Metallurgy for Non-Metallurgists

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Syllabus

- Heat treatment processes
- Manufacturing processes such as Rolling, Forging, Casting and Welding

Heat Treatment of Steel

- Most heat treating operations begin with heating the alloy into the austenitic phase field to dissolve the carbide in the iron
- Steel heat treating practice rarely involves the use of temperatures above 1040 C
- Classification
  - Heating and rapid cooling (quenching)
  - Heating and slow cooling

Purpose of heat treatment:

- Improvement in ductility
- Relieving internal stresses
- Grain size refinement
- Increase of strength and hardness
- Improvement in machinability and toughness

FACTORS INVOLVED

- Temperature upto which material is heated
- Length of time that the material is held at the elevated temperature
- Rate of cooling
- The surrounding atmosphere under the thermal treatment.

Types of Heat Treatment

- Annealing
- Normalizing
- Hardening
- Tempering
- Surface Hardening
- These differ mainly in the way material is cooled from an elevated temperature.

Effect of Quenching Medium

Medium	Severity of Quench	Hardness
air	small	small
oil	moderate	moderate
water	large	large

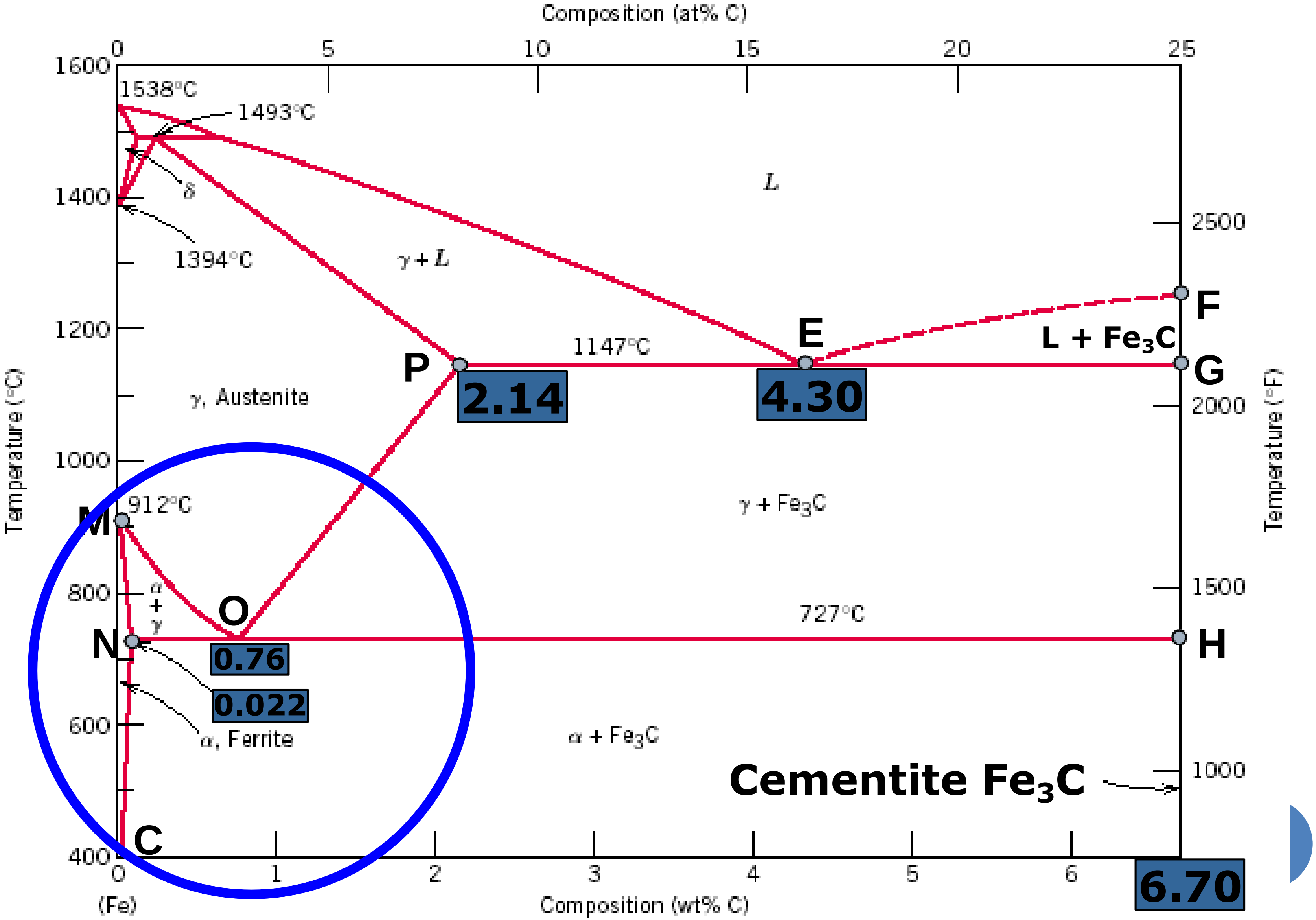
The severity of quench: water > oil > air

- During annealing, material is cooled in air and/or heating furnace itself.
- For hardening, material is immersed in water / oil quench bath.

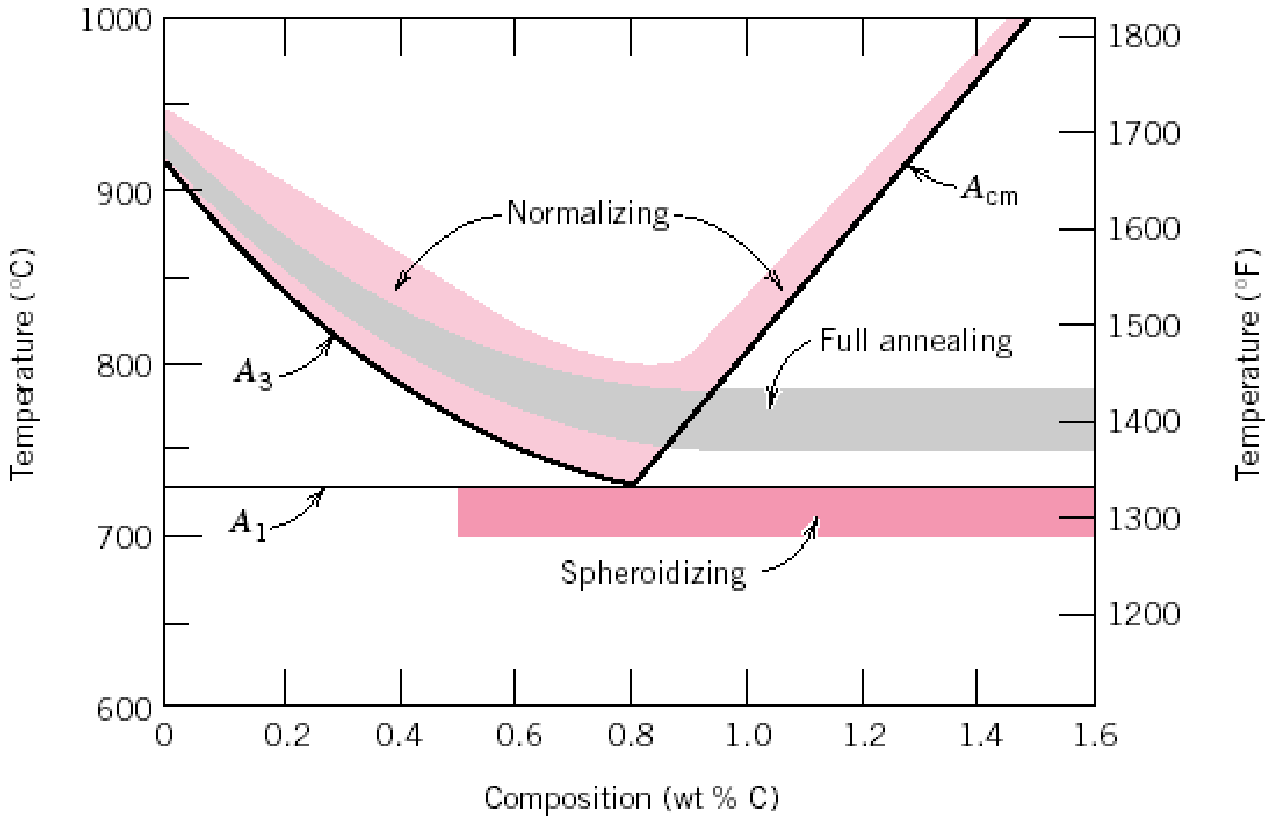
Effects of Heat treatment

Annealing & Normalizing	Hardening or Quenching		
Furnace Cooling	Air Cooling	Oil Quenching	Water Quenching
← Softer, less strong	Harder and stronger →		
← More ductile	More brittle →		
← Less internal stress	More internal stress →		
← Less distortion, cracking	More distortion, cracking →		

The Iron–Iron Carbide Phase Diagram



Heat Treatment of Steel



Annealing Process

- Material is exposed to an elevated temperature for an extended time period and then slowly cooled, allowing phase changes.
- Utilized for low- and medium-carbon steels.
- Full Annealing
- Process Annealing

  or Stress Relief Annealing
- Spheroidising

Three stages of annealing

- Heating to the desired temperature : The material is austenitized by heating to 15 to 40°C above the A_3 or A_1 lines until equilibrium is achieved (i.e., the alloy changes to austenite),
- Soaking or holding time: The material is held for 1h at the annealing temperature for every inch of thickness (a rule of thumb)
- Cooling to room temperature: cooling rate of 100 F/hr is typical for full annealing. Done in furnace itself.

Purposes of Annealing

1. Relieve Internal Stresses
   - Internal stresses can build up in metal as a result of processing.
     - such as welding, cold working, casting, forging, or machining.
   - If internal stresses are allowed to remain in a metal, the part may eventually distort or crack.
   - Annealing helps relieve internal stresses and reduce the chances for distortion and cracking.

Purposes of Annealing

2. Increasing Softness, Machinability, and Formability
    - A softer and more ductile material is easier to machine in the machine shop.
    - An annealed part will respond better to forming operations.
3. Refinement of Grain Structures
    - After some types of metalworking (particularly cold working), the crystal structures are elongated.
    - Annealing can change the shape of the grains back to the desired form.

Annealing

1. Heat to above Upper Critical Temperature, at which point the structure is all Austenite
2. Cool very slowly in the furnace.
3. Structure will now be large-grained pearlite.
4. Used to improve the properties of cast and forged steels prior to machining.

Process Annealing (Intermediate Annealing)

- A heat treatment used to negate the effects of cold work, i.e., to soften and increase the ductility of a previously strain-hardened metal
- In process annealing, parts are not as completely softened as they are in full annealing, but the time required is considerably lessened.
- Process annealing or stress-relief annealing is frequently used as an intermediate heat-treating step during the manufacture of a part.
- Recovery and recrystallization processes occur during the process.

Stress Relief Annealing

- Internal residual stresses may develop in metal pieces due to:
  - Plastic deformation processes (machining and grinding)
  - Non-uniform cooling of a piece that was processed or fabricated at an elevated temperature (welding or casting)
- Distortion and warpage may result if these residual stresses are not removed.

Stress Relief Annealing

- The material is heated to the recommended temperature, held long enough to attain a uniform temperature, and finally cooled to room temperature slowly

- The annealing temperature is ordinarily a relatively low one such that effects resulting from cold work and other heat treatments are not affected

Process Annealing

1. Heat to below Upper Critical Temperature to cause recrystallisation
2. Cool very slowly in the furnace.
3. Structure will now be equi-axed pearlite.
4. Used to maximise the ductility of low carbon steels and other materials after cold working.

Spheroidising

1. Heat to just below Lower Critical Temperature. (about 650-700 deg C)
2. Cool very slowly in the furnace.
3. Structure will now be spheroidite, in which the Iron Carbide has balled up.
4. Used to improve the properties of medium and high carbon steels prior to machining or cold working.

NORMALISING

- The name —normalising‖ comes from the original intended purpose of the process — to return steel to the —normal‖ condition it was in before it was altered by cold working or other processing.

- Heating the alloy to 55 to 85℃ above the A_3 or A_{cm} and holding for sufficient time so that the alloy completely transforms to austenite, followed by air cooling

Normalising

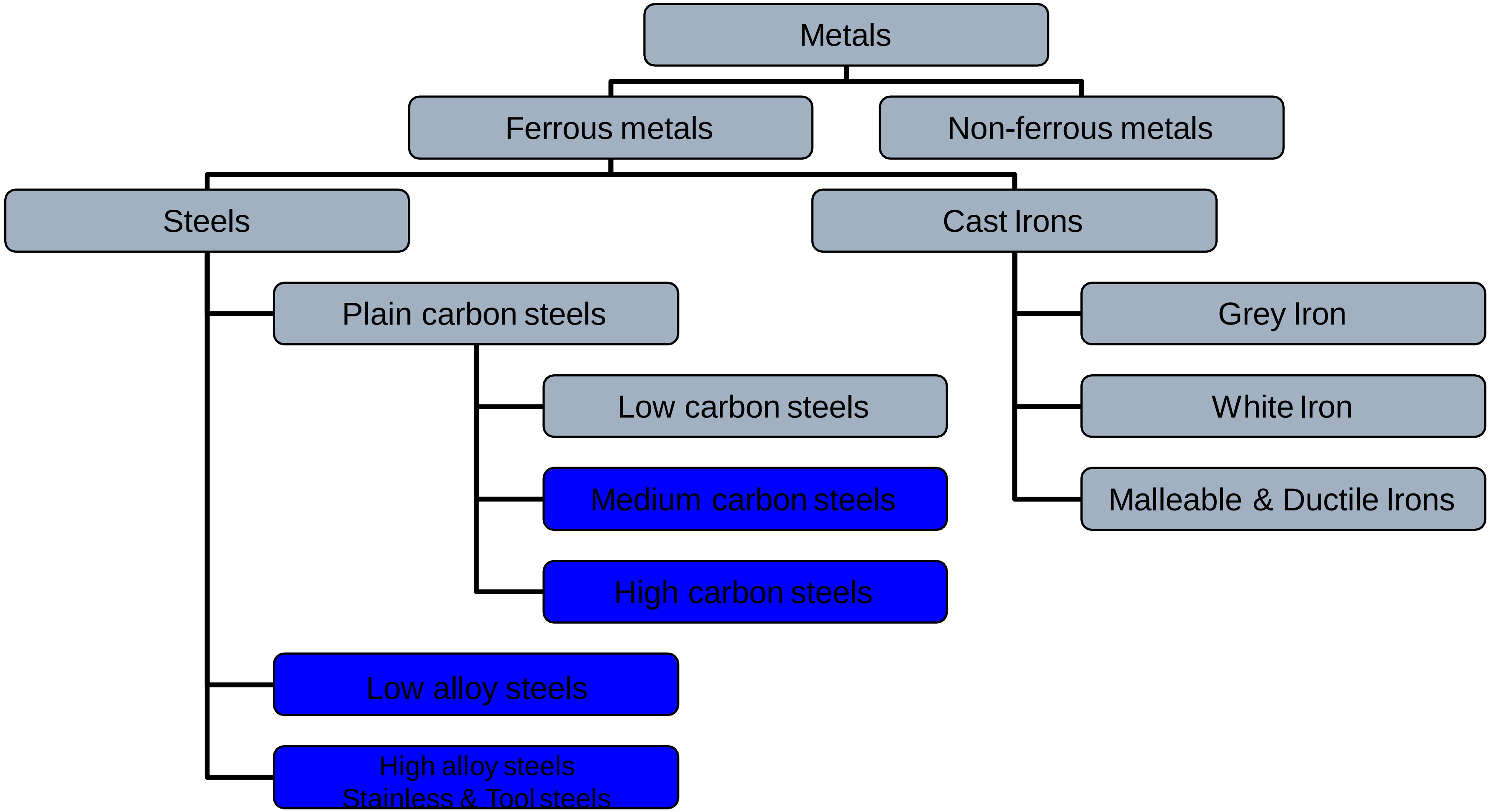
- To refine the grains and produce a more uniform and desirable size distribution for steels that have been plastically deformed
- Normalising does not soften the material as much as full annealing does.
- The cooling process does not leave the material as ductile or as internally stress-free.
- A normalised part will usually be a little stronger, harder, and more brittle than a full-annealed part.

Normalising

1. Heat to Upper Critical Temperature, at which point the structure is all Austenite
2. Cool slowly in air.
3. Structure will now be fine equi-axed pearlite.
4. Used to restore the ductility of cold or hot worked materials whilst retaining other properties.

Hardening

- Hardening of steels done to increase the strength and wear resistance
- Heated to 30-50 C above the upper critical temperature and then quenched
- The quicker the steel is cooled, the harder it would be



The steels shown in blue can be heat treated to harden them by quenching.

Hardening Temperatures

- The temperatures for hardening depend on the carbon content.
- Plain carbon steels below 0.4% will not harden by heat treatment.
- The temperature decreases from approx 820 C to 780 C as carbon content increases from 0.4% up to 0.8%.
- Above 0.8% the temperature remains constant at 780 C.
- Hardening temperature same as that for normalising

Quenching Media

Four commonly used quenching media:

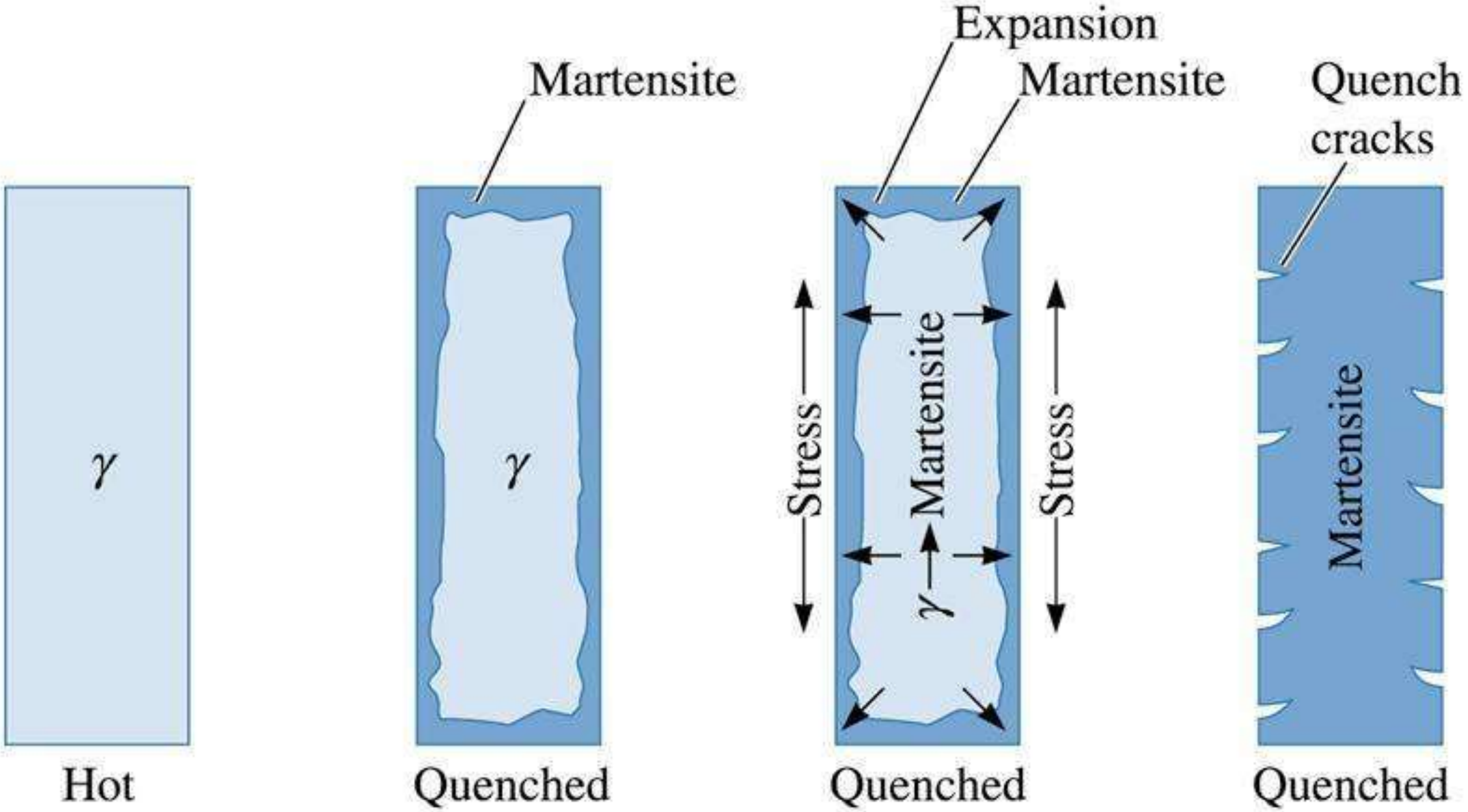
- Brine – the fastest cooling rate
- Water – moderate cooling rate
- Oil – slowest cooling rate
- Gas – used in automatic furnaces, usually liquid nitrogen, can be very fast cooling.

Too rapid cooling can cause cracking in complex and heavy sections.

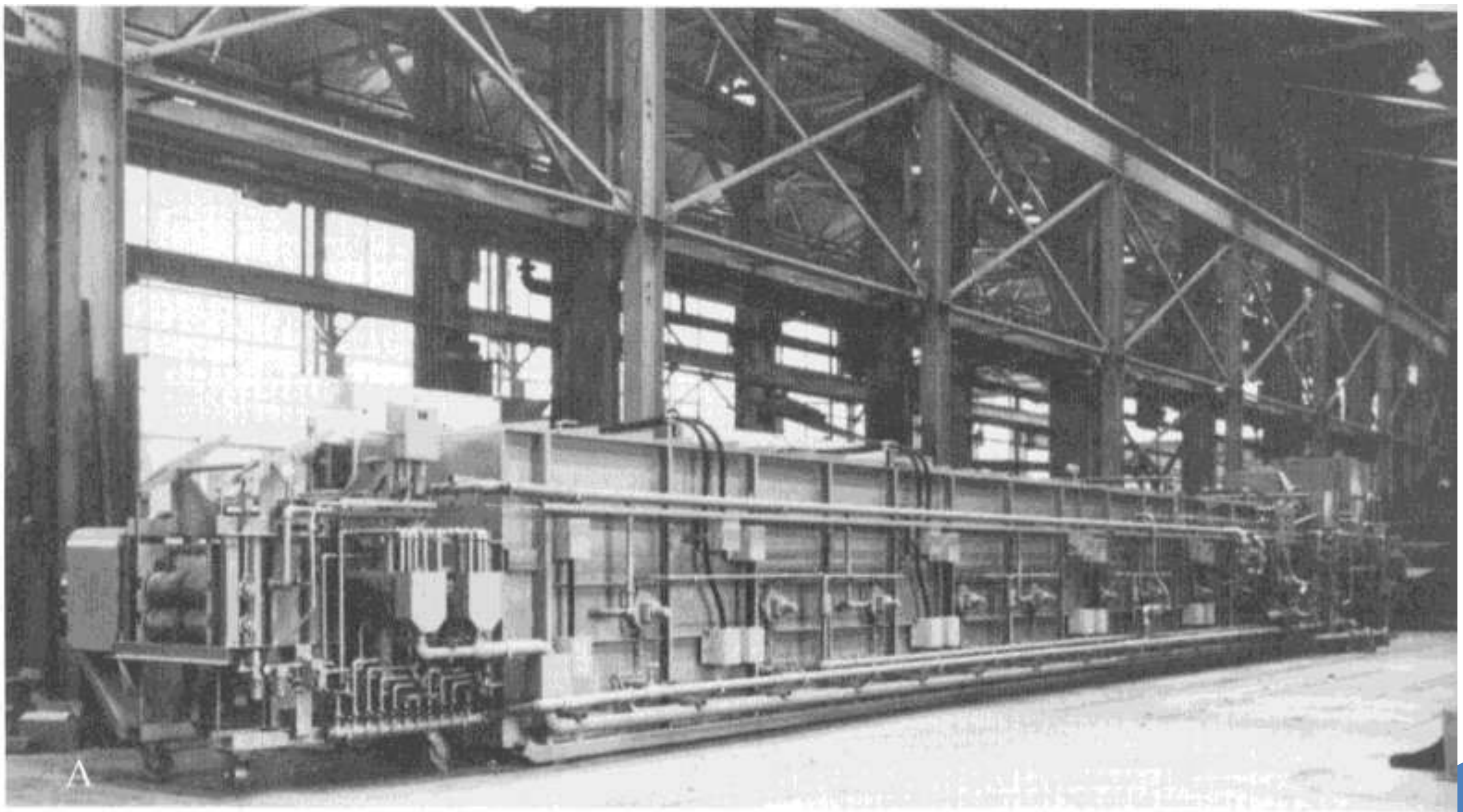
Hardenability

- The hardenability of a steel is broadly defined as the property which determines the depth and distribution of hardness induced by quenching.
- This is dependent upon the chemical composition of the steel alloy.
- The addition of Nickel, Chromium and Molybdenum will slow the transformation to other phases and allow more martensite to form.
- Most heat treatable steels are alloys rather than plain carbon steels.

QUENCH CRACKS



Furnaces Widely Used in Heat Treatment of Steels



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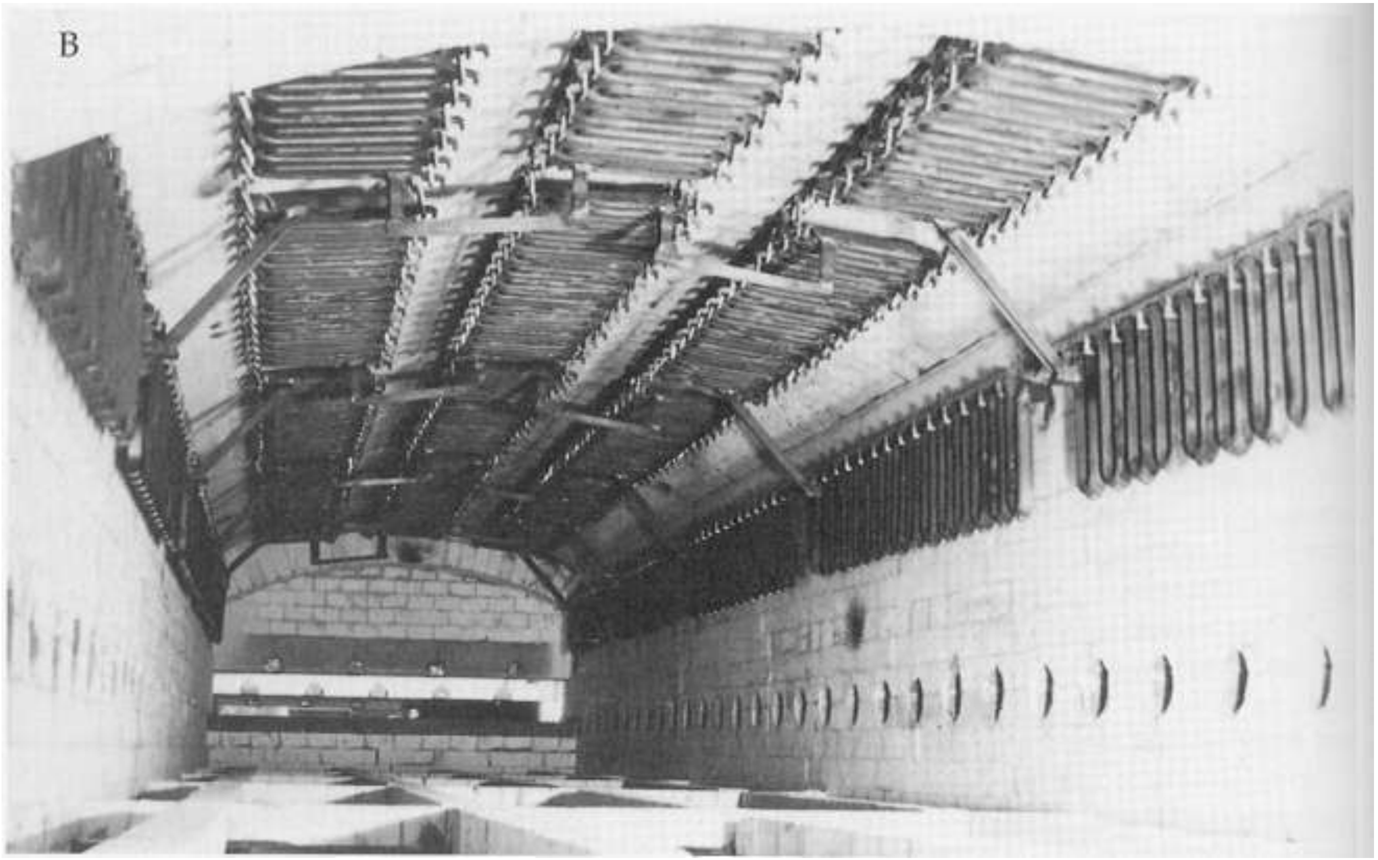


Tempering

- The brittleness of martensite makes hardened steels unsuitable for most applications.
- Different cooling rates between edge and core of components result in internal stresses.
- This requires the steel to be tempered by re-heating to a lower temperature to reduce the hardness and improve the toughness.
- This treatment converts some of the martensite to bainite.

Tempering Temperatures

COLOUR	HARDEST	APPROXIMATE TEMPERATURE (°C)	USES
Pale straw		230	Lathe tools, scrapers, scribers
Straw		240	Drills, milling cutters
Dark straw		250	Taps & dies, punches, reamers
Brown		260	Plane blades, shears, lathe centres
Brown/purple		270	Scissors, press tools , knives
Purple		280	Cold chisels, axes, saws
Dark purple		290	Screwdrivers, chuck keys
Blue	TOUGHEST	300	Springs, spanners, needles

Surface Hardening

- Selectively Heating the Surface - Rapidly heat the surface of a medium-carbon steel above the A_3 temperature and then quench.
- Case depth - The depth below the surface of a steel at which hardening occurs by surface hardening and carburizing processes.
- Case Hardening : Carburizing
- Cyaniding , Carbonitriding
- Flame Hardening,

Case Hardening

- The primary purpose of case hardening is to produce a surface which is resistant to wear while maintaining the overall toughness and strength of the steel core.
- Normally used on a steel with a low carbon content and introduces carbon by diffusion (carburising) into the local surfaces requiring treatment.
- Heating steel in the presence of a solid, liquid or gas rich in carbon.

Cyaniding

- Hardening the surface of steel with carbon and nitrogen obtained from a bath of liquid cyanide solution.
- Steel is heated in molten cyanide at about 850 C followed by quenching.
- Carbon and nitrogen are absorbed by steel.

Carbonitriding

- Hardening the surface of steel with carbon and nitrogen
- Steel is heated in a gaseous mixture of ammonia and hydrocarons

Nitriding

- Another process called Nitriding consists of the diffusion of nitrogen.
- Nitrogen is introduced into steel by passing ammonia gas through a muffle furnace containing the steel to be nitrided.
- Temperature used is below the lower critical temperature
- Greater resistance to wear and corrosion, greater surface hardness.

Flame Hardening

- Heating the surface being hardened above the upper critical temperature with an oxy acetylene flame before quenching it in a spray of water.
- This is a surface hardening process resulting in a hard surface layer of about 2mm to 6mm deep.
- The main difference between this process and other surface hardening processes is that the composition of the steel being hardened is not changed.

Flame Hardening

- The steel must itself have sufficient hardenability .
- Limits this process to steels having carbon contents of above 0.35%.
- Steels with carbon contents of 0.4%-0.7% are most suitable for this process.
- Steels with higher C content and high alloy steels may not be suitable as they a liable to cracking.
- Result similar to the conventional hardening process but with less hardness penetration.

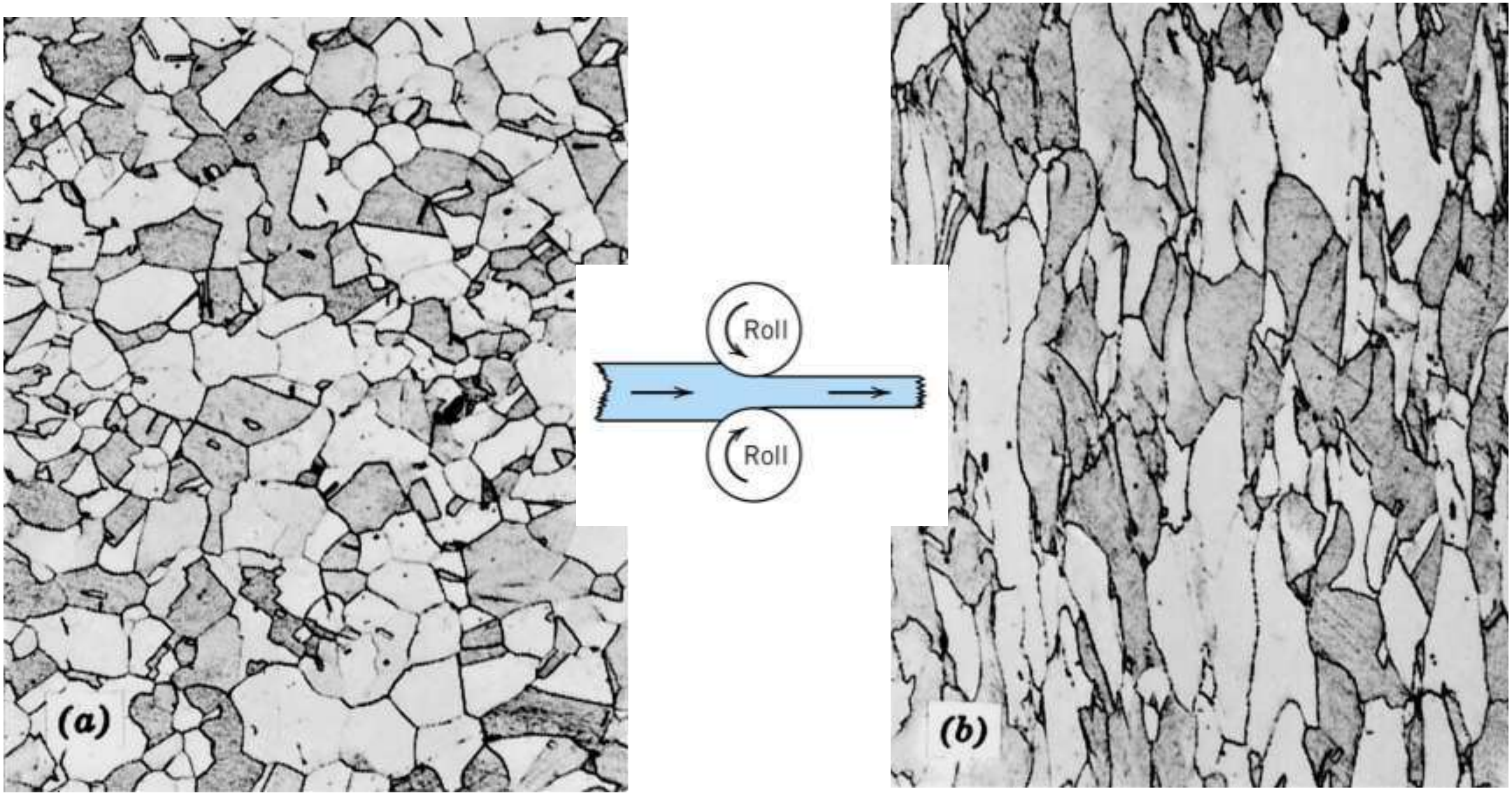
Induction Hardening

- Surface to be hardened is heated using inductive heating.
- Depth of hardness can be closely monitored by controlling current.
- Time required for the process is less.
- Used for producing hard surfaces on crankshafts, axles, gears etc.

Recovery, Recrystallization and Grain Growth

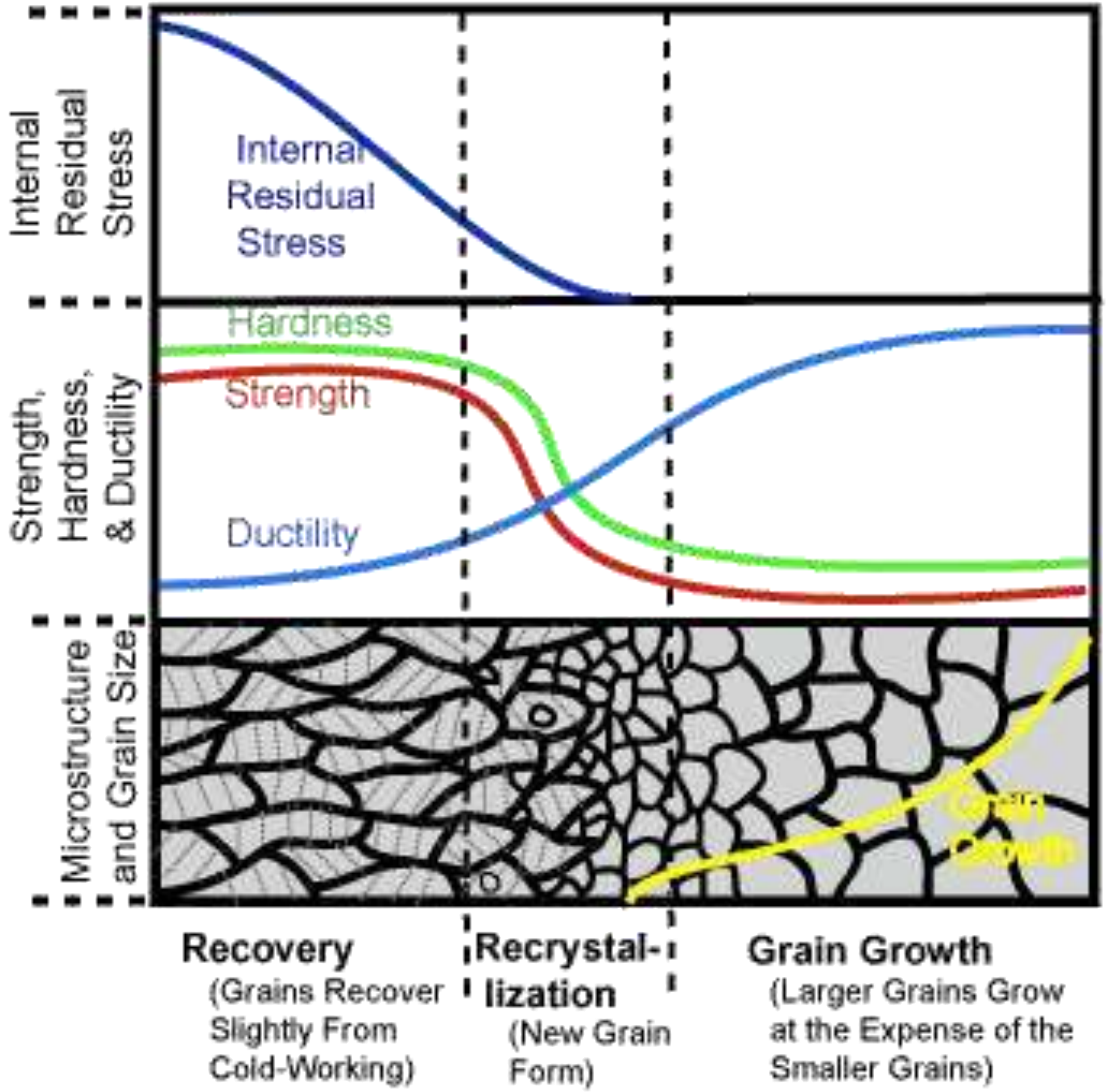
- The phenomena intimately associated with the annealing of a plastically deformed crystalline material
- Plastic deformation increases the density of point imperfections in crystalline materials.
- This leads to an increase in internal strain energy
- On annealing, the material tends to lose the extra strain energy and revert to the original condition.
- This is achieved by the processes of recovery and recrystallisation.

Alteration of Grain Structure as a Result of Plastic Deformation



(a)Before deformation the grains are equiaxed.

(b)The deformation has produced elongated grains.


Internal Residual Stress
Internal Residual Stress
Strength, Hardness, & Ductility
Hardness
Strength
Ductility
Microstructure and Grain Size
Recovery
(Grains Recover Slightly From Cold-Working)
Recrystal-lization
(New Grain Form)
Grain Growth
(Larger Grains Grow at the Expense of the Smaller Grains)

Recovery

- Takes place at low temperatures of annealing
- The point imperfections created during plastic deformations are absorbed at grain boundaries
- Dislocations of opposite sign come together and mutually annihilate each other.
- Some of the stored internal strain energy is relieved by virtue of dislocation motion, as a result of enhanced atomic diffusion at the elevated temperature.

Recrystallization

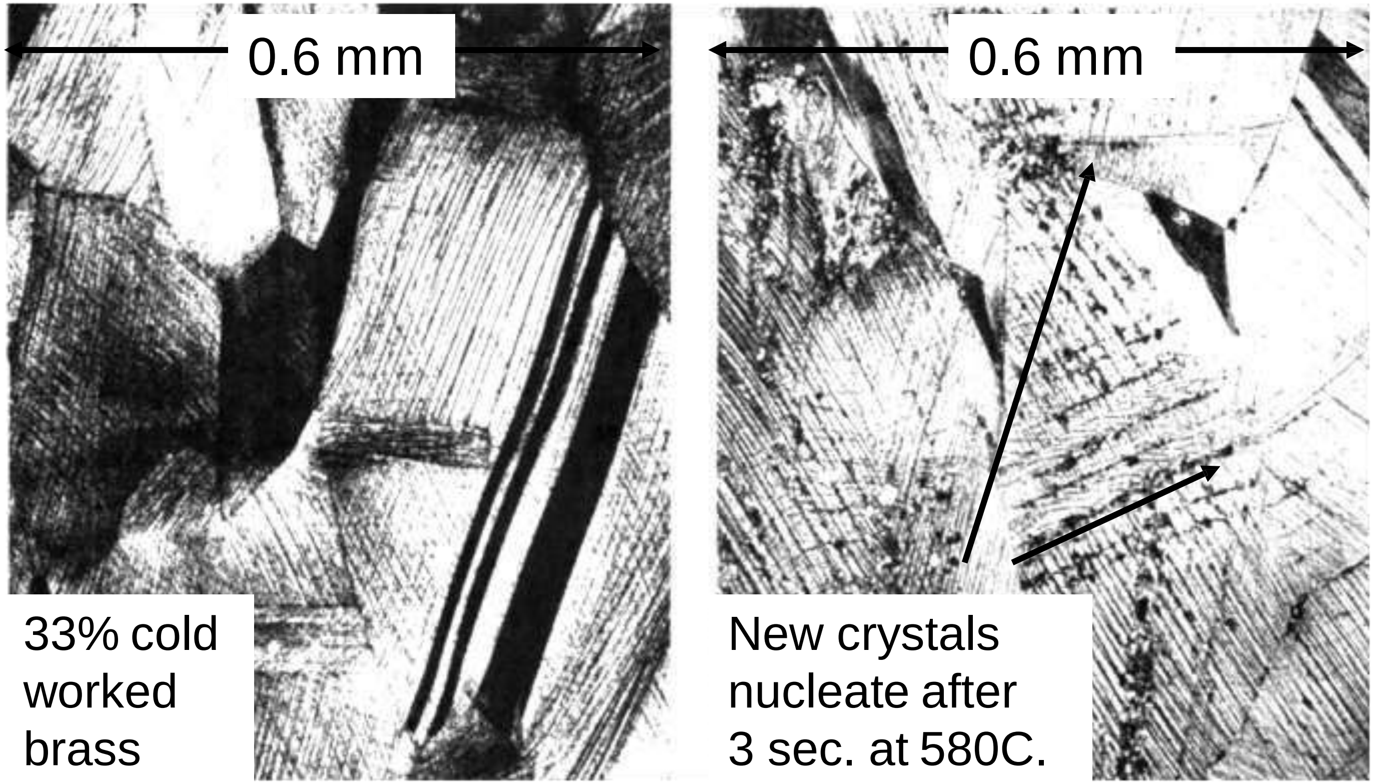
- The process of nucleation and growth of new strain free crystals, which replace the deformed crystals
- No change in crystal structure
- These equiaxed grains will have low dislocation densities and have characteristics of the pre cold-worked condition.

Grain Growth

- Increase in the average grain size on further annealing after all the cold worked material has recrystallised.
- Larger grains grow at the expense of smaller grains
- As the grains grow larger, rate of grain growth decreases.
- Larger grains will reduce the strength and toughness of the material.

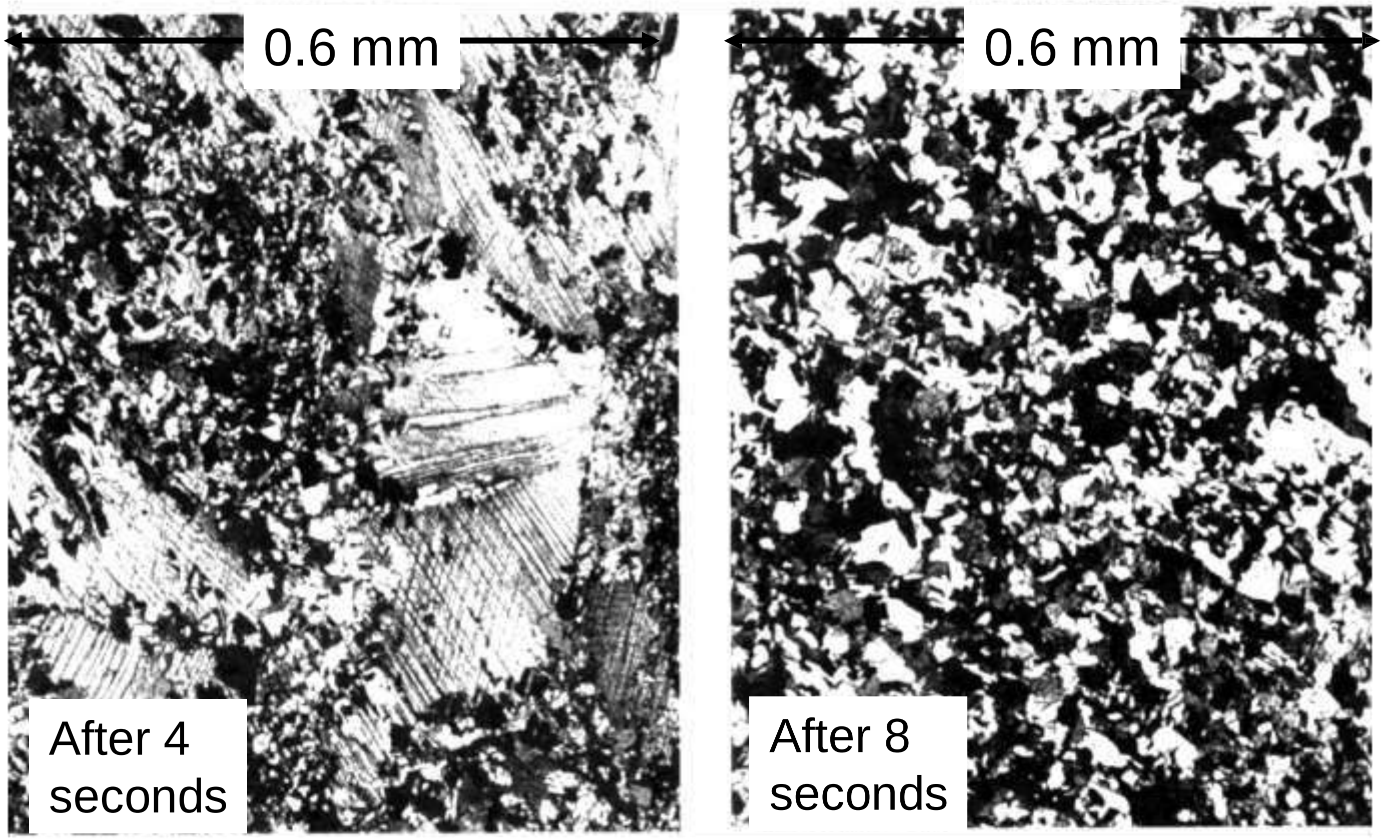
RECRYSTALLIZATION

- New crystals are formed that:
  - have a small dislocation density
  - are small
  - consume cold-worked crystals



Further Recrystallization

- All cold-worked crystals are consumed.



- FORMING PROCESSES - (a) Plastic Deformation Processes

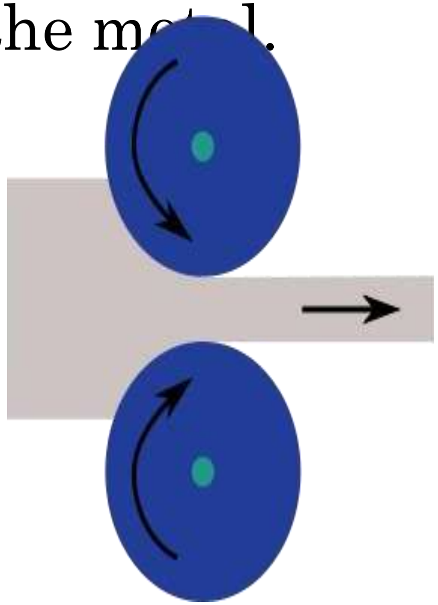
  (b) Metal Removal or Machining

- On the basis of applied force, further classified as –

  (a) Direct Compression type
  (b) Indirect Compression type
  (c) Tension type
  (d) Bending
  (e) Shearing

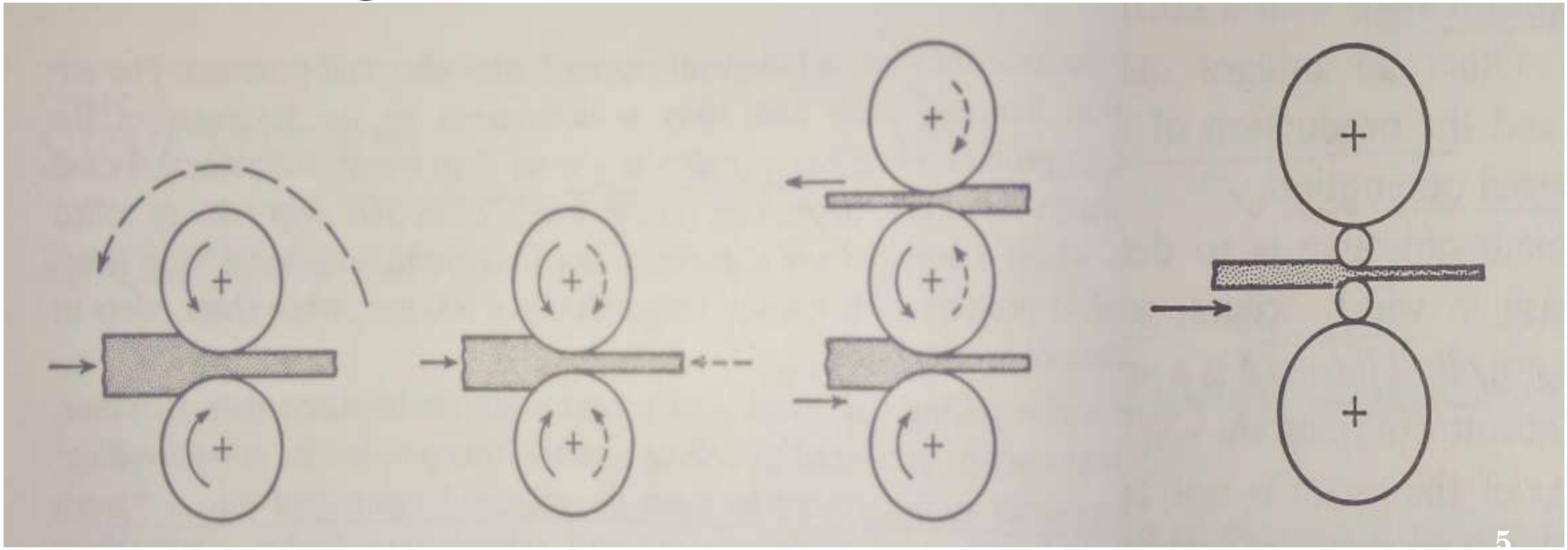
ROLLING

- The process of plastically deforming metals by passing it between rolls is known as rolling.
- The material is subjected to high compressive stresses from the squeezing action of the rolls and to surface shear stresses as a result of the friction between the rolls and the metal.



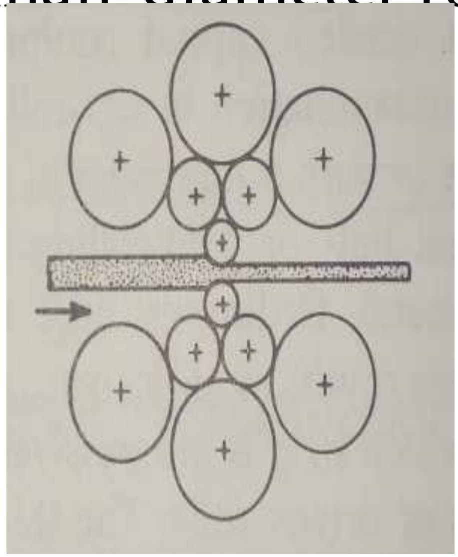
ROLLING MILLS (CLASSIFIED AS NUMBER OF ARRANGEMENTS OF ROLLS)

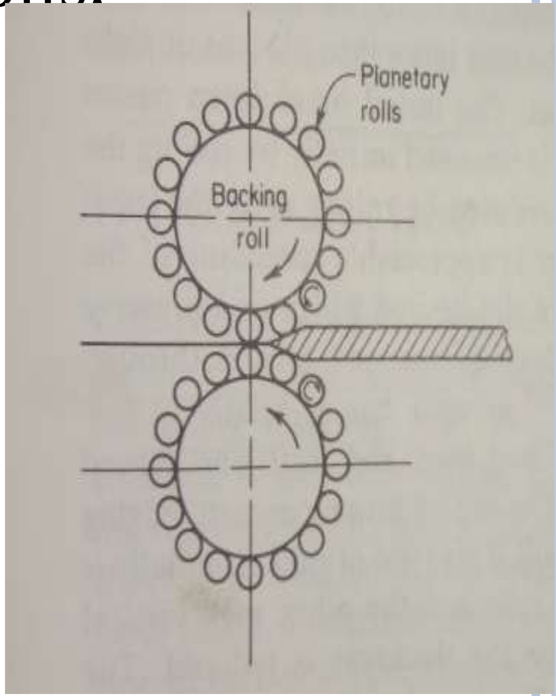
1. Two-high mill
2. Two-high reversing mill
3. Three-high mill
4. Four-high mill

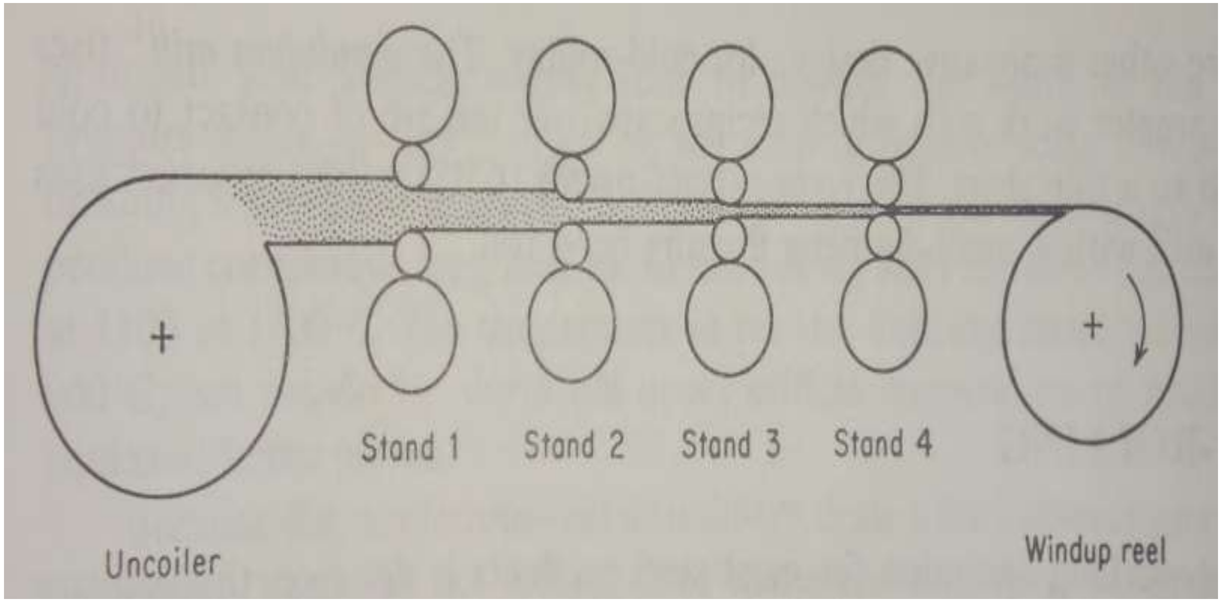


A large decrease in the power required for rolling can be achieved by the use of small-diameter rolls.

5. Cluster mill
6. Planetary mill
7. Four stand continuous

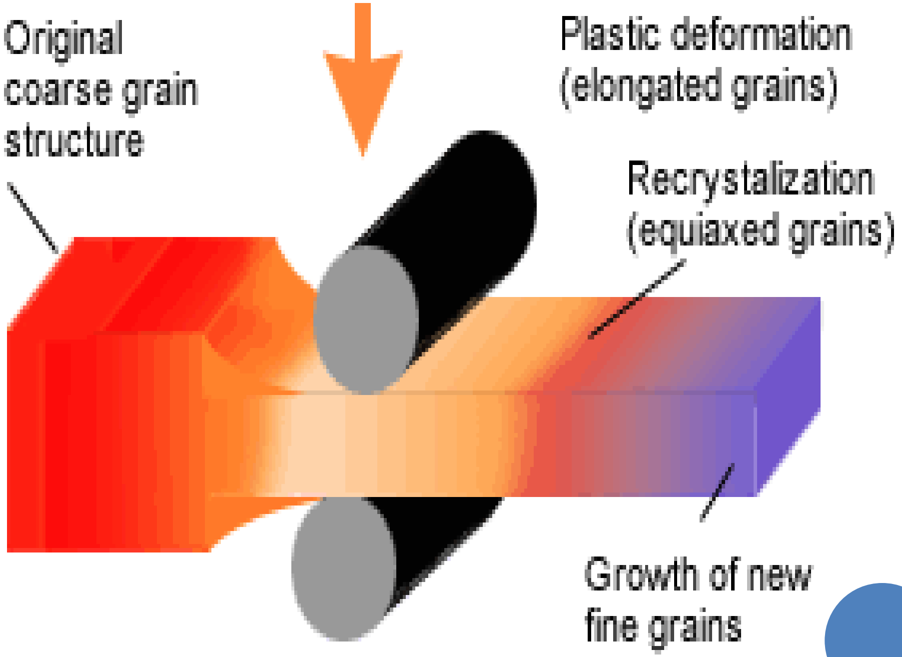


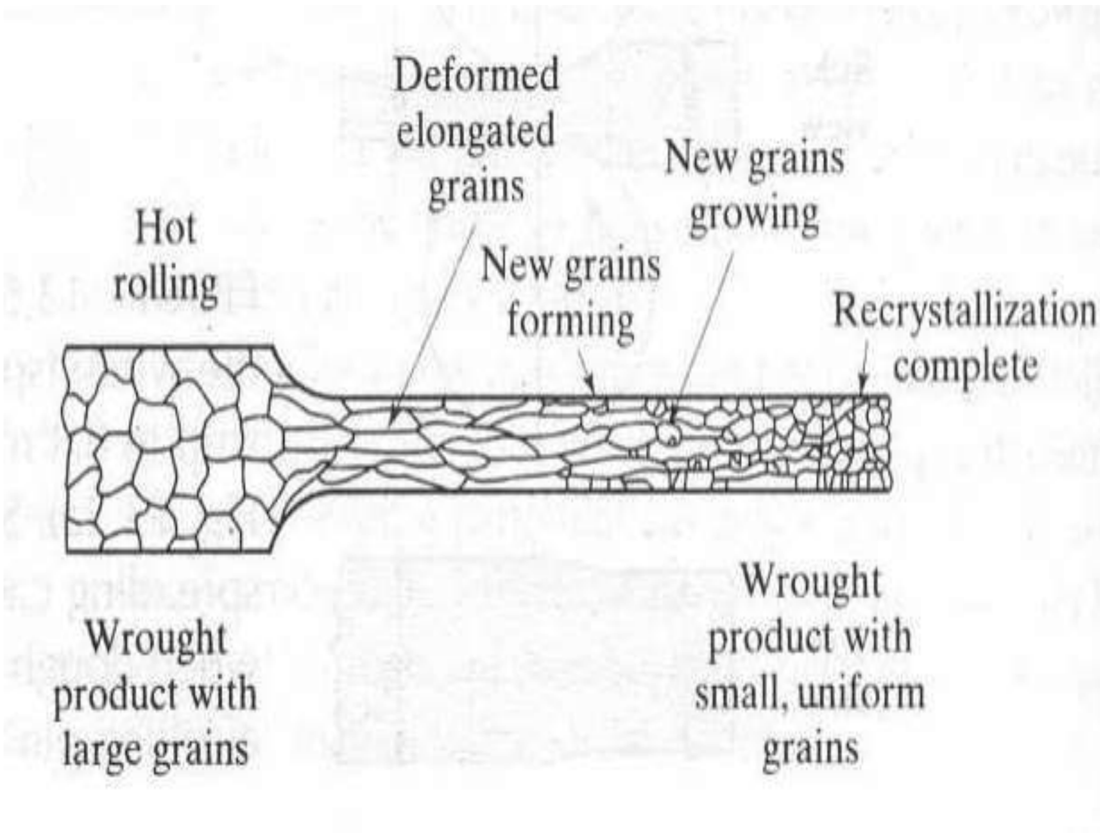




The initial breakdown of ingots into blooms & billets is generally done by <u>hot-rolling</u>. And then <u>cold-rolling</u> is to be done to get good surface finish and close control over dimension.

HOT ROLLING - occurs above the recrystallization temperature of the material.



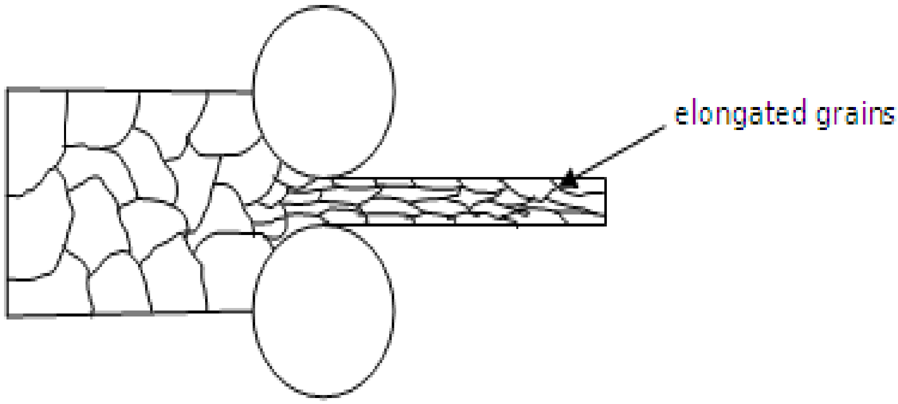


- Hot rolling is used mainly to produce sheet metal or simple cross sections, such as rail tracks.
- It will reduce the average grain size of metal, this improves the strength of material.

COLD ROLLING – Used to produce sheet & strip with superior surface finish and dimensional tolerance.

Also, the strain hardening results from the cold reduction may be used to give increased strength.

- Total reduction achieved will vary from 50 to 90 percent.
- The lowest %age reduction is taken in the last pass to permit better control of flatness, gage and surface finish.
- Done usually at room temperature.



- Four-high or cluster mills are used. (Al, Cu alloys)
- Cold rolling cannot reduce the thickness of a workpiece as much as hot rolling in a single pass.
- This process increases strength upto 20% via strain hardening.

$$H_{max} = \mu^2 R$$

H_{max} - Maximum thickness reduction in one pass
μ – Static friction coefficient
between rolls and metal R –
Radius of rolls

HOT ROLLING

1. Blowholes and porosity eliminates by welding together.
2. This will results into better ductility and toughness.
3. Surface decarburization of steels.
4. Not good surface finish.
5. Dimensional tolerance due to expan -sion/contraction of metal.

COLD ROLLING

1. Results in increased strength or hard -ness.
2. Better dimensional control.
3. Good surface finish.
4. Ductility decreases.
5. Yield point phenomenon (results in inhomogeneous deformation), occur in annealed steel sheet.

PRECAUTIONS

- The roll gap must be perfectly parallel, otherwise one edge of the sheet will be decreased more.
- It is necessary to know the elastic constant of mill. (elastic flattening of the rolls with increasing roll pressure results in a condition where the rolls eventually deform more easily than the workpiece)
- Roll speed must be constant during the operation.

DEFECTS IN ROLLING

General defects

- Surface Irregularities
- Non Metallic Inclusions
- Internal Pores

Operational defects

- Waviness
- Edge Cracking
- Center Split

- Surface irregularities – Raw material or ingot having irregularities due to scaling.

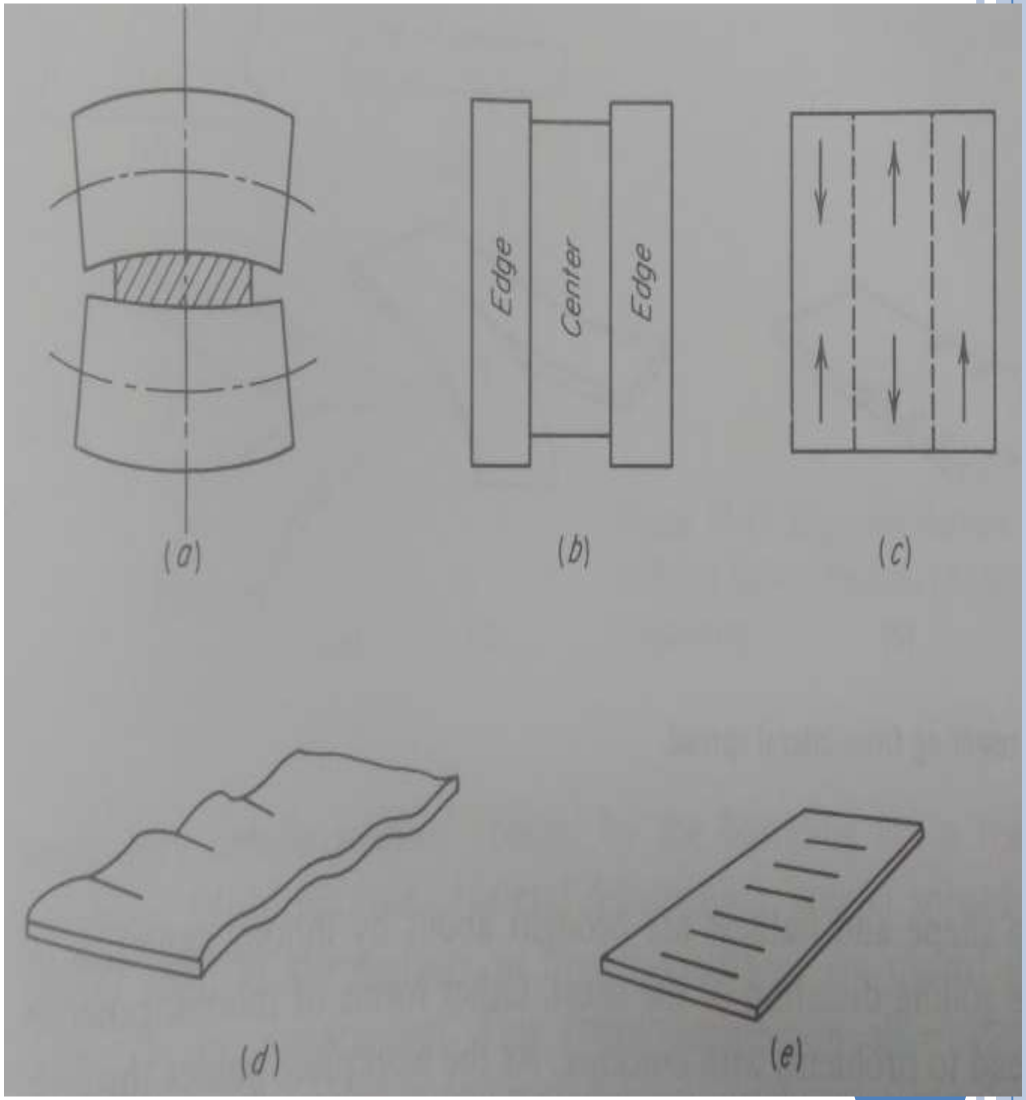
- Non-Metallic inclusions – Oxides, nitrides or silicates especially in steels, they may produce severe cracks separating the product into two halves.

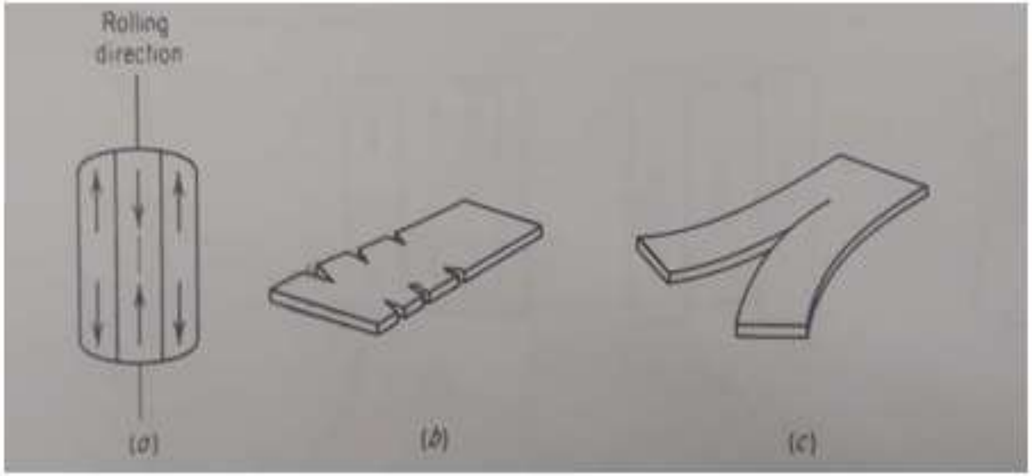
- Internal Pores – Due to presence of gases like hydrogen, oxygen, nitrogen. This leads to elongation of pores and product may become weaker.

- Waviness – Occurs because the roll gap is not perfectly parallel and due to the uneven speed of rolls.

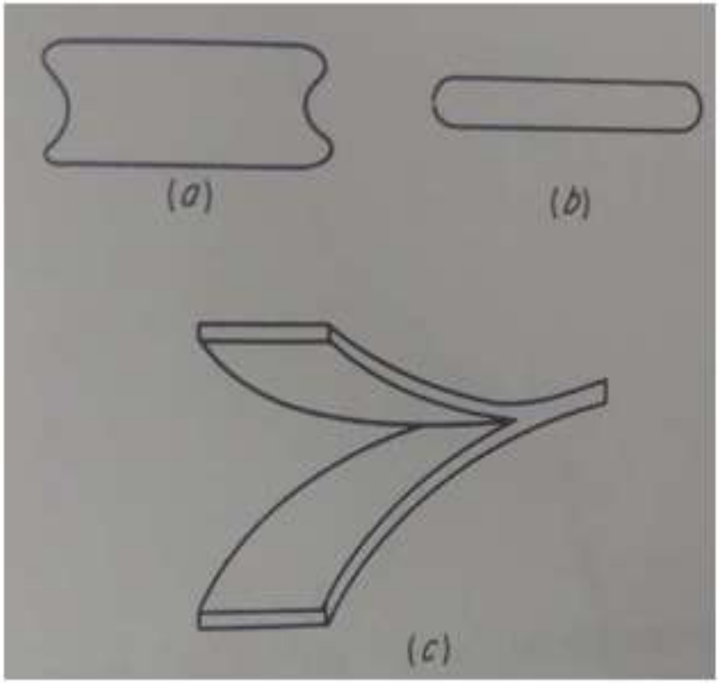
- Edge Cracking – Length of the center portion increases but the edges are prevented due to the frictional force.

(a)– edges of the sheet elongated to a greater extent in the longitudinal direction than the center.
(b)– If the edges are free to move relative to center.
(c)– Center portion of sheet is stretched in tension and the edges are compressed in rolling direction.
(d) – wavy edge or edge buckle.
(e)– Cracks in the center of the sheet.



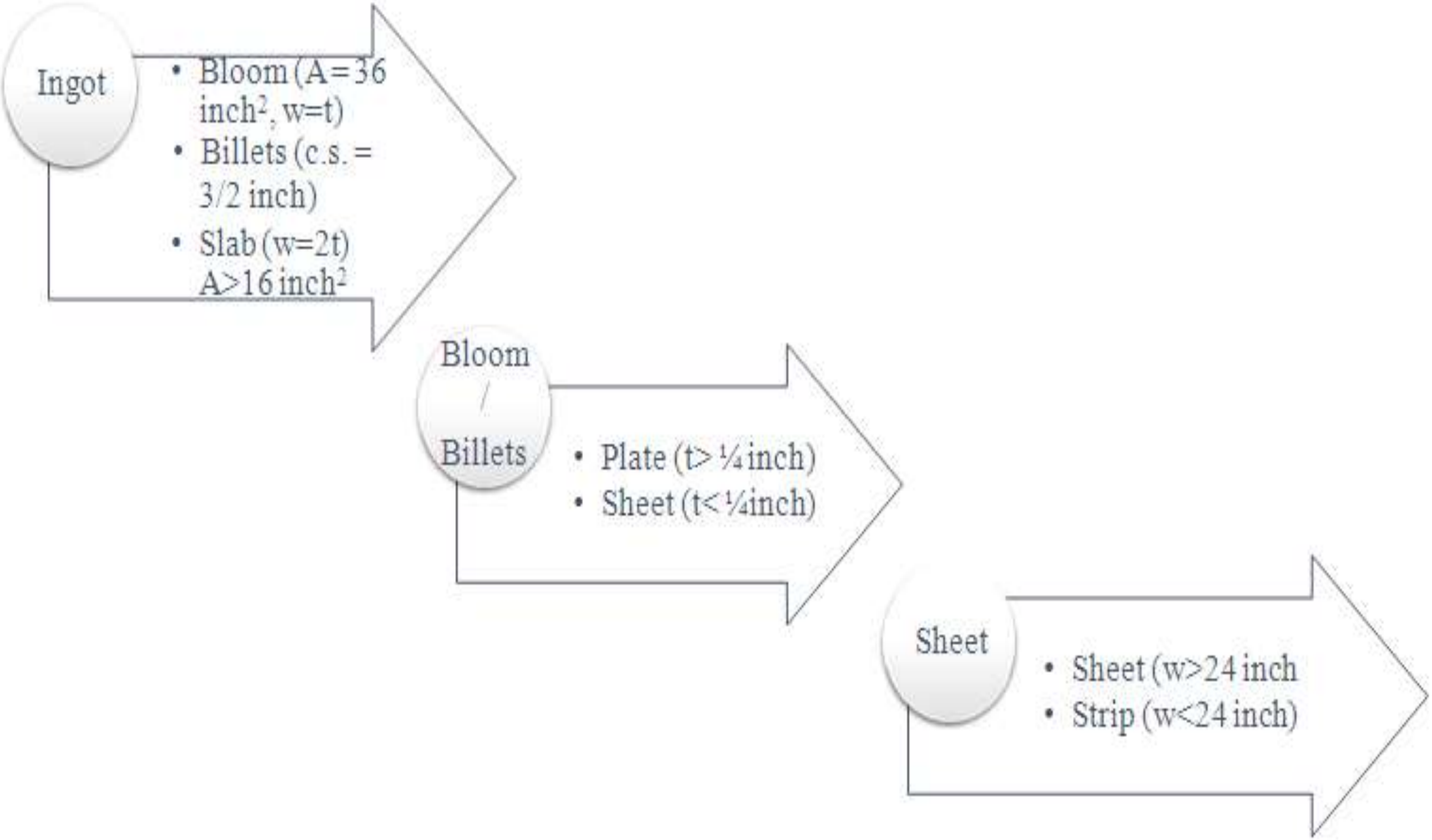


Defects resulting from lateral spread.
Edge cracking and center split.



(a) Light reduction
(b) Heavy reduction
(c) Alligatoring

ROLLING PRODUCTS–



METAL CASTING

1. History of Casting
2. Why Casting?
3. Basic casting process
4. Basic terms used in casting
5. Steps in casting process

Introduction

- A process based on the property of liquid to tak e up the shape of the vessel containing it.
- A cavity of desired shape is made, contained in a mold.
- Carried out in a foundry.

History of Casting

- Ancient process, started 5000 years ago.
- Jaivana- 50 tons cannon was built in 17th century in Jaipur.
- Used for making arrows, coins, knives etc.

World's largest Cannon in Jaipur, made by casting

Why Casting?

1. A job of 5m diameter and 10m length.
2. A job with a hole of 2m diameter, made of very hard material.
3. Parts of very complicated shapes.

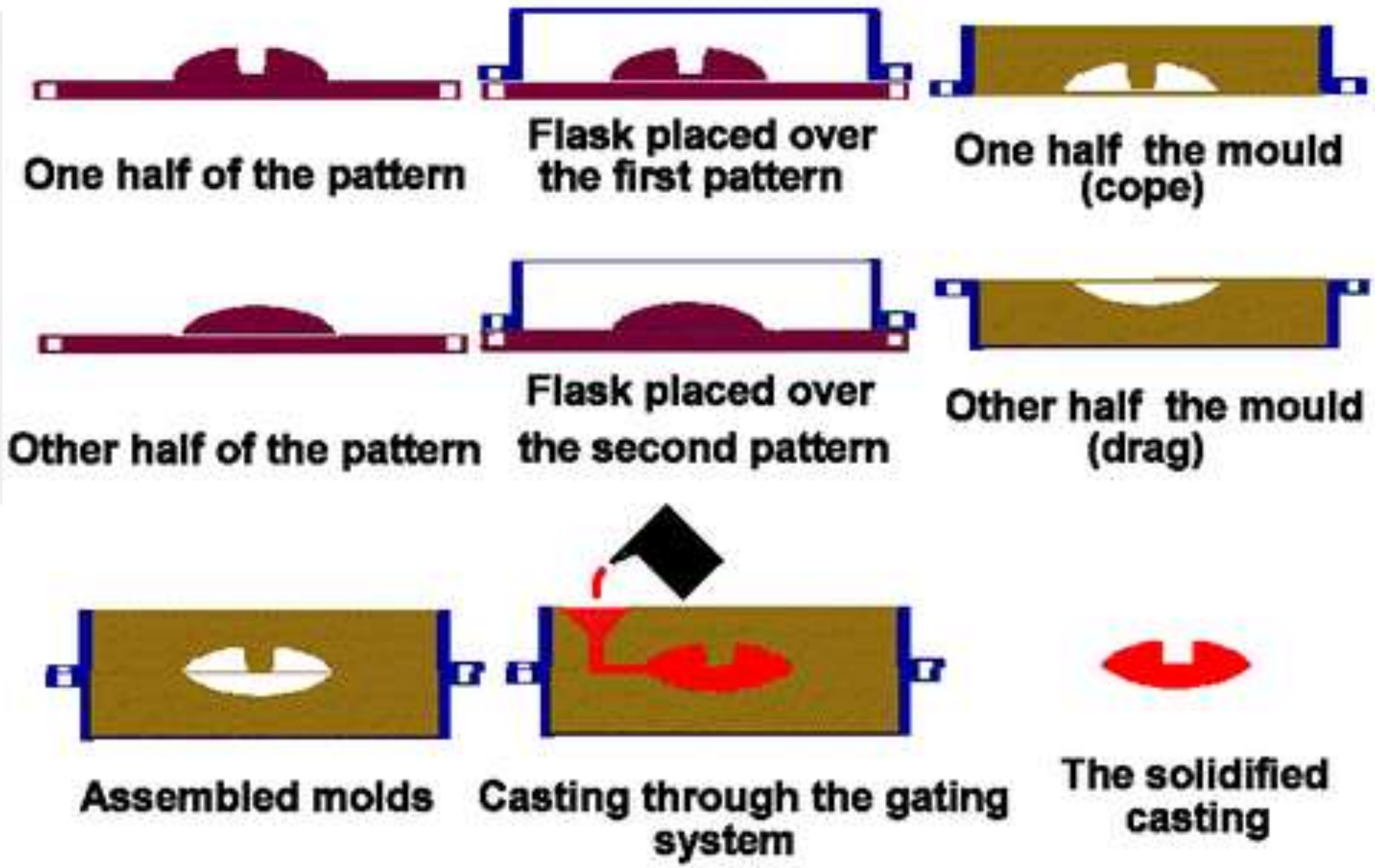
Have you seen any similar process before?

- What do we control?
  1. Size & shape of cavity and mold
  2. Mixture composition
  3. Temperature
  4. Cooling time
  5. Carefully remove it

Requirement for Casting?

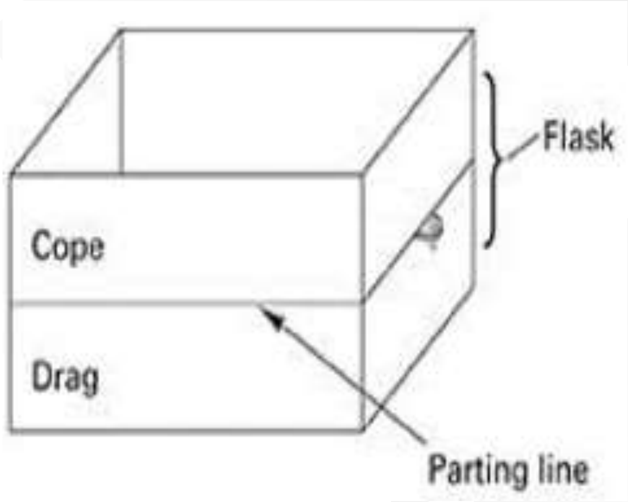
1. Cavity of desired shape- Mold
2. Molten metal
3. Proper channel to fill the molten metal

Basic Casting Process



Basic terms used in Casting

1. Pattern: Replica of the desired part
2. Mold- Container with a cavity within. Divided in two halves: Cope and Drag.
3. Gating system- Network of channels that deliv er molten metal to the cavity.



Basic steps in Casting

1. Pattern making
2. Mold making
3. Melting of metal and pouring
4. Cooling and solidification of metal
5. Cleaning of casting and inspection

Pattern

- Replica of the desired product
- Has somehow different dimensions than the ac tual part to be manufactured
- Used to form the mold cavity

1. Materials used
2. Types of patterns
3. Pattern Allowances

Pattern Materials

- Requirements:
  1. Easily shaped, worked, machined and joined
  2. Resistant to wear and corrosion
  3. Resistant to chemical action
  4. Dimensionally stable
  5. Easily available and economical

Pattern Materials

1. Wood:

- Easy availability, low weight and low cost
- Can be easily shaped
- More than 90% castings use wood patterns
- Absorbs moisture. So, distortions and dimensional chan ges occur
- Relatively lower life, hence suitable for small quantity pr oduction

Pattern Materials

2. Metal:

- Used for large quantity production and for closer dimensional tolerances
- Longer life
- Aluminum is mostly used.
- Other metals: cast iron, brass etc.

Pattern Materials

3. Plastic:

- Low weight, easier formability, smooth surfaces and durab ility
- Do not absorb moisture. So, dimensionally stable
- Corrosion resistance

Pattern Materials

4. Polystyrene:

- Changes to gaseous state on heating
- Disposable Patterns. Hence, suitable for single casting.
- When molten metal is poured into cavity, polystyrene tran sforms to gaseous state.
- Used mostly for small and complicated shaped castings.

Pattern Allowances

1. Shrinkage or contraction allowance
2. Draft or taper allowance
3. Machining or finish allowance
4. Distortion or camber allowance
5. Rapping allowance

COLOUR CODING FOR PATTERN

COLOUR CODING FOR PATTERN

- Pattern are coloured by using shellac paints.
- Colours gives protection and identifies the features of patterns.
- colour scheme is given as bellow

Colour	Indication
	Unfinished surface on casting
Black	Finished surface on casting
Yellow	Core prints
Black	Parting surface
Red/yellow strips	Seats for loose piece

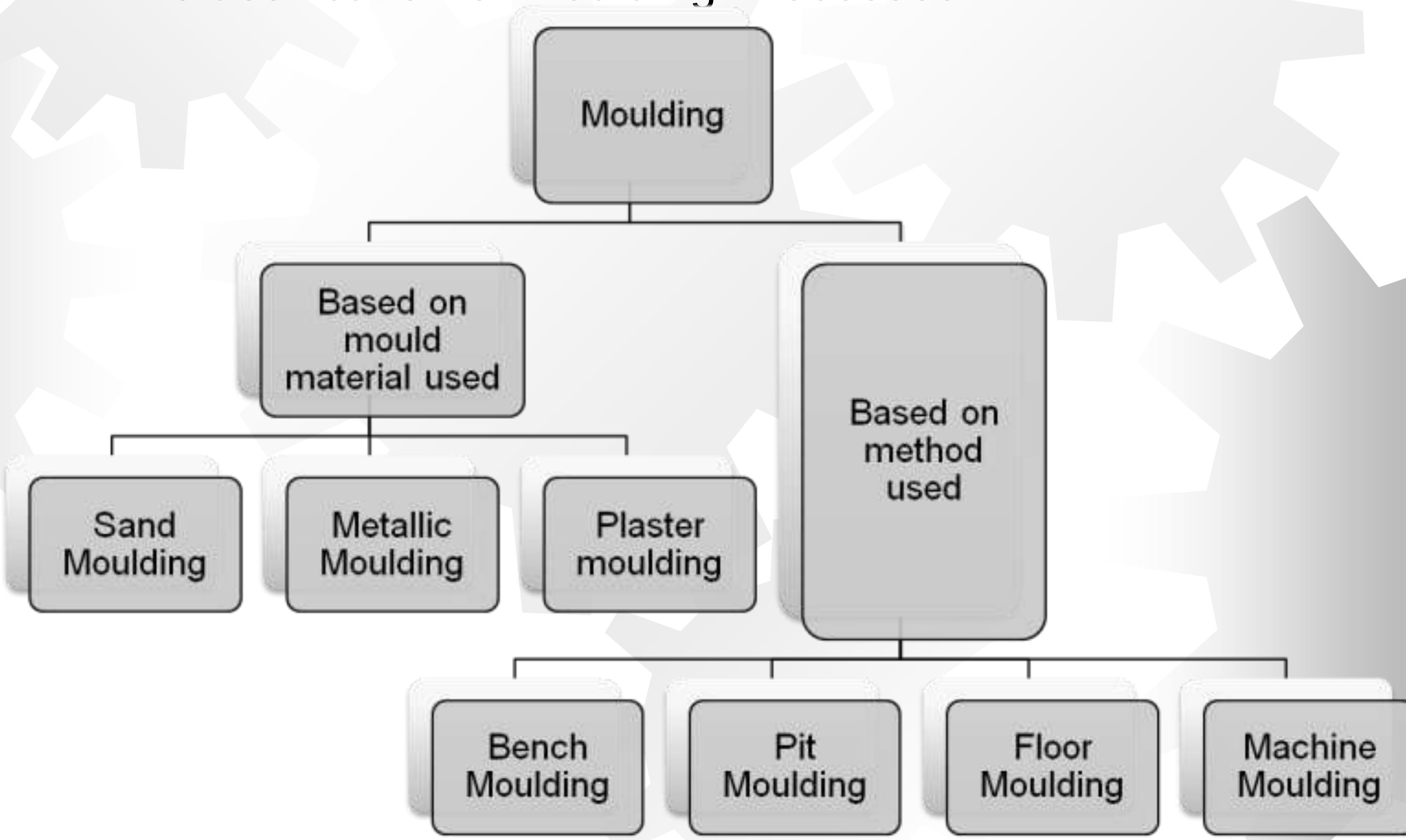
Moulding

- The term moulding process refers to the method of maki ng the mould and the materials used.
- Moulding processes have certain features in common-

1. The use of pattern.
2. Some type of aggregate mixture comprising a refractory and bi nders.
3. A means of forming the aggregate mixture around the pattern.
4. Hardening of aggregate or developing its bond while in contact with the pattern.
5. Withdrawal of the pattern from the mould.
6. Assembly of the mould and core pieces to make a complete m ould, metal then being poured into the mould.

Moulding

- Classification of Moulding Processes:



Types of Moulding Sands

- **Green Sand:**
- Natural sand prepared as a mixture of silica sand with 18-30 % clay and 6-8 % moisture.
- Fine, soft, light and porous.
- The name ‘Green sand’ employs for damped i.e. it contains moisture and the mould made of this sand is used immediately to pour the molten metal.
- Easily available and has low cost.

Types of Moulding Sands

- **Dry Sand:**

- Green sand that has been dried or baked in between 250° to 550° in suitable oven after the making mould and cores, is cal led dry sand.
- More strength, rigidity and thermal stability.
- Suitable for larger castings.

Types of Moulding Sands

- **Parting Sand:**
- It is used to keep away the green sand from sticking to the pattern and to allow the sand on the parting surface of the flasks to separate without clinging.
- It is free from clay and is dry.
- It is washed and non sticky sand

Types of Moulding Sands

- **Core Sand:**
- Used to make core.
- Should be stronger than the moulding sand.
- It is made by mixing core linseed oil with silica sand,
- It is also called as soil sand

Backing sand

- It usually contains burnt facing sand, moulding sand and clay.
- It is old and repeatedly used sand and used for baking facing sand
- It is filled behind the facing sand in the mould box or flask.

Facing sand

- It is mixture of floor sand and new moulding sand with suitable binder and moisture.
- It is used next to the parting surface and comes in contact with molten metal when poured into the mould
- It is used around a pattern to cover it upto 2.5 to 5cm

Core and core print

- Core is metal or sand body, which is set into the prepared mould before closing or pouring it .
- These are used to produce holes, projections, cavities in casting.
- core is kept on seat in the mould box prepared by pattern.
- Projection is made in mould box during moulding process.
- these projections made on mould box are known as core print.

Types of moulding

1. Bench moulding

- In this method small mould are made upon bench
- It is used to manufactured the green sand and dry sand mould.
- loose piece patterns are used for moulding.
- Ramming is done manually.
- Slow process and requires labours.
- it is having types

1. Two box moulding.
2. Three box moulding.
3. stacked moulding.

Floor moulding

- It is used for medium and part casting.
- It is carried out on the floor.
- In this moulding floor is act as drag and cope is rammed.
- It is time consuming.
- It requires labour.
- green sand and dry sand mould are made by this method
- It is also called as bending.
- Ex.wheels,pulleys,plates with ribs etc

Pit moulding

- It is used for large casting manufacturing.
- Pit is dug in the floor of foundry with bed of charcoal placed at the bottom of pit to help the escape of gases.
- cope is placed over the pit to complete the assembly.
- Sand is rammed and wall of pit are bricklined and plastered with Liam sand.
- Moulds are baked before pouring.
- Gates , runner, riser, pouring basin are made in cope.
- crane are used to lift the cope and position over drag.

Machine moulding

- It is suitable for large production
- It consist of following steps

1. Ramming of sand by jolting,squeezing in mould.
2. Rolling of mould through 180°.
3. Drawing of pattern from the mould by raising or lowering mould halves.
4. Types of machines used for making moulds are

- Jolt moulding machine.
- Jolt squeeze machine
- sand slinger

Types of Casting Methods

1. Centrifugal casting.

- In this process mould is poured and allowed to solidify during revolving.
- Due to rotation of mould the poured metal is subjected to centrifugal force.
- Centrifugal force is allowed molten metal to flow in the mould cavity.
- Dence metal is deposited on periphery of mould and start sophistication.
- Lighter slag, oxides, inclusions are get separated and moves towards centre.

Centrifugal casting

- There is no use of gates runner and riser.
- The axis of rotation may be horizontal or vertical.
- Applications
- Pipes , cylinder liners, bearings, bushes, gears fly wheels, gun barrels etc.

Shell moulding

- This process is used for smooth surface finish
- It consist of dump box which is partially filled with silica and thermoelectric resin.
- Then dump box is sealed with metallic pattern which is preheated about 250° c.
- When dump box is inverted mixture is get melted and forms the shell on pattern plate.
- Shell thickness varies from 5mm to 8mm.
- These two shells joint togather to form complete mould.

Shell moulding

- Applications.
- small pulleys ,motor housing, fan blades, cylinders, cylinder heads, break drums.

Investment casting

- It is also known as lost wax casting precision casting.
- This method is used for manufacturing jewellry,dental goods.
- It involves following steps.

1. Making of wax pattern sometimes mercury or plastic may be used.
2. provide wax made gates, runners, riser to the pattern.
3. Complete wax pattern put in box and filled with liquid mould material.
4. liquid around wax pattern solidifies and form mould
5. Then mould is heated to 150° to 800° c to remove wax

Investment casting

- Applications.
- surgical instruments.
- vanes and blades for gas turbine.
- costume jewellery.
- valve bodies.
- Reciprocating slides for cloth cutting machine.

Casting defects

Following are the casting defects arises during faulty processes in casting.

1. Blow holes.
2. Pin holes.
3. Shift.
4. Short runs.
5. Hot tears.
6. cold shuts.

WELDING

Welding is a process of metal joining

by applying heat and sometimes pressure

Classification of welding processes:

(i). **Arc welding**

- Carbon arc
- Metal arc
- Metal inert gas
- Tungsten inert gas
- Plasma arc
- Submerged arc
- Electro-slag

(ii). **Gas Welding**

- Oxy-acetylene
- Air-acetylene
- Oxy-hydrogen

(iii). **Resistance Welding**

- Butt
- Spot
- Seam
- Projection
- Percussion

(iv)Thermit Welding

(v)Solid State Welding

Friction

Ultrasonic

Diffusion

Explosive

(vi) Newer Welding

Electron-beam

Laser

(vii) Related Process

Oxy-acetylene cutting

Arc cutting

Hard facing

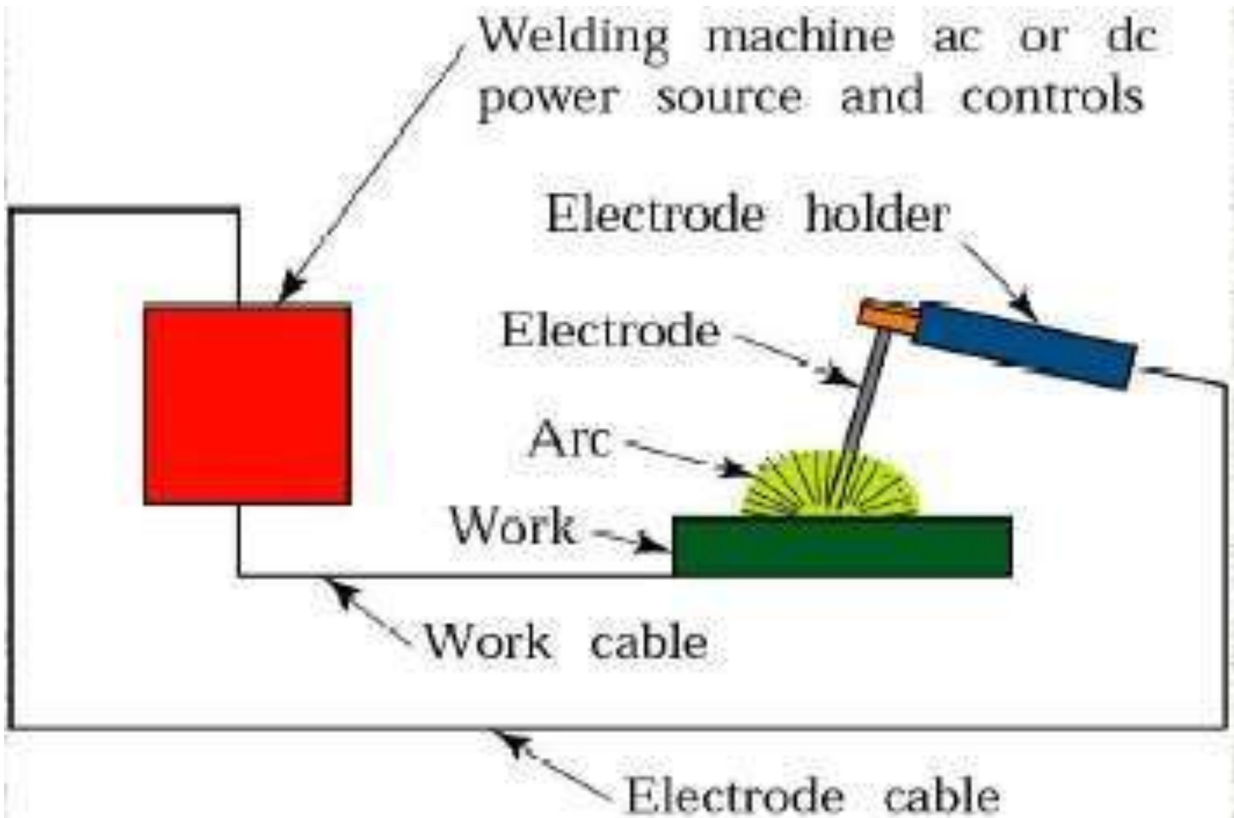
Brazing

Soldering

Arc welding

- **Equipments:**
- A welding generator (D.C.) or Transformer (A.C.)
- Two cables- one for work and one for electrode
- Electrode holder
- Electrode
- Protective shield
- Gloves
- Wire brush
- Chipping hammer
- Goggles

Arc Welding Equipments



Arc welding process

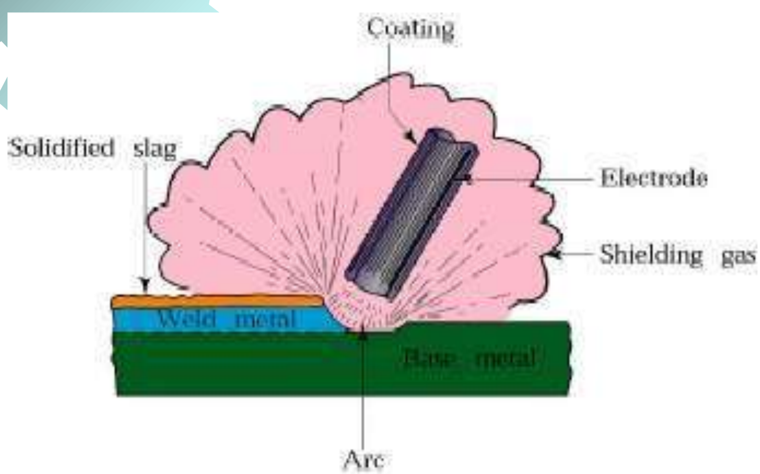
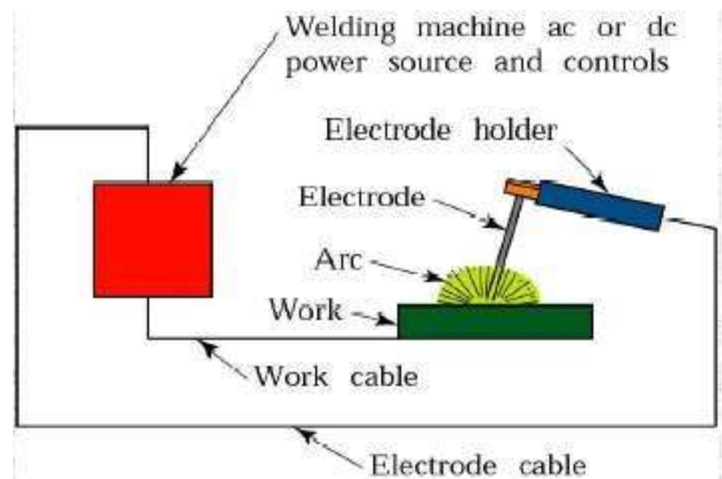
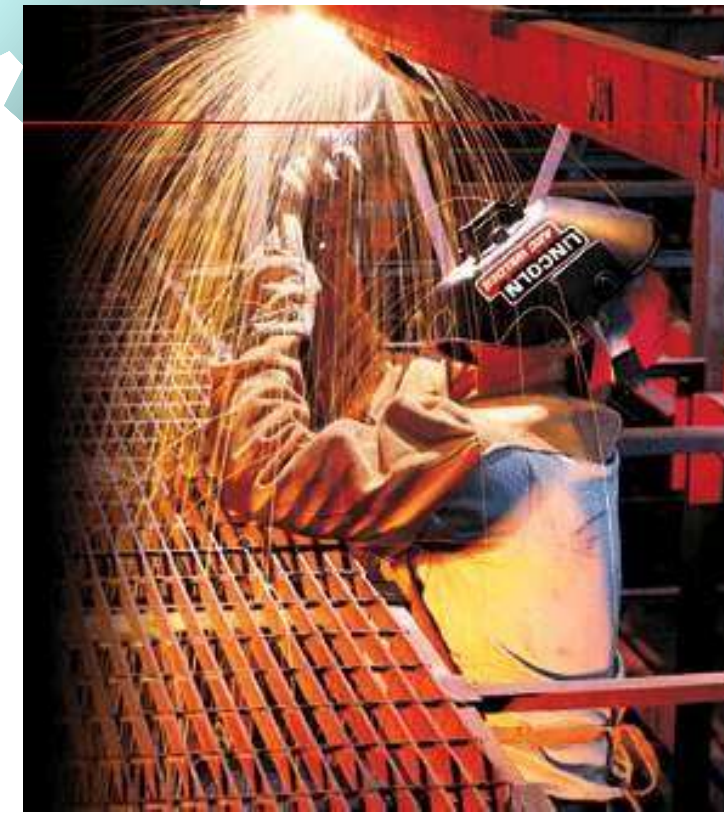
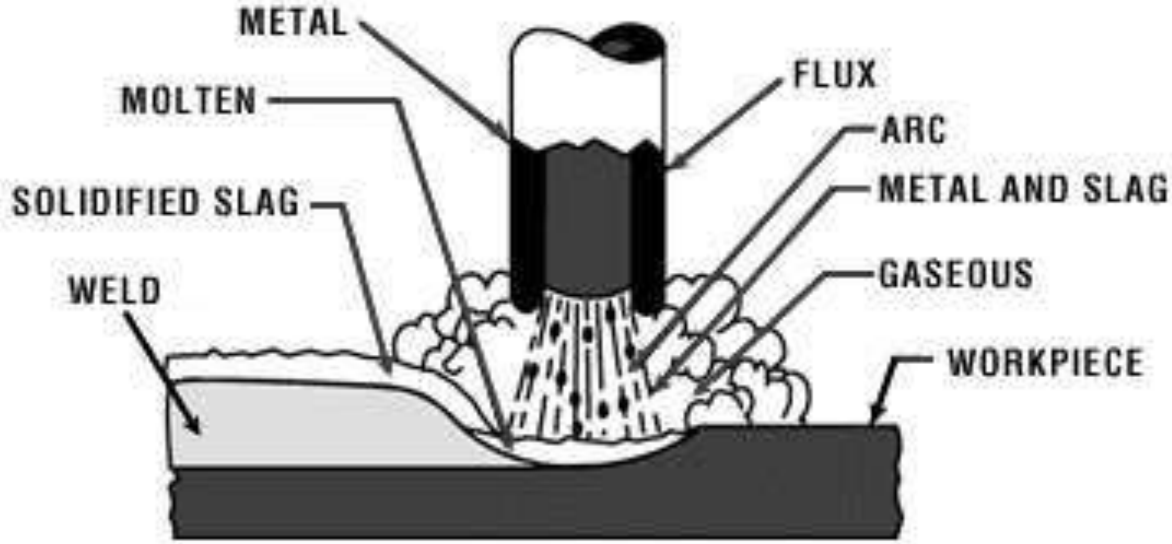


Fig : Schematic illustration of the shielded metal-arc welding process. About 50% of all large-scale industrial welding operations use this process.

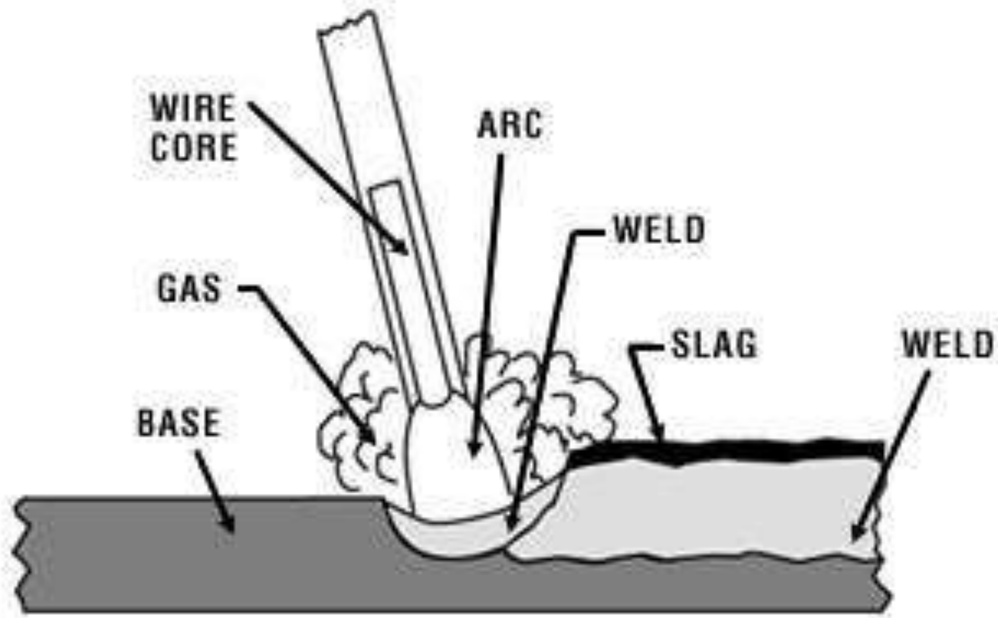
Fig : Schematic illustration of the shielded metal-arc welding process (also known as stick welding, because the electrode is in the shape of a stick).





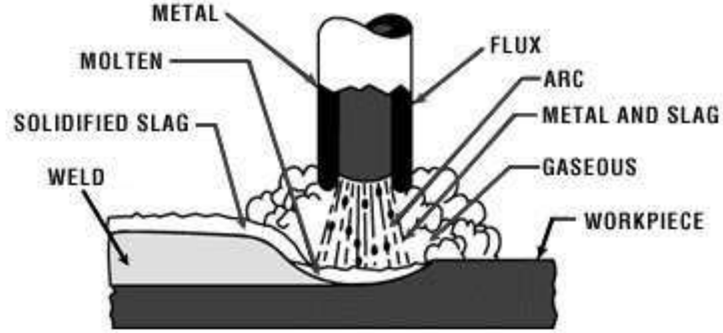


STICK WELDING PROCESS

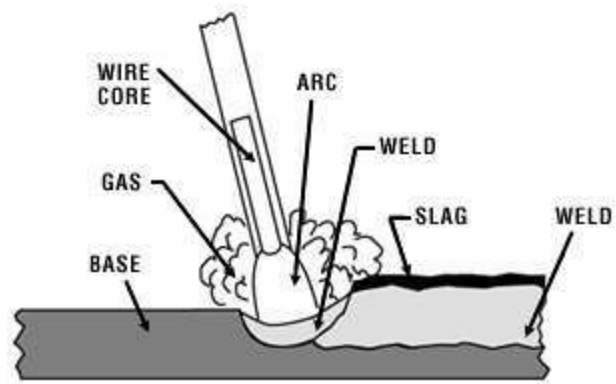


ELECTRODE

Metal arc welding



STICK WELDING PROCESS

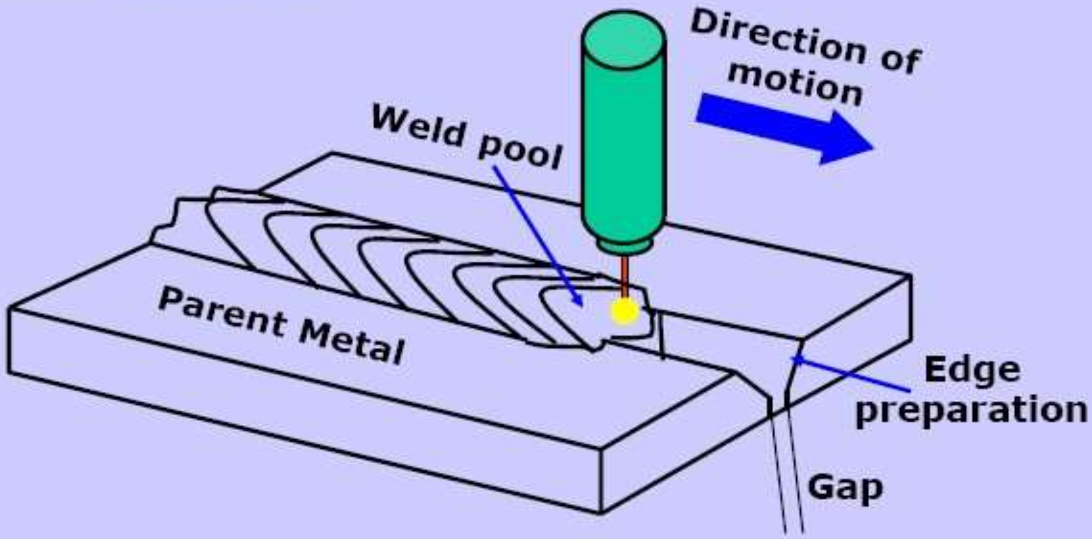


ELECTRODE

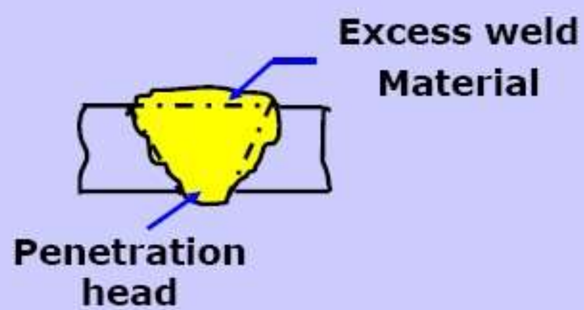
The Arc Welding Circuit

- The electricity flows from the power source, through the electrode and across the arc, through the base material to the work lead and back to the power source

Weld Joint Terminology



Cross section of Typical Weld



Functions of Coated Electrodes(flux coated)

1. Protects the weld from oxidizing with atmosphere by producing a shield of gas around the arc and weld pool
2. Provide the slag which floats at the top of molten metal so as to protect the weld from rapid cooling and to protect weld from atmosphere. The slag is then brushed off after weld gets cooled.

Terms used in welding :

Weld Pool :- Nature of deposition of the filler material in fusion zone is know as weld pool

Slag :- molten or fused flux is called as slag

Flux :- mixture of Borax and sodium carbonate is coated to electrode for shielding purpose.

Electric arc between the electrode and work piece closes the electric circuit. The arc temperature may reach 10000°F (5500°C), which is sufficient for fusion the work piece edges and joining them.

What is Arc Welding?

- Arc welding is most commonly used to join two pieces of metal
  - The welder creates an electric arc that melts the base metals and filler metal (consumable) together so that they all fuse into one solid piece of metal

Steel Pipe – Tack Welded

Root Pass or "Stringer Bead"

Final weld after several beads are made

Why is Welding Important?

- Many things around us are welded …
  - Pipelines that bring fresh water
  - Towers that carry electricity to houses
  - Cars and buses that take people where they need

Arc Welding Safety

- Protect yourself and others from potential hazards including:
  - Fumes and Gases
  - Electric Shock
  - Arc Rays
  - Fire and Explosion Hazards
  - Noise
  - Hot objects

Arc welding Advantages and limitations

Advantages

- Most efficient way to join metals
- Lowest-cost joining method
- Affords lighter weight through better utilization of materials
- Joins all commercial metals
- Provides design flexibility

Limitations

- Manually applied, therefore high labor cost.
- Need high energy causing danger
- Not convenient for disassembly.
- Defects are hard to detect at joints.

GAS WELDING

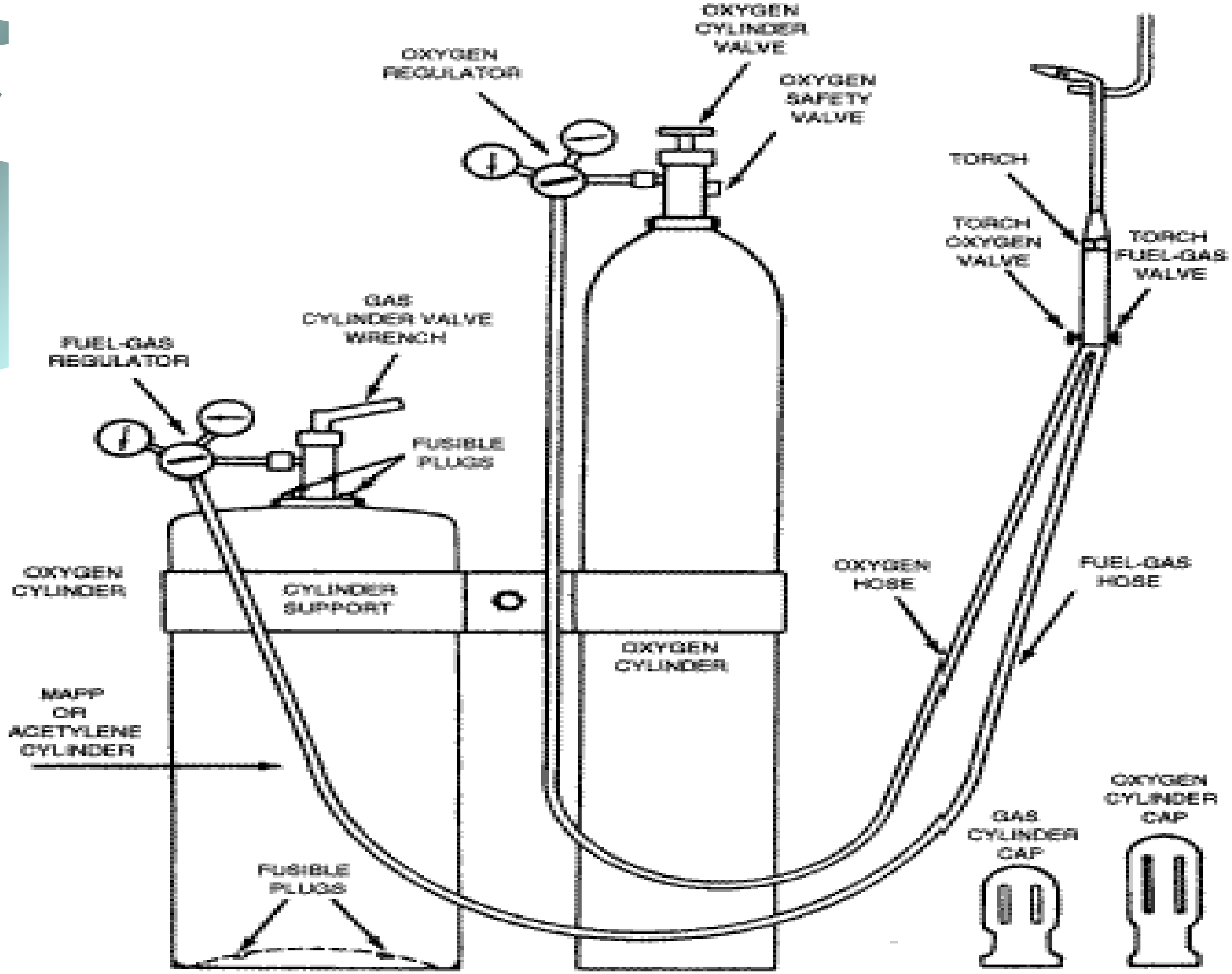
- Sound weld is obtained by selecting proper size of flame, filler material and method of moving torch
- The temperature generated during the process is 3300^0c
- When the metal is fused, oxygen from the atmosphere and the torch combines with molten metal and forms oxides, results defective weld
- Fluxes are added to the welded metal to remove oxides
- Common fluxes used are made of sodium, potassium. Lithium and borax.
- Flux can be applied as paste, powder,liquid.solid coating or gas.

GAS WELDING EQUIPMENT...

1. Gas Cylinders

2. Regulators
3. Pressure Gauges
4. Hoses
5. Welding torch
6. Check valve
7. Non return valve

Oxy-Acetylene welding



Torch Used in Oxyacetylene Welding

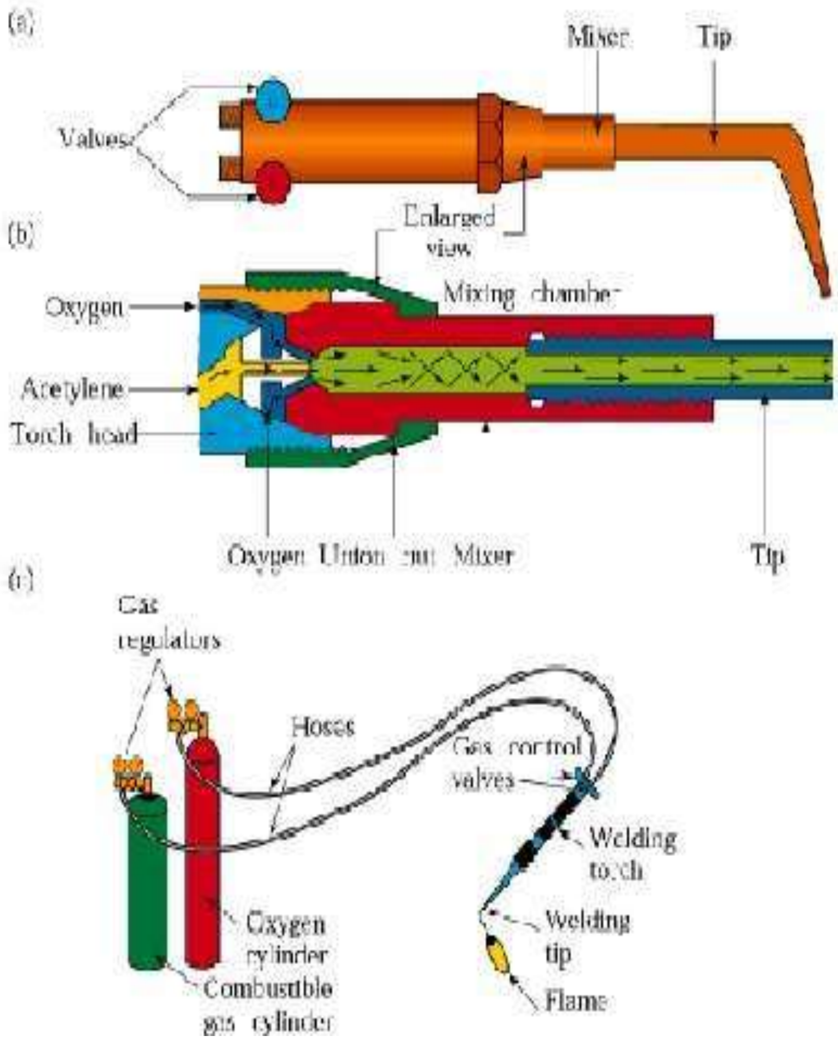


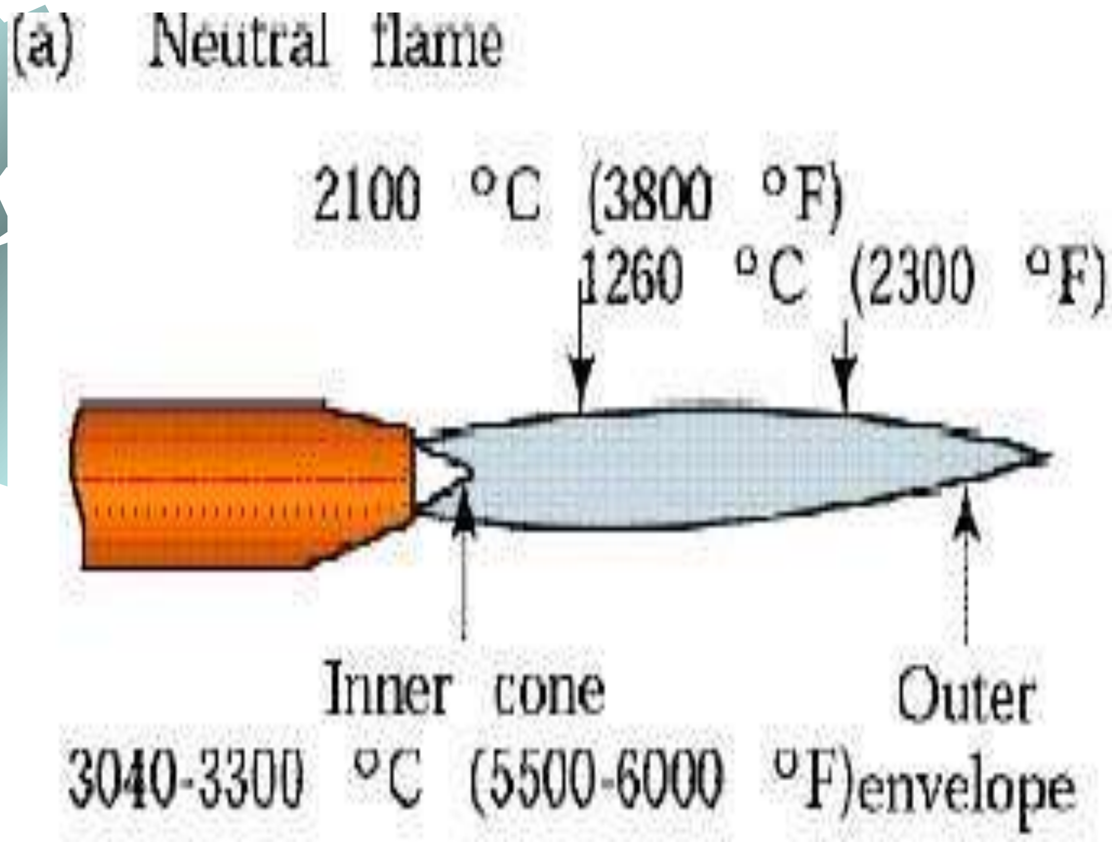
Fig : (a) General view of and (b) cross-section of a torch used in oxyacetylene valve is opened and the flame adjusted. (c) Basic equipment used in oxyfuel-gas welding. To ensure correct connections, all threads on acetylene fittings are left-handed, whereas those for oxygen are right-handed. Oxygen regulators are usually painted green acetylene regulators red.

TYPES OF FLAMES…

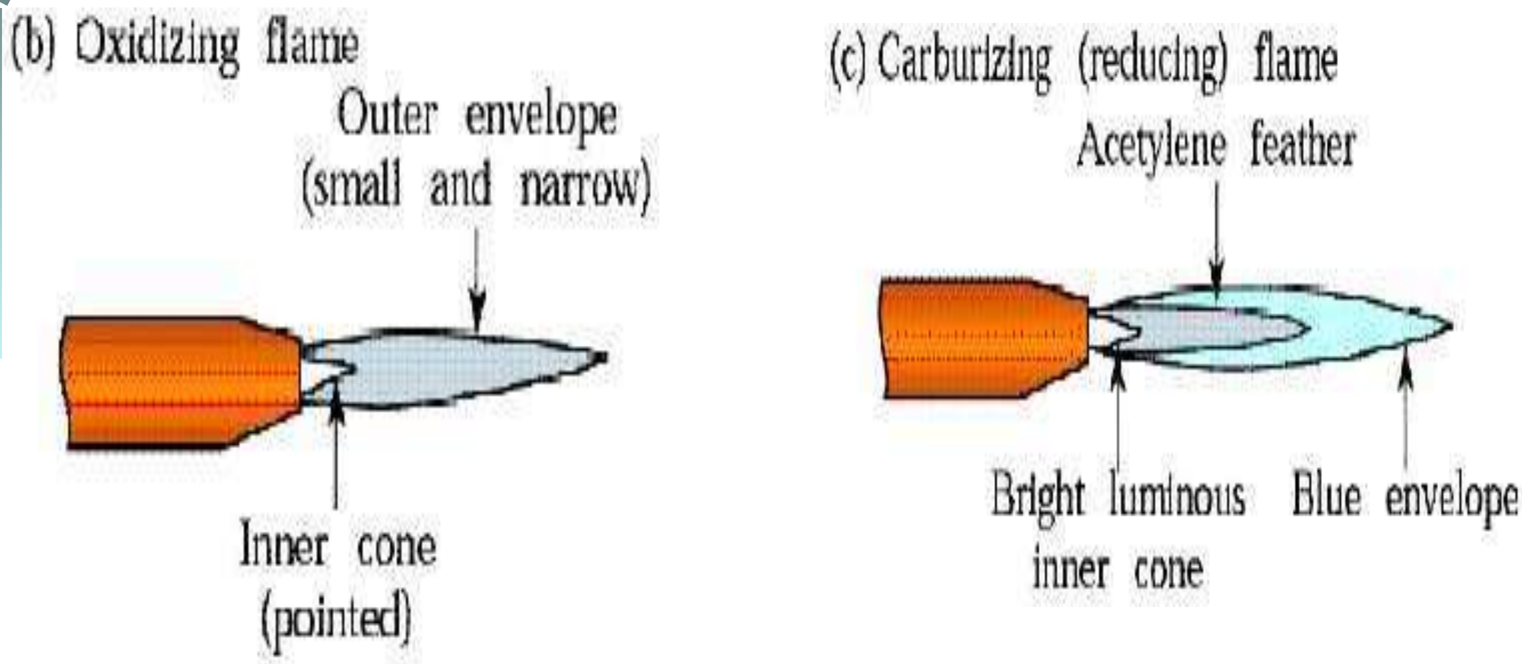
- Oxygen is turned on, flame immediately changes into a long white inner area (Feather) surrounded by a transparent blue envelope is called **Carburizing flame** (3000^0c)

- Addition of little more oxygen give a bright whitish cone surrounded by the transparent blue envelope is called **Neutral flame** (It has a balance of fuel gas and oxygen) (3200^0c)
- Used for welding steels, aluminium, copper and cast iron

- If more oxygen is added, the cone becomes darker and more pointed, while the envelope becomes shorter and more fierce is called **Oxidizing flame**
- Has the highest temperature about 3400^0c
- Used for welding brass and brazing operation



Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations: (a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing flame.



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Oxyfuel Gas Welding

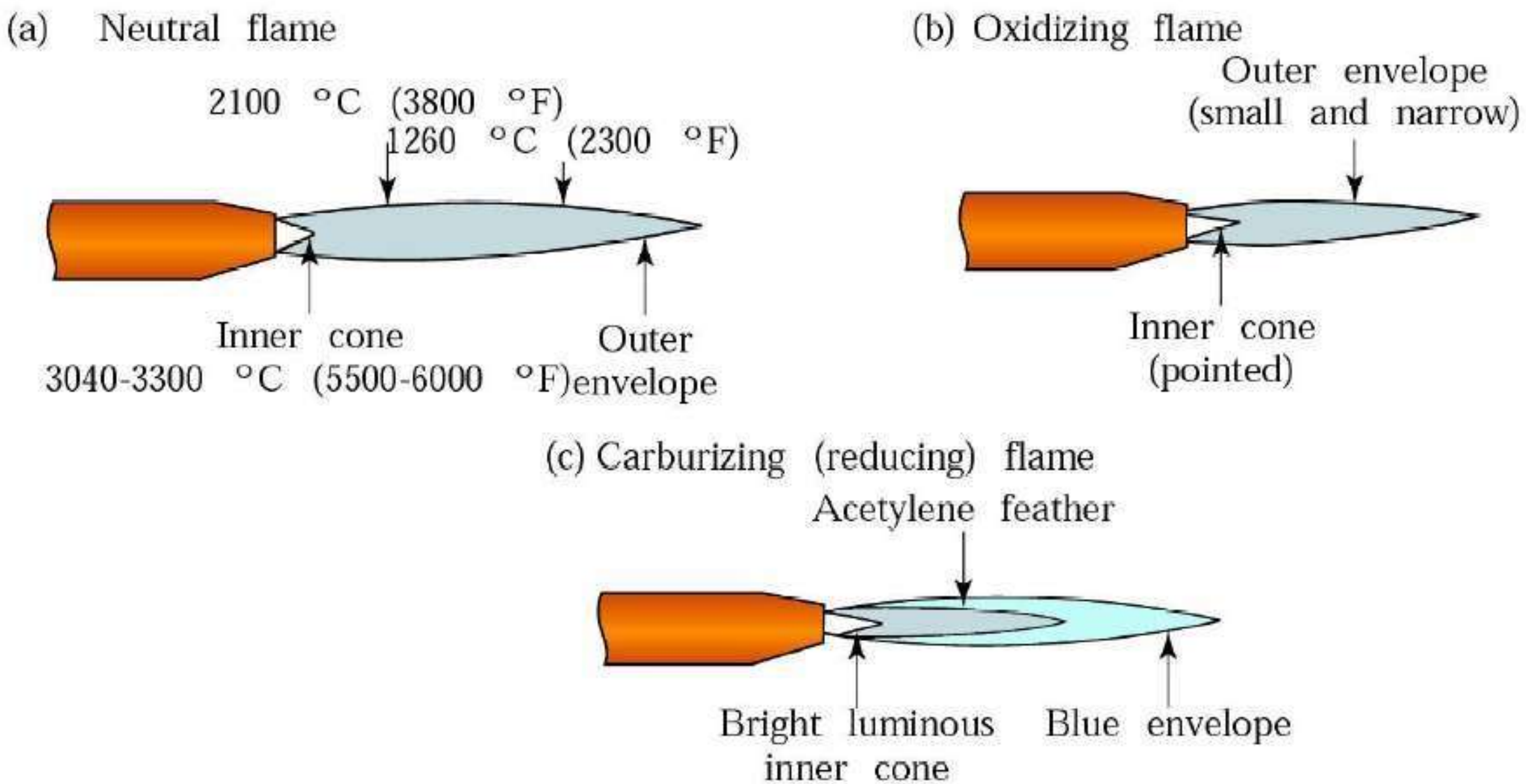
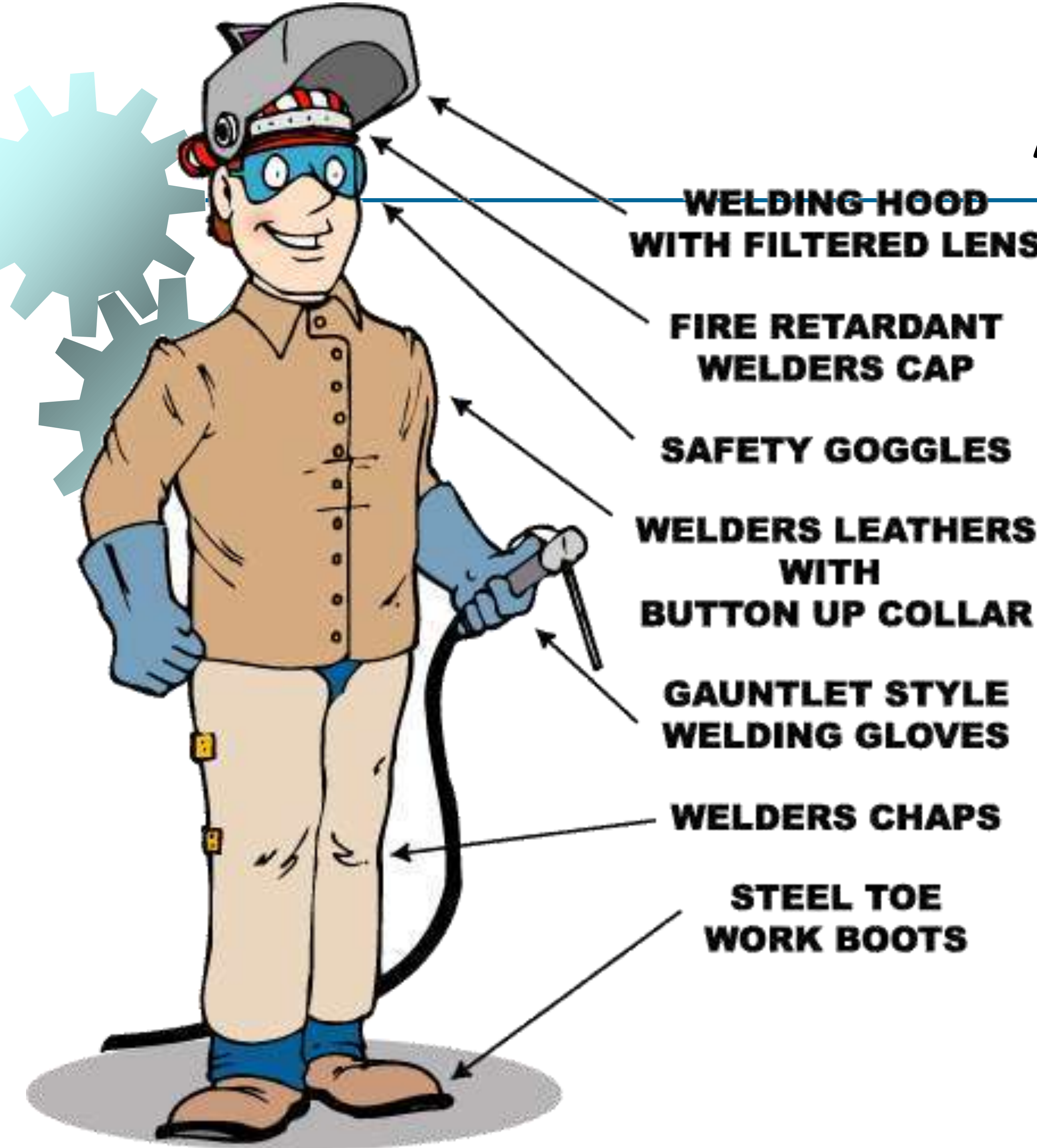


Fig : Three basic types of oxyacetylene flames used in oxyfuel-gas welding and cutting operations: (a) neutral flame; (b) oxidizing flame; (c) carburizing, or reducing flame. The gas mixture in (a) is basically equal volumes of oxygen and acetylene.


TECHMAN

Arc Welding


WELDING HOOD
WITH FILTERED LENS
FIRE RETARDANT
WELDERS CAP
SAFETY GOGGLES
WELDERS LEATHERS
WITH
BUTTON UP COLLAR
GAUNTLET STYLE
WELDING GLOVES
WELDERS CHAPS
STEEL TOE
WORK BOOTS

Protective Clothing

Welders must wear protective clothing for

- Protection from sparks, spatter and UV radiation
- Insulation from electric shock

- Protective clothing includes …
  - Fire-proof clothing without rolled sleeves, cuffs or frays
  - Work boots
  - Welding gloves, jackets, bibs, and fire-proof pants
  - Welding cap, helmet and safety glasses
  - Ear protection – ear plugs and muffs