TYPES OF WELDING PROCESSES

Welding processes divide into two major categories:

1) fusion welding, in which coalescence التلاحم is accomplished إنجاز by melting the two parts to be joined, in some cases adding filler metal to the joint; and

2) solid-state welding, in which heat and/or pressure are used to achieve coalescence, تحقيق التلاحم but no melting of the base metals occurs and no filler metal is added.

Fusion welding is the more important category. It includes:

1) arc welding,

2) resistance welding,

3) oxy-fuel gas welding, and

4) other fusion welding processes - ones منها that cannot be classified as any of the first three types.

1. ARC WELDING

Arc welding (**AW**) is a fusion-welding process in which coalescence الربط of the metals is achieved حققت by the heat of an electric arc between an electrode and the work. A generic عامة AW process is shown in Figure 1. An electric arc is a discharge of electric current across a gap in a circuit. It is sustained استدامة by the presence of a thermally ionized column of gas (called a plasma) through which current flows.

To initiate the arc in an AW process, the electrode is brought into contact with the work and then quickly separated from it by a short distance. The electric energy from the arc thus formed produces temperatures of 5500 ^oC or higher, sufficiently hot to melt any metal. A pool of molten metal بركة معدن المنصهر , consisting of base metal(s) and filler metal (if one is used) is formed near the tip of the electrode. In most arc welding processes, filler metal is added during the operation to increase the volume and strength of the weld joint. As the electrode is moved along the joint, the molten weld pool solidifies in its wake في أعقابه.

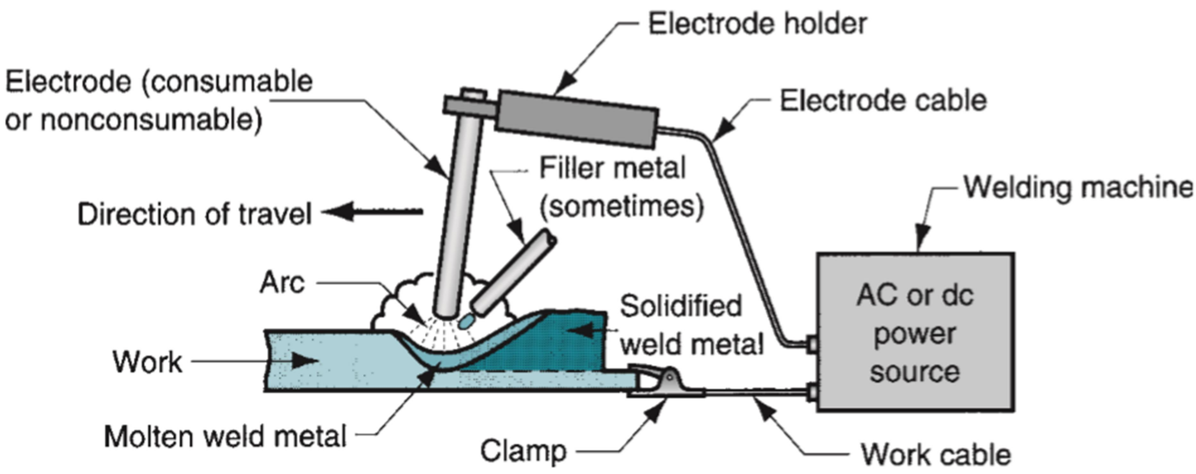

FIGURE 1. The basic configuration and electrical circuit of an arc welding process.

Movement of the electrode relative to the work is accomplished by either a human welder (manual welding) or by mechanical means (i.e., machine welding, automatic welding, or robotic welding). One of the troublesome aspects of manual arc welding is that the quality of the weld joint depends on the skill and work ethic of the human welder. Productivity is also an issue. It is often measured as arc time (also called arc-on time) - the proportion نسبة of hours worked that arc welding is being accomplished.

1.1. General Technology of Arc Welding

Before describing the individual AW processes, it is instructional to examine some of the general technical issues that apply to these processes.

Electrodes used in AW processes are classified as Consumable or Non-consumable.

a. Consumable electrodes provide the source of the filler metal in arc welding. These electrodes are available in two principal forms: rods (also called sticks) and wire. Welding rods are typically 225 to 450 mm long and 9.5 mm or less in diameter. The problem with consumable welding rods, at least in production welding operations, is that they must be changed periodically, reducing arc time of the welder. The advantage that it can be continuously fed in to the weld pool from spools البكرات containing long lengths of wire, thus avoiding تجنب the frequent interruptions الانقطاع المتكرر that occur when using welding sticks. In both rod and wire forms, the electrode is consumed مستهلكة by the arc during the welding process and added to the weld joint as filler metal.

b. Non-consumable electrodes are made of tungsten (or carbon, rarely), which resists melting by the arc. Despite its name وعلى الرغم من اسمه, a non-consumable electrode is gradually depleted نفدت during the welding process, similar to the gradual wearing of a cutting tool in a machining operation. For AW processes that utilize يستفادة non-consumable electrodes, any filler metal used in the operation must be supplied by means of a separate wire that is fed into the weld pool.

Arc Shielding At the high temperatures in AW, the metals being joined are chemically reactive to oxygen, nitrogen, and hydrogen in the air. The mechanical properties of the weld joint can be degraded تدهور by these reactions. Thus, protection حماية the arc from the surrounding air is provided in all AW processes. Arc shielding is accomplished يتم إنجاز by covering the electrode tip, arc, and molten weld pool with a blanket of gas or flux, or both, which inhibit exposure التي تحول دون التعرض of the weld metal to air. Common shielding gases include argon and helium, both of which are inert. In the ferrous metals welding, oxygen and carbon dioxide are used, usually in combination with **Ar** and/or **He**, to produce an oxidizing atmosphere جو مؤكسد or to control weld shape**.**

A flux is a substance مادة used to prevent the formation of oxides and other unwanted contaminants الملوثات, or to dissolve them تحللها and facilitate removal. During welding, the flux melts and becomes a liquid slag, covering the operation and protecting the molten weld metal. The slag hardens upon cooling and must be removed later by chipping التقطيع or brushing بالفرشاة . Flux is formulated to serve خدمة several functions:

(1) provide a protective atmosphere for welding, توفير أجواء حماية للحام

(2) stabilize the arc, and تثبيت القوس

(3) reduce splattering. وتقليل الرش

The method of flux application differs for each process. The delivery techniques include:

(1) pouring granular flux حبيبات التمويه onto the welding operation,

(2) using a stick electrode عصا قطب كهربائي coated with flux material in which the coating melts during welding to cover the operation, and

(3) using tubular electrodes أقطاب كهربائية أنبوبي in which flux is contained in the core and released as the electrode is consumed.

Power Source in Arc Welding both Direct Current (DC) and Alternating Current (AC) are used. AC machines are less expensive to purchase and operate, but are generally restricted مقيد to welding of ferrous metals. DC equipment can be used on all metals with good results and is generally noted for better arc control. In all arc-welding processes, power to drive the operation is the product of the current **I** passing through the arc and the voltage **E** across it. This power is converted into heat, but not all of the heat is transferred to the surface of the work. Convection الحمل الحراري, conduction التوصيل, radiation الإشعاع, and spatter account حساب ترشيش for losses that reduce the amount of usable heat.

1.2. Aw Processes - Consumable Electrodes

A number of important arc-welding processes use consumable electrodes.

Shielded Metal Arc Welding (**SMAW**) is an AW process that uses a consumable electrode consisting of a filler metal rod coated with chemicals that provide flux and shielding (Figure 2). The filler metal used in the rod must be compatible متوافق with the metal to be welded, the composition usually being very close to that of the base metal. The coating consists of powdered cellulose مسحوق السليلوز (i.e., cotton and wood powders) mixed with oxides, carbonates, and other ingredients المكونات, held together by a silicate binder. Metal powders are also sometimes included in the coating to increase the amount of filler metal and to add alloying elements. The heat of the welding process melts the coating to provide a protective atmosphere and slag for the welding operation. It also helps to stabilize the arc and regulate تنظيم the rate at which the electrode melts. During operation the bare metal end of the welding stick (opposite the welding tip) is clamped in an electrode holder that is connected to the power source. The holder has an insulated معزول handle so that it can be held and manipulated by a human welder. Currents typically used in SMAW range between 30 and 300 A at voltages from 15 to 45 V.

Selection of the proper power parameters depends on:

the metals being welded, electrode type and length, and depth of weld penetration required.

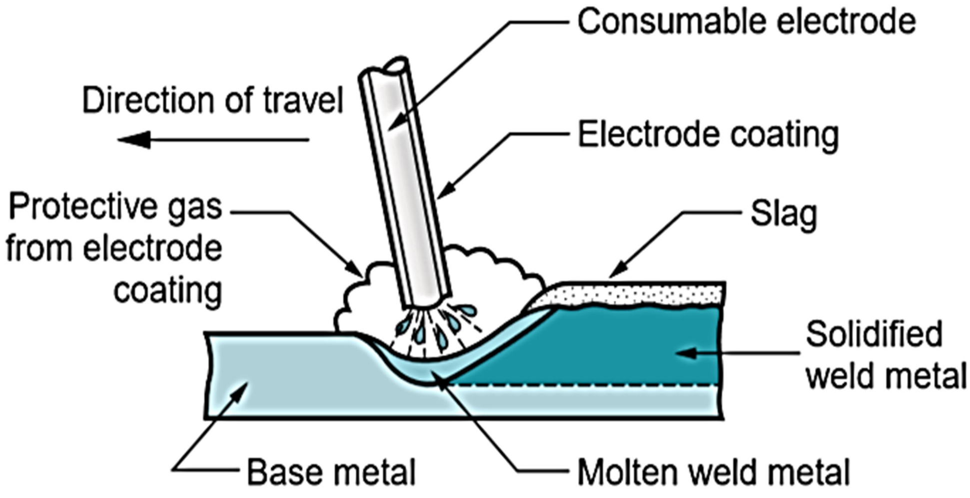

FIGURE 2. Shielded metal arc welding (SMAW).

SMAW is usually performed manually. Common applications include construction, pipelines, machinery structures, shipbuilding, job shop fabrication, and repair work. The equipment is portable and low cost, making SMAW highly versatile. Base metals include steels, stainless steels, cast irons, and certain nonferrous alloys. It is not used or seldom used for aluminum and its alloys, copper alloys, and titanium.

A disadvantage of SMAW

- As the sticks are used up (consumable electrode stick), they must periodically be changed. This reduces the arc time.
- The electrode length varies during the operation and this length affects the resistance heating of the electrode, current levels must be maintained within a safe range or the coating will overheat and melt prematurely قبل الأوان when starting a new welding stick.

Some of the other AW processes overcome the limitations of welding stick length in SMAW by using a continuously fed wire electrode.

Gas Metal Arc Welding (**GMAW**) is an AW process in which the electrode is a consumable bare metal wire, and shielding is accomplished by flooding فيض the arc with a gas. The bare wire أسلاك مكشوفة is fed continuously and automatically from a spool لفة through the welding gun (Figure 3). Wire diameters ranging from 0.8 to 6.5 mm are used, the size depending on the thickness of the parts being joined and the desired deposition الترسب rate. Gases used for shielding include inert gases such as argon and helium, and active gases such as carbon dioxide. Selection of gases (and mixtures of gases) depends on the metal being welded, as well as other factors.

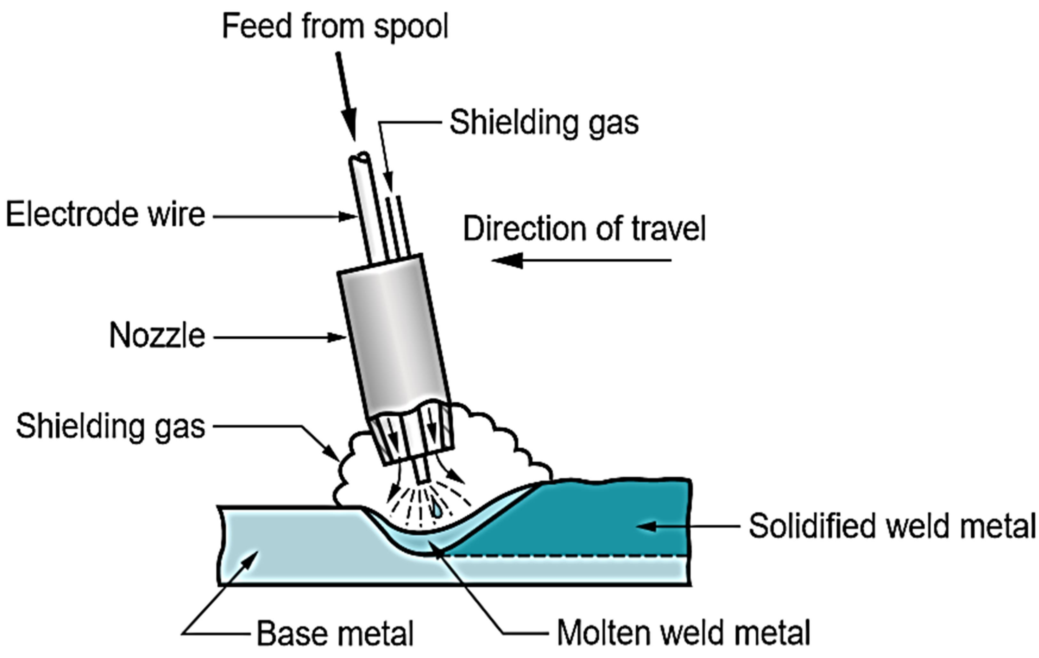

FIGURE 3. Gas metal arc welding (GMAW).

Inert gases are used for welding aluminum alloys and stain less steel, while CO_2 is commonly used for welding low and medium carbon steels. The combination of bare electrode wire and shielding gases eliminates يلغي the slag covering on the weld bead and thus precludes وهكذا يحول دون the need for manual grinding and cleaning of the slag. The GMAW process is therefore ideal for making multiple welding passes on the same joint. The name applied to this process was MIG welding (for Metal Inert Gas welding). Refinements التحسينات in GMAW for steel welding have led to the use of gas mixtures, including CO_2 and argon, and even oxygen and argon.

GMAW is widely used in fabrication operations in factories for welding a variety of ferrous and nonferrous metals. Because it uses continuous weld wire rather than welding sticks, it has a significant advantage over SMAW in terms of arc time when performed manually. For the same reason, it also lends itself to automation of arc welding. The electrode stubs كعوب remaining after stick welding also wastes النفايات filler metal, so the utilization استخدام of electrode material is higher with GMAW. Other features of GMAW include higher deposition الترسب rates than SMAW, and good versatility تعدد الاستخدامات .

Submerged Arc Welding (**SAW**) This process, developed during the 1930s, was one of the first AW processes to be automated. SAW is an arc-welding process that uses a continuous, consumable bare wire electrode, and arc shielding is provided by a cover of granular flux. The electrode wire is fed automatically from a coil into the arc. The flux is introduced into the joint slightly ahead of the weld arc by gravity from a hopper (Figure 4). The blanket بطانية of granular flux completely submerges the welding operation, preventing sparks, spatter, and radiation that are so hazardous in other AW processes. Thus, the welding operator in SAW need not wear the safety glasses and protective gloves. The portion of the flux closest to the arc is melted, mixing with the molten weld metal to remove impurities and then solidifying on top of the weld joint to form a glass like slag. The slag and unfused flux granules on top provide good protection from the atmosphere and good thermal insulation for the weld area, resulting in relatively slow cooling and a high-quality weld joint, noted for toughness and ductility. The unfused flux remaining after welding can be recovered and reused.

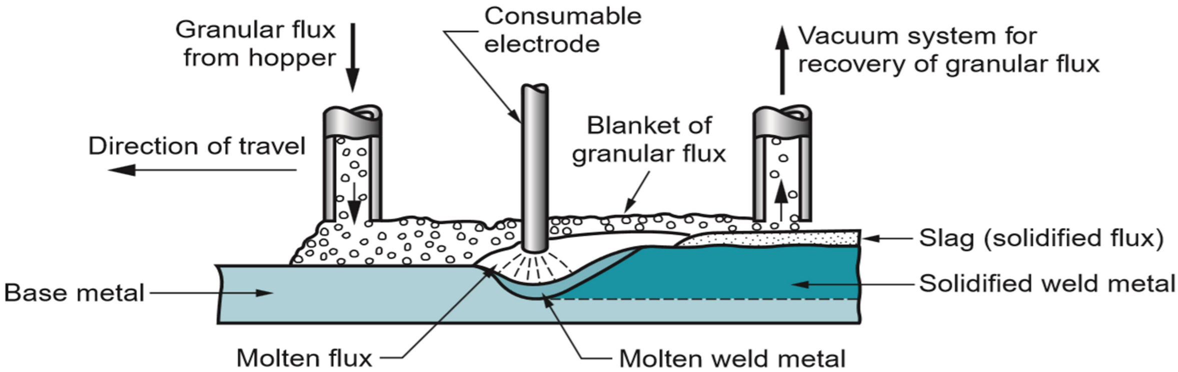

FIGURE 4. Submerged arc welding (SAW).

The solid slag covering the weld must be chipped away, usually by manual means. Submerged arc welding is widely used in steel fabrication for structural shapes (e.g., welded I-beams); longitudinal and circumferential seams for large diameter pipes, tanks, and pressure vessels; and welded components for heavy machinery. In these kinds of applications, steel plates of 25-mm thickness and heavier are routinely welded by this process. Low-carbon, low-alloy, and stainless steels can be readily welded by SAW; but not high-carbon steels, tool steels, and most nonferrous metals. Because of the gravity feed of the granular flux, the parts must always be in a horizontal orientation, and a backup plate is often required beneath the joint during the welding operation.

1.3. AW Processes - Non-Consumable Electrodes

AW processes discussed above use consumable electrodes. Gas tungsten arc welding, plasma arc welding, and several other processes use non-consumable electrodes.

Gas Tungsten Arc Welding (**GTAW**) is an AW process that uses a non-consumable tungsten electrode and an inert gas for arc shielding. The term **TIG** welding (**Tungsten Inert Gas** welding) is often applied to this process. GTAW can be implemented with or without a filler metal. Figure 5 illustrates the latter case. When a filler metal is used, it is added to the weld pool from a separate rod or wire, being melted by the heat of the arc rather than transferred across the arc as in the consumable electrode AW processes. Tungsten is a good electrode material due to its high melting point of 3410 C. Typical shielding gases include argon, helium, or a mixture of these gas elements. GTAW is applicable to nearly all metals in a wide range of stock thicknesses. It can also be used for joining various combinations of dissimilar metals. Its most common applications are for aluminum and stainless steel. Cast irons, wrought irons, and of course tungsten are difficult to weld by GTAW.
In steel welding applications, GTAW is generally slower and more costly than the consumable electrode AW processes, except when thin sections are involved and very-high-quality welds are required. When thin sheets are TIG welded to close tolerances, filler metal is usually not added. The process can be performed manually or by machine and automated methods for all joint types. Advantages of GTAW in the applications to which it is suited include high - quality welds, no weld spatter because no filler metal is transferred across the arc, and little or no post weld cleaning because no flux is used.

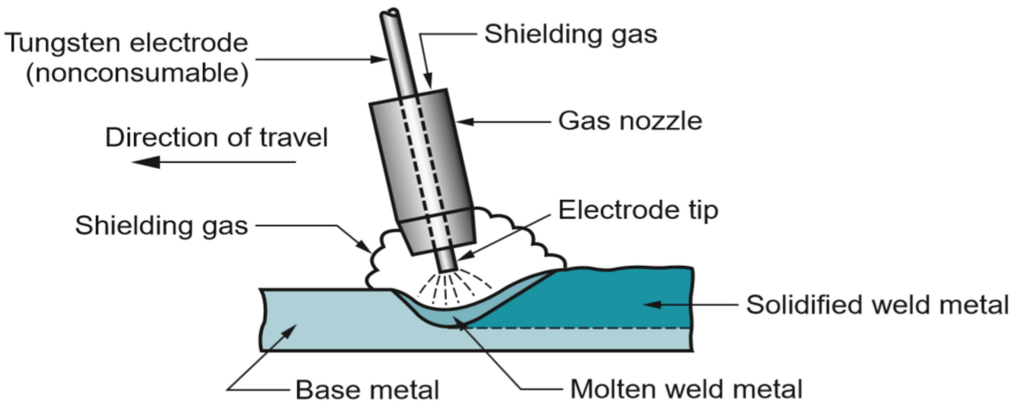

FIGURE 5. Gas tungsten arc welding (GTAW).

<u>Plasma Arc Welding</u> (**PAW**) is a special form of gas tungsten arc welding in which a constricted plasma arc is directed at the weld area. In PAW, a tungsten electrode is contained in a specially designed nozzle that focuses a high-velocity stream of inert gas (e.g., argon or argon–hydrogen mixtures) into the region of the arc to form a high velocity, intensely hot plasma arc stream, as in Figure 6. Argon, argon–hydrogen, and helium are also used as the arc-shielding gases. Temperatures in plasma arc welding reach 17,000 C or greater, hot enough to melt any known metal. The reason why temperatures are so high in PAW (significantly higher than those in GTAW) derives from the constriction of the arc. Although the typical power levels used in PAW are below those used in GTAW, the power is highly concentrated to produce a plasma jet of small diameter and very high power density. Plasma arc welding was introduced around 1960 but was slow to catch on. In recent years its use is increasing as a substitute for GTAW in applications such as automobile subassemblies, metal cabinets, door and window frames, and home appliances. Owing to the special features of PAW, its advantages in these applications include good arc stability, better penetration control than most other AW processes, high travel speeds, and excellent weld quality. The process can be used to weld almost any metal, including tungsten. Difficult-to-weld metals with PAW include bronze, cast irons, lead, and magnesium. Other limitations include high equipment cost and larger torch size than other AW operations, which tends to restrict access in some joint configurations.

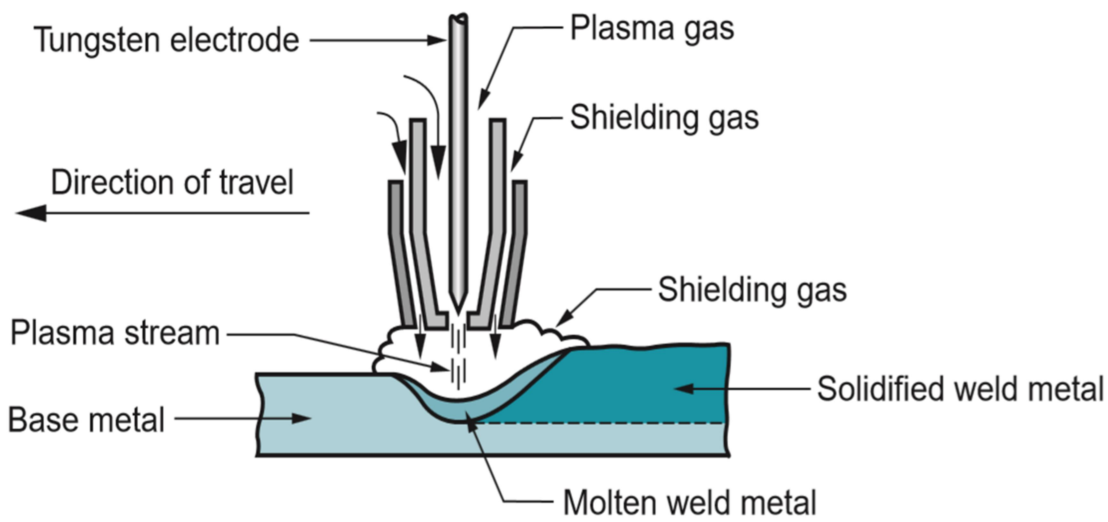

FIGURE 6. Plasma arc welding (PAW).