Leaving Cert

Engineering Revision Notes

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Leaving Cert

INDEX

1. POLYMERS

Monomer
A monomer is a molecule of a compound which reacts with other monomers to form a polymer.

Mer
A mer is a repetitive unit in a polymer.

Addition Polymerisation of Ethylene (Thermoplastics)

- Ethylene consists of 4 hydrogen atoms and 2 carbon atoms joined together by a double bond. (Primary and secondary bond)
- A catalyst is added which introduces a free radical. A free radical is a reactive atom containing an unpaired electron.
- The free radical joins onto one of the monomers causing the weak secondary bond between the carbon atoms to break.
- The mer cannot exist on its own as it now has an unpaired electron.
- It very rapidly links with other mers to form long chain like structures called polymers.
- To stop this reaction an inhibitor is added. This results in a large number of interwoven chains.
- Where these chains touch/overlap, secondary bonds called Van Der Waals forces are formed. These are weak bonds that will allow the polymer to soften whereby its shape can be altered by applying heat or pressure.

Condensation Polymerisation (thermosetting plastics)

- The polymer molecules react chemically to form new molecules with water/alcohol eliminated as a bi-product.
- It forms strong primary bonds with cross links between chains
- The polymer produced, once moulded, cannot be re-softened/re-moulded as a result
- E.g. Phenol Formaldehyde

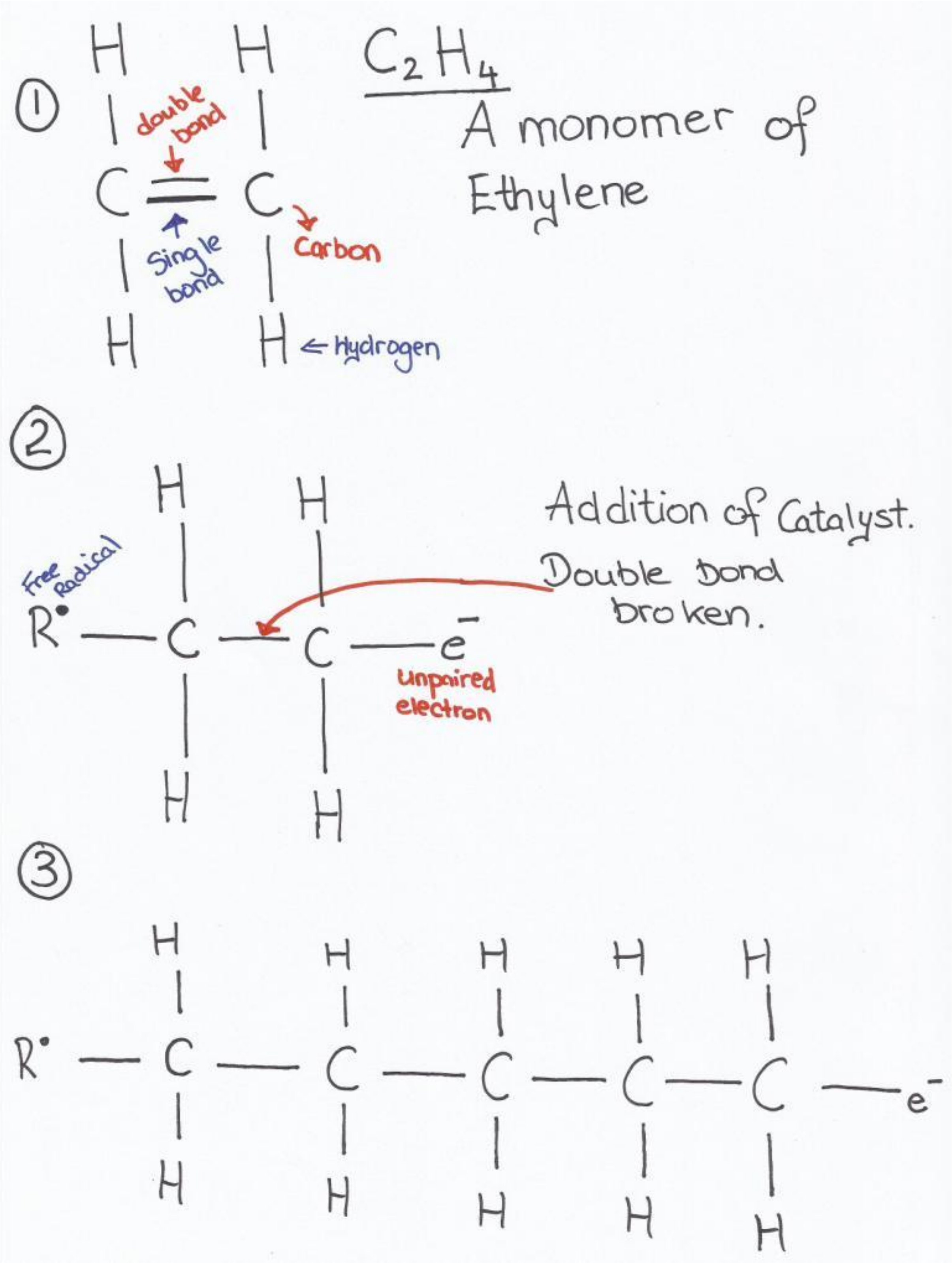

Fig. 1. Addition Polymerizations of an ethylene molecule.

Co-Polymer

Two unlike monomers joined together in a polymer chain. E.g. Poly Vinyl Acetate

Elastomer

A group of polymers consisting of linear chains that are coiled, entangled and are subject to cross linking. This allows these materials to be very elastic at room temperature.

Lubricants

Make the polymer easier to mould. Various types of waxes are used in small amounts.

Pigments

Give the Polymer colour

Stabilisers

Stabilisers are substances which stop a polymer ageing. They improve resistance to heat and light.

Vulcanisation

Natural rubber is processed with sulphur to form cross links between chain molecules to improve wear resistance and life. It is less flexible that natural rubber which is soft.

Van Der Waals Forces

Weak secondary bonds. May be disrupted by heat.

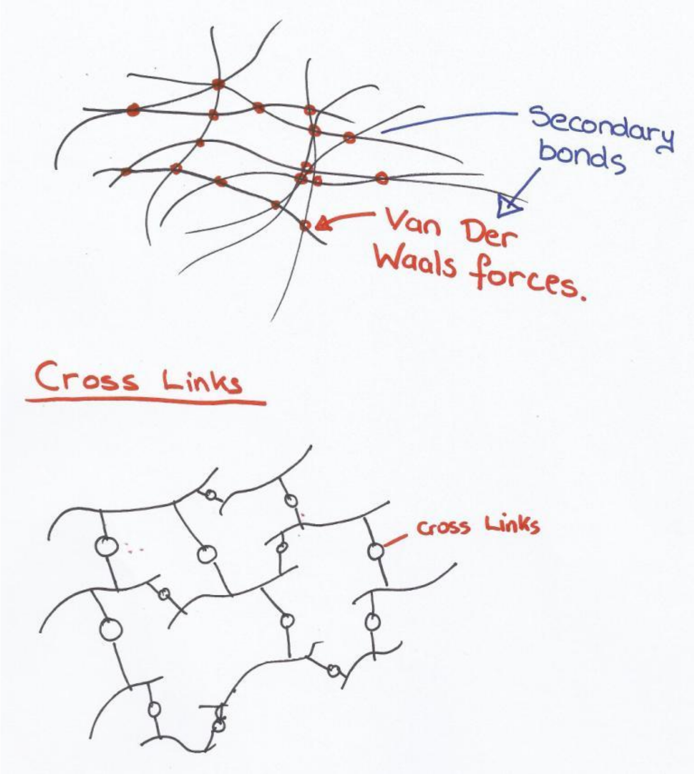

Fig. 2. Van Der Waals Forces vs. Cross Links

Differences between Thermoplastics and thermosetting plastics

	Thermoplastics	Thermosetting Plastics
Bonding	• Bonded by covalent bonds • Secondary bonds with weak Van Der Waals forces which can be broken down by heat	• Bonding by Covalent bonds. • Primary bonds held together by strong cross links.
Process	Addition Polymerisation • Monomers join up to form long chain like molecules called polymers. • These are arranged like spaghetti and when each polymer overlaps, weak temporary bonds called Van Der Waals forces are formed. • E.g. Polyethylene	Condensation Polymerisation • Forms strong primary bonds between chains. • Two monomers react to form a new molecule with water or alcohol emitted as a bi-product. • The polymer cannot be re-softened. • E.g. Phenol Formaldehyde
Properties	• Low melting points. • Easy to mould • Can be remoulded and are subject to disruption by heat. • Can be recycled . • Low tensile strength. • Secondary bonds between molecule chains.	• High melting points. • High tensile strength. • Can withstand high temperatures without losing their rigidity. • Primary bonds between molecule chains.

Thermosetting plastics

Compression Moulding

- Split formed mould.
- Polymer can be in powder or slug form.
- Combination of heat and pressure (coalescence) allows piece to be formed.
- Triggers chemical reaction cross linking and the object is removed.
- High quality finish
- E.g. Electrical fittings, Bottle tops.

Transfer Moulding

- The moulding powder is placed in a compartment above the mould where it is heated.
- The plunger forces the molten polymer into a cooled cavity.
- The polymer solidifies in the mould which is then opened and the product is removed.
- Used to make complex products.
- E.g. socket covers.

Thermoplastics

Extrusion

- The thermoplastic moulding powder is fed from a hopper into a heated chamber.
- A large archimedian screw moves the softening plastic through the chamber.
- This plastic is forced through a die at the end of the machine. The die gives te desired extruded shape which is then cooled by air or water and cut into lengths.
- It may also be cooled in a vacuum chamber.
- E.g. Piping.

Injection Moulding

- The thermoplastic in granule form is fed into a heated compartment by a hopper.
- A plunger forces the plastic along the machine barrel where they are melted by heaters.
- A torpedo compacts the materials.
- The softened materials are then forced into the mould by the torpedo where it cools and solidifies.

- The mould is opened and the plastic product is ejected.
- E.g. Lego

Calendering

- Continuous lengths of sheets are produced by calendaring.
- The material passes through a series of heated rollers to produce the desired thickness of the material.
- It is the cut to size or collected on a roll.
- E.G. Cling film.

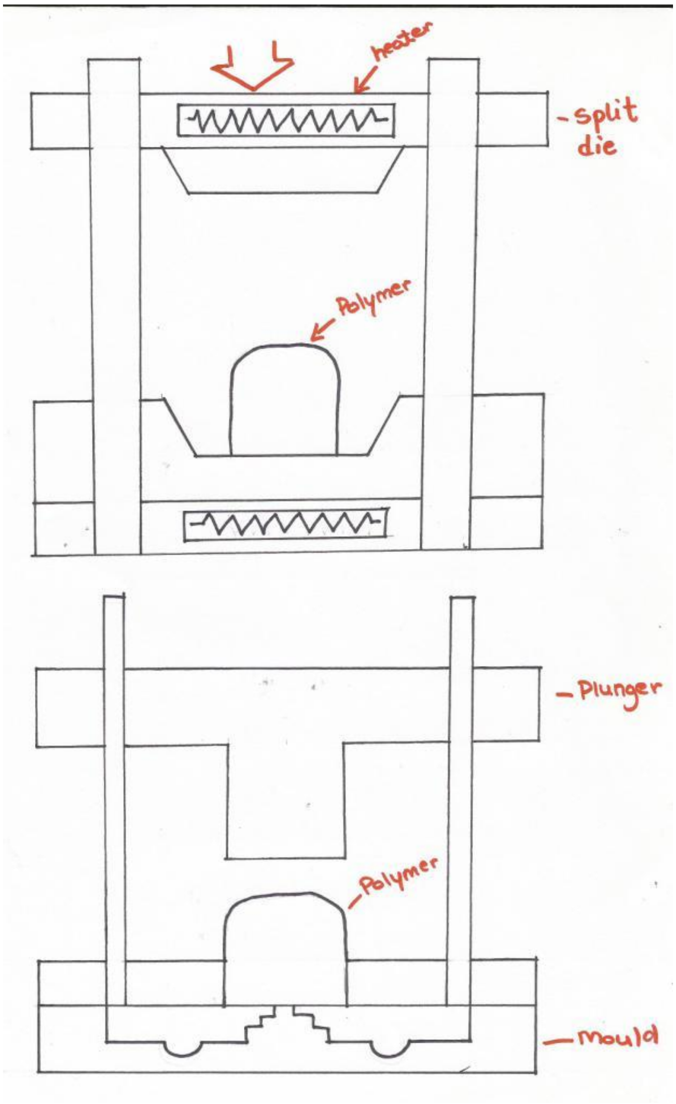

Fig. 3. Compression moulding (above) & Transfer moulding (below).

2. JOINING

MIG welding

- Semi automatic process.
- A consumable bare wire electrode fed continuously into the weld pool through torch by spool.
- An inert gas, e.g. argon, has a fluxing action and creates a protective shield around the weld pool.
- The feed and flow rate are set by the operator.
- Does not produce slag.
- Used on sheet metals.

TIG welding

- Utilises a non-consumable tungsten electrode
- An electric arc is formed between a non-consumable electrode and the metal being welded.
- An inert gas such as argon creates a protective gas shield.
- A filler metal is added manually.
- No slag is produced.

MIG vs. TIG welding

MIG	TIG
Semi-automatic **Argon gas** **Electrode is consumable.** **Spool**	**Manual** **Tungsten electrode: non-consumable** **Filler metal added manually** **Used on aluminium**

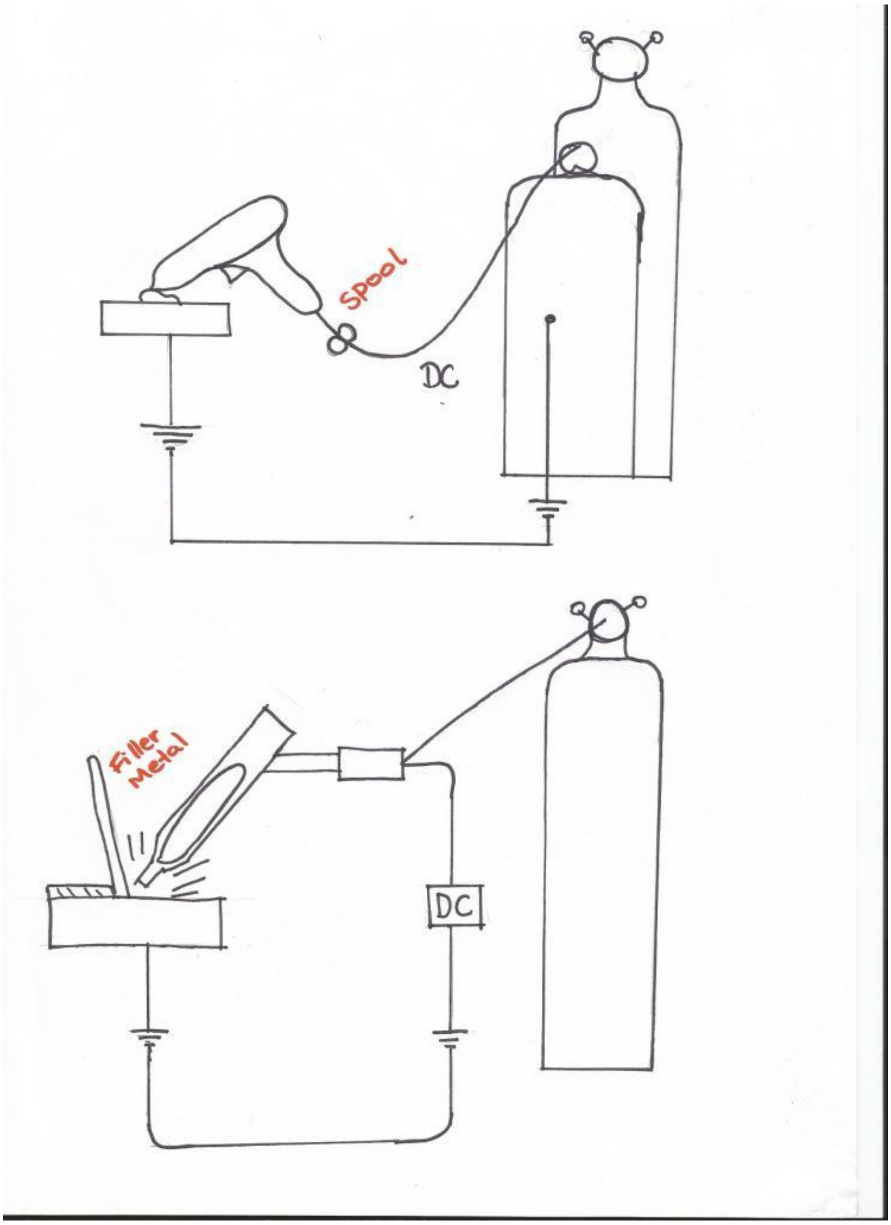

Fig. 4. MIG Welding (above) & TIG Welding (below)

Manual Metal Arc welding (MMA)

1. Circuit

Step-down Transformer

Converts high voltage AC to a lower voltage (220V to 80V-100V). This means the output current is greater than the input current. This is due to the primary coil having more windings than the secondary coil.

Smoothing Capacitor

Produces a more uniform direct current by smoothing the surges produced by the rectifier.

Rectifier

- Allows current to flow in one direction only.
- Converts AC to DC.
- Consists of four diodes arranged so to allow current to flow in one direction only.

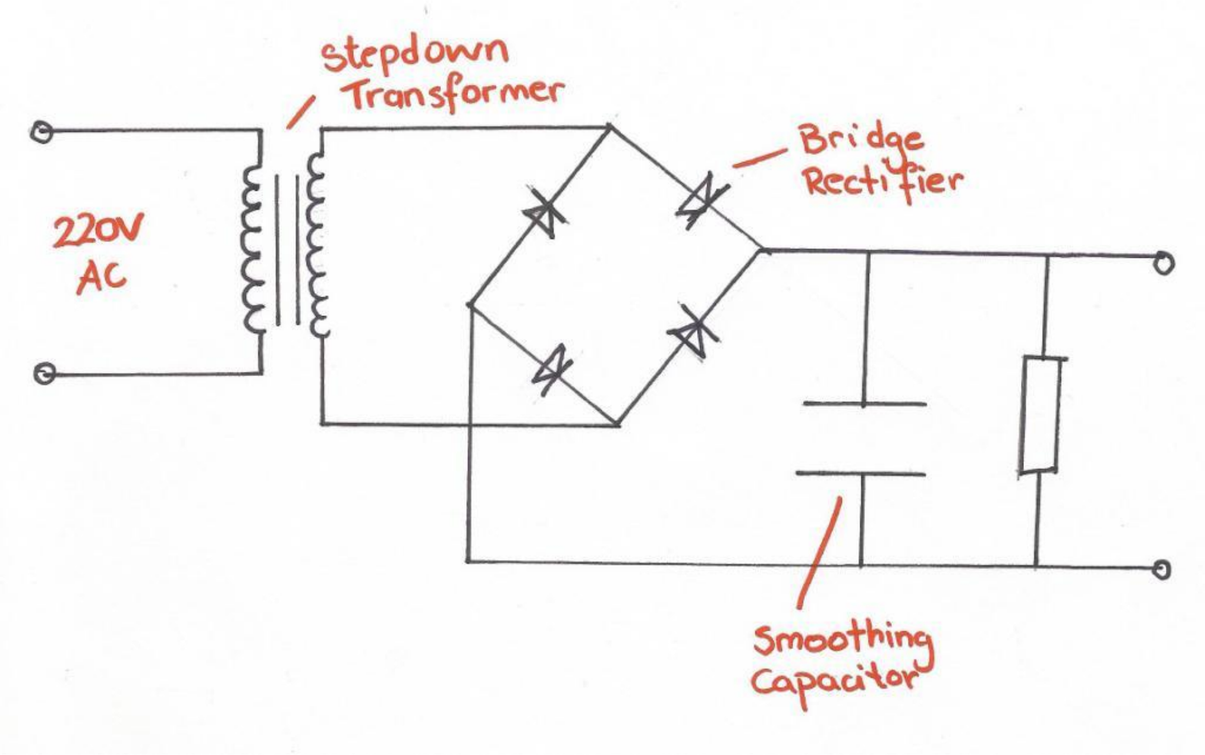

Fig. 5. Circuit for Manual Metal Arc Welding.

2. Safety

- Ensure equipment is well maintained.
- Wear protective clothing.
- Weld curtain/cubicle.
- Ventilation

3. Hazards

- Electric shock: Ensure conditions are dry, equipment is earthed and and insulated.
- UV Light radiation: Suitable weld shield/goggles. Use of welding curtain.
- Inhalation of fumes: Ventilation system.

4. Function of Electrode Coating

- Generates Carbon Dioxide shield to protect from oxidation by nitrogen and oxygen.
- Forms a slag.
- Facilitates striking of Arc.

5. Functions of Slag

- Fluxing action prevents contamination/oxidation of the weld by atmospheric gases.
- Allows the weld to cool slower, producing a better weld.
- Prevents cracks and brittleness in the weld.

Multi Run Welds

- Produces a finished weld that is more refined in structure than single run welds.
- Each run of welds has a post heating effect on the previous.

Oxy-Acetylene welding

- Oxy-Acetylene is a Fusion welding process.
- The joint edges are heated until the metals melt.
- The molten metals join and fuse.
- Oxidation is prevented by the envelope of products of combustion.

1. Acetylene

Acetylene would explode if directly compressed. Instead cylinders are filled with porous acetone which can absorb 25times the amount of acetylene. This is known as dissolved acetylene.

2. Safety

Colour Coding

The gas cylinders are colour coded for safety as follows:

	OXYGEN	**ACETYLENE**
Cylinder	Black	Maroon
Hose	Blue	Red
Thread	Right hand thread	Left hand thread

Flashback Arrestors

Flashback arrestors are fitted to the regulators to prevent the feedback of flame through the hose.

Gauges

- There are 2 gauges on each cylinder.
- The low pressure gauge shows supply in the torch.
- The high pressure gauge shows pressure in cylinder.

3. Flames

	Oxidising Flame	Carburising Flame
Gas in Excess	Oxygen	Acetylene
Temperature	3500	3150
Material	Copper, Brass	Aluminium, Alloy steel. Prevents Oxidation.
Size	Small Flame. Point, luminous inner cone.	Bigger flame
Sound	Hissing sound	Silent
Colour	Blue	Yellow/Orange

Submerged Arc Welding

- Uses bare wire electrode.
- Fed automatically from spool.
- Generates electric arc to heat metal/
- Flux in powder form.
- Fed using a hopper.
- Electric arc melts joint, flux and electrode.
- Excess flux is collected and re-used.
- Fully automated process.
- Used on Low carbon steels.
- E.g. Ship building and bridge construction.

Resistance Spot welding

- Components to be joined are placed between two non consumable electrodes and pressed together.
- The current is passed through the electrodes which generates the required heat.
- A nugget weld (circular mark) is formed.
- It is used on sheet metals.
- The process is energy efficient and does not require a filler metal.

Resistance Seam welding

- Uses copper rollers to provide a continuous run of overlapping spot welds.
- The current is set at intervals and is generated by a resistance to the flow of an electric current through the parent metals.
- The heat generated depends on time, resistance and current.

3. MATERIAL TESTING

3.1. Material Properties

Strength
The ability of a material to withstand forces of compression, tension, shear and torsion.

Tensile Strength
The maximum pulling stress a material can withstand without fracture.

Torsional Strength
The ability to resist twisting forces.

Hardness
The ability to resist abrasion, wear, indentation and scratching.

Ductility
Ability of a material to be stretched into a wire (e.g. copper).

Malleability
The ability to be flattened or shaped without rupture.

Toughness
Ability to withstand blows or impact.

Elasticity
Ability to return to original shape when freed from force distorting it.

Conductivity
Ability of a material to allow heat or electricity to flow though it.

3.2. General Definitions, Terms & Formulae

Young's Modulus

A measure of stiffness in a material $\frac{Stress}{Strain}$

Creep

Creep is the slow deformation of a metal over time, resulting from a constant load/force acting on the metal. Factors that contribute to creep include time, temperature and nature of the force. E.g. Lead is prone to creep.

Ultimate Tensile Strength (Max load)

$$\frac{Max\ load}{(Cross - sectional\ area)(\pi r^2)}$$

Proof Stress

$$\frac{Proof\ load}{CSA(\pi r^2)}$$

Fatigue

Fatigue is failure due to cyclic stressing (on/off loading). Failure begins as a crack and grows/spreads until failure due to stress. Factors that contribute to fatigue are sharp corners, time of exposure, nature of force and corrosion.

Factor of Safety

Is the degree of structural capacity beyond applied loads.

3.3. Non Destructive Testing (NDT)

X-ray Testing

- Radiation is passed through the material by an X-ray tube.
- If no faults are present, absorption is uniform on the negative photographic film.
- If a fault is present in the weld, less radiation is absorbed, thus producing a variation in the intensity of the emergent beam.
- This is detected on the negative photographic film.
- Where the defect exists, a dark spot forms.

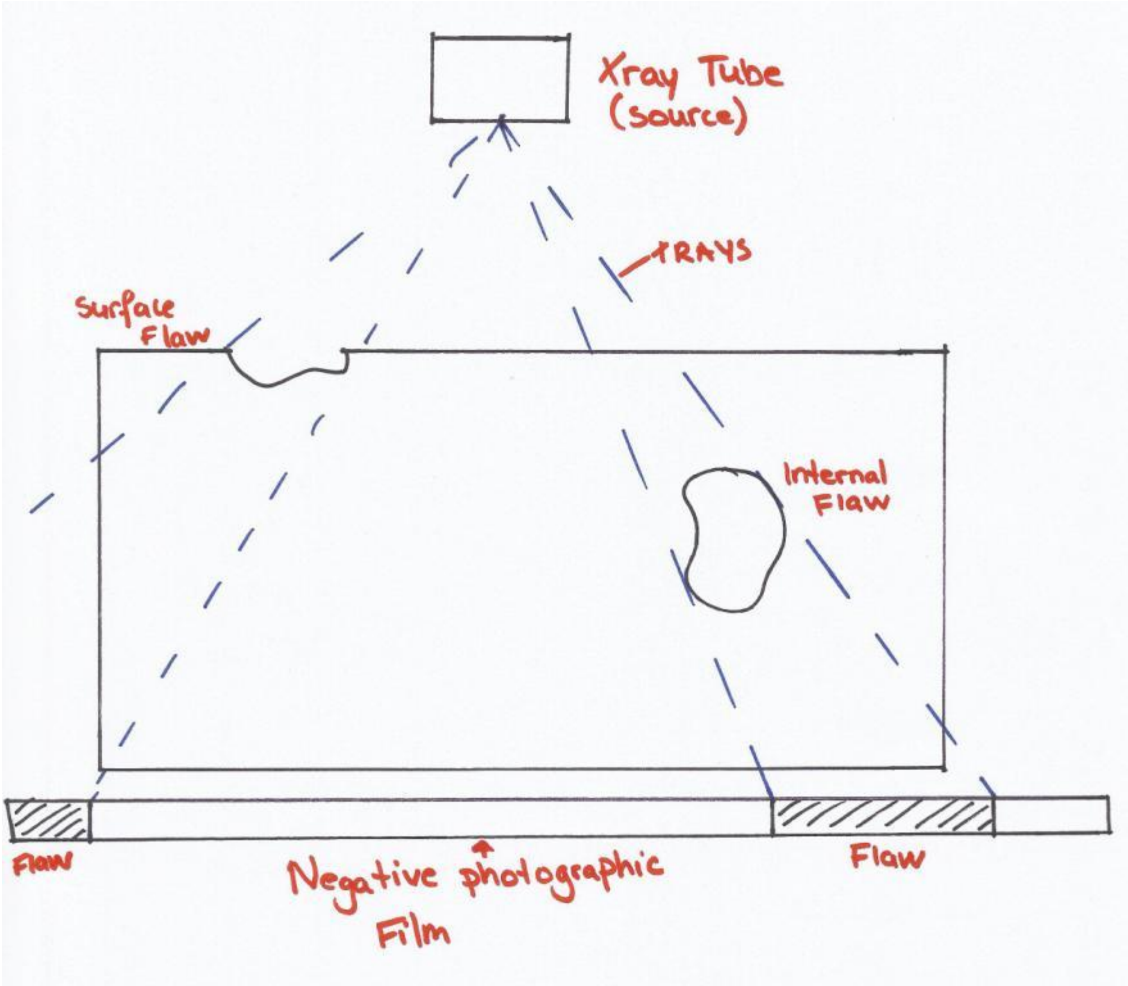

Fig. 6. XRAY Testing.

Eddy Current Testing

- A coil is charged with high frequency alternating current is placed close to a material.
- This produces Eddy Currents on the material.
- A magnetic field is created in the piece by the current.
- A defect will alter this magnetic field which will then be located by a search coil.
- This records and displays the faults.

Ultrasound/Ultrasonic testing

- Based on reflection of signals.
- High frequency vibrations are sent through the piece.
- These are reflected back once they reach the opposite surface of piece.
- If a flaw is present, the vibrations will be reflected back from it(the flaw). The amount of time for which it takes the vibration to return will be shorter than if no flaw were present.

Penetrant Dye test

- A dye is applied to the piece being tested and allowed to soak in for a sufficient period of time.
- If surface cracks are present, these will absorb the dye.
- The piece is then wiped clean.
- Chalk dust is then placed on the piece. This will absorb the dye in the crack and illustrate where the flaws are present.

Advantages of Non-Destructive Testing

- More economical as piece can be used if no flaw is present, especially if piece to be tested is expensive to manufacture.
- Can be applied to every piece.

3.4. Destructive Testing

Impact Testing

	Izod	**Charpy**
Striking Energy	167 Joules	300 Joules
Specimen	• Held Vertically • Clamped at one end • Notch faces striker	• Held horizontally • Clamped at both ends • Notch faces away

Hardness Testing

Brinnel

- Hardened Steel ball indenter.
- Not suitable for thin materials.
- Based on surface area of impression.

Vickers

- Pyramid indenter.
- 136° point angle on indenter.
- Length of Diagonal of impression measured

4. INTERNAL STRUCTURES OF MATERIALS

4.1 Bonding

Ionic Bonding
An ionic bond is the force of attraction between oppositely charged ions in a compound.
Ion
An ion is an atom that has gained or lost an electron.

Cation (+Ve)
A cation is an atom that has lost an electron. Metals tend to form cations as they are prone to losing their outer electron to other ions.

Anion (-Ve)
An anion is an atom that has gained an electron. Non metals tend to gain electrons or are electron acceptors.

Metallic Bond
A rigid lattice of positive ions (cations) suspended in a sea of valence electrons. Metallic bonds produce high melting points, ductility and malleability in material.

Covalent Bonding
Covalent bonding is the sharing of electrons.

4.2 Structures

BCC (Base centred cubic)

- Atoms are positioned at the corner of cube.
- Are brittle and less ductile than FCC structures.
- E.g. Tungsten, Sodium and Chromium.

FCC (Face centred cubic)

- Atoms are more tightly packed (more dense) in FCC structure.
- FCC structures are Malleable and ductile.
- E.g. Gold, silver, Aluminium, Nickel and copper.

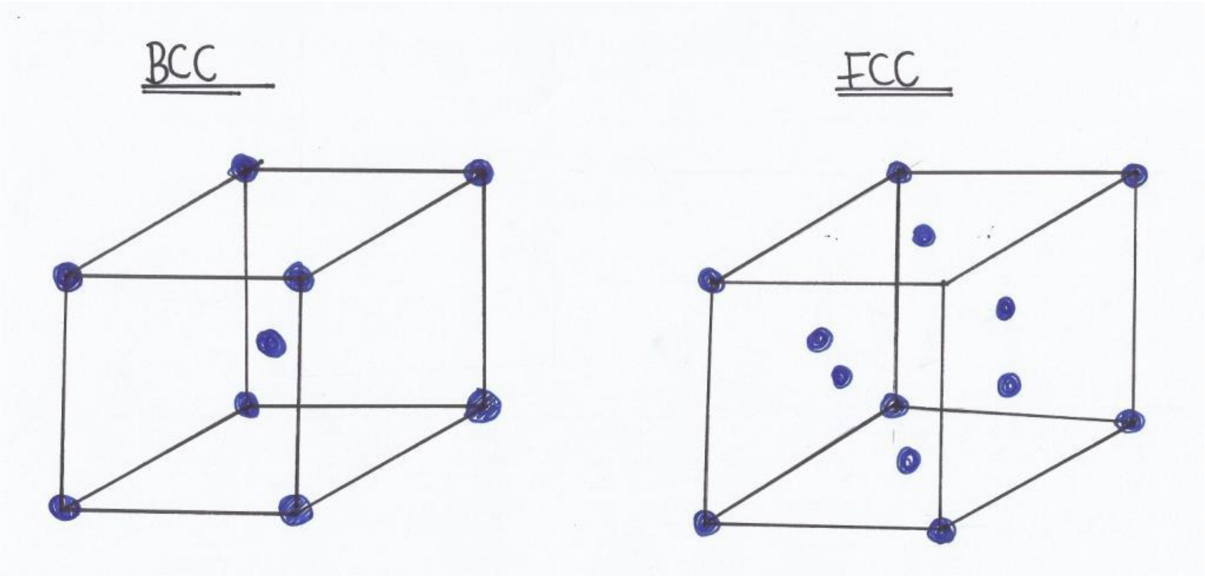

Fig. 7. Base centred cubic structure vs. Face Centred cubic structure.

Crystalline Structures

Bonded in a repeated structure e.g. BCC & FCC (Metals).

Amorphous Structures

Have no bonding pattern, arrangement is random. E.g. glass.

Allotropy

Allotropy is the ability of a material to exist in more than one crystalline form.
Steel has a BCC form when cold, but exists as FCC austenite when heated above the upper critical point.

Dendritic Growth

- Solidification starts at one point forming a nucleus.
- It grows in a similar manner to a seed, forming a seed crystal.
- As it grows, branches called dendrites grow in a tree like structure.
- The dendrites spread out and meet other dendrites and a crystal is formed.
- Grain boundaries are produced by impurities bonded together.

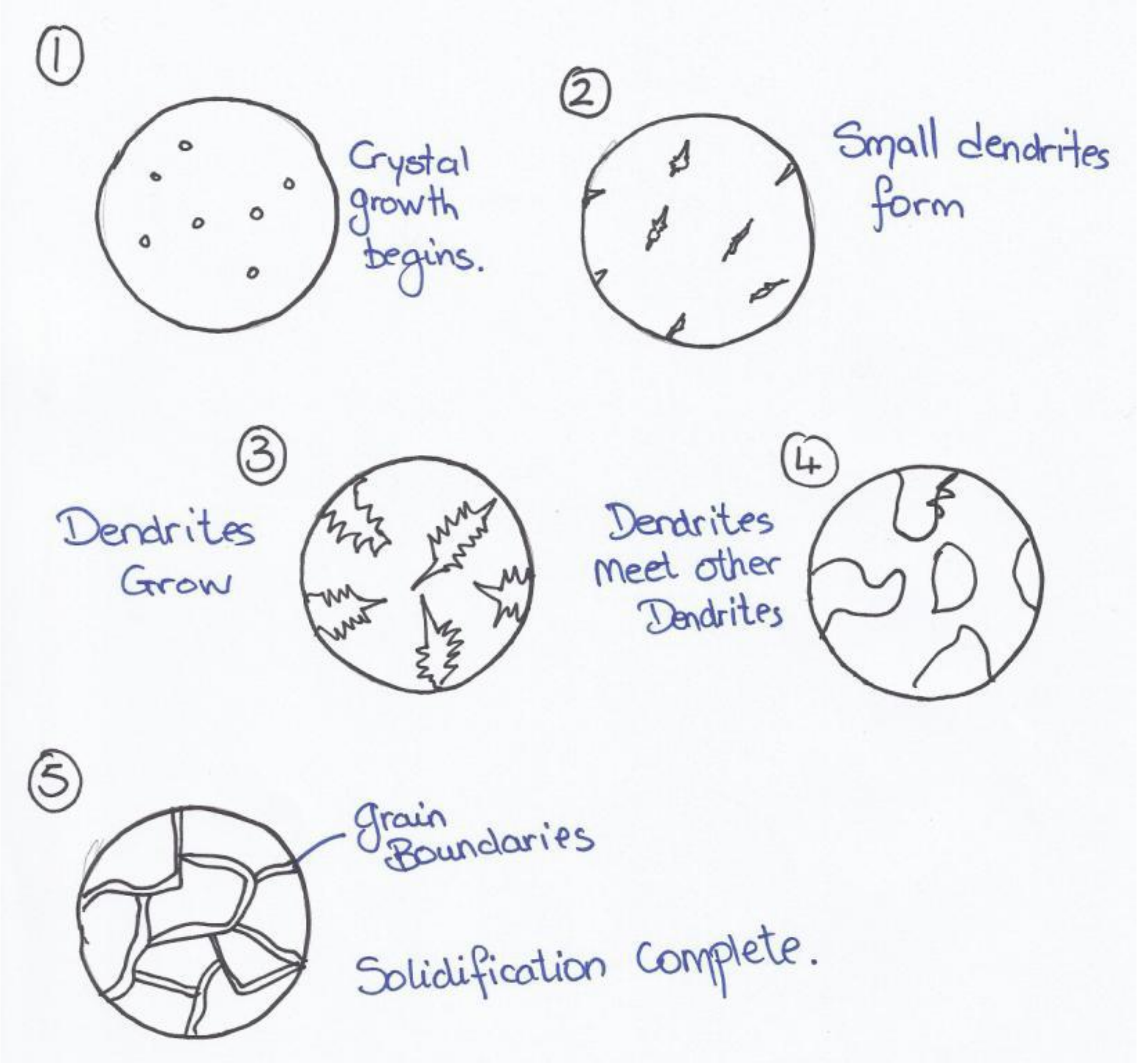

Fig. 8. Dendritic Growth.

4.3 Defects

Vacancy Site Defect

- Forms when an atom is missing from a structure.
- All the other atoms in the lattice are forced into the empty space and it becomes deformed in shape

Interstitial Defect

A foreign atom of a smaller element has moved into the space between atoms of the lattice of the base metal.

Substitute Defect

A substitute defect is where a foreign atom, usually larger in size replaces an original atom in the structure. This causes the lattice to become deformed.

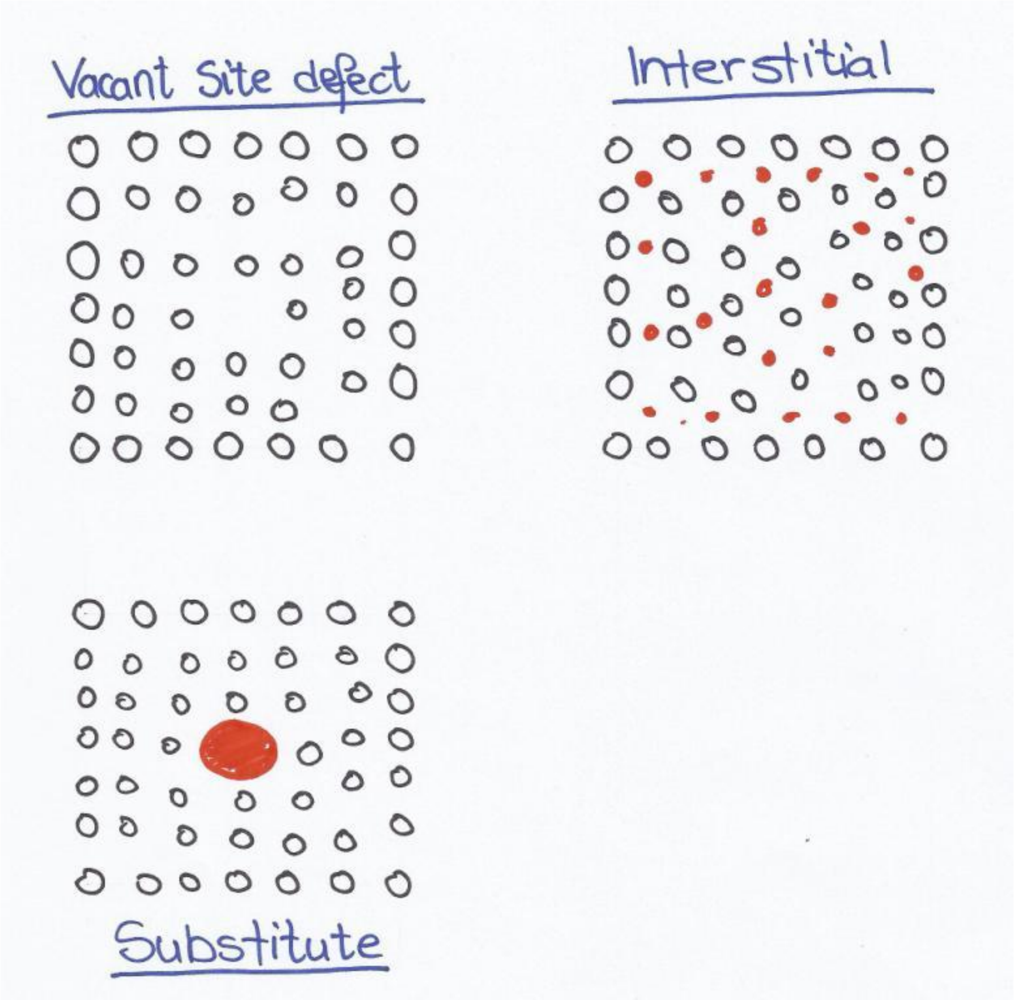

Fig. 9. Defects

Dislocation

- A dislocation occurs when there is a line fault (incomplete layer of atoms) in the metal when a shearing force is applied.
- This causes the fault to be pushed along until it reaches the edge of the crystal (grain boundary).
- When this happens it causes the grain to be deformed or change shape.
- A weakness is created which could lead to failure in the metal.
- Dislocations can be prevented by alloying and cold working.

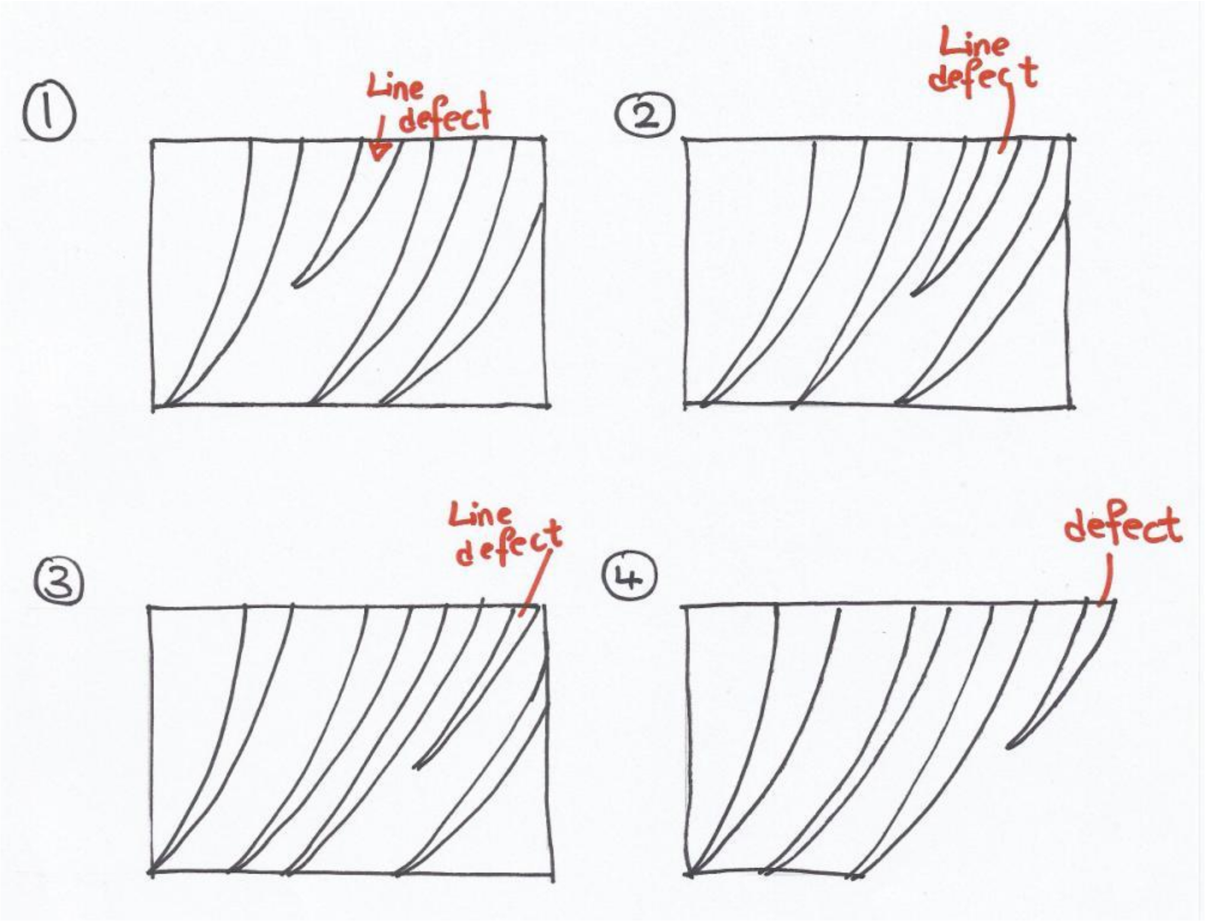

Fig. 10. Dislocation

5. COOLING CURVES

Solvus Line
Shows how much of one material is soluble in another at a certain temperature.

Liquidus Line
Between fully liquid state and beginning of solidification,

Solidus Line
Determines the end of solidification.

Pasty Region
Part Solid, Part liquid.

Solid Solution Alloy
Occurs when two metals are completely soluble in each other.

Eutectic Alloy
Occurs when two metals are soluble in each other in the liquid state but completely insoluble in the solid state.

Partial Solubility
Two metals completely soluble in each other in the liquid state but only partially soluble in each other in the solid state. E.g. lead and tin.

Latent Heat of fusion
The energy taken from or given to a substance when it changes from liquid to solid to liquid without any change in temperature.

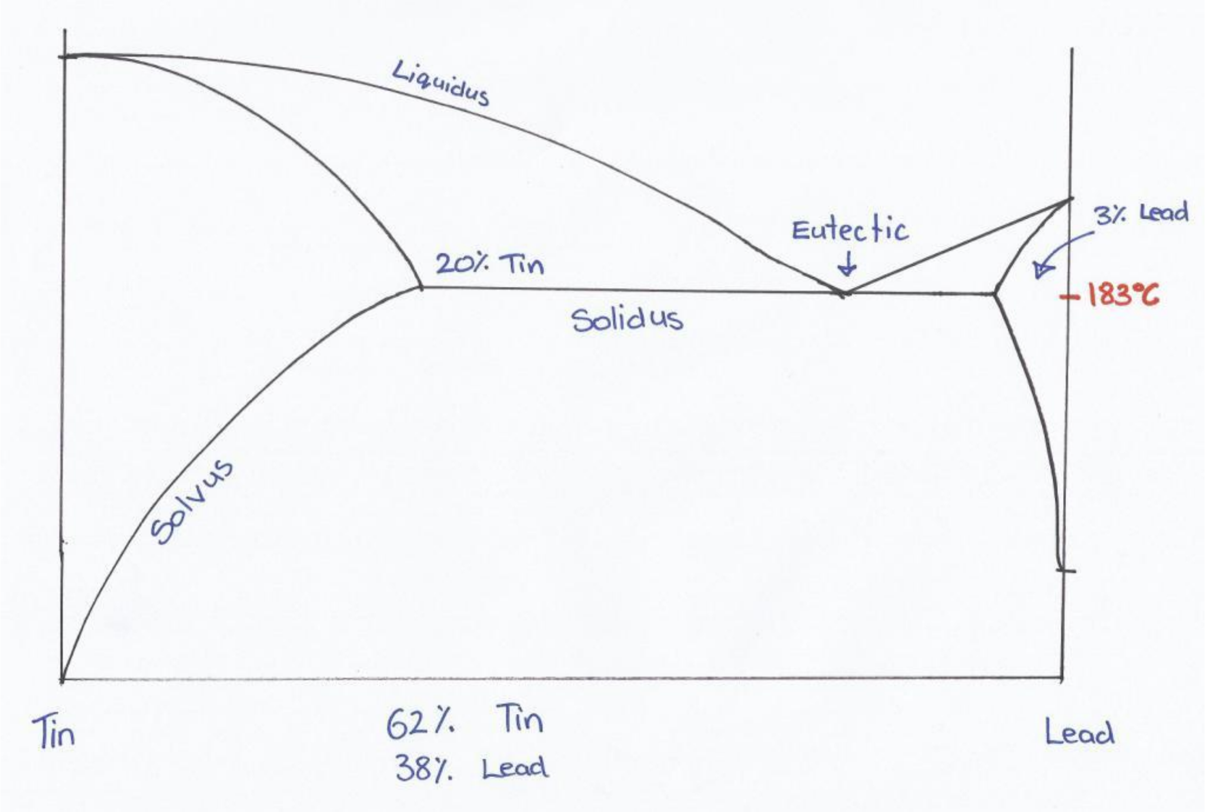

Fig. 11. Lead vs. Tin cooling curve

6. IRON CARBON EQUILIBRIUM DIAGRAMS

Lower Critical Point

- Occurs at 723°c.
- Temperature change occurs.
- The metal contracts dimensionally, glows less brightly and loses its magnetism.
- Known as Decalescence.

Upper Critical Point

- Varies depending on amount of carbon in the steel.
- Above this point, the metal exists as FCC austenite.

Eutectic Point

- Liquid to solid
- Occurs at 1140°C at 4.3% carbon
- Liquid steel changes to solid austenite and cementite.

Eutectoid Point

- Solid austenite changes to solid pearlite.
- Occurs at 723°C at .83% Carbon.

Ferrite

- Almost Pure Iron.
- Above a temperature of 1390°C or below 910°C, iron has a BCC lattice.
- Also known as alpha iron.
- Contains less than .2% Carbon.

Cementite

- Cementite is an inter-metallic compound of Iron and Carbon.
- It is a hard and brittle material.

Austenite

- Exists Between 1390°C and 910°C.
- Has a BCC structure.
- Also known as Gamma iron.

Pearlite

- Pearlite is a mixture of alternate layers of ferrite and cementite. It gives off a sheen similar to that of Mother of Pearl.
- Occurs at .83% Carbon. (Eutectoid Point)

Martensite

- Martensite has a body centred tetragonal shape.
- It occurs when austenite is quenched rapidly.
- It has a stretched axis due to its retention of carbon.
- It is a hard needle like structure.
- Strong but brittle.

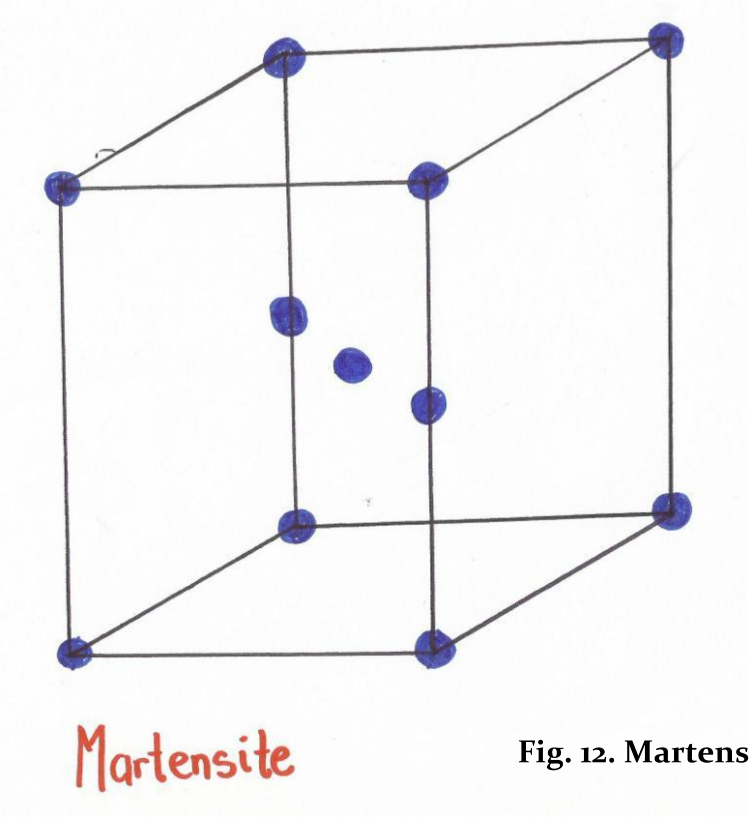

Fig. 12. Martensite

Allotropy of Iron

- Between 1390°C and 910°C, Iron has a FCC structure known as austenite.
- Above 1390°C and below 910°C iron exists in BCC structure known as ferrite.
- When iron changes from BCC to FCC at 1390°C, a slight shrinkage in volume occurs as the atoms are more tightly packed together.
- The reverse reaction, changing from FCC to BCC at 910°C causes an expansion in volume.

7. Heat Treatment

Treatment	Process	Result
Hardening	- The piece is heated to a cherry red colour and then cooled rapidly in water oils and brine. - At the cherry red colour the steel will have undergone structural changes (FCC to BCC, martensite) and the rapid cooling does not allow it to revert to its original condition.	Very hard and Brittle
Tempering .	- It is done by heating the article to a suitable temperature (500°C) below the reddening point of steel and then cooling it in oil or water. - The higher the temperature the greater the reduction in hardness and brittleness. - The temperature is gauged by the colour of the oxide film exhibited on the surface of the piece.	Allows the carbon to diffuse out of BCC Structure. Removes some of the hardness but increases toughness in martensite
Annealing	- Steel is annealed by heating it to a cherry red and allowed to soak to achieve uniform heating. It is then cooled very slowly. This can be carried out in the furnace by stitching it off when the steel has reached the correct temperature.	Annealing is done to soften metal and relieve internal stress in work hardened pieces. Refines grain size.
Normalising	- Normalising is carried out to refine the structure of steel and remove inner hardness caused by hammering, bending and rolling. - The steel is heated to a cherry red colour, approximately 50°C above its upper critical point and allowed to cool naturally in still air.	Produces harder steel than annealing. Improves Ductility and Toughness. Removes internal stresses. Refines abnormal grain structures.

Case Hardening	• Mild steel does not contain a sufficient amount of carbon to be hardened in the same way as High Carbon Steel is. • It is possible to increase the carbon content at the skin which can then be hardened. • It is a two stage process: 1)Carburising 2) Heat Treatment	Resists wear and breakage.
Pack Carburising	• The piece is placed in a box of powdered carbon. • The box is placed in a furnace and heated above its upper critical temperature. • The longer it is left, the higher the carbon content of the steel. • Applied to steels containing less than .2% carbon.	Increases carbon content of mild steel at the surface.
Spherodising	• Piece is heated to 700°C and soaked. • Iron Carbide forms as spheroids.	

Re-crystalisation

- Where new crystals begin to grow from the distorted or dislocated nuclei formed during cold working.
- The component is heated and new crystals grow until they have completely replaced the original distorted structure.

Temperature Measurement

Optical Pyrometer

- Compares the intensity of light from the filament of a lamp.
- The current flow is adjusted using a variable resistor to match the light of the furnace.
- When the filament disappears a temperature reading can be taken.

Thermo-electric Pyrometer

- Two dissimilar metals are joined together with a galvanometer placed at the cold junction.
- A rise in temperature at the hot junction creates a current.
- The temperature is then read at the galvanometer.

8. General

Sacraficial Protection (e.g. for a propeller on a boat)

- A plate of zinc, aluminium or magnesium is attached to the hull of the boat.
- The plate acts as an anode in an electro-chemical reaction with the propeller as the cathode.
- The anode will be sacrificed and need to be replaced periodically, protecting the object from corrosion.

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