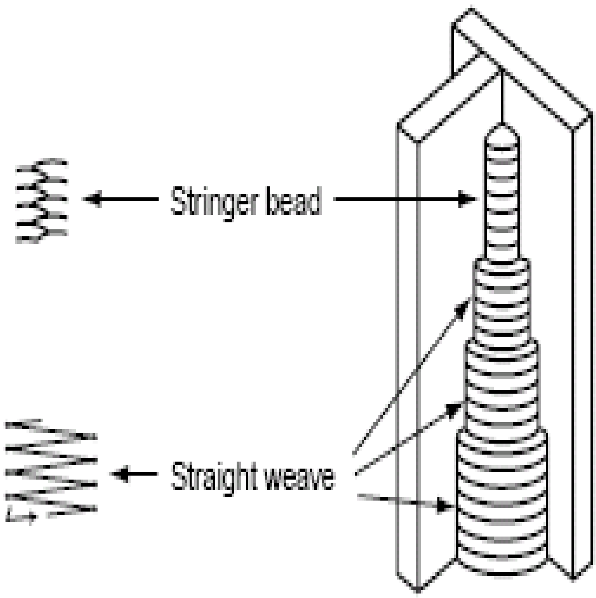
Mechanics Level - II

Based on March 2022, Curriculum Version 1



Module Title: - Performing Fillet Shielded Metal Arc Welding (SMAW)

Module code: IND MCS2 M05 0322

Nominal duration: 80Hour

Prepared by: Ministry of Labour and Skill

August, 2022

Addis Ababa, Ethiopia

Acknowledgement

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Acronyms

SMAW Shielded Metal Arc Welding

HAZ Heat Affected Zone

Introduction to the Module

In mechanics filed; the Performing Fillet Shielded Metal Arc Welding (SMAW) also known as manual metal arc welding this module cover skills, knowledge and attitudes required in carrying out Shielded Metal Arc Welding (SMAW) in fabrication and assembly of metal work.

This module is designed to meet the industry requirement under the mechanic's occupational standard, particularly for the unit of competency: Performing Fillet Shielded Metal Arc Welding (SMAW).

Module units

This module covers the units:

- Materials, tools and equipment
- Welding machine / equipment, accessories and fixtures
- Pre heating tools/ equipment
- Tack welding
- SMAW welds
- Remove defects and re-welding
- Quality weld conformance

Learning objectives of the Module

At the end of this session, the students will able to:

- Prepare materials, tools and equipment
- Set -up welding machine / equipment
- Set-up pre heating tools/ equipment
- Perform tack welding
- Perform SMAW welds
- Perform remove defects and re-welding
- Assure quality weld conformance

Module Learning Instructions:

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the "LAP test" giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit One: Materials, Tools and Equipment

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- welding works from order and drawings
- Correct size, type and quantity of materials.
- Materials
- Assemble /align Material specification.
- Welding machine and its accessories.
- Tools and equipment.
- Standardize working area

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify welding works from order and/or drawings
- Determine correct size, type and quantity of materials.
- prepare the materials
- Perform Assemble /align materials to specification.
- Identify welding machine and its accessories
- Prepare appropriate tools and equipment.
- Ensure safe standardize working area

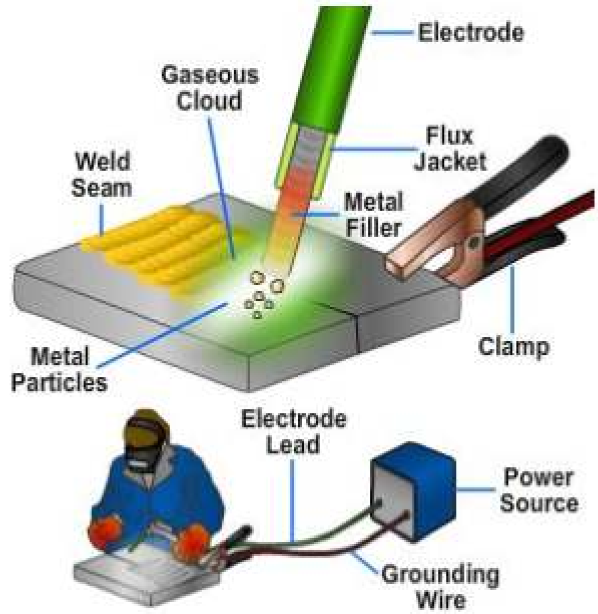
1. Welding works from order and drawings

1.1. Introduction to SMAW

Manual metal arc welding (MMA or MMAW)shielded metal arc welding (SMAW) informally as stick welding, is an electric arc welding process in which an electric arc between a covered metal electrode and the work generates the heat for welding. The filler metal is deposited from the electrode, and the electrode covering provides the shielding. Some slang names for this process are "stick welding" or "stick electrode welding'.

An electric current, in the form of either alternating current (AC) or direct current (DC) from a welding power supply, is used to form an electric arc between the electrode and the metals to be joined. The work piece and the electrode melt forming a pool of molten metal (weld pool) that cools to form a joint. As the weld is laid, the flux coating of the electrode disintegrates, giving off vapors that serve as a shielding gas and providing a layer of slag, both of which protect the weld area from atmospheric contamination. Because of the versatility of the process and the simplicity of its equipment and operation, shielded metal arc welding is one of the world's first and most popular welding processes.

It dominates other welding processes in the maintenance and repair industry, and though flux-cored arc welding is growing in popularity, SMAW continues to be used extensively in the construction of heavy steel structures and in industrial fabrication. The process is used primarily to weld iron and steels (including stainless steel) but aluminium, nickel and copperalloys can also be welded with this method



1.1Fig SMAW process

The shielded metal arc welding process is one of the simplest and most versatile arc welding processes. It can be used to weld both ferrous and non-ferrous metals**,** and it can weld thicknesses above approximately 18 gauges in all positions. The arc is under the control of the welder and is visible. The welding process leaves slag on the surface of the weld bead which must be removed.

- Area of application
- Structural work
- Pressure vessels
- Piping
- Maintenance welding
- Site construction
- General fabrication.

1.2. Advantages and disadvantages of shielded metal arc welding

Advantages of shielded metal arc welding

- Shielded Metal Arc Welding (SMAW) can be carried out in any position with highest weld quality.

- MMAW is the simplest of all the arc welding processes
- This welding process finds innumerable applications, because of the availability of a wide variety of electrodes.
- Big range of metals and their alloys can be welded easily.
- The process can be very well employed for hard facing and metal resistance etc.
- Joints (e.g., between nozzles and shell in a pressure vessel) which because of their position are difficult to be welded by automatic welding machines can be easily accomplished by flux shielded metal arc welding.
- The MMAW welding equipment is portable and the cost is fairly low.

Disadvantages (Limitations) of shielded metal arc welding

- Due to flux coated electrodes, the chances of slag entrapment and other related defects are more as compared to MIG and TIG welding.
- Duo to fumes and particles of slag, the arc and metal transfer is not very clear and thus welding control in this process is a bit difficult as compared to MIG welding.
- Due to limited length of each electrode and brittle flux coating on it, mechanization is difficult.
- In welding long joints (e.g., in pressure vessels), as one electrode finishes, the weld is to be progressed with the next electrode. Unless properly cared, a defect (like slag inclusion or insufficient penetration) may occur at the place where welding is restarted with the new electrode
- The process uses stick electrodes and thus it is slower as compared to MIG welding

1.3. Work order and drawing

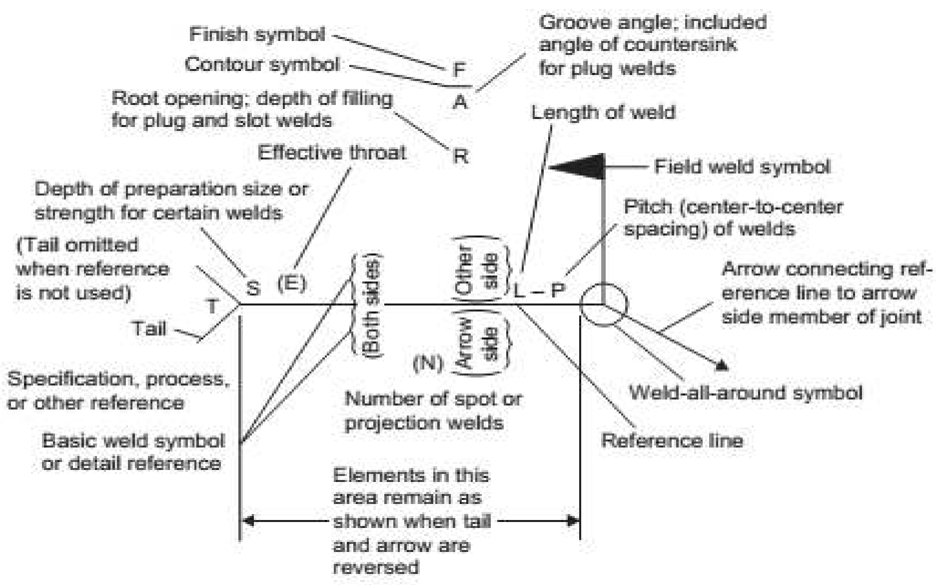
Work order is documents that summarize the detail of particular that must be done. Work order including the person requesting the work management authorization, the technical completing the work and he location deadline .they should detail the location of the work, instruction for the task and parts and tools required

2.1.1. Welding drawings symbol

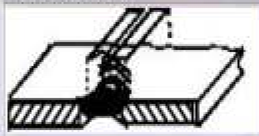
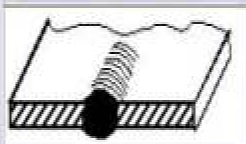
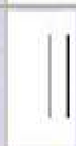
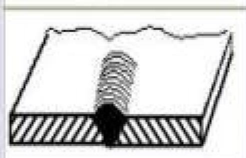
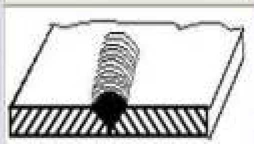
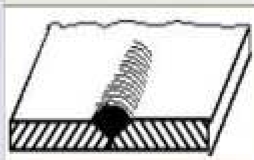
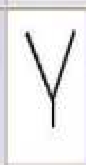
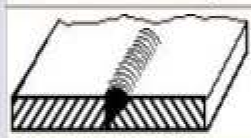
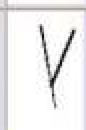
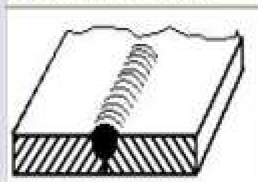
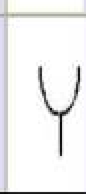
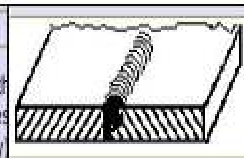
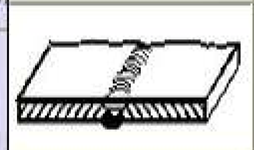
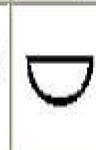
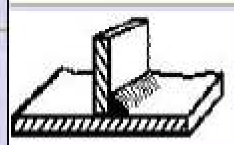
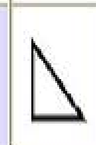
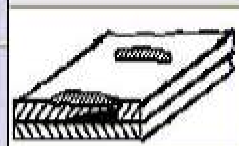
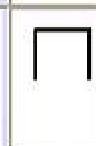
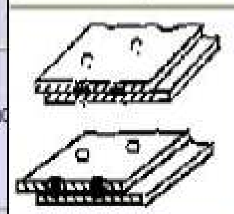
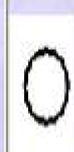
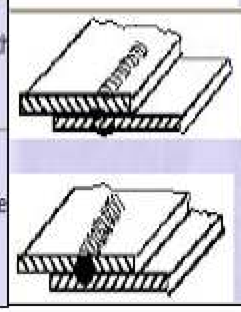
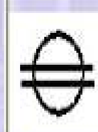
Symbols for indicating welded joints on engineering drawings were originally devised by individual drawing offices to provide more useful information than a simple arrow with the instruction 'weld here'. This practice was obviously unsatisfactory, especially when drawings were passed from one company to another and, to solve this problem, the numerous symbols in existence were rationalized to some extent by countries compiling their own standard specifications for welding symbols.

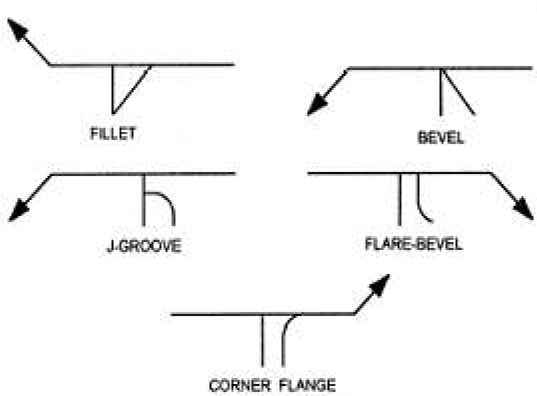
Welding works from order and drawings

The American system of symbolization is the AWS system, formulated by the American Welding Society (AWS). All AWS standards comply with the requirements of the American National Standards Institute (ANSI) and are designated ANSI/AWS. This system became widely used throughout the world, mainly because of the oil industry, and today is used by approximately half the world's welding industry. The rest of the world uses the ISO system, designed by the International Organization for Standardization (ISO). However, a number of countries, particularly those with wide trading links, may use one system in their own country but need to use the other to satisfy the requirements of an overseas customer



1.2Fig Standard location of elements on the welding symbol

Illustration (Fig)	Symbol	Description
		Butt weld between plates with raised edges*(the raised edges being melted down completely)
		Square butt weld
		Single-V butt weld
		Single-bevel butt weld
		Single – V butt weld with broad root face
		Single – bevel butt weld with broad root face
		Single – U butt weld (parallel or sloping sides)
		Single – J butt joint
		Backing run; back or backing weld
		Fillet weld
		Plug weld; plug or slot weld
		Spot weld
		Seam weld



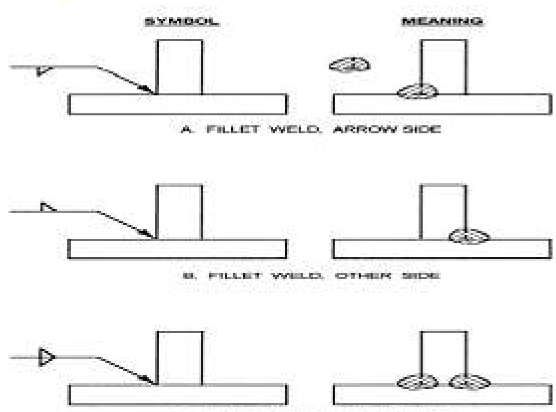


Fig .1.3Weld symbols applied to reference line Specifying weld location

2.1.2. Correct size, type and quantity of materials

2.1.3. Manual metal arc welding (MMAW) electrodes

The manual metal arc welding electrode consists of a core of wire surrounded by a flux coating. The wire is generally of similar composition to the metal to be welded. The flux is applied to the wire by the process of extrusion. For welding carbon and low alloy steels (the metals most commonly fabricated using the MMAW process) electrodes will have one of **four flux types**, either

- cellulose type coating
- retile type coating
- hydrogen controlled coating (low hydrogen)
- Iron powder type coating.

Functions of the flux coating

In the early days of arc welding, bare wire electrodes were used. The results obtained from these electrodes left much to be desired. Over the years, electrodes have improved and flux coatings have evolved to the stage where the deposited weld metal, in many cases, has better metallurgical properties than the parent metal.

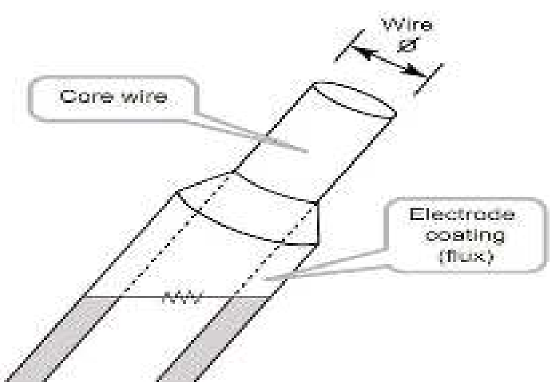


Fig1.4 5 construction

Coating Core wire

- Extruded as paste, dried to strengthen
- Dipped into slurry and dried (rare)
- wound with paper or chord (obsolete

- Solid or tubular
- 2mm to 8mm diameter,
- 250 to 450mm long

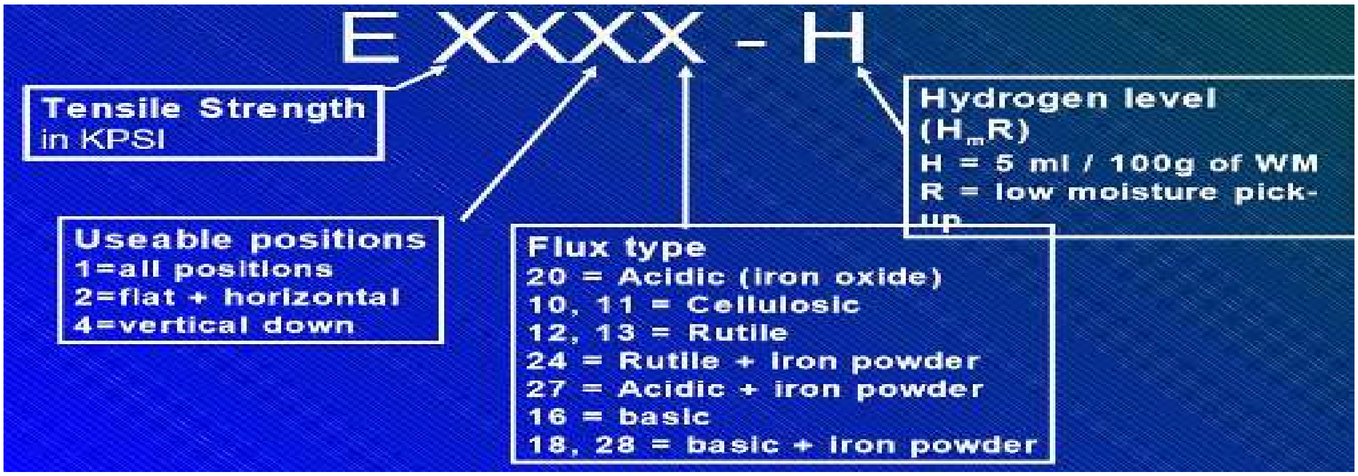


Fig1.5 electrode specification

Types of Flux

- Cellulosic
- Rutile
- Basic

1. Cellulosic coatings

As these electrode coatings are designed to operate with a definite amount of moisture in the coating, they are less sensitive to moisture pick-up and do not generally require a drying operation. However, in cases where ambient relative humidity has been very high, drying may be necessary.

2. Rutile coatings

These can tolerate a limited amount of moisture and coatings may deteriorate if they are over dried. Particular brands may need to be dried before use.

3. Basic and basic/retile coatings

Because of the greater need for hydrogen control, moisture pick-up is rapid on exposure to air. These electrodes should be thoroughly dried in a controlled temperature drying oven.

Typical drying time is one hour at a temperature of approximately 150 to 300 degrees C but instructions should be adhered to.

After controlled drying, basic and basic/rutile electrodes must be held at a temperature between 100 and 150 degrees C to help protect them from re-absorbing moisture into the coating. These conditions can be obtained by transferring the electrodes from the main drying oven to a holding oven or a heated quiver at the workplace

2.1.4. Quantity Calculations

A. the Basis of Estimates Manual describes the method of measurement, basis of payment and required rounding accuracy for frequently used items. Calculate quantities to one additional decimal place of precision compared to input.

B. Calculate quantities by construction phase for each individual component e.g. end bents, deck, traffic and pedestrian railings, expansion joints, bearings, reinforcing steel, riprap, slope pavement, etc. For multiple adjacent bridges, whether built in phases or at the same time, include quantities and quantity breakdowns with the individual bridge they are associated with. For adjacent bridges with continuous slope treatments or other similar features, e.g. median separated bridges, clearly indicate the quantity breakdowns for each bridge in the plans. For pay items with a sub-unit measurement, calculate the sub-units, and include the quantity in the plans only if required by the Basis of Estimates Manual

2.1.5. Classification and Uses of Metals

A, Ferrous metals

Ferrous metals may be defined as those metals whose main constituent is iron such as pig iron, wrought iron, cast iron, steel and their alloys. They are usually stronger and harder and are used in daily life products. They possess a special property that their characteristics can be altered by heat treatment processes or by addition of small quantity of alloying elements. Ferrous metals possess different physical properties according to their carbon content.

B, Non-ferrous metal

Non-ferrous metals are those which do not contain significant quantity of iron or iron as base metal. These metals possess low strength at high temperatures, generally suffer from hot

1. High corrosion resistance
2. Easy to fabricate, i.e., machining, casting, welding, forging and rolling
3. Possess very good thermal and electrical conductivity
4. Attractive color and low density

The various non-metals used in industry are: copper, aluminum, tin, lead, zinc, and nickel, etc., and their alloys

1.4. Prepare the materials

Before work pieces can be welded by means of gas fusion welding or arc welding, the weld edges must be cleaned. Oil, wax layers, paint or scale must be removed. The welding points must also **Sand blasting** be metallically clean, as without these preparations the welds would not last.

Lathing and other mechanical (chip removal) methods are very suitable methods for cleaning the welding points. Attention must be paid to ensuring that the tools always have

Sharply round cutting edges. Avoid lubricating the metal. Therefore, no coolants or lubricants may be used.

If weld preparation is carried out on aluminum, attention must be paid to ensuring that the abrasive has been explicitly approved or recommended for aluminum by the manufacturer. is also a possible method for preparing the weld. However, in this case attention must be paid to ensuring that the blasting material (grit or shot) is appropriately matched with the material to be welded. The manufacturers usually provide relevant information.

Manual cleaning is also a possible method for preparation of the weld. Only stainless steel brushes should be used for this. Other brushes can cause inclusions of carbon steel to occur in the parent metal. The diameter of the wire should be between 0.1 and 0.25mm. If the wires are too thin they smear the dirt and if they are too thick they cause deep scratches on the surface or edge to be welded.

1.5. Assemble /align Material specification

Welding is a well-known and widely-used method used to permanently join together two pieces of metal tubing or other wieldable material. To accomplish a weld of high integrity, the two pieces to be joined together must be properly aligned.

Misalignment during welding creates discontinuities at the abutment junction of the two pieces of wieldable material that can serve as havens for particle impurities. The existence of these particle "sites" is intolerable when the welding is being performed in connection with ultra-pure applications such as are common in the semiconductor industry.

Moreover, misalignment can result in a leaky junction that destroys the purity of the substance flowing through the tubing and creates a potentially dangerous external environment if the substance flowing through the tubing is toxic. Thus, it is highly desirable to minimize tube misalignment when welding.

Maintaining proper alignment during the conventional welding process, however, is a time-consuming and difficult task. The pieces of wieldable material to be aligned and welded must be clamped tightly in alignment before and during the welding process, or the pieces will tend to slip out of alignment before the weld is completed.

Alignment Tools

The most common tools used to layout and check joint fit-ups are straightedges,

A. squares,

B. levels

C. Hi-lo gauges.

A. squares

- Two types of squares are used for layout: pipefitter's square and a combination square.
- Pipefitter's square is used to measure angles and check square nests.
- Combination squares are smaller with blades typically 12" or 18" long.
- They have replaceable attachments that slide along the blade.

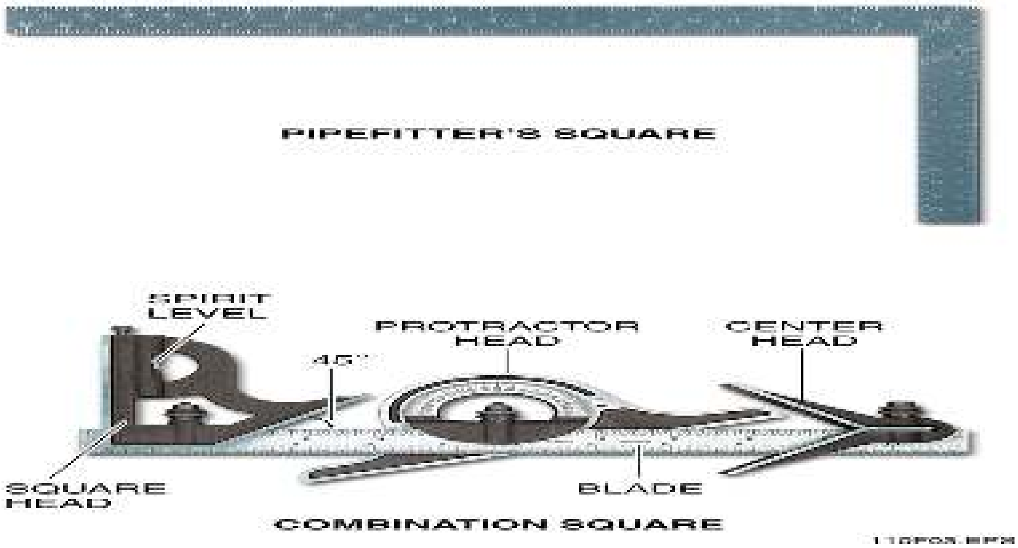


Fig. 1.6.Hi-lo-gauges

B, Levels

Levels come in a variety of sizes and shapes.

- Some have magnetized bases.
- Levels are used to check that layouts are level (horizontal) and plumb (vertical).
- Levels use a bubble in a glass vial to check level and plumb.
- Centering the bubble between the lines marked on the vial indicates level or plumb.

Some levels have a 45 degree vial

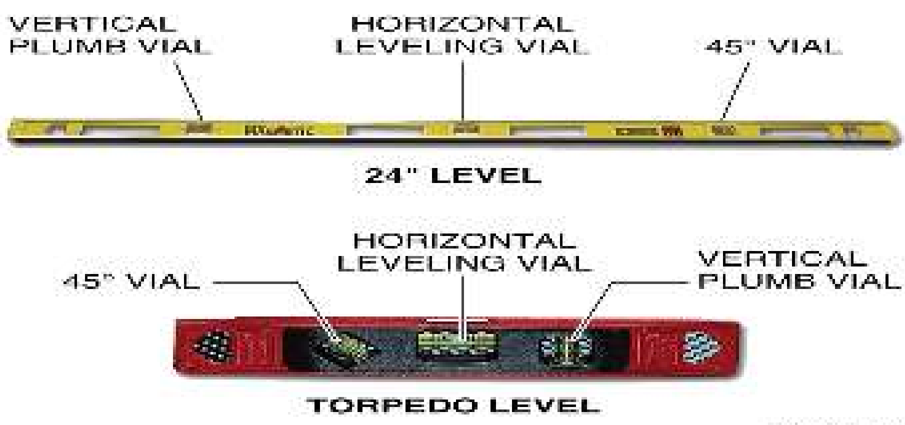


Fig. 1.7 level

C, Hi-Lo Gauges

- The primary purpose of a Hi-Lo gauge is to check for pipe joint misalignment.
- The name of the gauge comes from the relationship between the alignments of one pipe to the other pipe, which is called high-low

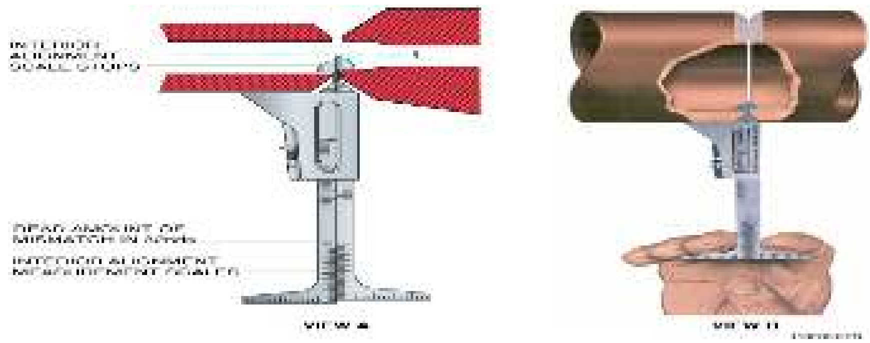


Fig. 1.8 Hi-Lo Gauges

1.6. Welding machine, accessories

1.6.1. Arc Welding Machine

Arc welding machines are classified as either AC or DC. DC welding machines may be motor driven generators, or rectifier welders, figure b. A rectifier is a device which converts AC to DC. Since the DC rectifier welder is most commonly used in shops and in school laboratories, the welding student should concentrate on that type

1.6.2. DC welding machines

Direct Current, Straight Polarity (DCSP)

When the parent metal is connected to the positive side of the welder, and the electrode (rod) holder is connected to the negative side of the welder; the circuit is in *straight polarity.* With the electrode negative the current travels from the electrode to the base metals Two-thirds of the total heat produced is released at the base metal and one-third is released at the electrode. **Direct Current, Reverse Polarity (DCRP)**

When the parent metal is connected to the negative side of the welder, and the electrode holder is connected to the positive (+) side of the welder, the circuit is called *reverse polarity.* With the electrode positive the current travels from the base metal to the electrode, figure d. Two-thirds of the total heat is released at the electrode and one-third is released at the base metal.

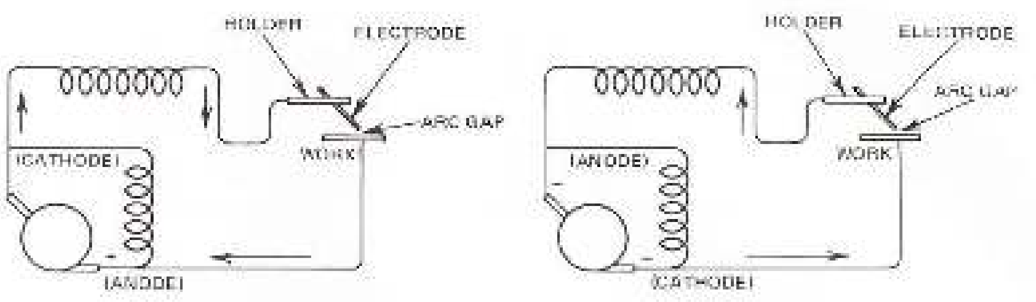


Fig .1.9.(a) wiring diagram, DCSPFig.1.0.(b) wiring diagram, DCRP

1.6.3. Alternating current

Most AC welders, figure e, have transformers which step down the voltage and increase the welding current. Electric current furnished by most electric utilities is 60-cycle, alternating current. (The current reverses its direction of flow 120 times per second.) Approximately 50 percent of the heat is released at the parent metal and 50 percent at the electrode.

Fig.1.11. Welding Machine

The following factors influence the selection of a power source:

- Type of electrodes to be used and metals to be welded
- Available power source (AC or DC)
- Required output
- Duty cycle
- Efficiency

- Initial costs and running costs
- Available floor space
- Versatility of equipment

Aspects	AC welding	DC welding
Power consumption	Low	High
Arc stability	Arc unstable	Arc stable
Cost	Less	More
Weight	Light	Heavy
Efficiency	High	Low
Operation	Noiseless	noisy
Suitability	Only ferrous	Suitable for ferrous and non ferrous
Electrode used	Only coated	bare electrode
Welding of thin sections	Not preferred	preferred

1.7. Tools and equipment

Welding cables

Welding cables are required for conduction of current from the power source through the electrode holder, the arc, the work piece and back to the welding power source. These are insulated copper or aluminium cables.

Electrode holder

Electrode holder is used for holding the electrode manually and conducting current to it. These are usually matched to the size of the lead, which in turn matched to the amperage output of the arc welder. Electrode holders are available in sizes that range from 150 to 500 Amps.

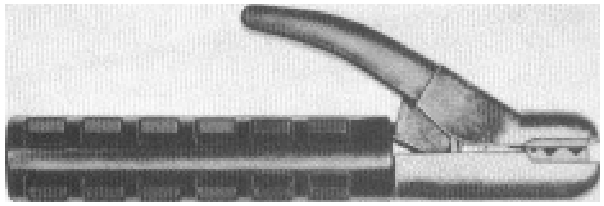


Fig.1.11 **Electrode holder**

Helmet

The helmet is generally made of fiber, and formed to cover the front half of the welder's head, figure I. An opening is provided in front of the eyes, and a clear-glass cover lens is installed in the opening. Behind the cover lens is a colored glass which filters the infrared and ultraviolet rays from the arc. The clear-glass lens is provided to catch the spatter from the welding process

Fig1.12.. Helmet

Chipping hammer

Chipping Hammer is used to remove the slag by striking.

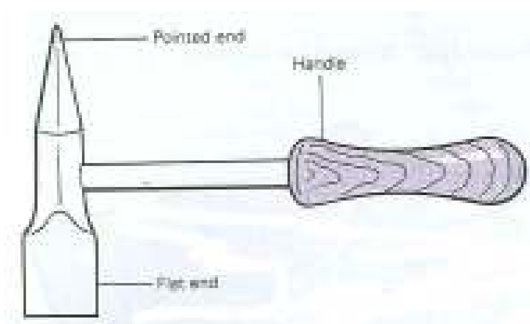


Fig.1.13.chipping hammer

Wire brush

- To produce a strong welded joint, the surface of the metal must be free of all foreign matter such as rust, oil, and paint
- Wire brush is used to clean the surface to be weld.

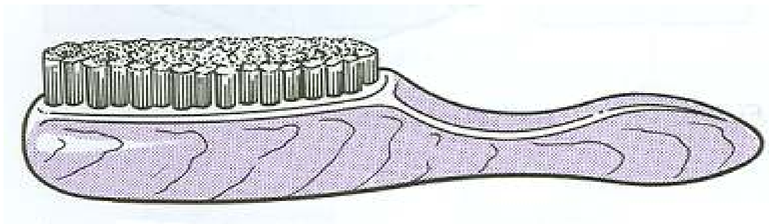


Fig.1.14. Wire brush

Ground Clamp

Clamps are used to fasten the cables to work piece or table where the work piece is positioned so the welding circuit will be completed, and some operate with spring pressure while others are magnetic**.**

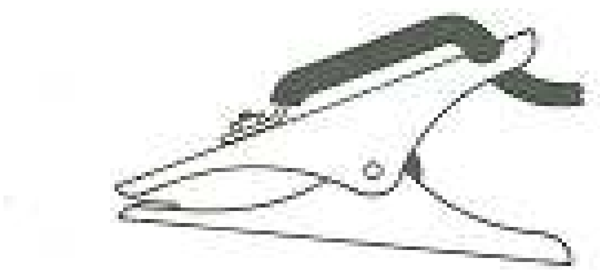


Fig.1.15. ground clam

1.8. Standardize working area

Tousling Standardize working area to achieve safe working conditions in the metal fabrication and welding industry, to implement 5S are five terms beginning with "S" utilized to create a workplace suited for visual control and lean production.***5S*** is a systematized approach to organize work areas, keep rules and standards, and maintain the discipline needed to do a good job.***5S*** means good housekeeping and workplace organization

All Personnel should be able to recognize the hazards which apply to their particular Occupation. Welding operators must also know the correct operating procedures for the Equipment.

An operator can be subjected to many safety hazards associated with the industry. As

With any other industrial worker, they may be injured through incorrect lifting practices,

Falling or tripping, or incorrect use of hand tools and machines. The operator will also encounter particular hazards associated with welding.

A clean, tidy workplace, free from combustible materials, is an essential requirement for the safety of welding personnel. Additionally, others working in the vicinity of welding operations are at risk from hazards such as electrocution, fumes, radiation, burns or flying slag and noise. They too must be protected if their health and safety is not to be put at risk.

Self-check - 1

Directions: Answer all the questions listed below.

Test-I choose

Instruction: **choose the best answer** for the give choice. You have given 1 Minute for each question. Each question carries 2 Point.

1. Which one of the following is not the function of electrode coating?

A. Provide deoxidizers and scavengers C. decrease deposit rate

B, Produce shielding gases D. Produce a slag covering

2. E7 043—H, what position is the number 4 indicates

A. All position C. hydrogen

C. Flux type D. vertical position

3. From the following one is the range to diameter of electrode

A.2 mm to 8 mm C. 200 mm to 500 mm

B, 250 mm to 450 mm D. 3

4. Which one the following not part of Welding machine, accessories

A. Electrode B, ground clamp

C. wire brush D. chipping hammer

5. Which of the Following are the other names of shielding metal arc welding?

A. Manual metal arc welding C. stick welding

B. submerged arc welding D. A and C

Test II: true or false

Instruction: Say true or false for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. The pieces of wieldable material to be aligned and welded must be clamped tightly in alignment before and during the welding process.
2. The primary purpose of a Hi-Lo gauge is to check for plate joint misalignment.

3. To accomplish a weld of high integrity, the two pieces to be joined together must be properly aligned

Part III short Answer writing

Instruction: write short answer for the given question. You are provided 3 minute for each question and each point has 5Points.

1. What is the difference ac and dc welding machine?
2. Write Types of Flux?

Operation sheet-1 Prepare the materials

Operation title: Prepare the materials

Purpose: prepared the material for SMAW welding

Instruction: Prepare the necessary material for perform SMW process

Tools and requirement:

PPE, hand grinding and layout tool

AC or DC welding machinery and accessory

Precautions: clean and prepare the material

Procedures in doing the task

Step1. Safety (clean work area &wear PPE)

Step2. Select proper tools and equipment.

Step3. Identify materials.

Step4. Lay out

Step5. Cut the metals.

Step6. Grinding metals.

Step7. Clean the metal

Step8. Clean the work area

Quality Criteria: according to SMA process

Precautions:

Lap Test

Task-1: Perform prepare material

`

Unit Two: Welding Machine / Equipment, Accessories and Fixtures

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Accessories and consumables.
- Connect welding machines
- current and voltage
- Stiffeners, rails and other jigs.
- distortion preventing measures

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify and selecting welding machine settings, accessories and consumables.
- Perform Connect welding machines
- Adjust current and voltage
- Provide and in conformity of Braces, stiffeners, rails and other jigs
- Apply distortion preventing measures

2. Welding machine settings, accessories and consumables

2.1. Welding machine settings

1. Turn power supply on
2. Connect work clamp
3. Select electrode
   a. Type
   b. Diameter
4. Adjust output
a. Polarity
b. Amperage
6. Insert electrode into electrode holder

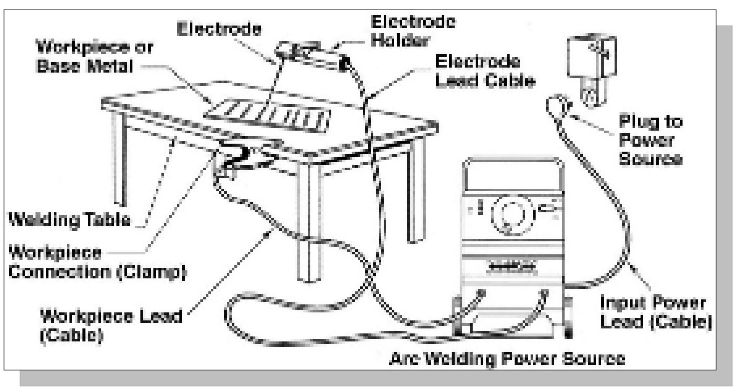


Fig.2.1weldimg machine set

2.2. Connect welding machines

To supply the electrical energy necessary for arc welding processes, a number of different power supplies can be used. The most common classification is constant current power supplies and constant voltage power supplies. In arc welding, the voltage is directly related to the length of the arc, and the current is related to the amount of heat input. Constant current power supplies are most often used for manual welding processes such as gas tungsten arc welding and shielded metal arc welding, because they maintain a relatively constant current even as the voltage varies. This is important because in manual welding, it can be difficult to hold the electrode perfectly steady, and as a result, the arc length and thus voltage tend to fluctuate. Constant voltage power supplies hold the voltage constant and vary the current, and as a result, are most often used for automated welding processes such as gas metal arc welding, flux cored arc welding, and submerged arc welding. In these processes, arc length is kept constant, since any fluctuation in the distance between the wire and the base material is quickly rectified by a large change in current. For example, if the wire and the base material get too close, the current will rapidly increase, which in turn causes the heat to increase and the tip of the wire to melt, returning it to its original separation distance.

2.3. Wiring up /setting to polarity indicated in the welding procedures

- Polarity indicates the direction of the Current in that circuit. Since the current moves in one direction only in DC welders, polarity is important because for some welding operations the flow of current must be changed.
- When the electrode holder cable is connected to the negative pole of the welding machine and the work to the positive pole, the polarity is direct current negative (DC) or more commonly referred to as straight polarity.
- If the electrode holder cable is connected to the positive pole of the welding machine and the cable leading to the work to the negative pole, the circuit is called direct current positive (DC +) or reverses polarity.
    - **Three different Polarities in welding**

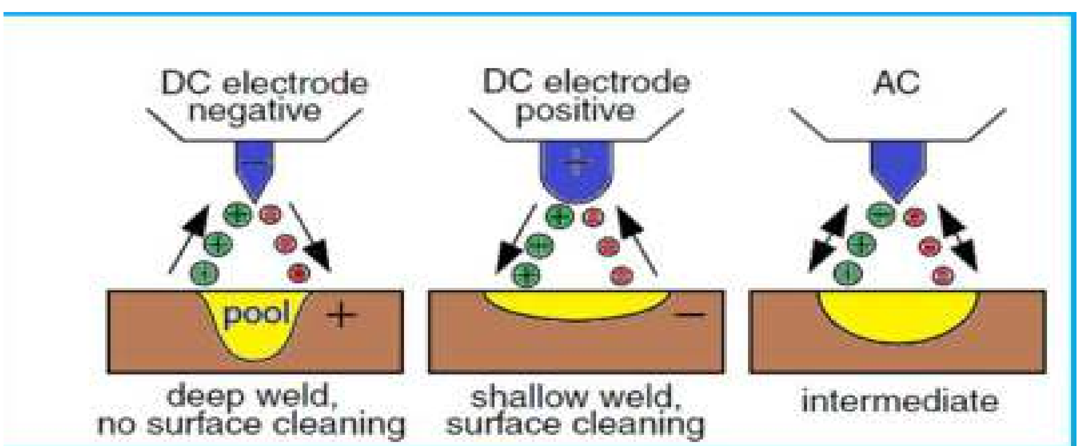


Fig 2.2 different Polarities

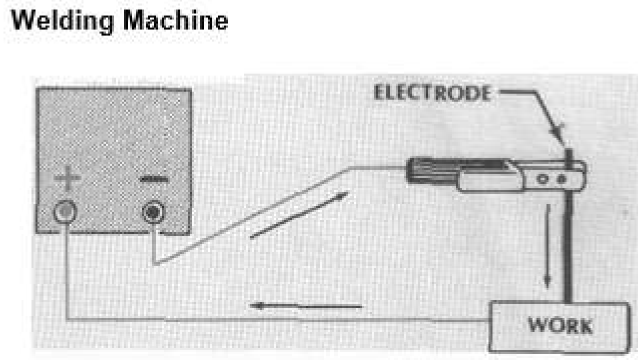


Fig 2.3 in the straight polarity circuit, current flows from the electrode to the work

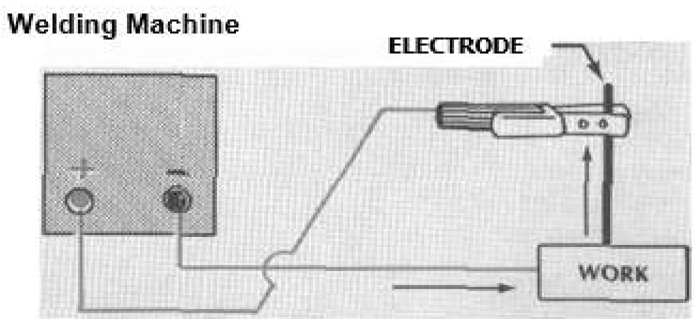


Fig.2.4 In the reverse polarity circuit, current flows from the work to the electrode.

2.4. Adjust current and voltage

Introduction

All arc welding processes have a few basic requirements for their operation. They must have a safe voltage available that is sufficient for the operator to get the arc started and be maintained. They also require sufficient amperage to provide the heat for melting of the parent metal and filler material

2.3.2Power supplies

To supply the electrical energy necessary for arc welding processes, a number of different power supplies can be used. The most common welding power supplies are constant current power supplies and constant voltage power supplies. In arc welding, the length of the arc is directly related to the voltage, and the amount of heat input is related to the current.

Constant current power supplies are most often used for manual welding processes such as gas tungsten arc welding and shielded metal arc welding, because they maintain a relatively constant current even as the voltage varies. This is important because in manual welding, it can be difficult to hold the electrode perfectly steady, and as a result, the arc length and thus voltage tend to fluctuate. Constant voltage power supplies hold the voltage constant and vary the current, and as a result, are most often used for automated welding processes such as gas metal arc welding, flux cored arc welding, and submerged arc welding. In these processes, arc length is kept constant, since any fluctuation in the distance between the wire and the base material is quickly rectified by a large change in current. For example, if the wire and the base material get too close, the current will rapidly increase, which in turn causes the heat to increase and the tip of the wire to melt, returning it to its original separationdistance.

The type of current used in also plays an important role in arc welding. Consumable electrode processes such as shielded metal arc welding and gas metal arc welding generally use direct current, but the electrode can be charged either positively or negatively.

2.3.3 Selection of type of Welding Current

It is important to consider various aspects while selecting suitable type of welding current for developing weld joints in a given situation. Some of the points need careful considerations for selection of welding current are given below.

1. Thickness of plate/sheet to be welded: DC for thin sheet to exploit better control over heat;

2. Length of cable required: AC for situations where long cables are required during welding as they cause less voltage drop i.e. loading on power source;

3. Ease of arc initiation and maintenance needed even with low current: DC preferred over AC;

4. Arc blow: AC helps to overcome the arc blow as it is primarily observed with DC only;

5. Odd position welding: DC is preferred over AC for odd position welding (vertical and overhead) due to better control over heat input.

6. Polarity selection for controlling the melting rate, penetration and welding deposition rate: DC preferred over AC

7. AC gives the penetration and electrode melting rate somewhat in between that is offered by DCEN&DCEP**.**

2.3.4Welding Currents

Generally, the amperage at which the rod runs most readily is indicated by the manufacturer.Differences in rod diameter and in material used for the flux coating require differences in the current settings used.

Table 2.1 indicates current settings which generally give satisfactory results.

Diameter of Electrode	Amperage Used					
	E-6010	E-601 1	E-6012	E-6013	I E-6020	E-6030
1/8"	80-120	80-120	80-130	70-120	100-140	100-140
5/32"	120-160	120-160	120-180	120-170	120-180	120-180
3/16"	140-220	140-220	140-250	140-240	*175-250*	*175-250*

Stiffeners, rails and other jigs

2.4.1 Fixtures and Tooling Holes

Tooling holes or other self-locating features on parts being welded into an assembly are of utmost importance and should therefore be part of the original design whenever possible. The significance of these features is the economical and quality impact they have on the finished product. This is especially true for smaller, close tolerance assemblies

2.4.2Use Jigs and Fixtures

Fixtures and jigs are devices used to hold the parts to be welded in proper relation to each other. This alignment is called fit-up. Good fit-up is required for obtaining high quality welds. Poor fit-up increases welding time and causes many poor quality welds. The size of the root opening has an effect on the speed at which the welding of the root pass can be accomplished. Root openings are used so that full penetration welds can be made. Root passes in joints with a proper root opening can be welded much faster than joints that have excessive root opening. Fixtures and jigs are used for three major purposes:

1. To minimize distortion caused by welding heat
2. To minimize fit-up problems
3. To increase the welding efficiency of the welder.

When a welder employs a welding fixture or jig, the components of a weldment can be assembled and securely held in place while the weldment is positioned and welded. The use of those devices is dependent on the specific application. These devices are more often used when a large number of similar parts are produced. Using fixtures and jigs, when possible can greatly reduce the production time for the weldment

2.4.3 Welding Jig

A jig is a large brace that keeps a welding project stable in the face of pressure, heat, motion, And force. A quality jig will streamline welding work by keeping parts together in a vice grip. Whether the welding is entirely manual, partially automatic, or fully robotic, a jig moves the work piece while the tool remains stationary.

2.4.4Stiffeners

Stiffeners are typically plate welded to the web. This plate cab be applied to either just one side of the web or both side. By addition of these extra plates we increase the moment of inertia of plate girder which enhances the rigidity in turns it prevents buckling

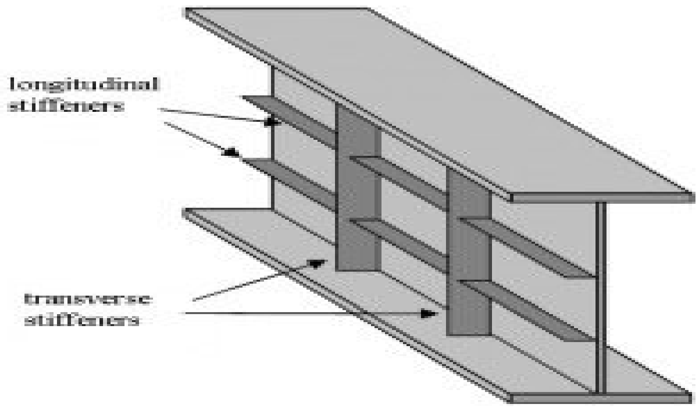


Fig2.5stiffeners

The **longitudinal stiffener** can increase shear and bending strengths of plate girder. Generally, they are not essential as transverse stiffeners.

Transverse stiffeners are provided under the outward projection of the flange. But, however there is also a chance that when the transverse stiffeners take load from the flange, they may exposed to *buckling*, as in case of a **column**. So to avoid the buckling of the stiffeners

2.5. Distortion preventing measures

2.5.1. The Nature of welding distortion

The definition of distortion given in the Oxford Dictionary states that it is 'the action or an act of distorting or twisting out of shape (permanently or temporary)'.Also, the distorted condition is 'a condition of the body ... in which it is twisted out of its natural shape'. Distortion is a problem that exists in all industrial metalworking processes that employ heat and has been a serious problem for engineers since the early 1930s. With the introduction of welding in shipbuilding, it became necessary to control the dimensional changes of metal plates, stiffeners and assemblies that occur during welding process. The magnitude of distortion is controlled in practice within specified tolerances, not only for aesthetic purposes but also to maintain structural integrity in service. The complex strain that develops during welding leads to internal forces that cause complex metal movement during welding and final distortion. There are three fundamental dimensional changes that occur during the welding process and in the ways in which distortion can appear

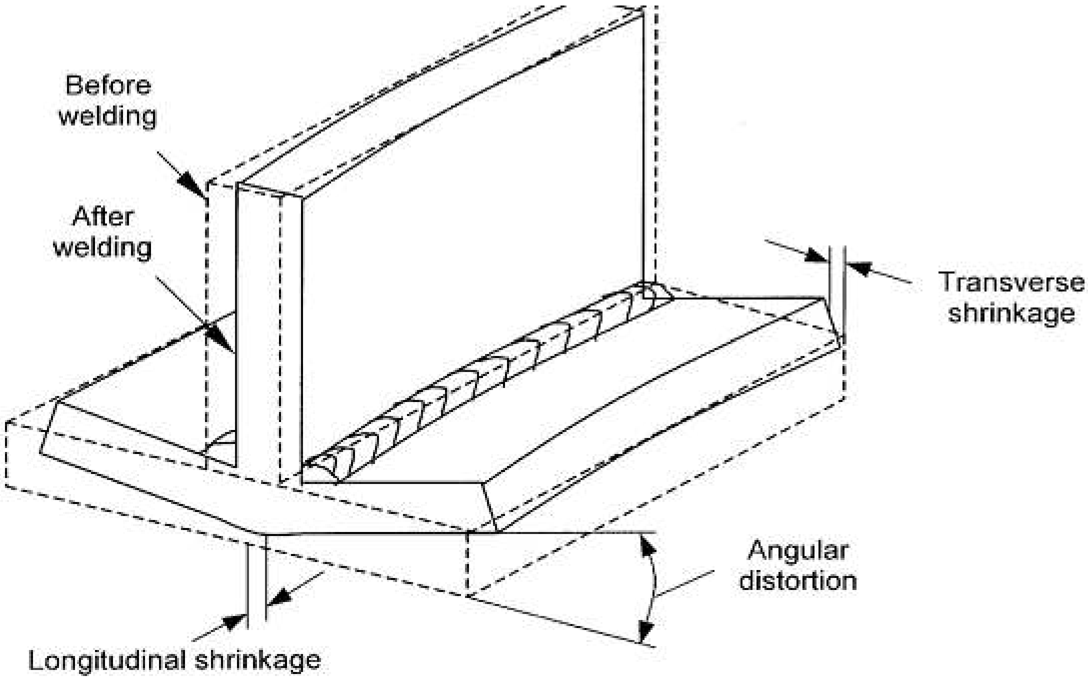


Figure 2.6 are principally

2.5.2 The types of Distortion

(a) Transverse shrinkage perpendicular to the weld line

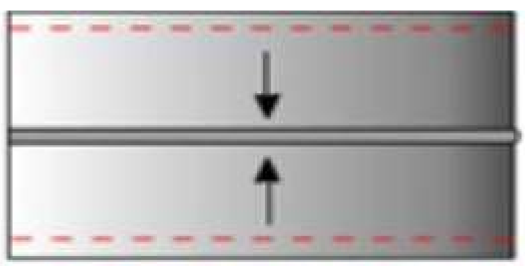


Figure 2.7Transverse shrinkage

(b) Longitudinal shrinkage parallel to the weld line

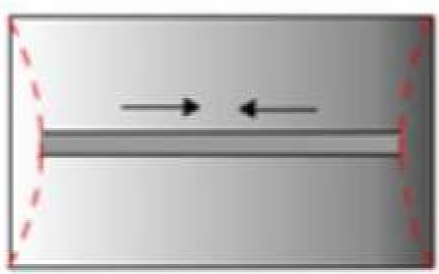


Figure 2.8 Longitudinal shrinkage

(c) Angular distortion around the weld line.

Figure 2.9 Angular distortion

(d)Bowing and dishing

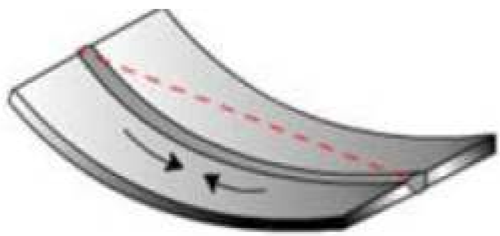


Figure 2.10 Bowing

(e)Buckling

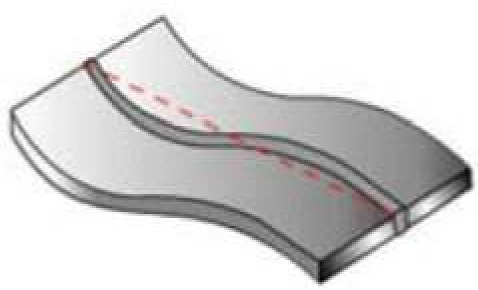


Figure 2.11 Bucklin

The severity of each of these will depend upon many factors. Depending on the configuration and dimensions of the structure it is possible to classify the basic types of distortion such as transverse and longitudinal shrinkage, rotational, angular, longitude dial bending, tensional and

Buckling distortion. The problem here is that in real structure, especially in the case of a complex structure, which has various types of joint, all these types of distortion are Combined.

2.5.2. Distortion Control

The process of minimizing the potential distortion in an object, such as controlling the stress distribution from welding. The methods of distortion control in welding have been well summarized in several publications as follows.

- **Prevention by design of welded structures**. At the design stage, welding distortion can often be prevented, or at least reduced, by considering:

(a) Weld placement closer to the neutral axis of a fabrication;

(b) The effect of stiffener spacing and plate thickness;

(c) reducing the size and amount of welding to the minimum required for strength, elastic stability and balanced design;

(d) Elimination of welds by forming the plate or using rolled or extruded section;

(e) joint-type design, which balances the thermal stress through the plate thickness;

(f) Use of new alternative construction materials (e.g. SPS).

Techniques based on assembly procedures and pre-welding conditions

These are:

(a) Minimization of residual stresses and initial distortion in delivered materials;

(b) Presetting method (which is mainly employed in subassemblies);

(c) restrained method entailing:

(i) Use of strong backs, jigs and fixtures,

(ii) Back-to-back assembly,

(iii) Tack welding and

(iv) Stiffening

2.5.3Correction of distortion

It is not always possible to control distortion within acceptable limits, especially with a new fabrication. In such circumstances, it is usually possible to remove distortion by producing adequate plastic deformation on the distorted member or section.

The required amount of plastic deformation can be obtained by thermal or mechanical methods.

- **Mechanical method**. Distorted members can be straightened with a press or jacks. When welded parts are small enough to be handled to straightening rolls or a press, it is often cheaper to straighten the parts cold after welding.
- **Thermal method.** The distorted area is straightened by heating spots or lines to 600–650 °C and quenching. This procedure will cause the material to upset during heating and then shrinkage stresses will tend to straighten the plate or beam. There are various ways in which such local heating can be applied to remove distortion, but it is only by experience that the best method can be selected for any particular job. In all cases the greatest danger is in over shrinking the area being heated, as this may cause even worse distortion

Self check-2

Test-I Matching

Instruction: select the correct answer for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

A	B
-------1. Longitudinal shrinkage	A. parallel to the weld line
--------2. Angular distortion	B. around the weld line
---------3. Transverse shrinkage	C. perpendicular to the weld line

Test II: choose

Instruction: **choose the best answer** for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. _____indicates the direction of the current in the circuit.
   A. Voltage C. polarity
   B. Amperage D. power
2. Which one of the following is the current flows from the electrode to the work piece
   A. Straight polarity C. indirect polarity
   B. Reverse polarity D. none of the above
3. The voltage is directly related to_______________
   A. The length of the electrode C. The amount of heat input.
   B. the length of the arc D. the amount of current input

Test II: true or false

Instruction: Say true or false for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. The selection of welding current dispending on the material thickness
2. Different diameter of electrode different current sitting

3. Tack welding is one of distortion control

   Note: Satisfactory rating –above 60% Unsatisfactory - below 60%

Operation sheet 2.1: Accessories and consumables.

Operation title: welding machine set-up

Purpose: To Identify and selecting welding machine set-up

Instruction: Use and read manual properly set-up SMAW welding machine

Tools and requirement

1. PPE
2. Welding machine and Accessories

Procedures in doing the task

Step 1. Wear personal protective clothes PPE

Step 2. Where necessary, wipe or dry any water / moisture / liquid spills around the work area.

Step 3. Remove any flammable matter from the area.

Step 4. Ensure that the area has adequate "ventilation" (fresh air).

Step 5. Where applicable, check that exhaust fans are running and that there is an adequate flow of air through the work area

Step 6. Remove all obstacles or debris that could otherwise cause you to slip, trip, snag or fall whilst you are welding.

Step 7. Position your welding machine in such a way that it is close enough for you to access during the operation

Step 8. Check where the welding cables will be laying and set them in such a way that they don't become "hazardous".

- **Quality Criteria:** properly set-up SMAW
- **Precautions:** properly set-up without damage machine and Accessories

Unit Three: Pre Heating Tools/ Equipment

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- heating equipment
- equipment and tool
- Store Tools and equipment

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Set-up pre-heating equipment
- Perform Operating equipment and tool
- Apply Store Tools and equipment's.

3. Heating equipment

3.1. Purpose of pre-heating

1. Reduce the risk of hydrogen cracking

Hydrogen is a very searching gas that can be liberated by oil, grease, rust etc. and water under the certain conditions. The greatest risk comes from hydrogen generated within the arc from damp or contaminated welding consumables, mainly fluxes or electrode coatings. Hydrogen will form into hydrogen porosity in the welds heat affected zone as the weld solidifies. Given the right conditions it can develop into hydrogen cracks also referred to as cold cracks.

Figure 3.1 hydrogen cracking

2. Heat Affected Zone (HAZ)

A hydrogen crack requires a hard microstructure which is created by a harden able material subject to fast cooling from 800°C(1472°F) to 500°C(932°F). These cracks form in the coarse-grain growth zone in the Heat Affected Zone (HAZ).This is a very hard form of steel crystalline structure. Cooling can be slowed down by applying preheat. Other factors that can help, is maintaining a high inter pass temperature (base materials temperature during welding). This will normally be done by increasing welding amperage and reducing travel speed

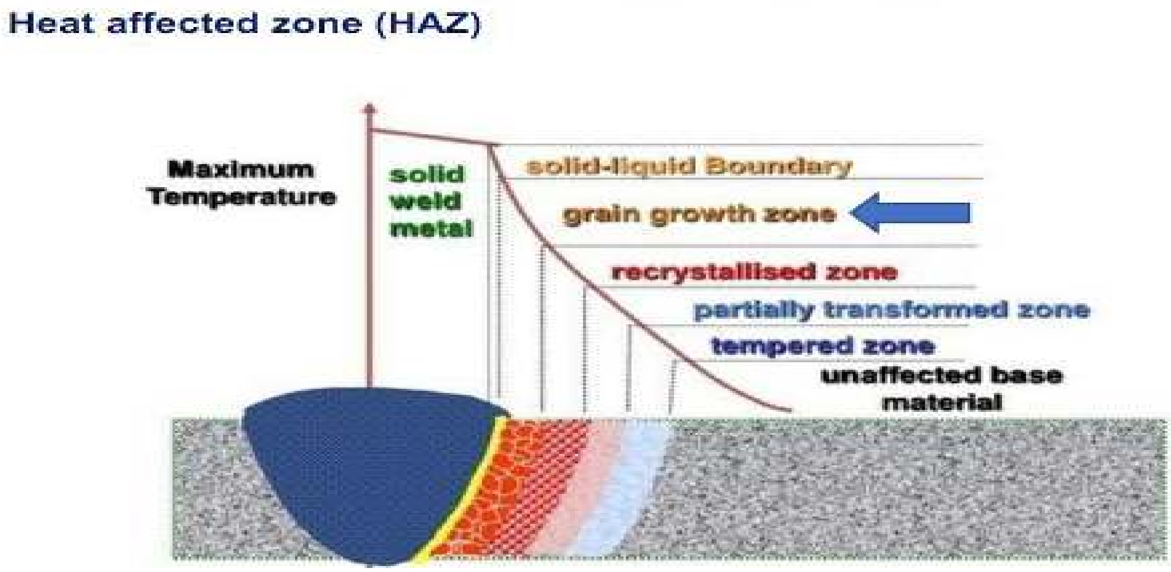


Figure 3.2heat affected zoom

3. **Reduce shrinkage stresses during cooling and improve the distribution of residual stresses.**

The heat developed during welding will result in expansion and contraction. The result can be distortion or stress build-up or a combination of the two. When a hot weld bead cools, it shrinks more than the surrounding cooler metal and thus is strained severely – sometimes so severely that the weld cracks. The more massive the joint, the more strain occurs in the weld bead. If the base metal around the joint is preheated, the base metal and the weld metal shrink more uniformly as the joint cools. This is usually helpful because less strain occurs in the weld bead If all

3 factors are present there is a strong likelihood for cracking to develop after welding and weld cracking is less likely to occur

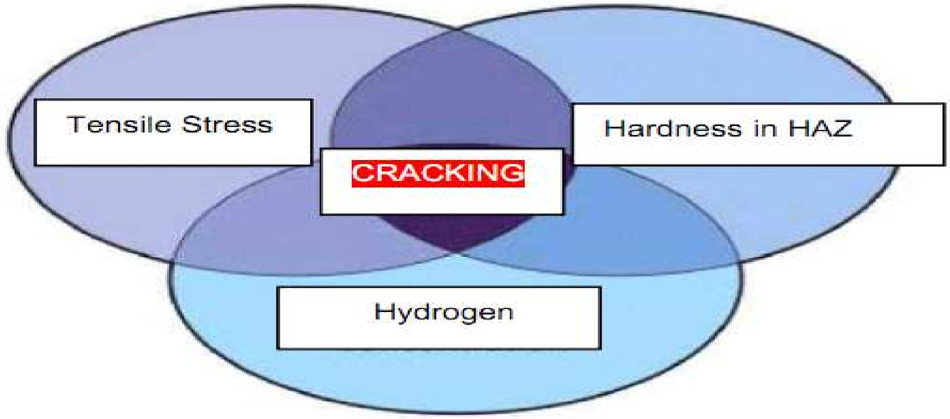


Figure 3.3 factors weld cracking

Typical Recommended Preheats for Various Steels and Cast Iron Welded by the SMAW Process.

Table 3.1

Type of Steel	Preheat
Low-Carbon Steel	Room Temperature or up to 200°F (93°C)
Medium-Carbon Steel	400-500°F (205-260°C)
High-Carbon Steel	500-600°F (260-315°C)
Low Alloy Nickel Steel -Less than ¼' (6.4 mm) thick -More than ¼' (6.4 mm) thick	Room Temperature 500°F (260°C)
Low Alloy Nickel-Chrome Steel -Carbon content below .20% -Carbon content .20% to .35% -Carbon content above .35%	200-300°F (93-150°C) 600-800°F (315-425°C) 900-1100°F (480-595°C)
Low Alloy Manganese Steel	400-600°F (205-315°C)
Low Alloy Chrome Steel	Up to 750°F (400°C)
Low Alloy Molybdenum Steel Carbon content below .150% Carbon content above .15%	Room Temperature 400-650°F (205-345°C)
Low Alloy High Tensile Steel	150-300°F (66-150°C)
Austenitic Stainless Steel	Room Temperature
Ferritic Stainless Steel	300-500°F (150-260°C)
Martensitic Stainless Steel	400-600°F (205-315°C)
Cast Irons	700-900°F (370-480°C)

3.1.3 Importance of Preheating

Preheating is especially important when welding:

Preheating is especially important when welding:

- Highly restrained weld joints.
- Thick materials (the rule of thumb on thickness and when to preheat varies by material type).
- Base materials that tend to be more brittle, such as cast iron, and when welding dissimilar materials.

When recommended by the base material manufacturer. This information often can be found in a table that specifies preheat temperature ranges for a given material thickness

- Highly restrained weld joints.
- Thick materials (the rule of thumb on thickness and when to preheat varies by material type).
- Base materials that tend to be more brittle, such as cast iron, and when welding dissimilar materials.

When recommended by the base material manufacturer. This information often can be found in a table that specifies preheat temperature ranges for a given material thickness Preheating also can be good for materials with a high-carbon equivalency, such as AISI 4130 and 4140. High carbon levels and/or additional alloys can make the material stronger and harder, but also more brittle and less ductile, which can lead to potential cracking issues.

How Are Parts Preheated

Once you have determined that the welding application requires preheating, consider the best method to use. Induction heating is one preheat option that provides consistent heat throughout the weldment. It offers fast time-to-temperature and is considered a very safe option for preheating

3.2. Equipment and tool

Essentially three methods commonly are used to preheat joints:

- Torch heating.
- Induction heating.
- Electrical resistance heating

3.2.1 Torch heating

Torch heating it's just a torch and you simply monitor its temperature with temperature-indicating sticks. Once you see the sticks melt, you know you've reached the minimum preheat temperature and you start welding. While it is portability and affordability method, also notes that it is, by its very nature, not as accurate as the other technologies available.

It is very easy to overheat the steel past your maximum inter-pass temperatures. You also don't get even heating all the way around the surface. You've got to manipulate the torch a lot. Once the welder starts welding, he/she may be able to keep the weld at the minimum preheat temperature via the welding process itself; however, on thicker sections of steel, the heat tends to bleed out very quickly. In situations like that, it's important to have a more controlled preheat process.

3.2.2Induction Heating

The most common methods for achieving a more controlled preheat temperature are induction heating and electrical resistance heating.

The equipment used for induction is considerably more expensive than that used for electrical resistance heating. However it does get your steel hotter quicker. It still offers you much more control than what you achieve with a torch. The induction method of preheating can use either a liquid-cooled braided hose or an air-cooled premade blanket wrapped around the material to be heated to create a magnetic field. The magnetic field excites the molecules in the material, which creates heat that radiates from the center of the material outward in all directions.

With an induction heating system you attach a thermocouple to the weld. The thermocouple senses the temperature of the steel and sends a signal back to the controller on the induction machine. Once the steel reaches the preheat temperature, it will maintain that temperature until the controller is adjusted. It has its ideal applications. For instance, when a shop is heating very thick sections of pipe and rotating them, this can be a good solution. Its limitation is that an induction machine can be used to heat just one weld joint at a time, and it has only a single point of control.

3.2.3Electrical Resistance Heating

A standard electrical resistance preheating machine, on the other hand, is built as a six-way unit, which means it is equipped to heat three joints at the same time, while offering six points of control.

Similar to the induction method, the pipe gets wrapped. However, the coils (flexible ceramic pads) that are used heat through conduction, and therefore heat from the outside going into the steel. The electrical resistance method (sometimes referred to as Cooper heat) also controls the preheat by using the feedback of a thermocouple.

It allows you more control, in the sense that you can add more controlling thermocouples For materials like alloy steel, where you need to tightly monitor your maximum interposes temperature and your preheat temperature, the electrical resistance method gives you more control over that is becoming widely used in power plants and other high-temperature applications. So in circumstances where you are using this type of material, using electrical resistance allows you to control each steel. It is also your most effective method of controlling maximum interposes."

It is a little slower with respect to actually setup, but when you are welding thick sections, that speed isn't as big a concern because you can prepare for more welds at once, Preheat time could also be a half hour compared to five minutes. That depends on the power available and the setups, so it is harder to quantify.

3.3. Store Tools and equipment

- Choose correct conditions to store tools
- Store in an appropriate safe location in accordance to the correct conditions
- Store safely when transporting

Consider the environment when cleaning equipment.

- Contaminants into waterways
- Wastage of water
- Recycling

Self check-3

Test-I choose

Instruction: **choose the best answer** for the give choice. You have given 1 Minute for each question. Each question carries 2 Point.

1. Which one of the following is the purpose of pre-heating?
   A. Reduce the risk of hydrogen cracking
   B. Increase the hardness of the weld heat affected zone
   C. Reduce shrinkage stresses
   D. All except B
2. From the following one is not the case to preheat the welding material
   A. When welding dissimilar material
   B. Base material that tend to be more ductile
   C. When the material are thick
   D. When recommended by the base material manufacturer
3. From the following which one is especially important Preheating welding:
   A. Material thickness
   B. Dissimilar material
   C. When recommended by manufacturer
   D. All

Test II: short Answer writing

Instruction: write short answer for the given question. You are provided 3 minute for each question and each point has 5Points.

1. What is the purpose preheated?
2. **Write** three methods commonly are used to preheat joints**?**

Note: Satisfactory rating –above 60% Unsatisfactory - below 60%

You can ask you teacher for the copy of the correct answers

Operation sheet 3.1 Operating equipment and tool

- **Operation title: Operating equipment**
- **Purpose:** To Perform Operating equipment and tool

Instruction: Use and read manual and follow the chart depending on the material set-up required temperature for preheat the welding material

- **Tools and requirement:**

1. PPE
2. Electrical resistance heating
3. Tong

Steps in doing the task

Step1.Safety (clean work area &wear PPE)

Step2. Select proper tools and equipment.

Step3. Prepare pre-heating equipment's.

Step4. Select pre-heating machine and equipment

Step5. Prepare materials

Step6. Perform pre heating

Step7. Cleaning the work area

- **Quality Criteria:** according standard

Precautions: to prevent the material from damage

Lap Test- perform Operating equipment

Unit Four: Tack Welding

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- fit joint free from rust
- root gap
- Alignment within code and standard.
- Backing plate, stiffener and running plate as requiring.
- Tack welding.

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Perform fit joint free from rust
- Perform root gap
- Check the alignment within code and standard.
- Install backing plate, stiffener and running plate as requiring.
- Perform tack welding.

4. Fit joint free from rust

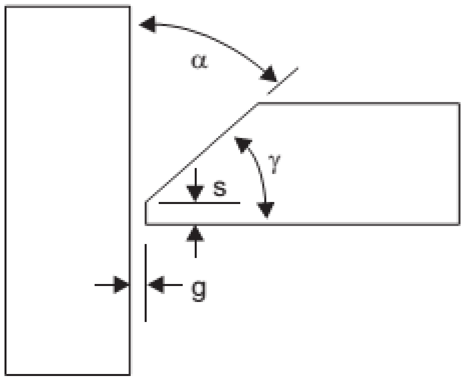
To produce good quality welds, the surfaces of the weld joint should be clean of rust, scale, dirt, oil and grease. Grinding is useful for removing rust and scale. Grease and oil must be removed from the joint surfaces by wiping or using degreasers. Scale, rust, dirt, oil, and grease can contaminate the weld metal and cause defects in the weld.

All tack welds must be thoroughly cleaned before proceeding with the final weld.
Both ends of each tack weld, representing start and stop (which are weak points often having unacceptable defects), must be ground to remove possible flaws and to present a very gradual slope that blends the weld's sides into the metal.

4.1. Root gap

When preparing and assembling components, care shall be taken to ensure compliance with the weld shapes and root openings (air gaps) specified in the manufacturing documents. With single- and double bevel butt welds in particular, care shall be taken to make an adequate root opening to achieve sufficient root penetration.

The root opening shall not exceed twice the specified gap. If the size of the gap permitted by this rule is exceeded locally over a limited area, the gap may be reduced by build-up welding of the side walls, subject to the consent of the Surveyor. With fillet welds, the "a" dimension shall be increased accordingly, or a single- or double-bevel weld shall be made if the air gap is large. Inserts and wires may not be used as fillers.



SINGLE BEVEL PREPARATION

Thickness $t \leq 19$ mm

$\alpha = 50°$

$s = 1.6 – 3.2$ mm

$g = 1.6 – 3.2$ mm

*Figure 4.1***g root gap**

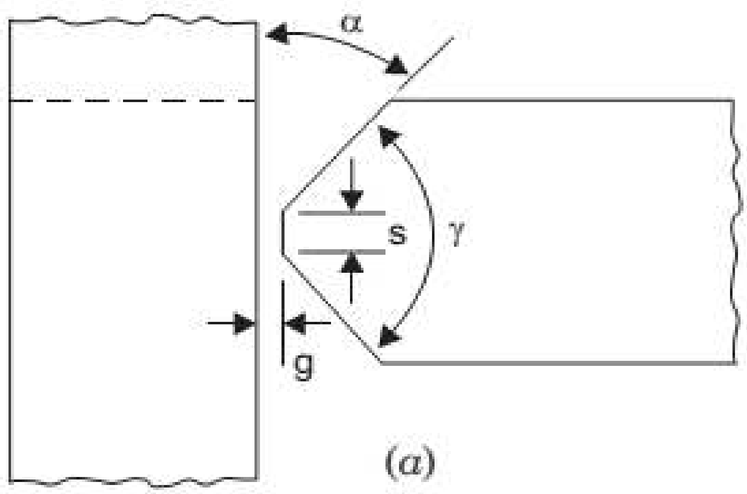


Figure 4.2

DOUBLE BEVEL PREPARATION

Thickness $t = 19$ to 51 mm

$\alpha = 50 – 55°$

$s = 0$ to 1.6 mm

$g = 1.6$ to 6.3 mm

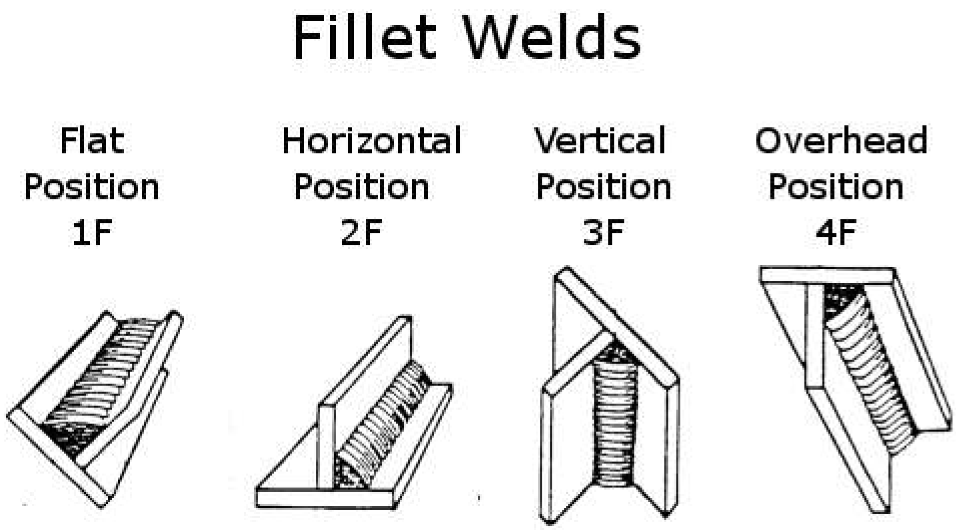


Figure 4.3 filet welding position

Fillet welding refers to the process of joining to piece of metal together when they are perpendicular at angle those welds are commonly referred to as tee joint

Flat Position (1G and 1F

The easiest type to perform is the flat position, which is also sometimes called the down hand position. It involves welding on the top side of the joint. In this position, the molten metal is drawn downward into the joint. The result is a faster and easier weld. In 1G and 1F, the number 1 refers to the flat position, while the letter G stands for a groove weld and letter F stands for a fillet weld.

Horizontal Position (2G and 2F)

This is an out of position welding position. It's a more difficult position compared to the flat position and it requires more skill from the welding operator to do them well.

2G is a groove weld position that involves placing the weld axis in a horizontal plane or approximately horizontal. As for the face of the weld, it should lie in an approximately vertical plane.2F is a fillet weld position, in which the welding is done on the upper side of the surfaces that is approximately horizontal that lies against a surface that is approximately vertical. In this position, the torch is usually held at a 45-degree angle.

Vertical Position (3F and 3G)

In this position, both the plate and the weld lie vertically or almost vertically. The 3F and 3G refer to vertical fillet and vertical groove positions.

When welding vertically, the force of gravity pushes the molten metal downward and so it has the tendency to pile up. To counteract this, you can use either an upward or downhill vertical position.

To control this in the upward vertical position, point the flame upward, holding it at a 45-degree angle to the plate. This way, the welder will use the metal from the lower parts of the work piece to weld against the force of gravity.

In the downhill position, the metal from the upper parts and the electric arc's kinetic forc are used

Overhead Position 4F 4G

In this position, welding is carried from the underside of the joint. It's the most complicated and difficult position to work in. The 4G and 4F positions stand for groove and fillet welds respectively.

In the overhead position, the metal deposited to the joint tends to sag on the plate, resulting in a bead with a higher crown. To prevent this, keep the molten puddle small. If the weld puddle becomes too large, remove the flame for a moment in order to allow the molten metal to cool.

4.2. Check the alignment within code and standard.

4.2.1. Alignment Methods.

Members to be welded shall be brought into correct alignment and held in position by bolts, clamps, wedges, guy lines, struts, and other suitable devices, or by tack welds until welding has been completed. The use of jigs and Fixtures are recommended where practicable. Suitable allowances shall be made for War page and shrinkage.

4.2.2. General Alignment Considerations

Types of misalignment parallel/bore misalignment parallel or bore misalignment occurs
when centerlines of driven equipment and engine are parallel but not in the same plane

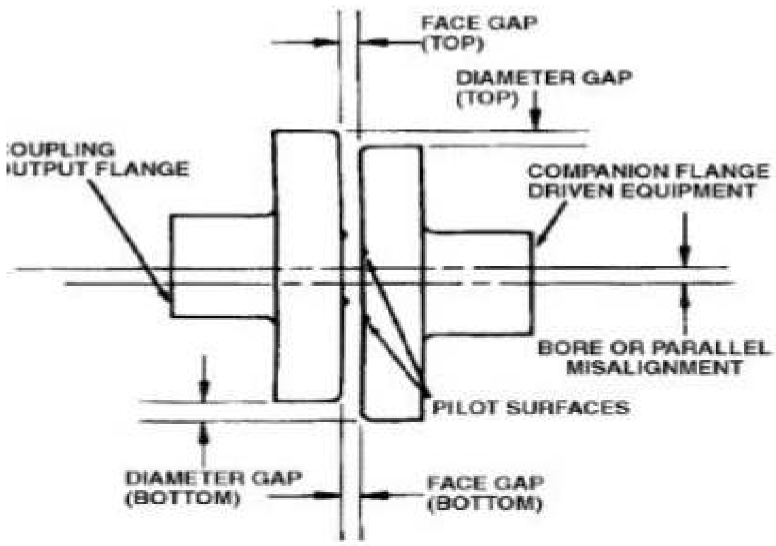


Figure 4.4 parallel misalignment

4.2.3. Install backing plate, stiffener and running plate as requiring

Stiffeners

Intermittent Fillet Welds Intermittent fillet welds used to connect stiffeners to beams and girders shall comply with the following requirements:

- Minimum length of each weld shall be 1-1/2 in. (40 mm).
- A weld shall be made on each side of the joint. The length of each weld shall be at least 25% of the joint length.
- Maximum end-to-end clear spacing of welds shall be twelve times the thickness of the thinner part but not more than 6 in. (150 mm).
- Each end of stiffeners, connected to a web, shall be welded on both sides of the joint.

Arrangement Stiffeners, if used, shall preferably be arranged in pairs on opposite sides of the web. Stiffeners may be welded to tension or compression flanges. The fatigue stress or stress ranges at the points of attachment to the tension flange or tension portions of the web shall comply with the fatigue requirements of the general specification. Transverse fillet welds may be used for welding stiffeners to flanges.

Single-Sided Welds. If stiffeners are used on only one side of the web, they shall be welded to the compression flange

4.2.4. Tack welding

The expression “Tack Welding” refers to a temporary weld used to create the initial joint between two pieces of metal being welded together. But don’t let the ‘temporary” nature of this weld fool you, Tack Welding is an integral part of the welding process and very important to the ultimate success of your welding projects.

Let’s use a basic welding exercise to demonstrate how Tack Welding works. Say you’re going to weld two pieces of steel together in order to form a basic right-angle joint. Once you have your pieces in position (typically using a c-clamp), make two short welds, one at either end of the joint seam. These two Tack Welds hold the pieces together, and from here you can complete the joint by filling in the seam between the points of the two Tack Welds.

Even though these two Tack Welds are just the initial part of the process, the welds should be fundamentally sound, considering they provide the foundation for the entire joint. Consider the welding exercise described above: c-clamps aren’t strong enough to hold the two pieces of steel together, because the stress of the heat from the welder will separate the pieces along the seam, pulling the joint apart and compromising the strength of the weld. Therefore, your two initial Tack Welds need to be rock-solid to ensure the two pieces remains tight and the overall joint weld is secure

Additional benefits of Tack Welding include: Tack welding is real welding, even if the welds are deposited in separate short beads. It performs the following functions:

- Holds the assembled components in place and establishes their mutual location
- Ensures their alignment
- Complements the function of a fixture, or permits its removal, if necessary

- Controls and contrasts movement and distortion during welding
- Sets and maintains the joint gap
- Temporarily ensures the assembly's mechanical strength against its own weight if
- hoisted, moved, manipulated, or overturned
- Reduces movement and distortion during the welding process
- Offers temporary joint strength if an object needs to be moved or repositioned during the welding process

Self-Check -4

Test I: true or false

Instruction: Say true or false for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. Weld joint not should be clean of rust, scale, dirt, oil and grease.
2. root openings air gaps specified in the manufacturing documents
3. Tack Welding is an integral part of the welding

Test II: short Answer writing

Instruction: write short answer for the given question. You are provided 3 minute for each question and each point has 5Points.

1. Define tack welding?
2. List four function of tack welding?
3. State the difference between tack welding and temporary welding?

Operation sheet-1root gap

Operation title: root gap

Purpose: to perform root gag

Instruction: to use Low carbon steel plates (S235) with the dimensions of 200*100*20mm are, they were tack welded 1F position the root gap show figure 4.1

Tools and requirement:

- AC or DC welding machine
- Helmet
- Wire brush
- C-clamp
- PPP
- Procedures in doing the task

Step1. Safety (clean work area &wear PPE)

Step2. Select proper tools and equipment..

Step3. Identify materials.

Step4. Prepare material based on the required

Step5. Align joints using d/t aligning method

Step6. Set up welding machine

Step7. Adjunct the welding machine

Step8. Clamp the ground cable

Step9. Perform tack welding

Step9. Performs root gap

Step10. Cleaning the work area

Quality Criteria: to perform tag perpendicular

Precautions:

Lap Test-

- Task-1: perform root gag tag 1F position

Unit Five: SAW Welding

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Root Pass
- Clean The Root Pass
- Filling Passes
- Capping
- Defects
- Weld Deposit
- Weld The Materials
- Clean The Joints

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Perform Root Pass
- Perform Clean The Root Pass
- Perform Subsequent Filling Passes.
- Perform Capping
- Removed Defects
- Ensure Weld Deposit.
- Perform Welding Material
- Perform Clean The Joints

5. SMW

5.1. Root Pass

The root pass is the initial pass deposited after the work piece is fit-up and tack-welded together. Where final visual inspection is concerned, the root pass and the cover or cap-pass is the decisive factors for determining whether or not welding was successful. If the work piece has been prepared with the correct groove design, and fit-up and the tack welding have been done correctly, welding the root pass can proceed.

It is important to start the initial weld of the root pass by starting the arc at least ¼ inches back (overlapping) on the tack weld and progress forward from there. This will allow the weld pool to develop, creating enough heat to cause proper melt through and fusion with the tack weld and tie into the keyhole. This same method must be repeated with each tie-in (restart) to complete the root pass.

Remember, the goal is to finish the root pass with complete fusion, both on the root side and the fusion face and toes of the weld. The factors the welder controls that influence fusion are amperage, travel and work angles, arc length, and travel speed. One other factor is the position of the weld. For example, vertical down-welding requires higher travel speeds and is limited to thinner pipe thicknesses. Vertical up-welding may be done with smaller diameter electrodes to allow for both proper root fusion and weld pool control. Root pass procedures vary with some alloys other than carbon steel. In the case of stainless steels, open root welding is accomplished by back purging the inside of the pipe with either argon or nitrogen gases. As an alternative, one of various types of consumable, backing rings, or backing tape can be used to prevent the root from oxidizing effects of atmospheric oxygen. Consumable inserts are commercially available for most common base metal alloys

Influence of Root Gap and Tack Weld on Transverse Shrinkage during Welding

The groove angle is 90^{o}. In this computation, four different values of initial root gap are assumed, namely 0.1, 0.5, 1.0 and 2.0 mm. the distribution of the Miss stress after the welding superposed on the deformed cross-section for the case in which the initial root gap is 0.5 mm. the root gap is completely closed after the welding. To closely examine the closure of the root gap and the shrinkage of the plate width, their distribution along the plate length are plotted. The shrinkage or the closure of root gap is shown by broken lines and that of plate width is

5.2. Few basic rules for the root pass:

- ✓ The thickness of the collars will be adapted according to the materials. A connection is made between collar thickness and operational weld ability (depth-to-width ratio). Consequently, for unalloyed steels, collar thicknesses vary between 2.5 and 3.5mm whereas for other steels, they tend to fall in the 2 to 2.5mm range. Thicknesses of less than 2.0mm are used only for duplex or super duplex-type stainless steels or possibly for titanium.
- ✓ The difference in level between the two collars shall not exceed 75% of the total collar thickness. Depending on the applications and materials, one criterion or the other will alternately set the f t-up conditions or the collar geometry. A difference in level of more than 1.5 or 2mm is often prohibitive due to construction codes (maximum tolerated level difference – case of the RCC-M or ASME for the nuclear industry
- ✓ A root sequence generally concerns the first 5 to 6 millimetres. This sequence forms a sufficiently thick support to avoid penetration by the first filling run. The first filling run is the first pass made with welding parameters that guarantee optimum productivity.
- ✓ Fit-up gaps on Narrow Gap welding cannot exceed 1mm. Even where the gap is close to a millimetre, it must be ascertained that the gap is reduced by welding shrinkage to avoid exceeding 0.5mm in immediate proximity to the front of the weld pool. Where this is not the case, a variation of just 1mm over the width of the groove would be detrimental to use of a single bead per layer procedure.
- ✓ Where there is a wide variation in fit-up conditions (gap and level difference), a borderline test campaign is recommended to find the average welding conditions (the parameters resulting in satisfactory penetration irrespective of fit-up conditions per position).
- ✓ A gap more readily results in collapse in the fl at position and concavity in the overhead position. It also increases the penetration width measured on the inside.
- ✓ Compared with a f t-up condition with no gap at the root face, the level difference will reduce the penetration width measured on the inside.

- ✓ Where there is a gap, the level difference accentuates the effects of the gap (risk of collapse).
- ✓ The single stringer bead procedure is not recommended for materials that cannot be welded without wire. This situation bars remitting which is almost essential to guarantee completion of the root sequence.
- ✓ The operational weld ability of the materials influences the size or even the geometry of the root. In the case of a Narrow Gap development, the question of variations from one casting to another must be raised. Are there many different castings and is the behaviour of those identified as "extreme" very different?
- ✓ The weld ability of the filler metal is an element to consider. The operational behaviour of the wire, irrespective of its compliance with the applicable standard, is a factor of success or failure on developing a welding procedure. Before selecting, a number of criteria must also be considered: hold in position (weld pools that are too runny or too pasty), mechanical behavior (exaggerated flexibility is detrimental to the feeding action) and excessive

5.3. Clean the root pass

After a **root pass** is laid in the **weld** joint, a 1/8 in or slightly thicker bonded wheel is typically used to grind out the area to remove excess build-up and reshape the face of the **root**.

This is particularly important when making multiple-pass welds. Complete removal of the slag for multiple pass welds prevents slag inclusions, porosity, and lack of fusion in the weld. After removal of the slag, a grinder is often used to grind the surface of the weld to give a more uniform surface. A wire brush is also often used to clean up the surface of the weld.

To remove the slag, strike the weld with a chipping hammer. Hammer the bead so the chipping is directed away from the body, and away from the eyes and face as pictured in Figure

- WARNING: Always wear safety glasses when chipping. Do not pound the bead too hard; otherwise the structure of the weld may be damaged. After the slag is
  - ✓ Loosened, drag the point end of the hammer along the weld where it joins the plate.

This will remove the remaining particles of slag. Follow the chipping with a good, hard brushing, using a stiff wire brush as illustrated Figure

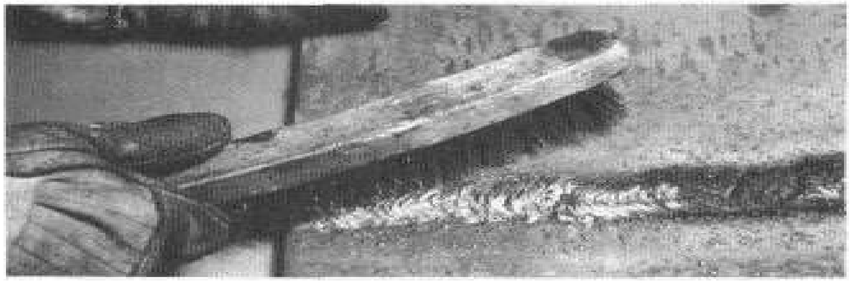


Fig.5.1After chipping, brush the weld with a wire brush

5.2.2 Cleaning tools: - in order to produce a strong weld joint the surface of the metal must be free from rust, oil &paint.

To clean these use the f/f tools.

- ✓ **Wire brush**:- a steel wire brush is used for cleaning the work & weld
- ✓ **Chipping hammer**:-is used to remove burrs & slag from the weld deposit. Produce a strong welded joint, the surface of the metal must be free of all foreign matter such as rust, oil, and paint.
- ✓ **Grinding machine: -** used to grind after welding to smooth the weld-meant

- A steel brush is used for cleaning purposes.

- After a bead is deposited on the metal, the slag, which covers the weld, is removed with a chipping hammer.

- Additional wire brushing follows the chipping operation.

- Complete removal of slag is especially important when several passes must be made over a joint.

- Otherwise, gas holes will form in the bead, resulting in porosity, which weakens the weld.

5.4. Filling passes

Once the root pass is completed, it must be cleaned thoroughly to ensure that any slag, cold starts, or any other irregularity, which may reduce fusion in the next passes, are re-moved. Inter pass cleaning chipping, wire brushing, and grinding are necessary steps in producing sound welds.

When using EXX10 and EXX11 class electrodes with SMAW, a hot pass may be used after brushing and grinding. Due to the turbulent nature of the arc, electrode manipulation, and narrow groove faces of the joint root, these electrodes tend to leave a weld face that can be more difficult to clean than those of welds made with low-hydrogen-type electrodes. a hot pass is a second pass, at higher welding cur-rents, used to help eliminate and float out any difficult to remove slag particles.

After the root pass and hot pass (if needed) are completed, the groove is filled by layering with overlapping weld beads. Fill passes are used to complete the interior portion of multi pass groove welds. Fill passes are used to nearly fill the groove, leaving only enough space for the cap passes, the final weld layer. It is necessary to maintain an even layer-by-layer approach at this stage.

5.5. Capping

5.5.1. Capping run or cosmetic pass

This pass is completed successfully when, as its name indicates, its sole purpose is to fulfill a cosmetic role. In other words, it is essential to fill the whole of the groove without under-thickness in excess of 1 or 1.5mm during the end of f filling stage. In this situation, the oscillation pass used for the capping run provides the surplus material required to join the two diameters without creating undercuts in the uphill part.

5.5.2. Weaving Capping Weld

It is possible to increase the fill rate of the rod by using a weaving motion. In the video a single weaving cap weld is used to complete a single v- joint. A slightly curved side to side motion is used to widen the weld and increase the fill. The direction is reversed when the arc reaches the edge of the v. The flux covering the weld will make the weld appear wider than it really is. It can be tricky to judge the width of weave necessary. One trick is to draw two chalk lines on some scrap, try to weave between the chalk lines leaving the weld at the edge, then remove the slag and see how close you got.

5.5.3. The Completed Cap

The cap weld is wider and lower than a single bead. Had the other side of the joint been prepared and welded in a similar manner the joint would have had close to full penetration. The advantage of welding both sides is it reduces distortion and reduces the number of passes required for complete penetration. The capping weld will shrink as it cools and pull the work into a bend. If the plate was welded from both sides the weld on the reverse would tend to straighten the work.

The cap pass is the final visible weld layer on a multi pass groove weld. Several factors must be met for the final weld and weld layer to be acceptable. First of all, the weld penetration including reinforcement has a minimum thickness equal to the base metal thickness. Second, the reinforcement height cannot exceed code requirements, and in most cases, this is 1/8” maximum. The cap pass width should be as narrow as possible while filling the groove completely. Finally, the weld must have a smooth transition to the base metal at the weld toes

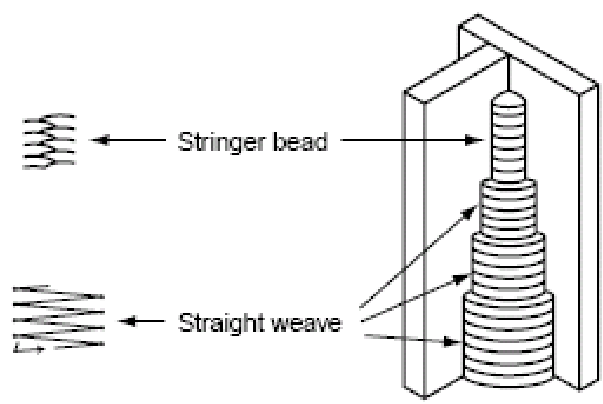


Fig.5.2root pass, hot pass, fill passes, and cap pass.

5.5.4. Remove defects

1 General Procedure

- Surface defects shall be removed by grinding with carbide burr cutters only. Abrasive-type wheels and stones are not allowed on vacuum base metal surfaces.
- Ground surface repairs shall be visually inspected to verify that the nonconformity has been removed or the indication reduced to an acceptable limit.
- The reduced material thickness shall be checked by a depth micrometer or an ultrasonic thickness gauge.

Repairs Requiring Welding

- Remove the defect by grinding with carbide burr cutters only or by chipping and grinding with carbide burr centers to an acceptable level. Abrasive-type wheels and stones are not allowed on vacuum welds.
- Visually inspect the area prepared for welding.
- Re-Weld in accordance with a Buyer approved welding procedure.
- Welded repairs shall be visually inspected after welding

5.6. Weld deposit

5.6.1. Formation of surface deposits

Electrodes that have been kept for long periods of time in non-ideal storage conditions usually form a white powdery deposit on the flux coating. This deposit is produced by a chemical reaction between the carbon dioxide in the atmosphere and the sodium silicate of the flux binder. This reaction forms crystals of sodium carbonate and silica powder. If there are heavy deposits on the covering it is possible that rusting of the core wire has occurred, which may lead to hydrogen-induced cracking. Heavy surface deposits indicate that are drying of the electrodes is required.

5.6.2. Deposition rate

The deposition rate is the rate that weld metal can be deposited by a given electrode or welding wire, expressed in pounds per hour. It is based on continuous operation, not allowing time for stops and starts caused by inserting a new electrode, cleaning slag, termination of the weld or other reasons. The deposition rate will increase as the welding current is increased.

When using solid or flux cored wires, deposition rate will increase as the electrical stick-out is increased, and the same amperage is maintained. True deposition rates for each welding filler metal, whether it is a coated electrode or a solid or flux cored wire, can only be established by an actual test in which the element is weighed before welding and then again after welding, at the end of a measured period of time.

The deposition rate describes how much usable weld metal will be deposited in one hour of actual arc-on time.

It based on continuous operation, not allowing time for stops and starts caused by inserting a new electrode, des lagging or other reasons.

5.6.1Comparison of Deposition Rate for different Welding process

Welding process	Typical Deposition Rate (kgr/hr)
Shielded Metal Arc Welding (SMAW)	2 ÷ 4
Fluxed Cored Arc Welding (FCAW)	5 ÷ 7
Submerged Arc Welding (SAW) - Wire	6 ÷ 9
Submerged Arc Welding (SAW) – Strip: 60x0,5 mm	12 ÷ 14
Electro Slag Welding (ESW) – Strip: 60x0,5 mm	22 ÷ 28

Table 5.1. Comparison of Deposition Rate for different Welding process

5.7. Weld the materials

SMAW is often used to weld carbon steel, low and high alloy steel, stainless steel, cast iron, and ductile iron. While less popular for nonferrous materials, it can be used on nickel and copper and their alloys and, in rare cases, on aluminum. The thickness of the material being welded is bounded on the low end primarily by the skill of the welder, but rarely does it drop below 1.5 mm (0.06 in). No upper bound exists: with proper joint preparation and use of multiple passes, materials of virtually unlimited thicknesses can be joined. Furthermore, depending on the electrode used and the skill of the welder,

5.8. Clean the joints

Once the root pass is completed, it must be cleaned thoroughly to ensure that any slag, cold starts, or any other irregularity, which may reduce fusion in the next passes, are removed. Inter pass cleaning–chipping, wire brushing, and grinding are necessary steps in producing sound welds. Due to the turbulent nature of the arc, electrode manipulation, and narrow groove faces of the joint root, these electrodes tend to leave a weld face that can be more difficult to clean than those of welds made with low-hydrogen-type electrodes. A hot pass is a second pass, at higher welding currents, used to help eliminate and float out any difficult to remove slag particles. After the root pass and hot pass (if needed) are completed, the groove is filled by layering with overlapping weld beads. Fill passes are used to complete the interior portion of multi pass groove welds. Fill passes are used to nearly fill the groove, leaving only enough space for the cap passes, the final weld layer. It is necessary to maintain an even layer-by-layer approach at this stage

Self-Check -5

Test I: true or false

Instruction: Say true or false for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. grinder is used to grind the surface of the weld to give a more uniform surface
2. Always wear safety gloves when chipping the slag after welding is completed
3. Chipping hammer is used to grind after welding to smooth the weld-meant
4. SMAW is often used to weld carbon steel

Test-I choose

Instruction: **choose the best answer** for the give choice. You have given 1 Minute for each question. Each question carries 2 Point.

1._____________is the second pass deposited after the root pass is fit up.

A. Root passes C. Cap pass

B. Filling pass D. Hot pass

2. After the root pass and hot pass (if needed) are completed, the groove is filled by

A. Hot pass
B. Cap pass
C. Filling pass
D. Sub Sequence pass

3. Which one of the following are not the reasons for poor welding

A. Machine adjustment too high or too low
B. proper movement of electrode
C. Electrode size too large or too small
D. Improper base metal preparation

Part III: Short answer writing

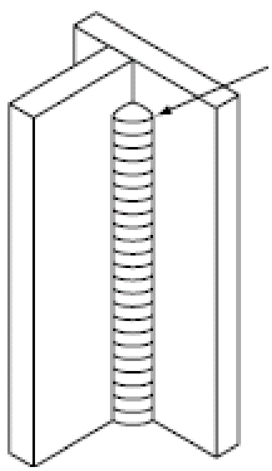
Direction: write the name of the part. Time allotted for each item is 2mniut and each question carry 4 point

1. What is Deposition rate?
2. What is the difference between roots pass and cap passé?

Operation sheet 5.1: Root passes

- **Operation title**: **Root passes**
- **Purpose:** to **perform Root passes**

1. **Instruction:** perform root pass to use Low carbon steel plates (S235) with the dimensions of 200*100*20mm joint position=3F, arc welding, diameter of electrode3.2,E6013 Finally perform the root pass on the prepared material in figure below.



Tools and requirement

1. AC or DC welding machine
2. Helmet
3. Wire brush
4. C-clamp
5. PPE
6. Steel plate

Steps in doing the task

Step1. Safety (clean work area &wear PPE)

Step2. Select proper tools and equipment.

Step3. Identify materials.

Step4. Prepare material based on the required

Step5. Align joints using d/t aligning method

Step6. Set up welding machine on stable position

Step7. Adjunct the welding machine based on the material weld

Step8. Clamp the ground cable

Step9. Perform tack welding based on standards

Step10. Perform root pass

Step11. After finishing the workcleaning the work area

Quality Criteria: perform any defect

Precautions: use the given procedure

Operation sheet 5.4filling passes

- **Operation title: filling passes**
- **Purpose: to perform filling passes**

Instruction: properly clean the root pass and perform filling passesto make a second pass fillet weld on a tee joint in the vertical position welding up (AWS Position 3F)

Tools and requirement

1. AC or DC welding machine
2. Helmet
3. Wire brush
4. C-clamp
5. PPE
6. Steel plate

Steps in doing the task

Step1. Safety (clean work area &wear PPE)

Step2. Select proper tools and equipment.

Step3. Identify materials (mild steel plate).

Step4. Prepare material based on the required

Step5. Align joints using d/t aligning method

Step6. Set up welding machine on stable position

Step7. Adjunct the welding machine based on the material weld

Step8. Clamp the ground cable

Step9. Perform subsequent filling passes

Step10. After finishing the work cleaning the work area

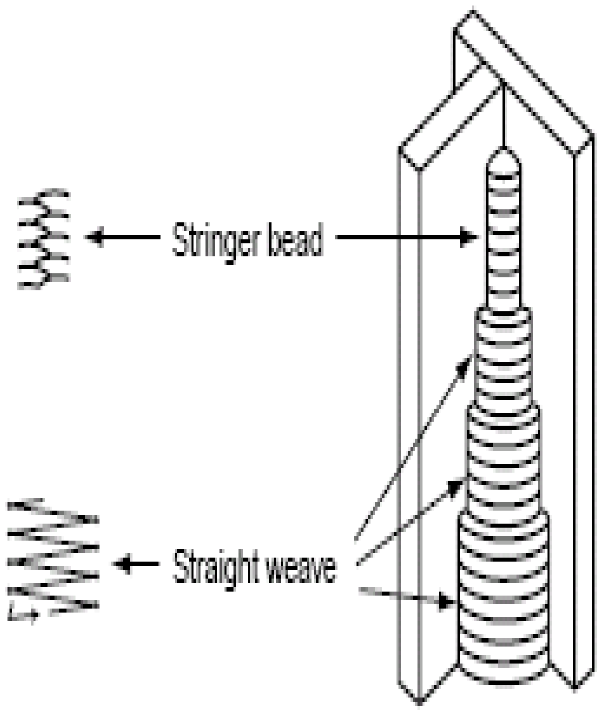
Quality Criteria: perform any defect

Precautions: use the given procedure

Operation sheet 5.4 Capping

- **Operation title:** Capping
- **Purpose**: To perform Capping

Instruction: To make a three pass fillet weld on a tee joint in the vertical position welding up (AWS Position 3F)



Tools and requirement

1. AC or DC welding machine
2. Helmet
3. Wire brush
4. C-clamp
5. PPE
6. Steel plate

Steps in doing the task

Step1. Safety (clean work area &wear PPE)

Step2. Select proper tools and equipment.

Step3. Identify materials (mild steel plate).

Step4. Prepare material based on the required

Step5. Align joints using d/t aligning method

Step6. Set up welding machine on stable position

Step7. Adjunct the welding machine based on the material weld

Step8. Clamp the ground cable

Step9. Perform tack welding based on standards

Step9. Perform Capping with good surface finish

Step10. After finishing the work cleaning the work area

Quality Criteria: perform according standard

Precautions: use

Lap Test-

Task1. Perform root pass weld

Task2. Perform subsequent filling passes weld

Task3. Perform Capping weld

Unit Six: Remove Defects and Re-Welding

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Weld Defects.
- Remove Welding Defects
- Visual Test
- Re-Welding Tasks

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Locate And Mark Weld Defects.
- Remove Welding Defects
- Perform Visual Test
- Informing Welding Defect Removal
- Perform Re-Welding Tasks

6. Welding Defect

6.1. Definition of welding defect

Defects can be defined as the irregularities formed in the given weld metal due to wrong welding process or incorrect welding patterns, etc. The defect may differ from the desired weld bead shape, size, and intended quality. Welding defects may occur either outside or inside the weld metal. Some of the defects may be allowed if the defects are under permissible limits but other defects such as cracks are never accepted.

Welding defects can be classified into two types as external and internal defects

6.1.1. External Welding Defects

1. Weld Crack
2. Undercut
3. Spatter
4. Porosity
5. Overlap

1. Weld Crack-

This is the most unwanted defect of all the other welding defects. Welding cracks can be present in the surface, inside of the weld material or at the hews effected zone.

Hot Crack – It is more prominent during crystallization of weld joints where the temperature can rise more than 10,000-degree Celsius.

Cold Crack – This type of crack occurs at the end of the welding process where the temperature is quite low. Sometimes cold crack is visible several hours after welding or even after few days.

Fig 6.1: Cracking

2. Undercut- When the base of metal melts away from the weld zone, then a groove is formed in the shape of a notch, then this type of defect is known as Undercut. It reduces the fatigue strength of the joint.

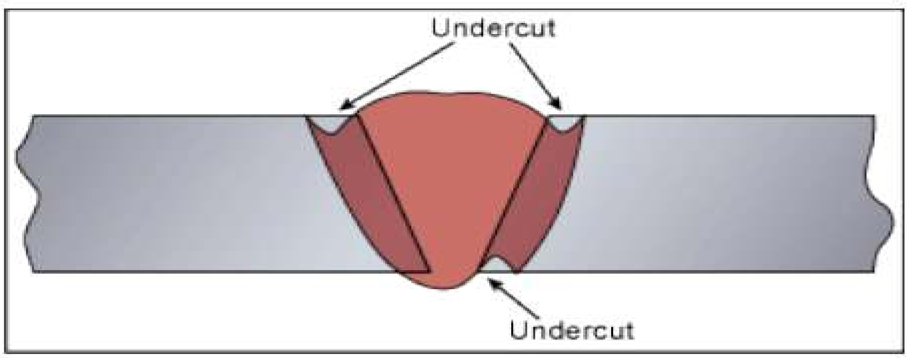


Fig 6.2: Undercut

4. Spatter- When some metal drops are expelled from the weld and remain stuck to the surface, and then this defect is known as Spatter.

Fig -6.3: Spatter

5. Porosity- Porosity in the condition in which the gas or small bubbles gets trapped in the welded zone.

Fig -6.4: Porosity

6. Overlap- When the weld face extends beyond the weld toe, and then this defect occurs. In this condition the weld metal rolls and forms an angle less than 90 degrees.

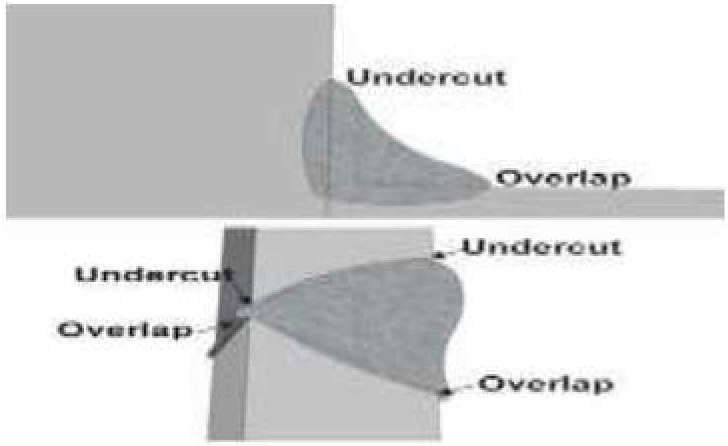


Fig -6.5:.5Overlap

6.1.2. Internal Welding Defects

1. Slag Inclusion

2. Incomplete Fusion

3. Necklace cracking

4. Incompletely filled groove or incomplete penetration

1. **Slag Inclusion**- If there is any slag in the weld, and then it affects the toughness and metal weld ability of the given material. This decreases the structural performance of the weld material. Slag is formed on the surface of the weld or between the Welding turns

: 

Fig -.6.7: Slag Inclusion

1 **Incomplete Fusion**- Incomplete fusions occurs when the welder does not accurately weld the material and the metal pre solidifies which leads to a gap which isnot filled with the molten metal

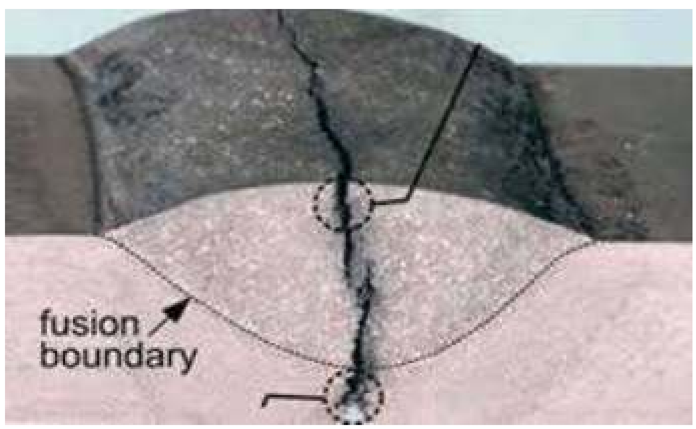


Fig -6.8: Incomplete Fusion

3 Necklace Cracking- It occurs in the use of welding where the weld does not penetrate properly. Therefore, the molten metal does not flow into the cavity and results in a cracking known as “Necklace Cracking

Fig -6.9: Necklace Cracking

4Incompletely Filled Groove or Incomplete Penetration- These defects occur only in the butt welds where the groove of the metal is not filled completely. It is also called as incomplete penetration defect.

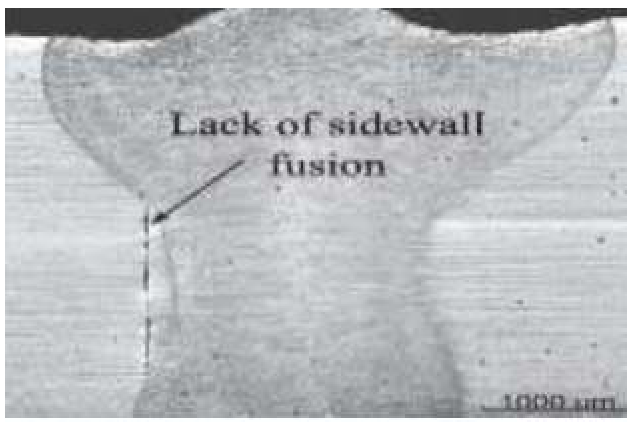


Fig -6.10: Incompletely Filled Groove or Incomplete Penetration

6.2. Remove welding defects

When weld defect from in weld they can weaken the joint .in some case, this results in complete failure of the element**.**

Basic steps removing welding defect

1. use marker to mark the defect of welding
2. Fasten the metal piece your with clamp or vice
3. Wear your protective equipment

4. Gradually let grinder removing the defect

6.3. Visual test

Non destructive evaluation

- Purpose of NDE

Verify quality and integrity of welds and base metal without damage

Data for assessment of a structure's safety and function

The Big Five NDE Methods

- Visual Examination (VT)
- Penetrate Examination (PT)
- Magnetic Particle Examination (MT)
- Ultrasonic Examination (UT)
- Radiographic Examination (RT)

Visual Examination (VT)

- Often the primary and sometimes only inspection
- Effective form of quality assurance
- Most extensively used NDE method
- Most widely used welding inspection method
- Human inspector visually examines for:

Conformance to dimensions, Cracks, cavities, incomplete fusion, and other surface defects

Advantages	Disadvantages
Easy	Requires experience
Quick	Need clean, lighted area
Inexpensive	Surface only
Comprehensive Measuring tools, lighting, cleaning	Requires experience

Table 6.1

6.4. Re-welding

Depend on the type of material being welded and the process in use. If the material is known to be metallurgic ally 'sensitive' to heat input, which could result in degradation of both the HAZ and weld deposit, it then becomes a question of complete removal of the welded joint and replacement with an inserted section Materials such as mild, low carbon and carbon-manganese steels, are considered to be very tolerant to heat input and may accept at least two or more re-weld operations. In the case of low alloy steels, re-welds will be governed by the heat-treated condition in which they were supplied. For the Cr-Mo steels, up to two re-welds may be carried out, but consideration needs to be given to the post-weld heat treatment operations and possible resultant degradation of the welded joint.With the 3xx series stainless steels, two re-welds may be tolerated, but in the case of the duplex and super duplex stainless steels, only one re-weld operation is advisable, and then with extreme care and control over the heat input. Ideally, for these complex metallurgical materials, avoidance of any form of re-weld operation is favored.

The aluminum alloys (5xxx) series can generally be regarded as a two re-weld operation but the (6xxx) series is far more sensitive to heat input and even a single re-weld operation is undesirable.

Of course when considering re-weld operations for whatever reason, consideration must be given to the following: material thickness, distortion problems, build up of residual stresses, and not forgetting the weld ability rating of the material.

Self-Check -6

Test I: true or false

Instruction: Say true or false for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. Spatter is one of Internal Welding Defects
2. re-welding Depend on the type of material
3. Cracks, cavities, incomplete fusion can be identify visually

Part II: Short answer writing

Direction: write the name of the part. Time allotted for each item is 2mniut and each question carry 4 point

1. What is welding defect?
2. Write at list three internal welding defects?
3. What is Visual Examination?

Note: Satisfactory rating –above 60% Unsatisfactory - below 60%

You can ask you teacher for the copy of the correct answers

Operation sheet 6.1Remove welding defects

- **Operation title:** Remove welding defects
- **Purpose:** To perform Remove welding defects
- **Instruction :**remove the defect of welding

Tools and requirement

1. Helmet
2. Wire brush
3. C-clamp
4. Hand grinding machine
5. Jig fixtures

Steps in doing the task

Step1. Remove any flammable matter from the area.

Step 2. Use marker to mark the defect of welding

Step 3. Fasten the metal piece your with clamp or vice

Step 4. Wear the appropriate personal protective equipment

Step 5. Gradually let grinder removing the defect

- **Quality Criteria:** according standard

Precautions: to prevent the material from damage

Lap Test-

- Task-1:Remove welding defects

Unit Seven: Quality weld conformance

This learning unit is developed to provide the trainees the necessary information regarding the following content coverage and topics:

- Welds Defects
- Welding Joints
- Welding Record
- OHS Procedures.
- Tools and Equipment

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Make Welds Free From Defects.
- Inspect Welding Joints
- Record Weld
- Observe OHS Procedures.
- Report Defective Hand Tools and Equipment

7.1. Most Common Types of Welding Defects

Incomplete Penetration

Incomplete penetration happens when your filler metal and base metal aren't joined properly, and the result is a gap or a crack of some sort. Check out the Figure below for an example of incomplete penetration

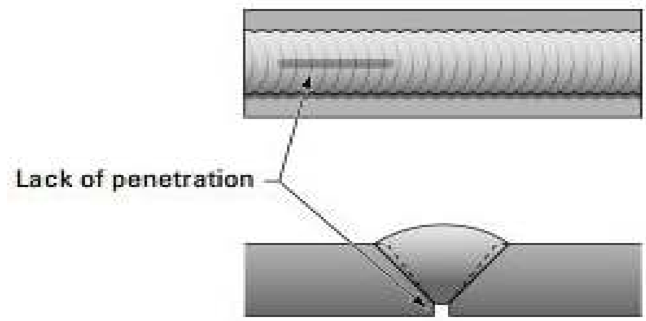


Fig -7.1 Incomplete Penetration

The groove you're welding is too narrow, and the filler metal doesn't reach the bottom of the joint.

- You've left too much space between the pieces you're welding, so they don't melt together on the first pass.
- You're welding a joint with a V-shaped groove and the angle of the groove is too small (less than 60 to 70 degrees), such that you can't manipulate your electrode at the bottom of the joint to complete the weld.
- Your electrode is too large for the metals you're welding.
- Your speed of travel (how quickly you move the bead) is too fast, so not enough metal is deposited in the join
- Your welding amperage is too low. If you don't have enough electricity going to the electrode, the current won't be strong enough to melt the metal properly

2. Incomplete Fusion

Incomplete fusion occurs when individual weld beads don't fuse together, or when the weld beads don't fuse properly to the base metal you're welding, such as in below.

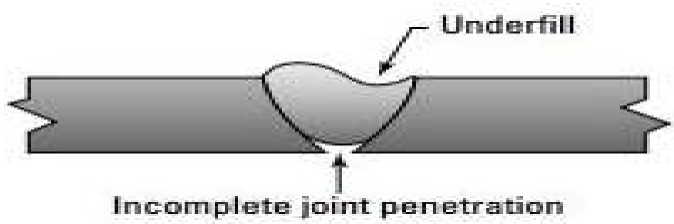


Fig 7.2 Incomplete Fusion

Here are a few more usual suspects when it comes to incomplete fusion causes.

- Your electrode is too small for the thickness of the metal you're welding.
- You're using the wrong electrode for the material that you're welding.
- Your speed of travel is too fast.
- Your arc length is too short.
- Your welding amperage is set too low

If you think your incomplete fusion may be because of low welding amperage, crank up the machine! But be careful: You really need only enough amperage to melt the base metal and ensure a good weld. Anything more is unnecessary and can be dangerous

3. Undercutting

Undercutting is an extremely common welding defect. It happens when your base metal is burned away at one of the toes of a weld. To see what I mean, look at Figure

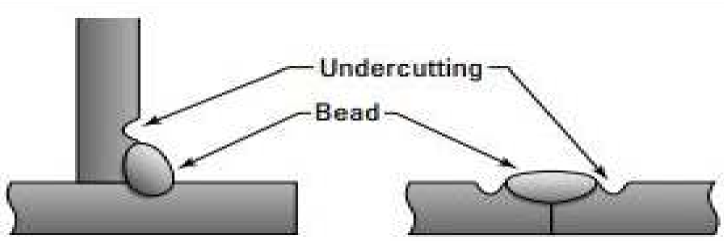


Fig -7.3Undercutting

Here are a few common causes of undercutting

- Your electrode is too large for the base metal you're welding.
- Your arc is too long.
- You have your amperage set too high.
- You're moving your electrode around too much while you're welding

4. Porosity

Porosity (tiny holes in the weld) can be a serious problem in your welds (especially stick or migwelds). Your molten puddle releases gases like hydrogen and carbon dioxide as the puddle cools; if the little pockets of gas don't reach the surface before the metal solidifies, they become incorporated in the weld, and nothing can weaken a weld joint quite like gas pockets. Take a gander at Figure for an example of porosity

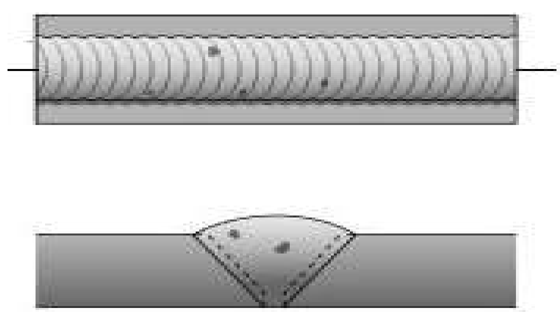


Fig -7.4Porosity

5 Hot cracks:

This type of crack occurs during welding or shortly after you've deposited a weld, and its cause is simple: The metal gets hot too quickly or cools down too quickly. If you're having problems with hot cracking, try preheating your material. You can also post heat your material, which means that you apply a little heat here and there after you've finished welding in an effort to let the metal cool down more gradually.

6 Cold cracks:

This type of crack happens well after a weld is completed and the metal has cooled off. (It can even happen days or weeks after a weld.) It generally happens only in steel, and it's caused by deformities in the structure of the steel. You can guard against cold cracking by increasing the thickness of your first welding pass when starting a new weld. Making sure you're manipulating your electrode properly, as well as pre- and post-heating your metal, can also help thwart cold cracking.

7. Crater cracks:

These little devils usually occur at the ending point of a weld, when you've stopped welding before using up the rest of an electrode. The really annoying part about crater cracks is that they can cause other cracks and the cracking cans just kind of snowball from there. You can control the problem by making sure you're using the appropriate amount of amperage and heat for each project, slowing your speed of travel, and pre- and post-heating

7.2. Welding joints

7.2.1. Inspecting Weld joint visually

Visual examination is the most important and the most universally accepted method of inspection. This procedure covers the visual examination of welding in components such as -plates, welds, etc. by using Visual and Optical aids and Gauges.

7.2.2. Ensuring Weld Quality through

There are two types of welding inspection

1. **Destructive testing (DT)**

- (DT) is the process of breaking the material at certain distance for inspection.
  - ✓ *Mechanical tests*
  - ✓ *Metallurgical tests*

2. **Non destructive testing (NDT)**

- Non destructive testing is also known as non destructive examinations or evaluation (NDE) or inspection.
  - ✓ *Visual Examination*
  - ✓ **X-ray fluorescence**
  - ✓ *Ultrasonic Examination (UT)*
  - ✓ **Eddy current etc.**

7.2.3Nondestructive testing (NDT)

Provides the ability to monitor various aspects of material and product quality without compromising part integrity. Many NDT technologies can be applied to ensure proper manufacturing and functionality. Three such techniques— visual inspection, ultrasonic's eddy current and X-ray fluorescence—can be used together in manufacturing operations to ensure use of proper materials, identify near surface cracking and provide volumetric detection of critical defects.

7.2.3. Visual Inspection

Procedure of Weld Joints

Visual inspection should be applied in the following ways.

1. During welding – check:

- Electrodes – compatibility of the electrode type to the weld metal, and joint preparation. This includes a check on the welding current, size of electrode, and speed of deposition
- root run – the appearance, penetration (if required) and any external defects will give a good indication of weld quality
- slag removal – ensure that all slag is completely removed after each run – particularly watch the toes of the root run
- inter-run – each run of weld metal is going to be part of the completed weld, so check each run individually – one bad run may ruin the whole weld. It is much easier to correct defects as they occur than to wait until the weldment is completed. Watch corners, weld junctions, craters and weld toes.

2. After welding – check:

- the final appearance of the weld, and the presence of external defects such as undercut, reinforcement, weld profile, craters, misalignment, porosity, cracks and slag inclusions – the external appearance of a weld gives a good indication of its quality
- Conformity – all welds should be checked against the drawings and/or specifications to ensure that they meet the requirements laid down. Aides to visual inspection are devices such as a torch, fillet gauges, calipers, other measuring devices, and a low powered (up to 10x) magnifying glass. The major limitation of visual inspection is that it will disclose only surface defects, and only defects that can be seen by the naked eye. Fine surface cracks may not be readily apparent by visual inspection, but may be easily detected by some other method. Fillet Weld Gauge is an essential weld quality testing tool. It is used to check fillet leg size, checking fillet throat size

Fillet Weld Gauge

Fig -7.5Undercutting

7.3. Welding record

The weld number and the welder's identification number are also recorded on beside the actual weld. Other information such as the serial numbers of the weld head and power supply may be entered into some orbital welding plants and printed out along with the weld program which identifies the parameters of the welding sequence, these are then file with the weld coupons to form part of the overall welding handover package.

These weld records are combined with the Material Test Reports (MTRs or materials certificates) which list the chemical composition and test data of the heats of materials used. Surface finish test reports, and results of pressure testing, passivation, and other documentation required by the Design Specification must be presented to and retained by the owner/user for a required period of time

7.3.1. Weld record Sheets Information

A weld record sheet is used to track the critical information for each specific weld completed in a system. Figure 1 below illustrates a typical weld record sheet which is sub divided into 4 main sections these being:

1. Header section
2. Weld information section
3. Material information section
4. Test information section

The weld record sheet is used in conjunction with the weld isometric drawing and is often printed on the back of the drawing or attached to the drawing. Where possible the design office should fill in the common information before printing to increase efficiencies and minimise the risk of error. The welder then generally fills out the weld information section and the weld inspector completes the final test information section.

Once complete the project engineer reviews it and verifies that all welds are completed, tested and accepted it can then be signed approved and included in the overall handover documentation package.

1. Header Section

Client: The company name who the work is being completed for.

Client project No.: A unique number assigned by the client for the work being completed.

Approved by: Signature of the person approving the weld record sheet

Project No.: A unique number assigned by the contractor for the work being completed. It is usually used to track costs and progress on a particular project.

Machine Serial No.: The serial number of the welding machine used to carry out the welding. It is unique to each machine and if faults are discovered and linked back to this machine, it makes it easier for all welds completed by this machine to be tracked and re-inspected after the fact.

***Machine model No**.:* The type of model of welding machine used to complete the welding.

System: The name of the system being welded, e.g. Pure steam, product etc..

***Line/Iso**. No.:* This is the isometric drawing number or the line number for which the welds that are being recorded are on.

Sheet No.: Sometimes there may be 3 or 4 isometrics for one line therefore they are grouped together as sheet 1 of 5, 2 of 5 etc.

2Weld Information Section

Weld No.: Unique number given to each weld in sequence so that there is complete traceability for every weld in the system

Welder No.: Unique number given to every welder in a company. This number is recorded on the Welder qualification record after a welder performs and passes their qualification tests.

This number is then recorded for every weld completed on both the weld record sheet and marked on the pipe beside each weld completed.

Weld Size: *Size of* the weld being completed. This is used to tie back to weld coupon log to ensure that only these size welds were completed once the correct size weld coupons were completed.

Weld date*:* The date the weld was completed.

Location: Where the weld was completed, i.e. in the workshop or out on site. Shop welds are usually much easier as they are completed on a bench with good access and minimum purging, while field welds are usually more difficult as access is usually more difficult and the complete system needs to be purged which is harder to achieve. In critical systems a reduced percentage of shop welds may be inspected while the client may insist that 100% of all field welds are inspected

Process: Automatic or manual, most welds should be automatic which are more consistent and therefore more likely to pass inspection. Manual welds are only used where the fitting to fitting distance is reduced to a point where the automatic weld heads will not fit and therefore a manual weld is required. These are only usually allowed by prior approval of the client and usually require 100% inspection.

3. Material Information Section

Component / Component: This identifies the different components either side of a weld, e.g. Pipe/elbow or elbow/tee etc..

Cast No. / Cast No.: Also known as the heat number it identifies the batch of material that the component was manufactured from. It was once a requirement that the cast number had to be the same each side of the weld to ensure consistent welding, however due to improved manufacturing techniques it is now possible for mills to repeatedly produce material which is consistent and which has tightly tolerance ingredient amounts. This consistency in the materials of the components ensures that the finished welds are of a high quality.

4. Testing Information Section

NDT Report No.: Non Destructive Test report No., this allows the weld record sheet to be cross referenced to the independent test report.

NDT type: Usually horoscope (optic fibre with a camera on the end that is pushed down the tube and rotated to record the internal profile of each weld. The horoscope is non hazardous, quick, can be carried out during normal working hours and gives instant feedback and there is generally used for 90% of the welds on a system. The other option is to X-ray the weld to get a radiographic picture of the weld; this is usually done on closing welds where it is not possible to gain access for the boroscope. X-rays are usually done at night out of hours to reduce the risk of exposure to radiation sources and the films have to be developed therefore the results are slower.

NDT date: The date the weld was inspected.

Accept or Reject: The result of the NDT inspection. See Phase 4, module 2 Unit 8 for accept / reject criteria.

Client : ____________ FAS Project No : ____________ System : ____________

Client Project No : ____________ Machine Serial No : ____________ Line/Iso No : ____________

Approved By : ____________ Machine Model No : ____________ Sheet : ______ of ______

Weld Information								Material Information				Test Information				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Weld No	Welders No	Weld Size	Weld Date	Location		Process		Component	Component	Cert No.	Cert No.	NDT Report No	NDT Type	NDT Date	Accept or Reject	Inspectors Initials
				Shop	F.W.	Auto	Man.									
1																
2																
3																
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7.4. OHS procedures.

Welding safety starts with an understanding of what could go wrong, and preparation for when it does. Risks include electric shock, injuries related in inhalation of toxic fumes, eye injury and skin burns. To start, protective clothing and equipment must be worn during all welding operation including helmets and shields. For arc welding, the electric arc is a very powerful source of light, including visible, ultraviolet, and infrared. During all electric welding processes, operators must use safety goggles and a hand shield or helmet equipped with a suitable filter glass to protect against the intense ultraviolet and infrared rays. When others are in the vicinity of the electric welding processes, the area must be screened so the arc cannot be seen either directly or by reflection from glass or metal. During all SMAW processes, the operators must use safety goggles to protect the eyes from heat, glare, and flying fragments of hot metals. Also be sure to keep MSDS sheets (Material Safety Data Sheets) for all hazardous materials. Every manufacturer provides MSDS sheets to keep you informed regarding any potential hazards, such as if a respirator is needed when working on a project. Welding safety starts with having the right protective gear. This includes

- **Respirator/Welders Mask**: There are multiple types of respirators. Buy the one that is made for welders and the type of projects you will be performing. If purchasing a mask with a filter, match the filter to the types of metals and coatings used.
- Keep the area clean and check any gasses for signs of leaks.
- **Ventilation**: All welding areas should have proper ventilation. Check with OSHA for
- **The up to date standards**. Poor ventilation leads to "plume poisoning". If you suspect that be inhaled a toxic plume seek medical help immediately.
- **Storage**: All flammables should be stored in a flammable liquids locker.
- **Eye protection**: welding eye protection protects against injuries from debris and from the effects of the ultraviolet light. Different types of helmets are made to protect you when performing different types of welding. These vary by shade number, having a passive or auto-darkening lens (automatically adjusts to welding rays) and comfort/fit.
- **Fire protection:** Sparks created during the welding process can start fires. For

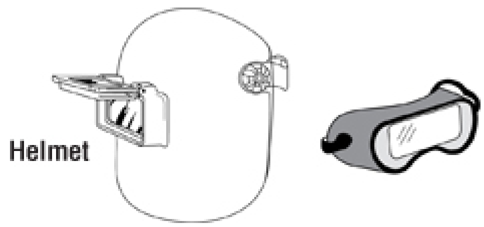
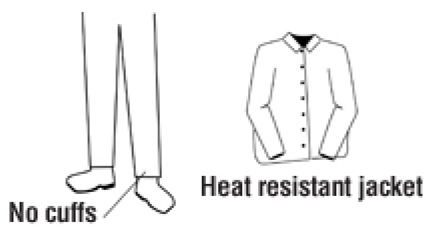
Welding Class C extinguishers are often used since these are for electrical fires. Sand

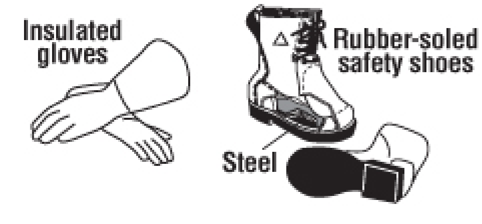
And water can also help to extinguish fires.

Welding - Personal Protective Equipment and Clothing

The chart below summarizes the types of personal protective equipment that can be used when welding.

Welding - Personal Protective Equipment			
Body Part	**Equipment**	**Illustration**	**Reason**

Eyes and face	Welding helmet, hand shield, or goggles		Protects from: • radiation • flying particles, debris • hot slag, sparks • intense light • irritation and chemical burns Wear fire resistant head coverings under the helmet where appropriate
Lungs (breathing)	Respirators		Protects against: • fumes and oxides
Exposed skin (other than feet, hands, and head)	Fire/Flame resistant clothing and aprons		Protects against: • heat, fires • burns • radiation Notes: pants should not have cuffs, shirts should have flaps over pockets or be taped closed
Ears – hearing	Ear muffs, ear plugs		Protects against: • noise Use fire resistant ear muffs where sparks or splatter may enter the ear, rather than plugs.

Feet and hands	Boots, gloves		Protects against: • electric shock • heat • burns and fires

- **Welding Safety Tip**: Use pliers when handling metals. If you believe a metal is cool, use the back of the hand and slowing bring it closer to the metal. You'll feel the heat as you get closer if it is too hot to handle
- **Prepare for Accidents:** Keep a first aid kit on hand that includes bandages and burn spray. Consider an option that exceeds ANSI (American National Standards Institute) and OSHA guidelines such as this first aid kit .

7.5. Tools and Equipment

Defective tools can cause serious and painful injuries. If a tool is defective in some way, do not use it. If tools and equipment are defective, attach an Out of Service tag with signature and date. Upon proof of repairs (a receipt), the tag will be removed and attached to the invoice for continuous monitoring of repairs dates completed.

Watch for problems like:

- Chisels and wedges with mushroomed heads.
- Split or cracked handles.
- Chipped or broken drill bits.
- Wrenches with worn out jaws.
- Tools that is not complete, such as files without handles.

To ensure safe use of hand tools, do not use a defective tool, inspect tools prior to use and verify that tools are repaired.

Air, Gas or Electric Power Tools

Watch for problems like:

- Broken or inoperative guards.
- Insufficient or improper grounding due to damage on double insulated tools.

- No ground wire (on plug) or cords of standard tools.
- The on / off switch not in good working order.
- Tool blade is cracked.
- The wrong grinder wheel is being used. The guard has been wedged back on

Self-Check -7

Test- I choose

Instruction: **choose the best answer** for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. Which one of the following are not the causes of undercut?
   A. Your electrode is too large for the base metal
   B. Your arc length is too long
   C. Your speed of travel too fast
   D. You have amperage set too high
2. __________is the welding defect in which the base metal is burned away at toes of weld
   A. Under cutting C. Cracks
   B. Porosity D. Incomplete fusion
3. In which type of crack happens well after a weld is completed and the metal has cooled off.
   A. Hot crack C Crater cracks.
   B. Cold crack D. Al
4. From the following one is destructive testing method
5. Mechanical tests C. X-ray fluorescence
6. Visual examination D. Eddy current
7. Which one of the following is section of welding record sheet
8. Test information C. Weld information
9. Material information D. Header E. All
10. __________non destructive testing method is based on principles of magnetism
11. Eddy current testing C. Ultrasonic examination
12. X-ray fluorescence D. Visual examination

Part II: True or False

Instruction: Say true or false for the give choice. You have given 1 Minute for each question. Each question carries 2 Point

1. Cast number isunique number given to every welder in a company.
2. Machine model number isthe type of model of welding machine used to complete the welding.
3. A weld record sheet is used to track the critical information for each specific weld completed in a system.

Operation sheet 7.1: Welding record

- **Operation title: Welding record**
- **Purpose:** apply **Welding record**
- **Instruction: use the welding record sheet**
- **Tools and requirement:**

1. Welding gauge
2. PPE
3. Magnification lanes
4. Welding recorded sheet

Steps in doing the task

Step1. Safety (clean work area &wear PPE)

Step2. Prepare tools and equipment.

Step3. Select inspection method.

Step4. Check the weld

Step5. If the weld does not correct

Step6. Re-weld the joint

Step9. Record the document.

Step10. Clean the work area

Quality Criteria: use standard record sheet