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قسم الهندسة المدنية

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Pedagogical course handout

BASIC TECHNOLOGIES

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For second year Bachelor's degree in civil engineering

(L2 Civil engineering)

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Summary

Figures List

PREFACE

This course is intended for second-year students studying for Bachelor in Civil Engineering. It aims of to enable students to acquire knowledge about the processes involved in obtaining and manufacturing parts and the techniques used to assemble them, so that they can familiarize themselves with general manufacturing concepts and develop their knowledge of how to use different materials and techniques that transform raw materials into finished objects through coordinated sequences of activities. They form the basis of all industrial production, determining efficiency, quality and profitability, and are chosen based on factors such as the material, the shape of the part, the precision required and the production volume. Processes can be grouped into broad categories, such as machining (material removal) and molding (shaping).

مقدمة

هذا الدرس مخصص لطلاب السنة الثانية الذين يدرسون للحصول على درجة الليسانس في الهندسة المدنية .. وتهدف إلى تمكين الطلاب من اكتساب المعرفة حول العمليات المتعلقة بالحصول على الأجزاء وتصنيعها، والتقنيات المستخدمة في تجميعها، حتى يتمكنوا من التعرف على المفاهيم العامة للتصنيع وتطوير معرفتهم بكيفية استخدام المواد والتقنيات المختلفة التي تحول المواد الخام إلى منتجات نهائية من خلال تسلسل منسق من الأنشطة وهي تشكل أساس كل الإنتاج الصناعي، وتحدد الكفاءة، والجودة والربحية، ويتم اختيارها بناءً على عوامل مثل المادة، وشكل القطعة، والدقة المطلوبة وحجم الإنتاج.

ويمكن تجميع العمليات في فئات عامة، مثل التصنيع الآلي (إزالة المادة) والقولبة (التشكيل).

INTRODUCTION

Ce cours s'adresse aux étudiants de deuxième année préparant une licence en génie civil. Il vise à permettre aux étudiants d'acquérir des connaissances sur les processus liés à l'obtention et à la fabrication de pièces, ainsi que sur les techniques utilisées pour les assembler, afin qu'ils puissent se familiariser avec les concepts généraux de la fabrication et développer leurs connaissances sur l'utilisation de différents matériaux et techniques permettant de transformer des matières premières en objets finis grâce à des séquences d'activités coordonnées. Ces processus constituent la base de toute production industrielle, déterminant l'efficacité, la qualité et la rentabilité, et sont choisis en fonction de facteurs tels que le matériau, la forme de la pièce, la précision requise et le volume de production.

Les processus peuvent être regroupés en grandes catégories, telles que l'usinage (enlèvement de matière) et le moulage (mise en forme).

I. METALLIC MATERIALS

1- INTRODUCTION

Materials are solids that man has developed over centuries and used without knowing much about their varied behavior.

Why is it that some materials are brittle at room temperature, while others are only brittle at very low or very high temperatures? How can some materials stretch without breaking and others not?

The research carried out over the last hundred years has shed a great deal of light on the subject and has made it possible to provide the industry with better quality materials.

2- MATERIALS CLASSIFICATION

a) **Ferrous metals:** Cast Iron and Steel

b) **Non-ferrousmetals:** Alloys (Cu-Zn, Cu-Sn, etc.)

c) **Natural materials:** Wood, Rubber, Leather, Glass, etc.

d) **Artificialmaterials:** Polymers, Plastics, PVC, Ceramics

3- MAIN METALLIC MATERIALS

d) **Steel**: steel is a material in which iron is the predominant element, its carbon content is generally less than 2.1% and it contains other elements; a limited number of chromium steels can have a carbon content of more than 2%, but this 2% value is the current limit separating steel from cast iron. It is the material with the greatest strength for the smallest cross-section and is the most widely used material in the world.

e) **Cast Iron:** In industry, iron is rarely used in its pure state. It is used in the composition of several alloys, one of the main ones being cast iron. This alloy is made up of between 2% and 6.67% iron and carbon. When carbon is present in cast iron, it is in the form of graphite flakes. Cast iron facilitates molding and its constantly improving characteristics mean that it also plays an important role in mechanical manufacturing.

f) **Alloys**: Alloys are produced to improve the properties of a metal or even to give it new properties. To make a homogeneous alloy, the metals of which it is composed must be miscible with each other. When they are heated, they must be able to mix perfectly so that the constituent species are no longer distinguishable. But as the elements are generally not perfectly miscible, certain proportions must be respected to ensure the production of a good alloy. They are used more and more, and their production is second only to that of ferrous metals.

4- ORIGIN OF MATERIALS

All these materials are obtained by processing subsoil products (ores, coal, hydrocarbons) or soil (wood).

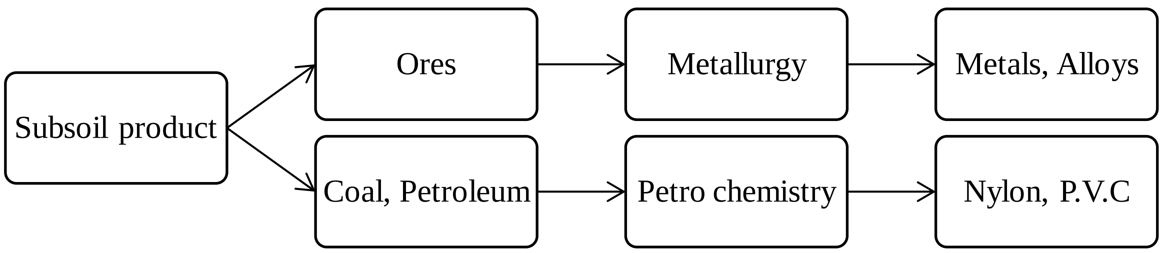


Figure 01: Origins of materials

5- PRACTICAL PROPERTIES OF METALLIC MATERIALS

5-3 Use Properties

b) **Mechanical:** Defined by mechanical tests

c) **Physical:** Density, Expansion, Color, Resistivity, Conductivity …etc.

d) **Chemical:** Resistance to the action of various chemicals and atmospheric agents.

5-4 Processing (shaping) properties

The ability of the material to produce an object of a specific shape, for example:

- By Pouring (Molding)
- By hot plastic forming (forging, stamping, laminating, etc.)
- Cold plastic forming (stamping, bending, cutting ...)
- Machining with cutting tools (turning, milling, drilling, etc.)

6- MECHANICAL PROPERTIES OF METALLIC MATERIALS

When designing a part, it is important to test samples of the metal you wish to use to determine its properties.

After manufacture, to check that the material of the part complies with the specifications, a sample is taken and subjected to mechanical tests:

d) Traction tests

e) Resilience tests

f) Hardness (Toughness) tests

II. POLYMERS

Natural polymers were the first materials used: wood and plant fibers, leather, animal tendons, wool, etc. Syntheticpolymers were developedbetween 1940 and 1945.

Polymers are mainly used for their:

- flexibility: textiles, gaskets, hoses, elastics, plastic films (packaging, bags);
- ease of shaping: molding objects of sometimes complex shape, containers (flasks, bottles, cans, vats);
- lightness (low density, some float in water): matrixes for composite materials (shipbuilding, aviation), every day's objects, etc.
- surface properties: non-stick (Teflon) or strong adhesion (tires, paint, glue);
- insulating, thermal, and electrical properties;
- resistance to various chemical environments: food, acids, etc.

The limits of use are:

- Temperature: their mechanical properties deteriorate as soon as the temperature rises, and most polymers deteriorate, burn or melt at moderate temperatures (below 300°C);
- degradation by ultraviolet rays, air (oxygen and ozone), and water;
- Their low hardness, low tensile strength and low resistance to erosion(except for fibers).

III. COMPOSITE MATERIALS

A composite material consists of the assembly of two or more materials of different natures. These materials complement each other to produce a heterogeneous material whose overall performance is superior to that of the individual components.

The main advantage of using composite materials lies in their excellent characteristics. They have significant advantages over traditional materials. They offer numerous functional advantages:

- Lightweight
- high fatigue resistance
- freedom of shape
- low maintenance
- Lowageing due to moisture, heat and corrosion (exceptcarbon aluminum)
- Insensitive to chemicals except paint strippers, which attack resins.
- Good electricalinsulation.
- Their low take-up rate is due to their cost.

There are two types of composite:

Mass-market Composites and **High-Performance Composites.**

IV. Non-Cutting Manufacturing Processes

Non-material-removal manufacturing processes can be divided into several categories:

a) Deformation Manufacturing Processes;

b) Fusion Manufacturing Processes;

c) Assembly Manufacturing Processes

1- DEFORMATION MANUFACTURING PROCESSES

Deformation manufacturing processes involve plastically deforming the material until the desired shape is obtained.

These processes can be hot or cold. Some of these processes have been in existence for several centuries (e.g. forging). They can offer many advantages, depending on the function of the parts being manufactured.

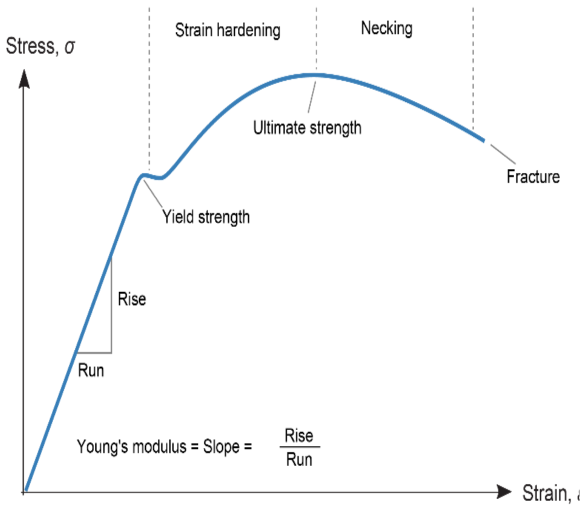


Figure 02: Standard Deformation Diagram

In the elastic domain, axial deformation is linear and reversible, but in the plastic domain, the evolution of deformation as a function of stress is no longer linear; deformation is permanent, and the end of the curve is marked by the phenomenon of striction, which corresponds to localized deformation.

2- INFLUENCE OF TEMPERATURE:

Generally, an increase in temperature leads to a decrease in yield strength. This phenomenon is often used to shape materials, as it requires less stress (and therefore less strain on the material) to obtain permanent deformation

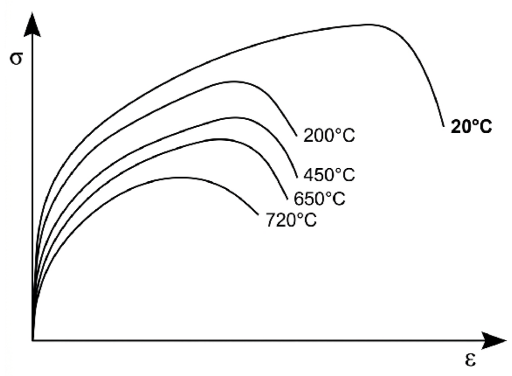


Figure 03: Influence of temperature on the deformation curve

V. THE FORGE

1- DEFINITION

The purpose of forging is to produce parts by hot plastic deformation under the action of impact or pressure. It requires the use of hand-operated tools for manual forging or machine-operated tools for mechanical forging.

2- CONDITIONS FOR GOOD FORGING

There are two limits to be respected

- The lower limit is set by the need for a material that is sufficiently malleable to ensure that the crystalline system is not excessively disturbed by the action of shock or pressure.

- The upper limit is set by the danger of internal oxidation of the material when it is heated to very high temperatures.

Example: Mild steel 750 to1300°C Hard steel 750 to1150°C

The materials are heated in furnaces powered by oil, coke or gas.

To avoid surface decarburization of steel and cast iron, the furnace must operate in a reducing atmosphere.

3- FORGING MACHINES (EQUIPMENT)

3-1 Impact equipment (sledgehammers and hammers)

The power hammer uses steam or compressed air as its driving force.

d) **Steal Hammer**: The tool consists of a hardened steel hammer attached to a striking mass raised by the action of steam acting under a piston.

The work-piece support consists of a hardened steel anvil attached to a solid cast iron part called a ***Chabotte***.

The power hammer is said to be single-acting when the steam acts under the piston to lift the striking weight, which then falls by its own weight onto the work-piece.

The hammer is said to have a double effect when the steam, after having raised the hammer, acts on the top of the piston to accelerate the descent of the striking weight, giving more force.

The striking weight varies from 100 to 30,000 kg and the descent height varies from 1 to 3 m.

e) **Compressed-air drop hammers:** have the same components as steam drop hammers. The compressed air can be produced by a compressor independent of the piston or forming part of it the striking mass varied from 25 to 2000Kg the number of blows per minute generally high 100 to 250.

f) **Mouton:** These are mechanical devices where the impact energy is solely due to the fall of striking mass. The drop height is greater than that of rammers and can vary between 3 and 6m.

The press is raised by the friction action of two rollers rotating in opposite directions.

3-2 <u>Machines working under pressure (hydraulic presses, etc.)</u>

e) **Presses:** The presses used for forging use either hydraulic pressure or the combined action of pressurized water and steam. Figure 4 shows a hydraulic press. Pressurized water acts on a forging piston and causes a crosshead carrying the anvil (heap), crushing the material on the anvil fixed to the lower beam. The force produced by these presses is very high, up to 4,000 tons.

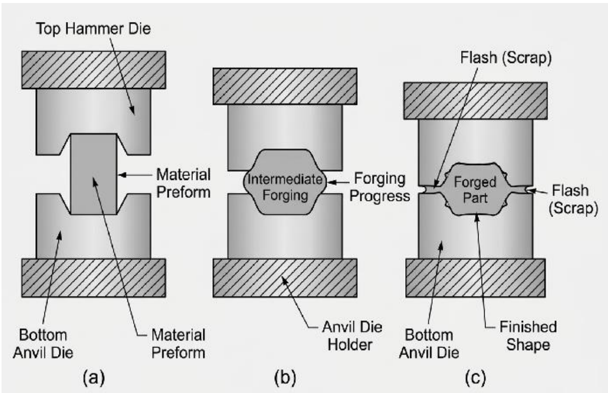


Figure 04: Illustration of mechanical forging

f) **Disadvantages of Forging:** Forging does not offer the same tolerance margins as machining, which means that it is reserved for parts requiring high strength but low precision. Forging cannot be used directly for mechanical parts requiring high dimensional accuracy.

g) Stamping and Die-Forging: After heating, this technology consists of forming rough parts by pressing them between two blocks (the dies) with the exact shape of the product to be made. This manufacturing technique presupposes the prior execution of tooling specific to the products to be made. Therefore, it is only used when the number of parts to be produced is high enough. It provides greater dimensional accuracy than free forging.

h) **Tools and Machinery:** A die set consists of two blocks of hard carbon steel (quenched and tempered) to give the metal maximum hardness and resilience (impact resistance).

The impression of the part required is engraved with a milling cutter or scraper in each of the two dies.

The machines used are either a drop hammer (impact) or a mechanical press (pressure). The excess material (burr) flows into a cavity around the impression.

In order for the part to be removed from the dies after deformation, it is necessary for these external faces to be highly undercut.

The heating temperature is high (generally T > 0.5 Tfusion).

Contact can be made either:

- By shock machines (V > 1m/s)
- By pressure machines (V < 1m/s).

4- <u>ADVANTAGES AND DISADVANTAGES OF THE TECHNIQUE</u>

4-1 Advantages

- Speed of part production
- Production of complex parts
- Several parts can be produced at the same time.

4-2 Disadvantages

- relatively high-cost price
- billet taken from a semi-finished product
- limited die life (8,000 parts/iron and 20,000 parts/brass)

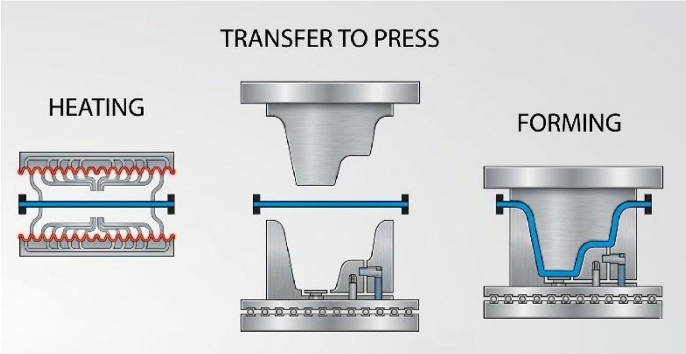


Figure 05: Diagram illustrating stamping

Die-forging is a process identical to stamping, but the term is reserved for non-ferrous alloys, such as aluminum alloys.

5- **LAMINATION**

Lamination is a manufacturing process using plastic deformation. It is applied to a variety of materials, such as metal or any other pasty material such as paper or pasta.

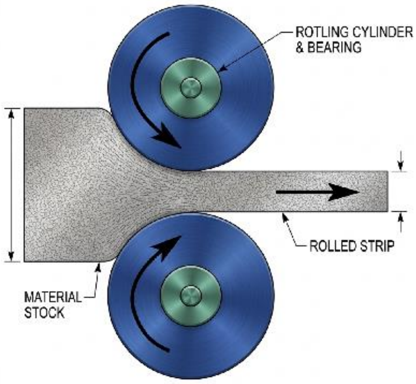


Figure 06: The Lamination

This deformation is achieved by continuous compression as the metal passes between two counter-rotating rolls known as a rolling mill. A rolling mill is an industrial installation designed to reduce and even out the thickness of metal.

6- **WIRE DRAWING**

Wire drawing makes use of the metal's plastic deformability. This cold transformation process consists of passing the metal through a calibrated orifice, the die, under the action of continuous traction. A lubricant is used so that the operation can be carried out several times in a row at high speed.

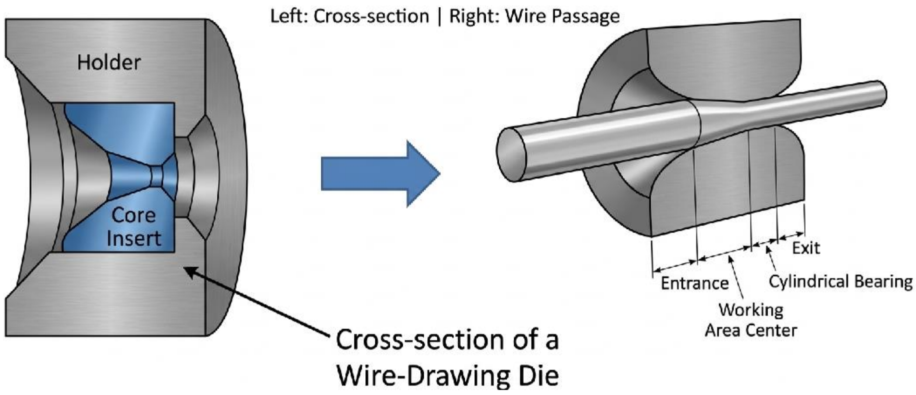


Figure 07: Illustration of Wire Drawing

f) **The die** has a specific geometry, calculated according to the wire material, the surface finish required and the drawing force applied.

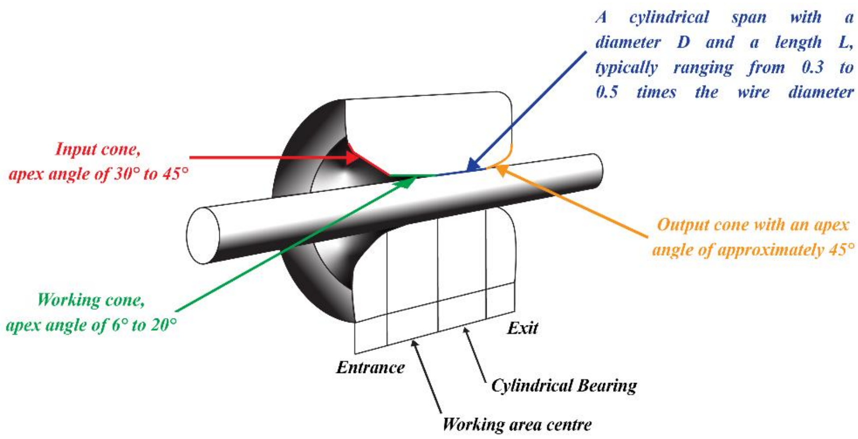


Figure 08: the die

To ensure good lubrication, a thick film of lubricant is preferable. Good lubrication can be promoted by forcing the lubricant into the die: there are lubricant pressure nozzles that are placed in a lubricant receptacle just before the die.

The type of lubricant used (soap in general) depends on the geometry of the die, the cylindrical bearing surface and the desired roughness of the wire produced.

g) Extrusion: Extrusion is the process of transforming a material in various forms into a continuous product with a well-defined cross-section. This cross-section, which is generally constant, is obtained by forcing the material to flow through an orifice of a shape adapted to the desired final profile.

The die into which the material is forced can have several shapes, depending on the cross-section to be obtained.

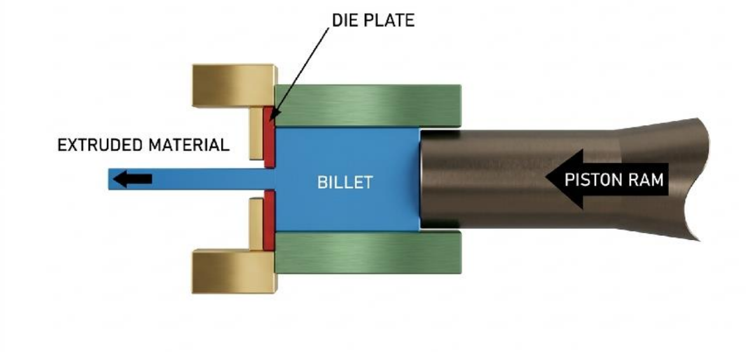


Figure 09: Diagram of the extrusion process

The success of the process depends to a large extent on controlling the required temperatures: those of the billets and the die.

The rate of production can be high, as the billets are rapidly fed into the press.The force applied by the piston can vary from a few hundred tons to over 20,000 tons.

h) Bending: Bending involves exerting a force on a part resting on one or more supports or embedded at one end. This force is exerted by a press. The part deforms beyond its elastic limit and therefore retains its bent shape (although there is a springback effect to be taken into account).

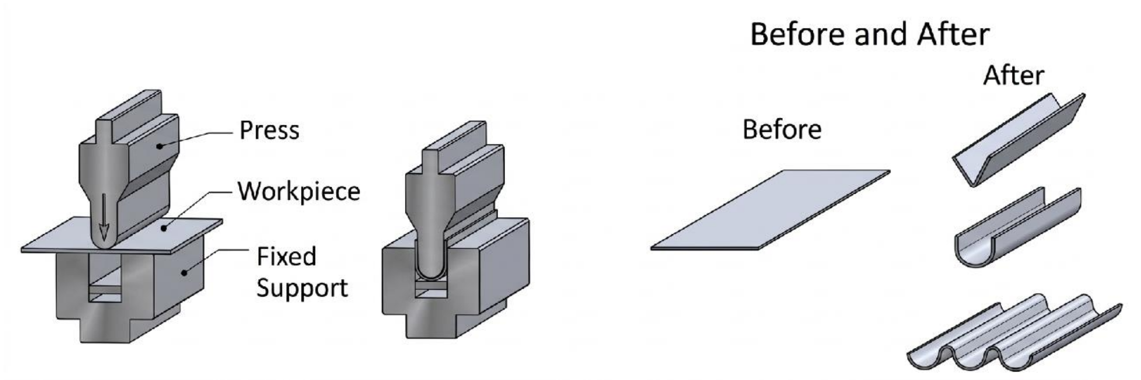


Figure 10: Example on Bending

i) Stamping: is a forming process involving the plastic deformation of a metal surface driven by a punch into a die. This process produces stamped sheet metal quickly and cheaply.

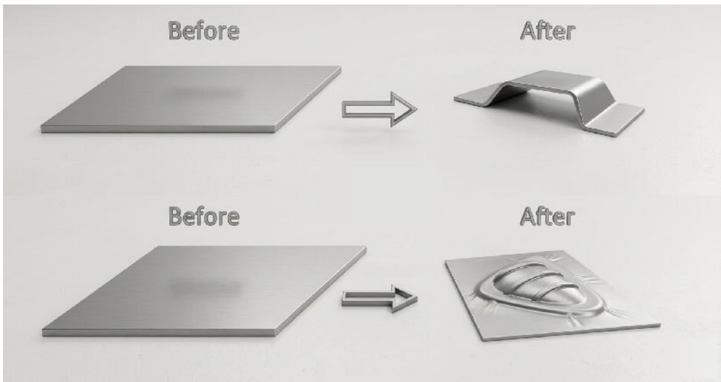


Figure 11: stamping work

j) Rolling: Rolling is used to bend sheet metal into tubes, screws or other shapes (mainly circular).

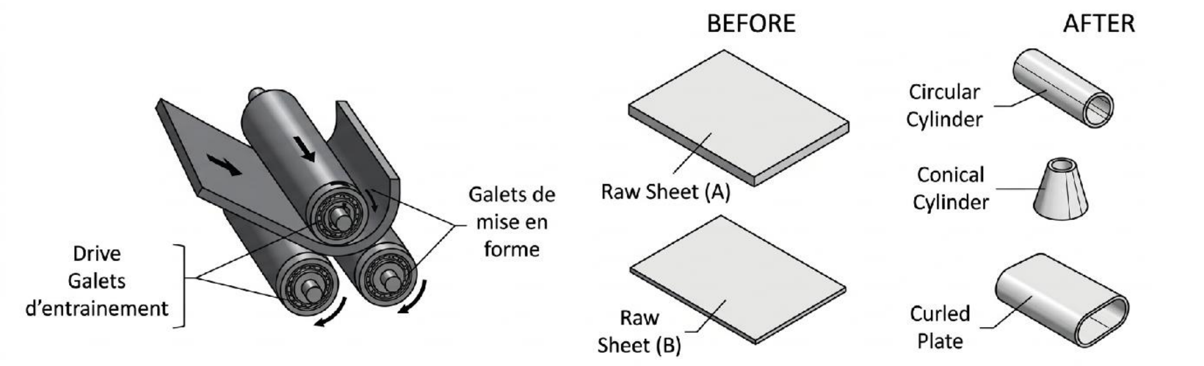


Figure 12: Example of Rolling

VI. MOLDING

1- OBTAINED BY (FUSION) MELTING (FOUNDRY OR MOLDING)

The process of making a material liquid so that it takes the shape of a mold.

c) Advantages:

- Little waste of raw materials;
- Allows creating highly complex shapes.

d) **Disadvantages**:

- Requires extensive and expensive tooling (especially for metal molds) ;
- The part to be obtained must have approximately constant or slightly varying thicknesses, no sharp edges (fillets and rounded edges are strongly recommended), and free surfaces;
- The surface finish (roughness) obtained is average;
- The precision obtained is average (material shrinkage and deformation whencooling);
- These last two disadvantages often mean that additional machining has to be carried out on the functional surfaces of the part;

There are two main molding techniques: Sand or metallic

1-1 Sandmolding

Demolding is carried out by destroying the mold. We therefore need to make as many molds as parts to be manufactured. There are several techniques for obtaining a sand mold (wet sand; thermal, chemical or physical hardening). The sand moldis obtained from a permanent model (generally in wood, resin or metal) or a single model (in wax or polystyrene) in the case of lost molding.

The advantage of this technique is that the sand is refractory (heat resistant) and the mold is inexpensive to make. On the other hand, the surface finish (Ra ≈ 3.2 μm) and precision obtained are fairly poor.

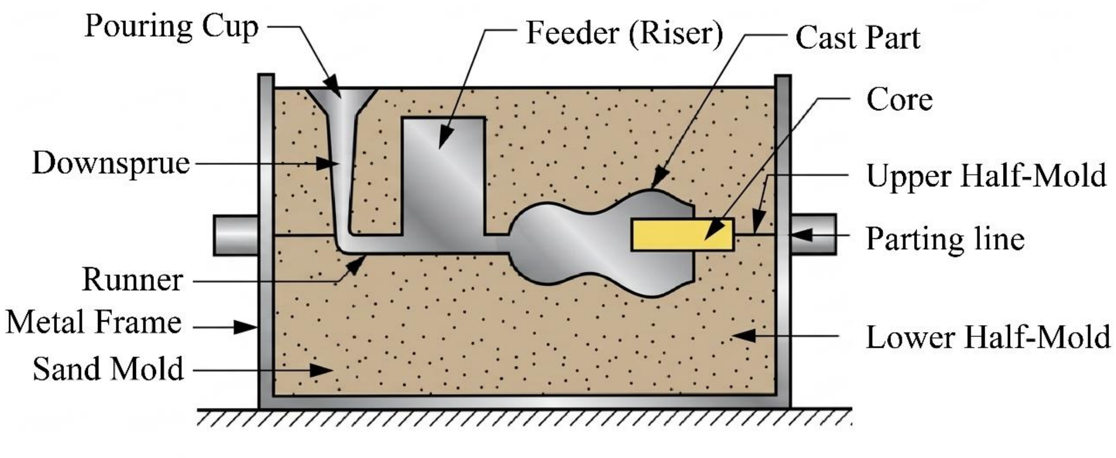


Figure 13: Sand Molding

This technique is well suited to small production series.

1-2 <u>Metal Molding (or Permanent Molding)</u>

The metal moldcan be reused several times. Demolding is made possible by the difference in material between the mold and the cast metal. The mold is always lubricatedbefore the molten metal is introduced (it is coated with a protective liquid to make it easier to demold).

Metal molding is classified into three categories according to the pressure at which the liquid material is introduced into the mold:

f) GravityMolding

At zero pressure, the liquid material is introduced from above and fills the mold by gravity.The surface finish (Ra ≈ 1.6 µm) and accuracy obtained are average.

This technique, whose tooling is less expensive than the others, is suitable for small production runs (series).

g) Low-pressure Molding

The pressure is low (0.2 to 2 bar) and the liquid material is introduced from below. The process is semi-automatic, and often seen as an improvement on gravity molding . The cost of the tooling is higher, production rates are higher, and the surface finish and precision are better.

This technique is suitable for both small and large production (series) runs.

h) Pressure Molding (or Injection Molding)

The injection pressure of the liquid material is high (between 50 and 200 bars). This process is often automated, enabling high production rates (up to 500 parts/hour). The cost of the tooling is very high. The surface finish and precision of the parts obtained are good. This technique is suitable for very large production runs.

i) Centrifugal Molding

The moldis rotated rapidly. The liquid material is poured inside sticks to the wall by centrifugal force and solidifies.

j) Insert Molding (or Over-molding)

This technique involves molding a material (often plastic) over a part, called an insert (often metal), inserted into the mold. To do this, the material to be over-molded must have a lower melting point than the material of the insert.

VII. OBTAINING BY REMOVING MATERIAL (MACHINING)

The final shape is obtained by tearing off small pieces of material (shavings).

The three most commonly used operations are turning, milling, and drilling; these will be covered in detail in this course.

1- TURNING (ON ONE LATHE)

In turning, the cutting movement is obtained by rotating the work-piece clamped between the jaws of a chuck or in a specific collet, while the feed movement is obtained by moving the cutting tool. Turning is mainly used to obtain shapes of revolution around the axis of rotation of the work piece.

There are conventional lathes (with manual feed) and numerically controlled (NC) lathes whose tool feed is fully programmable.

The axis rotation is associated with:

Z: translation along the spindle axis, positive when the tool moves away from the work-piece;

X: the other main direction of movement of the tool, positive as the tool moves away from the work-piece.

A, B, C: rotations around the X, Y, and Z axes respectively.

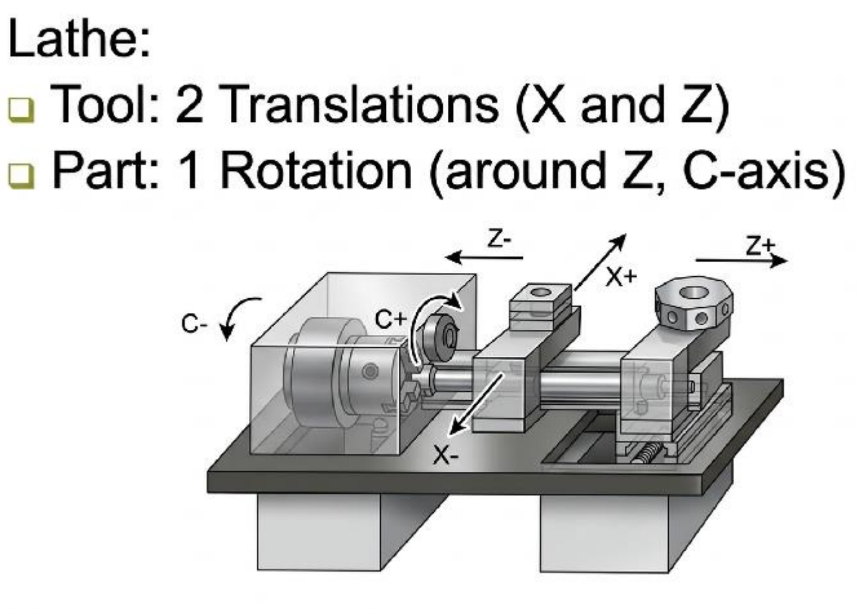


Figure 14: Example of a conventional lathe

The number of possible movements that the machine can make is counted in terms of the number of axes, only the rotation of the spindle (necessarily along the axis C) which drives the chuck and the work-piece is not counted.

c) Axis lathe (minimum): only tool translations along x and z are possible.

Possible additional axes (in **CN**):

- Axis Y (movementalong Y, in addition to X and Z);
- Axis C (motorized tool for drilling and milling operations);

From five axes upwards, weare talking about a machining center, not a lathe.

Moreover, a tool turret can be used to store several tools and change them by rotating around an axis (C or B), thus avoiding the need to stop, change the tool, re-zero and restart the machine (very useful in NC).

d) Isostatic positioning on a lathe (Turn)

On a lathe, the piece is clamped onto the chuck using jaws (usually 3 or even 4 jaws) distributed around the axis of rotation. The isostatic representation of positioning generally takes the form of two possible cases:

- Short centering: the gripping length of the piece (L) is less than 0.8 times the diameter (D).
- Long centering: L > 1.5.D.

2- ROUTING (ON A MILLING MACHINE)

In milling, the cutting movement is obtained by rotating the tool (the milling cutter), while the feed movement is obtained by moving the work-piece held in a vice (or a clamp or jaws, depending on the work-piece to be clamped). Conventional milling is mainly used to produce prismatic shapes, but NC milling can be used to produce highly complex shapes.

There are conventional milling machines (with manual feed) and numerically controlled (NC) milling machines whose tool feed is fully programmable.

X, Y and Z axes, with Z: spindle axis,

positive (when the tool is moving away from the part), and A, B, C: rotations around the X, Y, and Z axes respectively.

The number of possible movements that the machine can make is counted as the number of axes, only the rotation of the spindle (necessarily along the C axis) which drives the tool is not counted.

Axis 3 Milling machine (minimum): only the 3 translations of the part are possible.

Additional axes possible (in NC): simple or double inclination of the spindle axis (B and A axes), tool stop and part rotation (C axis), etc.

3- **DRILLING** (on a drill, lathe or milling machine): The term drilling means "obtaining a hole (blind or through) by machining". This hole can be made by a drill (on a drill, lathe, milling machine, etc.), by a drill bit on a crankshaft (hand drill), by cutting, by electro-erosion, etc.

VIII. WELDING

1- GENERAL POINTS

Welding is a process for permanently joining several metal components.

Welding, or metal soldering, is obtained by melting a filler metal with the base metal, unlike brazing and soldering where only the filler metal is melted.

2- WELDING PHENOMENA

Welding involves a number of phenomena:

- Metallurgy (diffusion, chemicalaffinity, etc.)
- Physical (increase in temperature)
- Mechanical (application of a compressive force)

3- WELDING CLASSES

3-1 Autogenous welding

The metals are assembled without filler metal or with a metal of the same chemical nature.

b) Heterogeneous welding

The metals are assembled with a filler metal whose chemical nature differs from that of the elements to be welded.

4- ADVANTAGES OF WELDING

4-1 Speed of execution

- Achieving a rigorous seal
- Economical for the manufacture of single parts or small series, it avoids the cost of the model (in the case of casting) or of shaping tooling. (in the case of plastic deformation)

5- CONDITION OF WELDABILITY OF A STEEL

a) Non-alloyed steel

Its carbon content is the only indication of weldability

$$\begin{cases} \%\,\mathrm{C} > 1.3\ Not\ weldable \\ \%\,\mathrm{C} > 0.7\ Slightly\ weldable \\ \%\,\mathrm{C} = 0.08\ \text{Perfectly weldable} \end{cases}$$

b) Alloy steel

There is the percentage of carbon plus the percentage of additions that comes into play.

Tremlet's relationship

CE = % C + % M/6 + % Ni/15 + % Cr/5 + % Mo/4 + % V/10 + % Cu/13

If $\begin{cases} \text{CE} < 0.4 \ \textit{Perfectly Weldable} \\ 0.4 < CE < 0.7 \ \textit{Poorly weldable} \\ \text{CE} > 0.7 \ \textit{Not weldable} \end{cases}$ CE : Carbon Equivalent

<u>Examples</u>

XC 32	0.32 % of carbon	less weldable
50 CV 4	CE = 0.5 % C +(4/4)/5 = 0.5+0.2 =0.7	Not Weldable

For thicknesses up to 20 mm we have:

$$\mathbf{CE = CE + 0.0254\ e}$$

6- PARTS REPAIR

Parts are always prepared according to the type of welding:

- mechanical stripping by brushing and grinding,
- chemical stripping and degreasing (chlorinated solvents should be avoided),
- edge preparation (chamfering), pre-heating...

7- TORCH WELDING OR OXY-ACETYLENE OR OXY-GAS WELDING

7-1 Definition :

- The flame is produced by the combustion of a mixture of oxygen and acetylene (or hydrogen, town gas, propane, etc.), which is mixed by the torch (fig.15).
- If necessary, the filler metal is fed in manually using a rod. Pickling fluxes are either incorporated into the rods or into a container in which the heated filler metal rod is dipped.
- Fluxes vary according to the materials to be joined. This process is used mainly for autogenous welding (filler metal and base metal of the same type) or heterogeneous welding (brazing and soldering).

7-2 Source of Heat

- The edges of the work-piece and the filler metal are melted by the combustion flame of a mixture of acetylene (C_2H_2) and oxygen (O_2).
- The two gases are mixed in suitable proportions in a torch.
- The composition of the mixture is controlled by two taps R1 and R2.

- The unit's flow rate is regulated by a copper nozzle with a calibrated orifice.
- The resulting gas mixture is ignited at the outlet.
- Fig.1 shows a cross-section of a low-pressure torch.

*7-3 **Torch power***

The normal power of the torch is expressed by its C2H2 consumption in litres/hour.

A set of nozzles is supplied with each appliance

N° 00 from 10 to 63 l/h	N° 2 from 1000 to 4000 l/h
N° 0 from 100 to 400 l/h	N° 3 > 4000 l/h
N° 1 from 250 to 1000 l/h	

*7-4 **Oxygen supply***

- The oxygen supplied by liquefying air is delivered in steel cylinders where it is compressed to a pressure of 1500 N/Cm^2.
- Since the working pressure of oxygen is 10 to 30 N/Cm^2, a pressure reducer must be fitted between the cylinder and the torch.
- The regulator is fitted directly to the cylinder valve and has two pressure gauges, one showing the gas pressure in the cylinder and the other after pressure reduction.
- A handwheel adjusts the gas pressure.

*7-5 **Acetylene supply***

Acetylene is a hydrogen carbide with the chemical formula C_2H_2. It is obtained by bringing water into contact with calcium carbide (C_2Ca).

$$\mathbf{C_2Ca + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2}$$

$Ca(OH)_2$: slaked lime

Acetylene is explosive, so it is dissolved in acetone at a pressure of 1500N/Cm^2 to avoid any danger.

The working pressure of the gas is 0.15 to 0.5 N/Cm^2.

*7-6 **La Flame***

- The normal oxyacetylene flame comprises two zones

1st zone: the sting which constitutes the hot zone (red flame)

2ndzone the plume: secondary flame of less bright.

If the torch is set correctly$\frac{\text{Volume of Oxygen}}{\text{Volume d'acetylene}} = 1$ the stinger should be as long as possible (5 to 6 mm for a 100 l spout).

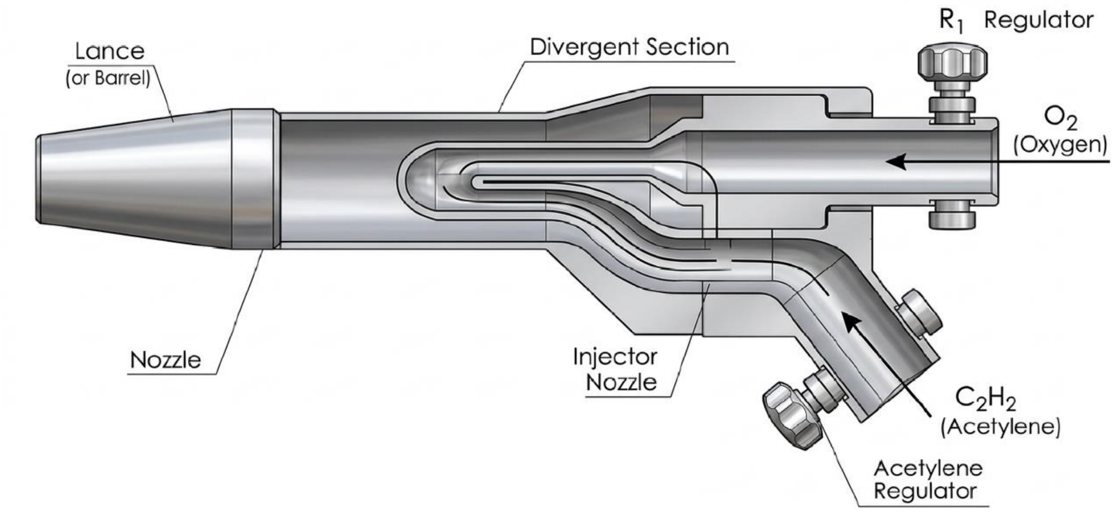


Figure 15: Oxy-acetylene Torch

7-7 __Type of the flame__

- ***Neutral or normal flame:*** this is the flame normally used for welding. The sting is bright white in colour and has a very clear shape at the nozzle outlet.
- ***Oxidizing flame:*** this is a flame with an excess of oxygen. The plume and stinger are shortened. The flame emits a hissing sound. The plume is brighter.

The flame is adjusted by opening taps R1 and R2, always starting with an excess of acetylene.

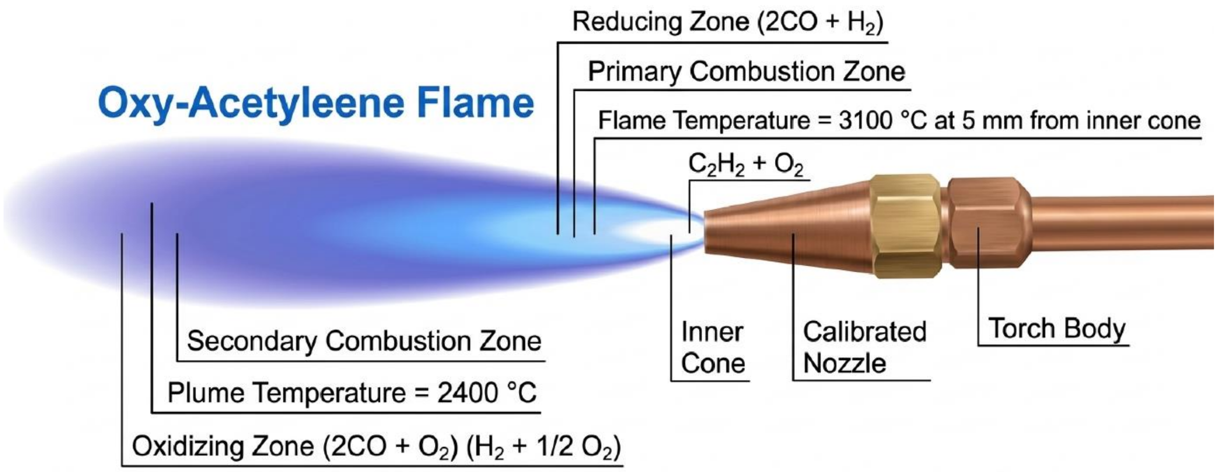


Figure 16: Description of the neutral oxyacetylene flame

8- __BRAZING__

8-1 __Definition__: This operation consists of joining metal parts using a filler metal with a lower melting point than the parts to be joined.

8-2 Conditions of good Brazing

A good braze joint depends essentially on

- The material forming the joint
- The state of the contact surface (pickled, degreased, etc.)
- Wetting

8-3 Wetting

If a drop of molten metal is placed on a metal substrate maintained at room temperature, the drop cools rapidly and does not spread. On the other hand, if the temperature of the substrate is varied, a greater or lesser amount of spreading can be observed from a given temperature.

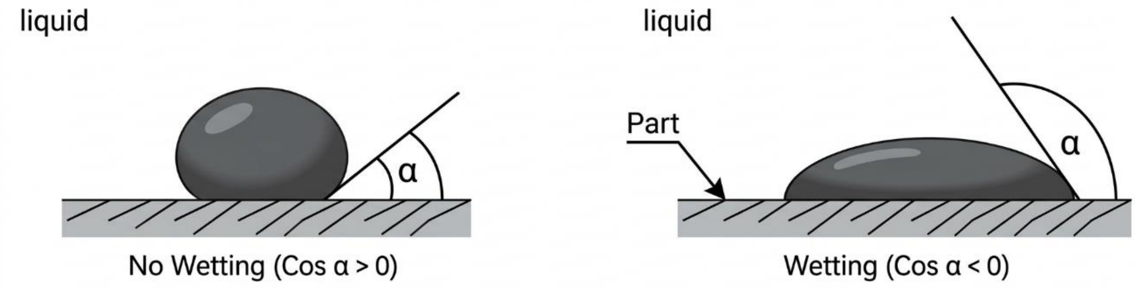


Figure 17: Molten metal drop solidifying on plate

8-4 Preparation of Surfaces

It must be exposed by removing oils, greases, paints and oxides.

The methods used can be

- Chemical: solvents, electrolytic baths, acids (HCl, H_2SO_4 , HNO_3 , HF, ...)
- Mechanical: grinding, machining, sandblasting, etc.…

8-5 Strength of a brazed joint

$$KL > e.\frac{Rm}{Rg}$$

K = 0.8 Coefficient of joint

L : Overlapping length

Rm : Resistance of the part with the smallest cross-section

Rg: Average braze shear strength

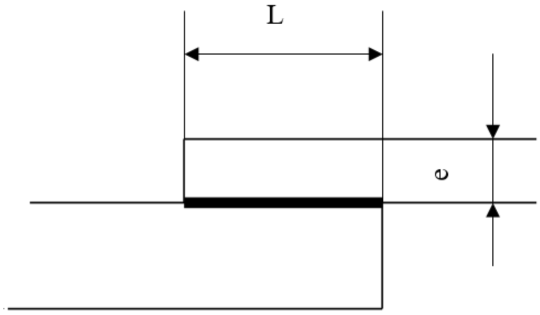


Figure 18: Diagram of a Brazing Assembly

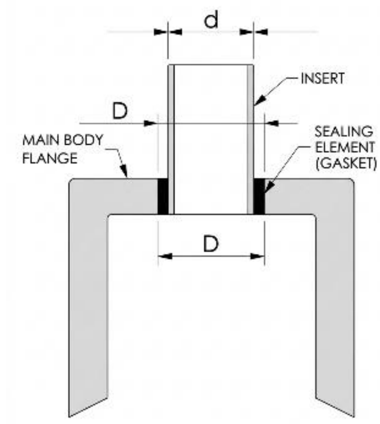


Figure 19: Diagram showing a Set

Filler metal	**T_f (°C)**	**Sets**
Cu	1080	0.03 to 0.15
Ag-Mn	960	0.05 to 0.15
Cu-Zn	890-950	0.05 to 0.25
Ag-Cu-Zn	670-750	0.02 to 0.1
Cu-P	700	0.05 to 0.2
Al-Si	570-580	0.1 to 0.2

Measured set goes cold $J = (D-d)/2$

If two different metals are joined together, the more dilatable being located inside the bore, there will be variations in clearance during heating and cooling, which is why it is important to provide a sufficiently large clearance when cold so that a suitable capillary space remains at the wetting temperature.

During cooling, there will be an increase in clearance expressed by the relationship

$$\Delta J = D/2(\alpha_2 - \alpha_1)(Tc - Tf)$$

Tc : Heating temperature

T_f : Room temperature

α_2, α_1 : Coefficient of expansion of metals ($\alpha 2 > \alpha 1$)

8-6 Heating systems used

- Air-gas mixture for low temperatures.
- Oxy-acetylene flame for high temperatures.
- Flame or electric resistance furnace (controlled atmosphere).

8-7 Choice of using an oxyacetylene flame

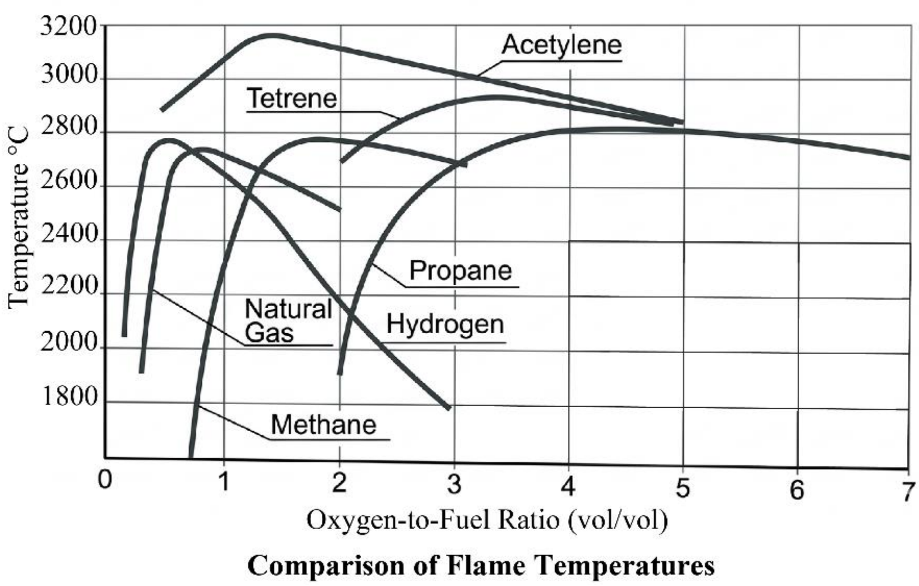


Figure 20: Comparison of the temperature of various flames

9- **ELECTRIC ARC WELDING**

9-1 Definition:

This was the most commonly used process, increasingly replaced today by the more advantageous MIG-MAG process.

The electrode melts simultaneously with the base metal to form the weld bead, which is covered by a protective slag (formed by the coating of the electrode).

An electrode holder holds the rod.

9-2 Welding unit

Its role is to deliver a low-voltage, high-amperage electric current Figure 21.

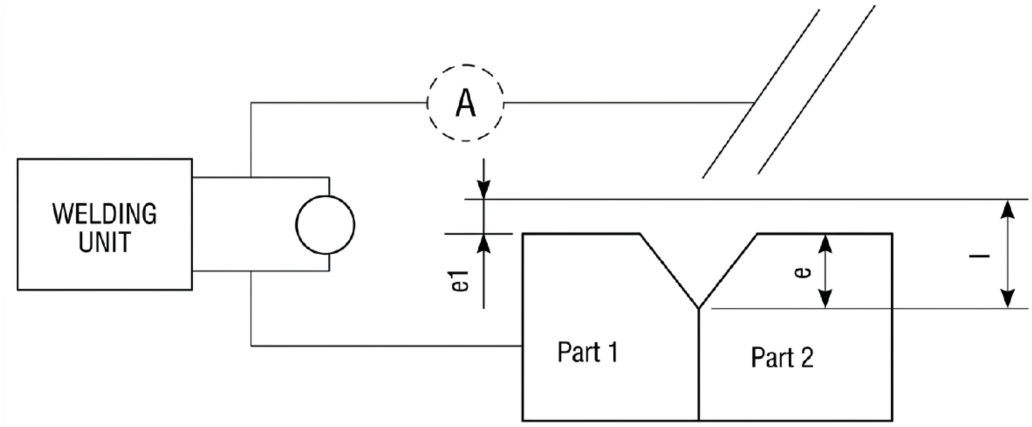


Figure 21: Schematic diagram of an arc welding installation

9-3 ***Electrode***

Also known as a welding rod, it consists of a metal wire (core) and a sheath (coating)

9-4 ***Roles of the Electrode***

It conducts the arc-generating current between itself and the parts to be welded, and also acts as a filler metal.

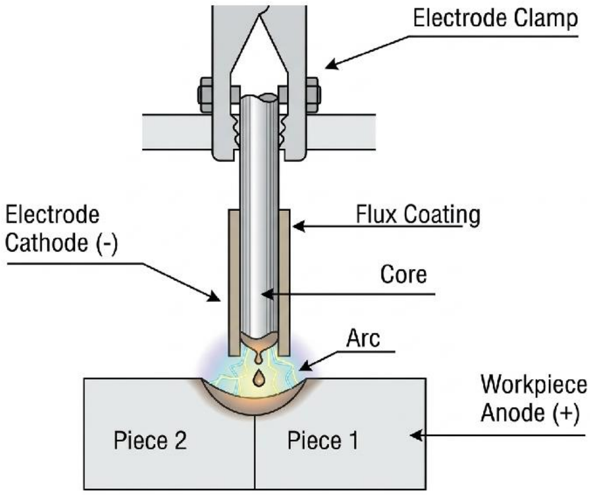


Figure 22 :Arc Producing Electrode

- Most electrodes have a coating based on (titanium salt, silicate, sodium carbonate, potassium carbonate).
- The coating makes it easier to ignite the arc and creates a curtain by melting, insulating the molten metal from atmospheric gases.

- The intensity of the current must be chosen according to the type and diameter of the electrode, and the nature of the work.
- The diameter of the electrodes depends on the thickness of the parts to be welded.

9-5 <u>Advantages of arc welding</u>

- 4 times faster than torch welding
- Localized heating means low heat dispersion.

9-6 <u>Condition of the Arc existence</u>

The electric arc is a form of electric current flowing through a non-conducting or poorly conducting gaseous atmosphere. The existence of the arc is made possible by a thermionic effect which manifests itself in the emission of electrons during heating, an emission which occurs as soon as sufficient P.D.D. is applied between the two electrodes.

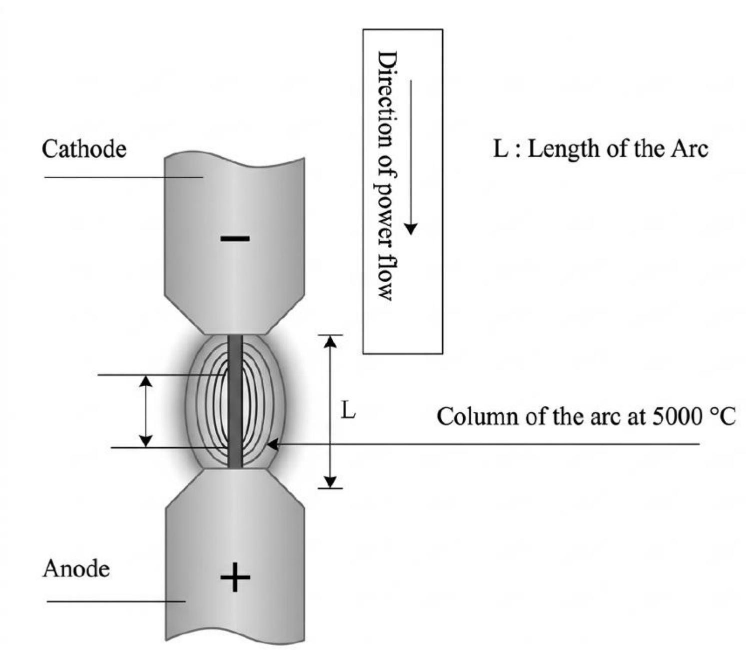


Figure 23: Diagram of an Electric Arc

9-7 <u>Welding current</u>

This is indicated by the manufacturer on the electrode packs.

$$I_S = 50\,(Ø - 1)$$

<u>with</u> I_S : intensity in amperes

Ø : Core Diameter in (mm)

$$\begin{cases} US = 25\,V & \text{For} \quad IS = 100A \\ US = 0.04IS + 20 & \text{For} \quad 100A < IS < 500A \\ US = 40V & \text{For} \quad IS > 500A \end{cases}$$

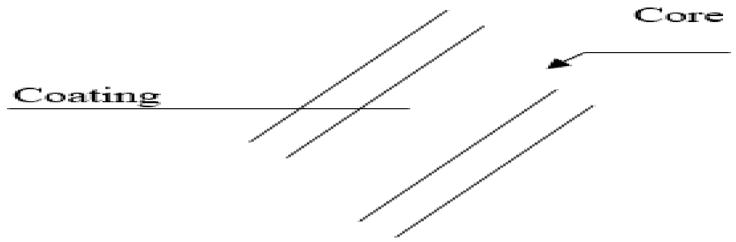


Figure 24: Cross-section of an electrode

10- <u>RESISTANCE WELDING</u>

10-1 <u>Definition</u>**:** Welding without filler metal by passing a high intensity electric current combined with a pressure effect.

10-2 <u>Spot-welding</u>

Welding is carried out between two copper or copper alloy electrodes with flat or curved frustoconical ends.

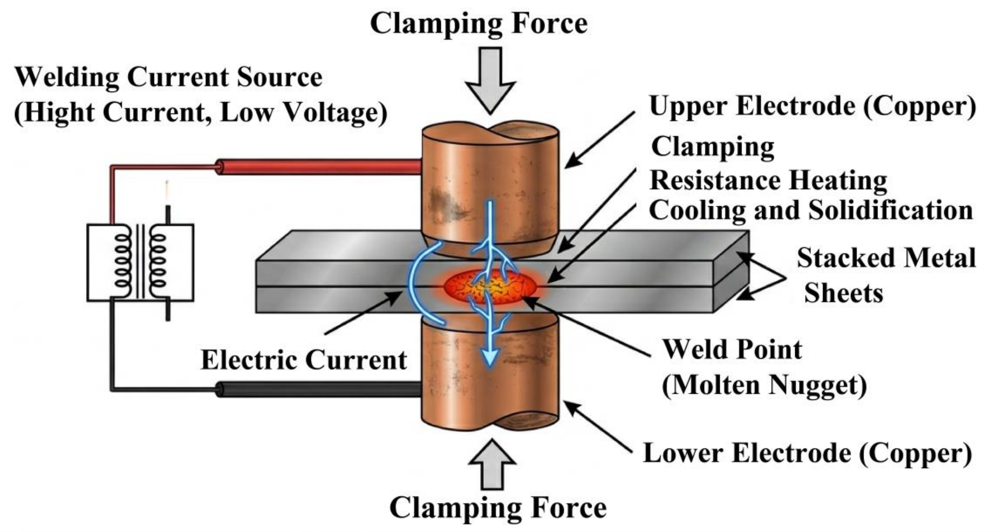


Figure 25: Basic principle of spot welding

10-3 ***Cycles***

d) Bonding: This is a compressive force exerted by two copper electrodes (E1, E2) cooled by circulating water and brought into contact with the areas to be bonded

e) Welding :The thicknesses of the two parts form an electrically resistant unit.

If an intense current (low voltage, high intensity) is passed from electrode E1 to electrode E2 for a suitable period of time,heating will occur, causing the uncooled areas to melt. Melting of the uncooled areas.

f) Maintenance :When the current is cut off,the force still applied forges the weld.

The molten core is containedin a plastic metal envelope.

10-4 ***Wheel welding***

This process produces a continuous or discontinuous weld line. The electrodes are wheels (discs) which rotate.These rollers compress the work-pieces, ensure the flow of electric currentand advance the sheets.

A special device regulates the rapid rate at whichthe current is interrupted and then restored.

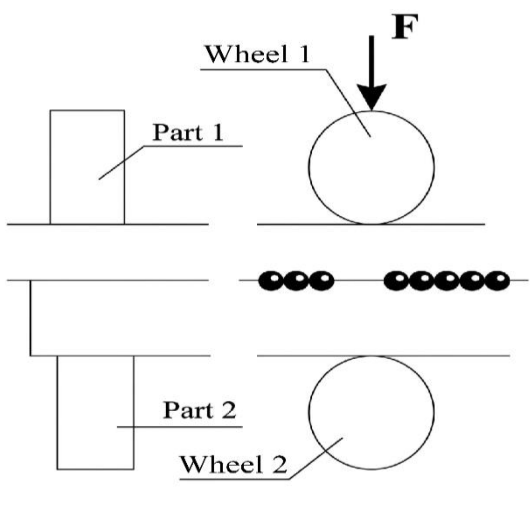


Figure 26: Schematic diagram of seam welding principle

11- **GAS SHIELDED WELDING**

11-1 Welding T.I.G M.A.G

This is gas metal arc welding with a fusible electrode wire.

The wire, in reel form, is fed automatically and continuously by a reel and drive rollers to the torch, which is held in the hand. The diagram shows the principle of semi-automatic gas-shielded welding. The heat required to melt the parts to be welded is provided by a free electric arc that shoots up between the wire electrode and the parts.

The arc and molten bath are protected by an inert gas (Argon) or an active gas (CO_2).The arc is formed between the automatically advancing filler wire and the base metal.

The spool of wire is in a reel: the wire passes through a system of rollers called capstans and is guided by a coaxial sheath to the torch in the torch. The electric arc is sent between the workpiece and the fusible wire. The welder presses a trigger to release the gas, create the electric arc and unwind the wire.

11-2 __T.I.G Welding__

This is arc welding under a neutral gas flow (argon, helium or argon-helium) with a non-melting refractory electrode (pure tungsten or thorium tungsten, cerium tungsten or zirconium tungsten) and a filler metal rod.

The welder holds the torch in one hand to establish the arc with the workpiece and the welding rod in the other hand to form and feed the molten metal.

12- **__RULES TO BE RESPECTED__**

Certain rules must be respected

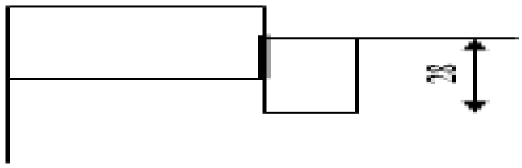
- Organise the relative position of the components to be welded according to the forces to which the assembly will be subjected in service.
- Welding resists tensile stresses well, and compression stresses better, but bending, twisting or impact work should be avoided.
- When studying a welding problem, include its own action on the area bordering the weld, as there may be structural modifications (work hardening, quenching) and therefore an influence on the mechanical properties.
- Try to neutralize stresses and strains due to expansion and shrinkage, possibly by heat treatment before or after welding.

APPLICATION EXERCISES

Exercise 1: Determine the weldability quality of the following steels

42C4 18CD4 XC48 20M4

Exercise 2: We want to assemble two parts by electric arc welding, the base metals are A30 and the filler metal is copper.



1- What is the class of this welding? Justify your answer.
2- Give a name to this type of welding and justify your answer.
3- Calculate the voltage Us(V) required for welding.
4- Determine the resistance of the weld joint.
5- Calculate the nominal energy En and the dissipated energy Ed

We give: Is(A) = 425 K = 0.8 $T_{fusion\ Cu} < T_{fusion\ A30}$ ν = 0.5 cm/s η = 0.8

Exercise 3: We want to join two parts using resistance welding. The machine performs 34 welds per minute and operates at a frequency of 50Hz. The force exerted by the machine is 330daN under 12300A.

Given: Welding time = 15 periods Docking time = Holding time = Twice the welding time

Calculate:

1- The hot time and then the cold time for a weld spot
2- The duty cycle
3- Illustrate all the given and calculated values with a detailed diagram.
4- Calculate the energy required for local melting of the parts.

Exercise 4: What are the disadvantages of welding types you are familiar with?

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