Unit-2: Cutting Tool Materials and Introduction to welding processes

(Subject: Workshop Technology/Workshop Practice)

Cutting Tool Materials: Properties and uses of cutting tool material viz; High-speed steel, tungsten carbide, cobalt steel, cemented carbides, ceramics and diamond.

Cutting Fluids: Introduction, Function and its types, Specification and selection of cutting fluid.

Welding Processes: Electric arc welding: working principle, use of AC and DC current in welding, TIG welding, MIG welding, Introduction to gas welding.

CUTTING TOOL MATERIALS CHARACTERISTICS

Cutting materials should have the following characteristics;

1. **Hot hardness:** The material must remain harder than the work at elevated operating temperature.
2. **Wear Resistance:** The material must withstand excessive wear even though the relative hardness of the tool-work material changes.
3. **Toughness:** It actually implies a combination of strength and ductility. The material must have sufficient toughness to withstand shocks and vibrations to prevent breakages.
4. **Cost and easiness in fabrication:** The cost and easiness of fabrication should have within reasonable units.

TYPE OF CUTTING TOOL MATERIALS

There are many types of cutting process done in different conditions. In such conditions along with the general requirements of the cutting tool, they need some unique properties. To achieve these properties the cutting tools are made up of different material. The material chosen for a particular application depends on the material to be machined, type of machining, quantity and quality of production.

According to the material used the tools are classified into

1. High Speed Steel tool (HSS)
2. Tungsten carbide
3. Cobalt Steel
4. Cemented carbides
5. Ceramics
6. Diamond

1. **High Speed Steel (HSS)**: This is a high carbon steel in which the various alloying elements (Tungstun, Molybdenum, Chromium, Vanadium and Cobalt) have been added in larger amounts (up to 25%) as compared to alloy tool steels to improve hardness, toughness and wear resistance properties. These materials are deep deep hardening and can be quenched in oil, air or salt. They are capable of retaining their hardness up to

600^{o} C. They can be safely operate at 2-3 times higher sppeds than those possible with high carbon steel tools. Three important types are classified as;

(a) 18-4-1 High Speed Steel: It contains
Tungsten =18%
Chromium=4%
Vanadium=1%
Carbon=0.75% approx.
These elements form hard carbides which resist tempering, thus improving of the hardness at red heat. It is considered as one of the best all purpose tool steels.

(b) Molybdenum High Speed Steel, It contains;
Molybdenum=6%
Tungsten =6%
Chromium=4%
Vanadium=1%
It has excellent toughness and cutting ability and is cheaper than other types of steels

(c) Super High Speed Steels, It contains;
Tungsten =20%
Chromium=4%
Vanadium=2%
Cobalt=12%
These are also called cobalt high speed steels

Surface treatment used in the HSS

Super finishing - Reduce friction.
Nitriding - Increase wear resistance.
Chromium electroplating - Reduce friction.
Oxidation - Reduce friction
High-speed steel tools are used in drills, milling cutters, single point lathe tools, broaches.
Cutting speed range - 30-50 m/min, Temperature - 650°C
Hardness – up to HRC 67
T-Type - Tungsten predominant type
M-Type - Molybdenum dominant type

2. Tungsten carbide: The basic ingredient of most cemented carbides is tungusten carbide which is extremely hard. Pure tungsten is mixed under high heat at about 1500^{o}C, with pure carbon in the ratio of 94 % and 6% by weight. The compound, tungsten carbide, is then mixed with cobalt until the mass is entirely homogenious.. In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes through a process called sintering for use in industrial machinery, cutting tools, abrasives etc. Carbide tools are made by brazing or silver soldering the formed inserts on the end of the commercial steel holders.

The following is a list of Tungsten Carbide properties. Different Grades of Tungsten Carbide will differ in strength, rigidity, and other properties, but all Tungsten Carbide Material falls into the basic properties listed below.

(a) **Strength**- Tungsten carbide has very high strength for a material so hard and rigid. compressive strength is higher than that of cast or forged metals and alloys.

(b) **Rigidity**- Tungsten carbide compositions range from two to three times as rigid as steel and four to six times as rigid as cast iron and brass.

(c) **Impact Resistant**- For such a hard material with very high rigidity, the impact resistance is high. It is in the range of hardened tool steels of lower hardness and compressive strength.

(d) **Heat and oxidation resistance** - Tungsten-base carbides perform well up to about 1000°F in oxidizing atmospheres and to 1500°F in non-oxidizing atmospheres

(e) **Thermal Conductivity** - Tungsten carbide is in the range of twice that of tool steel and carbon steel.

(f) **Electrical Conductivity** - Tungsten carbide is in the same range as tool steel and carbon steel.

(g) **Specific Heat** - Tungsten carbide ranges from about 50% to 70% as high as carbon steel.

(h) **Weight** - The specific gravity of tungsten carbide is from 1-1/2 to 2 times that of carbon steel.

(i) **Hot Hardness** - With temperature increase to 1400°F, tungsten carbide retains much of its room temperature hardness. At 1400°F, some grades equal the hardness of steels at room temperature.

(j) **Methods of Fastening** - Tungsten carbide can be fastened to other materials by any of three methods; brazing, epoxy cementing, or mechanical means. Tungsten carbide's low thermal expansion rate must be carefully considered when preforms are provided for grinding or EDM.

(k) **Coefficient of Friction** - Tungsten carbide compositions exhibit low dry coefficient of friction values as compared to steels.

(l) **Wear-Resistance** - Tungsten carbide wears up to 100 times longer than steel in conditions including abrasion, erosion and galling. Wear resistance of tungsten carbide is better than that of wear-resistance tool steels.

(m) **Dimensional Stability** - Tungsten carbide undergoes no phase changes during heating and cooling and retains its stability indefinitely. No heat treating is required.

3. **Cobalt Steel**: This is also called cobalt high speed steel because cobalt is added from 2 to 15%, in order to increase the cutting efficiency especially at high temp. This steel, on an average contains 20% tungsten, 4% chromium, 2% vanadium and 12% cobalt. Since the cost of cobalt steel is more, therefore, it is mainly used for heavy cutting operations which impose high pressure and temp. on the tool.

4. Cemented carbide: The carbide tools are produced by powder metallurgy technique i.e. by using metals in their powder form. The final mixture of powder consists of various amounts of hard particles and a binding metal. The hard particles give the materials hardness and abrasion resistance, while the binding metal provides the roughness. It consists of tungsten, tantalum and titanium carbide with cobalt as a binder. Cemented carbide tools are extremely hard, they can withstand very high-speed cutting operation. Carbide tool does not lose their hardness up to 1000° C. A high cobalt tool is used for a rough cut while low cobalt tool used for finishing operations.

Cutting speed range - 60-200m/min
Temperature - 1000°C
Hardness – up to HRC 90

5. Ceramics: Most common ceramic materials are aluminum oxide and silicon nitride. Powder of ceramic material Compacted in insert shape, then sintered at high temperature. Ceramic tools are chemically inert and possess resistance to corrosion. They have high compressive strength. They are stable up to temperature 1800°C. They are ten times faster than HSS. The friction between the tool face and chip are very low and possess low heat conductivity, usually no coolant is required. They provide the very excellent surface finish
Cutting speed 300-600m/min
Temperature - 1200°C
Hardness – up to HRC 93

6. Diamond: It is the hardest material known and it is also expensive. It possesses very high thermal conductivity and melting point. Diamond offers excellent abrasion resistance, low friction coefficient and low thermal expansion. It is used in machining very hard material such as carbides, nitrides, glass, etc. Diamond tools give a good surface finish and dimensional accuracy. They are not recommended for machining steel.

Different elements used in cutting tool materials and their properties are

Element	**Properties**
Tungsten	Increases hot hardness Hard carbides formed Abrasion resistance

Molybdenum	Increases hot hardness Hard carbides formed Improving resistance
Chromium	Depth hardenability during heat treat hard carbides are formed improving abrasion resistance some corrosion resistance
Vanadium	combines with carbon for wear resistance retards grain growth for better toughness
Cobalt	Increases hot hardness, toughness
Carbon	Hardening element forms carbides

TOOL WEAR

Tool wear is the inevitable cause tool failure in the machining process. The extent of tool wear has a strong influence on dimensional accuracy and surface finish obtained. The gradual wear of the tool occurs at three principal locations of a cutting tool. According to this cutting tool wear is classified into

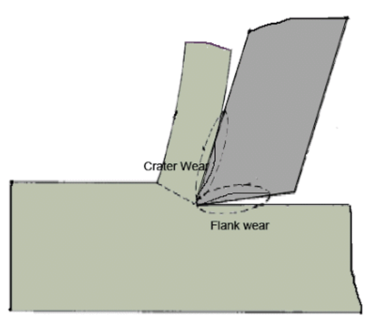
1. Flank wear
2. Crater wear
3. Corner wear

1. Flank wear

Flank wear occurs at the tool flanks, where it contacts with the finished surface, as a result of abrasion and adhesion wear. The cutting force increases with flank wear. It affects the great extent of mechanics of cutting.

2. Crater wear

Crater wear happens on the tool face at a short distance from cutting edge by the action of chip flow over the face at very high temperature. The crater wear is mainly due to diffusion and abrasion. The depth of crater measures the crater wear; the surface measuring instrument can measure it. The cutting edge may break from tool due to excessive cratering.



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3. Corner wear (nose wear)

It occurs at tool nose radius. Corner wear shortens the cutting tool, cause a significant dimensional error in machining. It is considered as part of flank wear since there is no distinguishing boundary between them.

TOOL LIFE

There are three types of tool failures

1. Fracture failure: this mode of failure occurs when the cutting force at the tool point becomes excessive, causing it to fail *suddenly* by brittle fracture.

2. **Temperature failure**: this failure occurs when the cutting temperature is too high for the tool material, causing the material at the tool point to *soften*, which leads to plastic deformation and loss of the sharp edge.

3. **Gradual wear**: gradual wearing of the cutting edge causes loss of tool shape, reduction in cutting efficiency, accelerated wear, and final tool failure in a manner similar to a temperature failure

Tool life generally indicates, the amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed.

Tool life is always assessed or expressed by span of machining time in minutes, whereas, in industries besides machining time in minutes some other means are also used to assess tool life, depending upon the situation, such as

(a) No. of pieces of work machined
(b) Total volume of material removed
(c) Total length of cut.

The tool life is expressed by an equation as

$VT^n=C$ where, V=cutting speed (m/min.), T=time period (min.), C-Taylor`s constant

n = Taylor's exponent depending mainly on cutting tool material
n = 0.05 to 0.1 for H.C steels.
n = 0.1 to 0.2 for H.S.S
n = 0.2 to 0.4 for carbides
n = 0.4 to 0.6 for ceramics
n = 0.7 to 0.9 for diamond

FACTORS AFFECTING TOOL LIFE

The life of the cutting tool **is affected by the various factors mentioned below:**

(i) Properties of work piece material

a. With the increase in hardness of work piece, forces and power consumption increases and tool wear increases. So tool life decreases.
b. When ductility of work piece increases, forces and power consumption decreases, tool wear decreases. So tool life increases.
c. But there is no quantitative relationship available between properties of work and tool life.

(ii) Tool Geometry

As the tool geometry changes, like when rake angle increases, the tool life will increase. But there is no quantitative relationship between tool geometry and tool life.

(iii) Use of Cutting Fluid

a. When the cutting fluid is used during machining it is acting as a lubricant in friction zone and carrying away the heat during machining.
b. So forces in machining with the use of cutting fluid. It increases by 25 to 40 %.

(iv) Process Parameters

a. Cutting speed
b. Feed
c. Depth of cut

CUTTING FLUIDS

Cutting fluid is a type of coolant and lubricant designed specifically for metalworking processes, such as machining and stamping. There are various kinds of cutting fluids, which include oils, oil-water emulsions, pastes, gels, aerosols (mists), and air or other gases. They may be made from petroleum distillates, animal fats, plant oils, water and air, or other raw ingredients. Cutting fluids are used to improving tool life, reducing workpiece thermal deformation, improving surface finish and flushing away chips from the cutting zone. Cutting fluids can be divided in to four types:

1. Straight oils
2. Soluble oils
3. Synthetic fluids
4. Semi-synthetic fluids

1. **Straight oils**: Straight oils are non-emulsifiable and are used in machining operations in an undiluted form. They are composed of a base mineral or petroleum oil and often contains polar lubricants such as fats, vegetable oils and esters as well as extreme pressure additives such as Chlorine, Sulphur and Phosphorus. Straight oils provide the best lubrication and the poorest cooling characteristics among cutting fluids.
2. **Soluble oils**: Soluble Oil fluids form an emulsion when mixed with water. The concentrate consists of a base mineral oil and emulsifiers helps to produce a stable emulsion. They are used in a diluted form (usual concentration = 3 to 10%) and provide good lubrication and heat transfer performance. They are widely used in industry and are the least expensive among all cutting fluids.

3. **Synthetics fluids**: Synthetic Fluids contain no petroleum or mineral oil base and instead are formulated from alkaline inorganic and organic compounds along with additives for corrosion inhibition. Synthetic fluids often provide the best cooling performance among all cutting fluids.
4. **Semi-synthetic fluids:** These are essentially combination of synthetic and soluble oil fluids and have characteristics common to both types. The cost and heat transfer performance of semi-synthetic fluids lie between those of synthetic and soluble oil fluids.

FUNCTIONS OF CUTTING FLUIDS

1. Cutting fluid cools the work piece and tool by carrying away the heat generated during machining.
2. It acts as lubricant at the friction zones, hence tool life increases.
3. As friction gets reduced, the forces and electricity power consumption decreases.
4. Using cutting fluids produces better surface finish to the work piece.
5. It causes to break the chips into small pieces.
6. It washes away the chips from the tool.
7. It prevents the corrosion of chips and machine.
8. Improves dimensional accuracy and control on the work piece.
9. It permits maximum cutting speed hence the time for machining reduce and cost of manufacturing increases.

PROPERTIES OF AN IDEAL CUTTING FLUIDS

Cutting fluids should have low viscosity to permit free flow of the liquid.

1. It should posses good lubricating properties.
2. It should have high specific heat, high heat conductivity and high heat transfer coefficient.
3. It should be non-corrosive to work and machine.
4. It should be non-toxic to operating person.
5. It should be odourless.
6. It should stable in use and storage.
7. It should be safe.
8. It should permit clear view of the work operation.

Most commonly used cutting fluids are

Cast Iron: No cutting fluids are used.

Steels: Lord oil with mineral oil is used.

Alloy steel: Sulphur brass oil with mineral oil is used.

Copper: Soluble oil with 90 to 95% of water is used.

Aluminium: Mineral oil with soluble oil cutting fluids are used as cutting fluids.

SELECTION OF CUTTING FLUIDS

To select a cutting fluid for metal working operations, the advantages and disadvantages of metalworking cutting fluids should be compared through review of product literature, supplier information, and usage history.

The following factors should be considered when selecting a cutting fluid

- Cost and life expectancy
- Fluid compatibility with work materials and machine components
- Speed, feed and depth of the cutting operation
- Type, hardness and microstructure of the metal being machined
- Ease of fluid maintenance and quality control
- Ability to separate fluid from the work and cuttings
- Optimal concentration and pH ranges
- Storage practices

WELDING

Definition: Welding is a process in which two or more parts are joined permanently at their touching surfaces by a suitable application of heat and/or pressure. Often a filler material is added to facilitate coalescence. The assembled parts that are joined by welding are called a weldment. Welding is primarily used in metal parts and their alloys.

Welding processes are classified into two major groups:

1. **Fusion welding**: In this process, base metal is melted by means of heat. Often, in fusion welding operations, a filler metal is added to the molten pool to facilitate the process and provide bulk and strength to the joint. Commonly used fusion welding processes are: arc welding, resistance welding, electron beam welding and laser beam welding.

2. **Solid-state welding**: In this process, joining of parts takes place by application of pressure alone or a combination of heat and pressure. No filler metal is used. Commonly used solid-state welding processes are: diffusion welding, friction welding, ultrasonic welding.

CLASSIFICATION OF WELDING PROCESSES

1. **Arc welding**
    a. Carbon arc
    b. Metal arc
    c. Metal inert gas
    d. Tungsten inert gas
    e. Plasma arc
    f. Submerged arc
    g. Electro-slag
2. **Gas Welding**
    a. Oxy-acetylene
    b. Air-acetylene
    c. Oxy-hydrogen
3. **Resistance Welding**
    a. Butt
    b. Spot
    c. Seam

d. Projection

e. Percussion

4. **Thermit Welding**
5. **Solid State Welding:**

Friction

Ultrasonic

Diffusion

Explosive

SELECTION OF WELDING PROCESS

A wide range of welding processes are available to choose. These were developed over a long period of time. Each process differs in respect of their ability to apply heat for fusion, protection of the weld pool and soundmen of welds joint the so performance of the weld joint. However, selection of a particular process for producing a weld joint is dictated by the size and shape of the component to be manufactured, the metal system to be welded, availability of consumables and machines, precision required and economy. Whatever process is selected for developing weld joint it must be able to perform the intended function for designed life. Welding processes with their field of applications are given below:

- Resistance welding: Automobile
- Thermit welding: Rail joints in railways
- Tungsten inert gas welding: Aerospace and nuclear reactors
- Submerged arc welding: Heavy engineering, ship building
- Gas metal arc welding: Joining of metals (stainless steel, aluminium and magnesium) sensitive to atmospheric gases

Advantages and Limitation of Welding as a Fabrication Technique Welding is mainly used for the production of comparatively simple shape components. It is the process of joining the metallic components with or without application of heat, pressure and filler metal. Application of welding in fabrication offers many advantages, however; it suffers from few limitations also. Some of the advantage and limitations are given below.

Advantages of welding are enlisted below:

1. Permanent joint is produced, which becomes an integral part of work piece.
2. Joints can be stronger than the base metal if good quality filler metal is used.
3. Economical method of joining.

Disadvantages of welding are enlisted also below:

1. Labour cost is high as only skilled welder can produce sound and quality weld joint.
2. It produces a permanent joint which in turn creates the problem in dissembling if of sub-component required.
3. Hazardous fumes and vapours are generated during welding. This demands proper ventilation of welding area.
4. Weld joint itself is considered as a discontinuity owing to variation in its structure, composition and mechanical properties; therefore welding is not commonly recommended for critical application where there is a danger of life.

APPLICATIONS OF WELDING

General applications

- The welding is widely used for fabrication of pressure vessels, bridges, building structures, aircraft and space crafts, railway coaches and general applications besides shipbuilding, automobile, electrical, electronic and defense industries, laying of pipe lines and railway tracks and nuclear installations.
- Specific components need welding for fabrication includes

1. Transport tankers for transporting oil, water, milk etc.
2. Welding of tubes and pipes, chains, LPG cylinders and other items.
3. Fabrication of Steel furniture, gates, doors and door frames, and body
4. Manufacturing white goods such as refrigerators, washing machines, microwave ovens and many other items of general applications

ARC WELDING METHODS

1. Metal arc welding

It is a process of joining two metal pieces by melting the edges by an electric arc. The electric arc is produced between two conductors. The electrode is one conductor and the work piece is another conductor. The electrode and the work piece are brought nearer with small air gap. (3mm app.)

When current is passed an electric arc is produced between the electrode and the work piece. The work piece and the electrode are melted by the arc. Both molten piece of metal become one. Temperature of arc is about 4000°C Electrodes used in arc welding are coated with a flux. This flux produces a gaseous shield around the molten metal. It prevents the reaction of the molten metal with oxygen and nitrogen in the atmosphere. The flux removes the impurities from the molten metal and form a slag. This slag gets deposited over the weld metal. This protects the weld seam from rapid cooling. Fig.1 shows arc welding process.

Equipments:(Refer Fig 2)

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

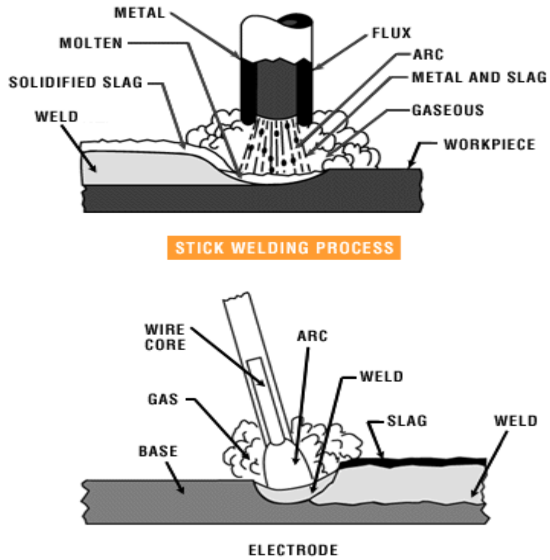


Fig. 1 Arc Welding

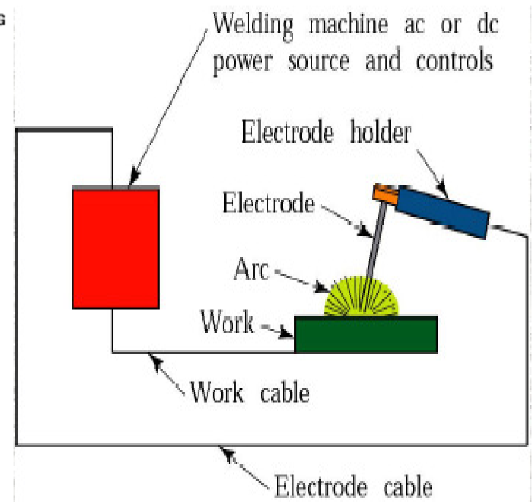


Fig 2 Electric Arc Welding Equipments

Advantages

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

Limitations

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

2. Carbon arc welding

In carbon arc welding, the intense of heat of an electric arc between a carbon electrode and work piece metal is used for welding. DC power supply is used. The carbon electrode is connected to negative terminal and work piece is connected to positive terminal, because positive terminal is hotter (4000°C) than the negative terminal (3000°C) when an arc is produced. So carbon from the electrode will not fuse and mix up with the metal weld. If carbon mixes with the weld, the weld will become weak and brittle. To protect the molten metal from the atmosphere the welding is done with a long arc. In this case, a carbon monoxide gas is produced, which surrounds the molten metal and protects it.

COMPARISON OF A.C. AND D.C. ARC WELDING

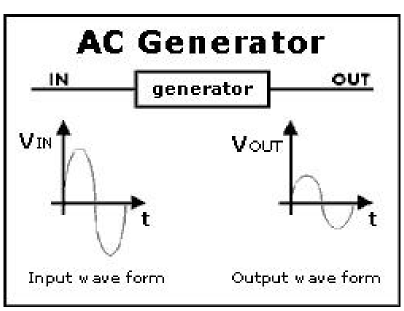
	Alternating Current (from Transformer)	Direct Current (from Generator)
1	More efficiency	Less efficiency
2	Power consumption less	Power consumption more
3	Cost of equipment is less	Cost of equipment is more
4	Higher voltage – hence not safe	Low voltage – safer operation
5	Not suitable for welding non ferrous metals	suitable for both ferrous non ferrous metals
6	Not preferred for welding thin sections	preferred for welding thin sections
7	Any terminal can be connected to the work or electrode	Positive terminal connected to the work Negative terminal connected to the electrode

THE POWER SOURCE

The polarity of the power source output current distinguishes two further categories:

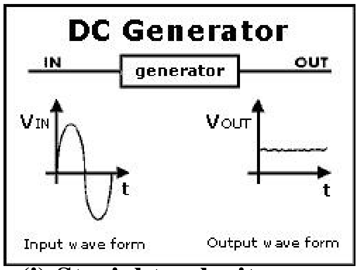
(a) Alternating Current (AC) Power Source

The power source output current takes the form of a sine wave, which changes its polarity at regular intervals, with a frequency of 50 cycles per second (Hertz). It is obtained using a transformer, which converts the mains current into a suitable current for welding. This is for electromechanical welding machines.



(b) Direct Current (DC) Power Source

The power source output current has a continuous wave form, which is obtained by means of a device, the rectifier, which is situated at the base of the transformer and can convert from alternating to direct current. If the welding circuit has a direct current (DC) power source, it can be further classified according to the method of connecting the power source poles to the material to be welded:



(i) Straight polarity connection

Straight polarity connection occurs when the clamp cable (with the electrode holder clamp) is connected to the negative pole (-) of the power source and the earth cable (with the earth clamp) to the positive pole (+) of the power source. The electric arc concentrates the heat produced on the piece and causes its melting. In this way, as the core of the electrode melts, it is deposited and penetrates into the welding joint.

(ii) Reverse polarity connection

Reverse polarity connection occurs when the clamp cable (with the electrode holder clamp) is connected to the positive pole (+) of the power source and the earth cable (with the earth clamp) to the negative pole (-) of the power source. The heat of the electric arc is mostly concentrated at the tip of the electrode. Each type of electrode requires a specific current type (AC or DC) and, in the case of DC current, a specific polarity: the choice of the electrode therefore depends on the type of power source used. Incorrect use will cause arc stability problems and hence also welding quality problems.

SHIELDED-METAL ARC (SMAW) OR STICK WELDING

This is an arc welding process wherein coalescence is produced by heating the work piece with an electric arc setup between a flux-coated electrode and the workpiece. The electrode is in a rod form coated with flux. Fig.3 illustrates the process.

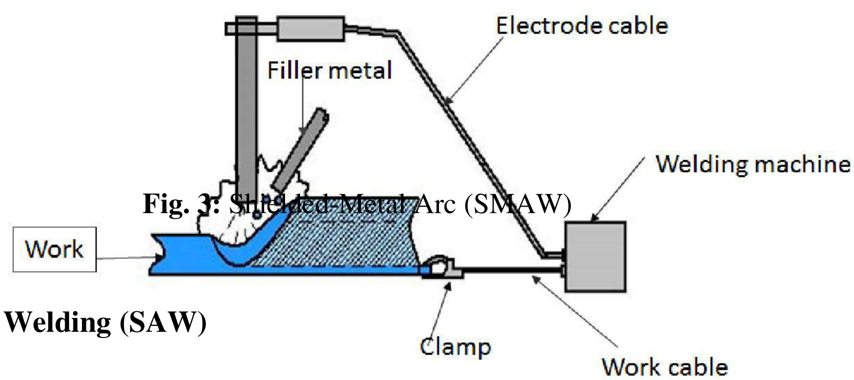


Fig. 3: Shielded-Metal Arc (SMAW)

Submerged Arc Welding (SAW)

This is another type of arc welding process, in which coalescence is produced by heating the work piece with an electric arc setup between the bare electrode and the work piece. Molten pool remains completely hidden under a blanket of granular material called flux.

The electrode is in a wire form and is continuously fed from a reel. Movement of the weld gun, dispensing of the flux and picking up of surplus flux granules behind the gun are usually automatic.

Gas-Metal Arc Welding (GMAW)

In this process an inert gas such as argon, helium, carbon dioxide or a mixture of them are used to prevent atmospheric contamination of the weld. The shielding gas is allowed to flow through the weld gun. The electrode used here is in a wire form, fed continuously at a fixed rate. The wire is consumed during the process and thereby provides filler metal. This process is illustrated in Fig. 4.

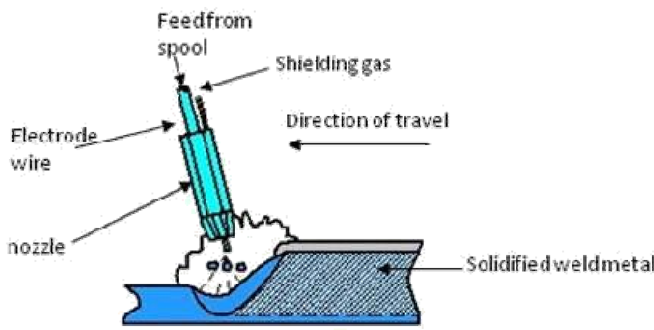


Fig. 4: Gas-Metal Arc Welding

Gases used for Gas Shielded Metal Arc Welding Process

Argon

Although argon is very suitable for non-ferrous metals and alloys, if it is used for welding steel the process becomes unstable and the weld profile uneven. Mixtures of argon and oxygen result in more stable process and gives optimum welding conditions for various metals.

Helium

If helium is used as the shielding gas, it requires significantly greater gas flow than argon. It is usually used mixed with argon e.g. argon – 15% helium for certain high nickel alloys, argon – 50% helium for copper welding.

Carbon Dioxide

Pure CO_2 is the cheapest of the shielding gases and can be used for welding steel up to 0.4% C and low alloy steel. CO_2 is not suitable for stainless steel because the corrosive resistance of the weld is reduced.

Argon + CO_2 (5% and “20%)

The addition of CO2 to argon for the welding of steels improves the ‘wetting’ action, reduces surface tension and makes the molten pool more fluid. The mixture is more expensive than pure CO2 but gives a smoother, less critical arc with reduced spatter and a flatter weld profile.

Argon + Nitrogen (15-20%)

The mixture can be used instead of pure argon for copper welding. Arc voltages are higher, giving greater heat output for a given current value thus reducing the pre-heating requirements. If pure nitrogen is used the droplets are of coarse size and there is more spatter and porosity with poor weld appearance.

GAS-TUNGSTEN ARC WELDING (GTAW)

This process is also known as tungsten–inert gas (TIG) welding. This is similar to the **Gas-Metal Arc Welding** process. Difference being the electrode is non consumable and does not provide filler metal in this case. A gas shield (usually inert gas) is used as in the GMAW process. If the filler metal is required, an auxiliary rod is used.

GAS WELDING

Oxy-Acetylene welding

In gas welding, a gas flame is used to melt the edges of metals to be joined. The flame is produced at the tip of welding torch. Oxygen and Acetylene are the gases used to produce the welding flame. The flame will only melt the metal. A flux is used during welting to prevent oxidations and to remove impurities. Metals 2mm to 50mm thick are welded by gas welding. The temperature of oxyacetylene flame is about 3200°C. Fig 3 shows Gas welding equipments.

Gas Welding Equipment

1. Gas Cylinders

Pressure

Oxygen – 125 kg/cm^2

Acetylene – 16 kg/cm^2

2. Regulators

Working pressure of oxygen 1 kg/cm^2

Working pressure of acetylene 0.15 kg/cm^2

Working pressure varies depends upon the thickness of the work pieces welded.

3. Pressure Gauges

4. Hoses

5. Welding torch

6. Check valve

7. Non return valve

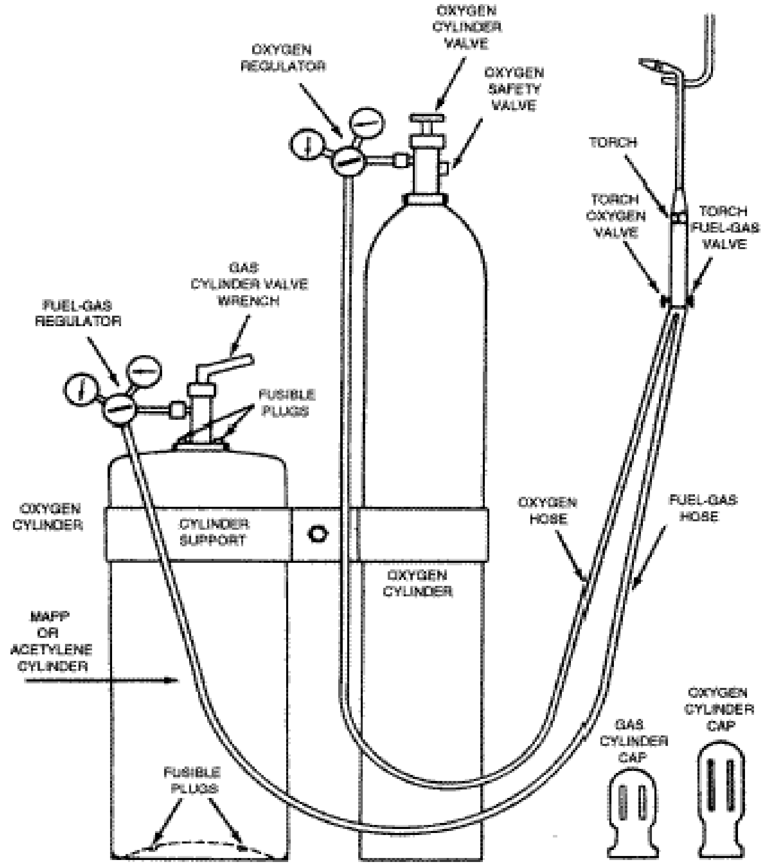


Fig- 3. Gas Welding Equipment

Types of flames

- When acetylene is burned in air, it produces a yellow sooty flame, which is not enough for welding applications
- Oxygen is turned on, flame immediately changes into a long white inner area (Feather) surrounded by a transparent blue envelope is called Carburizing flame (3000^0C)
- This flames are used for hardening the surfaces
- Addition of little more oxygen give a bright whitish cone surrounded by the transparent blue envelope is called Neutral flame (It has a balance of fuel gas and oxygen)
- Most commonly used flame because it has temperature about 3200^0C
- Used for welding steels, aluminium, copper and cast iron
- If more oxygen is added, the cone becomes darker and more pointed, while the envelope becomes shorter and more fierce is called Oxidizing flame
- Has the highest temperature about 3400^0C

- Used for welding brass and brazing operation

Fig 4 shows the types of flames.

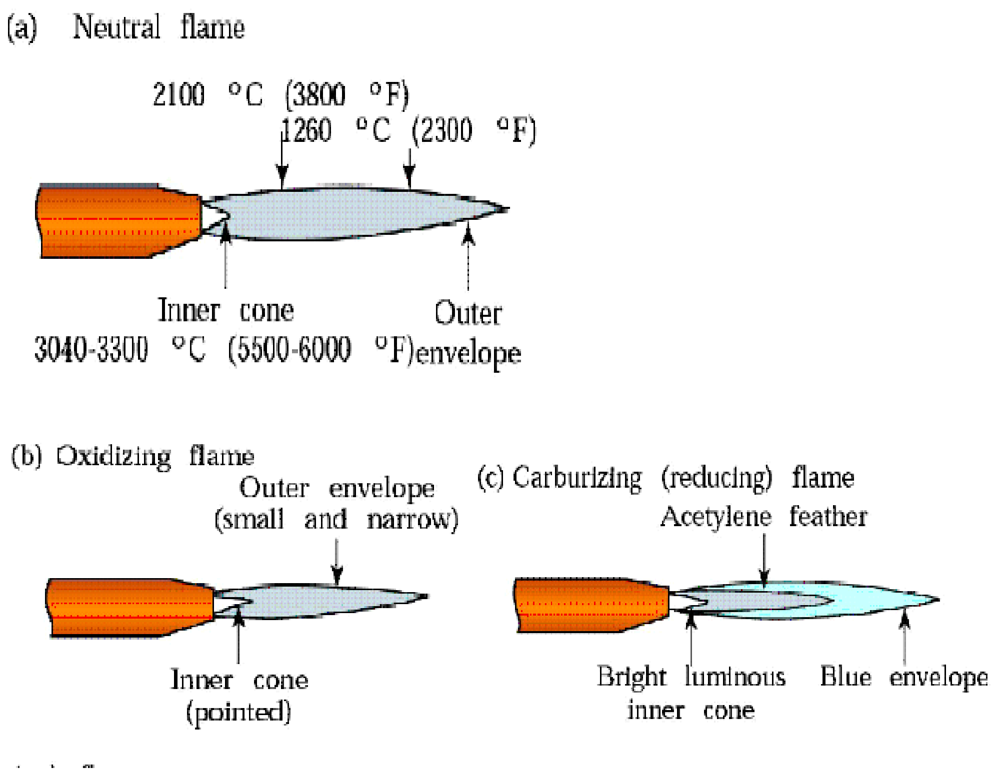


Fig 4. Types of Gas Flames

Advantages

1. Equipment has versatile
2. Same equipment can be used for oxy acetylene cutting and brazing by varying the torch size
3. Heat can controlled easily

Disadvantages

1. Slower process
2. Risk is involved in handling gas cylinders

WELD JOİNT

There are 5 basic joint types in welding

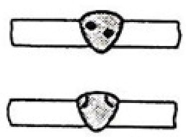
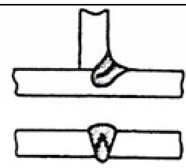
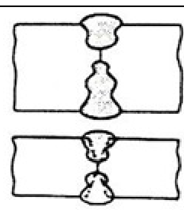
- Butt joint: Two materials are in the same plane, joined from the edges.
- Corner joint:The corners of two materials form a right angle and joined.
- Lap joint: Two parts overlaps.
- Tee joint: One part is perpendicular to the other, making a T shape.

- Edge joint: Edges of the two materials joined.

WELDABILITY

It is the ease of a material or a combination of materials to be welded under fabrication conditions into a specific, suitably designed structure, and to perform satisfactorily in the intended service

WELD DEFECTS AND THEIR CAUSES

Fault		***Cause***
Porosity		• Insufficient CO2 shielding because of flow rate, frozen value, clogged nozzle, draughts. • Torch angle too low.
Cracking		• Dirty work – grease, paint, scale, rust • Weld bead too small
Undercutting		• Travel speed too high • Backing bar groove too deep • Current too low for speed
Lack of penetration		• Current too low – setting wrong • Wire feed fluctuating • Joint preparation too narrow • Angle too small, Gap too small • Torch angle too low
Lack of fusion		• Uneven torch manipulation • Insufficient indulgence (short circuiting arc) • Voltage too low
Slag inclusions		• Incorrect technique • Current too low • Irregular weld shape
Spatter – • on work • on nozzle • in weld		• Voltage too high • Insufficient inductance

TERMINOLOGY

1. **Arc-Welding**: The process of fusing two pieces of metal together with an electric arc as source of heat.

2. **A. C. –** Alternating current, an electric current in which the direction of flow is reversed continuously and very rapidly.

3. **Arc** – Flow of current across a narrow gap in the electric circuit.

4. **Arc Blow** – Arc blow may be encountered with the use of a direct current welding machine. The current flowing constantly in one direction causes the steel to become magnetized. The magnetized field deflects the arc making it difficult to leave the arc in the crater. This condition is not noticed with A. C. due to the high rate of change of direction of current. Arc blow may be controlled and the magnetic effect is overcome by changing position of the ground cable.

5. **Arc cutting** – Using a welding electrode and high amperage setting to cut metal. The electrode tip is moved back and forth across the kerf to carry out the molten metal.

6. **Arc Length** – The distance through the center of the arc from the end of the steel core of the electrode to the bottom of the crater.

7. **Arc Voltage** – The voltage across the gaseous zone of the arc, which varies, with the length of the arc.

8. **A. W. S.** – American Welding Society.

9. **Bare electrode** – A rod of solid metal used in welding. It does not have a heavy chemical covering or coating.

10. **Base Metal** – Metal that is being processed by cutting or welding.

11. **Bead** – A continuous deposit of weld material.

12. **Bevel** – The angled flat surface of a plate edge like one side of a vector.

13. **Chipping** – Using hammer and light blows to remove slag from surface weld.

14. **Coated Electrode** – Metal rod or wire covered with chemicals, which stabilized the arc and improve the fusion of metals.

15. **Crater** – A depression at the end of an arc weld bead, caused by the force of the arc as it is withdrawn.

16. **Current** – Flow of electricity through a circuit.

17. **D. C.** – (Direct current), an electric current in which the direction of flow is constantly in the same direction.

18. **Deposited metal** – Metal that has been added by a welding process.

19. **Distortion** – When metal is heated and cooled, forces of expansion and contraction push and pull metal pieces being welded. Metal which pulled permanently out of position is distorted.

20. **Electrode** – Metal rod or wire which conducts current from the electrode holder through the arc to the base metal. The tip end of the electrode melts in the heat of the arc and the molten portion is carried across the arc and deposited in or on the base metal. Electrodes are coated.

21. **Electrode holder** – A device used for gripping the metallic end of electrode. The holder should be light in weight and made in such fashion that the heat generated in holder is not uncomfortable to the hand if used with high welding amperages.

22. **Electrode Lead** – The welding cable which constitutes the electrical path between the electrode terminal of the machine and the electrode holder.

23. **Flat position welding** – A position of welding in which weld metal is deposited from the upper side of the joint and the face of the weld is approximately horizontal.

24. **Flux** – A fusible material used to dissolve and prevent the formation of oxides, nitrides, or other undesirable inclusions formed in welding and to aid the fusion or adhesion of metal.

25. **Forehand welding** – A welding technique used with carbon arc or oxyacetylene where the flame is directed toward the progress of weld. The flame is woven from side to side to preheat the joint ahead of the application. The flame is kept between the filler rod and the completed weld.

26. **Fusion** – Melting metals until the molten portions mix with each other.

27. **Galvanized** – The coating of steel with zinc for the purpose of preventing rust.

28. **Gas pocket (blow hole)** – A cavity in a weld caused by gas inclusion.

29. **Gloves** – Covering for hands of the weld operator, usually made of leather.

30. **Ground** – Connection which makes the part to be welded a part of the electric circuit.

31. **Metal Arc Cutting** – The process of serving metals by melting with the heat of the metal arc.

32. **Open-circuit Voltage** – The voltage between the electrode and ground when no current is following in the welding circuit.

33. **Overhead position of welding** – making a fillet weld above the head of the welder.

34. **Pass** – One direction movement of the electrode in welding.

35. **Peening** – Mechanical working of metal by means of hammer blows.

36. **Penetrating** – The depth of fusion of a weld or the distance from the original surface of the base metal to that point at which fusion ceases.

37. **Porosity** – The presence of gas pockets or inclusions in deposited weld metal.

38. **Preheating** – Heating base metal to a temperature of 200-600 degrees Fahrenheit in order to avoid the development of stresses in the metal during welding. Methods of preheating include the forge, oxyacetylene, and carbon arc torch.

39. **Reversed Polarity** – The arrangement of arc welding leads wherein the work is the negative terminal and the electrode is the positive terminal in the welding circuit.

40. **Straight polarity** – The arrangement of arc welding leads where in the work is attached to the positive terminal and the electrode to the negative terminal of the welding circuit.

41. **Single pass** – Completion of a bead in one continuous movement of the electrode.

42. **Slag** – Deposit of impurities and materials from the coating of the electrode upon the surfaces adjoining the bead.

43. **Slag inclusion** – Non-metallic material held in a deposit of weld metal.

44. **Spatter** – Hot slag or weld metal leaves the path of the arc and lodges on surfaces adjoining the bead.

45. **Transformer** – Device placed in an electric circuit to reduce voltage and increase amperage. The A. C. welder in its simplest form consists of a primary coil and a secondary coil. The primary coil, takes current from the 230-volt circuit. The secondary coil, with no direct electrical connection, delivers a transformed current at a lower voltage and higher amperage to the welding arc.

46. **Undercut** –Groove made in base metal along bead edges by the heat and force of the arc and left unfilled bu deposited weld metal.

47. **Welding leads** – Conductors, usually special, extra-flexible rubber covered copper welding cable, furnishing an electrical path between the source of welding power, the electrode holder, and the work.

48. **Vertical position of welding** – Making a fillet weld on a vertically positioned metal.

49. **Volt** – Measure of pressure causing flow of electrical current.

50. **GMAW**: Gas Metal Arc Welding

51. **MIG**: Metal Inert Gas

52. **MAG**: Metal Active Gas

53. **Shielding gas**: Inert gas that protects the weld from contamination during welding.

54. **Filter lens**: Lens in welding helmet that blocks harmful rays during welding.

55. **COATED ELECTRODES:** The coated electrode consists of a core and a coating. The core consists of a metal conductor rod whose sole purpose is to supply welding material to the piece. The material used depends on the base material: for carbon steels, for which electrode welding is most widespread, the core is in mild steel. During welding the core melts slightly before the coating does. The coating is the most important part of the electrode and has many functions.