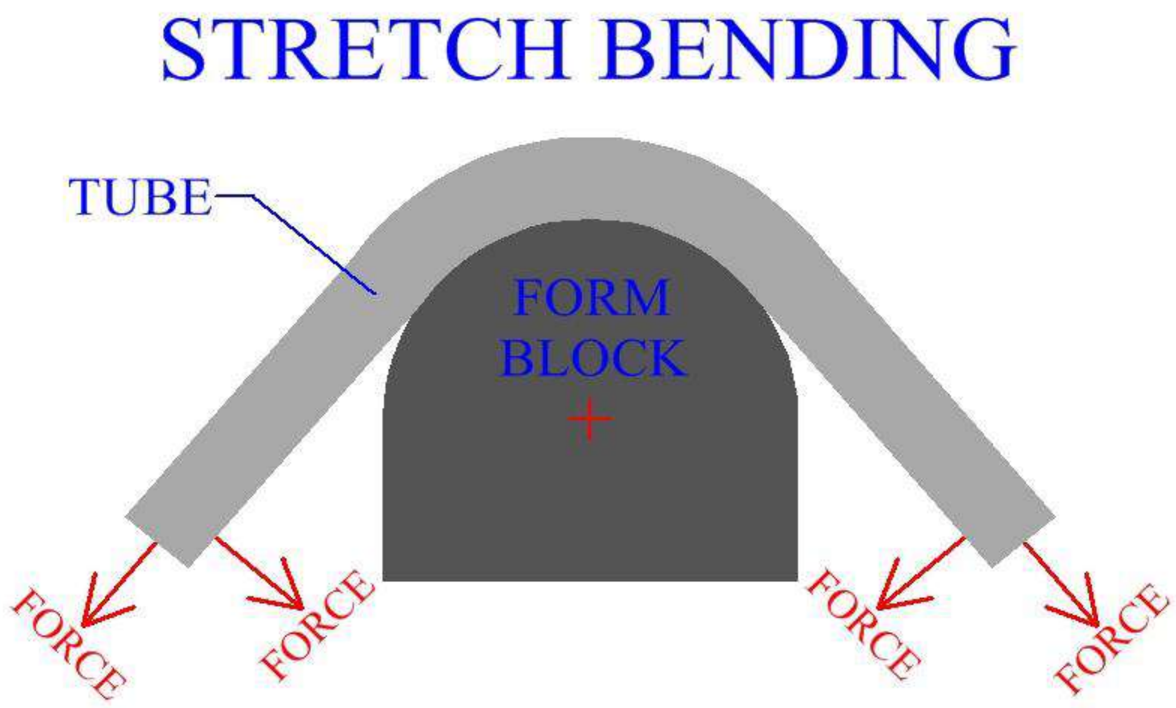
Bending

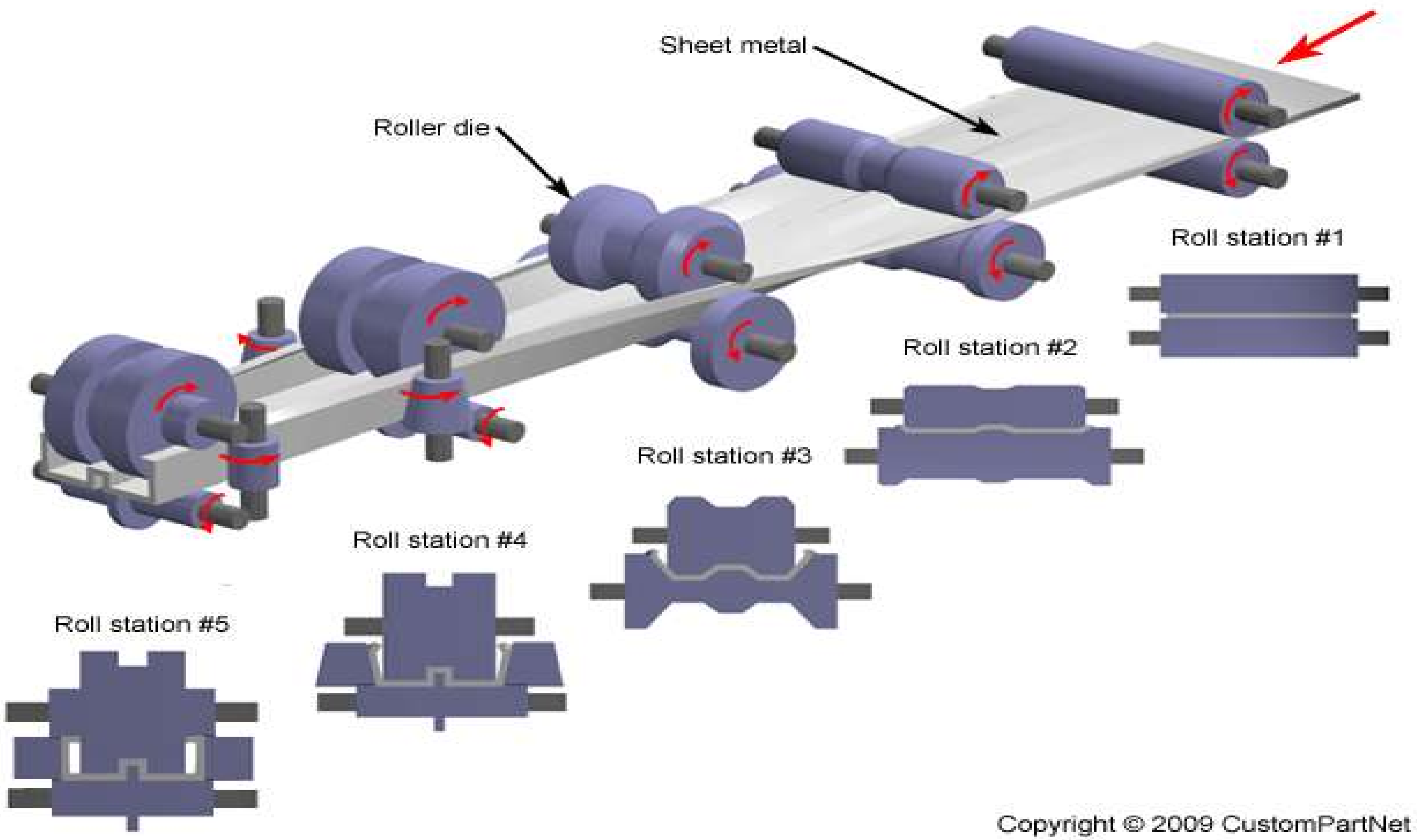
forming process causes the sheet metal to undergo the desired shape change by bending without failure.

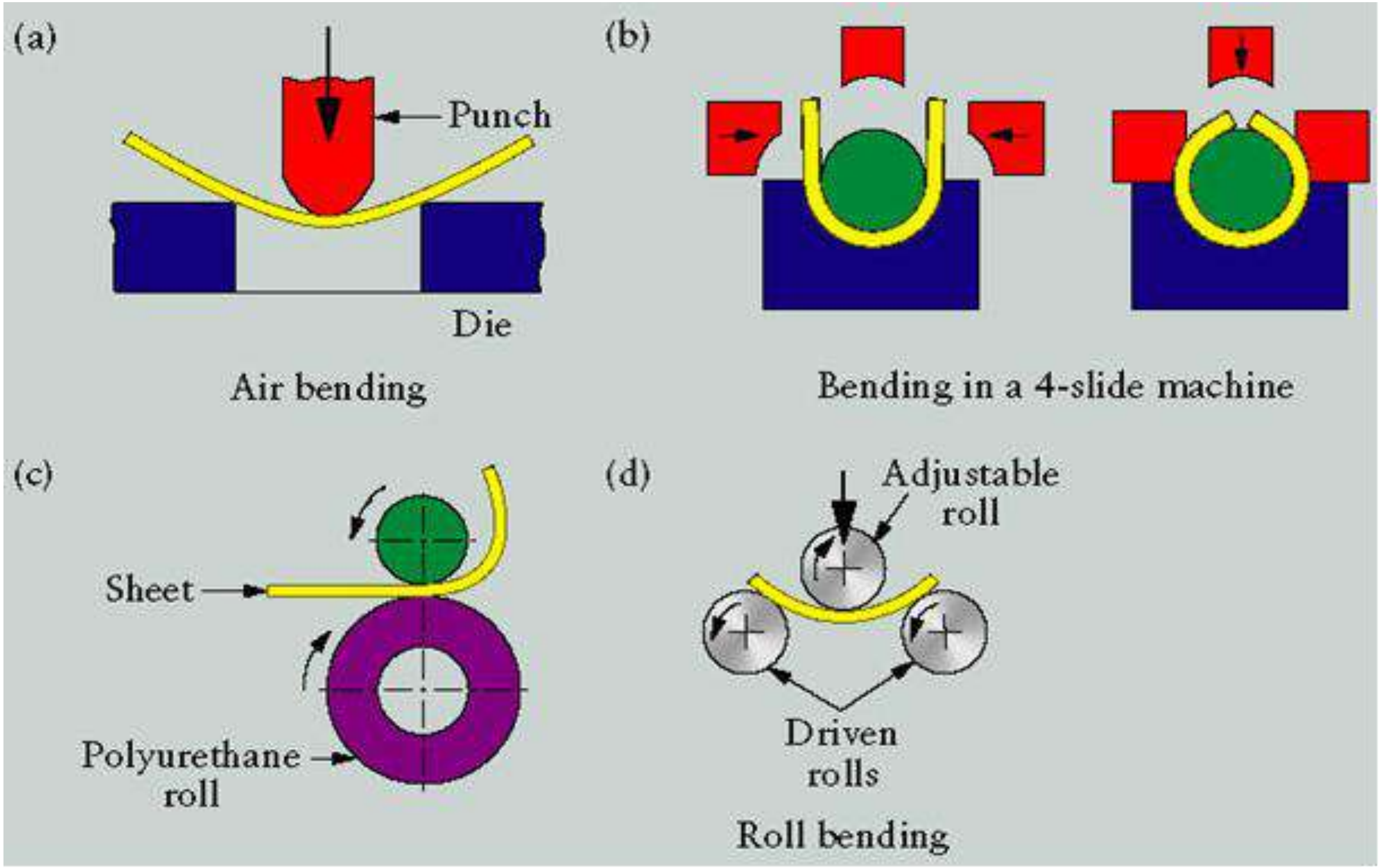


Stretching

forming process causes the sheet metal to undergo the desired shape change by stretching without failure




Sheet metal
Roller die
Roll station #1
Roll station #2
Roll station #3
Roll station #4
Roll station #5
Copyright © 2009 CustomPartNet


(a)
Punch
Die
Air bending
(b)
Bending in a 4-slide machine
(c)
Sheet
Polyurethane roll
(d)
Adjustable roll
Driven rolls
Roll bending

The requirements that lead to the development of nontraditional machining

- Very high hardness and strength of the material. (above 400 HB.)
- The work piece is too flexible or slender to support the cutting or grinding forces.
- The shape of the part is complex, such as internal and external profiles, or small diameter holes.
- Surface finish or tolerance better than those obtainable conventional process.
- Temperature rise or residual stress in the work piece are undesirable.

Conventional Machining VS NonConventional Machining

- The cutting tool and workpiece are always in physical contact, with a relative motion against each other, which results in friction and a significant *tool wear*.

- In non-traditional processes, there is no physical contact between the tool and workpiece. Although in some non-traditional processes tool wear exists, it rarely is a significant problem.

- Material removal rate of the traditional processes is limited by the mechanical properties of the work material. Non-traditional processes easily deal with such difficult-to-cut materials like ceramics and ceramic based tool materials, fiber reinforced materials, carbides, titanium-based alloys.

Continue…

- In traditional processes, the relative motion between the tool and work piece is typically rotary or reciprocating. Thus, the shape of the work surfaces is limited to circular or flat shapes. In spite of widely used CNC systems, machining of three-dimensional surfaces is still a difficult task. Most non-traditional processes were develop just to solve this problem.

- Machining of small cavities, slits, blind or through holes is difficult with traditional processes, whereas it is a simple work for some non-traditional processes.

- Traditional processes are well established, use relatively simple and inexpensive machinery and readily available cutting tools. Non-traditional processes require expensive equipment and tooling as well as skilled labor, which increases significantly the production cost.

Classification OF Processes

- Mechanical Metal removal Processes
- It is characterized by the fact that the material removal is due to the application of mechanical energy in the form of high frequency vibrations or kinetic energy of an abrasive jet.

- 1. Ultra sonic Machining (USM).
  2. Abrasive Jet Machining (AJM).
  3. Water Jet Machining (WJM).

- Electro-Chemical
- It is based on electro-chemical dissolution of materials by an electrolyte under the influence of an externally applied electrical potential.

1. Electro-Chemical Machining (ECM).
2. ECG

3 ECD

- Thermal Method

The material is removed due to controlled, localized heating of the work piece. It result into material removal by melting and evaporation.

The source of heat generation in such cases can be widely different.

1.Electric Discharge Machining (EDM).

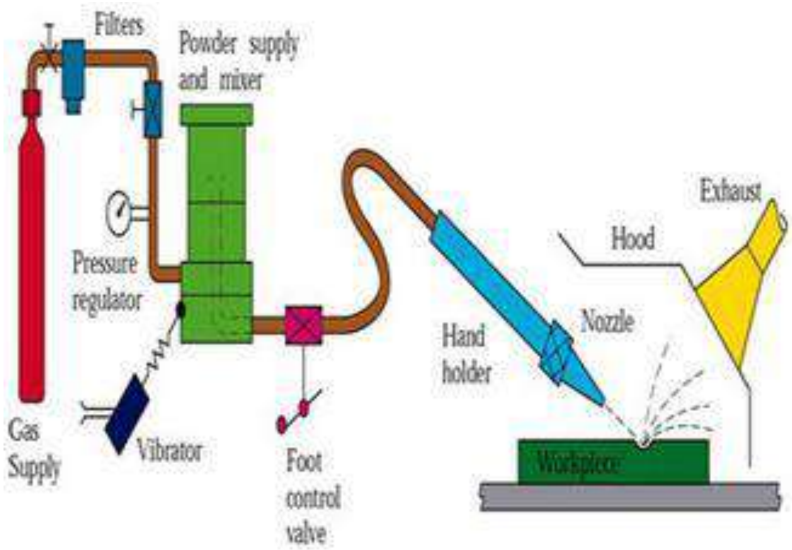
2. Plasma Arc Machining (PAM).

3. EBM 4. LBM

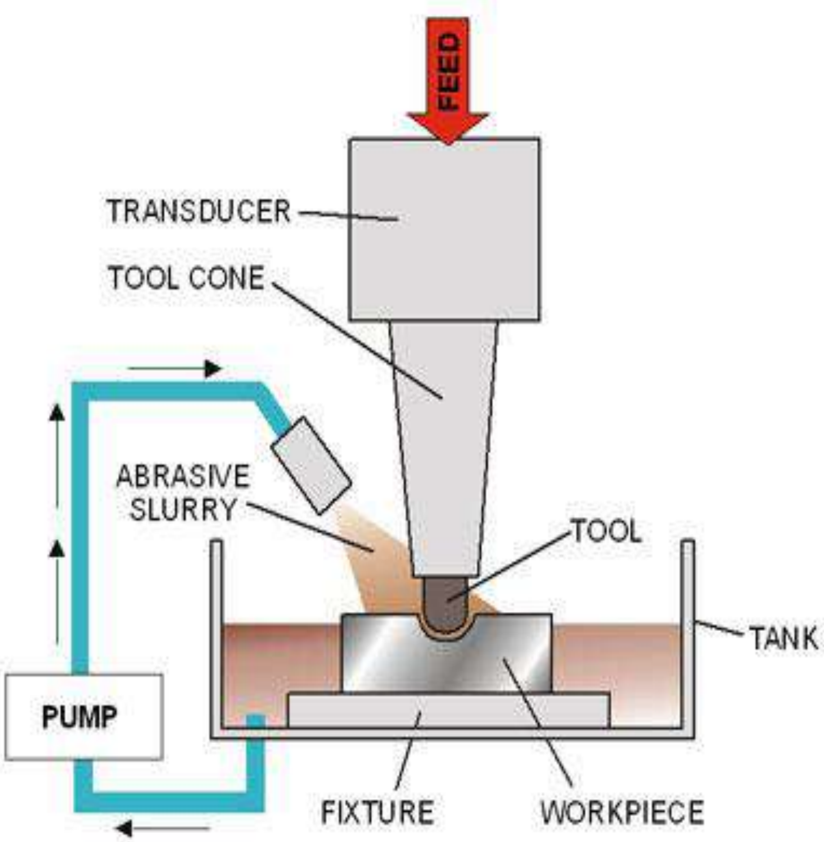
Abrasive Water-Jet Cutting

- A stream of fine grain abrasives mixed with air or suitable carrier gas, at high pressure, is directed by means of a nozzle on the work surface to be machined.
- The material removal is due to erosive action of a high pressure jet.
- AJM differ from the conventional sand blasting process in the way that the abrasive is much finer and effective control over the process parameters and cutting. Used mainly to cut hard and brittle materials, which are thin and sensitive to heat.

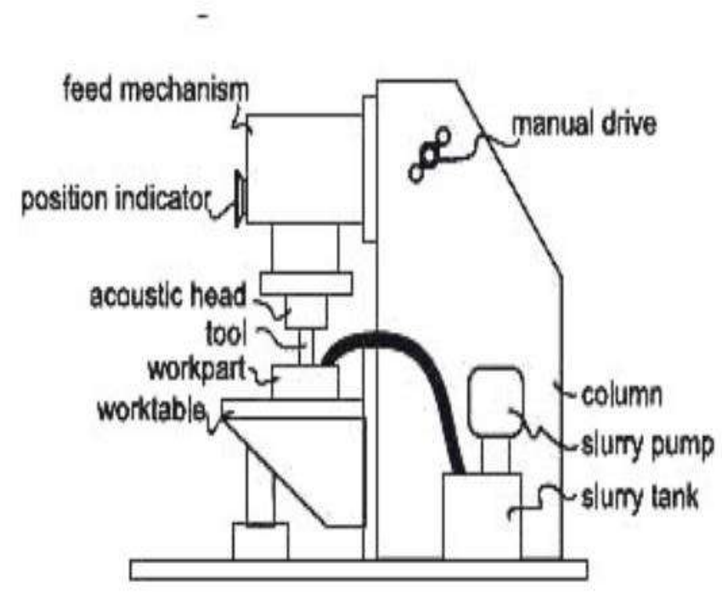
Abrasive Jet Machining Setup



Ultrasonic Machining (USM)



Ultrasonic Machine Parts



Principal components of an ultrasonic machine.

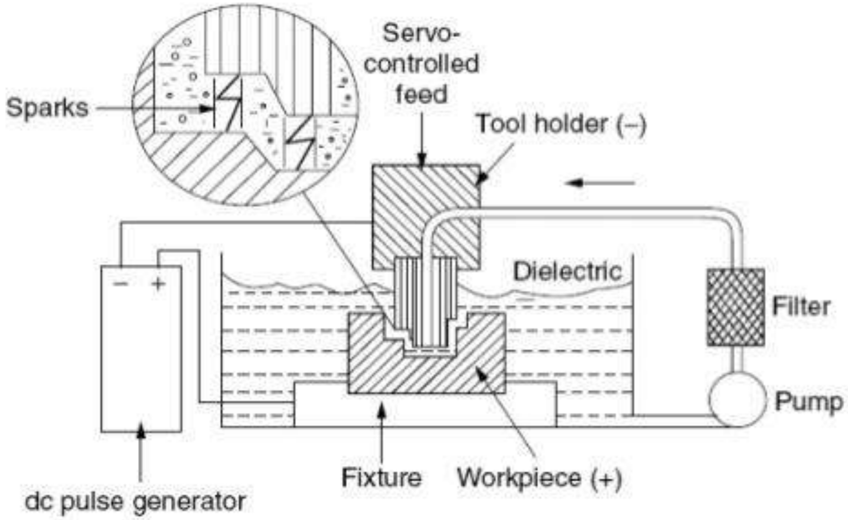
Ultrasonic Machining (USM)

- Ultrasonic machining (USM) is the removal of hard and brittle materials using an axially oscillating tool at ultrasonic frequencies [18–20 kHz]
- During that oscillation, the abrasive slurry of B_4C or SiC is continuously fed into the machining zone between a soft tool (brass or steel) and the workpiece.
- The abrasive particles are, therefore, hammered into the workpiece surface and cause chipping of fine particles from it.
- The oscillating tool, at amplitudes ranging from 10 to 40 µm, imposes a static pressure on the abrasive grains and feeds down as the material is removed to form the required tool shape.
- USM is characterized by the absence of any deleterious effect on the metallic structure of the workpiece material.

ELECTRICAL DISCHARGE MACHINING

- Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion.
- In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape.
- In the EDM process an electric spark is used to cut the workpiece, which takes the shape opposite to that of the cutting tool or electrode.
- Generally the workpiece is made positive and the tool negative. Hence, the electrons strike the job leading to crater formation due to high temperature and melting and material removal.

ELECTRICAL DISCHARGE MACHINING



Electro discharge machining (EDM) Diagram

Electric Discharge Machining (EDM)

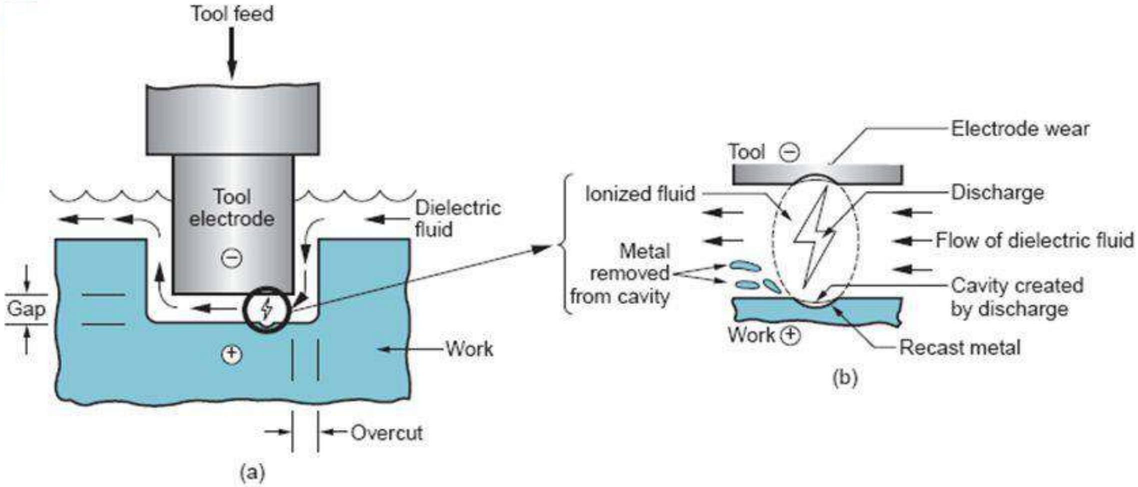
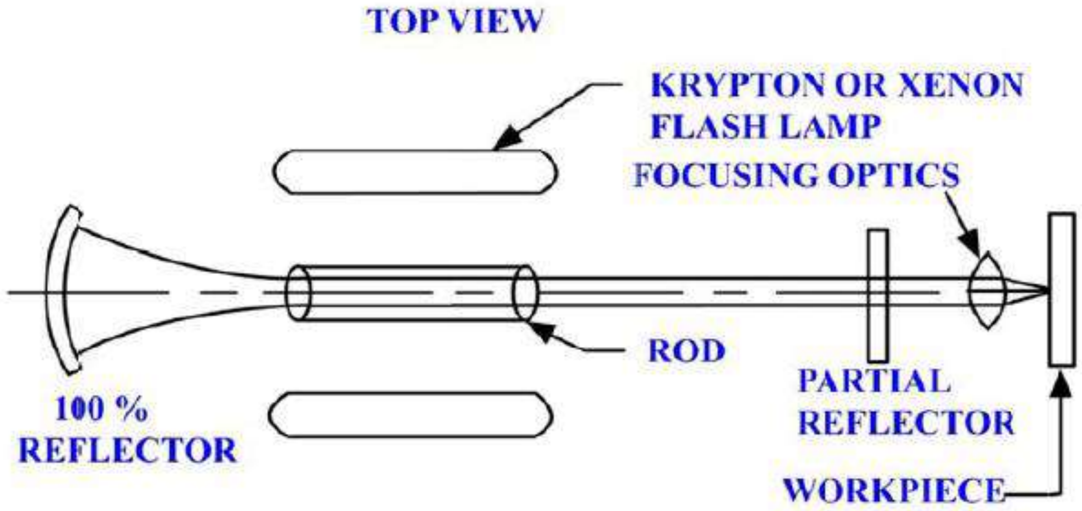


FIGURE 26.7
Electric discharge machining (EDM): (a) overall setup, and (b) close-up view of gap, showing discharge and metal removal.

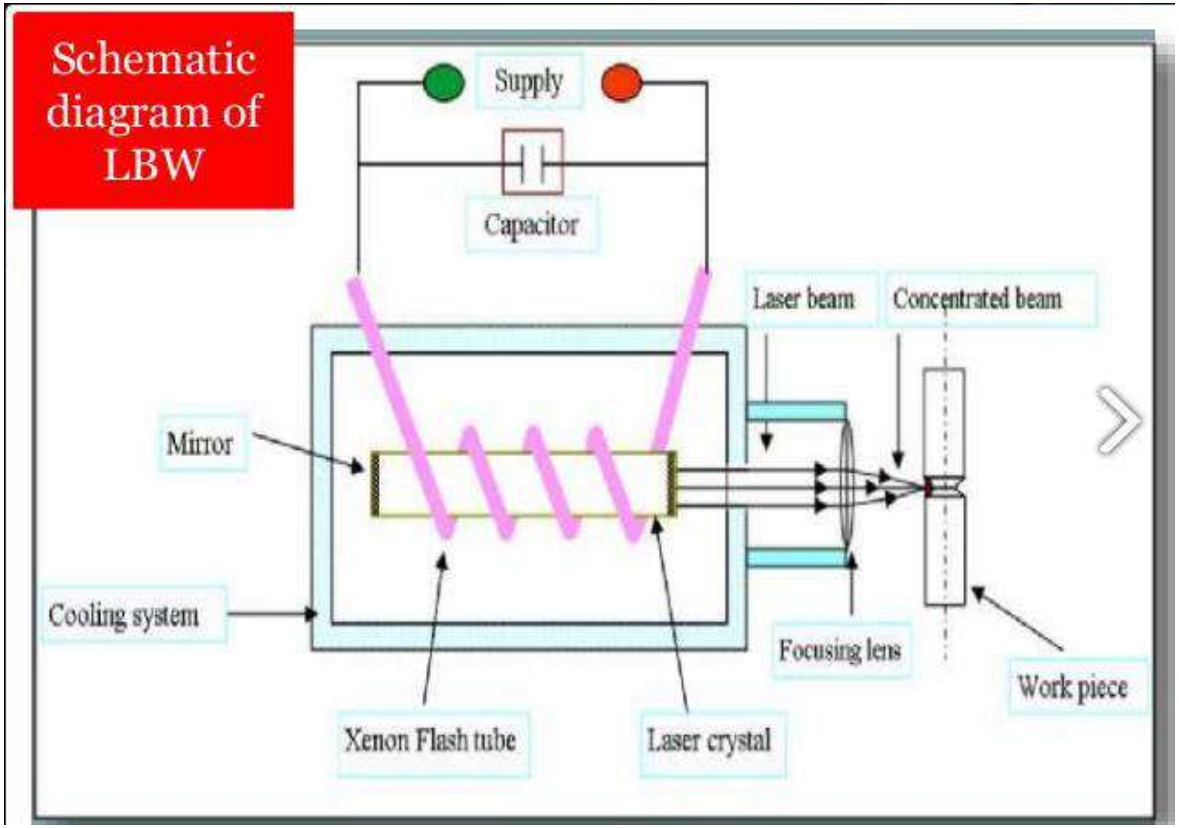
Laser Welding

- **"light amplification by stimulated emission of radiation."**
- Electrons are atomic particles that exist at specific energy levels. These energy levels are unique and are different for every atom or molecule.
- Electrons in outer rings are at higher energy levels than those in the inner rings. A flash of light can bump electrons to higher energy levels by the injection of energy. When an electron drops from an outer ring to an inner ring or level, the excess of energy is given off as light.
- The wavelength or the color emitted is related to the amount of energy released.

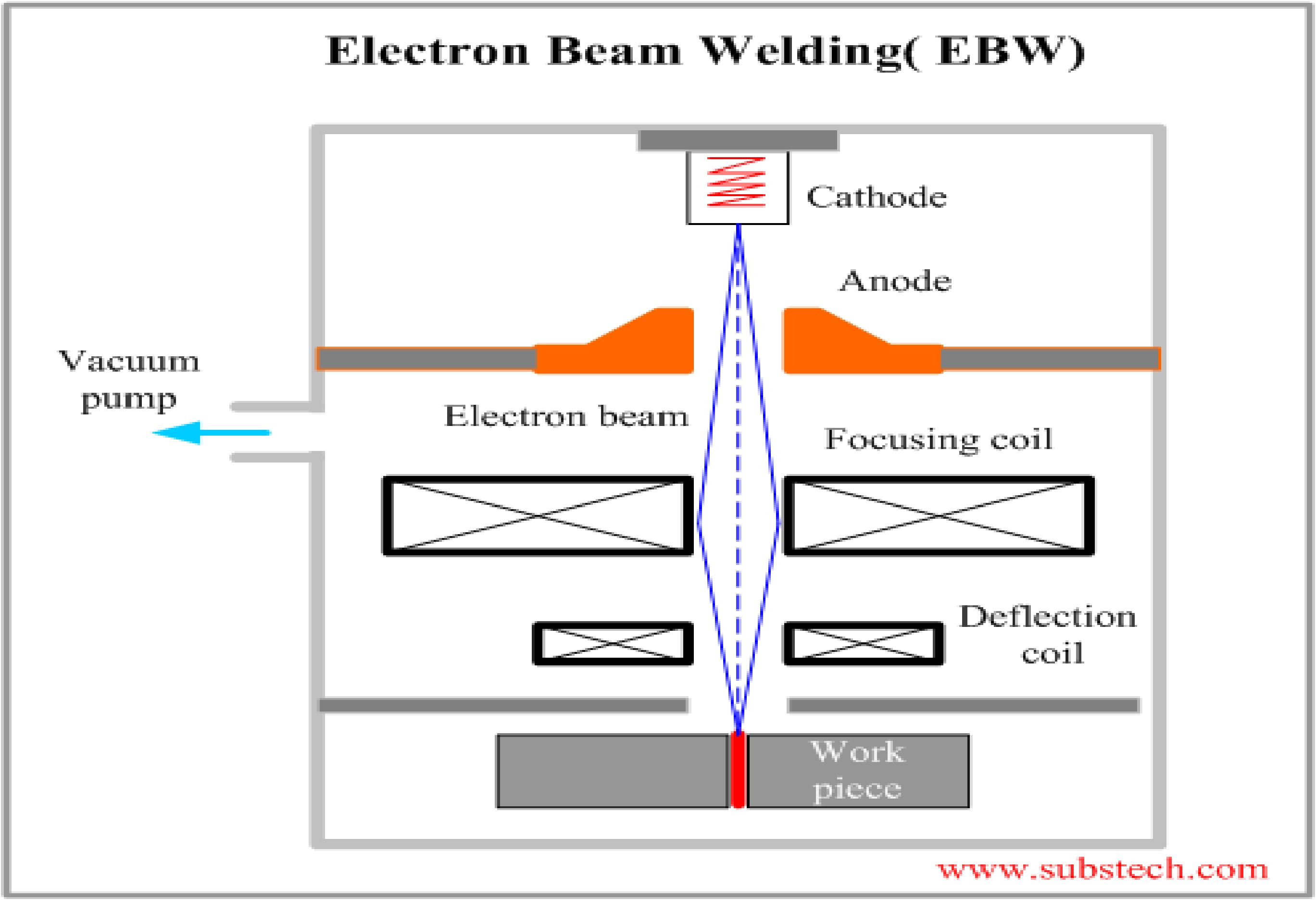
Laser Welding



Laser Welding



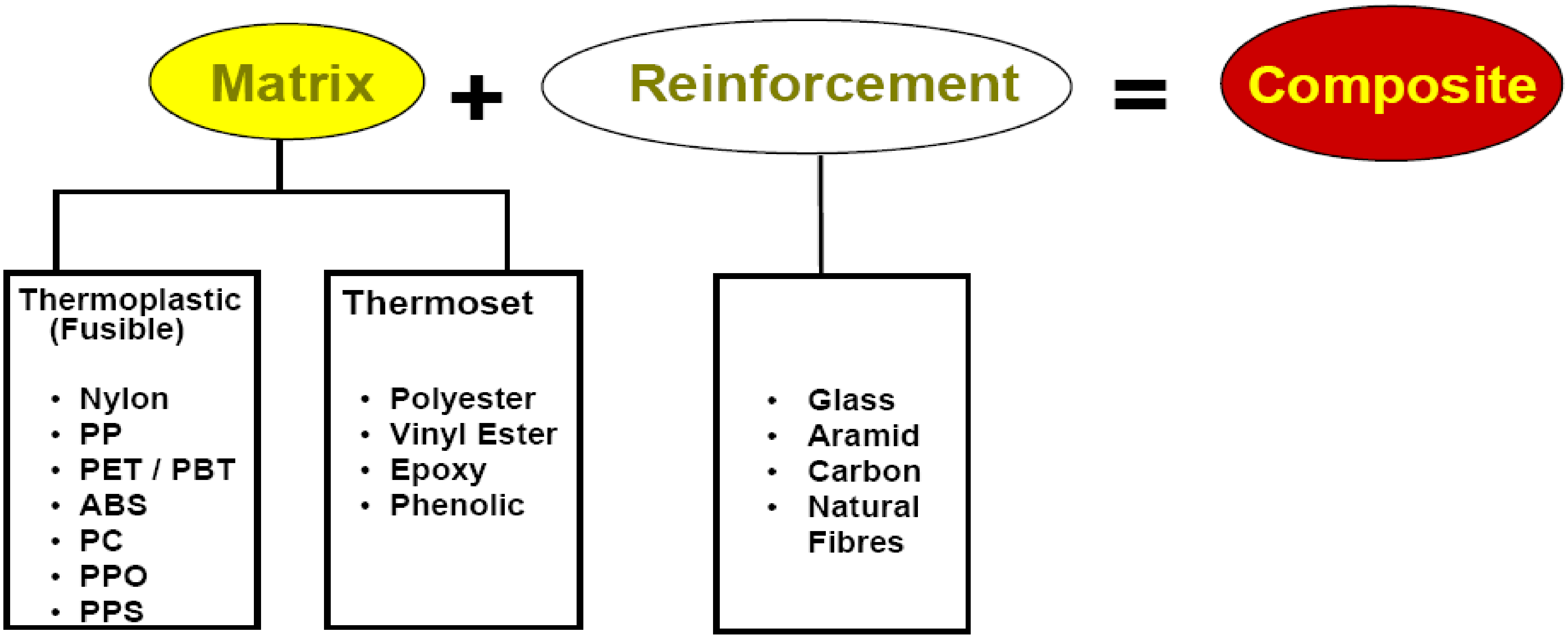
Electron Beam Welding



Unit-V

AIRCRAFT COMPOSITES

What are composites ?



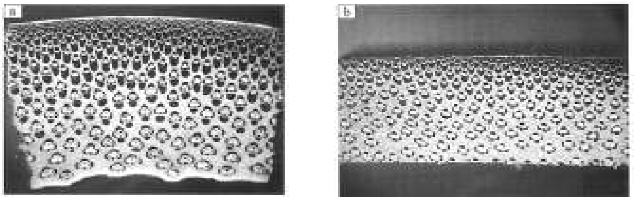
Why Composites ?

- A composite is a mixture of two or more phases (materials).
- A better or unique combination of properties is realized when different materials (or phases) are combined
- The primary needs for all the advanced composites are:
  - *light weight, higher operating temperatures, greater stiffness, higher reliability and affordability*

- **What makes a material a composite?**
- Composite materials are formed by combining two or more materials that have quite different properties.
- The different materials work together to give the composite unique properties, but within the composite you can easily tell the different materials apart – they do not dissolve or blend into each other.

What are composites made of ?

- Human learns from 'mother nature' to develop new composite materials
- Natural Composites: wood and bamboo, shells, bones, muscles, other tissues and natural fibres (silk, wool, cotton, jute, sisal)



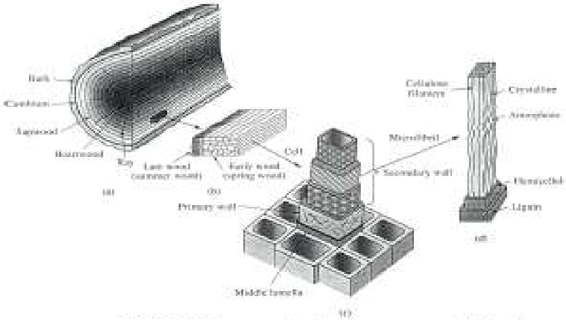
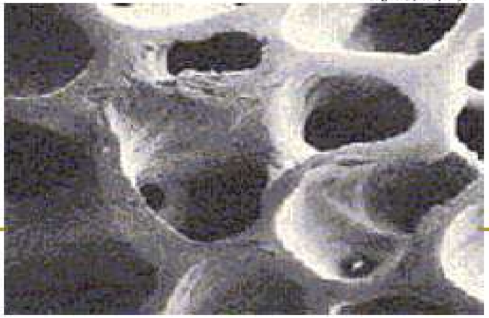


FIGURE 17-1 The structure of wood: (a) the macrostructure, including a layer str ture outlined by the annual growth rings, (b) detail of the cell structure within one annual growth ring, (c) the structure of a cell, including several layers composed of microfibrils of cellulose fibers, hemicellulose fibers, and lignin, and (d) the microfibril aligned, partly crystalline cellulose chains.



Four Classes of Materials

- Composites can be produced using three classes of materials: polymers, Metals and Ceramics

ENGINEERING MATERIALS

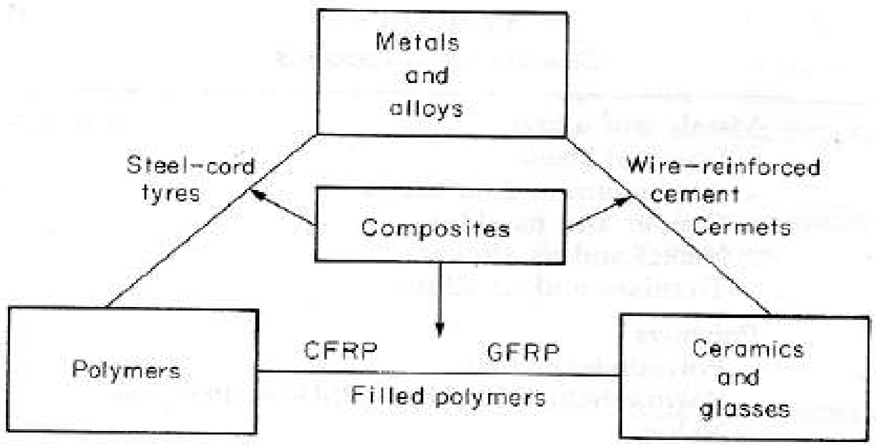


Fig. 1.1. The classes of engineering materials from which articles are made.

- **Making a composite**
- Most composites are made up of just two materials. One material (the **matrix** or **binder**) surrounds and binds together a cluster of fibres or fragments of a much stronger material (the **reinforcement**).
- In the case of mud bricks, the two roles are taken by the mud and the straw; in concrete, by the cement and the aggregate; in a piece of wood, by the cellulose and the lignin. In fibreglass, the reinforcement is provided by fine threads or fibres of glass, often woven into a sort of cloth, and the matrix is a plastic.

Definition

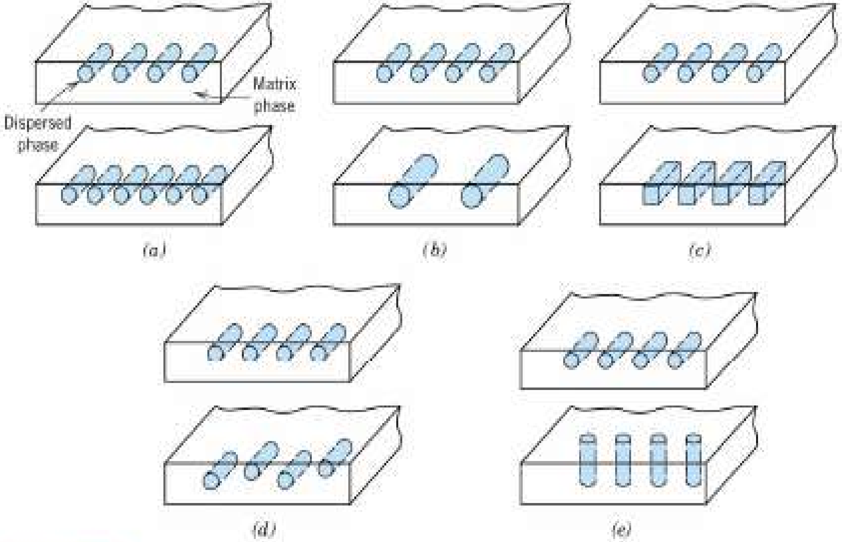


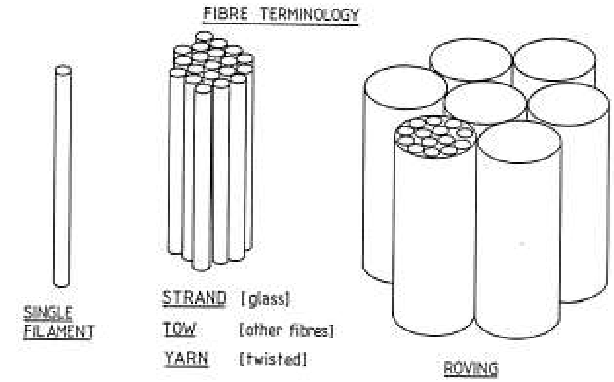
FIGURE 16.1 Schematic representations of the various geometrical and spatial characteristics of particles of the dispersed phase that may influence the properties of composites: (*a*) concentration, (*b*) size, (*c*) shape, (*d*) distribution, and (*e*) orientation. (From Richard A. Flinn and Paul K. Trojan, *Engineering Materials and Their Applications*, 4th edition. Copyright © 1990 by John Wiley & Sons, Inc. Adapted by permission of John Wiley & Sons, Inc.)

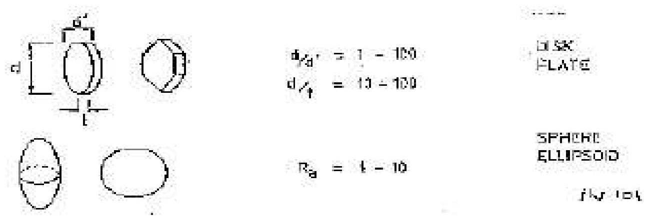
Two phase composite:

- **Matrix** is the continuous phase and surrounds the reinforcements
- **Reinforcement** is the dispersed phase, which normally bears the majority of stress

Reinforcements

- A reinforcement is the strong, stiff integral component which is incorporated into the matrix to achieve desired properties
- The term ‘reinforcement’ implies some property enhancement
- Different types
  - Fibres or Filaments: continuous fibres, discontinuous fibres, whiskers
    - Particulates reinforcements may be of any shape, ranging from irregular to spherical, plate-like or needle-like, nanoparticles
- They have a low ductility





Matrix

- Made from Metal, polymer or ceramic
- Continuous phase
- Some ductility is desirable
- Functions
  - Binds the reinforcements (fibers/particulates) together
  - Mechanically supporting the reinforcements
  - Load transfer to the reinforcements
  - Protect the reinforcements from surface damage due to abrasion or chemical attacks
  - High bonding strength between fiber and matrix is important

So why use composites?

- The greatest advantage of composite materials is strength and stiffness combined with lightness. By choosing an appropriate combination of reinforcement and matrix material, manufacturers can produce properties that exactly fit the requirements for a particular structure for a particular purpose.
- Modern aviation, both military and civil, is a prime example. It would be much less efficient without composites. In fact, the demands made by that industry for materials that are both light and strong has been the main force driving the development of composites. It is common now to find wing and tail sections, propellers and rotor blades made from advanced composites, along with much of the internal structure and fittings. The airframes of some smaller aircraft are made entirely from composites, as are the wing, tail and body panels of large commercial aircraft.
- In thinking about planes, it is worth remembering that composites are less likely than metals (such as aluminium) to break up completely under stress. A small crack in a piece of metal can spread very rapidly with very serious consequences (especially in the case of aircraft). The fibres in a composite act to block the widening of any small crack and to share the stress around.

- The right composites also stand up well to heat and corrosion. This makes them ideal for use in products that are exposed to extreme environments such as boats, chemical-handling equipment and spacecraft. In general, composite materials are very durable.
- Another advantage of composite materials is that they provide design flexibility. Composites can be moulded into complex shapes – a great asset when producing something like a surfboard or a boat hull.
- The downside of composites is usually the cost. Although manufacturing processes are often more efficient when composites are used, the raw materials are expensive. Composites will never totally replace traditional materials like steel, but in many cases they are just what we need. And no doubt new uses will be found as the technology evolves. We haven't yet seen all that composites can do.

Particulate Reinforced Composites

- The particulates are harder and stiffer than the matrix material
- The particulates are of macro-, micro- or nano-scopic scale
- The improvement of mechanical behaviour depends on the interface bonding
- Examples:
  - Silica-epoxy composites (electronic moulding compound)
  - Cermets (WC or TiC reinforced cobalt or nickel)
  - Concrete (aggregate-gravel and sand-reinforced cement)
  - SiC or Al_2O_3 particle reinforced Al matrix.

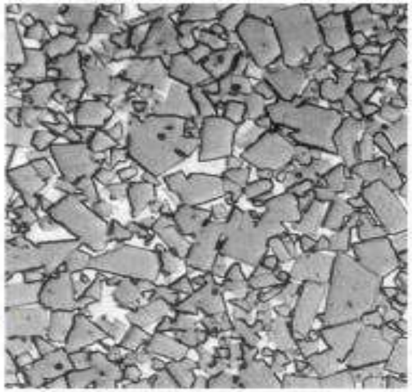
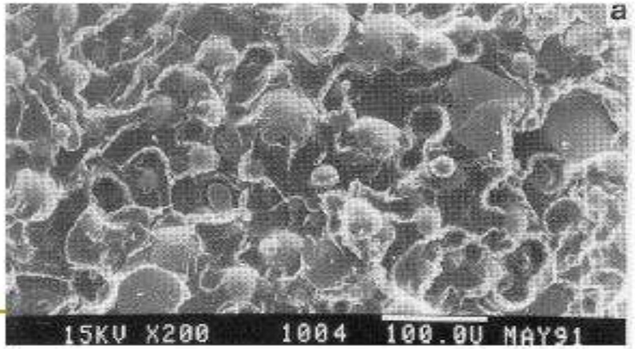


FIGURE 17.4 Photomicrograph of a WC–Co cemented carbide. Light areas are the cobalt matrix; dark regions, the particles of tungsten carbide. 100×. (Courtesy of Carboloy Systems Department, General Electric Company.)



Fibre-reinforced Composites (FRC)

- Mechanical properties of FRC depend on
  - Fiber properties
  - Degree to which an applied load is transmitted to the fibers by the matrix phase: good interfacial bond between fiber and matrix is necessary
- Depending on the matrix material
  - Polymer matrix composites (PMC)
  - Metal matrix composites (MMC)
  - Ceramic matrix composites (CMC)

Polymer-Matrix Composites (PMCs)

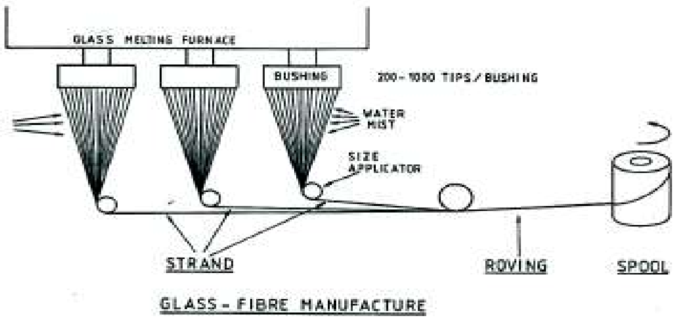
- Consists of a polymer resin as the matrix
- Being used in the greatest diversity and largest quantities
- Glass fiber-reinforced polymer composites (GFRPs)
  - Produced in the largest quantities

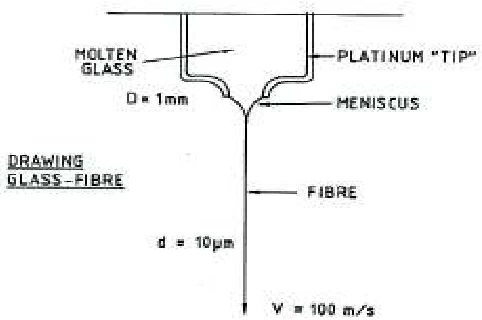
Carbon fiber-reinforced polymer composites (CFRPs)
  - High performance composites

Aramid fiber-reinforced polymer composites (AFRPs)
  - High strength, high modulus & high impact resistance composites

Glass Fiber-Reinforced Polymer (GFRP)

- Glass fibres (or Fibre Glass) : Easy to manufacture, chemical resistance
- Glass fibre surface is coated with a thin polymer layer, i.e. "size", to protect the fibre surface from damage
- GFRPs' use temperature is limited below 200°C due to polymer matrix
- Major applications of GFRPs
  - Automotive, marine vehicle bodies, pipes, storage containers, industrial flooring





Manufacturing of Glass Fibres

Carbon Fiber-Reinforced Polymer (CFRP)

Carbon fibers:

- High specific modulus and specific strength even at high temperature
- Good physical and mechanical properties
- Expensive manufacturing processes
- Organic precursors: rayon, polyacrylonitrile (PAN) and pitch
- Diameter: 4 to 10 μm, coated with epoxy size to improve adhesion with matrix
- Major Applications of CFRPs: aircraft structural components, sporting goods, rocket motor cases, pressure vessels, etc.

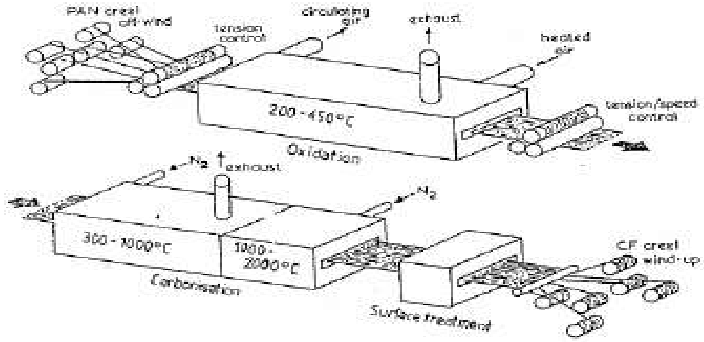
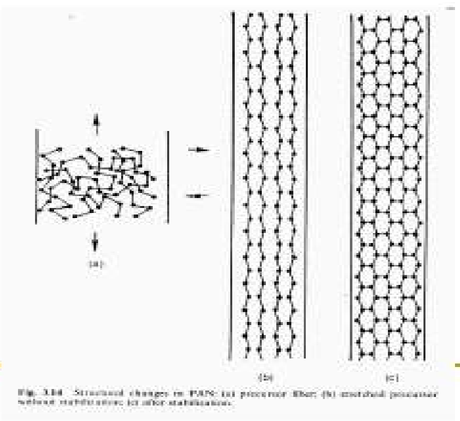


FIG. 3. Schematic production of carbon fibre.



Aramid-Fiber-Reinforced Polymer (AFRP)

Aramid fibers (Kevlar)

- Thermoplastic material: poly-paraphenylene terephthalamide (PPTA)
- High tensile properties and weak compressive properties.
- Mechanically stable between –200 and 200°C
- Chemically weak to degradation by strong acids and bases.

Major applications of AFRPs

- Bullet-proof vests, sporting goods, ropes, missile cases, pressure vessels, automobile brakes and clutch linings

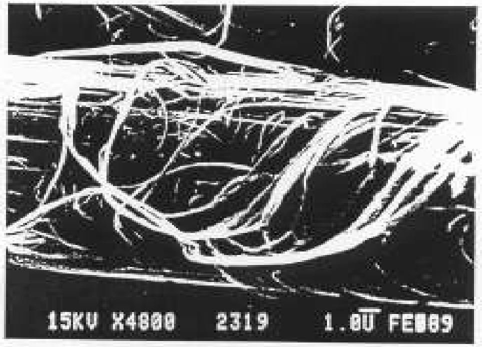


Figure 6. Scanning electron microphotograph of a fibrillated Kevlar 49 fiber. After Kim and Mai [8].

Typical Properties of Continuous and Aligned GFRP, CFRP and AFRP

Property	*Glass (E-glass)*	*Carbon (High Strength)*	*Aramid (Kevlar 49)*
Specific gravity	2.1	1.6	1.4
Tensile modulus			
Longitudinal [GPa (10^6 psi)]	45 (6.5)	145 (21)	76 (11)
Transverse [GPa (10^6 psi)]	12 (1.8)	10 (1.5)	5.5 (0.8)
Tensile strength			
Longitudinal [MPa (ksi)]	1020 (150)	1240 (180)	1380 (200)
Transverse [MPa (ksi)]	40 (5.8)	41 (6)	30 (4.3)
Ultimate tensile strain			
Longitudinal	2.3	0.9	1.8
Transverse	0.4	0.4	0.5

Applications of Polymer matrix Composites

- Aerospace: wings, fuselages, landing gears, rudders/elevators, rotor blades, satellite structure
- Automobile: body panels and frames, bumpers, leafsprings, drive shafts, seat housing, tyres and other ground transportation vehicles (bullet train).
- Marine (e.g. Catamaran) : boat hulls, decks, masts, propeller shafts, wind surfer
- Chemical plants: process pipes, tanks, pressure vessels, oil field structures

- Sporting goods: tennis rackets, golf clubs, hockey sticks, fishing rods, baseball bats, bicycles, skis, canoes, bow, swimming pools
- Construction: Bridge decks, repair of concrete decks, bridges, columns; FRP re-bars
- Biomedical: teeth, filler, bone replacements, artificial limbs
- Electrical: Panels, switch gear, insulators, moulding compounds, conductive adhesives
- Others: wind turbine blades, musical instruments, umbrellas, pens, lighters

Applications of Polymer matrix Composites

BK117 composite airframe

- CFRP and CFRP/aramid nomex sandwich in autoclave technique
- monolithic CFRP frames

BL 11-KEA (Bern and Lucia Hinz)

- design GFRP sandwich (foam core)
- rudder: CFRP-Nomex
- wing span: 10 m (12m²)
- fuselage: 6.75 m
- empty weight: 440/MTOW:720kg

Boeing 787 Dreamliner

- Largest passenger aircraft
- Made of largest amount of carbon fibers

Stealth Aircrafts

- Extensive use of carbon fibre composites to make them undetectable by radars

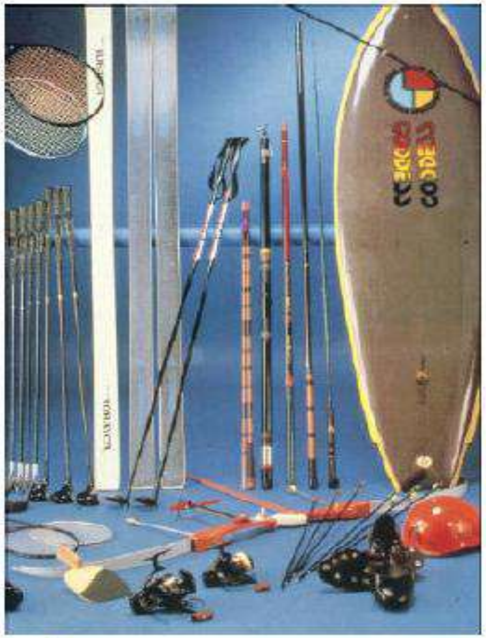
Boeing 777 Worldliner

- Longest-range passenger aircraft

SR-71 "Blackbird"

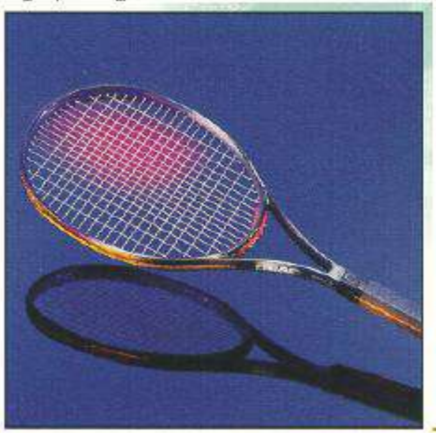
B-2 bomber

Sporting Goods

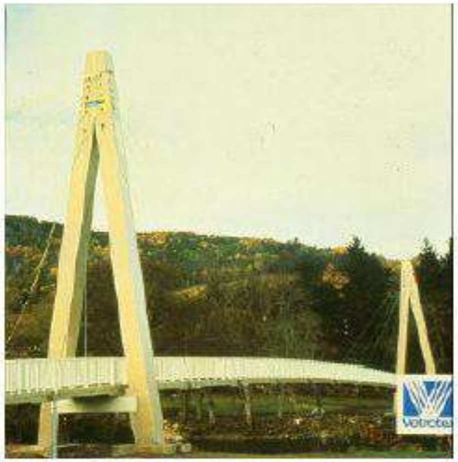


Hercules monocoque

- composite conform design without metal fittings
- sandwich design with honeycomb core
- low weight (9,5 kg), high stiffness
- CFRP disc wheels
- high prestige



Leading tennis racket manufacturers rely on the advanced performance characteristics of our carbon, glass and hybrid prepregs.

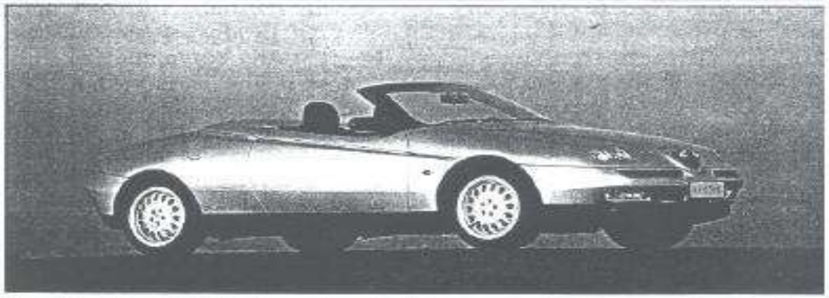


GFRP pedestrian bridge:

- Length 120 m, main span: 63 m
- GFRP polyester resin
- pultrusion profiles are adhesive bonded at construction site

Automobile Body Components

The 1996 Ford Taurus Mercury Sable carries a breakthrough SMC front end moulded by The Budd Co.



The Alfa Romeo Spider has a Class-A SMC bonnet which incorporates headlam and grille apertures and the top part of the wings.

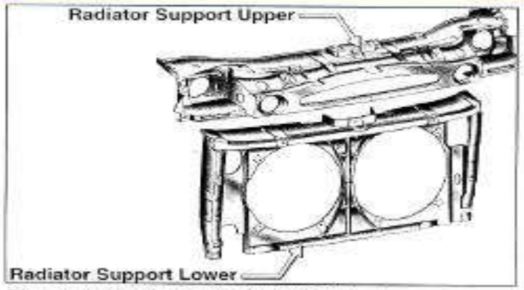
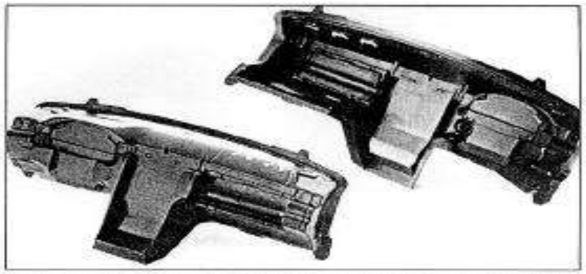
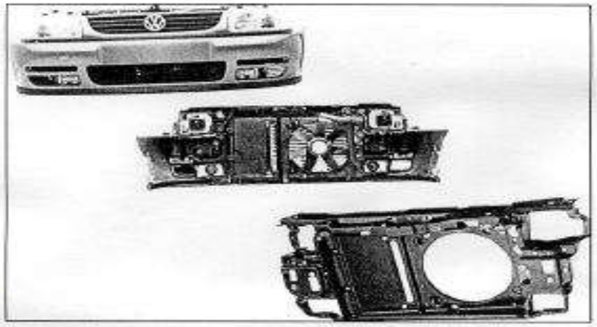


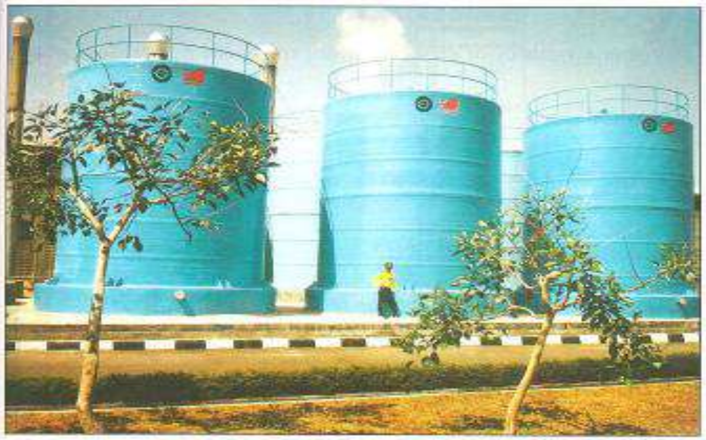
Diagram showing the two piece Ford SMC front end.



The instrument panel carrier for the Mercedes E-class is made from GMT. Scrap material is recycled into a battery carrier for VW.



The Polo features the second GMT front end Rfas Kunststofftechnik has undertaken for VW. The Golf A4 will follow in 1997.



Large vessels, such as these 6 m diameter 200 tonnes water tanks for PT Karya Pangan Inti Sejati, are made on-site.

Electronics Applications

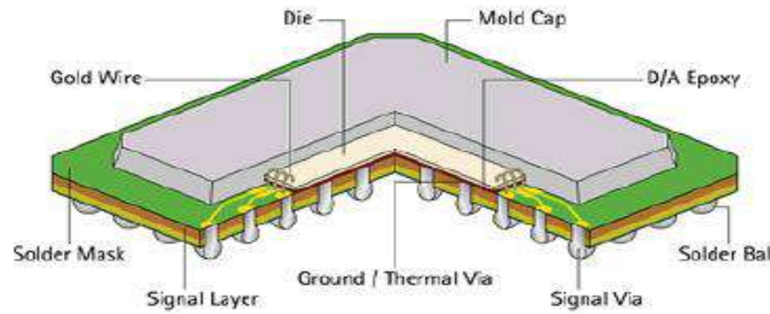
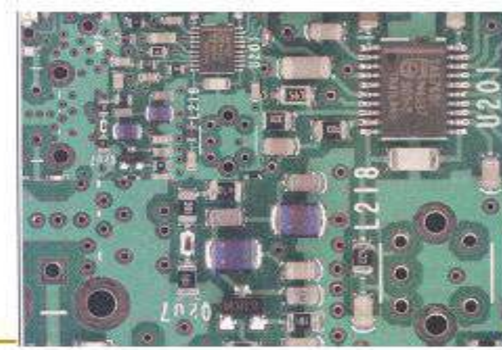


FIGURE 2: 45 m Tri Cat fast catamaran ferry built by FBM Marine Ltd.



Metal-Matrix Composites (MMC)

- The matrix is more ductile than the reinforcements
- The reinforcement may improve specific strength/stiffness, abrasion resistance, creep resistance, thermal conductivity and dimensional stability of the overall composites
- Advantages over PMC
  - Higher operating temperatures
  - Non-flammability
  - Greater resistance to degradation by organic fluids
- Disadvantages
  - Expensive & higher density

- Matrix materials
  - Superalloy (e.g. single crystal Ni based alloys), Al, Mg, Ti, Cu
- Reinforcements
  - C, SiC, B, Al_2O_3 fibers, SiC, Al_2O_3 particles

Applications:

- Automobile engine components
- Aerospace structures (e.g. space shuttle orbiter, telescope made from B or C fibers-Al matrix composites)
- Turbine engines (W fiber-superalloy composites)

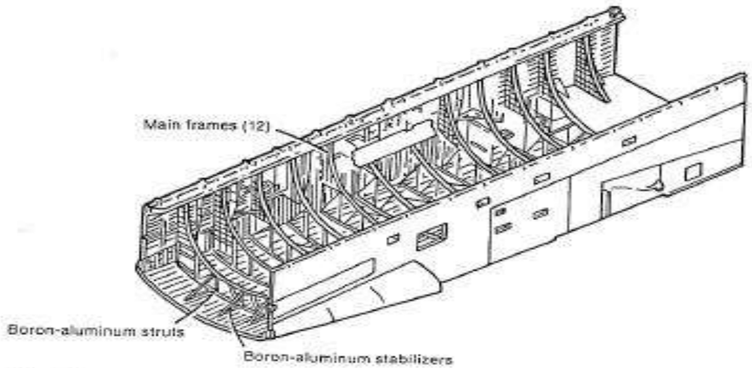


Fig. 22 Schematic of mid-fuselage structure of space shuttle. Source: Ref 4

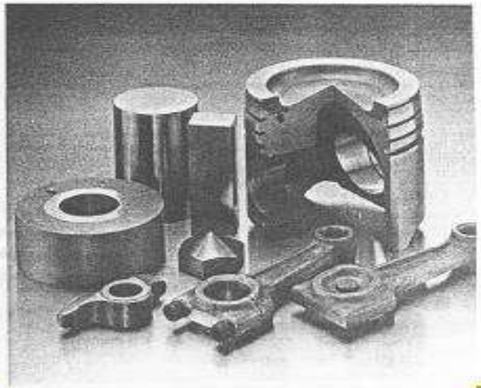
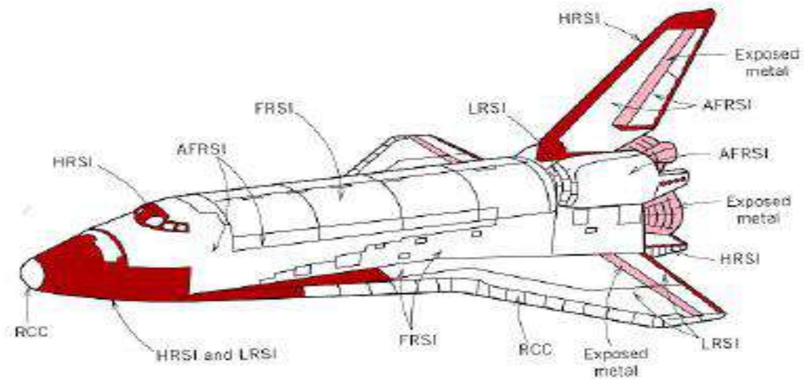
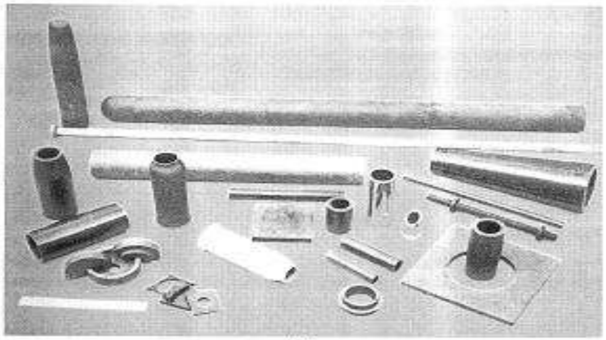


FIG. 1.3 Automobile engine components made of SiCw/Al composite (cou of Tokai Carbon Co.)

Ceramic-Matrix Composites (CMC)

- For use in high temperature and severe stress applications, e.g. automobile and aircraft gas turbine engines
- **Advantages**
  - High strength and modulus
  - Very high service temperature
  - Reduced weight (lower fuel consumption)
- **Disadvantages**
  - Very brittle





(b)

Fig. 4.11 Some commercially available fiber-reinforced ceramic components made by the Lanxide Corporation: (a) fiber-reinforced ceramic composites for applications in high-temperature gas turbine engine components; (b) heat exchanger and radiant burner tubes, flame tubes and other high-temperature furnace parts made from particle-reinforced ceramic composites (courtesy of Lanxide Corporation)

Putting it together – the science and technology of composite materials

•Australia, like all advanced countries, is taking a big interest in composite materials, which many people see as 'the materials of the future'. The main concern is to get the costs down, so that composites can be used in products and applications which at present don't justify the cost. At the same time researchers want to improve the performance of the composites, such as making them more resistant to impact.

•One new technique involves 'textile composites'. Instead of the reinforcing fibres being put in place individually, which is slow and costly, they can be knitted or woven together to make a sort of cloth. This can even be three-dimensional rather than flat. The spaces between and around the textile fibres are then filled with the matrix material (such as a resin) to make the product.

- This process can quite easily be done by machines rather than by hand, making it faster and cheaper. Connecting all the fibres together also means that the composite is less likely to be damaged when struck.
- With the costs coming down, other uses for composites are beginning to look attractive. Making the hulls and superstructures of boats from composites takes advantage of their resistance to corrosion. The Australian Navy’s new minehunters have composite hulls, since the magnetic effect of a steel hull would interfere with mine detection.
- Also in the pipeline are carriages for trains, trams and other 'people movers', made from composites rather than steel or aluminium. Here the appeal is the lightness of the composites, as the vehicles then use less energy. And we are going to see more and more composites in cars for the same reason.

INTRODUCTION TO NANOMATERIAL

- **Nanomaterials** is the study of how materials behave when their dimensions are reduced to the nanoscale. It can also refer to the materials themselves that are used in nanotechnology.
- A unique aspect of nanotechnology is the vastly increased ratio of surface area to volume present in many nanoscale materials which opens new possibilities in surface-based science, such as catalysis

- A number of physical phenomena become noticeably pronounced as the size of the system decreases.
- These include statistical mechanical effects, as well as quantum mechanical effects, for example the "quantum size effect" where the electronic properties of solids are altered with great reductions in particle size.
- This effect does not come into play by going from macro to micro dimensions. However, it becomes dominant when the nanometer size range is reached.
- Additionally, a number of physical properties change when compared to macroscopic systems.
- One example is the increase in surface area to volume of materials. Novel mechanical properties of nanomaterials is the subject of nanomechanics research.
- Their catalytic activity reveals novel properties in the interaction with biomaterials.

What is the effect of nonmaterial?

- Materials reduced to the nanoscale can suddenly show very different properties compared to what they exhibit on a macroscale, enabling unique applications.
- For instance, opaque substances become transparent (copper);
- inert materials become catalysts (platinum);
- stable materials turn combustible (aluminum);
- solids turn into liquids at room temperature (gold);
- insulators become conductors (silicon).
- Materials such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscales.
- Much of the fascination with nanotechnology stems from these unique quantum and surface phenomena that matter exhibits at the nanoscale.

- Nanosize powder particles (a few nanometres in diameter, also called nanoparticles) are potentially important in ceramics, powder metallurgy, the achievement of uniform nanoporosity and similar applications.
- The strong tendency of small particles to form clumps ("agglomerates") is a serious technological problem that impedes such applications.

Materials used in nanotechnology

- Fullerenes and carbon forms
- Nanoparticles and Colloids

Fullerenes and carbon forms

- Allotropes of carbon
- Aggregated diamond nanorods
- Buckypaper
- Carbon nanofoam
- Carbon nanotube
- Nanoknot
- Fullerene chemistry
- Bingel reaction
- Endohedral hydrogen fullerene
- Prato reaction
- Fullerenes in popular culture
- Endohedral fullerenes
- Fullerite
- Graphene
- Potential applications of carbon nanotubes
- Timeline of carbon nanotubes

Nanoparticles and Colloids

- Colloid
- Diamondoids
- Nanocomposite
- Nanocrystal
- Quantum dot

Fullerenes

- The fullerenes are a class of allotropes of carbon which conceptually are graphene sheets rolled into tubes or spheres.
- These include the carbon nanotubes which are of interest due to both their mechanical strength and their electrical properties.
- For the past decade, the chemical and physical properties of fullerenes have been a hot topic in the field of research and development, and are likely to continue to be for a long time.
- In April 2003, fullerenes were under study for potential medicinal use: binding specific antibiotics to the structure to target resistant bacteria and even target certain cancer cells such as melanoma.

- The October 2005 issue of Chemistry and Biology contains an article describing the use of fullerenes as light-activated antimicrobial agents.
- In the field of nanotechnology, heat resistance and superconductivity are some of the more heavily studied properties.
- A common method used to produce fullerenes is to send a large current between two nearby graphite electrodes in an inert atmosphere. The resulting carbon plasma arc between the electrodes cools into sooty residue from which many fullerenes can be isolated.
- There are many calculations that have been done using ab-initio Quantum Methods applied to fullerenes. By DFT and TDDFT methods one can obtain IR, Raman and UV spectra. Results of such calculations can be compared with experimental results.

Nanoparticles

- Nano particles or nano crystals made of metals, semiconductors, or oxides are of interest for their electrical, optical, and chemical properties. Nano particles have been used as quantum dots and as chemical catalysts.
- Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. A bulk material should have constant physical properties regardless of its size, but at the nano-scale this is often not the case. Size-dependent properties are observed such as quantum confinement in semiconductor particles, surface plasmon resonance in some metal particles and superparamagnetism in magnetic materials.

- Nanoparticles exhibit a number of special properties relative to bulk material. For example, the bending of bulk copper (wire, ribbon, etc.) occurs with movement of copper atoms/clusters at about the 50 nm scale. Copper nanoparticles smaller than 50 nm are considered super hard materials that do not exhibit the same malleability and ductility as bulk copper.
- The change in properties is not always desirable. Ferroelectric materials smaller than 10 nm can switch their magnetisation direction using room temperature thermal energy, thus making them useless for memory storage.

- Suspensions of nanoparticles are possible because the interaction of the particle surface with the solvent is strong enough to overcome differences in density, which usually result in a material either sinking or floating in a liquid. Nanoparticles often have unexpected visible properties because they are small enough to confine their electrons and produce quantum effects. For example gold nanoparticles appear deep red to black in solution.
- Nanoparticles have a very high surface area to volume ratio. This provides a tremendous driving force for diffusion, especially at elevated temperatures. Sintering can take place at lower temperatures, over shorter time scales than for larger particles. This theoretically does not affect the density of the final product, though flow difficulties and the tendency of nanoparticles to agglomerate complicates matters. The surface effects of nanoparticles also reduces the incipient melting temperature.

Potential applications of carbon nanotubes

Structural

- **clothes**: waterproof tear-resistant
- **combat jackets**: MIT is working on combat jackets that use carbon nanotubes as ultrastrong fibers and to monitor the condition of the wearer.
- **concrete**: In concrete, they increase the tensile strength, and halt crack propagation.
- **polyethylene**: Researchers have found that adding them to polyethylene increases the polymer's elastic modulus by 30%.
- **sports equipment**: Stronger and lighter tennis rackets, bike parts, golf balls, golf clubs, golf shaft and baseball bats.
- **space elevator**: This will be possible only if tensile strengths of more than about 70 GPa can be achieved. Monoatomic oxygen in the Earth's upper atmosphere would erode carbon nanotubes at some altitudes, so a space elevator constructed of nanotubes would need to be protected (by some kind of coating). Carbon nanotubes in other applications would generally not need such surface protection.
- **ultrahigh-speed flywheels**: The high strength/weight ratio enables very high speeds to be achieved.
- **Bridges**: For instance in suspension bridges (where they will be able to replace steel), or bridges built as a "horizontal space elevator".

Electromagnetic

- **chemical nanowires**: Carbon nanotubes additionally can also be used to produce nanowires of other chemicals, such as gold or zinc oxide. These nanowires in turn can be used to cast nanotubes of other chemicals, such as gallium nitride. These can have very different properties from CNTs - for example, gallium nitride nanotubes are hydrophilic, while CNTs are hydrophobic, giving them possible uses in organic chemistry that CNTs could not be used for.

- **computer circuits**: A nanotube formed by joining nanotubes of two different diameters end to end can act as a diode, suggesting the possibility of constructing electronic computer circuits entirely out of nanotubes. Because of their good thermal properties, CNTs can also be used to dissipate heat from tiny computer chips. The longest electricity conducting circuit is a fraction of an inch long. (Source: June 2006 National Geographic).

- **electric motor brushes**: Conductive carbon nanotubes have been used for several years in brushes for commercial electric motors. They replace traditional carbon black, which is mostly impure spherical carbon fullerenes. The nanotubes improve electrical and thermal conductivity because they stretch through the plastic matrix of the brush. This permits the carbon filler to be reduced from 30% down to 3.6%, so that more matrix is present in the brush. Nanotube composite motor brushes are better-lubricated (from the matrix), cooler-running (both from better lubrication and superior thermal conductivity), less brittle (more matrix, and fiber reinforcement), stronger and more accurately moldable (more matrix). Since brushes are a critical failure point in electric motors, and also don't need much material, they became economical before almost any other application.

- **solar cells**: GE's carbon nanotube diode has a photovoltaic effect. Nanotubes can replace ITO in some solar cells to act as a transparent conductive film in solar cells to allow light to pass to the active layers and generate photocurrent.
- **transistor**: developed at Delft, IBM, and NEC.

Chemical

- **biotech container**: Nanotubes can be opened and filled with materials such as biological molecules
- **hydrogen storage**: Research is currently being undertaken into the potential use of carbon nanotubes for hydrogen storage. They have the potential to store between 4.2 and 65% hydrogen by weight. This is an important area of research, since if they can be mass produced economically there is potential to contain the same quantity of energy as a 50l gasoline tank in 13.2l of nanotubes.
- **water filter**: Recently nanotube membranes have been developed for use in filtration. This technique can purportedly reduce desalination costs by 75%. The tubes are so thin that small particles (like water molecules) can pass through them, while larger particles (such as the chloride ions in salt) are blocked.

Mechanical

- **oscillator**: fastest known oscillators (> 50 GHz).
- Liquid flows up to five orders of magnitude faster than predicted by classical fluid dynamics.
- **slick surface**: slicker than Teflon and waterproof.

In electrical circuits

- Carbon nanotubes have many properties—from their unique dimensions to an unusual current mechanism—that make them ideal components of electrical circuits. Currently, there is no reliable way to arrange carbon nanotubes into a circuit.
- The major hurdles that must be jumped for carbon nanotubes to find prominent places in circuits relate to fabrication difficulties. The production of electrical circuits with carbon nanotubes are very different from the traditional The IC fabrication process is somewhat like
- sculpture - films are deposited onto a wafer and pattern-etched away. Because carbon nanotubes are fundamentally different from films, carbon nanotube circuits can so far not be mass produced.

Some other important applications

- Metallic and semiconducting nanotubes
- Carbon Nanotube Interconnects
- Carbon Nanotube Transistors
- Challenges in Electronic Design and Design Automation
- As fiber and film

MAGNETIC MATERIAL

- When a material is placed within a magnetic field, the magnetic forces of the material's electrons will be affected. This effect is known as Faraday's Law of Magnetic Induction. However, materials can react quite differently to the presence of an external magnetic field. This reaction is dependent on a number of factors, such as the atomic and molecular structure of the material, and the net magnetic field associated with the atoms. The magnetic moments associated with atoms have three origins. These are the electron orbital motion, the change in orbital motion caused by an external magnetic field, and the spin of the electrons.

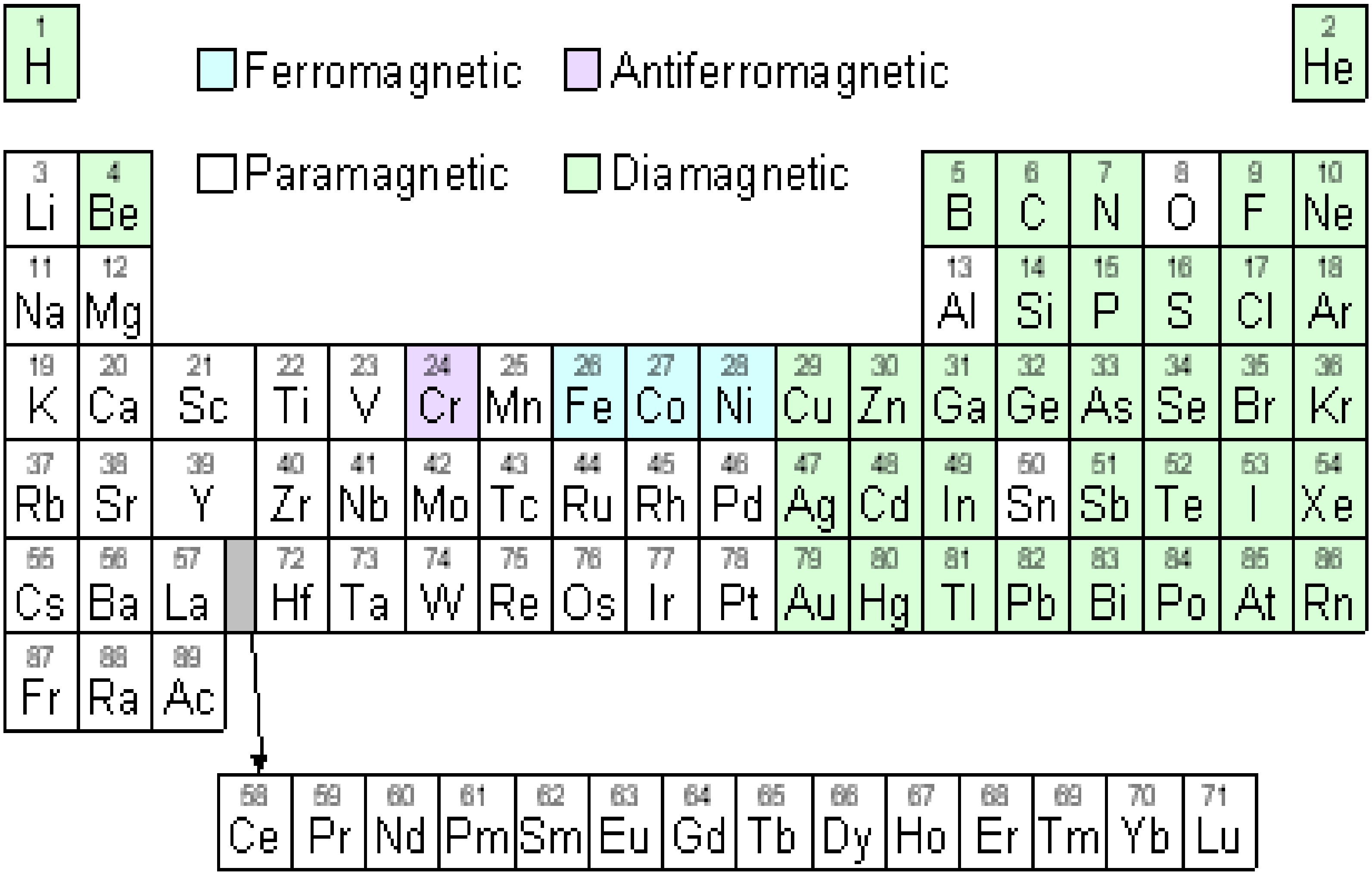
- In most atoms, electrons occur in pairs. Electrons in a pair spin in opposite directions. So, when electrons are paired together, their opposite spins cause their magnetic fields to cancel each other. Therefore, no net magnetic field exists. Alternately, materials with some unpaired electrons will have a net magnetic field and will react more to an external field. Most materials can be classified as diamagnetic, paramagnetic or .ferromagnetic.

Applications

- Magnetic materials encompass a wide variety of materials, which are used in a diverse range of applications.
- Magnetic materials are utilized in the creation and distribution of electricity, and, in most cases, in the appliances that use that electricity.
- They are used for the storage of data on audio and video tape as well as on computer disks.
- In the world of medicine, they are used in body scanners as well as a range of applications where they are attached to or implanted into the body.
- The home entertainment market relies on magnetic materials in applications such as PCs, CD players, televisions, games consoles and loud speakers.

Classification

- Magnetic materials are classified in terms of their magnetic properties and their uses.
- If a material is easily magnetised and demagnetised then it is referred to as a soft magnetic material, whereas if it is difficult to demagnetise then it is referred to as a hard (or permanent) magnetic material.
- Materials in between hard and soft are almost exclusively used as recording media and have no other general term to describe them.
- Other classifications for types of magnetic materials are subsets of soft or hard materials, such as magnetostrictive and magnetoresistive materials.


Ferromagnetic
Antiferromagnetic
Paramagnetic
Diamagnetic
1 H
2 He
3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
55 Cs 56 Ba 57 La 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
87 Fr 88 Ra 89 Ac
58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu

- **Diamagnetic** metals have a very weak and negative susceptibility to magnetic fields. Diamagnetic materials are slightly repelled by a magnetic field and the material does not retain the magnetic properties when the external field is removed. Diamagnetic materials are solids with all paired electron resulting in no permanent net magnetic moment per atom. Diamagnetic properties arise from the realignment of the electron orbits under the influence of an external magnetic field. Most elements in the periodic table, including copper, silver, and gold, are diamagnetic.

- **Paramagnetic** metals have a small and positive susceptibility to magnetic fields. These materials are slightly attracted by a magnetic field and the material does not retain the magnetic properties when the external field is removed. Paramagnetic properties are due to the presence of some unpaired electrons, and from the realignment of the electron orbits caused by the external magnetic field. Paramagnetic materials include magnesium, molybdenum, lithium, and tantalum.

- **Ferromagnetic** materials have a large and positive susceptibility to an external magnetic field.
- They exhibit a strong attraction to magnetic fields and are able to retain their magnetic properties after the external field has been removed.
- Ferromagnetic materials have some unpaired electrons so their atoms have a net magnetic moment.
- They get their strong magnetic properties due to the presence of magnetic domains.

DIELECTRIC (INSULATORS) INTRODUCTION

- A dielectric material is a substance that is a poor conductor of electricity, but an efficient supporter of electrostatic fields. If the flow of current between opposite electric charge poles is kept to a minimum while the electrostatic lines of flux are not impeded or interrupted, an electrostatic field can store energy. This property is useful in radio frequencies. Dielectric materials are also used in the construction of radio-frequency transmission lines.

Characteristics

- They have the value of resistivity . (**Electrical resistivity** also known as **specific electrical resistance**) is a measure of how strongly a material opposes the flow of electric current. A low resistivity indicates a material that readily allows the movement of electrical charge. The SI unit of electrical resistivity is the ohm metre, $\rho = RA/L$).
- Negative temperature coefficient of resistant (α).
- Large insulation resistant.
- They have very conductor to hear and electricity.

- In practice, most dielectric materials are solid. Examples include porcelain (ceramic), mica, glass, plastics, and the oxides of various metals.
- Some liquids and gases can serve as good dielectric materials.
- Dry air is an excellent dielectric, and is used in variable capacitors and some types of transmission lines.
- Distilled water is a fair dielectric. A vacuum is an exceptionally efficient dielectric.

- An important property of a dielectric is its ability to support an electrostatic field while dissipating minimal energy in the form of heat. The lower the *dielectric loss* (the proportion of energy lost as heat), the more effective is a dielectric material.
- Another consideration is the *dielectric constant*, the extent to which a substance concentrates the electrostatic lines of flux.
- Substances with a low dielectric constant include a perfect vacuum, dry air, and most pure, dry gases such as helium and nitrogen.
- Materials with moderate dielectric constants include ceramics, distilled water, paper, mica, polyethylene, and glass. Metal oxides, in general, have high dielectric constants.

Uses

- In electrical Insulation.
- They are used as insulators and capacitors.
- Used in strain gauge and sonar devices.
- Formvar is a suitable insulating material for low temp. applications. It is the trade mane of polyvinyl formal.
- As a dielectric materials.

SEMICONDUCTOR(INSULATOR) Introduction

- A **semiconductor** is a solid material that has electrical conductivity in between that of a conductor and that of an insulator; it can vary over that wide range either permanently or dynamically.
- Semiconductors are tremendously important in technology. Semiconductor devices, electronic components made of semiconductor materials, are essential in modern electrical devices.
- Examples range from computers to cellular phones to digital audio players. Silicon is used to create most semiconductors commercially, but dozens of other materials are used as well.
- They have widely used for making solid state devices.

- Semiconductor is classified by two categories
- Intrinsic-in which the elemental form of pure silica (Si) and Pure germanium (Ge) are intrinsic. In intrinsic form they are not useful. They are therefore doped by dopen to make extrinsic semiconductor.Extrinsic form are directly useful and are widely employed in manufacturing of solid state devises.
- .
- Dominant carrier concentrations in an extrinsic semiconductor classify it as either an n-type or p-type semiconductor. The electrical properties of extrinsic semiconductors make them essential components of many electronic devices.

P-type semiconductors

- As opposed to n-type semiconductors, p-type semiconductors have a larger hole concentration than electron concentration.
- The phrase 'p-type' refers to the positive charge of the hole. In p-type semiconductors, holes are the majority carriers and electrons are the minority carriers.
- P-type semiconductors are created by doping an intrinsic semiconductor with acceptor impurities.
- P-type semiconductors have Fermi energy levels below the intrinsic Fermi energy level.
- The Fermi energy level lies closer to the valence band than the conduction band in a p-type semiconductor.

Utilization of extrinsic semiconductors

- Extrinsic semiconductors are components of many common electrical devices. A semiconductor diode (devices that allow current flow in only one direction) consists of p-type and n-type semiconductors placed in junction with one another. Currently, most semiconductor diodes use doped silicon or germanium.
- Transistors (devices that enable current switching) also make use of extrinsic semiconductors. Bipolar junction transistors (BJT) are one type of transistor. The most common BJTs are NPN and PNP type. NPN transistors have two layers of n-type semiconductors sandwiching a p-type semiconductor. PNP transistors have two layers of p-type semiconductors sandwiching an n-type semiconductor.

SUPER CONDUCTOR -Introduction

- *Superconductors* are those elements, compounds and alloys of metal and nonmetals which exhibits extra ordinary magnetic and electrical behavior at extremely low temperatures (near absolute zero). Such low temperatures are not practically favorable for wide application.
- *Superconductors*, materials that have no resistance to the flow of electricity, are one of the last great frontiers of scientific discovery. Not only have the limits of superconductivity not yet been reached, but the theories that explain superconductor behavior seem to be constantly under review.
- Superconductors have the ability to conduct electricity without the loss of energy.

Properties of super conductors

- Super conducting materials exhibit the following extraordinary properties below their critical temperatures.
- The magnetic flux density, B=0.
- The relative permeability, μ_r=0.
- The specific resistant, ρ=0.
- The magnetic susceptibility, X=-1.
- The power (copper) loss, I^2R=0.

Types

On the basis of working Temperature.
i. low temp. super cond.
ii. High temp. super cond.
On the basis of kind of material.
i. metallic super conductor
ii. Inter metallic compound superconductor
iii. Ceramic super conductor.
iv. Alloy super conductors
On the basis of kind of material.
i. magnetic grade super conductor
ii. Nonmagnetic grade super conductor

Superconductivity

- **Superconductivity** is a phenomenon occurring in certain materials at extremely low temperatures, characterized by exactly zero electrical resistance and the exclusion of the interior magnetic field.
- The electrical resistivity of a metallic conductor decreases gradually as the temperature is lowered.
- However, in ordinary conductors such as copper and silver, impurities and other defects impose a lower limit. Even near absolute zero a real sample of copper shows a non-zero resistance.
-

Applications

- Superconducting magnets are some of the most powerful electromagnets known. They are used in MRI and NMR machines and the beam-steering magnets used in particle accelerators.
- They can also be used for magnetic separation, where weakly magnetic particles are extracted from a background of less or non-magnetic particles, as in the pigment industries.

Introduction-BIOMATERIALS

- A biomaterial is any material, natural or man-made, that comprises whole or part of a living structure or biomedical device which performs, augments, or replaces a natural function.

or

- a nonviable material used in a medical device, intended to interact with biological systems

or

- A biomaterial is essentially a material that is used and adapted for a medical application

Biomaterial Applications

- Biomaterials are used in:
- Joint replacements
- Bone plates
- Bone cement
- Artificial ligaments and tendons
- Dental implants for tooth fixation
- Blood vessel prostheses
- Heart valves
- Skin repair devices
- Cochlear replacements
- Contact lenses

- Ti alloy and carbon fiber-X-ray equipments
- Liquid crystal polymer- optical fiber
- Separation membranes- medical and biotechnology.
- High temp. super conductor- medical imagine machine, magnetic resonance imaging (MRI)

Thank You