UNIT 13 THERMAL CUTTING

Structure

13.1 INTRODUCTION

In the previous unit various welding processes are discussed. But it is not always joining of metals, often we have to cut the metals as well. In this unit we are going to discuss the thermal cutting process.

In this unit we are going to describe how the same technique can be used to even cut the metal with the combination of oxygen and many other gases.

Thermal cutting describes a group of cutting processes used to sever or remove or gouge metals by high-temperature exothermic reaction of oxygen with the base metal. With some oxidation resistant metals, the reaction can be aided by the use of a chemical flux or metal powder.

In this unit, we shall discuss several cutting processes. It shall include oxyfuel gas cutting, Arc cutting processes etc. It will also include processes such as cutting through metal section several feet thick with oxygen lance cutting, flux cutting, flame drilling etc. in brief.

Objectives

After reading this unit, you should be able to know the

- details of various cutting processes,
- different fuel gases used for thermal cutting and their selection criterion,
- equipment used for thermal cutting, and

- safety practices which are to be followed.

13.2 OXYFUEL GAS CUTTING

Oxyfuel gas cutting (OFC) processes sever or remove metal by the chemical reaction of oxygen with the metal at elevated temperatures. A flame of fuel gas burning in oxygen maintains the necessary temperature. In the case of oxidation resistant metals, the reaction is aided by adding chemical fluxes or metal powders to the cutting oxygen stream.

The process has been called by various other names such as burning, flame cutting, and flame machining. The oxygen stream performs the actual cutting operation. The oxygen-fuel gas flame is the mechanism used to raise the base metal to an acceptable preheat temperature range and to maintain the cutting operation.

The OFC torch is a versatile tool that can be readily taken to the work site. It is used to cut plates up to 2.0 m thick. Because the cutting oxygen jet has a 360° 'cutting edge', it provides a rapid means of cutting both straight edges and curved shapes to required dimensions without expensive handling equipment. Cutting direction can be continuously changed during operation.

13.2.1 Principles of Operation

There are two operations in gas cutting. A heated flame is directed on the metal to be cut and raises it to bright red heat or ignition point. Then a stream of high pressure oxygen is directed onto the hot metal.

The oxyfuel gas cutting process employs a torch with a tip (nozzle). The functions of the torch are to produce preheat flames by mixing the gas and the oxygen in the correct proportions and to supply a concentrated stream of high purity oxygen to the reaction zone. The oxygen oxidises the hot metal and the melting point of this oxide is well below the iron, therefore this oxide is melted immediately and blown away by the oxygen stream from the joint. The cutting torch mixes the fuel and oxygen for the preheating flames and aims the oxygen jet into the cut. The torch cutting tip contains a number of preheat flame ports and a centre passage for the cutting oxygen (see Figure 13.1). The preheat flames are used to heat the metal to a temperature where the metal will react with the cutting oxygen. The oxygen jet rapidly oxidises most of the metal in a narrow section to make the cut. Metal oxides and molten metal are expelled from the cut by the kinetic energy of the oxygen stream. Moving the torch across the work piece at a proper rate produces a continuous cutting action. The torch may be moved manually or by a mechanised carriage. The accuracy of a manual operation depends largely on the skill of the operator. Mechanised operation generally improves the accuracy and speed of the cut and the finish of the cut surfaces.

Figure 13.1 : Cutting Torch Tip

When a piece is cut by an oxygen cutting process, a narrow width of metal is progressively removed. The width of the cut is called a *kerf* (as shown in Figure 13.2). Control of the kerf is important in cutting operations where dimensional accuracy of the part and squareness of the cut edges are significant factors in quality control. With the

OFC process, kerf width is a function of the size of oxygen port, type of tip used, speed of cutting, and flow rates of cutting oxygen and preheating gases. As material thickness increases, oxygen flow rates must usually be increased. Cutting tips with larger cutting oxygen ports are required to handle the higher flow rates. Consequently, the width of the kerf increases as the material thickness being cut increases.

Kerf width is especially important in shape cutting. Compensation must be made for kerf width in the layout of the work, or the design of the template. Generally, on materials up to 50.0 mm thick, kerf width can be maintained within + 0.4 mm.

When the speed of the cutting torch is adjusted so that the oxygen stream enters the top of the kerf and exits from the bottom of the kerf along the axis of the tip, the cut will have zero *drag*. If the speed of cutting is increased, or if the oxygen flow is decreased, the oxygen available in the lower regions of the cut decreases. With less oxygen available, the oxidation reaction rate decreases, and also the oxygen jet has less energy to carry the reaction products out of the kerf. As a result, the most distant part of the cutting stream lags behind the portion nearest to the torch tip. The length of this lag, measured along the line of cut, is referred to as the *drag* (Ref. Figure 13.2).

Drag may also be expressed as a percentage of the cut thickness. A ten percent drag means that the far side of the cut lags the near side of the cut by a distance equal to ten percent of the material thickness.

An increase in cutting speed with no increase in oxygen flow usually results in a larger drag. This may cause a decrease in cut quality. There is also a strong possibility of loss of cut at excessive speeds. Reverse drag may occur when the cutting oxygen flow is too high or the travel speed is too low. Under these conditions, poor-quality cuts usually result. Cutting stream lag caused by incorrect torch alignment is not considered to be drag.

Figure 13.2 : End View of Cutting Tip

Cutting speeds below those recommended for best quality cuts usually result in irregularities in the kerf. The oxygen stream inconsistently oxidises and washes away additional material from each side of the cut. Excessive preheat flame results in undesirable melting and widening of the kerf at the top. The terminology used in oxyfuel cutting and the end view of the cutting tip is shown in Figure 13.2.

13.2.2 Chemistry of Oxygen Cutting

The process of oxygen cutting is based on the ability of high purity oxygen to combine rapidly with iron when it is heated to its ignition or kindling temperature, above 870°C. The iron is rapidly oxidised by the high-purity oxygen and heat is liberated by several reactions. The balanced chemical equations for these reactions are the following :

$$Fe + O = FeO + \text{heat (267 kJ), first reaction}$$

$$3Fe + 2O_2 = Fe_3O_4 + \text{heat (1120 kJ) second reaction}$$

$$2Fe + 1.5O_2 = Fe_2O_3 + \text{heat (825 kJ), third reaction}$$

The tremendous heat release of the second reaction predominates over that of the first reaction, which is supplementary in most cutting applications. The third reaction occurs to some extent in heavier cutting applications. Stoichiometrically, 0.29 m^3 of oxygen will oxidise 1 kg of iron to Fe_3O_4.

In actual operations, the consumption of cutting oxygen per unit mass of iron varies with the thickness of the metal. Oxygen consumption per unit mass is higher than the ideal stoichiometric reaction for thicknesses less than approximately 40 mm, and it is lower for greater thicknesses. For thicker sections, the oxygen consumption is lower than the ideal stoichiometric reaction because only part of the iron is completely oxidised to Fe_3O_4. Some unoxidised or partly oxidised iron is removed by the kinetic energy of the rapidly moving oxygen stream.

Chemical analysis has shown that, in some instances, over 30 percent of the slag is unoxidised metal. The heat generated by the rapid oxidation of iron melts some of the iron adjacent to the reaction surface. This molten iron is swept away with the iron oxide by the motion of the oxygen stream. The concurrent oxidising reaction heats the layer of iron at the active cutting front.

The heat generated by the iron-oxygen reaction at the focal point of the cutting reaction (the hot spot) must be sufficient to continuously preheat the material to the ignition temperature. Allowing for the loss of heat by radiation and conduction, there is ample heat to sustain the reaction. In actual practice, mill scale or rust frequently covers the top surface of the material. That layer must be melted away by the preheating flames to expose a clean metal surface to the oxygen stream. Preheating flames help to sustain the cutting reaction by providing heat to the surface. They also shield the oxygen stream turbulent interaction with air.

The alloying elements normally found in carbon steels are oxidised or dissolved in the slag without markedly interfering with the cutting process. When alloying elements are present in steel in appreciable amounts, their effects on the cutting process must be considered. Steels containing minor additions of oxidation resistant elements, such as chromium and nickel, can still be oxygen cut. However, when oxygen resistant elements are present in large quantities, modifications to the cutting technique are required to sustain the cutting action. This is true for stainless steels. In the oxyfuel gas cutting, quality of the oxygen plays an important role. So it is necessary to study the effect of oxygen quality on the cutting action.

Oxygen

Oxygen used for cutting operations should have a purity of 99.5 percent or higher. Lower purity reduces the efficiency of the cutting operation. A one percent decrease in oxygen purity to 98.5 percent will result in a decrease in cutting speed of approximately 15 percent, and an increase of about 25 percent in consumption of cutting oxygen. The quality of the cut will be impaired, and the amount and tenacity of the adhering slag will increase. With oxygen purities below 95 percent, the familiar cutting action disappears, and it becomes a melt and wash action that is usually unacceptable.

SAQ 1

(a) If it is said that maximum drag to be maintained is 20%, what does it mean?

(b) How can we achieve good quality of the cut?

(c) What is the effect of thickness on oxygen consumption?

(d) In case of steels sometime cutting techniques are to be modified. Why?

(e) If accuracy required is high and oxygen purity is below 95%, will it be acceptable? If not, why?

13.2.3 Preheating Fuels

Preheating fuels perform a particular function. Understanding of the function will help in proper selection of the fuel. In this section preheating fuel functions and their individual characteristics are discussed.

Functions of the preheat flames in the cutting operation are the following :

- Raise the temperature of the steel to the ignition point,
- Add heat energy to the work to maintain the cutting reaction,
- Provide a protective shield between the cutting oxygen stream and the atmosphere, and
- Dislodge from the upper surface of the steel any rust, scale, paint, or other foreign substance that would stop or retard the normal forward progress of the cutting action.

A preheat intensity that raises the steel to the ignition temperature rapidly will usually be adequate to maintain cutting action at high travel speeds. However, the quality of the cut will not be the best. High quality cutting can be carried out at considerably lower preheat intensities than those normally required for rapid heating. On most larger cutting machines, dual range gas controls are provided that limit high-intensity preheating to the starting operation. Then the preheat flames are reduced to lower intensity during the cutting operation, to save fuel and oxygen and provide a better-cut surface.

A number of commercially available fuel gases are used with oxygen to provide the preheating flames. Fuel gases are generally selected because of availability and cost. Combustion intensity or specific flame output for various fuel gases is another important consideration in fuel gas selection.

Fuel Selection Criterion

The following are some general factors for consideration when selecting a preheat fuel :

- Time required for preheating when starting cuts on square edges and rounded corners, and also when piercing holes for cut starts,
- Effect on cutting speeds for straight line, shape, and bevel cutting,
- Effect of the above factors on work output,
- Cost and availability of the fuel in cylinder, bulk, and pipeline volumes,

- Cost of the preheat oxygen required to burn the fuel gas efficiently,
- Ability to use the fuel efficiently for other operations, such as welding, heating, and brazing, if required, and
- Safety in transporting and handling the fuel gas containers.

For best performance and safety, the torches and tips should be designed for the particular fuel selected.

Fuel Gases

Acetylene

Acetylene is widely used as a fuel gas for oxygen cutting and also for welding. Its chief advantages are availability, high flame temperature, and widespread familiarity of users with its flame characteristics. Combustion of acetylene with oxygen produces a hot, short flame with a bright inner cone at each preheat port. The hottest point is at the end of this inner cone. Combustion is completed in the long outer flame.

Depending on the ratio of oxygen and acetylene, the flame may to be adjusted to reducing (carburising), neutral, or oxidising, as shown in Figure 13.3. The neutral flame, obtained with a ratio of approximately one part oxygen to one part acetylene, is used for manual cutting. As the oxygen flow is decreased, a bright streamer begins to appear. This indicates a reducing flame, which is sometimes used to rough-cut cast iron.

Figure 13.3 : Oxyacetylene Flame [P. T. Houlderoft or Dave Smith]

When excess oxygen is supplied, the inner flame cone shortens and becomes more intense. The flame temperature increases to a maximum at an oxygen-to-acetylene ratio of about 1.5 to 1. An oxidising flame is used for short preheating times and for cutting very thick sections.

The high flame temperature and heat transfer characteristics of the oxyacetylene flame are particularly important for bevel cutting. Acetylene in the free state should not be used at pressures higher than 103 kPa gage, or 207 kPa absolute pressure. At higher pressures, it may decompose with explosive force when exposed to heat or shock.

Methylacetylene-Propadiene Stabilized (MPS)

MPS is a liquefied, stabilised acetylene like fuel that can be stored and handled similarly to liquid propane. MPS is a mixture of several hydrocarbons, including propadiene (allene), propane, butane, butadiene, and methylacetylene. Methylacetylene, like acetylene, is an unstable, high-energy, triple-bond compound. The other compounds in MPS dilute the methylacetylene sufficiently to make the mixture safe for handling. The mixture burns hotter than either propane or natural gas. It also affords a high release of energy in the primary flame cone, another characteristic similar to acetylene. The outer flame gives relatively high heat release, like propane and propylene. The overall heat distribution in the flame is the most even of any of the gases.

A neutral flame is achieved at a ratio of 2.5 parts of torch-supplied oxygen to 1 part MPS. Its maximum flame temperature is reached at a ratio of 3.5 parts of oxygen to 1 part of MPS. These ratios are used for the same applications as the acetylene flame.

Although MPS gas is similar in many characteristics to acetylene, it requires about twice the volume of oxygen per volume of fuel for a neutral preheat flame. Thus, oxygen cost will be higher when MPS gas is used in place of acetylene for a specific job. To be competitive, the cost of MPS gas must be lower than acetylene for the job.

MPS gas does have an advantage over acetylene for underwater cutting in deep water. Because acetylene outlet pressure is limited to 207 kPa absolute, it is usually not applicable at depths below 6m of water. MPS can be used there and at greater depths, like hydrogen. For a particular underwater application, MPS, acetylene, and hydrogen should be evaluated for preheat fuel.

Natural Gas

The composition of natural gas varies depending on its source. Its main component is methane (CH_4). The ratio of torch supplied oxygen to natural gas is 1.5 to 1 for a neutral flame. The flame temperature with natural gas is lower than with acetylene. It is also more diffused and less intense. The characteristics of the flame for carburising, neutral, or oxidising conditions are not as distinct as with the oxyacetylene flame.

Because of the lower flame temperature and the resulting lower heating efficiency, significantly greater quantities of natural gas and oxygen are required to produce heating rates equivalent to those of oxygen and acetylene. To compete with acetylene, the cost and availability of natural gas and oxygen, their higher gas consumptions, and their longer preheat times must be considered. The use of tips designed to provide a heavy preheat flame, or cutting machines that allow a high-low preheat setting, may compensate for deficiencies in the lower heat output of natural gas.

The torch and tip designs for natural gas are different from those for acetylene. The delivery pressure for natural gas is generally low and the combustion ratios are different.

Propane

Propane is used regularly for oxygen cutting in a number of plants because of its availability and its much higher total heat value (Mj/m^3) than natural gas. For proper combustion during cutting, propane requires 4 to 4.5 times its volume of preheat oxygen. This requirement is offset somewhat by its higher heat value. It is stored in liquid form and is easily transported to the work site.

Propylene

Propylene, under many different brand names, is used as fuel gas for oxygen cutting. One volume of propylene requires 2.6 volumes of torch supplied oxygen for a neutral flame and 3.6 volumes for maximum flame temperature. Cutting tips are similar to those used for MPS.

Advantages and Disadvantages

Oxyfuel gas cutting has a number of advantages and disadvantages compared to other metal cutting operations, such as sawing, milling, and arc cutting.

Advantages

Several advantages of OFC are as follows :

(i) Steels can generally be cut faster by OFC than by mechanical chip removal processes.

(ii) Section shapes and thicknesses that are difficult to produce by mechanical means can be severed economically by OFC.

(iii) Basic manual OFC equipment costs are low compared to machine tools.

(iv) Manual OFC equipment is very portable and can be used in the field.

(v) Cutting direction can be changed rapidly on a small radius during operation.

(vi) Large plates can be cut rapidly in place by moving the OFC torch rather than the plate.

(vii) OFC is an economical method of plate edge preparation for bevel and groove weld joint designs.

Disadvantages

There are a number of disadvantages with oxyfuel gas cutting of metals. Several important ones are as follows :

(i) Dimensional tolerances are significantly poorer than machine tool capabilities.

(ii) The process is essentially limited commercially to cutting steels and cast iron, although other readily oxidized metals, such as titanium, can be cut.

(iii) The preheat flames and expelled red hot slag present fire and burn hazards to plant and personnel.

(iv) Fuel combustion and oxidation of the metal require proper fume control and adequate ventilation.

(v) Hardenable steels may require preheat, postheat, or both to control their metallurgical structures and mechanical properties adjacent to the cut edges.

(vi) Special process modifications are needed for OFC of high alloy steels and cast irons.

13.2.4 Equipment

There are two basic types of OFC equipment: manual and machine. The manual equipment is used primarily for maintenance, for scrap cutting, cutting risers off castings, and other operations that do not require a high degree of accuracy or a high quality cut surface. Machine cutting equipment is used for accurate, high quality work, and for large volume cutting, such as in steel fabricating shops. Both types of equipment operate on the same principle.

No one should attempt to operate any oxyfuel apparatus until trained in its proper use or under competent supervision. It is important to follow closely the manufacturer’s recommendations and operating instructions for safe use.

Manual Equipment

A setup for manual OFC requires the following :

- One or more cutting torches suitable for the preheat fuel gas to be used and the range of material thicknesses to be cut.
- Torch cutting tips to cut a range of material thicknesses.
- Oxygen and fuel gas hoses.
- Oxygen and fuel gas pressure regulators.
- Sources of oxygen and fuel gases to be used.
- Flame strikers, eye protection, flame and heat resistant gloves and clothing, and safety devices.
- Equipment operating instructions from the manufacturer.

Mechanised Equipment

Mechanised OFC will require additional facilities depending on the application :

- A machine to move one or more torches in the required cutting pattern.
- Torch mounting and adjusting arrangements on the machine.
- A cutting table to support the work.
- Means for loading and unloading the cutting table.
- Automatic preheat ignition devices for multiple torch machines

Mechanised OFC equipment can vary in complexity from simple hand-guided machines to very sophisticated numerically controlled units.

Torches

The functions of an OFC torch are as follows :

- To control the flow and mixture of fuel gas and preheat oxygen.
- To control the flow of cutting oxygen.
- To discharge the gases through the cutting tip at proper velocities and volumetric flow rates for preheating and cutting.

Gas Pressure Regulators

The ability to make a successful cut requires not only the proper choice of cutting torch and tip for the fuel gas selected, but also a means of precisely regulating the proper gas pressures and volumes. Regulators are pressure control devices used to reduce high source pressures to required working pressures by manually adjusted pressure valves. They vary in design, performance, and convenience features. Gas pressure regulators are designed for use with specific types of gases and for definite pressure ranges.

Gas pressure regulators used for OFC are generally similar in design to those used for oxyfuel gas welding (OFW). Regulators for most other fuel gases are similar in design to acetylene regulators. For OFC, regulators with higher capacities and delivery pressure ranges than those used for OFC.

Other Equipment

Tinted goggles or other appropriate eye protection devices are available in a number of different shades. Tip cleaners, wrenches, strikers, and all appropriate safety devices including protective clothing should be used.

13.2.5 Operating Procedures

In the operation of OFC equipment, the recommendations of the equipment manufacturer in assembling and using the equipment should always be closely followed. This will prevent damage to the equipment and also insure its proper and safe use.

Regulators

The oxygen and fuel gas regulators must be clean and in good working condition. If there is oil, grease, or foreign material on a regulator or other equipment, or if the equipment is damaged, it must not be used prior to being properly cleaned or serviced by a qualified repair technician. Hoses must be in good condition and of appropriate size to provide adequate volume and pressure of both oxygen and fuel gas to the cutting torch.

Operating the Torch

The manufacturer's recommendations for lighting, testing, and using the equipment should always be followed. Only a spark lighter or other recommended lighting device should be used. Shaded or tinted eye protection and other appropriate clothes must be worn.

The most widely accepted manner to light the torch is to open the fuel-gas valve slightly, and light the gas with a spark lighter. Adjust the fuel gas until a stable flame is maintained at the end of the tip. Open the oxygen preheat valve slowly and increase the flow until the desired flame is attained. The intensity of the flame may be adjusted by slightly increasing or decreasing the volumes of both gases.

Flame Adjustment

Flame adjustment is a critical factor in attaining satisfactory torch operation. The amount of heat produced by the flame depends on the intensity and type of flame used. Three types of flames can be set by properly adjusting the torch valves. A carburising flame with acetylene, MPS, or propylene is indicated by trailing feathers on the primary flame cone or by long yellow-orange streamers in the secondary flame envelope. Propylene-based fuels, propane, and natural gas have a long, rounded primary flame cone. A carburising flame is often used for the best finish and for stack cutting of thin material.

A neutral flame with acetylene, MPS, or propylene is indicated by a sharply defined, dark primary flame cone and a pale blue secondary flame envelope. Propane and propylene base fuels and natural gas have a short and sharply defined cone. This flame is obtained by adding oxygen to a carburising flame. It is the flame most frequently used for cutting.

An oxidising flame for acetylene or MPS has a light colour primary cone and a smaller secondary flame shroud. It also generally burns with a harsh whistling sound. With propane and propylene base fuels and natural gas, the primary flame cones are longer, less sharply defined, and have a lighter colour. This flame is obtained by adding some oxygen to the neutral flame. This type of flame is frequently used for fast, low-quality cutting, and selectively in piercing and quality bevelling.

While operating OFC equipment a corrective action must be taken to extinguish flashback *which is the burning of the flame in or behind the torch mixing chamber.* It is a serious condition, and corrective action must be taken to extinguish it. The torch oxygen valve should be turned off immediately and then the fuel gas valve. Causes of flashback can be failure to purge the hose lines before lighting the torch or overheating of the torch tip.

A backfire is the momentary recession of the flame into the torch tip followed by immediate reappearance or complete extinguishing of the flame.

After this condition, the torch is still workable. If backfiring continues, the torch or tips, or both, should be removed from service for cleaning and possible repair.

SAQ 2

(a) What precautions should be taken while using the OFC equipment?

(b) What is the procedure of lighting the cutting torch?

(c) How the flame can be adjusted to carburising flame in case of oxyacetylene cutting?

(d) If the clean cut is the requirement, what should be the preheat fuel and its proportion with oxygen?

13.3 ARC CUTTING PROCESSES

The intense heat of the electric arc can melt very small area of metal. Molten metal is removed by gravity or gas pressure leaving a cavity or cut. Oxygen, air or inert gases along with an electric arc are used to cut and gouge metal. The cutting speeds of arc cutting processes are generally very high. In arc processes either a carbon or metal electrode is used. There are number of arc cutting processes like Carbon arc cutting, Shielded metal arc cutting, Gas metal arc cutting etc. Plasma arc cutting is an easily used and accurate process. Some of the commonly used arc cutting processes are discussed in this section.

13.3.1 Carbon Arc Cutting

This process is generally used only when arc or oxyfuel gas cutting is not available. The amperages used for carbon arc cutting are generally higher than for welding on the same metal thickness.

Before starting the cutting, the carbon electrode should be ground to a very sharp point. The length of the taper should be 6 - 8 times the electrode diameter. The electrode should stick out from the electrode holder a distance equal to 10 times the electrode diameter. This is necessary to reduce electrical resistance and heating effect on the electrode. The electrode angle should be about 20 degrees from vertical to cut completely. The carbon arc method of cutting is successful on cast iron because the temperature of the arc is sufficient to melt the iron oxides formed.

Figure 13.4 : Carbon Arc Cutting on Cast Iron

The cut should be made from top to bottom, or vertically down. This will keep the molten metal flowing out of the gauge area. The graphite form of carbon electrodes is preferred because high currents are needed.

In this method base metal is melted by the heat of the arc. Metal is removed from the kerf by the force of the arc and gravity. The quality of the cut is generally poor. This method is used in small shops where more efficient and expensive equipment is generally not available.

13.3.2 Shielded Metal Arc Cutting (SMAC)

Electric arc process with covered metal electrodes can also be used to remove the metal. Generally covering of the electrode disintegrates at a slower rate than the metal center of the electrode. This action creates a deep recess at the arc end of the electrode and produces a jet action that tends to blow the molten metal away. Shielded metal arc cutting electrodes may be used for cutting stainless steel, copper, aluminium, bronze, nickel, cast iron, manganese, steel or alloy steels.

In the case of SMAC, extra metal which is due to the melting of the electrode has also to be removed, so the extra care has to be taken to remove this metal.

13.3.3 Plasma Arc Cutting (PAC) Principles

The major difference between PAC and Plasma Arc Welding (PAW) is the velocity of the orifice gas. PLASMA ARC CUTTING uses the principle of passing an electric arc through a quantity of gas travelling through a restricted outlet. The electric arc heats the gas as it travels through the arc. The gas is heated to such a high temperature that it turns into what is called PLASMA. Plasma is the fourth state of matter - not a gas, liquid, or a solid. A great deal of heat energy is required to change the gas to a plasma. The heat required is furnished by the electric arc. It is this heat in the plasma which heats the base metal. The heat of the plasma is released on the metal as the plasma turns back to a gas. Using the plasma process, temperatures as high as 25,200^{o}F (14,000^{o}C) have been reached.

Cutting torches used has several ports. Only the center port has the arc plasma, while the surrounding ports provide a shielding gas protection. Gas flow may be as high as 250 cu. Ft./hr. Nitrogen is often used as the plasma gas. The shielding gas for mild steel is CO_2 or air. An argon and helium mixture is used as the shielding gas for aluminium.

Figure 13.5 : Plasma Arc Cutting Process

Two types of plasma arc cutting processes are :

(i) Transfer arc,

(ii) Non-transfer arc.

Figure 13.6 : Plasma Torches

Power supply and gas settings play crucial role in PAC. In the transfer arc process, the arc will go out when the cut is completed. Once the cut runs off the metal there is no longer a complete circuit through the base metal. When the arc goes out, the gas will also stop flowing. If an automatic carriage is being used, it will also stop, due to the wiring of the circuits. In the non-transfer process, the operating switch must be opened when the end of the cut is reached.

Plasma arc cutting may be done in any position, and it will cut virtually any metal. The ability makes it a very useful and versatile process. Plasma arc cutting may be done under several inches (mm) of water as well with slight modifications and precautions.

Oxygen Arc Cutting

Oxygen arc cutting is a method of cutting, piercing, and gouging metals by the use of an electric arc and a stream of oxygen. A consumable electrode is used that consists of a ferrous metal tube covered with a non-conductive mineral covering. Oxygen is conveyed through the bore of the tube to the area heated by the arc, producing an oxidation reaction in a manner similar to oxyfuel gas cutting. Oxygen arc cutting is used to cut alloy steels aluminium and cast iron. These metals are difficult to cut using oxyfuel gas cutting process. This process is also used on carbon steel. Oxygen arc cutting is primarily used in underwater applications.

13.4 OTHER CUTTING PROCESSES

13.4.1 Metal Powder Cutting

The metal powder cutting process (POC) is a technique for supplying an OFC torch with a stream of iron-rich powdered material. The powdered material accelerates and propagates the oxidation reaction and also the melting and spalling action of hard-to-cut materials. The powder is directed into the kerf through either the cutting tip or single or multiple jets external to the tip or through the preheated orifice of the tip. When the first method is used, gas-conveyed powder is introduced into the kerf by special orifices in the cutting tip. When the powder is introduced externally, the gas conveying the powder imparts sufficient velocity to the powder particles to carry them through the preheat envelope into the cutting oxygen stream. Their short time in the preheat envelope is sufficient to produce the desired reaction in the cutting zone.

In cutting low carbon steels a pre-heating flame raises the temperature to ignition point. This is the temperature at which oxidation of the iron occurs and iron oxide is formed when a jet of oxygen is blown to the area which is further blown away by the jet resulting in narrow cut. For the sequence to occur, the melting point of the oxide formed must be lower than that of the metal being cut. This is the case in low carbon steel whereas in the case of stainless steels and non-ferrous metals the oxide formed have a melting point higher than that of the parent metal.

When attempting to cut stainless steel with ordinary oxy-acetylene equipment the chromium combines with oxygen at high temperature and forms a thin coating of oxide having a melting point higher than that of the parent metal. It is difficult to remove these oxides, further oxidation does not occur and the cut cannot continue.

In the powder cutting process oxygen stream react with finely divided powder and raises the temperature so high that the refractory oxides melt fluxed and eroded resulting in an unhindered cut. Some of the powders react chemically with the refractory oxides produced in the kerf and increase their fluidity. The resultant molten slag is washed out of the reaction zone by the oxygen jet. Fresh metal surfaces are continuously exposed to the oxygen jet and powder. Iron powder and mixtures of metallic powders, such as iron and aluminium, are used.

Cutting of oxidation resistant steels by the powder method can be done at approximately the same speeds as oxygen cutting of carbon steel of equivalent thickness. The cutting oxygen flow must be slightly higher with the powder process.

In cutting any metal by the method, correct dispenser setting, dry air and powder, clean powder passages and leak tight joints all help towards ensuring a good quality cut. Speed of powder flow is first adjusted to the correct amount for the particular work in hand by trial cuts.

13.4.2 Flux Cutting

This process is primarily intended for cutting stainless steels. The flux is designed to react with oxides of alloying elements, such as chromium and nickel, to produce compounds with melting points near those of iron oxides. A special apparatus is required to introduce the flux into the kerf. With a flux addition, stainless steels can be cut at a uniform linear speed without torch oscillation. Cutting speeds approaching those for equivalent thickness of carbon ste el can be attained. The tip sizes will be larger, and the cutting oxygen flow will be somewhat greater than for the carbon steels.

13.4.3 Oxygen Lance Cutting

This method can be used for baring or cutting holes in concrete, brick, granite etc. by means of heat generated by chemical reactions.

Oxygen lance cutting (LOC) is an oxygen cutting process that uses oxygen supplied through a consumable steel pipe or lance (it is a long length of ordinary steel tubing or pipe). Preheat required to start the cutting is obtained by other means.

The lance consists of a tube that is approximately 3 m long and 6.5 - 9.5 mm diameter and is packed with steel wires. One end of the tube is threaded or snap connected and is connected by means of a flexible hose to an oxygen supply to operate the lance. The free end is heated using oxyfuel gas cutting or welding torch to cherry red and oxygen is passed down the tube. When the burning end of the lance is brought close to the workpiece, the heat of the flame melts the work. Rapid oxidation of the wires begins at the heated end with great evolution of heat giving rise to a self sustained exothermic reactions. The end of the pipe burns continuously and new length is added to the lance. Heat output after this the heating is removed is often increased by adding magnesium and aluminium.

13.4.4 Flame Gouging

This method is used for cutting the grooves with very smooth contours in steel plate without even penetrating the plates. It is an extension of oxy-acetylene cutting process. In this method principle of operation is same as that of oxy-acetylene process, except that a special type of nozzle is used in standard cutting blow pipe. The cutting torch may have a straight 75°or 180° angle head together with a range of special gouging nozzles.

In gouging a large orifice low velocity jet is used instead of high velocity jets. Gouging is used extensively to remove deep defects in steel revealed by radiographic, magnetic, and other non-destructive inspection methods.

The most common gouging job is to remove tack welds that initially hold work together until the welder can make the final weld. Gouging is also used for removing weld defects, blowholes, or sand inclusions in castings; for welds made on temporary brackets or supports; for removing flanges from piping and pressure-vessel heads; and for removing old tubes from boilers. Flame gouging is used in demolition work and preparing specially shaped plate edges for welding.

13.4.5 Flame Drilling

Flame drilling is used to make relatively shallow holes in bars or heavy steel sections. Such holes might be used for centring massive pieces of steel in a lathe or inserting tools for making seamless pipe. The operation is similar to making a piercing start in a plate. Use straight-bore tips. Continue the hole until you think it's deep enough. It is very difficult to drill a blind hole to a precise depth using this method.

13.5 PROCEDURES FOR DANGEROUS COATINGS

In the last section various methods used for cutting the metals have been discussed. But it is important to take into account the effects of coatings sometimes covering those metals. In some cases high temperaturs and chemical reactions involved during cutting can react with the coating materials to produce harmful effects like poisonous fumes. So it is important to take care while cutting the materials with coatings. This section is devoted to this aspect of themal cutting.

Zinc-Coated Steels

The most commonly used coated steel is galvanised (zinc -coated) steel. When zinc is burned it produces fumes of zinc oxide that look like white smoke. Zinc-oxide fumes can produce fever, chills, and a splitting headache for a day and thereafter person recovers. Galvanised steels are used to make air conditioning and heating ductwork, rain spouts and gutters, prefabricated farm and factory buildings, the underparts of automobiles to stop rust, highway guard rails and culverts, and some types of corrosion-resistant steel wire and fence posts. If you have to cut a lot of zinc-coated steel, use a filter mask to stop the fumes and work in a well-ventilated area. A related product, aluminium-coated steels, would not cause problems.

Lead-Coated Steels

Lead-coated steels are more dangerous. The lead-oxide fumes can produce lead poisoning. Use a filter mask, and work in a well-ventilated area when cutting lead-coated steels. A supplied-oxygen mask would be even better.

Lead or lead-tin-coated sheet steels are used as roofing materials on some commercial buildings and churches and as gutters and downspouts. Lead-coated steels include lead-tin alloy coatings called terne plate. Terne plate is used to make auto and tractor gas tanks and electric equipment chassis because the lead coating is easy to solder things to, while the steel underneath makes the product strong and rigid.

A more likely lead-poisoning hazard for torch operators is cutting structural steel in demolition work. Some structural steels are coated with a red-lead primer. Remember that an old structural column may be coated with a lead primer and then finished with cement so that you can not immediately see the redlead surface on the steel. (Check for it with a chipping hammer.)

Electroplated Coatings

The third group of surfaces to be especially careful with are electroplated coatings. These include chrome-plated steel bumpers, which have a layer of copper under a layer of nickel under a layer of chrome. Cut them while wearing a filter mask, but one is better off not cutting them at all.

Never cut anything that is coated with cadmium or mercury. You are not likely to find mercury coating anything you will cut, but cadmium can occur. It is a highly corrosion resistant silvery electroplated coating sometimes-used on nuts, bolts, and other kinds of fasteners. Cadmium fumes are more poisonous than lead. Most fastener manufacturers have stopped using it, but you can still find it in scrap and old parts.

Although it is not a coated metal, beryllium is a material you are never likely to flame-cut (at least not with oxyfuel). Its fumes are highly poisonous. The only place you are likely to find beryllium used is in beryllium-copper alloys. These high-strength, corrosion-resistant alloys are not very common and cannot be flame-cut with the oxyfuel process. They are reddish-orange to red-brown-coloured alloys.

Pre-painted Steels

Some sheet steels now come pre-painted or coated with plastics by the steel producer before they arrive at the plant. Plastic-coated steel pipes are also in use; the plastic is usually a liner on the inside diameter. Whenever you flame-cut these materials, remove the plastic far enough on either side of the cut so that you would not burn the coating to produce harmful fumes.

Do not breathe fumes from burning paint or plastic in any instance. Besides smelling awful paint fumes also may contain lead, while the plastic smoke can have all sorts of strange things in it. Structural steels often are primed with lead-containing paints. These lead primers usually are dark red. Other colours, including gray, also are used now.

Degreased Steels

Plates sometimes are cleaned of oil with degreasers or solvents before you get them. Do not breathe fumes from these cleaning compounds. Many of these coatings can be removed with a damp cloth. If you are not sure how to clean the plate, ask somebody. Burning solvent fumes can hurt your lungs and nervous system. Some of the fumes will damage you permanently.

13.5.1 Safe Practices

In case of welding or thermal cutting it is important for the operator to take certain precautions to avoid untoward incidences. Some of them are listed below

Use a Mask

In general, wear a filter mask for dust and fumes, and a supplied-oxygen mask for gases where you can run out of air. Remember that a filter mask or a gas mask is not a supplied-oxygen mask. The filter mask stops particles down to a certain size, depending upon the filter. The gas mask adsorbs gases. This does not supply oxygen if you run out while working inside an enclosed tank or in a sewer or excavation. Only a mask with a tank of air or a long breathing air supply line is safe when the oxygen in the work area is reduced. Most work in plants would not involve flame-cutting coated steels. But the safety director will be happy to provide the right mask for your work if you ever need it.

- If you have doubts about cutting any material with which you are not familiar, find out first or do not do it at all. Most of the time you will be cutting familiar materials. It is not right to think that you will run into these flame-cutting risks every day, but you know about them for those rare instances when you might have a problem.
- Fumes are a potential health hazard. When the process is used in an enclosed or semi-enclosed area, exhaust ventilation should be provided and the operator should be equipped with a respirator. Noise from the operation may exceed safe levels in some circumstances. When necessary, ear protection should be used by the operator. Fire is another potential hazard and combustible materials should be cleared away from the cutting area for a distance of at least 10 m.

- Appropriate protective clothing and equipment for any cutting operation will vary with the nature and location of the work to be performed. Some or all of the following may be required :
  - (i) Tinted goggles or face shields with filter lens
  - (ii) Flame resistant gloves
  - (iii) Safety glasses
  - (iv) Flame resistant jackets, coats, hoods, aprons, etc.
  - (v) Hard hats
  - (vi) Leggings and spats
  - (vii) Safety shoes
  - (viii) Flame extinguishing protective equipment
  - (ix) Supplemental breathing equipment
  - (x) Other safety equipment

13.6 SUMMARY

Thermal cutting processes involve mainly two operations. First is heating of the metal to a very high temperature to reach the ignition point followed by the use of high pressure oxygen jets. These two operations are mainly to melt the metal and to blow away the molten metal.

In thermal cutting once the cutting has started, heat to keep the cut going is generally provided by the heat produced due to chemical reaction and the heating jet.

In this unit, various cutting processes have been discussed. Though the principle of cutting remains the same still all these processes differ from each other with respect to the cutting technique and equipment and fuels used during the process.

13.7 KEY WORDS

Cruciform Test : A test in which a cruciform specimen is tested in tension.

Cutting Electrode : An electrode with a covering that aids the production of such an arc that molten metal is blown away to produce a curve or cut in the work.

Kerf : The void left after metal has been removed in thermal cutting.

Metal-Arc Cutting : Thermal cutting by melting, using the heat of an arc between a metal electrode and the metal to be cut.

Oxygen-Arc Cutting : Thermal cutting in which ignition temperature is produced by an electric arc, and cutting oxygen is conveyed through the center of an electrode, which is consumed in the process.

FURTHER READING

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