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كلية العلوم والتكنولوجيا
قسم العلوم والتقنيات

CORE TECHNOLOGY

2nd YEAR MECHANICAL ENGINEERING

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Preface

This handout, intended for students in the 2nd year of the common core of technology, aims to:

- Provide multidisciplinary knowledge using different types of materials; metals and their alloys, ceramics, polymers and composites;

- Allow the student to become familiar with the different shaping techniques (with and without material removal) of materials used in cutting-edge industrial fields (mechanics, aerospace, naval aviation, steel industry, medical, etc.).

The approach of this module is based on the relationships between the structure, microstructure, development, usage properties and manufacturing processes of these materials in the industrial field. It relates the types of bonds and the different levels of structuring of the material with the mechanical properties.

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INTRODUCTION

There are four basic manufacturing processes for producing desired shape of a product. These are casting, machining, joining (welding, mechanical fastners, epoxy, etc.), and deformation processes.

 Casting process exploit the fluidity of a metal in liquid state as it takes shape and solidifies in a mould. It's the primary manufacturing process.

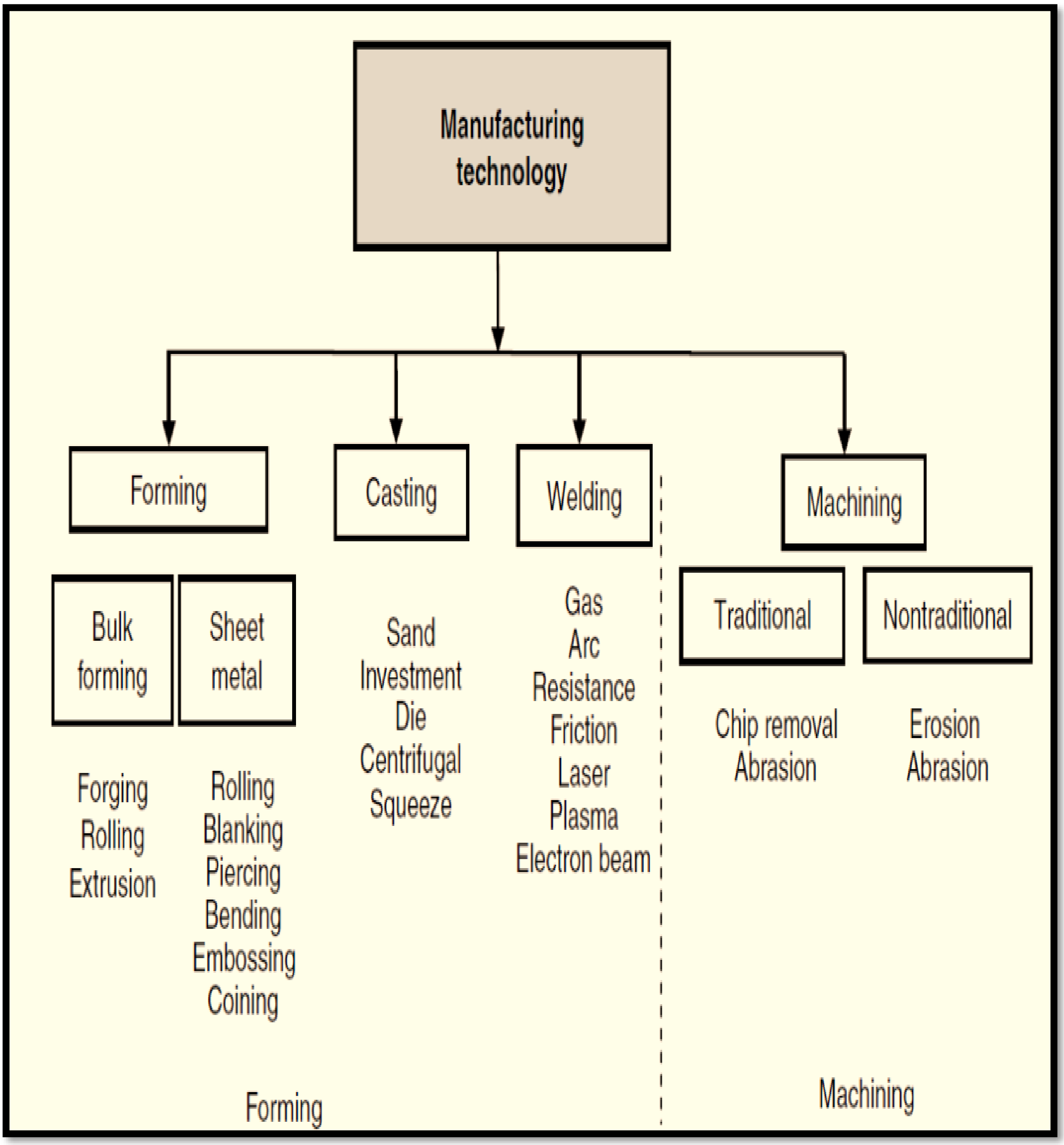
 Machining processes provide desired shape with good accuracy and precision but tend to waste material in the generation of removed portions.

 Joining processes permit complex shapes to be constructed from simpler components and have a wide domain of applications.

 Deformation processes exploit a remarkable property of metals, which is their ability to flow plastically in the solid state without deterioration of their properties. With the application of suitable pressures, the material is moved to obtain the desired shape with almost no wastage. The required pressures are generally high and the tools and equipment needed are quite expensive. Large production quantities are often necessary to justify the process.

Manufacturing is the industrial activity that changes the form of raw materials to create products or in other word manufacturing has been accurately defined as the activities that are performed in the conversion of "stuff" to "useful thing" (product). It is the application of physical and chemical processes to alter the geometry, property and/or appearances of given starting material to make part or product. The derivation of the word manufacture reflects its original meaning: to make by hand. As the power of the hand tool is limited, manufacturing is done largely by machinery today. Manufacturing technology constitutes all methods used for shaping the raw metal materials into a final product. The development of new tool materials opened a new era for the machining industry in which machine tool development took place.

CLASSIFICATION OF MANUFACTURING PROCESSES



Chapter I

MATERIALS

METALS, ALLOYS AND THEIR DESIGNATIONS

1. Generalities :

The choice of material used in industry depends on a number of criteria:

- Mechanical characteristics: yield strength, mass, hardness, impact strength, etc.
- Physical and chemical characteristics: corrosion behaviour, ageing, etc.
- Processing characteristics: machinability, weldability, hardenability, etc.
- Economic characteristics: price, availability, industrial experience, etc.

1.1. Volumic mass

Materials	Steel	Aluminium alloy	Bronze	Nylon	Class Fibre	Carbon Fibre
kg/m^3	7800	2700	8900	1000	2500	1750

1.2. Electrical properties

Type of material	**Resistivity en Ω.m**	**Electrical behaviour**
Polystyrene Nylon Glass	10^{20} 5.10^{12} 10^{17}	*INSULATION*
Ferrous alloys Aluminium Copper	$9{,}8.10^{-8}$ $2{,}8.10^{-8}$ $1{,}7.10^{-8}$	*CONDUCTORS*

1.3. Thermal properties

Type of material	**Conductivity W/(m/K)**	**Thermal behaviour**
Glass wool Concrete Nylon Glass	0.04 1 0.25 1,2	*THERMAL INSULATION*
Iron Aluminium Copper	80 237 390	*THERMO CONDUCTOR*

1.4. Corrosion resistance of some materials

Gold	**Aluminium**	**Stainless steel**	**Copper**	**Zinc**	**Steel**
Less susceptible to corrosion	→	→	→	→	More sensitive to corrosion

2. Standard designation of metals and alloys

The materials used are rarely pure or perfectly homogeneous mixtures, but more often in the form of alloys with standardised designations.

The designation of materials is subject to ‘standards’ which enable a coding system to be adopted for use by manufacturers. These standards are evolving and we need to evolve with them.

There are several types of materials:

- Ferrous metals and alloys
- Non-ferrous metals and alloys
- Plastic materials
- Composite materials
- Other materials

2.1. Ferrous alloys

2.1.1. Steels (standard NF EN 10025)

Steels are alloys of iron and carbon [**Fe + (0.08 to 1.7%) C**], possibly with additional elements:

- General purpose steels (example: **S235 / E360**)
- Tool steels (example: **42Cr Mo 4** / **100 Cr 6**)
- Heat treatment steels (example: **C 50 / 20 Ni Cr 6 / 42 Cr Mo 4**)
- Stainless steels (example: **X 30 Cr 13 / X 5 Cr Ni 18-10**)

Steels classified into two groups:

- Non-alloy steels (ordinary and special steels, etc.).
- Alloy steels (low and high alloy).

A. Job classification / Classification par emploi

The designation begins with the letter ‘**S**’ for general purpose steels and the letter ‘**E**’ for engineering steels, followed by the minimum yield strength value in Mega Pascal (MPa).

Example:

- **S235** (general-purpose steel, yield strength 235MPa)
- **E320** (mechanical engineering steel, yield strength 320MPa)

In the case of cast steel, the letter «**G**» precedes the designation, (example: **GS235**)

B. Classification by chemical composition

- **Non-alloy steels**

They contain a low carbon content; they are widely used in mechanical engineering. Most are available as merchant rolled products (sections, beams, bars, etc.) in standardised sizes.

Application: These steels have been not produced for a specific application.

Designation: The letter '**C**' followed by the percentage of carbon multiplied by 100.

Example: **C 35** (steel with 0.35% of carbon)

- **Low-alloy steels**

For these steels, no additional element reaches 5% by mass.

Application:

They are chosen for their high resistance characteristics.

Designation:

- A number equal to 100 times the carbon content,
- The chemical symbols of the addition elements in order of decreasing content,
- The contents of the main addition elements multiplied by 4, 10, 100 or 1000 (see table below)
- Any additional information concerning weldability (S), mouldability (M) or cold formability (DF).

Example : **35 Cr Mo 4 S**

- Steel with 0.35% of Carbon,
- 1% of chrome,
- Lest than 1% of Molybdenum.
- The letter **S** indicates that this steel can be welded.

Table of chemical and metallurgical symbols Multiplier factor

Elements	Chemical symbol	Metallurgical symbol	Multiplier factor
Aluminium	Al	A	10
Nitrogen	N	N	100
Boron	B	B	1000
Chromium	Cr	C	4
Cobalt	Co	K	4
Copper	Cu	U	10
Magnesium	Mg	G	10
Manganese	Mn	M	4
Molybdenum	Mo	D	10
Nickel	Ni	N	4
Phosphorus	P	P	100
Lead	Pb	PB	10
Silicon	Si	S	4
Sulphur	S	F	100
Titanium	Ti	T	10
Tungsten	W	W	4
Vanadium	V	V	10

- **High-alloy steels.**

High-alloy steels have at least one additive element with a content ≥ **5%** by mass.

Application: These steels are reserved for specific uses.

Example: In a humid environment, we use stainless steel, which is highly alloyed with Chromium (**Cr > 11%**).

Designation:

- The letter « **X** »
- A number equal to **100** times the carbon content,
- Chemical symbols of the addition elements in order of decreasing content,
- In the same order, the levels of the main elements.

Example:

X6 Cr Ni Mo Ti 17-12

- High-alloy steel with **0.06%** of Carbon,
- **17%** of Chromium,
- **12% of Nickel,**
- Molybdenum (< **12%**),
- Titanium (< **12%**).

- **X4 Cr Mo S 18**

- High-alloy steel with **0.04%** of Carbon,
- **18%** de Chromium,
- Molybdenum (< **18%**),
- Sulphur (< **18%**).

2.1.2. Cast iron (Alloy of iron with 1.67% to 4.2% carbon). /

Cast irons are alloys of iron and carbon [**Fe + (1.67% to 4.2%) C**], they have excellent castability. They can there for be used to produce castings with complex shapes. They are must fragile (brittle), difficult to weld and have good machinability.

A. Lamellar graphite cast irons / Les fontes à Graphite Lamellaire

Lamellar graphite cast irons, known as 'grey cast irons', are widely used because they:

– They are economical
– They absorb vibrations well,
– Good castability and machinability,
– Have low oxidation,
– Good resistance to wear caused by friction,

- Good resistance to compressive stress.

Applications : Crankcases, frames, engine blocks, parts with complex shapes, etc...

Designation:

- **EN** : prefix,
- **GJL**: symbol for lamellar graphite cast iron,
- **Number**: designating the value of minimum tensile strength by extension in **MPa** (mega Pascal).

Example :

- **EN-GJL-300**
- Cast iron with lamellar graphite
- Minimum elastic strength: **Re mini = 300Mpa**

B. Spheroidal graphite malleable cast irons

Spheroidal graphite cast irons are obtaining by adding a small quantity of magnesium before casting. They are lighter and have better mechanical strength than grey cast iron.

Applications: Brake callipers, rocker arms, crankshafts, piping subjected to high pressure.

Designation:

- **EN:** prefix,
- **GJMW:** symbol for spheroidal graphite cast iron,
- **Number:** value of minimum tensile strength in MPa.
- **Number:** value representing the percentage of elongation after rupture.

Example:

EN-GJS-400-18

- Spheroidal graphite cast iron

- Minimum elastic strength: **Remini = 400Mpa**
- Elongation: **A% = 18**.

2.2. Non-ferrous alloys

2.2.1. Aluminium and its alloys

Aluminium is obtaining from an ore called Bauxite. It is light (density = 2.7) and a good conductor of electricity and heat. It has low mechanical strength, is ductile and easy to machine. It is highly resistant to corrosion. Application: aerospace, due to its lightweight.

Designation:

The designation uses a numerical code. It may be following by a designation using chemical symbols.

Example:

EN-AW-2017 (Al Cu 4 Mg Si)	Aluminium alloy with 4% Copper, Magnesium and Silicon (less than 4%)

2.2.2. Copper and Copper alloys.

There are many different copper alloys, the best known of which are:

- Bronze,
- Brass,
- Cupro-Aluminium,
- Cupro-Nickel,
- Nickel Silver.

Bronze	**Copper + Etain**
Brass	**Copper + Zinc**
Cupro-Aluminium	**Copper + Aluminium**
Cupro-Nickel	**Copper + Nickel**
Nickel Silver	**Copper + Nickel + Zinc**

Brass is easy to machine and has good corrosion resistance. They can be casting or forged. They are using for turned parts, tubes, etc.

Bronzes have good corrosion resistance, a low coefficient of friction and are easy to cast. They are using to make bearings and friction rings, among other things.

Designation:

This is a numerical code. It may be following by a designation using chemical symbols.

Example:

CW612N (Cu Zn 36 Pb 3)	Copper alloy with 36% Zinc and 3% Lead

Chapter II

PROCESSES FOR OBTAINING PARTS WITHOUT REMOVING MATERIAL

1 - Metal Casting Process

Casting is one of the oldest manufacturing processes. It is the first step in making most of the products for which it's called basic manufacturing process. Steps to be followed for a casting operation:

a) Making mould cavity

b) Liquefy or melt the material by properly heating it in a suitable furnace.

c) Liquid or molten metal is poured into a prepared mould cavity

d) allowed to solidify

e) product is taken out of the mould cavity, trimmed and made to shape

Casting consists of pouring a liquid metal into an impression which flows by gravity or under pressure and which takes the shape of the impression as it solidifies.

More attention should be given on the following for successful casting operation:

(i)Preparation of moulds of patterns

(ii)Melting and pouring of the liquefied metal

(iii)Solidification and further cooling to room temperature

(iv) Defects and inspection

Advantages of casting process:

- Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized.

- Possible to cast both ferrous and non-ferrous materials

- Tools are very simple and expensive

- Useful for small lot production

 Weight reduction in design

 No directional property

• There are certain parts (like turbine blades) made from metals and

alloys that can only be processed this way. Turbine blades: Fully casting + last machining.

• Size and weight of the product is not a limitation for the casting process.

Limitations:

 Accuracy and surface finish are not very good for final application

 Difficult to remove defects due to presence of moisture

 Metal casting is a labour intensive process

 Automation: a question

Casting Notes :

- The melting temperature of the cast metal must be lower than the melting temperature of the material constituting the mold.
- A metal mold is called a “shell.”
- Casting makes it possible to obtain complicated parts economically.
- Cast iron is more moldable than steel. Molten cast iron is more fluid than molten steel. The

stages of molding:

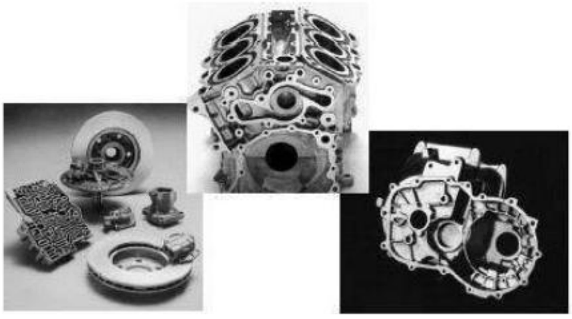
1. Melt the metal

2. Pour it into the mold

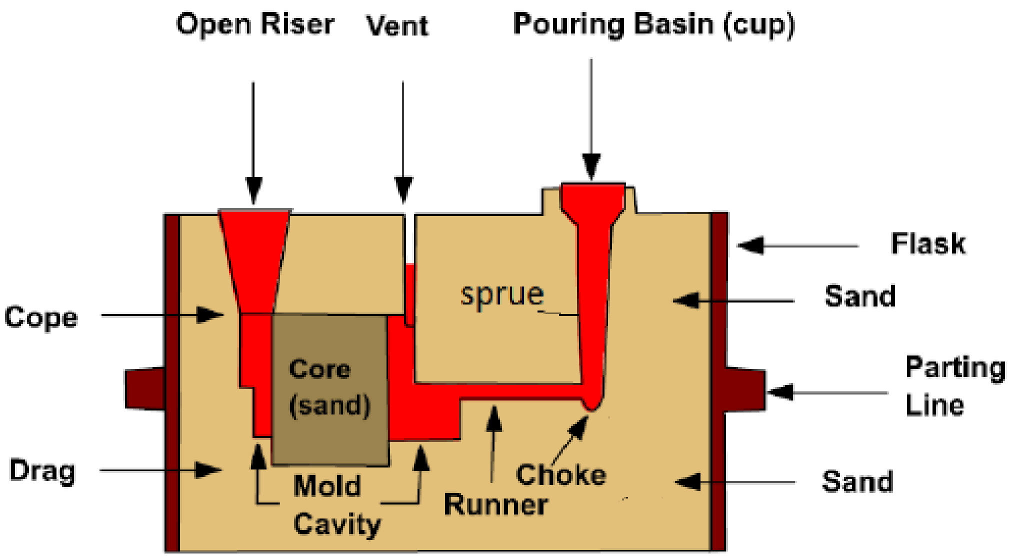
3. Let it cool

Applications:

Cylindrical bocks, wheels, housings, pipes, bells, pistons, piston rings, machine tool beds etc.



Typical sand mould



Mould Section and casting nomenclature

links: https://www.youtube.com/watch?v=3DesU9GqtWU
https://www.youtube.com/watch?v=ePBotA2MTVg
https://www.youtube.com/watch?v=M95bhPrDwA0

Important casting terms

Flask: A metal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as:

drag – lower moulding flask,

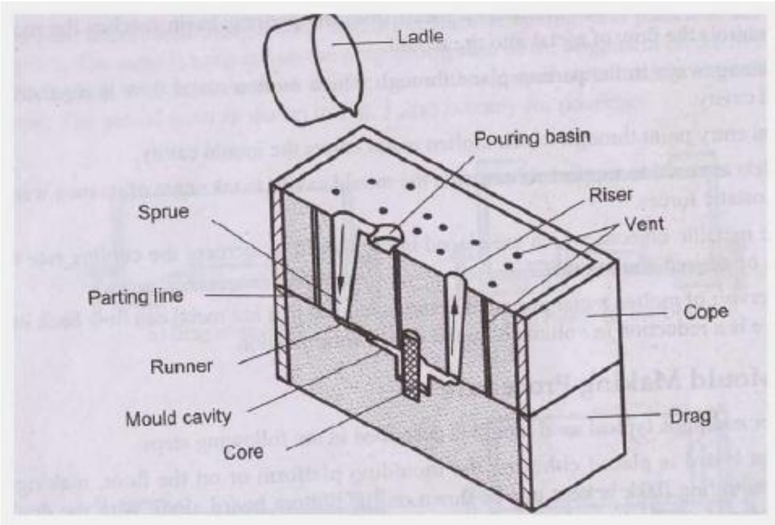
cope – upper moulding flask,

cheek – intermediate moulding flask used in three piece moulding.

Pattern: It is the replica of the final object to be made. The mould cavity is made with the help of pattern.

Parting line: This is the dividing line between the two moulding flasks that makes up the mould.

Moulding sand: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.



Sand mould ready for pouring

Facing sand: The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings.

Bottom board – Board used to start mould making (wood)

Backing sand – used and burnt sand

Core: A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.

Pouring basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured.

Sprue: The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of metal into the mould.

Runner: The channel through which the molten metal is carried from the sprue to the gate.

Gate: A channel through which the molten metal enters the mould cavity.

Chaplets: Chaplets are used to support the cores inside the mould cavity to take care of its own weight and overcome the metallostatic force.

Riser: A column of molten metal placed in the mould to feed the castings as it shrinks and solidifies. Also known as "feed head".

Vent: Small opening in the mould to facilitate escape of air and gases.

Steps in making sand castings:

The basic steps in making sand castings are,

(i) Pattern making,

(ii) Core making,

(iii) Moulding,

(iv) Melting and pouring,

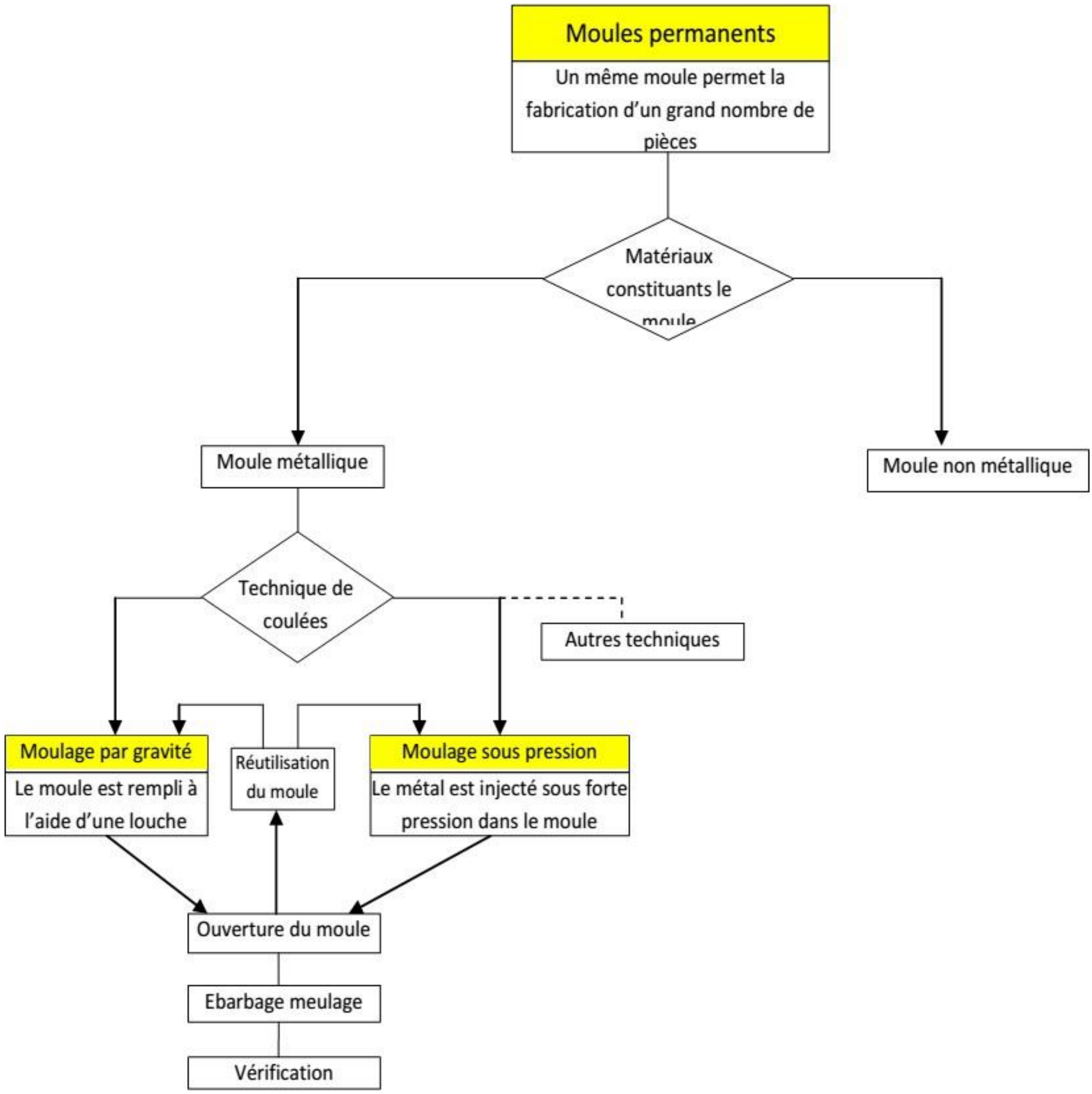
(v) Cleaning

1.1 Castings techniques

There are two casting techniques:

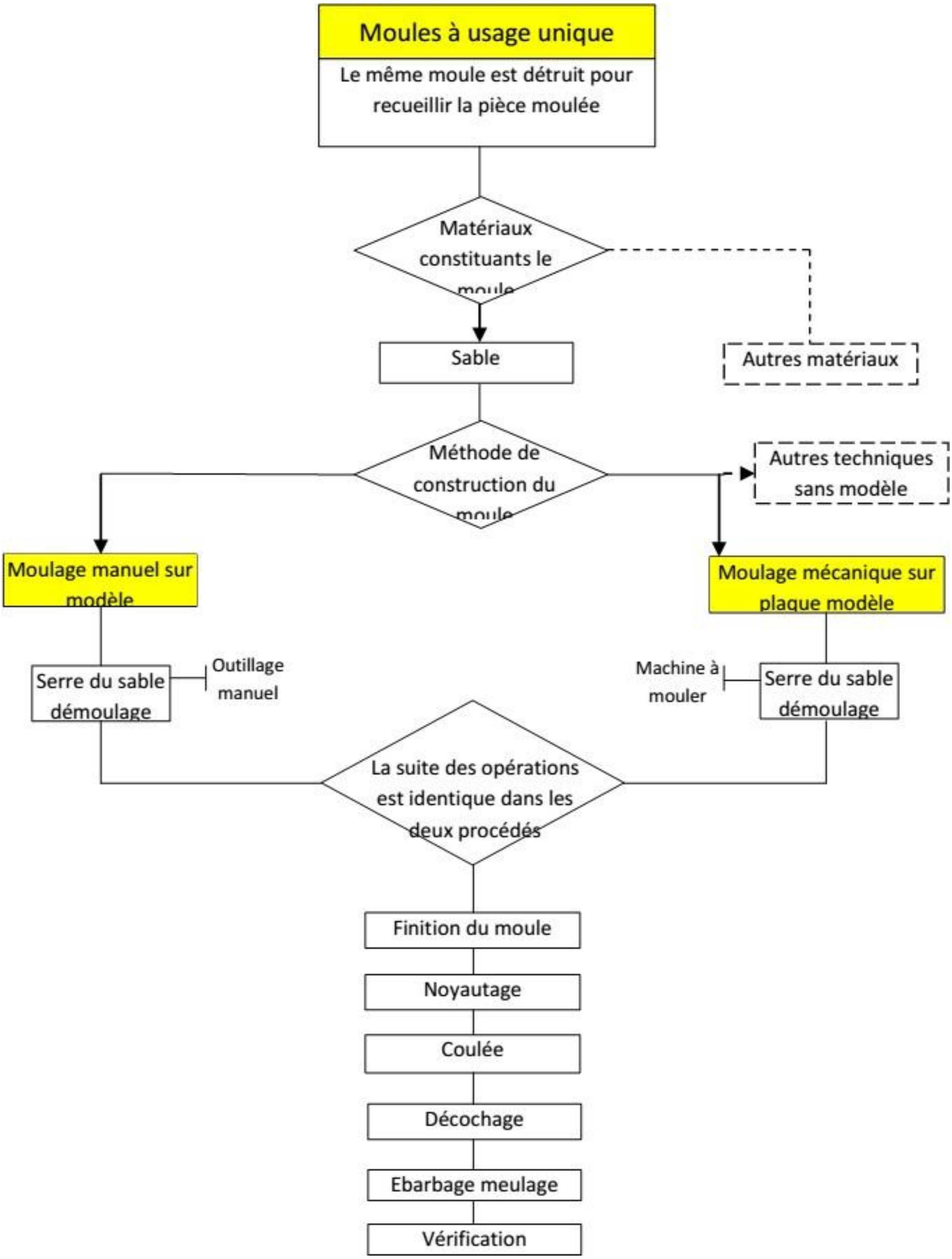
- **With permanent molds**
- **With single-use molds**

1.1.1 With permanent molds



Molding flowchart with permanent molds

1.1.2 With single-use molds



Flowchart of molding with single-use molds

2 - Bending (Rolling):

Bending (rolling) consists of bending a flat sheet. A sheet of metal is deformed to arrive at a conical or cylindrical part of revolution. This is done by tools which are cylinders with the same profile as the part to be deformed in various numbers and arrangements around the part.

https://www.youtube.com/watch?v=FLEf0jHO9Co

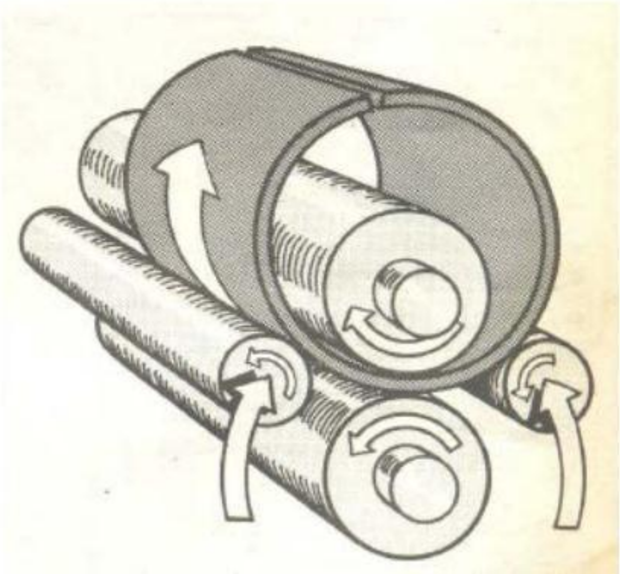


Fig.02. Principle diagram of bending

3- Pushing on the lathe

It consists of pressing a sheet of metal (the blank) against a form (the mandrel) using a tool. The blank and the mandrel are rotated by the lathe.

https://www.youtube.com/watch?v=-IiIW40eCIU

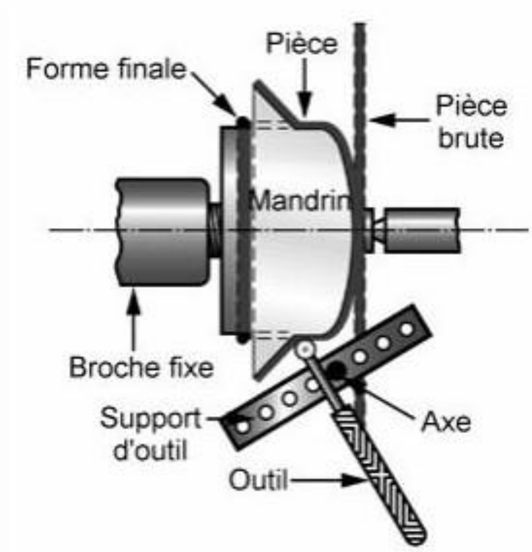


Fig.03. Schematic diagram of the lathe turning

3 – Rolling

Rolling is a manufacturing process by plastic deformation. It concerns different materials such as metal or any other material in pasty form such as paper. This deformation is obtained by continuous compression when passing between two counter-rotating cylinders called rolling mills1. A rolling mill is an industrial installation whose purpose is to reduce the thickness of a material (usually metal). It also allows the production of profiled bars (long products).

Laminage à froid de tôle fine
(document SANDVIK)

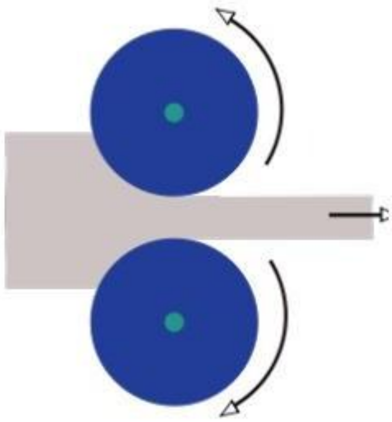


Fig.04. Operating diagrams (Rolling)

https://www.youtube.com/watch?v=TzmoFn9p5fg

5- Wire drawing:

The wire rod obtained by rolling operations is an intermediate product, especially in the manufacture of electric cables, whose wire must have a smaller diameter. The operation which allows the reduction of the wire diameter is called wire drawing, the wire drawing machine is called a wire drawing machine. The principle of wire drawing is to use the plasticity of the metal to reduce the diameter of the wire, by passing it through a calibrated orifice, called a die under the combined effect of applying a tensile force **T** and a radial compression force **P.** The die constitutes the fundamental element of the wire drawing operation. The shape which should be given to it has been the subject of numerous theoretical and experimental works. It consists of a hard-core **A,** generally made of tungsten carbide or diamond, hooped into a steel frame **B.**

https://www.youtube.com/results?search_query=Le+tr%C3%A9filage+

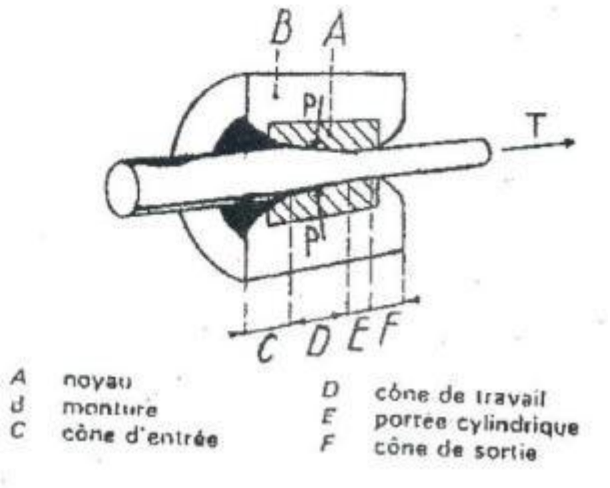


Fig.05. Profile of a die

Fig.06. Wire drawing machine

6 . The cutting

6.1 . Stamping

Stamping is a shaping process widely used in industry, allowing the production of parts with a non-developable surface from thin sheet metal, mounted on a press. The sheet metal, called a "blank", is the raw material which has not yet been stamped. The operation can be carried out with or without a blank clamp to hold the blank against the die while the punch deforms the sheet.

https://www.youtube.com/watch?v=uOepuKgVqxY

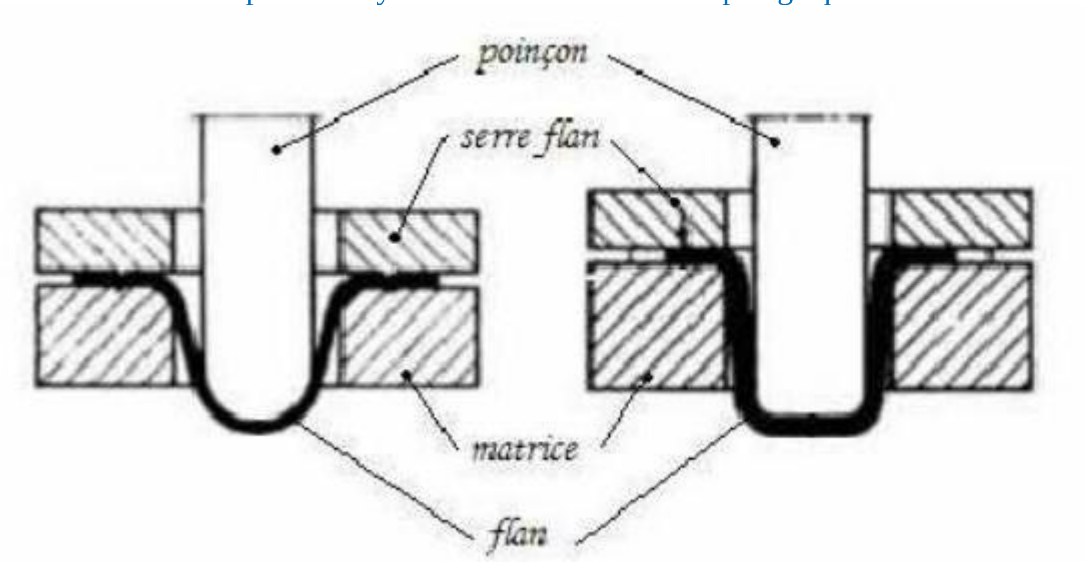


Fig.07. Schematic diagram of stamping

6.2 Waterjet cutting

The principle of this technology, which originated in the 1960s and was initiated by a certain Doctor Norman Franz, consists of projecting a stream of water at a very high speed, between 600 and 900 metres per second, through a nozzle with a small diameter, between 0.05 and 0.5 mm. The diameter of the water jet that will come into contact with the material to be cut corresponds to the diameter of the nozzle. In order to cut the material, the pressure of the jet must be able to reach up to 4000 bars. The material is cut by tearing off the material. For more difficult or harder materials, an abrasive is added to the water jet.

https://www.youtube.com/watch?v=4T2FRFFn_2c

Using this technique

- *Metal cutting*
- *Cutting of minerals, glass, ceramics*
- *Cutting of food products*
- *Cutting of plastics, rubbers, composites*
- *Cutting of textiles, papers, cardboards, leathers*
- *Descaling, cleaning of turbines*

- *Ship hull stripping*
- *Nuclear decontamination*
- *Demolition, drilling and cutting in buildings*

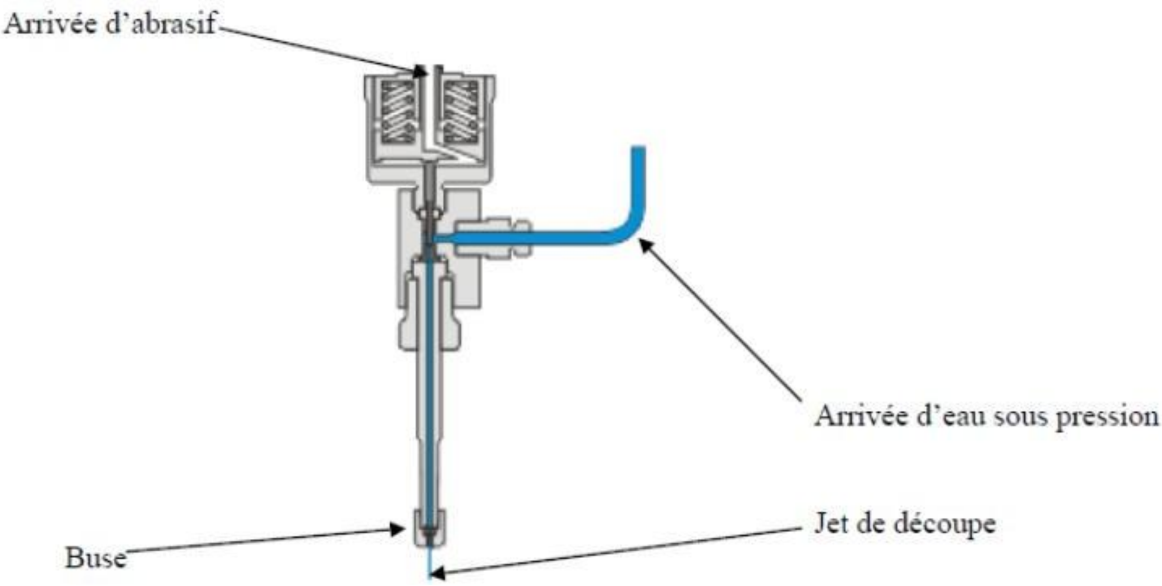


Fig.08. Water cutting operating diagram

6.3 . Laser cutting

Laser, like oxycutting, is a thermal cutting process. The laser source emits a light beam that is focused (concentrated) in an optical system (focal length) according to the principle adopted in a camera. The power thus obtained can reach up to 10,000 kilowatts per square centimeter.

The high thermal power leads to rapid melting and then partial or total evaporation of the material. A gas flow envelops the light beam, expelling the molten material from the cutting slot (kerf). Laser cutting can be divided into two sub-processes:

- Sublimation cutting: the material evaporates under the effect of heat. This process is used for metals as well as other materials such as wood, ceramics or plastics.

- Fusion cutting: the material melts under the effect of heat and is expelled using a gas jet. This process is used for stainless steels or non-ferrous metals. This process allows higher cutting speeds than with sublimation cutting. Laser cutting has many advantages, high cutting speed, high power limited to a heat-affected zone, low deformation, high precision of the order of 1/10th of a mm.

https://www.youtube.com/shorts/DynuQJZ_AKs

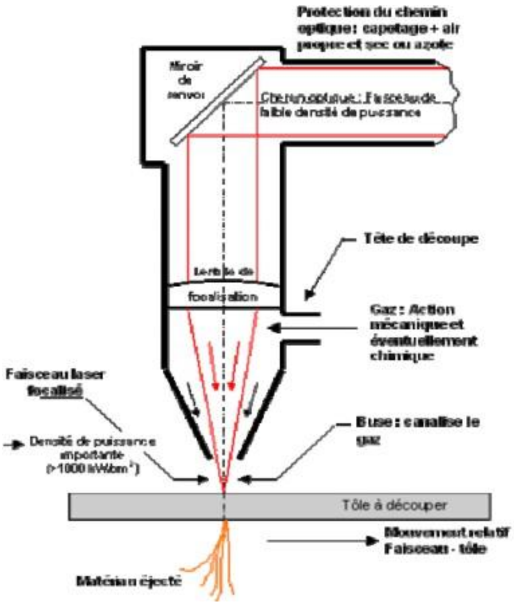


Fig.09. Schematic diagram

7- Folding

Bending is a shaping process without removing material, allowing sheet metal to be bent by a punch in a die. It is a bending of very small radius obtained by a localized bending force.

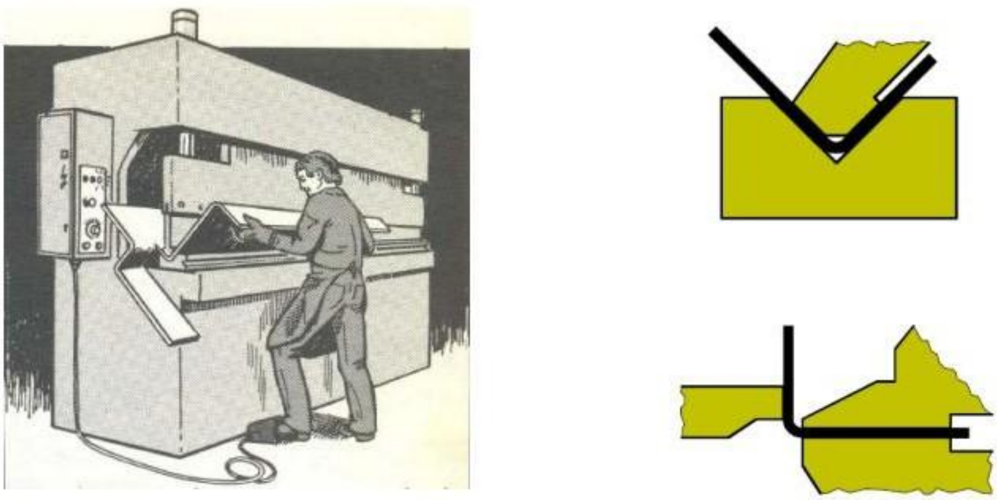


Fig.10. Diagrams of mechanical actions

https://www.youtube.com/watch?v=heRUo6yw2vs

8- Sintering and powder metallurgy

Sintering is a process for manufacturing parts that involves heating a powder without melting it. Under the effect of heat, the grains weld together, which forms the cohesion of the part. The best-known case is that of pottery firing.

It makes it possible to obtain hard but fragile materials, with controlled porosity, chemically inert (low chemical reactivity and good resistance to corrosion) and thermally.

It allows the dimensions of the parts produced to be controlled: as there is no change in state, variations in volume and dimensions are not very significant compared to melting (no shrinkage phenomenon).

In powder metallurgy, sintering is a process that allows mechanical parts or other objects to be produced from more or less fine powders. First, these powders are agglomerated by various processes to form a preform, which is then heated to acquire a certain cohesion.

Sintering can be carried out with or without binder, on very diverse materials.

https://www.youtube.com/watch?v=c3YszEPIc7Y

9- Forging

Forging is a manufacturing process involving the shaping of metal using localized compressive force. The blows are delivered with a hammer (often a power hammer) or a die. Forging is often classified according to the temperature at which it is performed:

- Cold forging (performed at room temperature)
- Warm forging (performed at elevated room temperature)
- Hot forging (a type of hot working)

Application:

- Crankshaft and Connecting rod for I.C. Engines
- Turbine disc, gear wheel, bold head, hand tools
- Many types of structural components

Benefits of forging:

- 1. It improves the structure as well as mechanical properties of the metallic parts.
- 2. Forged components can withstand unpredictable load.
- 3. Forged parts are consistent in shape with the minimum presence of voids and porosities.
- 4. Forging can produce parts with high strength to weight ratio.
- 5. Forging processes are very economical for moderate to high volume productions.

Drawbacks of forging:

- 1. Initial cost of dies and the maintenance cost are high
- 2. In hot forging, due to high temperature, there is rapid oxidation on the surface resulting poor finish
- 3. Forging are usually costlier than casting
- 4. Forging operations are limited to simple shape

Classification of forging

1. smith forging
2. drop forging
3. press forging
4. machine forging

1: Smith forging

This is the traditional forging operation done openly or in-openly dies by the village black smith or modern shop floor by manual hammering or by the power hammer. The process involves heating the stock in the black smith hearth and then beating it over the anvil. To get the desire shape the operator has to manipulate the component in between the blows. The types of operation available are fullering, flattering, bending, upsetting and swaging.

2: Drop forging

This is the operation done in closed impression dies by means drop hammer here the force for shaping the component is applied in a series of blows.

Drop forging utilizes a closed impression die to obtain the desire shape of the component, the shaping is done by the repeated hammering given to the material in the die cavity. The equipment use for delivering for blows are called drop hammers. The drop forging die consists of two halves. The lower halve of the die is fixed to the anvil of the machine, while the upper halve is fixed to ram. The heated stock is kept in the lower die, while the ram delivers 4-5 blows on the metal spreads and completely fills in the die cavity. When the two die of halves closed the complete is formed. The typical products obtained in drop forging are cranks, crank shaft, connecting rods, wrench, crane hooks etc. The types of operations are fullering, edging, bending, blocking, finishing and trimming etc.

3: Press forging

Similar to the drop forging, the press forging is also done in closed impression dies with the expectation that the force is continuous squeezing type applied by the hydraulic press. Press forging dies are similar to drop forging dies as also the process in press forging, the metal is shaped not by means of a series of blows as in drop forging, but by means of a single continuous squeezing action. This squeezing is obtained by means of hydraulic presses. Because of the continuous action of by hydraulic presses, the material gets uniformly deform throughout its entire depth, the press forging dies with the various impression, such as fuller, bender and finisher impression properly arranged.

4: Machine forging:

Unlike the press or drop forging where the material is drawn out, in machine forging the material is only upset to get the desire shape. As it involves the upsetting operation some time it is simply called as upset forging. Originally this was developed for making bolts head in a continuous fashion, but now there are fairly large number of diverse. Uses of this process: Because of the beneficial grain flow obtain from upsetting. It is used for making gears, blanks, shafts, excels, and similar parts. Upsetting machine called up setter are generally horizontal acting. The die set consists of die and corresponding punch or a heading tool. The die consists of two parts, one called the stationary gripper die which is fixed to the machine frame and the other movable gripper die which moves along with the die slide of the up setter. The stock is held then between these two grippers dies.

10. Die-cutting and stamping

Die-forging and stamping are two synonymous terms. It is a mechanical manufacturing process carried out by presses on which "dies" are fixed. It allows the production of large series of parts.

Forging by die-forging consists of forming by plastic deformation after heating raw parts made of alloys such as steel, aluminum, copper, titanium, nickel, etc.

Two dies are used, a movable upper one and a fixed lower one. The dies hollow out the shape of the part. The “slug” part is compressed between two dies. The shaping is done by impacts between the two dies. The excess metal is cut into a burr in the recess provided for this purpose. The burr is then cut off following the contour of the part.

Die-cast parts have remarkable mechanical characteristics: due to the significant and rapid plastic deformations involved, die-casting refines the structure and allows the orientation of the fibers; this gives die-cast parts high general characteristics, in particular, high fatigue resistance. Dies must ensure:

- *Joint plane*
- *Extra thickness during machining*
- *3°-7° clearance*

https://www.youtube.com/watch?v=Qaajq_FORhM

Chapter III

MATERIAL REMOVAL PROCESSES

Material Removal Processes–Metal Cutting Process

A family of shaping operations, the common feature of which is removal of material from a starting work parts the remaining part has the desired geometry

- Traditional Process (Machining)–Material removal by a sharp cutting tool, e.g., turning, milling, drilling
- Nontraditional Processes-Various energy forms other than sharp cutting tool to remove material. e.g., Laser and Electron Beam machining
- Abrasive processes–Material removal by hard, abrasive particles, e.g., grinding

Machining by material removal consists of progressively reducing the dimensions of the part by removing the metal cold and without deformation using a tool. The quantity of material removed is called chips and the instrument with which the material is removed is called a cutting tool. The operator uses machines called machine tools to carry out the machining of a part.

Why Machining is Important

- Variety of work materials can be machined
- Most frequently used to cut metals
- Variety of part shapes and special geometric features possible, such as:
  - Screw threads
  - Accurate round holes
- Very straight edges and surfaces
- Good dimensional accuracy and surface finish

Disadvantages with Machining

- Wasteful of material: Chips generated in machining are wasted material, at least in the unit operation
- Time consuming: A machining operation generally takes more time to shape a given part than alternative shaping processes, such as casting, powder metallurgy, or forming

Machining in Manufacturing Sequence: Generally performed after other manufacturing processes, such as casting, forging, and drawing

- Other processes create the general shape of the starting work part
- Machining provides the final shape, dimensions, finish, and special geometric details that other processes cannot create.

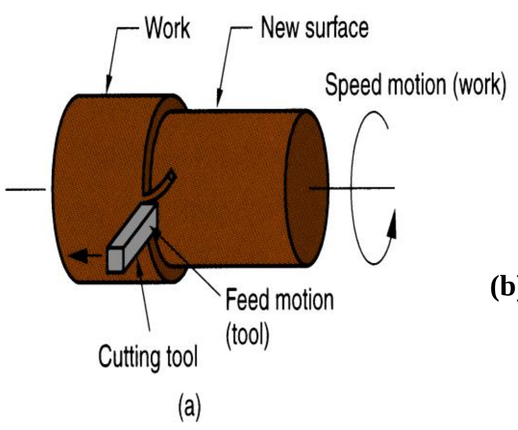
Machining Operations:

- Most important machining operations: Turning, Drilling, Milling
- Other machining operations: Shaping and planning, Broaching, Sawing

1- The Turning

Turning is a mechanical manufacturing process by cutting (removal of material) using single point cutting tool to removes material from a rotating work piece to form a cylindrical shape. It is carried out on machine tools called lathes.

During turning, the part rotates around its axis "Cutting movement", while the tool engages its surface to a determined depth "Penetration movement". The tool is driven by a continuous feed movement parallel or perpendicular to the axis of the part.



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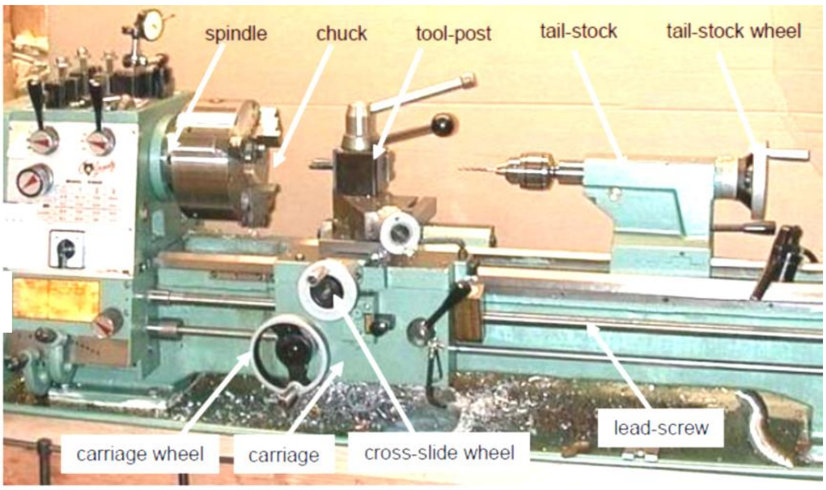


Fig 1. (a) Turning (b) A manual lathe with its important parts labeled

1.1 Turning operations:

Turning: to remove material from the outside diameter of a workpiece to obtain a finished surface.

Facing: to produce a flat surface at the end of the workpiece or for making face grooves.

Boring: to enlarge a hole or cylindrical cavity made by a previous process or to produce circular internal grooves.

Drilling: to produce a hole on the work piece.

Reaming: to finishing the drilled hole.

Threading: to produce external or internal threads on the work piece.

Knurling: to produce a regularly shaped roughness on the workpiece.

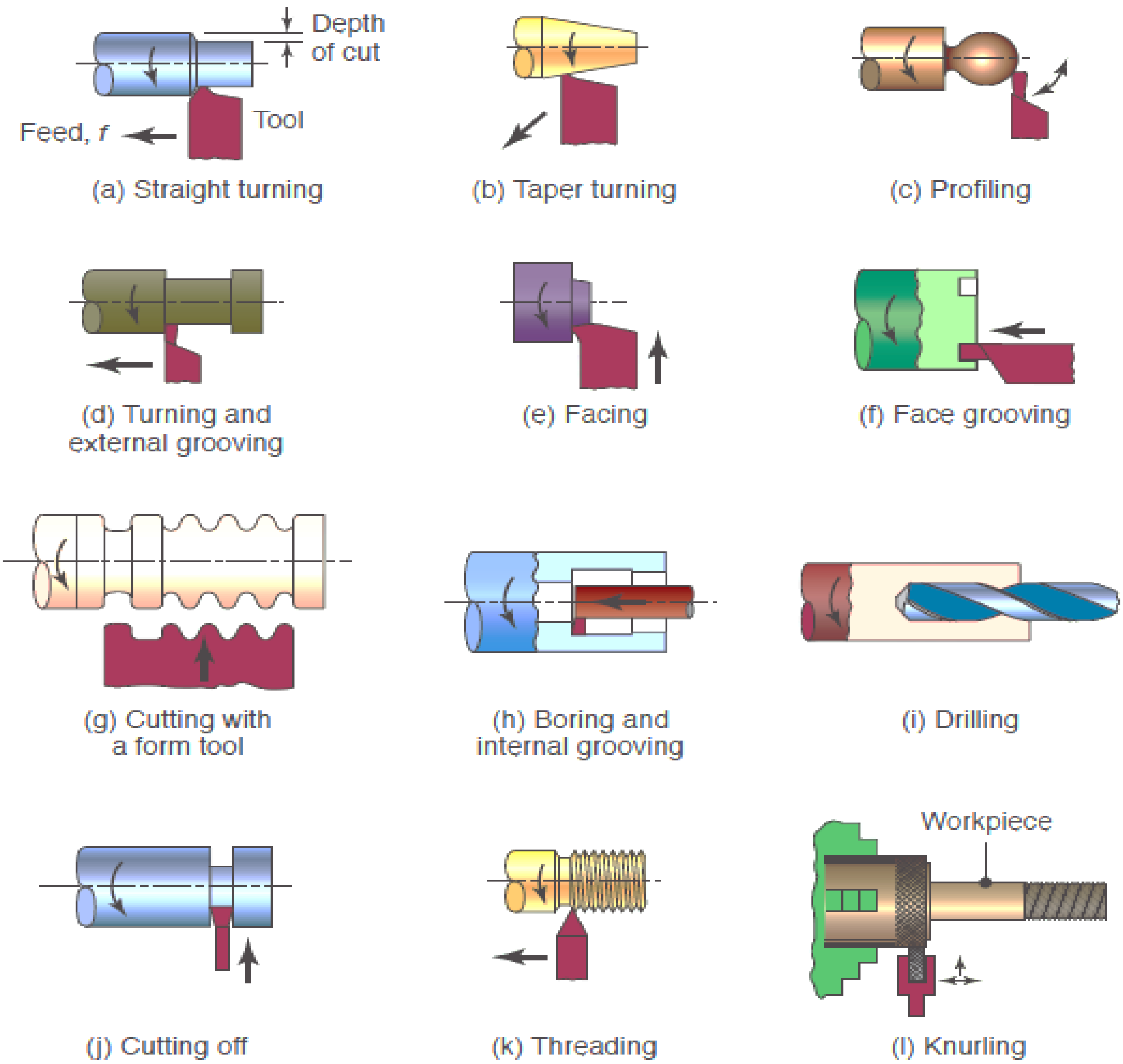


Fig.2. Principle Turning operations

a) Straight turning

b) Taper turning

c) Profiling

d) Turning and external grooving

e) Facing

f) Face grooving

g) Cutting with a form tool

h) Boring and internal grooving

i) Drilling

j) Cutting off

k) Threading

l) Knurling

2- The drilling

Used to create a round hole, usually by means of a rotating tool (drill bit) with two cutting edges. The term drilling covers all methods for making cylindrical holes in a workpiece using cutting tools by removing chips. In addition to short hole drilling and deep hole drilling, this concept also includes various subsequent machining operations, such as broaching, boring, reboring and some forms of finishing such as sizing and roller burnishing.

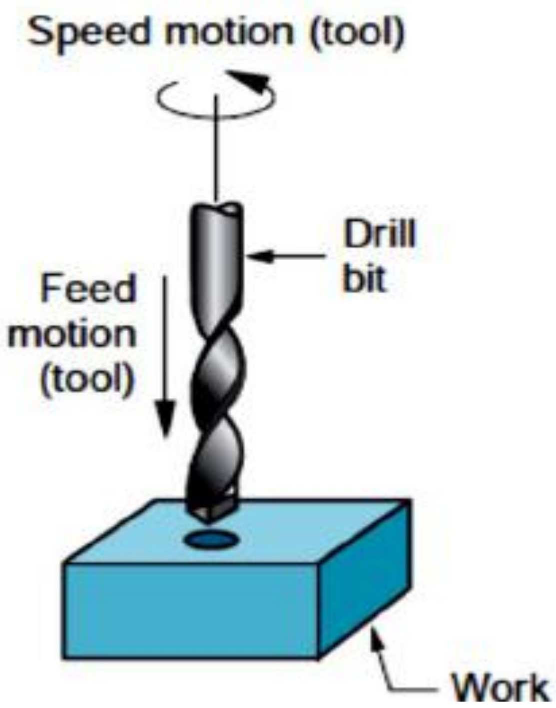


Fig.3. The drill bit

Fig.4. The Drilling

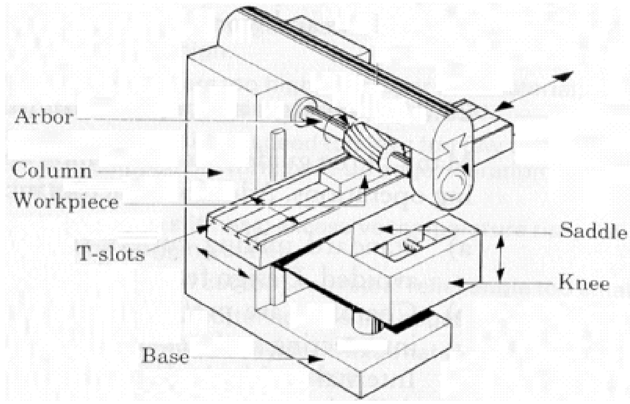
3- Milling

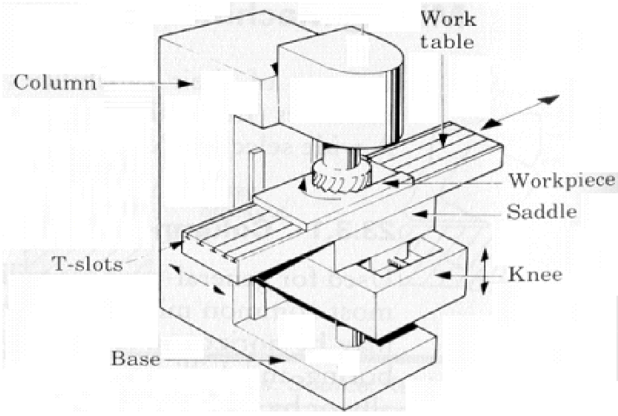
3.1 Definition: Milling is a machining process by removing material. It is characterized by the use of a machine tool called a milling machine and the use of a special cutting tool called a *milling cutter with* cutting edges called "teeth" moved across work to cut a plane or straight surface.

A milling cutter is a tool with multiple cutting edges:

- The “milling cutter” tool rotates: this is the rotational movement (MR)
- The part moves horizontally: feed movement (FM)
- The “cutting motion” results from the combination of the rotational motion and the feed motion. The “depth of cut” is set by the movement of the part (MP).

3.2. Principle Milling operations





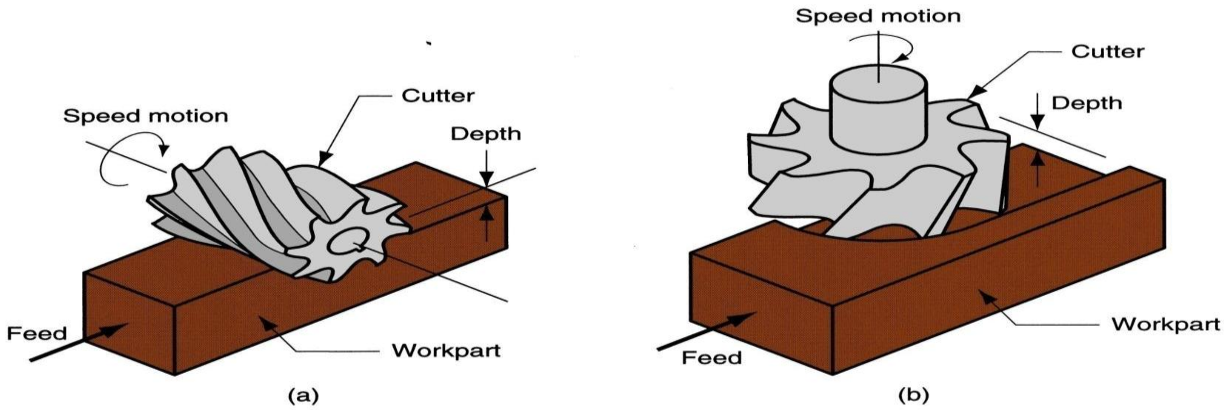


Fig 5. (a) peripheral milling on a horizontal mill (b) Face milling on a vertical mill

- **Peripheral milling**
    - Cutter axis is parallel to surface being machined
    - Cutting edges on outside periphery of cutter
- **Face milling**
    - Cutter axis is perpendicular to surface being milled
    - Cutting edges on both the end and outside periphery of the cutter

4- Shaping and Planing

Similar operations both use a single point cutting tool moved linearly relative to the work part in low cutting speeds due to start-and-stop motion. A straight, flat surface is created in both operations.

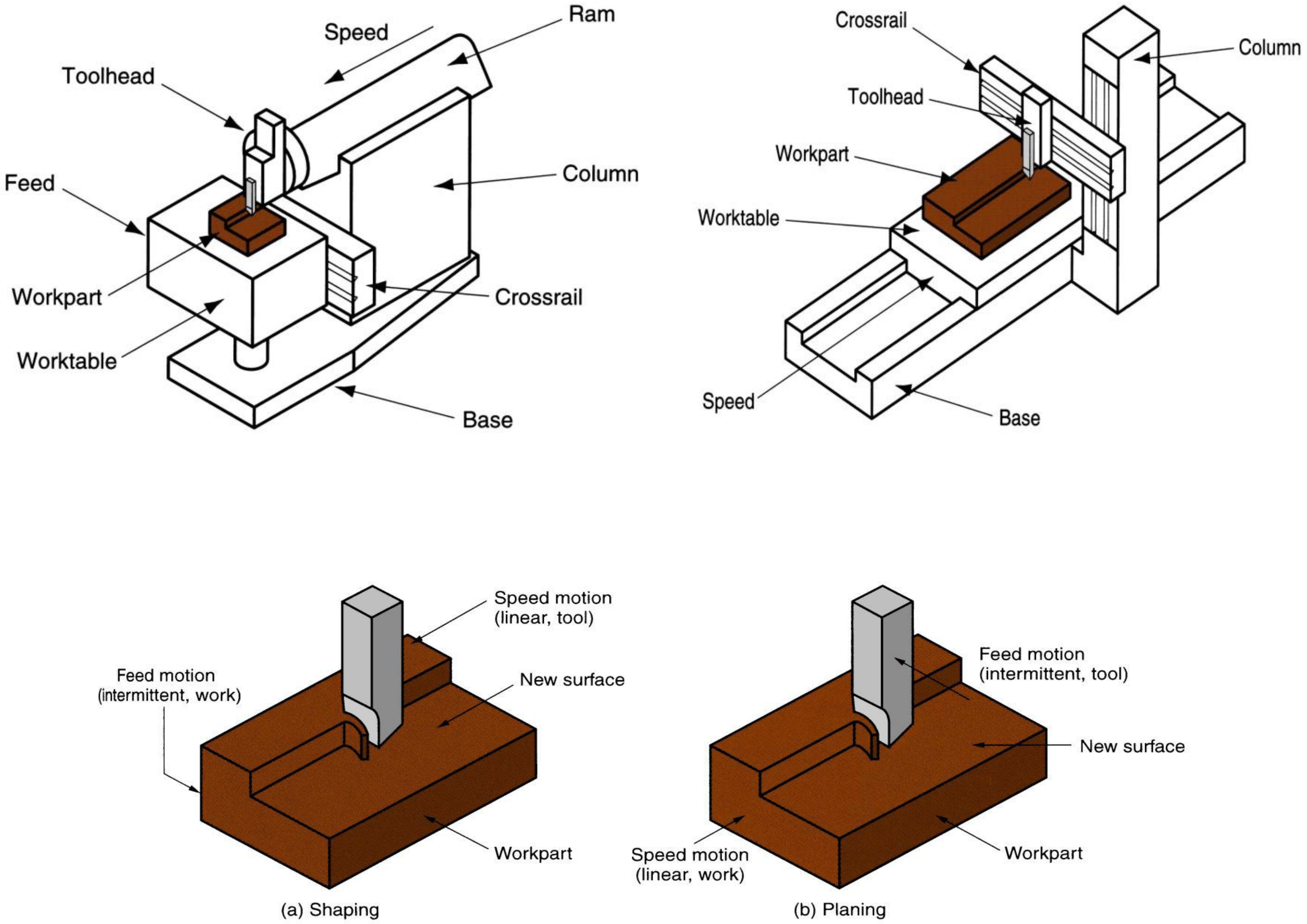


Fig.6 (a) Shaping, and (b) planing

5. Broaching

Broaching is capable of mass-production of complex geometry parts, especially when complicated hole-shapes are required to be machined. The broach tool has a series of cutting teeth along the axis of the tool. As the broaching tool is pulled with force along the part to be cut, each tooth cuts a tiny chip. Thus, the first few sets of teeth to engage the part remove most of the material, which the last few provide a finishing cut with very small amount of material removal. The geometric shape of the last set of teeth is identical to the required geometry of the designed part.

(a)

(b)

Fig. 7(a) Broaching machine, (b) images of broaching tools

6- The Grinding processes

Grinding is a material removal process in which abrasive particles having sharp edges are bonded to form a grinding wheel that operates at very high surface speeds.

The cutting tool used is an abrasive wheel having many numbers of cutting edges. The machine on which grinding the operation is performed is called a grinding machine. Grinding is done to obtain very high dimensional accuracy and better appearance. The accuracy of grinding process is 0.000025mm. The amount of material removed from the work is very less.

6.1. Grinding machine operations

The process of grinding is the operation of removing excess material from metal parts by a grinding wheel made of hard abrasives. The following operations are generally performed in a grinding machine.

1. Cylindrical grinding
2. Taper grinding
3. Gear grinding
4. Thread grinding

6.1.1 Cylindrical grinding

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

The upper table of the grinding machine is set at 0° during the operation.

6.1.2 Taper grinding

Taper grinding on long workpieces can be done by swivelling the upper table. If the workpiece is short, the wheel head may be swivelled to the taper angle. Another method of grinding external taper is to adjust the face of the grinding wheel by a diamond tool dresser to the required angle. In this case, the table and the wheel head are not swivelled.

6.1.3 Gear grinding

The teeth of gears are ground accurately on gear grinding machines for their shape. Gear grinding is done by the generating process or by using a form grinding wheel. The generating process makes use of two saucer shaped grinding wheels. These wheels are used to grind two faces of successive teeth.

6.1.4 Thread grinding

Thread grinding machines are used to grind threads accurately. The grinding wheel itself is shaped to the thread profile. These formed grinding wheels have one or multi threads on them. Surface, cylindrical and form grinding intended for the production of high-quality mechanical parts. As for cutting and sharpening, these applications are mainly oriented towards the production of cutting tools. However, the quality criteria are also the same geometric and metallurgical qualities. Abrasive machining mainly uses grinding wheels and abrasive belts.

Fig.8. Cylindrical grinding machine

Fig.9. Sharpening

7- Sawing

Sawing is used to cut the correct sized workpiece from a large raw material stock. There are several types of saws (Figure 10):

- Hacksaws: straight blade, moving in a reciprocating motion;
- Bandsaws: straight blade, ends welded together to make a loop, moving continuously in one direction;
- Circular saws: blade in the shape of a circular disk, rotating continuously.

This is a process that allows profiles (round, square, flat tubes, etc.) to be cut using a blade, causing the part to be separated into two parts. Modern automatic saws allow several options, the most common of which are adjusting the blade speed, lubrication, and adjusting a cutting angle. Lubrication is strongly recommended to prevent overheating and premature wear of the teeth.

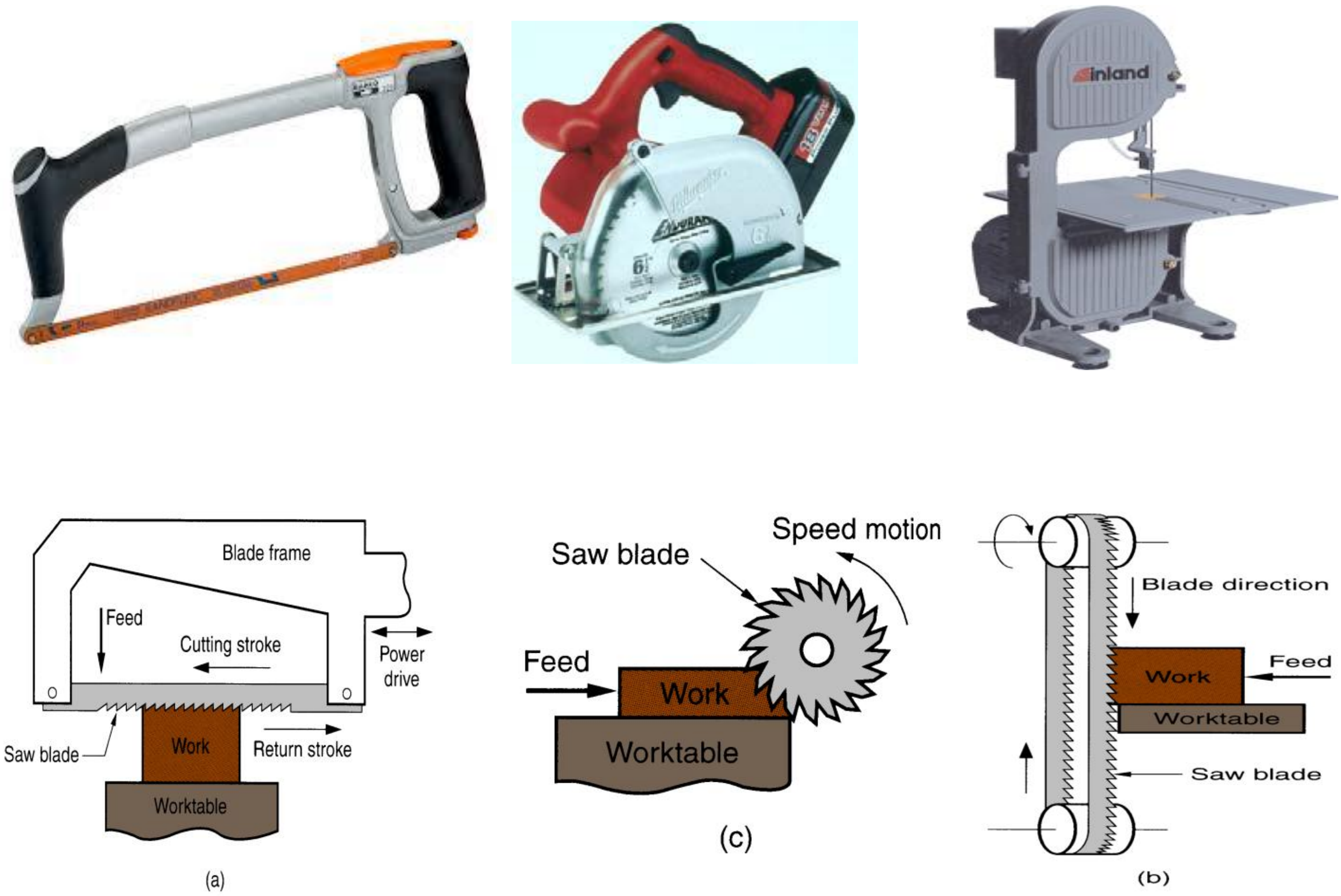


Fig. 10. sawing operations: (a) power hacksaw (b) circular saw (c) bandsaw (vertical)

7.1 Hand saw: It is a tool that allows you to manually saw pieces. A frame composed of a handle and a blade and a system that allows the tension of the blade.

7.2 Band saw: It is an automatic or semi-automatic machine. The operator lowers the blade manually in the case of a semi-automatic saw.

7.3 circular saws: It is also an automatic or semi-automatic saw, whose blade will exert a reciprocating motion, as opposed to band saws which provide continuous unwinding.

Chapter IV

JOINING
&
ASSEMBLY PROCESSES

1. Classification of Joining Processes

Joining is an all-inclusive term covering processes such as welding, brazing, soldering, adhesive bonding, and mechanical fastening. Some important aspect of manufacturing and assembly operations:

1. Simple product may be impossible to manufacture as a single piece

2. The product is easier and more economical to manufacture as individual components.

3. Products need to be designed to be able to be taken apart for maintenance or replacement of their parts

4. Different properties may be desirable for functional purposes of the product

5. Transporting the product in individual components and assembling them later

- Joining processes fall into three major categories:

1. ***Welding***

2. ***Adhesive bonding***

3. ***Mechanical fastening***

- Welding processes are classified into 3 categories:

1. Fusion welding

2. Solid-state welding

3. Brazing and soldering

All joining processes can be categorized based on the type of joint produced under two categories:

A. **Permanent Joint**

B. Temporary joint

Permanent Joint: the joint is made such that it has the properties similar to the base metal of the two parts. Also, permanently joined parts cannot be separated in to their original shape, size and surface finish.

A temporary joint can be easily dismantled separating the original parts without any damage to them.

All the joining processes can also be categorized under five headings, based on the process used for making the joint,

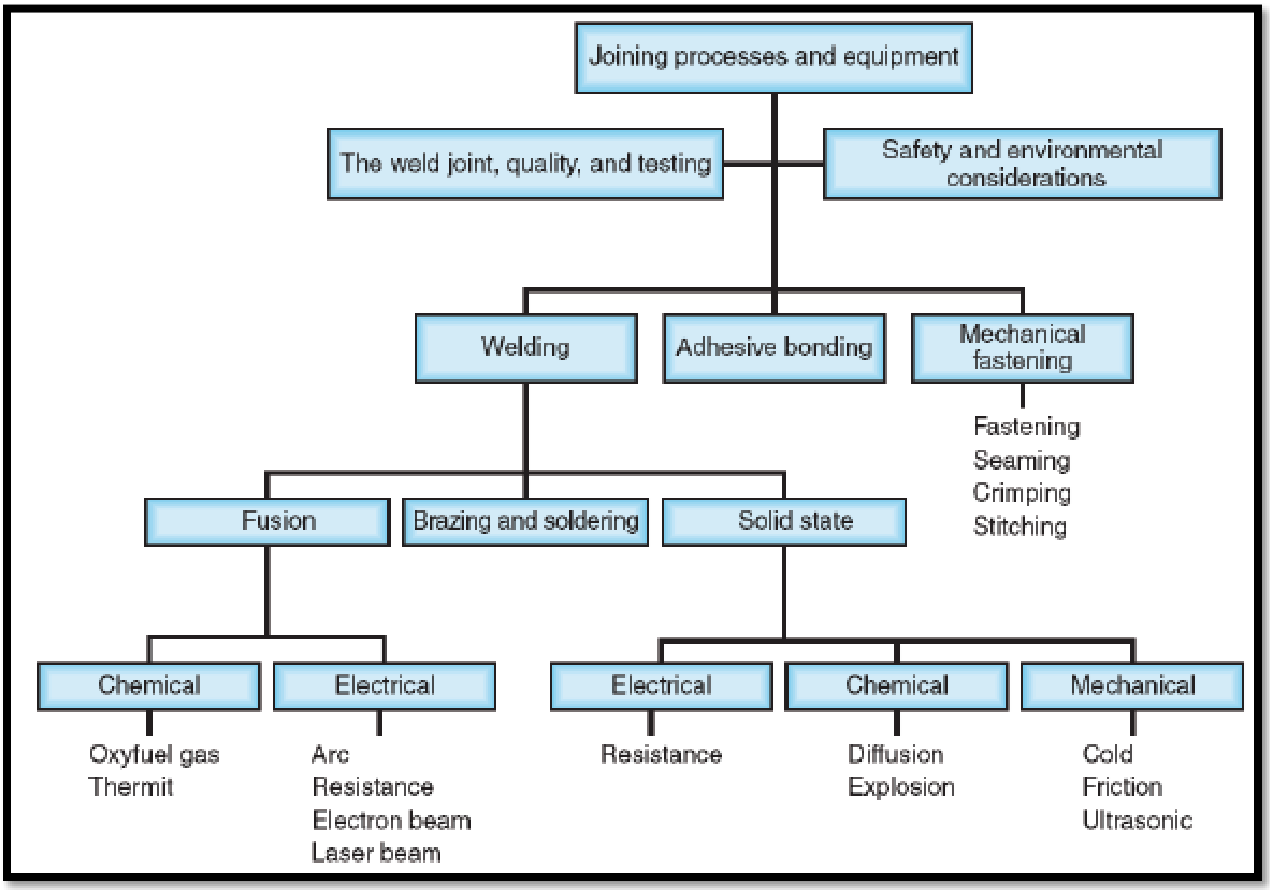
I. Welding

II. Brazing

III. Soldering

IV. Adhesive bonding

V. Mechanical fasteners (rivets, bolts and nuts, screws, etc.,)



I. Welding

Welding process can be defined as the process of metallurgically joining two pieces of metals by fusing to produce essentially a single piece of the metal. The welding process joins two pieces of metal by applying intense heat or pressure or both to melt the edges of the metal so that they fuse permanently. In welding filler material may also be used. The heat required for the process of welding can be obtained by using an electric arc, electric current, gas flame or chemical reaction. Depending upon the source of heat employed for welding process, welding processes are classified in to two main categories:

1. **GAS Welding:**

In this process, the heat required for fusing the material is obtained from an electric arc.

2. **ARC Welding:**

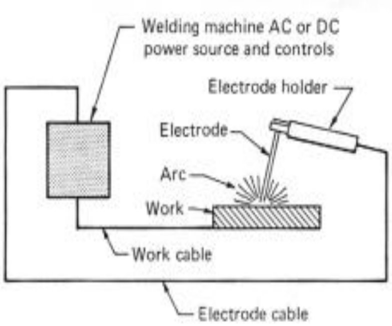
In this process, the heat required for fusing the material is obtained in the form of a flame obtained by burning a mixture of oxygen and some other combustible gas such as acetylene.

Welding is the most common joining process for metals. In fusion welding, the joint is made by melting the metal at the interface, so that upon solidification, the components are fused, or joined together. In many cases, extra metal is melted along the joint, to completely fill the joint region.

1. Fusion welding

1.1. Oxy-Acetylene Welding (in general, **O**xy-**F**uel Gas-**W**elding, OFW). A mixture of acetylene gas (C_2H_2) and oxygen gas are mixed; acetylene is highly flammable, so the mixture can be lighted and burns generates very high temperatures of up to 3000°C (Figure 4.1 (a)). The flame is used to melt the metal at the joint, along with a filler rod to provide some extra material to fill the gap. The filler rod is coated with **flux**. The flux is a chemical with two uses: part of it evaporates, and the vapor surrounds the region around the molten metal, preventing oxidation. Another part of the flux melts, and dissolves impurities and metal oxides; since these are lighter than the molten metal, they float to the surface and can be removed by a finishing process later.

1.2. Arc Welding. Here, the metal is heated by maintaining a very high voltage between the electrode and the metal. This results in dielectric breakdown of the air gap, causing a discharging arc. The temperature at the arc can reach up to 30,000°C (almost ten times oxy-fuel torches). Notice from Figure 4.1 (b) that the metal is used as one electrode, and the filler rod as the other electrode; either DC or AC can be used, with typical current ranging between 50A ~300A and typical power of 10kW or more. Typically, DC welders are used for sheet metal, while high power requirements of thick members need AC supply.

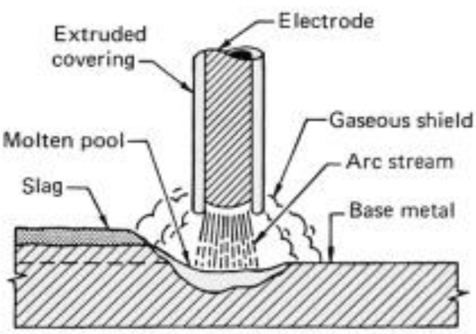


(a) (b) (c)

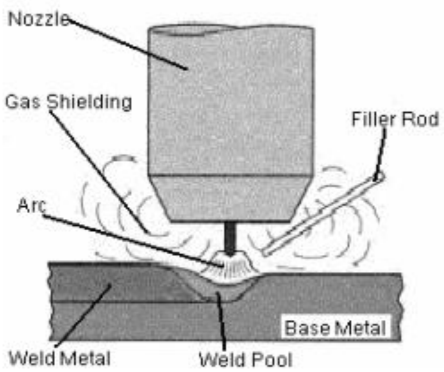
Figure 4.1: (a) Gas welding (b) Schematic of Arc welding
(c) Arc welding is easier to automate using Robots

1.2.1. Gas Shielded Arc Welding:

The most common form is **MIG Welding (Metal Inert Gas Welding)** (Figure 4.2 (a))**.** Here, and inert gas such as Argon or an Argon/Helium mixture is injected to surround the region of the weld. This ensures that the molten metals are shielded from the atmospheric oxygen, and therefore do not oxidize. The electrode may be consumable (i.e. made from the filler material) or non-consumable. Another common form is **Tungsten Inert-Gas Arc welding** (**TIG Welding**) (Figure 4.2 (b)). Here, the arc is formed between a non-consumable tungsten electrode and the metal being welded. Gas is fed through the torch to shield the electrode and molten weld pool. If filler wire is used, it is added to the weld pool separately. TIG welding can yield better quality and more precise welds. Welding Aluminum almost always requires TIG or MIG welding, since Al oxidizes easily, and molten Al must not be exposed to oxygen. TIG is also commonly used for welding Titanium, Magnesium, especially thin section welding.



(a)



(b)

Figure 4.2: (a) **MIG** welding (b) **TIG** welding

1.2.2. Plasma Arc Welding.

Plasma is high temperature ionized gas composed of electrons and ions. Plasma arcs are formed by creating the plasma gas by using an arc, and forcing it out as a focused beam through a tiny nozzle. It is useful for deep, narrow welds (Figure 4.3 (a)).

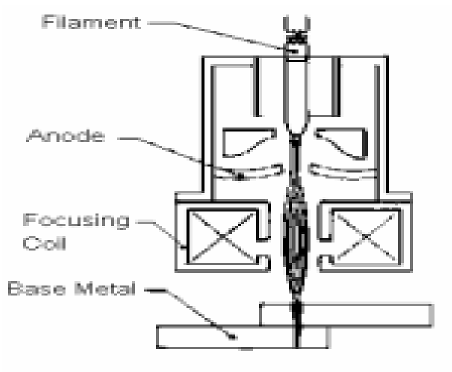
1.2.3. Electron Beam Welding.

An electron beam gun creates a stream of electrons (by causing a heated cathode to discharge in a near-vacuum tube.) The beam is focused electro-magnetically, and hits upon the metal, where the kinetic energy of the electrons is converted to heat, causing melting. The process is useful for narrow, deep welds, but is expensive (Figure 4.3(b)).

1.2.4. Laser-beam Welding.

A high-power laser can be used to melt metal, and therefore can be used to cut, weld, etc. Typical high-power lasers include Nd: YAG and CO_2 lasers, with power levels up to 100kW. This is a very versatile welding process, and can be used for high speed, narrow, deep, welds; it is also useful for high precision, low distortion welds (Figure 4.3(c)).

(a)



(b)

(c)

Figure 4.3: (a) Plasma arc welding (b) Electron Beam Gun making a lap weld (c) Laser welding of a gear

2. Solid State Welding

If two parts with very clean surfaces are brought together, the atoms in the lattices at the interface tend to create new bonds across the surfaces – creating a weld. This type of weld does not melt the material, so it is called a solid-state weld. Two important properties that facilitate solid state welding are (a) surfaces must be very clean, and (b) high pressure and temperature improve the diffusion process.

1.1. Cold welding.

This process is useful for joining two dissimilar metals. A common example is seen in rolled sheets that are used to make coins in some countries; another example is construction of bi-metal strips (Figure 4.4).

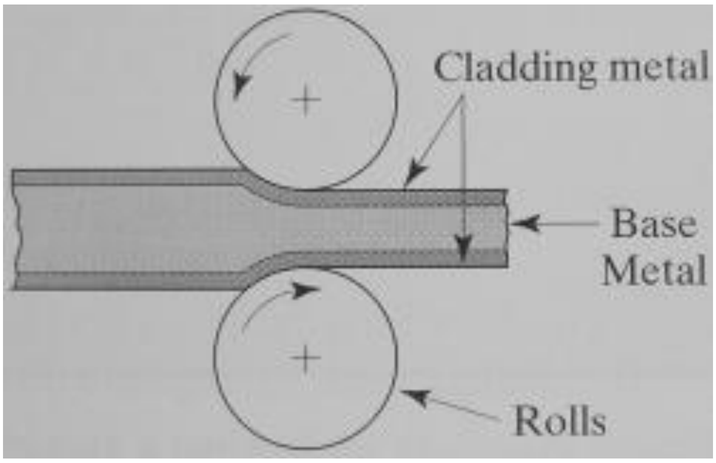


Figure 4.4. Roll bonding

1.2. Ultrasonic welding.

The two components are held together with a static normal force, and a high frequency, low amplitude orthogonal (i.e. shearing) vibration is applied. The vibration causes the surfaces to rub against each other, breaking up all contaminants and oxide layers, and the resulting clean surfaces weld together. The interface temperature in this process reaches maximum of $0.3\text{~}0.5T_m$ – in other words, there is no melting/fusion.

1.3. Resistance welding.

Here, metal strips are welded by holding them together by a force, and raising their temperature by passing a current through the interface. Resistance welding is commonly used in several applications, to make butt joints, lap joints, seam joints etc. Examples include pan-handle welding, automobile mufflers, band-saw blades, seam-joints in automobile bodies and automobile components, etc. Some examples are shown in Figure 4.5 and Figure 4.6 below.

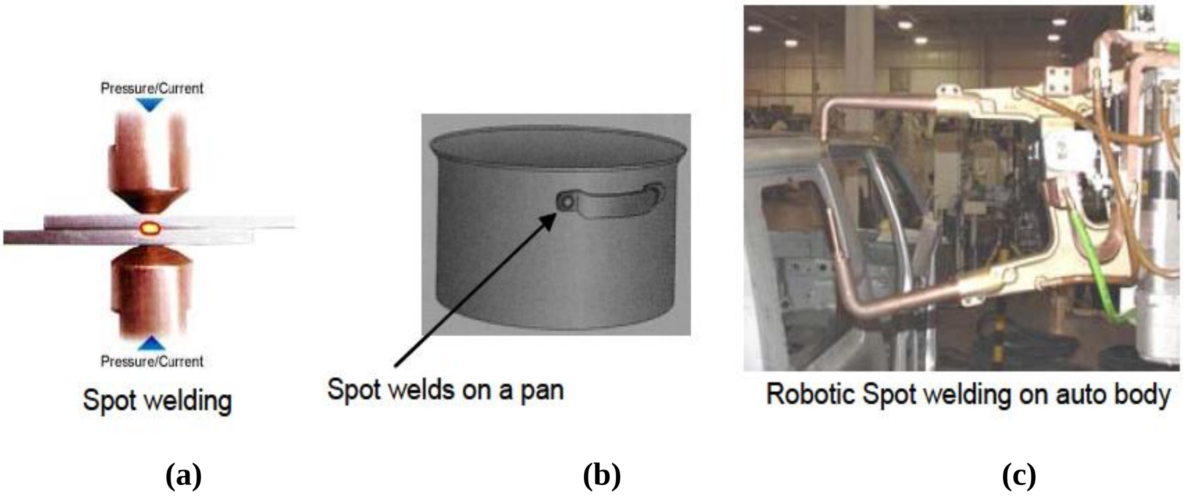


Figure 4.5. (a) Spot welding (b) and (c) Examples of resistance welding

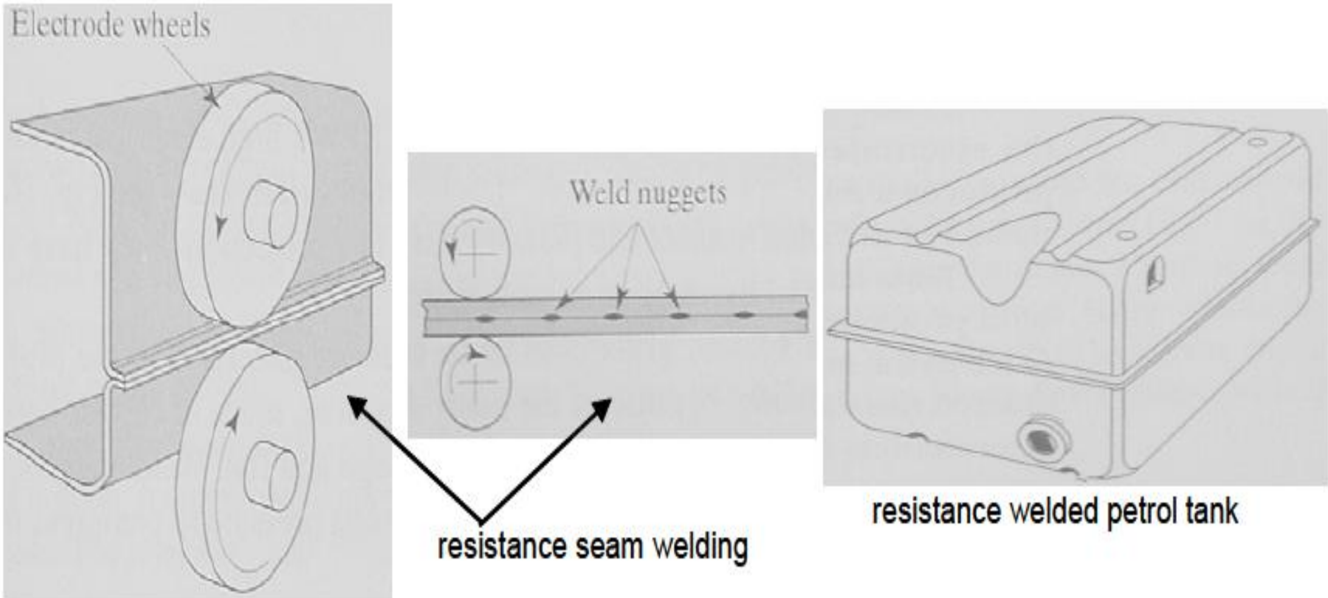


Figure 4.6. Seam welding (a type of resistance welding)

II. Brazing

In brazing, the filler material is a metal with T_m lower than that of the metals being joint. The filler is placed in the joint (or near it), and the metals are heated till the filler melts (but not the components). The melted filler material fills the joint and, on cooling, creates a brazed joint. In some cases, oxy-acetylene gas welding may be used for this process, with the filler made of a low T_m metal rod. Fluxes are used in brazing, for the same reasons as in welding. In some cases, capillary forces cause the brazing material to flow evenly into the joining interface (see example below).

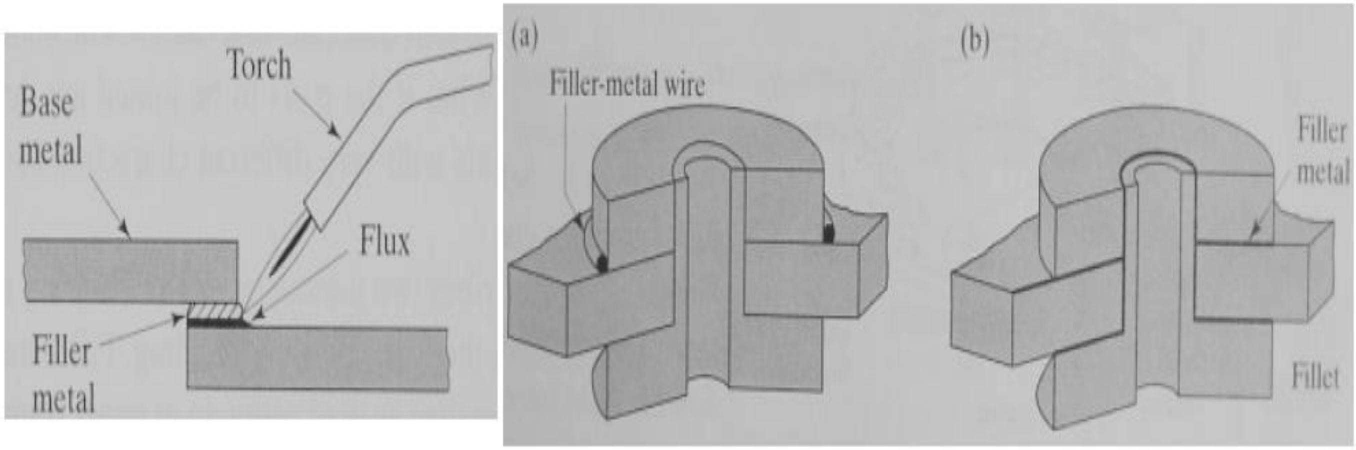


Figure 4.7. (a) Brazing (b) Furnace brazing

III. Soldering:

Solder is a very low T_m metal alloy (Lead + Tin), melting at around 200°C. This is very useful to create joints in electronic circuits, which need not withstand large forces, but should be made with low energy, low temperature processes. We shall look at different types of soldering when we study electronics manufacturing processes.

IV. Gluing (Adhesive bonding):

Gluing may be the most common method of joining in different applications. You can see examples of various types of gluing operations in many common products. Common concerns in the selection of adhesives: (a) Impact strength (b) Shear strength (c) Peeling/tensile strength (d) Service temperature (d) Curing conditions [aerobic or anaerobic, speed of cure, temperature of curing, UV curing] (e) moisture resistance (f) electrical conductivity (g) toxicity (h) maximum gap size. The following table lists common adhesive systems, their properties, and uses.

Adhesive type	Notes	Applications
Acrylic	two component thermoplastic; quick setting; impact resistant, strong impact and peel strength	fiberglass, steel, plastics, motor magnets, tennis racquets
Anaerobic	thermoset; slow, no-air curing – cures in presence of metal ions	sealing of nut-and-bolts, close-fitting holes and shafts, casting micro-porosities etc.
Epoxy	strongest adhesive; thermoset; high tensile strength; low peel strength	metal parts (especially Nickel), ceramic parts, rigid plastics
Cyanoacrylate	thermoplastic; high strength; rapid aerobic curing in presence of humidity	[common brand: Crazy glue™] plastics, rubber, ceramics, metals
Hot melt	thermoplastic polymers; rigid or flexible; applied in molten state, cure on cooling	footwear, cartons and other packaging boxes, book-binding
Polyacrylate esters (PSA)	Pressure sensitive adhesives	all types of tapes, labels, stickers, decals, envelops, etc.
Phenolic	thermoset, oven curing, strong but brittle	acoustic padding, brake lining, clutch pads, abrasive grain bonding
Silicone	thermoset, slow curing, flexible	gaskets and sealants
Formaldehyde	thermoset	joining wood, making plywood
Urethane	thermoset, strong at large thickness	fiberglass body parts, concrete gap filling, mold repairs
Water-based	cheap, non-toxic, safe	wood, paper, fabric, leather

V. Mechanical fasteners (rivets, bolts and nuts, screws, etc.,)

The *permanent joining* processes, which are mechanical in nature, are, in principle, derivatives of the basic metal working processes. These are often referred to *fasteners*. The most common *mechanical joining* methods are rivet, nut and bolts, staple, seam joint etc. *Figure 4.9* schematically depicts a number of mechanical joints.

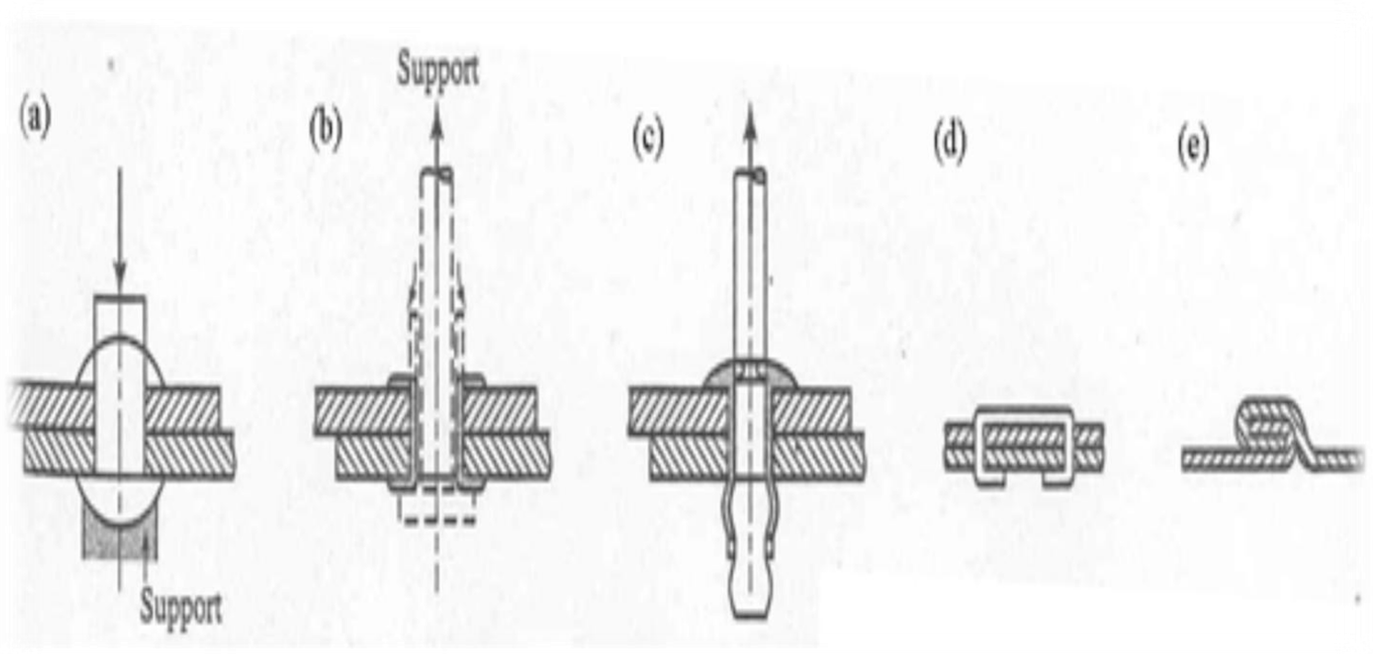


Figure 4.8. Schematic presentation of five mechanical joints: (a) rivet, (b) tubular rivet (c) blind rivet, (d) staple, (e) seam

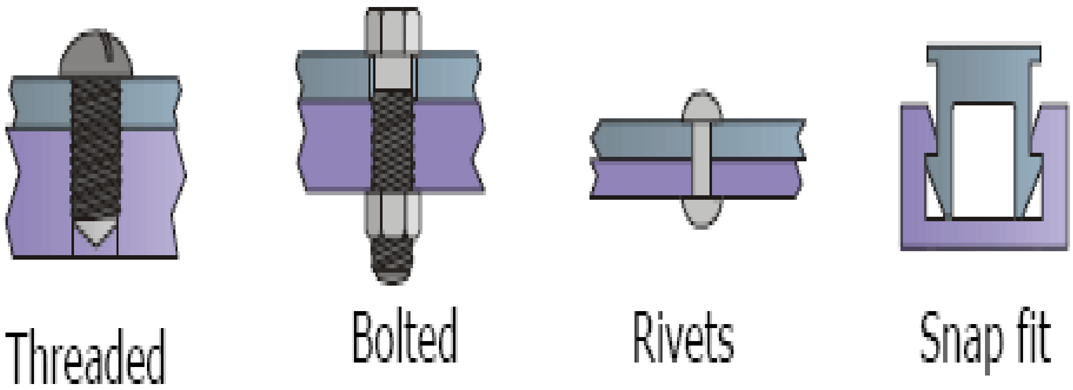


Figure 4.9. Schematic presentation of five mechanical joints: threaded, Bolted, rivets, Snap fit

Mechanical fasteners are most widely used for temporary joints with the exception of rivets, which need to be broken or destroyed for dismantling.
Welding and adhesive bonding are used to make permanent or semi-permanent joint.
Brazing and soldering are considered to form permanent joints, but for repair or replacement, we can dismantle them by heating.
Brazing is distinguished from soldering by the melting temperatures of the filler material. If the filler material melts below 450°C, it is soldering; but if the filler material melts above this temperature, the process is brazing.
The choice of particular joining process depends upon several factors such as application, nature of loads or stresses, joint design, material involved, and size and shape of the component.

Remarks:

- Any shape and material almost
- Disassembled (except rivets, etc.)
- Least expensive for low volume (standardized)
- Problems: strength, seal, insertion, loosening

Bibliographic references:

- Manuel de technologie mécanique, Guillaume SABATIER, et al Ed. Dunod.
- Memotech : productique matériaux et usinage BARLIER C. Ed. Casteilla
- Sciences industrielles MILLET N. ed. Casteilla
- Memotech : Technologies industrielles BAUR D. et al, Ed. Casteilla
- Métrologie dimensionnelle CHEVALIER A. Ed. Delagrave
- Perçage, fraisage JOLYS R et LABELL R. Ed. Delagrave
- Guide des fabrications mécaniques PADELLA P. Ed. Dunod
- Technologie : première partie, Bensaada S et FELIACHI d. Ed. OPU Alger