Unit - II

Welding

Welding is defined as "a material joining process which produces coalescence of material by heating them to suitable temperature with or without application of pressure and with or without use of filler metal."

- Autogeneous welding (No filler used)
- Hetrogeneous (→ same different filler used in metal
- Homogeneous) → same filler wed a metal

⇒ Advantages of welding

1. Permanent joint
2. Low manufacturing cost
3. Flexibility in design
4. Similar/dissimilar metal can be joined
5. Repair work.

⇒ Disadvantages of welding

1. Require skilled labour
2. Residual stresses can remain after welding
3. Distortion in metal can took place.

DATE: __/__/____
PAGE: _____

Classification of welding processes

1) Fusion Welding

(a) Gas Welding
(b) Electric Arc Welding
(c) Thermit welding

2) Pressure Welding

→ Resistance Welding
- Butt resistance welding
- Flash resistance welding
- Spot resistance welding
- Projection resistance welding
- Percussion resistance welding

3) Miscellaneous welding

(a) TIG (Tungsten Inert Gas) Welding or GTAW (Gas Tungsten Arc welding)
(b) MIG (Metal Inert Gas) Welding
(c) Submerged Welding
(d) Electro Slag

4) Modern Welding

(a) Electron beam welding
(b) Ultrasonic welding
(c) Laser beam welding
(d) Explosive welding

5) Allied Processes

(a) Soldering (b) Brazing

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DATE : __/__/____
PAGE : ____

Fusion Welding

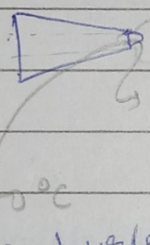
(a) Gas Welding

O_2 & C_2H_2 (Acetylene) ke combination ki help se welding.

(b) (Imp) Types of flames

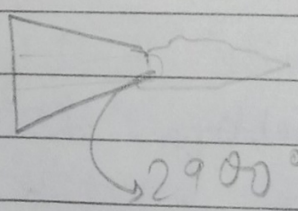
(i) Neutral Flame

- For this flame, ratio of acetylene & oxygen are equal to 1:1.
- This type of flame has a temperature of about 3100°C.
- Neutral flame is used to weld carbon steel, cast iron, aluminium, etc.



(ii) Carburising Flame

- For this flame, excess of C_2H_2 is used. ($C_2H_2 > O_2$)
- It is used for welding of medium carbon steel, nickel, etc.



(iii) Oxidising flame

- Excess of O_2 is used. ($O_2 > C_2H_2$)
- It produces roaring sound.
- It is used for welding of copper, brass, bronze, etc.

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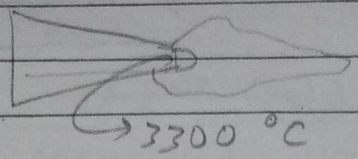


→ Equipments for gas ~~cylinder~~ welding

(i) Oxygen Cylinder

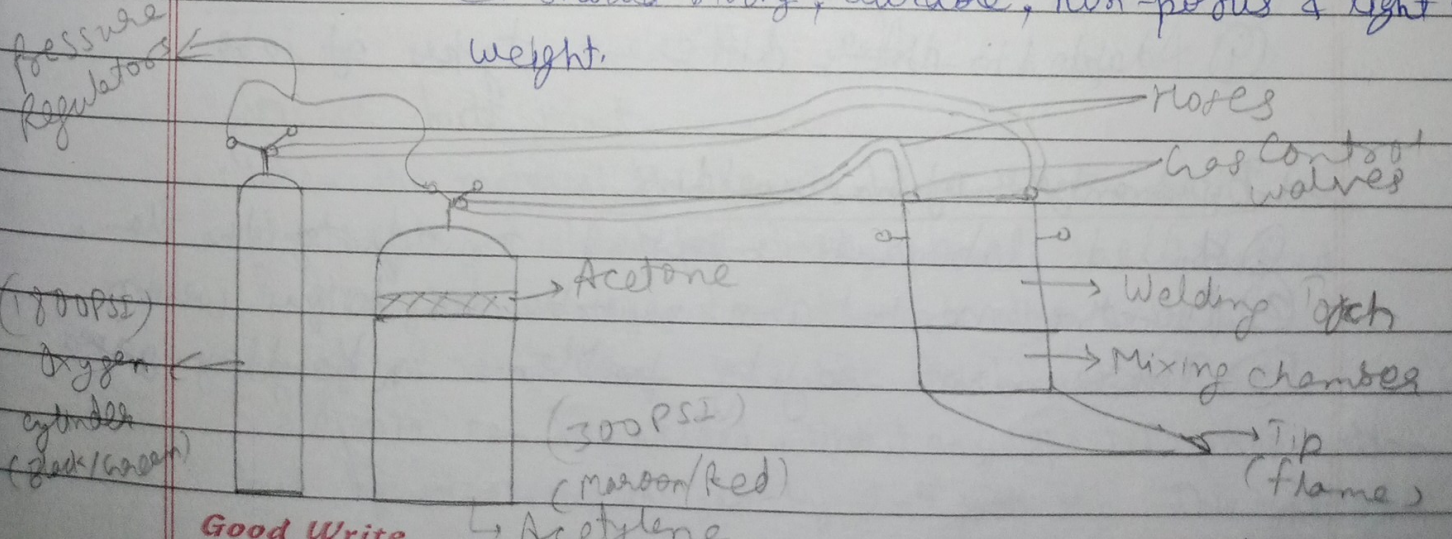
- It is made of steel & usually painted black in colour. It contains compressed O_2 at pressure of 1800 to ~~PSI~~ 2000 PSI.

(ii) Acetylene Cylinder

- It is painted maroon in colour.
- Acetylene gas is highly explosive; therefore it is wetted with acetone that allows acetylene to be safely contained in cylinder.
- Pressure inside cylinder is around 300 PSI.

(iii) Welding Hoses

- Hoses are rubber pipes used to connect gas of cylinders.
- They are painted black or green for oxygen & red or maroon for acetylene.
- It should strong, durable, non-porous & light in weight.



Oxy - Acetylene Gas welding setup

[1 PSI = 0.07 kg/m²]

(iv) Check valves

Check valves are installed between hoses & torch to prevent backflow of gases.

(v) Pressure Regulator

The cylinder are provided with pressure regulator to control the working pressure of oxygen & acetylene.

(vi) Welding Torch

It allows oxygen & acetylene to flow in required volume & ignite at the tip.

[Note: In gas cutting all setup is of gas welding but welding torch is replaced with cutting torch.]

⇒ Advantages of Gas welding

1. Portable
2. Easily available
3. Process is versatile.
4. Adapted to different types of jobs.

⇒ Disadvantages of Gas welding

1. Skilled labour is required for adjusting the flame.
2. Reactive metal are unsuitable to gas welding
3. There are safety problems in handling gases

→ Application of gas welding

① Joining the ferrous & non - ferrous material.

② Used in industry & ~~steel~~ sheet metal fabrication.

□ Types of Joint

① Butt joint ② Lap joint ③ T joint ④ Corner/Edge joint

→ ~~Single~~ square butt joint

→ Single u butt joint

→ Double u butt joint

□ Position of welding

① Vertical ② Horizontal ③ Flat ④ Overhead

□ Types of Joint

① Butt Joint

→ Square butt joint

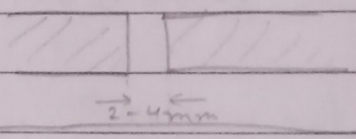
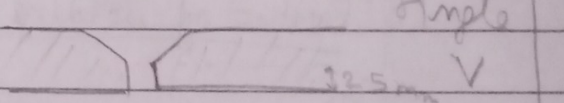
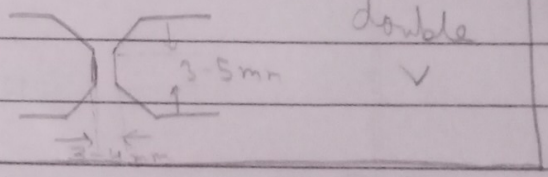
• When the material thickness doesnot exceed 5mm, it is often welded by simply placing the sheared & straightened edges close to each other with a gap of 1-2 mm). Even the plate thickness b/w 5 & 8 mm can be welded without any special preparation but by increasing the gap by 2-4 ~~yes~~ mm. This type of

joint is referred as square butt joint.
- However, when the material thickness exceeds 8mm, it is often difficult to achieve full penetration with square edge preparation. The edges are then prepared by machining to V-configuration.

- When the plate thickness is usually above 20mm, it is better to have double V edge preparation. This helps in achieving good quality welds without distortion.

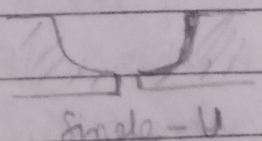
Just Read

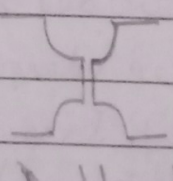
Joint edge preparation for built welds

Plate Thickness	Electrode size in mm (diameter)	Joint Preparation
Upto 5-8	3-4	
4-96	4-5	
2-60	4-6	

→ Single-U & double-U

When the thickness is greater than 20 mm, we go for single-U and double-U.





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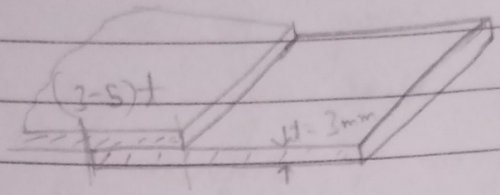
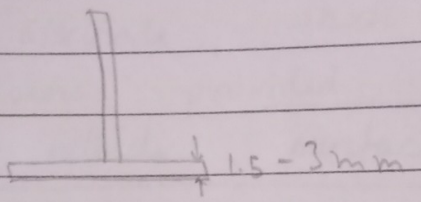
(2) Lap Joint

If thickness is less, than 3mm, then lap joint is used. It is the joint in which plates overlap each other. This is adopted when the width of lap usually b/w 3 to 5 times the thickness or t of the plate.



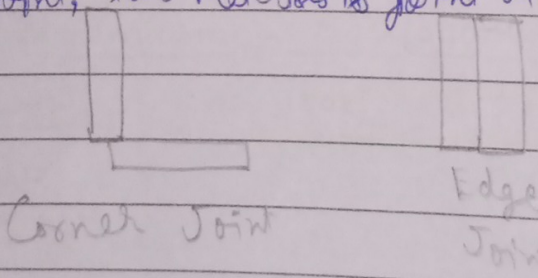
(3) T Joint

T joint is used when the thickness varies from 1-2mm. 10-20mm.



(4) Corner / Edge Joint

This welding joint refers to instances in which two materials meet in the "corner" to form an L-shape. In edge joint, two materials is joint at edges.



□ Positions of Welding

Welding is performed in different positions :-

DATE : __/__/____
PAGE : _____

(i) Horizontal

(ii) Vertical

(iii) Flat

(iv) Overhead

⇒ Arc Welding Electrode -

Electrodes commonly used are of two type

1.) Bare Electrodes
2.) Coated Electrodes.

→ (Bare Electrodes are cheaper but welds produce through these are of poor quality) (They also require high degree of skill on the part of welder). They are, therefore, very (rarely used in modern welding practice).

More popularly used electrode in metal arc welding is coated Electrode which carry a core of bare Metallic wire provided with coating or covering on outside surface.

* Mild steel is most commonly used for material for core wire. other metals & Alloys are also used depending on welding conditions & requirement some of other materials are - Low Alloy steel Nickel steel, chromium - Molybdenum steel, vanadium steel, Aluminium, phosphor - Bronze etc.

* Electrode coverings -

The common ingredients of flux which help in slag formation & metal refining are - Asbestos, mica, silica, titanium dioxide iron oxide, Magnesium carbonate, calcium carbonate & different Alumines.

→ Ingredients used for producing reducing Atmosphere include cellulose, calcium carbonate, wood floor, starch, dextrin etc.

→ Iron powder provide high deposition rate.

→ Ferro Manganese & manganese oxide provide Alloying Elements.

→ Potassium silicate & Potassium titanate are Principal are stabilizers.

other Materials that help in are stability are - titanium dioxide, feltspar & mica.

⇒ For light & Medium coated Electrode, thickness of covering vary from 10% to 55% of the total diameter of Electrode.

⇒ selection of Electrodes depend on following factors -

1.) Availability of current - A.C or D.C
2.) composition of the base metal
3.) Thickness of the base Metal
4.) welding position - Flat, Horizontal, vertical or overhead.
5.) Expected physical properties of welded Joint - strength, ductility, Appearance etc
6.) Amount of penetration required in welding.

Q.4→ Explain electric arc welding in detail with diagram.

Ans:- Principle of Arc

i) A suitable gas is kept b/w the work & electrode.
ii) A high current is passed through the circuit.
iii) The electric energy is converted into heat energy producing a temperature of 3000°C to 4000°C.
iv) The heat melts the edge to be welded and molten pool is formed.
v) On solidification the welding joint is obtained.

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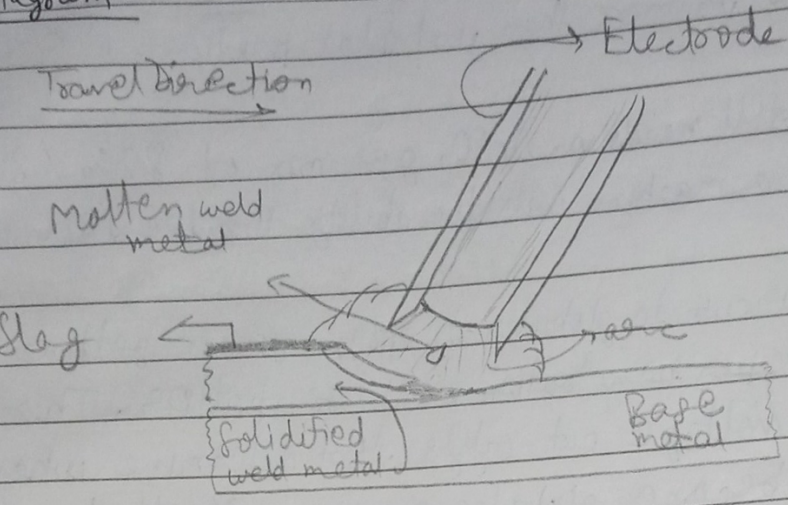
Formation

DATE : __/__/____
PAGE : _____

- Diagram



* (• The welding in which the electric arc is produced to give heat for the purpose of joining two surface is called electric arc welding.)

x The joining by fusing of two or more pieces of metal together by using the heat produced from an electric arc.

• The ~~arc~~ arc is like a flame of intense heat that is generated ~~by~~ from the electrical current.

- Arc Welding Equipment

a) Welding Transformer
b) Electrode
c) Electrode Holder
d) Workpiece clamp
e) Chipping Hammer
f) Wire brush
g) Protective shield

Workpiece Clamp → It is used for ~~connecting or~~ transferring current from the power source to the electrode holder and produces arc to the workpiece back to the powersource.

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DATE: __/__/____
PAGE: _____

Electrode Holder →
It is designed to have the capacity of clipping the electrode manually in order to receive current & create the arc.

Chipping Hammer →
It is made of a wooden or rubber handle. It is used to reduce slag that occur during welding.

Wire Brush →
It is used to clean dirt and to wipe away rust from the metal before welding.

Protective Shield →
It is used to protect our eyes from the harmful radiation.

Welding Transformer →
Here step down transformer is used which receives current from the supply main supply at 400 - 440 voltage and transforms it to the required voltage for welding.

Advantages
i) Simple Welding Equipment
ii) Inexpensive power source
iii) Process is fast.
iv) Equipment can be used for multiple function.
v) It give superior temperature at point of welding.

DATE : ___/___/____
PAGE : _____

- Disadvantages

b) i) It require skilled operators.
ii) Not used for the welding of thin metals.
iii) It cannot be used for welding of reactive metals such as aluminium etc.

- Application

7) i) It is used in repairing of broken part of machines.
ii) It is also used for welding process in shipbuilding.

- Working

→ Intense heat at the arc melts the tip of electrode.
→ Tiny drops of metal enter the arc stream and are deposited on the ~~parent~~ parent metal.
4) → As molten metal is deposited, a slag forms over the bead which serve as an insulation against air contaminents during cooling.
→ After a weld pass is allowed to cool; the oxide layer is removed by a chipping hammer and then cleaned with a wire brush before the next pass.

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DATE: __/__/____
PAGE: _____

Use of AC in arc welding

i) It is cheaper.

ii) Its maintenance is easier.

iii) More economical since it has no moving parts.

iv) It is less suitable for use at low current.

v) Bare electrode cannot be used in A.C.

vi) Maintenance of short arc is difficult.

vii) It can be used only when AC main supply is available.

viii) Different fixed polarities are not available.

ix) It is generally not preferred for welding of sheet metal.

Use of DC in arc welding

i) It is costly.

ii) Its maintenance cost is high.

iii) It carries many moving part it is costly.

iv) It is better suited for use at low current.

v) Both bare & coated electrode is used.

vi) Maintenance of short arc is easier.

vii) It can be in both condition and also use in absent of AC main supply.

viii) Different fixed polarities can be used for welding.

ix) It is more preferred because starting of arc is easier and the arc remains steady.

Pressure Welding

◦ Resistance Welding

In resistance welding, weld is made by combination of heat, pressure & time.

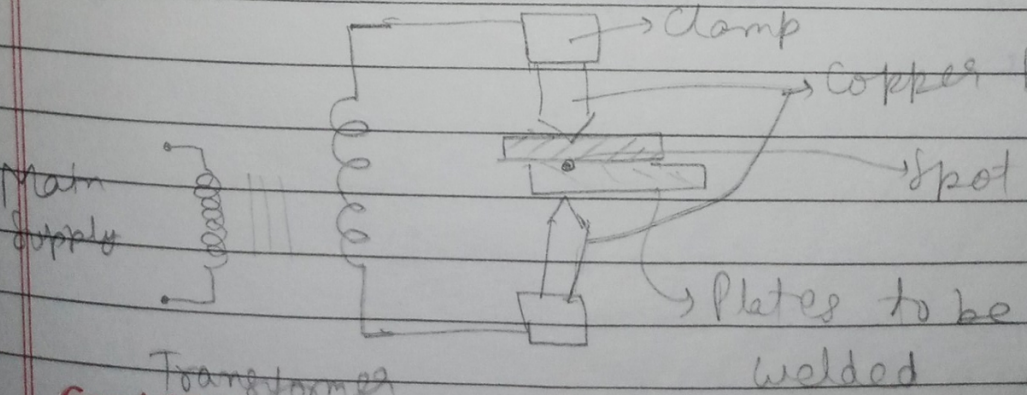
It is defined as resistance of material to be welded to current flow that causes localized heating of the part that has to be welded.

Heat generated in this process is given by

$$H = I^2 R T$$

where H = Heat generated in joule
I = Current in Ampere
R = Resistance in Ohm
T = Flow time of current in sec.

⇒ Resistance spot welding



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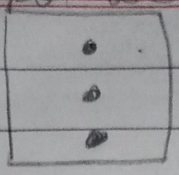
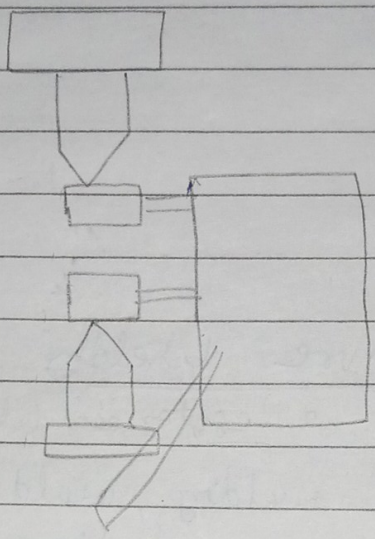
DATE: ___/___/_____
PAGE: _____

Spot weld





→ Principle is same as resistance welding.

→ Spot welding is a type of resistance welding used to weld various sheet metal of thickness from ~~0.5~~ 0.5 to 3 mm.

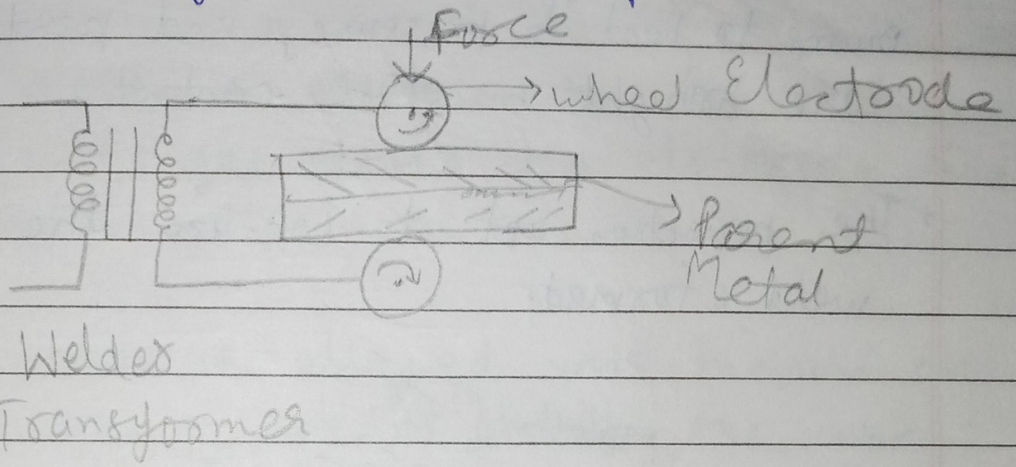
→ The process uses two copper shaped electrode to concentrate welding current and force b/w materials to be welded. This result is spot formation of a nugget of welded material after current is removed.

→ ~~In this~~

⇒ Resistance Seam welding

→ In this weld, is formed by a series of overlapping spot weld made progressively along the joint by two rotating wheel electrodes.

→ Force is applied by the wheel to produce continuous joint.



→ Principle is same as resistance welding.

⇒ Percussion Welding

It consists of holding the parts at a small distance with their end faces opposite to each other, bringing them closer at a fast speed after switching on the current, thus creating an arc b/w their end faces just before they come in contact and completing the weld under impact. Some of the metal may squeeze out of the joint, but is very small.

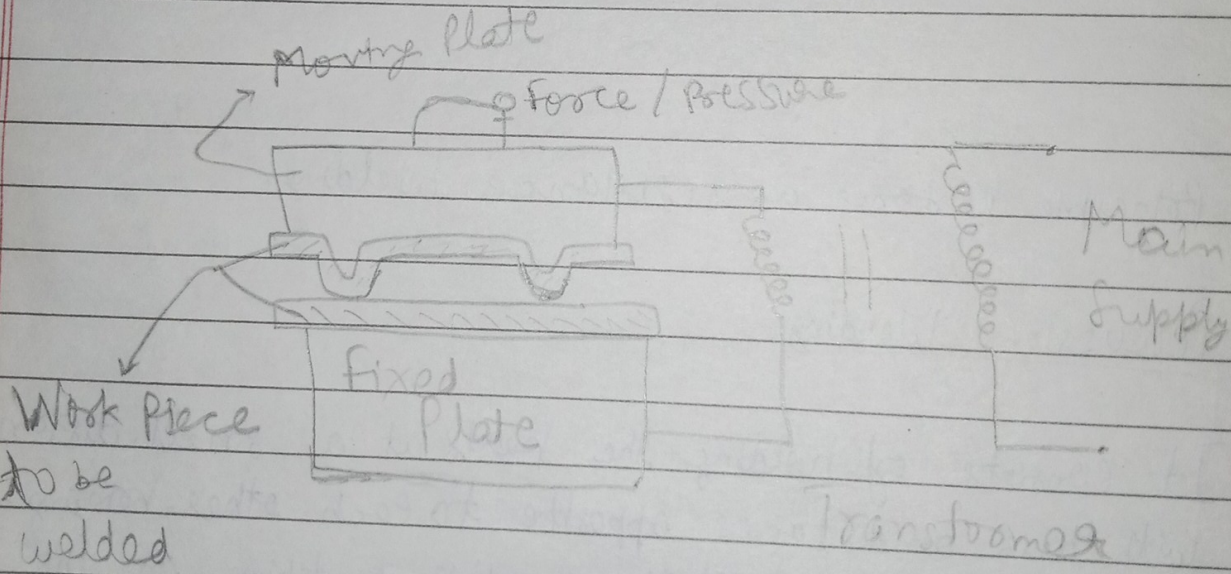
DATE: / /
PAGE:

⇒ Resistance Projection Welding

→ In this process, small projections are raised on one ~~side~~ side of plate with punch & ~~dye~~ a die assembly & the other plate is fixed.

→ During welding process ; projection ~~com~~ collapse owing to heat & pressure, and part to be joined are brought in close contact.

→ The projection act to localize the heat & thus weld is formed.



Note: Functions of flux ?

□ miscellaneous welding

DATE: __/__/____
PAGE: _____

Imp
-> TIG (Tungsten Inert Gas)

or GTA (Gas Tungsten Arc) welding

→ This process uses non-consumable tungsten electrode which is mounted in electrode gun.

→ Electrode holder is designed to furnish the flow of inert gas around the electrode and around the arc. (Argon, helium is used)

→ Tungsten electrode is alloyed with thorium or Zircona which is used to stabilize the arc.

→ Inert gas (helium, argon) is supplied to welding zone to effectively displace the atmosphere around the weld pool.

→ If filler rod is required, a welding rod is fed into welding zone & melted with base to metal.

→ Welding is done by striking the arc b/w workpiece & tungsten electrode.

→ Both AC & DC power can be used.

a) DCSP (Direct Current Straight Polarity) → Tungsten electrode (-ve), workpiece (+ve) is used for mild steel, stainless steel & titanium. (magnesium)

→ used for more thicker materials (workpiece)

bcoz +ve has more heat.

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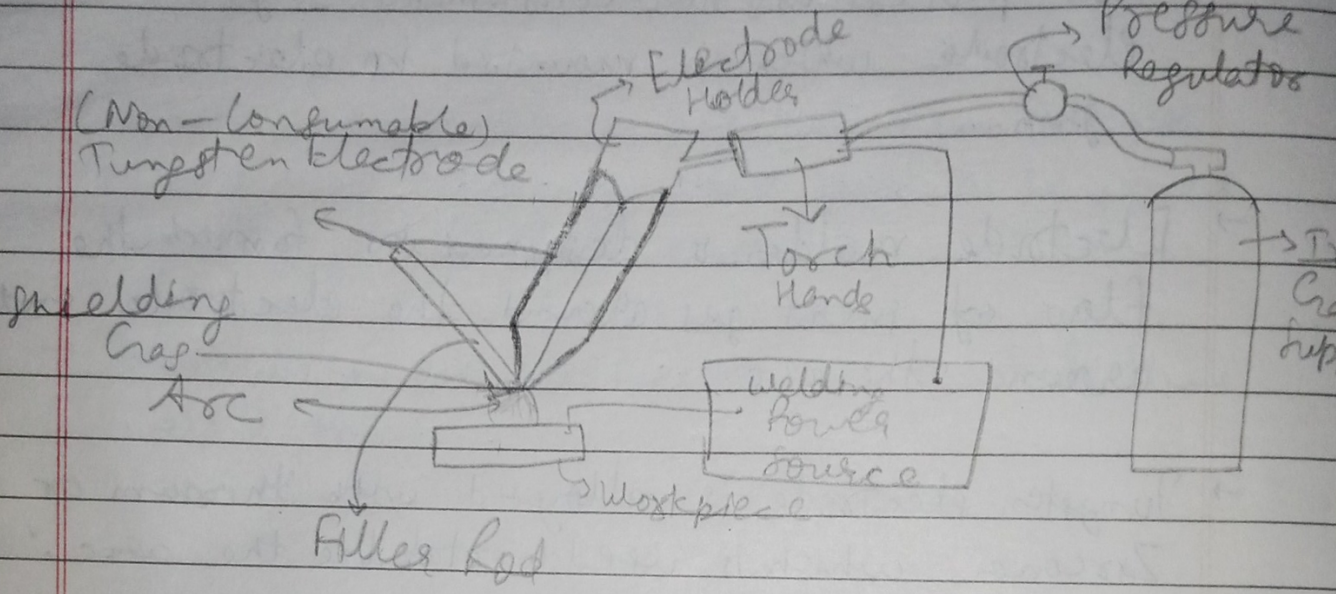
→ for thin workpiece

DATE: __/__/____
PAGE: _____

b) DCRP (Direct Current Reverse Polarity) → Tungsten electrode (+ve), workpiece (-ve) is used for welding of aluminium.



Arc ⇒ Heat ⇒ fusion

⇒ MIG or GMAW

(Metal Inert Gas welding) (Gas Metal Arc Welding)

→ It is a semi-automatic or automatic arc welding process in which continuous and consumable wired electrode & a shielding gas are fed through welding gun.

→ Following equipment are used in GMAW process as follows:

a) Welding gun & wired feed unit:

→ GMAW welding gun consist of key parts:
a control switch, a contact tip, power cable, gas nozzle, electrode & gas hose.
→ When control switch is pressed; it initiate the wire feed resulting in formation of electric arc b/w electrode & work piece.
→ Wire feed unit supplies electrode to work piece.

b) Power supply:

→ Mostly it uses constant voltage supply.
→ Generally, DC current power supply is used for MIG.

c) Electrode:

→ A continuous spool of wire electrode reel is used; which is consumable.

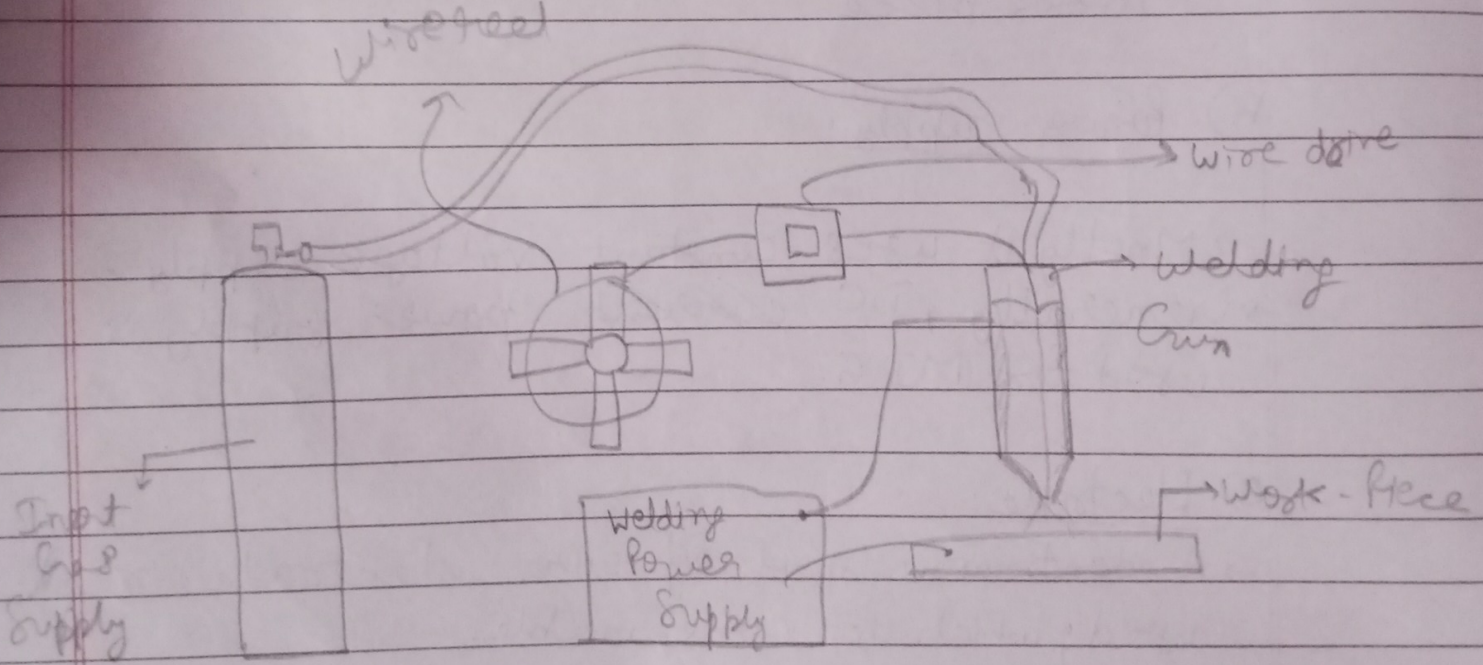
d) Shielding Gas:

→ It protects the weld from outer atmosphere. Generally used shielding gas are argon, heltrom, etc.

DATE: __/__/____
PAGE: _____

Working / Operation

The typical setup for GMAW process is shown in figure. The consumable electrode in the form of wire reel, which is fed at constant rate, through feed rollers. The welding torch is connected to gas supply cylinder which provide the necessary inert gas.
The electrode & workpiece are connected to welding power supply; the power supplies are generally of constant voltage type. The current from welding machine is changed by changing the rate of feeding of electrode wire.



Setup of MIG / GMAW

Common points of MIG and TIG are :

- Both use same gases for shielding depending on the metals to be welded.
- Both can be used for welding metals like stainless steel, non-ferrous alloys and aluminium.
- Gas flow and its controls are same in both.
- Cleaning the weld is important in both cases.
- No flux is required for both.

Differences between TIG and MIG

TIG (GTAW)	MIG (GMAW)
1. TIG welding uses a permanent, non-consumable tungsten electrode.	1. MIG uses consumable continuous coil electrode of same chemical composition as the material being welded.
2. TIG welding electrode serves the purpose of producing the arc only. Filler rod is added separately.	2. MIG welding electrode serves both the purposes of poducing the arc as well as of filler metal.
3. TIG is not as fast as MIG because in this, separate filler rod is added.	3. MIG is fast as compared to TIG because electrode and filler metal is same, which is in the form of wire.
4. TIG welding requires a skilled operator.	4. No so much skill is required for an operator.
5. If filler metal is added, operator's both hands are engaged. So work must be held in position with clamps or fixtures.	5. In MIG welding, the wire electrode and gases come from the same run and thus can be made easily automatic.
6. TIG welding usually uses DCSP (direct current straight polarity), but in case of welding thin sheets DCRP (direct current reverse polarity) is used.	6. MIG uses both types of polarities. Generally DCRP is used.
7. TIG welding torch is water-cooled.	7. Generally no water-cooling is necessary.
8. Tungsten if by chance comes in contact with the molten metal causes contamination of the weld pool.	8. No such problem is there with MIG (no tungsten electrode).
9. TIG welding is not used often for welding plates thicker than 6 mm.	9. It is best suited for thick (more than 6 mm) jobs.
10. Penetration is not so much deeper as with MIG.	10. Deeper penetrations can be obtained as compared to TIG.

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DATE: __/__/____
PAGE: _____

▫ function of flux (Coating present in coated electrode)

1. It provides shield around the arc & protect it from outer atmosphere.
2. Slag being lighter in weight, floats over surface & help in uniform cooling and ~~prevent~~ prevent from oxidation during cooling process.
3. It also provides alloying elements to the molten metal.
4. It helps in stabilising the arc.
5. It also helps in controlling the bead shape.

Note → Weld bead:

Amount of material deposited in single pass of weld.]

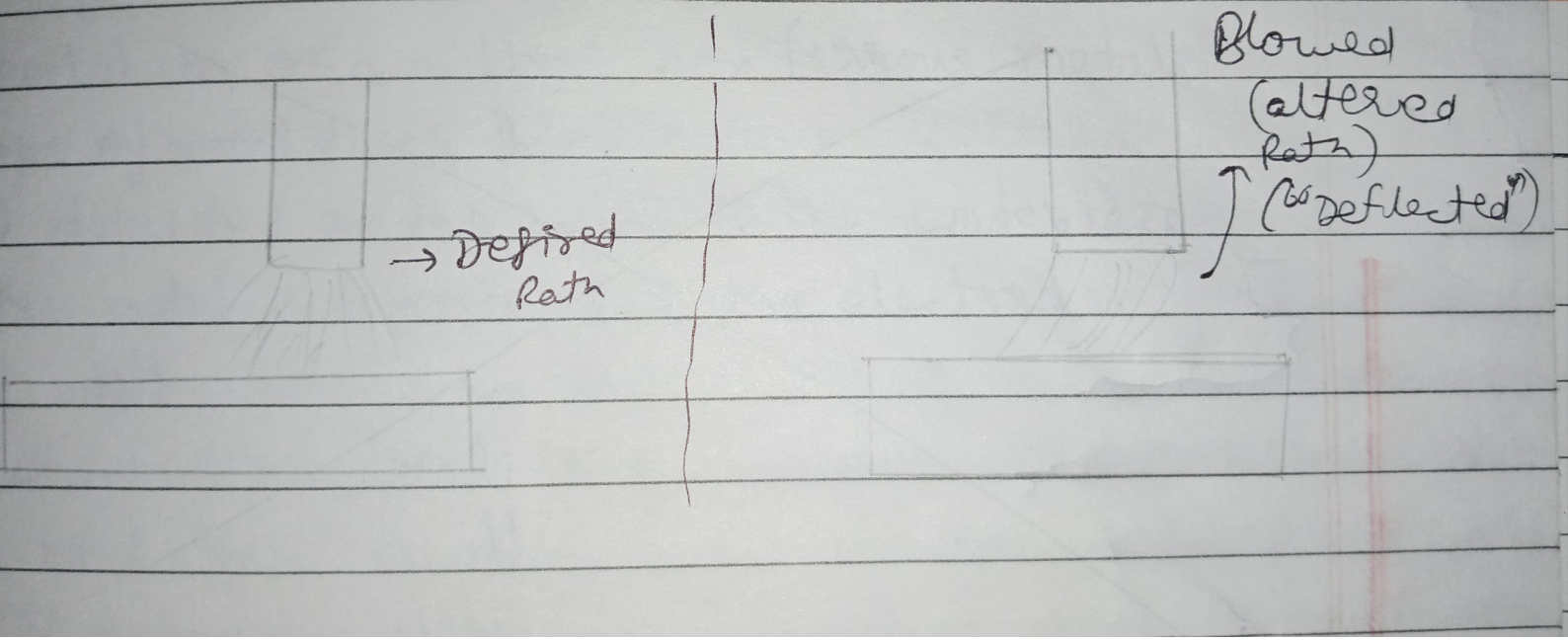
▫ Arc Blow

→ The deflection of arc from its intended path is called Arc Blow. It is due to magnetic forces acting on arc as the current flows through electrode.

→ Concentration of magnetic forces are more at ends therefore chances of arc blow is greater at beginning / end of weld.

→ Arc blow can be reduced by controlling current and arc length.

DATE : ___/___/_____
PAGE : _____



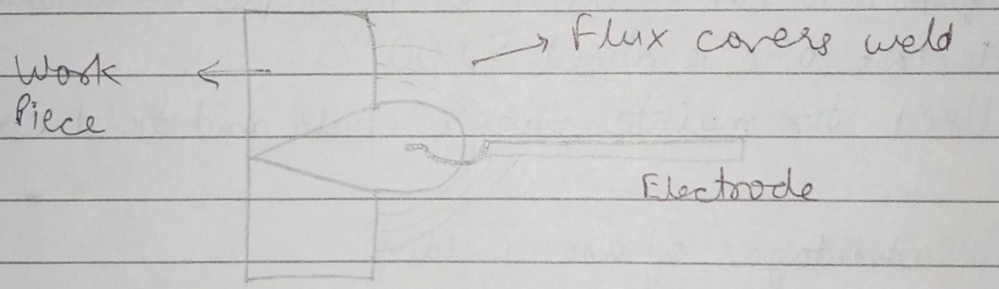
□ Miscellaneous Welding (Continued ...)

DATE: __/__/____
PAGE: _____

□ Submerged Arc Welding (SAW)

1) Submerged arc welding is provided by arc b/w base metal and electrode. Pressure is not applied in this process.
2) Filler metal is obtained from electrode and same time from supplementary welding rod.
3) Shielding is obtained from blanket of Granular flux which is laid directly over weld area. The weld is submerged under this layer of flux, hence it is known as submerged arc welding.

→ It is normally operated in automatic and mechanized mode. Current ranging from 200 to 1500 A.



Advantages of SAW

i) High deposition rate
ii) Deep weld penetration
iii) Weld Bead are smooth

Limitation of SAW (Process)

i) Since weld can't be seen, it is more difficult to guide the electrode.
ii) It is mainly done in flat position.
iii) Not suitable for metal less than 5mm thickness.

(VVI) Defects of welding

1) Porosity

It is caused by

i) Gases released during melting of weld area gets trapped during solidification.

ii) By chemical reaction during welding.

iii) Due to contaminants.

It can be reduced by

i) Proper selection of electrode and filler metal.

ii) By pre-heating the weld area.

iii) Proper cleaning

iv) Reducing welding speed

2) Slag Inclusion

Slag are compound such as oxides, electrode coating material, dirt and dust that are trapped in weld zone.

→ It can be prevented by:

i) proper cleaning of weld surface

ii) providing enough shielding gas.

3) Incomplete fusion or penetration

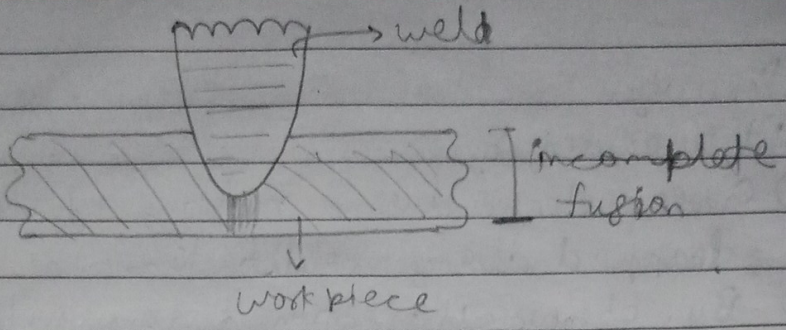
Incomplete penetration occur when depth of welded joint is insufficient.

→ Penetration can be improved by :-

i) Increasing heat input

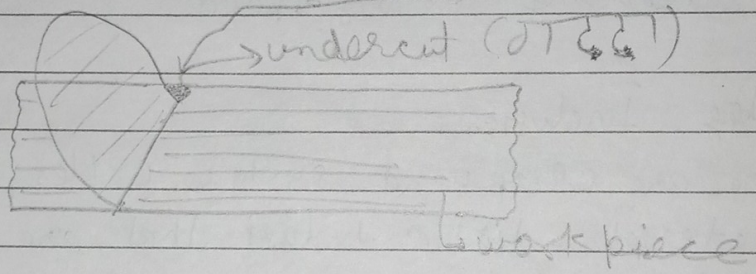
ii) Reducing travel speed

iii) Ensuring the surface to be joint properly.



4) Under cutting

Under cutting result from melting away waste metal and generation of grooves in shape of sharp ~~recess or~~ recess or notch.



5) Overlap

It is surface discontinuity caused due to poor welding ~~pro~~ process or by improper selection of material.

6) Cracks

Cracks occur due to :—

i) Thermal stresses in weld zone

ii) Inability to contract during cooling.

7) Surface Damage

It is due to spatter, surface discontinuity, etc.

small droplets of molten metal and get solidify at metal surface

☐ Miscellaneous Welding (Continued ---)

DATE: __/__/____
PAGE: ____

☐ Electroslag Welding

Principle: Arc + Resistance ; DCRP is used.

Initially the ~~or~~ arc is being created b/w ~~starting~~ block and the copper coated ~~electrode~~ wire

- Initially the arc is being created b/w starting block and the copper coated electrode wire followed by addition of flux.

- Welding progresses in the vertical direction and due to that temperature of the molten pool keeps on increasing.

- A pair of water cooled cu shoes is being provided on the sides to avoid any spillage of liquid metal to the sides.

- Once the temperature of the molten pool reaches a particular value; arc is switched off and the molten pool is ~~it~~ so hot that it starts consuming the wire without any arc.

- Temperature is controlled in the fashion to minimize the heat affected zone.

- If the heat ~~affect~~ affected zone increases; it may cause distortion of the plate

- The point when molten metal is not able to consume any more wire, arc is restarted again.

DATE: __/__/____
PAGE: _____

* Application

1. The process is used to join two thick plates along the edges.
2. Building the ship
3. Welding is done with joint in vertical ~~posit~~ position; it can be used for welding plates of thickness 20mm to 40mm.
4. It is also used ~~in~~ extensively in the heavy ferrous industry.
5. Extensive use in the construction ~~of~~ pressure ~~vessels~~, press frames, water turbine and heavy plate fabrication industries.

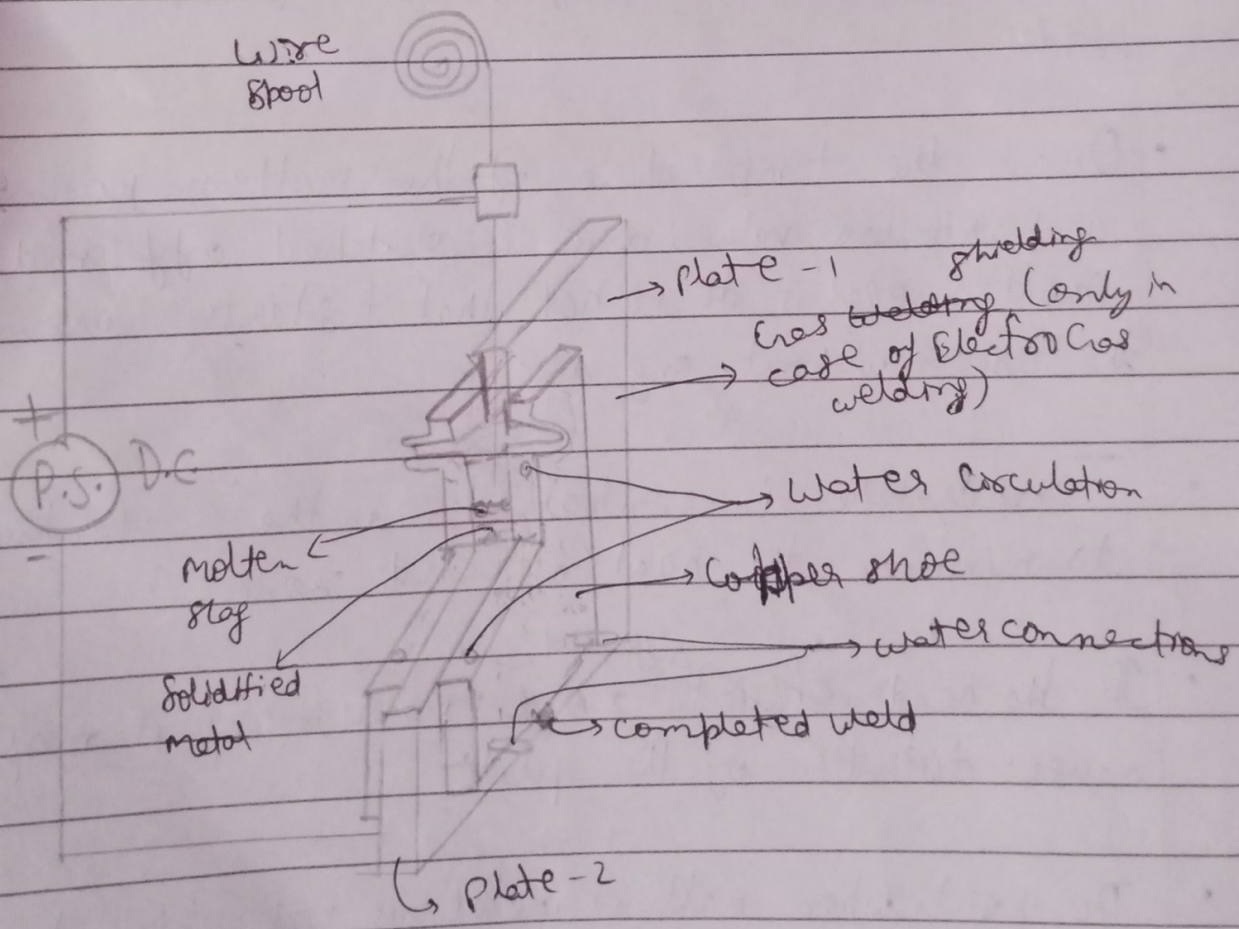


Fig. Electro Slag Welding

(e) Explain different mode of Metal transfer in MIG Process.

Ans 1) Short circuit Transfer

They are also called Dip transfer (The electrode touched the work piece (or when wire dipping into the weld pool then the) then the Metal transfer takes place that's why it is called Short circuit transfer

Characteristics

i) Suitable for all position welding
ii) Lack of fusion (If Machine setup not proper)
iii) Relatively low heat input process
iv) Unstable arc (If Machine setup not proper)
v) Suitable for ferrous Metal (Steel)
vi) Shielding gas CO_2 (100%) & Mixture of CO_2 & Argon

2) Spray transfer

Metal transfer in form of small droplet & fine spray (droplet size is generally much smaller than the wire dia)

The process of Material left from the electrode and attached to the work piece is due to the High current a Strong electromagnetic force generated blw & electrode and work piece and & Material detached to the electrode and then attached to the work piece It is called pinch effect

Characteristics

i) Good deposition rate
ii) Good penetration & fusion compared to dip transfer
iii) Less spatters

3) Pulsed transfer
It is Modified Version of spray transfer process
In this power source switches between high peak current and low background current
Low Background current → • Maintain the arc
• Keep the wire tip
• Maintain average

High current pulse → • Droplet detachment
• High pulse current gene
high electromagnet force
causing pinch effect

Characteristics
i) Very low spatters
ii) Suitable for all positions
iii) Flexibility

4) Globular Transfer
Here the transfer of Material in the form of droplet blw the electrode & work Piece
Size of droplet are large
Use gravity to transfer the Metal
Characteristics
i) Irregular metal transfer
ii) Medium Heat input
iii) Medium Deposition Rate
iv) Limited to flat & Horizontal Positions

	Spray transfer	Globular Transfer	Short Circuit transfer	Pulse Spray Transfer
	Droplet size much Smaller than wire diameter	Droplet size around 3 times the wire diameter	Small wire size Metal transfer by direct contact	Droplet size usually much Smaller than wire diameter
Current	320 A & up	150 A to 400 A	180 A & less	220 A & up
	Electromagnetic force	Use gravity to transfer Metal	Lower voltage Compared to Spray transfer	Electromagnetic force Most dominant force