Welding

Release 1.0.1

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CHAPTERS:

"Life is made of ever so many partings welded together."
- Charles Dickens

CHAPTER

ONE

INTRODUCTION

I don't want to bore you with the story how we came to write this book. It's just a intention to provide a good resources for CTEVT and other technical students. I hope with our efforts and your help this book will grow and become a dear for all learners.

We're extremely interested in your feedback. The online version of this book will let you comment on any part of the book, and discuss it with other readers. We'll do our best to read all the comments posted there, and to respond to as many as possible. If you prefer email, please drop us a line at binary.science98@gmail.com. Either way, we'd love to hear from you! We're glad you're here, and we hope you find Carpentry as exciting, fun, and useful as we do.

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CHAPTER

TWO

CHAPTER 1: SAFETY PRECAUTION OF WELDING

2.1 Definition of safety

Safety measures should not be ignored or overlooked because it results in dangers like electric shock, arc radiation, fire and explosion and overexposure to fumes and gases. A good welder should familiarize himself with safety guidelines and practices. Precaution to be taken care while working in workshop:

1. Safety of Workshop
2. Safety of Equipment
3. Personal Safety

2.2 Safety of workshop

1) Workshop should be built in place where air can pass easily

2) Workshop are should be in bright

3) Workshop should be easily cleanable.

4) Machine inside workshop should be arranged with proper plan.

5) A workshop should have Cupboard, Box, Tools Box etc. to hold Tools and Equipment in proper order.

6) Flammable materials must be kept in separate place.

7) For welding works, workshop should have Portable Booth which prevents the rest people in workshop from its lightening effect.

8) Workshop should have Fire extinguisher and Water in reachable place.

9) Workshop should have First Aid box for unwanted mishaps

10) Always keep Record card for keeping record of machine parts repair or change to avoid unnecessary accidents

2.3 Safety of equipment's

1) Always read the user manual provided by manufacturer before operating machines.

2) Ensure that machine that runs on electricity must have proper earthing.

3) Never use fuse bigger than needed or required.

4) Never give machine overload and avoid working for long hours continuously

5) Always use oil in machine if machine have moveable parts.

6) If machine changes its usual working voice, then seek expert to fix.

7) Always use trolley while moving oxygen or fuel gas from one location to another.

8) Tie the cylinder to trolley or else with chain to prevent cylinder from falling.

9) Never use electrode holder with bad insulin.

2.4 Personal safety

Some of the necessary personal safety are as follows:

1) Keep the area around you clean and tidy.

2) Build the habit of following instructions and doing work with care

3) Know your tools and keep them in respective locations

4) Always wear protective wearable like apron, goggles, masks, shoes etc. while welding.

5) Always have focus on work at hand and avoid unnecessary talks while working.

6) Never look weld with naked eye during welding

7) Always empty the flammable materials before welding Oil tanks or cylinder or Container of Pipe

2.5 Safety precaution during arc welding

Some of necessary safety precaution to be followed during arc welding are as follows:

1) Safety precaution during gas welding Always keep your face out of weld plume and do not breathe gas created by flame.

2) Indoor welding requires adequate ventilation or fume extractor.

3) Safety glasses and ear plugs must be worn.

4) Mask and protective clothes, boots, gloves and helmet must be worn.

5) Respirators must be used to avoid dangers from fumes and oxides.

6) Do not wear jewelry like ring and synthetic clothes.

7) Remove all ignition sources like matches and lighters from work area and post “no smoking” signs in the area.

8) Do not weld on surfaces that are still wet with a degreasing solvent.

9) Storage of compressed gas cylinders need to be done according to fire code guidelines.

10) Ensure the area is well ventilated and protect cylinders from contact with ground, ice, snow, water, salt, high temperatures and corrosion.

11) Do not drag, slide or drop cylinder and lift cylinder by the valve cap.

2.6 Accidents prone to Industries and inside Factories

There are various reasons for industrial accidents and they are unsafe working conditions, unsafe acts and other causes like slippery floors and noisy environments. According to research from Tribhuvan University led by Dr. Rohit Kumar Pokharel in Nepalese industries, sixty-one percent of workers had experience at least one accident while working and thirty-seven percent work without meal while sixteen percent work even during illness.

Different accidents that happens frequently inside factories and industries are as follows:

1) Falling of working weakness or slippery floor.

2) Eye damage due to dust and blare.

3) Skin mishaps like burn, cut, wounds, allergies etc.

4) Stuck by falling object. For example, 7 workers died and 35 were injured when the Itahari brick kiln collapse.

5) Dislocate of body parts by falling, piercing and cutting. Machinery not maintained in proper condition also causes mishaps.

6) Hearing defects due to noise in factories.

7) Blast when explosive elements activates.

8) Burning of factories premises when fire catches.

9) Gas leak cause the problem in respiratory system and prone to firing.

10) Nuclear leak can cause nuclear disaster around the industry surrounding. For example, a nuclear plant in Japan after earthquake leaks 520 tons of radioactive water into the sea.

2.7 What's Next

chapter2

CHAPTER

THREE

CHAPTER 2: ARC WELDING

3.1 Introduction in brief/ History

As we are familiar with the common welding activity which involves joining of two metals using filler or heat or pressure in order to create a whole object.

Welding is hugely applied industrial practice for joining metals. From joining the frame of your study table to build huge transportation things, welding is inevitable in every construction and manufacture.

3.2 Definition of welding

The American Welding Society (AWS) has given the most satisfying definition for the term welding which is:

"Welding is a materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone and with or without the use of filler material".

3.3 Applications of welding

1) Repairs
2) **Aeronautical Industry:** To build the body of airplanes and other components
3) **Automobile Industry:** To build the vehicles like Bus, car, bicycle, bike etc.
4) **Railways:** To construct body of rail, tracks and stations
5) **Machine Industry or Workshops:** When machines are prepared welding is necessary to make the component.
6) **Building Industries:** To build big industries also welding is necessary

7) Construction of Bridge and Dams
8) Utensils making Industries
9) Ornament making Industries
10) Ship making Industries
11) Ordnance Factories etc.

3.4 Advantages of welding

1) Welding is more economical and much faster process than other process like riveting, bolting, casting etc.

2) If properly done, it results in permanent joints having strength equal or sometimes more than base metal.

3) General Welding equipment is not very costly

4) Welding permits considerable freedom in design

5) Welding can also be mechanized

6) Leakage proof (both liquid and gas) joints can be made.

7) Different metals can be joined as a whole in simple ways

8) If welded place does not look good, then welded metal can be removed using machine and taken back to previous form

3.5 Disadvantage of welding

1) It results in residual stresses and distortion of the work pieces.

2) Welded joint needs stress relieving and heat treatment

3) Welding emits harmful radiations, fumes and spatter harmful for your eyes and skin.

4) Smoke coming out while welding is harmful for our respiration.

5) Skilled welder is required for production of good welding.

6) Edges preparation of the welding jobs are required before welding

7) Jigs and fixtures are needed to hold and position the parts to be welded

8) Heat treatment is necessary after welding of metals.

3.6 Basic requirements for a good weld

3.6.1 1) Heat Energy

In order to join two metals together they must be melt first near to their melting point. So, to melt those metals we need a heat source. Commonly used heat sources are – Gas Flame, Electric Arc, Blacksmith, Radiant energy, Laser beam and so on.

3.6.2 2) Protection

We have to think in long term protection of our welded material. When we left the welded surface or joint exposed to environme

a) Flux coating in metal surface

b) Applying inert gases

c) Applying non-reactive substances

3.6.3 3) Cleaning

Before welding any metal surface, we must ensure that metal does not have any oxidization and dirt in its surface. If we weld metal with oxidized or dirty surface, then weak joint is formed. Dirt can be like oil, dust, lubricants, gas or rust. So, we use techniques like Wire brushing, Filing, using Machine and so on to clean the metal surface before they are subjected to welding.

3.6.4 4) Mixing

A good welding should possess the same qualities as that of base metal. The more quality of joint differs from metal quality the

a) By using `De-oxidizer`

b) By performing `pre heat and post heat`.

c) By using `good filling material`.

d) By controlling the `mixture used in base metal`.

3.7 Ways of joining metals

To assemble the different parts of machines different types of joining methods are needed and some are discussed below:

1) Riveting A rivet which is a metal fastener that has a cylindrical post with a head is placed in a drilled or punched hole to join two metals. Applications: Channel gates, aircrafts and ships, bridges etc.

2) By using nut and bolt or screw joints Metal are often joined using nuts and bolt and it is popular form of joining metals. Applications: turbines, hand pumps, vehicles etc.

3) Joints by folding Applications: bridges and vehicle wheels.

4) Soldering In soldering, metals are joined by heating filler metal below 427 degree Celsius. Applications: Consumer electronics, automotive and photovoltaic industries.

5) Brazing Metals are joined by heating filler metal above 427 degree Celsius. Applications: Electronics, automotive and heavy transport industries.

6) Glue Some special glues used to join metals are epoxy, silicone, polyurethane and tapes. It joins metal but is not as durable and strong as welding. Surface preparation is necessary before applying glue for joining metals. Applications: Pipe thread sealant, thread locker, toys etc.

7) By welding Welding is the common way of joining metals. It provides simple, durable and strong weld. Applications: Vehicles, home decoration and doors, ships and aircrafts etc.

3.8 What's Next

chapter3

CHAPTER

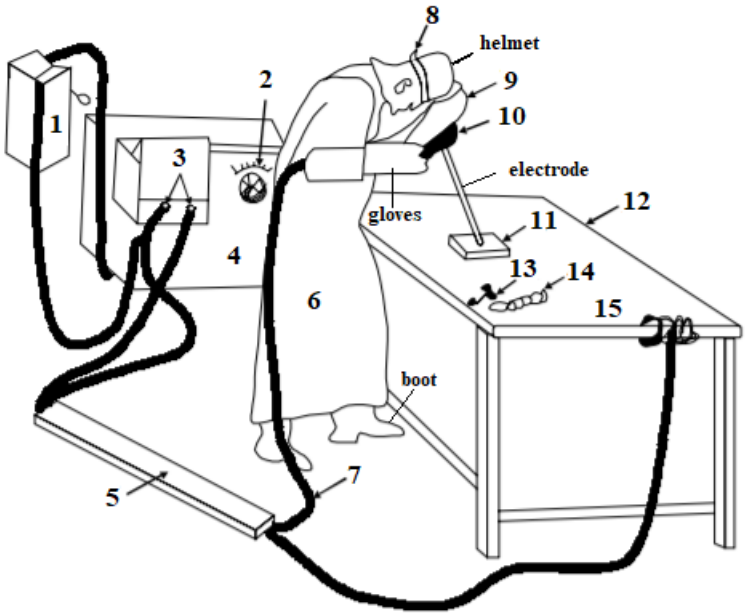
FOUR

CHAPTER 3: ARC WELDING MACHINE AND EQUIPMENTS

4.1 Introduction

In arc welding process, an electric arc between an electrode and a workpiece or between two electrodes is used to weld base metals. Majority of arc welding processes uses shielding gas while rest uses coating or fluxes to prevent weld joint from surrounding environment.

4.2 Figure of welding machine with different parts



(1) Switch box	(2) Current reading scale	(3) Secondary terminals
(4) Welding machine	(5) Channel for cable protection	(6) Protective apron
(7) Welding cable	(8) Protective glasses strap	(9) Hand shield
(10) Electrode holder	(11) Workpiece	(12) Welding table
(13) Chipping hammer	(14) Wire brush	(15) Earth clamp

Fig. Arc welding setup

4.2.1 1) Power source:

AC and DC both can be used for electric arc welding. Power source is required to maintain the arc between electrode and the base metal. The factors that influence on the selection of a power source are efficiency, duty cycle, floor space, initial and running costs, versatility of equipment, type of electrode to be used, availability of power source (AC or DC) and required output. Both AC and DC are used in electric arc welding according to demand of welding process being used.

I) DC Generator:

- It is run either by an electric motor or diesel engine.
- It supplied voltage in range of 15 to 50 volts and output current in range 200 to 600 ampere.
- Polarities will be fixed

II) AC Transformer:

It is static piece of equipment used either for raising or lowering the voltage of an AC supply with a corresponding decrease in the current.

- It is low cost and ease of operation
- Noiseless in nature
- It has variable polarity

The following factor influences the selection of a power source:

- Available power source (AC or DC)
- Types of electrodes and base metals to be used
- Required output
- Duty cycle
- Efficiency
- Initial costs and running costs
- Available floor space
- Versatility of equipment

4.2.2 2) Welding cables:

It is required for conduction of current from the power source through the electrode holder, the arc, the workpiece and finally back to the welding power source. These cables are insulated copper or aluminum cables.

4.2.3 3) Welding electrodes:

An electrode is a piece of wire or a rode of a metal or alloy, with or without coatings. An arc is setup between workpiece and electrode. Welding electrodes can be classified as:

A) **Consumable Electrodes**

a) `Bare Electrodes`

b) `Coated Electrodes`

B) **Non-consumable Electrodes**

a) `Carbon or Graphite Electrodes`

b) `Tungsten Electrodes`

Consumable electrode is made of different metals and their alloys. The end of this electrode starts melting when arc is struck between the electrode and workpiece resulting electrode itself as a filler metal.

Non-consumable electrodes do not melt during welding. These electrodes are made up of high melting point materials like carbon, pure tungsten or alloy tungsten.

4.2.4 4) Googles:

Protective googles are used to protect the eyes of the welder from the light sparks produced during welding.

4.2.5 5) Wire brush:

Before the welding is performed, the surface of workpiece is cleaned using wire brush.

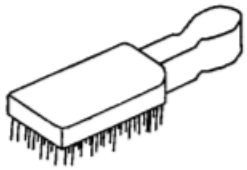


Fig. Brush

4.2.6 6) Protective clothing

Welder or an operator should wear protective clothes with long sleeves like apron to secure body from direct exposure of heat.

4.2.7 7) Earth clamp:

The earth clamp is clamped to the welding table or the job itself so that electrical circuit is complete. The reason to do so is to minimize the chances of shock due to insulation or other failure in machine.

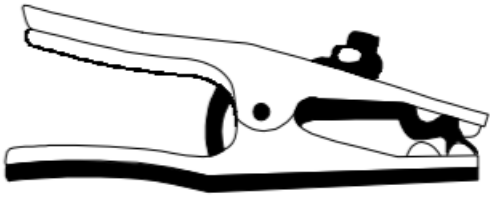


Fig. Earth clamp

4.2.8 8) File:

It is a hand tool used to remove fine amounts of materials from workpiece.

4.2.9 9) Chipping hammer:

A chipping hammer is used to remove slags from workpiece after welding is done.

4.2.10 10) Safety Goggle:

It is for the protection of eyes and the supervision of weld bead.

4.2.11 11) Electrode holder:

It is used for holding the electrode manually and to conduct the current to it. It varies in size from 150 to 500 Amps.

4.2.12 12) Hand screen:

A face shield is also used to protect eyes from the light sparks produced during welding.

4.2.13 13) Hand gloves:

It is for the protection of hand while operating welding manually.

4.2.14 14) Welding gauges:

It allows us to determine the size of joints, joint width and height, depth and width of preparation, angle of bevel, included angle, root gap, dept of root face, convexity, smoothness of transition weld to the base metal and leg length.

4.2.15 15) Current regulating hand wheel:

Current regulation is achieved by movement of a lever or wheel, which varies the strength of the magnetic field between primary and secondary windings. This is the better way of achieving smooth control of current in compare to other method which uses reactor or a choke.

4.2.16 16) Electric oven:

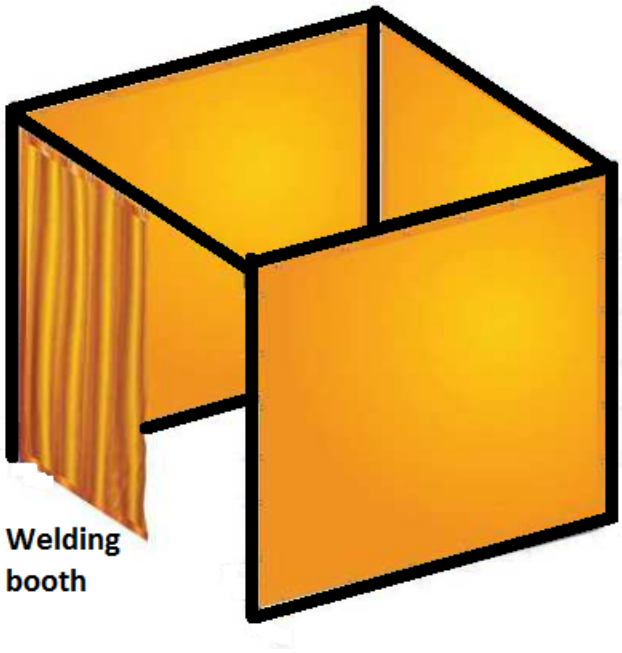
Electric oven is used for storing electrodes according to the electrode supplier recommendation because temperature requirements varies for different electrodes types. For good and sound weld electrodes should be heated properly.

4.2.17 17) Center punch:

It is the tool to mark the pattern of welding. The depth of the punch should not exceed 0.3 mm because the arc cannot ignite on a center punch struck too deeply.

4.2.18 18) Welding booth:

It is the room required for welding which helps to prevent the coworkers from sparks, gases and noise. It should have ventilation with good flow of air. Walls should be painted with black, brown or yellow to prevent welding light from reflecting.



4.2.19 19) Welding table:

Table provides great comfort while welding in small jobs. Its legs are made from angle iron or pipe and a fixed thick plate is placed over the legs. The place on table can be constructed in such way it can be moved up and down according to our requirement. On one of is leg, a box is made to keep electrodes and a plate is made on another leg to hold earthing clamp.

4.2.20 20) Tong:

It is a hand tool which helps to take workpiece from one place to another place. It is made from low carbon steel.

4.3 Classification of welding machine

On the basis of AC and DC current, machine set can be categorized in:

1. **Motor Generator Set**
2. **Engine Driven Generator Set**
3. **AC or Transformer Set**
4. **Rectifier Set**

4.3.1 Motor Generator Set

This set is used to convert voltage, phase and frequency of power. It is a set or collection of motor and a generator mechanically coupled through the common shaft. It mainly converts electric power to any other type of power. Its arc voltage ranges from 15 to 45 volts but open circuit voltage ranges from 60 to 1000. It has the efficiency of 60%. We can even change the polarity according to our need which is helpful while welding thin and thick metals. Similarly, Motor generator set has capacity of 20 to 1000 amperes. The diagram of a motor generator set is shown below,

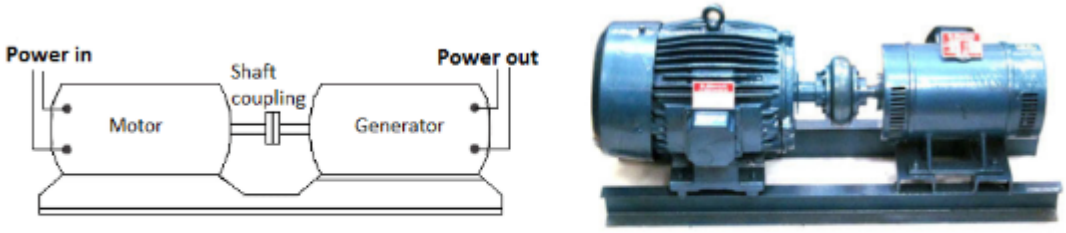


Fig. Motor generator set

Motor Generator are made targeting single or multiple operator. We are provided with following tools to keep machine under our control.

i. **Startor**
ii. **Polarity Switch**
iii. **Volt/Ampere Switch**
iv. **Current Control**

Startor

The main work of startor is to start and stop the Machine. After connecting to the power supply, we should push green button to start the machine and push red button to stop the machine.

Polarity Switch

We need to change the polarity to weld the metals considering the qualities of metal and electrode. So, to change that polarity we use this polarity switch.

Direct Current (DC) always flows from positive pole to negative pole whereas Alternating Current (AC) flow in both direction (positive to negative pole and vice versa for 50 to 60 times a second). Therefore, we can only perform polarity change in DC but not in AC.

Volt/Ampere Switch

The main function of this switch is to show the supplied electric current in volt and ampere. Some machine has two different meters to show voltage and current reading while other have single meter to show both readings. Some machines even use this switch to show the polarity.

Current Control

Its main function is to supply necessary current according to electrode used and thickness of workpiece or base metal.

4.3.2 Engine Driven Generator Set

Engine Driven Generator Set can perform welding with the help of diesel or petrol. Since it is not depended in electric supply, we can take it to anywhere necessary. However, it is noisy and expensive to buy and maintain. It can be expensive for working and maintenance.

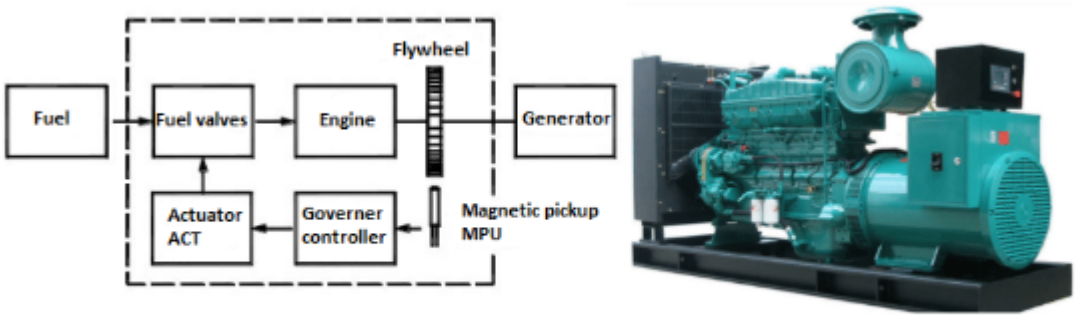


Fig. Engine driven generator set

Necessity of D.C. Generator

- To convert AC supply into DC
- To perform welding in places with no electric power supply
- To select the polarity and to weld non-ferrous metals easily

Parts of D.C. Generator

- Main Poles
- Body or Yoke
- Armature
- Commutator
- Carbon Brushes
- Fan
- Prime Mover

4.3.3 AC or Transformer Set

This machine is special type of Step-Down Transformer which increases or decreases the line voltage or ampere to required voltage or ampere as needed in arc welding.

1. It is cheaper in cost

2. This machine is used widely because of its light weight, smaller size, less noisy, with no movable parts, less power consumption and higher functionalities.

3. It has low arc blow.

4. It can perform task in both Single Phase and Three Phase whereas Single phase is used for light task while latter is used for heavy tasks.

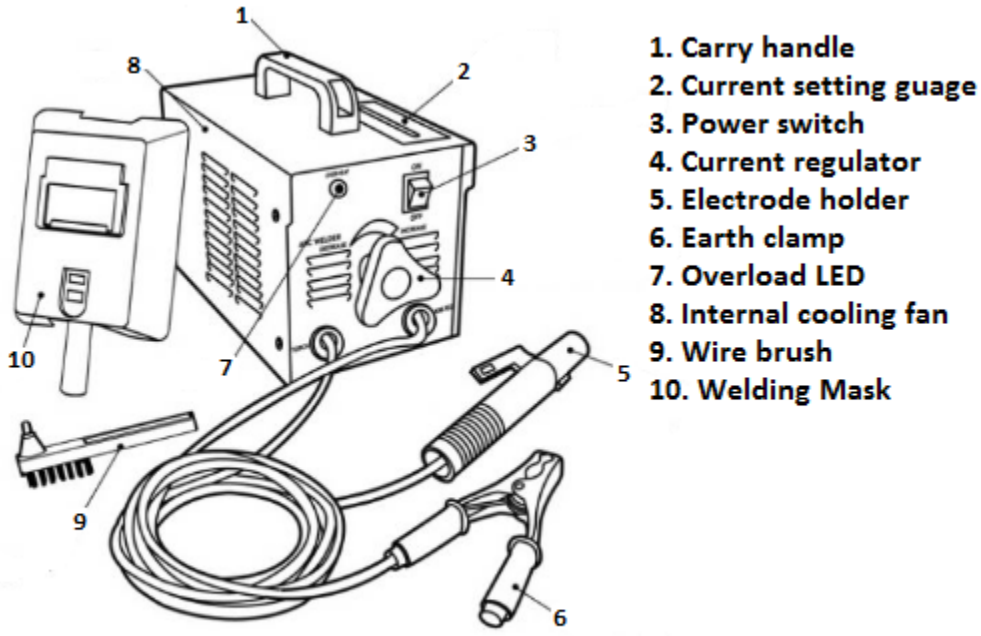


Fig. AC Transformer Set

While performing welding it is important to control and set current. There are different techniques to achieve control the current and they are as follows:

i. Movable Coil Method

ii. Variable Resistance Method

iii. Variable Choke Method

AC Transformer:

AC Transformer transforms the supplied main AC supply into required AC supply for welding. It is of two types:

i. **Air Cooled**
ii. **Oil Cooled**

Air Cooled (no oil requirement):

1) It mainly converts from low voltage to high ampere and high voltage to low ampere

2) Lots of thin cores made up of thin Silicon Silicate are kept inside the Transformer. Those cores are further insulated to prevent from electric shorts. Those cores are wrapped from left and right side by coil made up of Aluminum or Brass. The coil from where electricity is passed is considered as Primary Winding (PW) and other is Secondary Winding (SW). Electrode (-) is kept in SW while Earthing clamp (+) is kept in PW. No wire should touch the area of both winding.

3) From PW current supply according to capacity of welding machine is passed. Then, current flows towards coil and eventually magnetic force is generated in iron core. After that, magnetic force changes direction and passes to SW. As a result, electro motive force (emf) is induced which is used for our welding purposes. (+) and (-) both gets heat of 50%.

4) To cool the Transformer from getting heated up, a fan run by electric supply is there.

5) It has meter to show current and handle to increase/decrease the current supply.

Oil Cooled (oil required):

1) Here all internal components are winded and placed inside iron box. Transformer inside of that box is immersed in oil because of that there is no necessity of fan to cool down the machine.

2) Oil maintains current flow and also temperature. There is a handle to increase or decrease the current according to requirement.

Care and Maintenance of AC Transformer:

1) Transformer body should have proper earthing

2) Change the oil after certain period of time

3) Always follow the instruction provided by manufacturer

4) Never run the machine for long period in full capacity

5) Switch off the machine before repairing the machine

6) Machine should be installed in safe place from sun and rain

7) Cover the machine with clothes during idle time to safe from dust

4.3.4 Rectifier Set

This type of set provides both AC and DC current. Normally, switch or lever are provided to start the machine. It is a type of AC Transformer but has extra Rectifier stack coated with Selenium which converts AC to DC. Rectifier set has better efficiency than motor generator set and can weld all types of metal. It can also be used as Tig machine and is noiseless as well as controllable.

Fig. Semi- Automatic Rectifier set

Care and Maintenance of Rectifier:

1) All connections must be well tightening.

2) Apply oil or lubricant every three month in Shaft where fan is attached

3) Do not switch on/off the Switch while machine is running

4) Run machine only when fan is present

4.4 Power source

Necessity of Power Source:

1) To supply AC and DC current required for arc welding.

2) To generate High voltage (OCV) and Low voltage (AV) to perform Arc Striking and Maintaining Arc respectively while welding.

3) To convert into required current and volt while performing Arc Welding

4) To maintain proper relationship between Arc Voltage and current.

5) To work with all types of electrodes for welding

Selection of Power Source:

To select the proper Power Source, we need to follow the following points carefully:

1) Know beforehand whether you need AC or DC or both current supply for your work

2) Be careful while choosing the ampere capacity of the machine.

3) Look for machine that can maintain the constant Voltage and Current

4) If you need to perform welding away from place where machine is kept, then you need to select machine with remote controllable functionality

5) Machine should be able to use both small and big electrodes

6) Machine must be able to supply same rate of current without fluctuation despite supply voltage varies

7) If there is no electricity available, then Engine Driven Generator must be selected.

8) Maintenance cost should be cheaper of that machine

9) Be careful on initial investment on machine

4.5 Comparison of arc welding machine set

Table 1: comparison

	Motor Generator set	Rectifier set	Transformer set
Initial cost	**It is expensive.**	It is cheaper than motor generator and costlier than transformer.	**It is cheaper.**
Weight	**It is heavier.**	It is lighter than motor generator and costlier than transformer.	**It is lighter.**
Floor space	**It requires large space.**	It does not require large space.	**It too does not require large space.**
Moving parts	**It has movable parts.**	It has no movable parts.	**It too does not have movable parts.**
Maintenance	**It is expensive for maintenance.**	It is easier for maintenance.	**It is easier for maintenance.**
Power Input	**It needs more electric power.**	It needs less electric power.	**It needs less electric power.**
Noise	**It is noisy.**	It is less noisy.	**It is less noisy.**
Arc blow	**It has arc blow problem.**	Arc blow problems appears in DC but not in AC current.	**It does not have arc blow problem.**
Life	**It works for long span of time.**	It has life span of about 7 years.	**It has the longest lifespan among all.**
Stability of Arc	**It does not have arc stability.**	It has arc stability.	**It is difficult to maintain arc stability.**
Metal	**Both ferrous and non-ferrous metals can be welded.**	Both ferrous and non-ferrous metals can be welded.	**Only ferrous metals can be welded.**
Efficiency	**It has efficiency of 60%.**	It has efficiency of 84%.	**It has efficiency of 67%.**

4.6 Duty cycle

Duty cycle is the ratio of arcing time to the weld cycle time multiplied by 100. Welding cycle time is either 5 minutes as per European standard or 10 minutes as per American standard. If arcing time is 5 minutes continuously then as per European and American standards duty cycle is 100% and 50 % respectively. At 100% duty cycle minimum current is drawn.

The welding current which can be drawn at a duty cycle can be calculated from given equation:

```
DR x IR2 = I2 x D100



Where, DR   = Required duty cycle
       IR     = Current at required duty cycle
       I    = Current at 100% duty cycle
       D100 = 100% duty cycle
```

4.7 Polarity

Polarity helps to understand how much electricity is passed in which pole and in which direction on arc welding. It results from the fact that electrical circuit has both negative and positive pole. DC flows in one direction resulting in constant or fixed polarity. Similarly, AC flows in both direction (half time one direction and other half in other direction) changing its polarity 120 times per second with 60-hertz current.

Polarity can be changed in two ways:

1. Straight Polarity
2. Reverse Polarity

4.7.1 Importance of Polarity:

The electric circuit is created when we turn on the welder has a negative and a positive pole and this property is called polarity. Polarity is important in welding because selection of right polarity affects the strength and quality of the weld. Selection of wrong polarity will lead to lots of spatter, bad penetration and lack of control of our welding

4.7.2 Choice of Polarity:

We choose polarity based on the quality and size of workpiece and type of electrolyte. We can choose polarity as instructed by the manufacturer.

4.7.3 Identification of Wrong Polarity:

1) If workpiece and electrode does not melt at same time.

2) If electrode gets heated up more than normal case.

3) If penetration is low

4) If we cannot move the electrode around easily

5) If we hear the unusual or abnormal sound

6) Difficulty in keeping arc stable

7) If welded bead has blunder and so on.

4.8 Straight polarity

If electrode holder is connected to negative pole and Earthing Clamp is connected to positive pole, then such polarity is called Straight Polarity. Here, current flows from electrode to workpiece. Similarly, 2/3 of the total arc heat is generated in workpiece while rest of the heat energy is focused in electrode.

Advantages Straight polarity:

1) We can use thin or medium coated electrode

2) While welding thick metal plates huge amount of penetration and fusion can be achieved which results in proper fusion of base metal.

3) Suitable for metals with high melting temperatures such as stainless steel, titanium

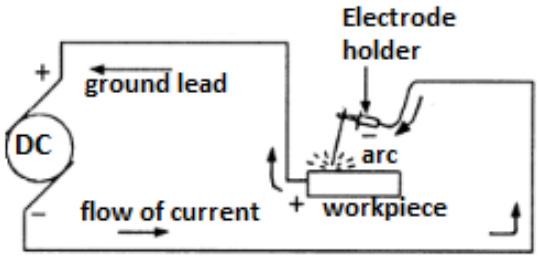


Fig. Straight polarity

4.9 Reverse polarity

If electrode holder is connected to positive pole and earthing clamp is connected to negative pole, then such polarity is called Reverse Polarity. Here, current flows from workpiece to electrode. Also, (2/3) rd of the total arc hear is generated in electrode holder and rest of the heat energy is generated in workpiece.

Advantages of Reverse Polarity:

1) Arc cleaning action is good.

2) Suitable for welding thin plates

3) Suitable for welding metals with low melting temperature like copper, aluminum.

4) Suitable for positional welding

5) Can use electrode with thick coating

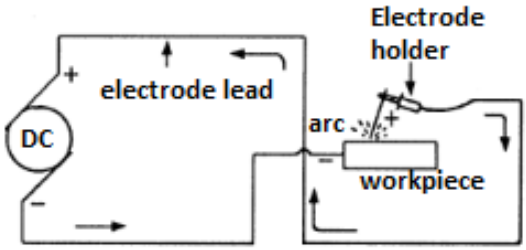


Fig. Reverse polarity

4.10 Advantages of AC arc welding machine over DC

1) AC can be supply over longer distances using step up transformers but DC cannot be transmitted by this method.

2) AC is cheaper to generate than DC.

3) AC generators (85%) have higher efficiency than DC (60%).

4) Maintenance cost will be less due to non-movable parts.

5) No chances for Arc blow in AC whereas Arc blow can occur in DC.

4.11 Advantages DC arc welding machine over AC

1) Electrodes with thin coating can be used

2) We can operate in any place with no electricity supply since it runs with petrol or diesel.

3) We can increase and decrease the flow of current while wielding since it is remote operable.

4) We can operate in safe manner due to its less open circuit voltage (around 30 volt)

5) We can perform good weld for different metals since both positive and negative pole have different temperature.

4.12 Care and maintenance of arc welding machine

If we want to keep our generator's work performance in same pace and to increase its lifespan as well, we need to perform following statements carefully:

1) Regular checkup of water level in Radiator and oil level in engine.

2) Change the Engine Oil once it works for 250 hours.

3) Apply lubricants once a week in barring near to fan.

4) Check for oil leak in tank and pipe.

5) If motor is generator, then electric motor should be given proper earthing.

6) Do not run machine in Weak Phase.

7) Check the connection of electric supply.

8) Do not use Polarity Switch while machine is running.

9) Check out for Carbon Brushes condition regularly.

10) Clean the Generator every 3 months using air compressor.

4.13 What's Next

chapter4

CHAPTER

FIVE

CHAPTER 4: CLASSIFICATION OF WELDING METHODS

5.1 Introduction

The process of welding has been evolved in recent years with the advent of technology. Welding can be classified into several categories:

1) On the basis of fusion and pressure welding

2) On the basis of Metal to be Welded

3) On the basis of energy source for welding

4) Arc and non-arc welding

5) On the basis of material state

6) On the basis of with or without filler

7) On the basis of welding material used etc.

However, fusion welding and pressure welding is mostly used classification as it covers all processes in both the categories irrespective of heat source and welding with or without filler material. In pressure welding, molten metal solidifies under pressure or semi-solid metal cools under pressure while in fusion welding, molten metal solidifies freely and external application of pressure is not required for this process except resistance welding group where substantial contact pressure needs to be maintained during welding for the sound weld.

All the welding processes can be categorized under two broad heading:

1. Plastic or Pressure Welding
2. Fusion or Non-Pressure Welding

5.1.1 Plastic or Pressure Welding

In plastic welding, the metal pieces to be joined are heated to a plastic state and forced together by external pressure. For example, making of gold ornaments by goldsmith.

5.1.2 Fusion or Non-Pressure Welding

In fusion welding, the metal pieces to be joined are heated to a molten state and are allowed to solidify together into a single inseparable joint. For example, joining of iron rods to create an Iron railing

Classification on the basis of fusion and pressure welding is further illustrated in given tree diagram.

5.1.3 Classification on the basis of Metal to be Welded

I. **Autogeneous Welding**

II. **Homogeneous Welding**

III. **Heterogeneous Welding**

Autogenous Welding:

It is the one way of performing fusion welding without applying any filler material externally (base material can be melted to use as filler material.) For instance, Tungsten Inter Gas (TIG) and oxy-fuel welding processes can be performed in autogenous welding.

Advantages:

- Fusion welding on thin sheets is possible
- Cost effective since no extra cost for filler material.
- No post grinding is necessary
- Weld appearance is good.

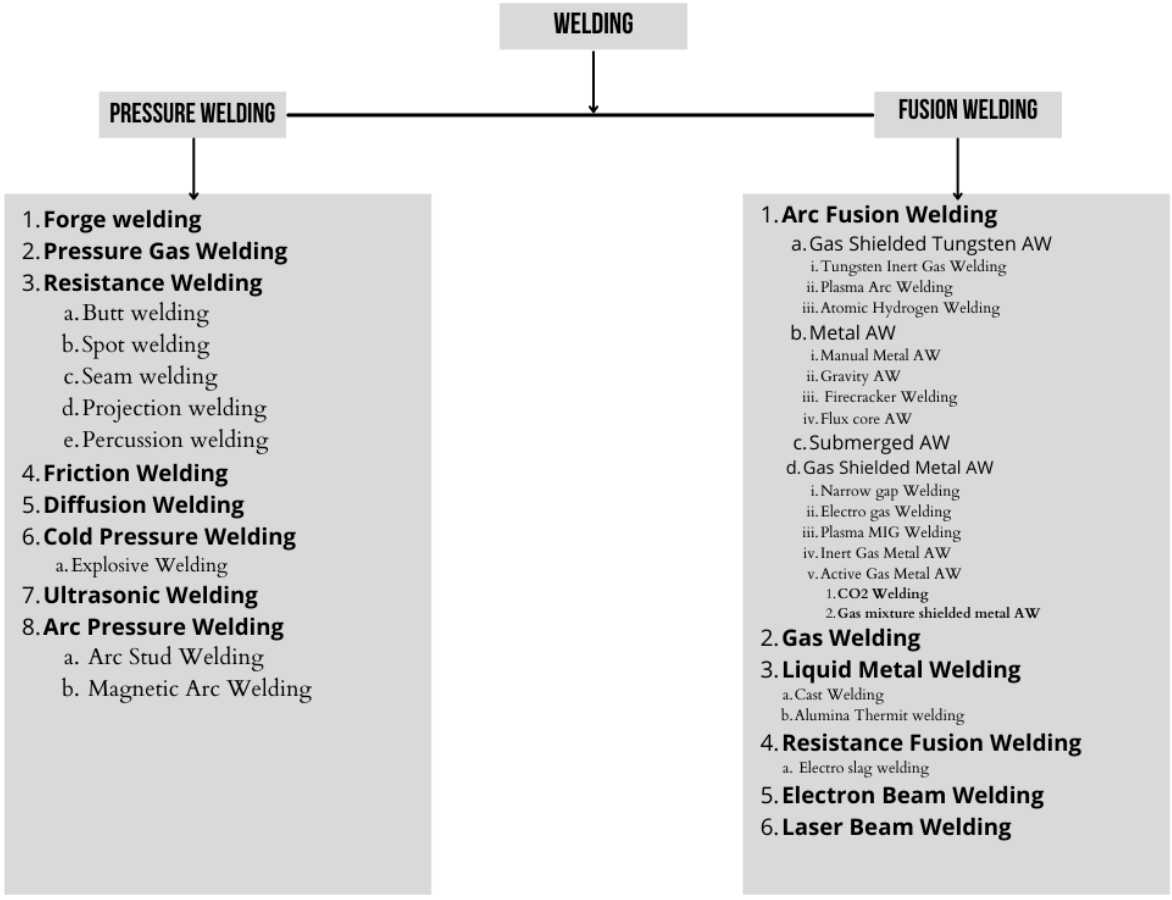


Fig. 1: Figure. Classification on the basis of fusion and pressure welding

Disadvantages:

- Only butt join with no root gap between parent parts is possible.
- Thickness of sheet is limited to 2- 3 mm for sound welding.
- Strength of joint is less than base plates.
- Oil, rust or scale should be removed completely for sound weld

Homogenous Welding:

It is another way of performing fusion welding with the application of external filler material whose metallurgical composition is almost same as that of base metals.

For instance, Manual Metal Arc Welding and Gas Metal Arc Weld use consumable filler material so they are Homogenous Welding.

Advantages:

- Thick plates can be welded with proper edge preparation
- Joints are reliable and strong.
- Low chances of crack formation due sufficient supply of molten metal.
- Joints like butt, lap, tee and corner are possible to perform while wielding.

Disadvantages:

- Thin sheets cannot be joined.
- Grinding is necessary to remove excess filer material which could cause reinforcement.
- Weld bead appearance is not lovely.
- Expensive since extra cost is required for filler material and maintenance.

Heterogeneous Welding:

It is another way of performing fusion welding with the application of external filler whose metallurgical composition is substantially different than that of the base metals. Using this process, we can join two different kinds of metals. Filler material must have low melting point than that of base or parent metal. Initially, base metal should be heated near melting point and then welding must be started immediately using filler rod. That filler rod melts before base metal and spread around joint. Finally, strong joint is achieved once it cools down.

For instance, Brazing and soldering are common heterogeneous joining.

Advantages:

- Thick plates can be welded efficiently with proper edge preparation
- Joints like butt, lap, tee and corner are possible to perform while wielding.
- Joints are reliable and strong.
- Stress and corrosion resistance can be enhanced by choosing appropriate filler material.

Disadvantages:

- Expensive due to costly filler material and maintenance.
- Appearance of weld bead is not good.
- Sputter may produce if process materials are not chosen properly like metal compatibility.
- Grinding is necessary to remove excess filer material which could cause reinforcement.

5.2 Classification of welding and allied process

As we know there are different welding, brazing and soldering methods are being used in industries today. The general classification of welding and allied process is given below:

```
A. WELDING PROCESSES

    1. Oxy-Fuel Gas Welding Processes
        a) Air -Acetylene Welding
        b) Oxy -Acetylene Welding
        c) Oxy-Hydrogen Welding
        d) Pressure Gas Welding

    2. Arc Welding Processes
        a) Carbon Arc Welding
        b) Shielded Metal Arc Welding
        c) Submerged Arc Welding
        d) Gas Tungsten Arc Welding
        e) Gas Metal Arc Welding
```

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```
        f) Plasma Arc Welding
        g) Atomic Hydrogen Welding
        h) Electro-slag Welding
        i) Stud Arc Welding
        j) Electro-gas Welding

    3. Resistance Welding
        a) Spot Welding
        b) Seam Welding
        c) Projection Welding
        d) Resistance Butt Welding
        e) Flash Butt Welding
        f) Percussion Welding
        g) High Frequency Resistance Welding
        h) High Frequency Induction Welding


    4. Solid-State Welding Processes
        a) Forge Welding
        b) Cold Pressure Welding
        c) Friction Welding
        d) Explosive Welding
        e) Diffusion Welding
        f) Cold Pressure Welding
        g) Thermo-compression Welding


    5. Thermit or Thermo Chemical Welding Processes
        a) Thermit Welding
        b) Pressure Thermit Welding

    6. Radiant Energy Welding Processes
        a) Laser Welding
        b) Electron Beam Welding

B. ALLIED PROCESSES

    1. Metal Joining or Metal Depositing Processes
        a) Soldering
        b) Brazing
        c) Brazing Welding
        d) Adhesive Bonding
        e) Metal Spraying
        f) Surfacing

    2. Thermal Cutting Processes
        a) Gas Cutting
        b) Arc Cutting
```

5.3 Forge welding

It is one of the oldest welding techniques which is also famously called as Black Smith welding. This process involves of joining two metal pieces to increase the length by pressing or hammering them when they are at the forging temperature (or plastic temperature). Using this technique, we can weld Mild Steel, Carbon Steel as well as Wrought Iron.

In this process two metal pieces to be joined are heated in a forge or furnace to a melting temperature and they are united together by pressure which involves hammering, rolling, drawing or squeezing. It is limited to light work because all welding is performed by hand sledge and also a slow manual process. There is also a probability of an oxide scale formation on tile surface. This oxidization process can be counteracted by covering the surfaces with a fluxing material. Borax combined with salt ammoniac is commonly used a flux. The forge welding is highly recommended for such metals, which have a large welding temperature ranges like low carbon steel and wrought iron. The more carbon content in the metal the more care should be given to it.

5.4 Use of flux in forge welding

Oxidization occurs when a metal combines oxygen which makes atoms of metal loses its electrons as a result a layer of scale is formed in metal surface. For example, when iron is exposed to moisture environment scaling (or rusting) occurs in iron surface. Flux is used to remove dirt and prevent metal surface from direct environment exposure. Applying flux on iron pipe prevents it from getting rust due to contact of rain and heat from environment.

Mainly used Fluxes are:

- Silicon or Pure Sand
- Borax
- Salt ammoniac
- Sodium Chloride

On the basis of pressure, forge welding can be categorized in three types:

- Hammer Welding
- Die Welding
- Roll Welding

We should carefully follow following tasks for forge welding a good joint:

1) Keep area around furnace or Hearth clean and tidy

2) Use Hard Coke for fire

3) Right amount of air should be supplied in furnace to minimize chances of oxidization
4) Be careful while making edges of metal
5) Metal should not have scale and other dirt in its surface
6) We should choose right Flux material
7) Do not waste time after taking metal out of furnace
8) Clean the surface of Anvil before hammering and make sure it has firm position

5.5 What's Next

chapter5

CHAPTER

SIX

CHAPTER 5: ARC WELDING TECHNIQUE

6.1 Introduction

Arc welding is a welding process where coalescence is produced by heating with an electric arc, with or without applying pressure and also with or without applying filler metal depending upon base metal thickness. Shielded Metal Arc Welding (SMAW) is known as one of the oldest, simplest and versatile among other welding techniques and is widely (i.e. approximately 50%) used in industrial application and maintenance welding.

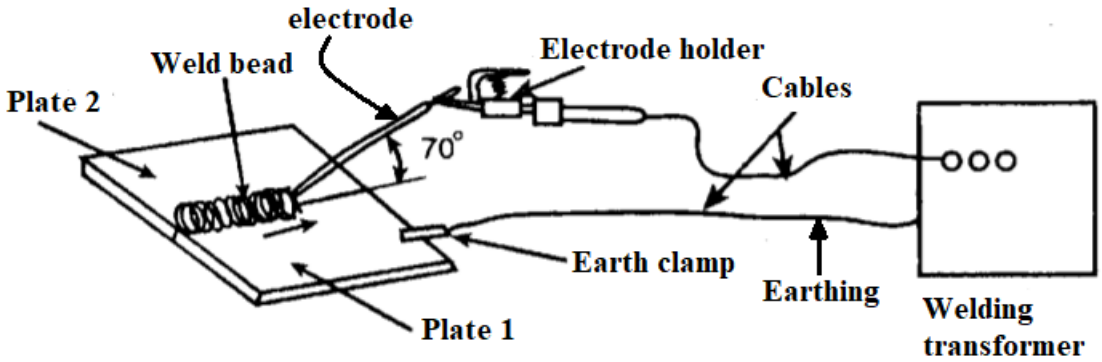

Fig. Arc Welding Principle

Procedures of arc welding are as follows:

1) The surface of workpiece to weld should be cleaned and the edges of the plates may be filed for perfect joint and greater strength.

2) The earth clamp is clamped to the plate to be weld and the welding rod is held in the electrode holder as shown in given figure.

3) The electric arc melts the welding rod and joins two metal plates together. Ensure the gap of 3 mm between the workpiece and the welding rod.

4) After welding is done, remove the slag using chipping hammer.

6.2 Dividing of heat energy

We can calculate the heat generated from `shielded metal arc welding` and `submerged arc welding methods`. To calculate the heat energy produced while welding, following steps can be followed

```
Work done (W) = Voltage required (V) x Current required (I) x Welding time (T)

Heat = Arc Voltage x Current x Time
```

If arc is travelled S distance at constant time applying V voltage and I current then heat produced well be

```
( V x I x 60 ) / S

(i.e. joules per mm length of joint)
```

```
For example: Calculate the heat generated from welding when a welder
applies arc voltage of 25 volts,current of 400 ampere and travel
speed of arc was 100 mm per minute.

Here, we have given
Voltage applied (V) = 25
Current applied (I) = 400
Travel speed of arc (S) = 100
Heat generated (W) =?

We know that,   W   =   (V x I x 60) / S
                    =   (25 x 400 x 60) / 100
```

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```
                    =   6 Kilo Joules per mm

Therefore, 6 KJ of heat is generated while welding for the given data.
```

6.3 Arc striking method in welding work

Arc striking is the foremost and most important work need to be done before welding. Arc striking can be done from two differe

1. **Scratching method**
2. **Tapping method**

6.3.1 Scratching method

Before starting to weld, the following typical steps should be considered:

- Wear the proper personal safety equipment like a welding helmet, welding gloves, protective clothing, and footwear.
- Make proper ground connection to the workpiece.
- Select proper type and size of electrode.
- Properly secure the electrode in the holder.
- Polarity of the machine should coincide with that of the electrode.
- Inspect machine and adjust necessary current for the job.

After arranging all the required equipment nearer to welding table along with arc machine setup, arc striking can be started. Then, with angle of 70 to 80 degrees scratch the workpiece as you scratch a matchbox with a matchstick. Once connection between positive and negative poles establishes then sparking occurs. As soon as the sparking occur, lift the electrode up to 6 millimeters and after few seconds bring the electrode down to hold normal arc. In this way arc striking can be done before every welding.

6.3.2 Tapping method

After going through pre-striking steps of above tapping method can be performed. Tapping method involves a tap in workpiece with electrode and draw back. At the instant the electrode touches surface of workpiece, current flows through the point of contact and as electrode is withdrawn then an electric arc is formed where end of the electrode as well as spot on the workpiece melts. It is the best method because it minimizes arc strikes. It also has high chance of sticking the electrode to the workpiece. Therefore, it needs practice

6.4 Arc length and its effect

As you know when electrode is touched with workpiece then sparking occurs. After that electrode is hold up and arc forms betw

1. **Long arc**
2. **Short arc**
3. **Correct arc**

6.4.1 Long arc

If the arc length is longer than the diameter of electrode's core-wire then that arc is called long arc.

Effects of long arc:

i. Fusion and penetration will be low
ii. No concentration of heat on one position
iii. High chances of overlap
iv. Filler material falls in workpiece as droplets
v. Welding bead contains porosity
vi. More electrodes are needed etc.

6.4.2 Short arc

If the arc length is shorter than the diameter of electrode's core-wire then that arc is called short arc.

Effects of short arc:

i. Fusion and penetration will be high.
ii. Difficult for stabilizing arc.
iii. Welding speed becomes slow.
iv. Welding bead will have irregular heights.
v. Electrode melts fast
vi. Electrode and electrode holder get over-heated.

6.4.3 Correct arc

If the arc length is equal to the diameter of electrode's core-wire then that arc is called short arc.

Effects of correct arc:

i. Fusion and penetration will be right.
ii. Welding joint will be strong.
iii. It has very low spatter
iv. Electrode is used less in number.
v. Less slag enters in welded bead.
vi. Electrode melts in same pace.

6.5 Travel speed of electrode rod

Speed of electrode rod should not be either too fast or too slow. If the speed of electrode rod is fast then melted metal cools and solidifies in faster pace which eventually leads to bead ripples. And if the speed of electrode rod is slow then bead of the weld gets high and wide. Following steps need to be considered for arc travel speed:

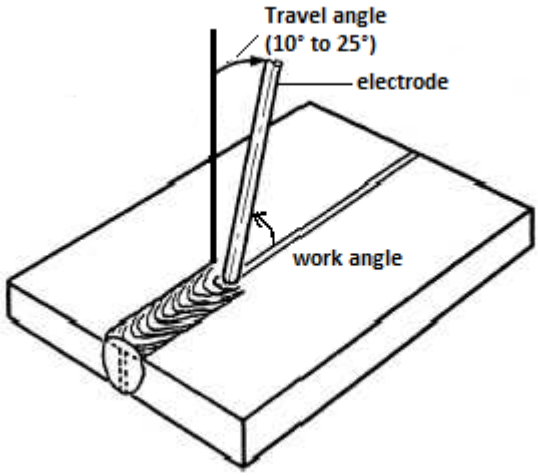
1) The speed must be lowered as the material thickness starts increasing.

2) Forehand welding technique is used for higher welding speeds.

3) According to the material thickness and joint, the welding current and arc speed is increased and vice-versa.

Note: In forehand welding method, the torch is angled so that the electrode is fed in same direction as arc travel.

6.6 Angularity of electrode



The angle formed between workpiece and electrode is known as angularity of electrode. The angularity of electrode depends on the nature of workpiece joints and position. A small difference in angle does not affect the weld appearance or quality but large difference affects. Welding angle consists of two positions and they are work angle and travel angle. Work angle is the angle formed from the horizontal measured at right angles in the travel direction of welding. Travel angle is the angle formed in the direction of welding.

6.7 Multi weld run process

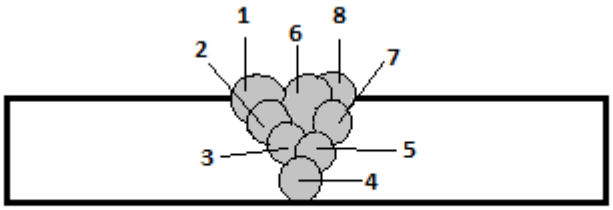
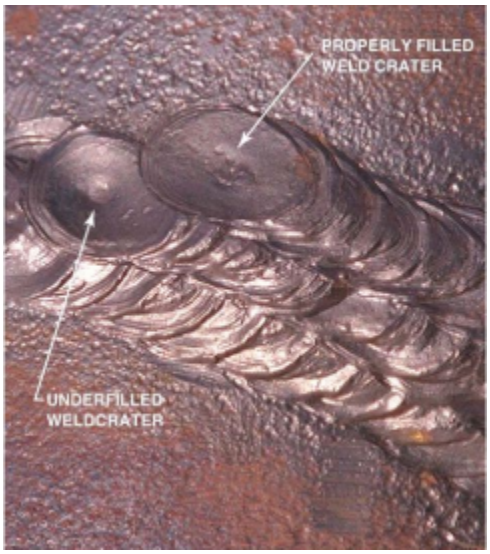


Fig. Multi weld run

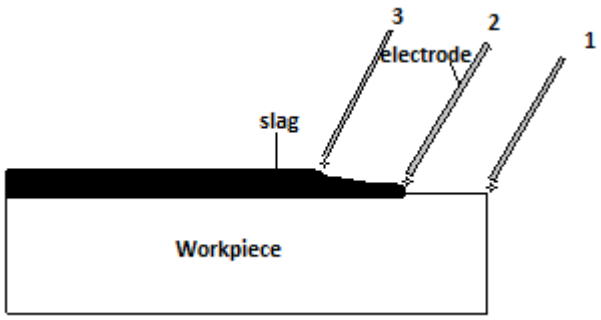
Sometimes we have to weld according to the nature of workpiece. Welding is done after edge preparation on workpiece. Welding is done is various ways like single run (one bead), double run (two beads) and multi run (many beads). This technique helps to prevent workpiece from getting hard after overheat. Although multi-weld run process is applicable to all metals with different thickness but the factors like cost, risk of weld defects, need of pre-heating, residual stress and distortion increases as the thickness of metal increases.

6.8 Crater

Crater is formed when metal melts and forms a pool like structure after it came in contact with welding electrode. Depth and size of crater gives idea about the level of penetration. For a strong weld it is necessary for metal to melt and mix well with filler material. The weld bead crater must be cleaned before next welding because it could cause slag inclusion.



6.9 Methods of restarting new bead



A depression in the base metal is formed when you burn workpiece without any filler at the end of the weld bead. To restart a new bead, weld from the end of the crack and weld back into where the weld stopped.

Initially, use chipping hammer and brush to clear slag formed at the end of weld up to 12 mm. Then, start welding from opposite direction as shown in given figure i.e. from position 1 to position 3. This method gives beautiful appearance as well as strong weld.

6.10 What's Next

chapter6

CHAPTER

SEVEN

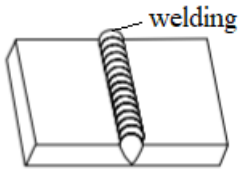
CHAPTER 6: WELDING JOINTS AND POSITIONS

7.1 Introduction to welding positions

There are mainly four types of welding positions which are given below":

1. **Flat position**
2. **Horizontal position**
3. **Vertical position**
4. **Overhead position**

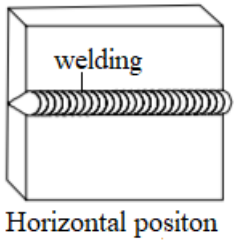
7.1.1 Flat position



Flat position

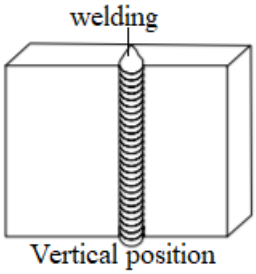
Here, welding is performed from the upper side of the joint and the face of the weld is approximately horizontal. This is the simplest and the most convenient position for welding which gives excellent welded joints in fast speed with minimum risk of fatigue.

7.1.2 Horizontal position



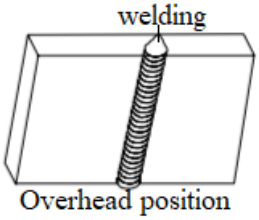
In HP, the plane of the workpiece is kept vertical and the weld is deposited in horizontal surface. Metal deposition rate is next to that achieved in flat position. It is commonly used welding in vessels and reservoirs.

7.1.3 Vertical position



In VP, the plane of the workpiece is vertical and the weld is deposited upon a vertical surface. Due to force of gravity on the molten metal, it is difficult to produce satisfactory welds in this position. The welder must control the metal in constant pace to avoid the run and drop from the weld. Vertical welding can be of types viz., vertical-up and vertical-down. Vertical-up welding is preferred when strength is the main concern whereas vertical-down welding is used for sheet metal welding and for a sealing operation.

7.1.4 Overhead position



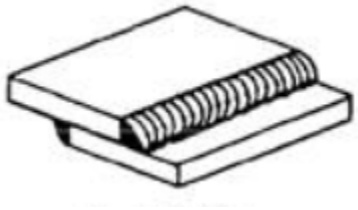
In OP, welding is even more difficult than vertical position because of greater gravitation pull against the molten metal. The force of the flame against the weld serves to counteract the pull of gravity. The plane of the workpiece is horizontal whereas the welding is carried out from the underside. It is a best practice to use very short arc and basic coated electrodes for overhead welding.

7.2 Introduction on welding joints

Welding is the manner in which materials fit together. To obtain sound welds, it is desirable that weld should completely penetrate the metal thickness. The heat will not be able to melt the joint edges to their entire thickness. So, edges of joining surfaces of metals are prepared first before welding. Different edge preparations may be used for welding butt joints, are given below:

7.3 Different types of welding joints

7.3.1 1. Lap joint



Lap joints are formed by overlapping one part over another and then welded. This type of joint is done to join two pieces with d

a) Fillet weld

b) J groove weld

c) Bevel groove weld

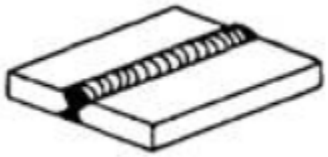
d) Flare bevel groove weld

e) V groove weld

f) Plug weld

g) Spot weld

7.3.2 2. Butt joint



Butt joints are formed by placing the ends of two parts together.

Different types of butt welding are:

a) Square butt weld

b) J groove weld

c) Bevel groove weld

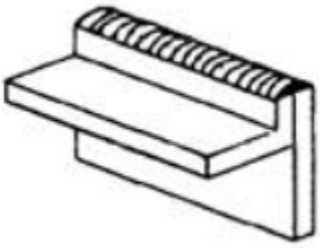
d) U groove weld

e) V groove weld

f) Flare V groove weld

g) Flare bevel groove weld

7.3.3 3. Edge joint



It is the joint formed by welding the edges of two parts together where the edges of two sheets are adjacent and parallel at the point of welding.

Different types of edge joint are:

a) Square groove weld

b) J groove weld

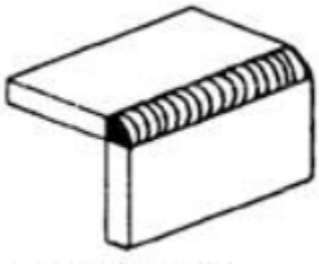
c) Bevel groove weld

d) U groove weld

e) Edge flange weld

f) Corner flange weld

7.3.4 4. Corner joint



In corner joint, the corner of two parts are placed at right angle and joined to form a shape of L.

Different types of corner joint are:

a) Fillet weld

b) J groove weld

c) Bevel-groove weld

d) U groove weld

e) V groove weld

f) Flare V groove weld

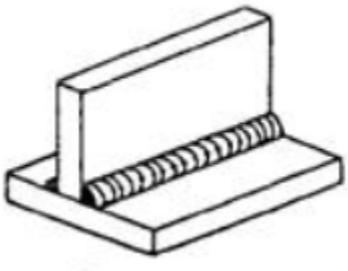
g) Spot weld

h) Corner flange weld

i) Square groove weld

j) Edge weld

7.3.5 5. T joint



In a Tee-joint, one joint is the right angle to the other joint in the approximate shape of the letter “T”. These joints are a type of fillet weld and can be implemented while welding pipe or tube onto a base plate.

Different types of T-joints are:

a) Fillet weld

b) J-groove weld

c) Bevel-groove weld

d) Plug weld

e) Slot weld

f) Melt-through weld

g) Flare-bevel groove weld

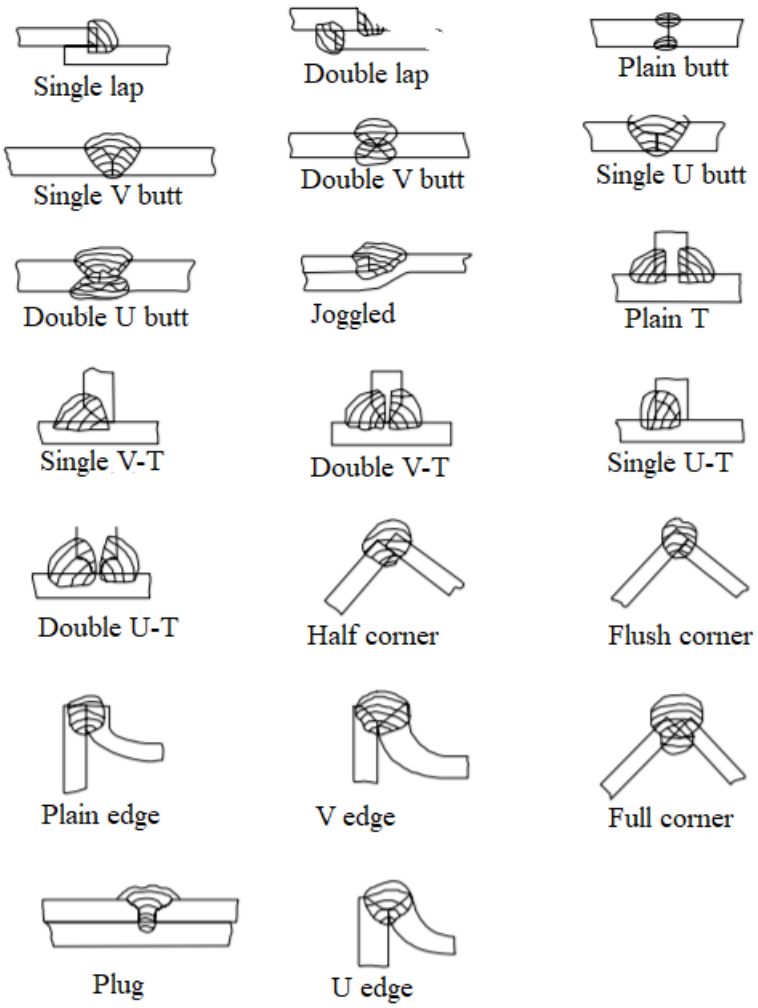


Fig. Different types of welding joints

7.4 What's Next

chapter7

CHAPTER

EIGHT

CHAPTER 7: ELECTRODES

8.1 Introduction

Electrode or the welding rod is a piece of wire connected to the welding machine through which current is fed to join two metals together. It is available without flux coating and with flux coating. One end of electrode is left without coating for electrode holder to hold. It is used to overcome the defects of metal and make stronger joints.

8.2 Types of welding electrode

There are two types of welding electrodes depending upon the process of welding and they are:

1. **Consumable electrodes**
2. **Non-consumable electrodes**

8.2.1 Consumable Electrodes

Consumable electrodes have low melting point, therefore, are used in metal inert gas (MIG) welding. It is made from materials like mild steel and nickel steel. It is easy to use and maintain but need precaution while replacing electrodes in electrode holder. It can be categorized as bare electrodes and coated electrodes.

Bare electrodes do not have any coating in it and are employed where coated electrodes are not required thus makes welding cheaper.

Coated electrodes have coating in them. It is further divided into three sub-categories according to coating factor and they are:

i. `Light coated electrodes`
ii. `Medium coated electrodes`
iii. `Shield arc or Heavily coated electrodes`

Light coated electrode has coating factor of 1.25. It is applied to electrodes for enhancing arc stability as well as removing impurities like oxides and phosphorous. It produces thin slag and provides smoother and neater welds.

Medium coated electrode has coating factor of 1.45.

Heavily coated electrode has coating factor ranging from 1.6 to 2.2. It has proper and well-defined composition. It is employed in heavy duty jobs like welding cast iron.

Note: There are three different types of heavy coated electrodes and they are:

- Electrodes with cellulose coating
- Electrodes with mineral coating
- Electrodes with both cellulose and mineral coating.

8.2.2 Non-Consumable Electrodes

Non-consumable electrodes are not consumed or does not melt during welding. A little reduction in the length of electrode does occur due to the vaporization and oxidation process while welding. These electrodes have high melting point and are unable to fill the gap in the workpiece. Non-consumable electrodes are made from materials like pure tungsten, graphite or carbon coated with copper. These electrodes are made as cathode and the workpieces as anode. Shielding gases should be used while welding to protect welding area from oxygen and surrounding atmosphere.

On the basis of materials used, non-consumable electrodes are of two types:

i. `Carbon or Graphite electrode`

ii. `Tungsten electrode`

Carbon electrodes are used in arc welding and cutting. It can be without coating or with coating of copper. Its melting point is 3350 degree Celsius.

Tungsten electrode are used in TIG welding. It can be made with either pure tungsten, tungsten with 1% thorium, tungsten with 2% thorium or tungsten with 0.3-0.5% zirconium content. Pure tungsten is used for lighter welding applications. Its melting point is 3422 degree Celsius.

8.3 Methods of using electrode

Welding of good welds comes from experience and with time. Electrode could get damage if you stick it for long time in one position of workpiece.

The methods of using electrode are as follows:

1) You must keep the electrodes dry.

2) Do not bend the electrodes because it harms the electrode coating.

3) Electrode has 20 to 25 millimeters of uncoated region on one end. Electrode should be hold by electrode holder in that region only.

4) You should stop the welding when electrode's length shortens below 40 millimeters.

5) Selection of election is necessary according to the nature of welding.

6) All the small pieces of used electrodes should be collected in on box.

8.4 Specification of electrode

Electrodes with varied sizes are required according to the thickness of our workpiece. Similarly, information like length of electrode and the electric current requirement of electrode are also necessary. Given below is the data for electrode based on British system.

Table 1: .

Electrode Sizes (S.W.G)	14	12	10	8	6	4
Thickness (inch)	1/16″	3/32”	1/18″	5/32”	3/16″	1/4”
Length (inch)	12″	14”	18″	18”	18″	18”
Current (Ampere)	30-60	50-70	100-120	180-200	180-200	250-300
Workpiece thickness	up to 3 mm	up to 3 mm	up to 6 mm	up to 12mm	up to 12mm	up to 12mm

8.5 Functions of electrode coating

Electrode coating performs many functions depending upon coating constituents, during welding to improve weld metal properties. The important functions are as follows:

1) Improves the electric conductivity in the arc region which improve the arc ignition and stabilization of the arc.

2) Formation of slag, which;

a) Influences size of droplet.

b) Protects the droplet during transfer and molten weld pool from atmospheric gases.

c) Protects solidified hot metal from atmospheric gases.

d) Reduces the cooling rate of weld seam.

3) Formation of shielding gas to protect molten metal.

4) Improve deposition rate with addition of iron powder in coating.

5) Provide deoxidizers like Si and Mn in form of FeSi and FeMn.

6) Alloying with certain elements such as Cr, Ni, Mo to improve weld metal properties.

8.6 Selection of electrode

You must consider some factors before selecting welding electrodes and they are:

1) The electrode rod should have greater tensile strength compared to parent metals.

2) The specification of base metals. Since, electrode should have less thickness than of base metal.

3) The joint type and welding position.

4) Power source of welding i.e. AC or DC.

5) Quality of welding.

6) Skill and knowledge of welder.

7) Cutting of electrode.

8.7 Handling and storage of electrode

Electrode gets affected by moisture easily and should be kept in containers that gives moisture free environment. Some of the information on handling as well as storing electrodes are given below:

1) To keep the electrodes in right condition, place them with silica gel in drying cabinet.

2) Grab the group of electrodes in hand and rub together to find the dryness of electrodes. If sharp metallic sound is heard then they are dry else they are not.

3) If the electrodes are wet then they produce porosity, crack and violet arc.

4) If electrodes are wet then they should be heated in oven for around 2 hours at the temperature of 230 to 260 degrees Celsius.

5) Electrodes should not be bended while storing because it damages the coating.

6) Electrode boxes should not be stacked and thrown from height.

8.8 Weaving

A steady, uniform motion of the electrode produces a satisfactory bead. A slight weaving or oscillating motion keeps the metal in molten state a little longer and allows the gas to escape, bringing slag to the surface. Weaving results in wider bead with better penetration.

8.9 Walkability

It is the ability of material to weld or fuse with similar materials without cracking.

The factors that affects the weldability of metal are as follows:

1) Melting point of metal

2) Thermal conductivity (Metals like Aluminum and Copper having high thermal conductivity are difficult to weld materials.)

3) Reactivity

4) The coefficient of thermal expansion of metals

5) Electrical resistance

6) Surface condition

8.10 What's Next

chapter8

CHAPTER

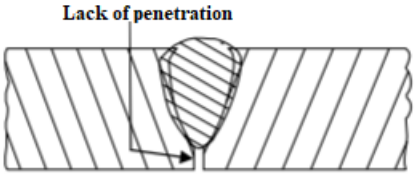
NINE

CHAPTER 8: WELDING DEFECTS AND INSPECTION

9.1 Welding defects

There are some welding defects and they are as follows:

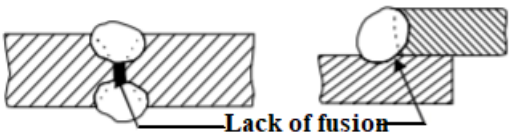
9.1.1 a) Lack of penetration



This type of defect occurs when the filler metal fails to penetrate into the joint. The reason for such failure can be:

- Inadequate de-slagging
- Incorrect edge penetration
- Incorrect welding technique

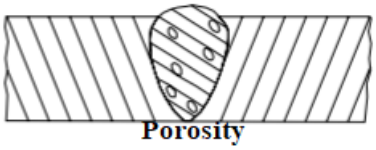
9.1.2 b) Lack of fusion



It is the situation when the filler metal fails to fuse with the parent metal and the reason can be:

- Selection of incorrect welding technique
- Insufficient heat
- Too fast welding process

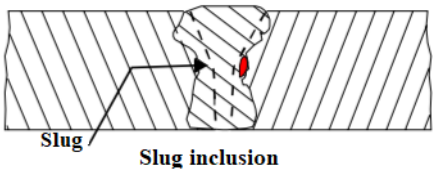
9.1.3 c) Porosity



This defect is caused by the trapping of gas during the welding process. Porosity means the small holes throughout the weld met

- Dampness
- Fast cooling of the weld
- Chemicals in the metal

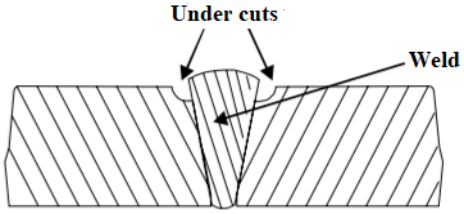
9.1.4 d) Slag Inclusion



It is the defect caused when the slag or other impurities are trapped in the weld. The reasons for such situation are:

- If slag from previous runs are not cleaned
- Poor cleaning and preparation of the base metal before welding.

9.1.5 e) Undercuts



It is the groove or slot along the edges of the weld. This defect are caused by:

- Too fast welding process
- Inappropriate welding technique
- Too great a heat build-up

9.1.6 f) Overlays

Overlays consists of metal on the parent metal without fusing with it. This defect is because of:

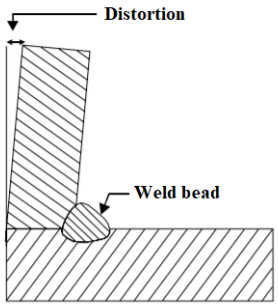
- Contamination of the parent metal
- Insufficient amount of heat

9.1.7 g) Blowholes

Blowholes are the large holes in the weld and they are caused when:

- Gas is trapped.
- Filler of parent metals are contaminated

9.1.8 h) Distortion

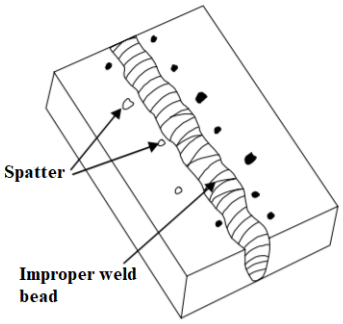


Distortion is the situation where metal is distorted because of expansion and contraction of the heated portion of metal in weldi

- High cooling rate
- Small diameter electrode
- Poor clamping and

- Slow arc travel speed

9.1.9 i) Poor weld bead appearance



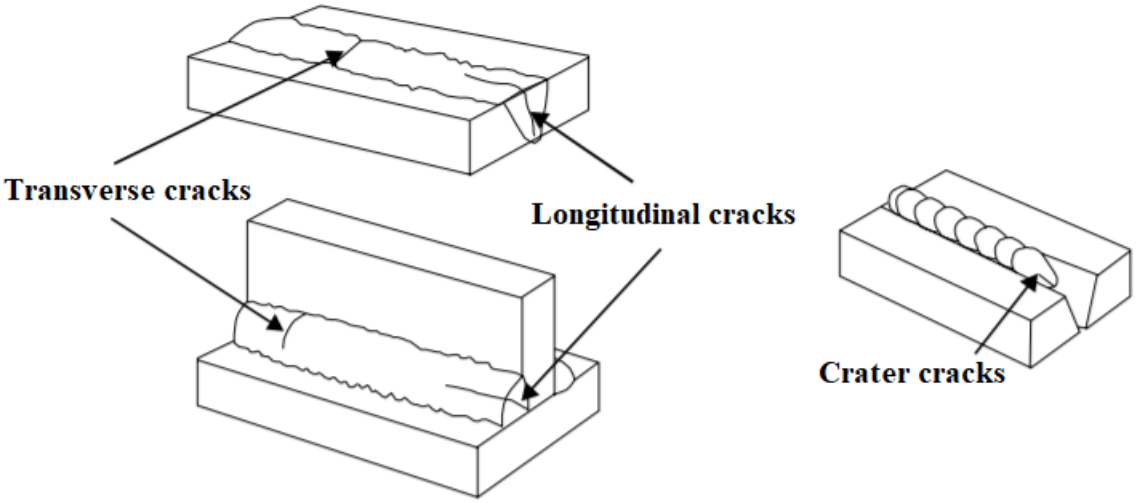
It is formed when the width of the weld bead deposited is not uniform or straight. It can form because of following reasons:

- Improper arc length
- Inappropriate welding technique
- Damaged electrode coating
- Poor electrode
- Earthing connection

9.1.10 j) Cracking

Cracks can be formed in both weld metal or in the parent metal. The reasons for cracking can be:

- Unsuitable parent metals used for welding
- Inappropriate welding technique



9.1.11 k) Burn through

It is the collapse of the weld pool and the reasons of burn through are:

- High heat concentration
- Poor edge preparation

9.1.12 l) Excessive penetration

This defect means the weld metal extends above the surface or protrudes through the root of the weld. The reasons for excessive

i. Incorrect edge preparation
ii. High heat concentration
iii. Too slow welding process

9.2 Introduction of welding inspection

Welding is the most essential part of today's industrial age. It is because of development in welding that today ships, rockets, aeroplanes, houses, machines, electronic devices and other are being made. Welding only is not enough if there is no quality. Therefore, inspection and test both are also equally important for increasing the reliability and durability in welded materials. Inspection of welding can be done in three phases and they are:

1. **Inspection before welding**
2. **Inspection during welding**
3. **Inspection after welding (types in basic)**

9.2.1 Inspection before welding:

Before going to welding process, it is also necessary to analyze the structure of workpiece. If workpiece itself is of poor quality t

i. Analysis of workpiece quality
ii. Selection of welding method
iii. Selection of skilled manpower
iv. Weldability of filler material
v. Required machine and equipment
vi. Electrode according to workpiece
vii. Welding joints and positions

9.2.2 Inspection during welding

Similarly, inspection during the welding can be done following given steps:

i. Examining the arc length while welding
ii. Inspecting whether welded metal is bonding well or not
iii. Applying right amount of current
iv. Making right angularity of electrode
v. Constant speed while welding
vi. Carefulness and alertness while welding
vii. No entry for foreign matters.
viii. Arc blow should not be there.

9.2.3 Inspection after welding (types in basic)

Once welding is done, joints need to be inspected very carefully. Those joints with fine outward finish could have defects inside.

i. **Non-destructive test**
ii. **Semi-destructive test**
iii. **Destructive test**

Non-destructive test:

This type of test does not require cutting, splitting and breaking of workpiece.

It is a simple mechanical test which can be performed by following methods:

a) Visual examination
b) Paraffin oil test
c) Stethoscope test
d) Ultrasonic test
e) Hydraulic pressure test
f) Magnetic particle test
g) X-ray test
h) Gamma ray test
i) Dye penetrate test
j) Air test

Semi-destructive test:

A small part of welded metal is cut-off from the workpiece and installed as before after the test is done. This type of test is known as semi-destructive test.

There are normally three methods for performing semi-destructive test and they are:

a) Cutting test
b) Acid etching test
c) Drilling test

Destructive test:

Destructive test is used to get physical and mechanical properties of workpiece. Once this test is performed, the workpiece cannot be used again. Destructive test is done by twisting, breaking, cutting, stretching and hitting.

There are some tests under destructive test and they are:

a) Tensile test

b) Bend test

c) Impact test

d) Nick break test

e) Hardness test

f) Fillet Rupture test

9.3 Types of metal

Metal are class of substance characterized by high electrical and thermal conductivity and other characteristics like malleability

1. **Ferrous**
2. **Non ferrous**

9.3.1 Ferrous Metal

Ferrous are those metal that are alloys of iron and other elements.

Some examples of ferrous metal are alloy steel, carbon steel, wrought iron and cast iron.

9.3.2 Non-Ferrous Metal

Non-Ferrous metals do not have iron in it.

Some examples of non-ferrous metal are copper, aluminium, silver and gold.

Table 1: Difference between ferrous and non-ferrous metal

S/n	Ferrous metal		Non-ferrous metal
1.	High concentration of iron is present.		Does not have any iron in them at all.
2.	Prone to rust when exposed to moisture.		It does not rust as ferrous when exposed to moisture.
3.	It is attracted by magnet.		It is not attracted by magnet.
4.	While hammering or beating it produces metallic sound.		It does not produce metallic sound.
5.	It has high melting point.		It has low melting point.
6.	It is used in heavy constructional works and tool manufacturing.		It is used in making pipes, roofing and small machine parts.

9.4 Physical properties of metal

Metals have their distinct physical properties and they are:

1. **`Color of metal`** (i.e. Color of aluminium is white.)
2. **`Specific weight`** (i.e. Aluminium weighs 2.7gf/cm3)
3. **`Magnetic property`** (i.e. Aluminium is not attracted to magnet)
4. **`Conductivity`** (i.e. Aluminium is a good conductor.)
5. **`Melting point`** (i.e. Aluminum starts melting when temperature reaches 660 degree Celsius.)
6. `Molecular Structure`

9.5 Mechanical properties of metal

Mechanical properties of metal are as follows:

1. Ductility
2. Elasticity
3. Hardness
4. Malleability
5. Brittleness
6. Sonority (i.e. Sound produced upon hitting the metal.)

9.6 Method of metal identification

Some of the popular methods on metal identification are as follows:

1. Visualization test (i.e. Color and surface appearance)
2. Magnetic test
3. File test
4. Oxy-Acetylene torch test for heat conductivity
5. Spark test by observing sparks at grinding wheel under subdued light.
6. Chip test by removing a small portion of material from metal with a sharp cold chisel.
7. Hardness test and so on.

9.7 Effects of welding heat

1) While welding metal is heater over the range of temperature up to fusion and is allowed to cool. Such heating and cooling causes metallurgical and mechanical effects on workpiece around the heat affected zone.

2) Distortion and the residual stress are the result of mechanical effect after welding.

3) The residual stress reduces the load carrying capacity of the structure formed by the help of welding. Preheating the whole structure is necessary to reduce the residual stress.

4) Gas pockets and porosity can be formed in the final weld when dissolved gases becomes free from the metal. The welded metal in molten state can dissolve in ore gases like oxygen and nitrogen. As the metal cools and losses its dissolving capacity and dissolved gases becomes free from the metal creating the gas pockets.

9.8 What's Next

chapter9

CHAPTER

TEN

CHAPTER 9: STANDARD WELDING SYMBOL

10.1 Introduction

Blueprints or drawing of final products are provided to worker or welders before the welding jobs starts. Welder studies the blueprints and plans according to it. There are standard symbols used in welding industry to make the similar understanding about any task. The main elements of welding symbols are:

1. Reference line
2. Arrow
3. Basic weld symbol
4. Dimension and other data
5. Finish symbol
6. Tail
7. Supplementary symbol
8. Specification, process or other symbol

10.2 Standard location of welding symbol element

Welding symbols have their standard location to ease welder from complexity of design. The figure with symbol on standard loc

1. Type of joint
2. Position of joint
3. No of weld
4. Method of welding
5. Edge preparation
6. Requirement of full or partial welding
7. Size and depth of the bead

8. Length of the weld
9. Further direction and so on.

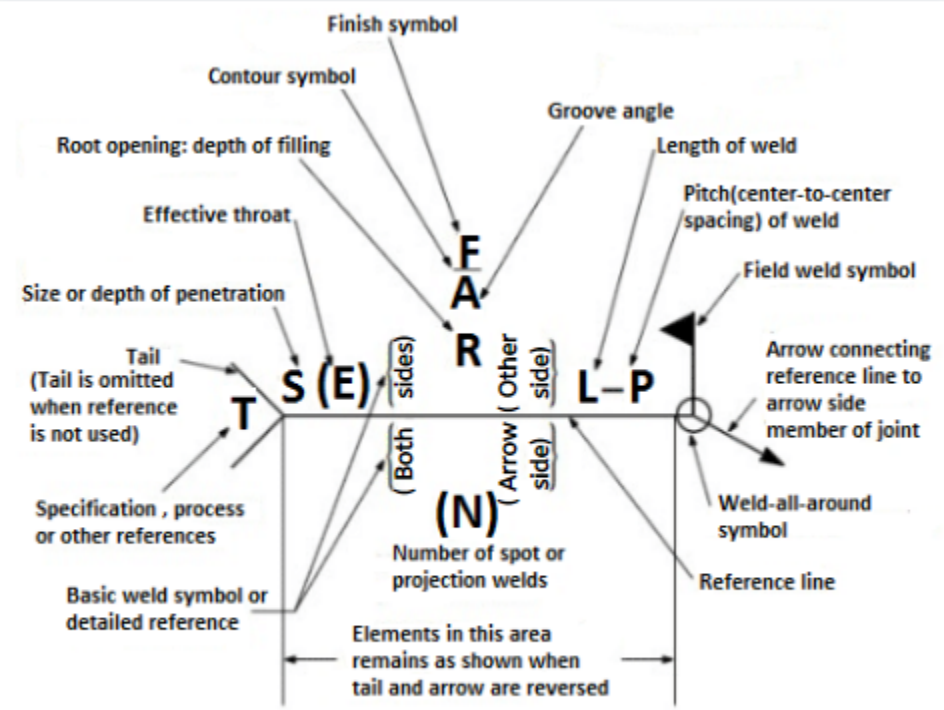
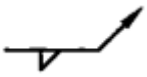
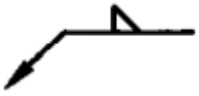
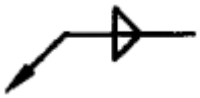
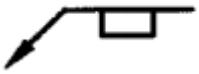
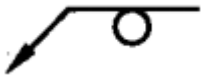
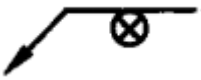
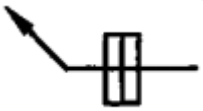
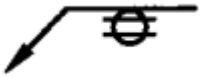
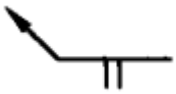
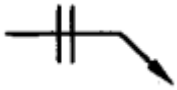
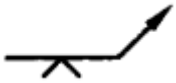
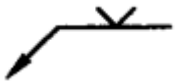
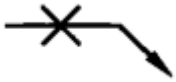
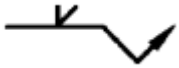
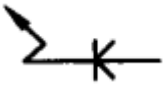
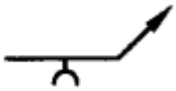
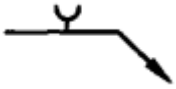
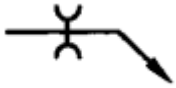
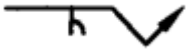
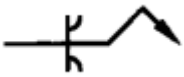
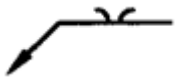
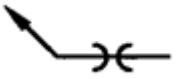
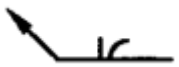
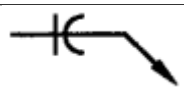
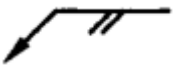
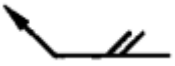
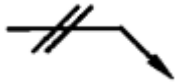


Fig. Standard location of welding symbol element

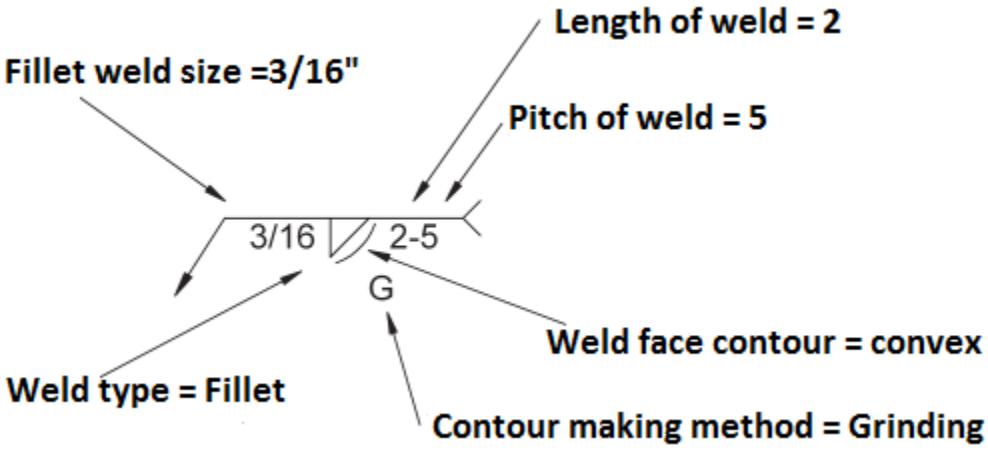
10.3 Basic welding symbol

Location Significance	Arrow side	Other side	Both side
Fillet			
Plug or Slot			Not used
Spot or Projection			Not used
Stud		Not used	Not used
Back			Not used
Surfacing		Not used	Not used
Edge			
Seam			Not used

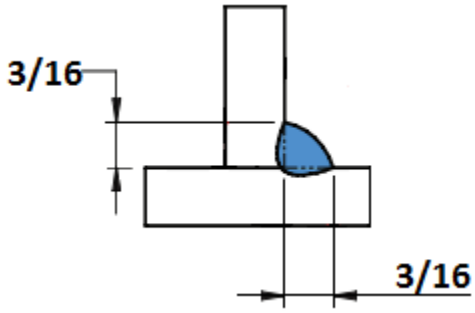
Symbols for different groove according to location signification is given below:

Location Significance	Arrow side	Other side	Both side
Square			
V			
Bevel			
U			
J			
Flare - V			
Flare - Bevel			
Scarf for Brazed joint			

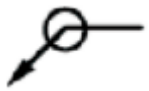
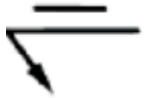
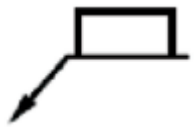
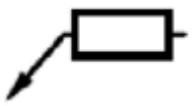
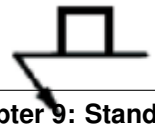
Example of a welding symbol for a fillet weld



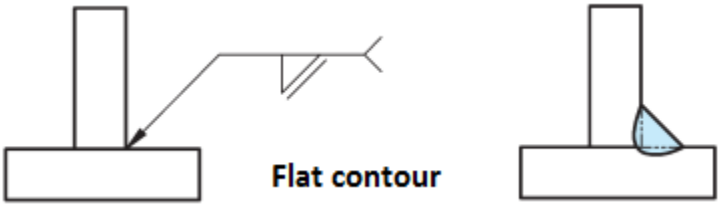
The given information is shown in the drawing below:



10.4 Supplementary symbol

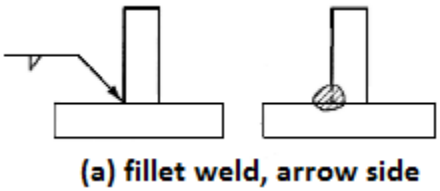
S/n	Description	Other side
1)	Weld all around	
2)	Field weld	
3)	Melt through	
4)	Concave contour	
5)	Convex contour	
6)	Flush contour	
7)	Backing (rectangle)	
8)	Spacer (rectangle)	
		
9)	Consumable inert (square)	

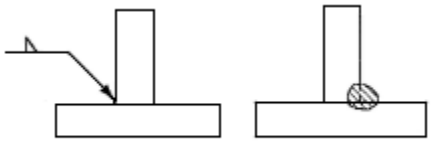
Some of the implementations are shown below:



10.5 Importance of position of arrow

While preparing the drawing or blueprint of welding with standard symbols, an arrow should touch the location where welding is required. A location touched by arrow is known as arrow side. A position of arrow as symbol in left side and its implementation in right side is shown in figures below:





(b) fillet weld, other side

(c) fillet weld, both sides

10.6 What's next?

This will be the end of our journery. To dive deep in the welding field there are lots of resouces available...

CHAPTER

ELEVEN

INDICES AND TABLES

- genindex
- modindex
- search

11.1 Our Help

If you have any trouble please email at binary.science01@hotmail.com

11.1.1 Your help

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This project has been financed by us (i.e. Ashish Lamichhane and Pradeep Khanal) to make it here. Currently, we are not accepting donations.