Oxy-fuel welding

Oxy-fuel welding (commonly called oxyacetylene welding, oxy welding, or gas welding in the U.S.) and oxy-fuel cutting are processes that use fuel gases and oxygen to weld and cut metals, respectively. Pure oxygen, instead of air, is used to increase the flame temperature to allow localized melting of the work piece material (e.g. steel) in a room environment. A common propane/air flame burns at about 2,000 °C (3,630 °F), a propane/oxygen flame burns at about 2,500 °C (4,530 °F), and an acetylene/oxygen flame burns at about 3,500 °C (6,330 °F).

Oxy-fuel is one of the oldest welding processes, besides forge welding. Still used in industry, in recent decades it has been less widely utilized in industrial applications as other specifically devised technologies have been adopted. It is still widely used for welding pipes and tubes, as well as repair work. It is also frequently well-suited, and favored, for fabricating some types of metal-based artwork. As well, oxy-fuel has an advantage over electric welding and cutting processes in situations where accessing electricity (e.g., via an extension cord or portable generator) would present difficulties; it is more self-contained, in this sense — hence "more portable".

In oxy-fuel welding, a welding torch is used to weld metals. Welding metal results when two pieces are heated to a temperature that produces a shared pool of molten metal. The molten pool is generally supplied with additional metal called filler. Filler material depends upon the metals to be welded.

Torches that do not mix fuel with oxygen (combining, instead, atmospheric air) are not considered oxy-fuel torches and can typically be identified by a single tank (Oxy-fuel cutting requires two isolated supplies, fuel and oxygen). Most metals cannot be melted with a single-tank torch. As such, single-tank torches are typically used only for soldering and brazing, rather than welding.

Uses

Oxy-gas torches are or have been used for:

- Welding metal:
- Cutting metal:
- Depositing metal to build up a surface, as in hardfacing.
- Also, oxy-hydrogen flames are used:
- In stone working for "flaming" where the stone is heated and a top layer crackles and breaks. A steel circular brush is attached to an angle grinder and used to remove the first layer leaving behind a bumpy surface similar to hammered bronze.
- In the glass industry for "fire polishing".
- In jewelry production for "water welding" using a water torch (an oxyhydrogen torch whose gas supply is generated immediately by electrolysis of water).
- In automotive repair, removing a seized bolt.

In short, oxy-fuel equipment is quite versatile, not only because it is preferred for some sorts of iron or steel welding but also because it lends itself to brazing, braze-welding, metal heating (for annealing or tempering, bending or forming), rust or scale removal, the loosening of corroded nuts and bolts, and is a ubiquitous means of cutting ferrous metals.

Regulator

The regulator is used to control pressure from the tanks to the required pressure in the hose. The flow rate is then adjusted by the operator using needle valves on the torch. Accurate flow control with a needle valve relies on a constant inlet pressure to it.

Most regulators have two stages: the first stage of the regulator is a fixed-pressure regulator whose function is to release the gas from the cylinder at a constant intermediate pressure, despite the pressure in the cylinder falling as the gas in the cylinder is used. This is similar to the first stage of a scuba-diving regulator. The adjustable second stage of the regulator controls the pressure reduction from the intermediate pressure to the low outlet pressure. The regulator has two pressure gauges, one indicating cylinder pressure, the other indicating hose pressure. The adjustment knob of the regulator is sometimes roughly calibrated for pressure, but an accurate setting requires observation of the gauge.

Some simpler or cheaper oxygen-fuel regulators have only a single stage regulator, or only a single gauge. A single-stage regulator will tend to reduce its outlet pressure as the cylinder is emptied, requiring manual readjustment. For low-volume users, this is an acceptable simplification. Welding regulators, unlike simpler LPG heating regulators, retain their outlet (hose) pressure gauge and do not rely on the calibration of the adjustment knob. The cheaper single-stage regulators may sometimes omit the cylinder contents gauge, or replace the accurate dial gauge with a cheaper and less precise "rising button" gauge.

Gas hoses

The hoses are specifically designed for welding and cutting metal. The hose is usually a double-hose design, meaning that there are two hoses joined together. These hoses are color-coded for visual identification and their threaded connectors are handed to avoid accidental mis-connection: oxygen is right-handed as normal, fuel gases use a left-handed thread.[3] These left-handed threads also have an identifying groove cut into their nuts.

Color-coding of hoses varies between countries. In the USA, oxygen is green, and the fuel hose is red. In the UK, the oxygen hose is blue (black hoses may still be found on old equipment), and the acetylene fuel hose is red. Where LPG fuel, such as propane, is used, the fuel hose should be orange, indicating that it is compatible with LPG. LPG will damage an incompatible hose, including most acetylene hoses.

Connections between flexible hoses and rigid fittings are made by a crimped hose clip over a barbed spigot. Often referred to as 'O' clips. The use of worm-drive or Jubilee clipsis specifically forbidden in the UK. The hoses should also be clipped together at intervals approximately 3 feet apart. (Not recommended for cutting applications. Because beads of molten metal given off by the process can become lodged between the hoses where they are held together, and burn through releasing the pressurised gas inside, which in the case of fuel gas usually ignites).

Non-return valve

Acetylene is not just flammable, in certain conditions it is also an explosive. Although it has an upper flammability limit in air of 81%, acetylene's explosive decomposition behaviour makes this irrelevant. If a detonation wave enters the acetylene tank, the tank will be blown apart by the decomposition. Ordinary check valves that normally prevent back flow can not stop a detonation wave as they are not capable of closing before the wave passes around the gate, and for that reason a flashback arrestor is needed. It is designed to operate before the detonation wave makes it from the hose side to the supply side.

Between the regulator and hose, and ideally between hose and torch on both oxygen and fuel lines, a flashback arrestor and/or non-return valve (check valve) should be installed to prevent flame or oxygen-fuel mixture being pushed back into either cylinder and damaging the equipment or making a cylinder explode.

European practice is to fit flashback arrestors at the regulator and check valves at the torch. US practice is to fit both at the regulator.

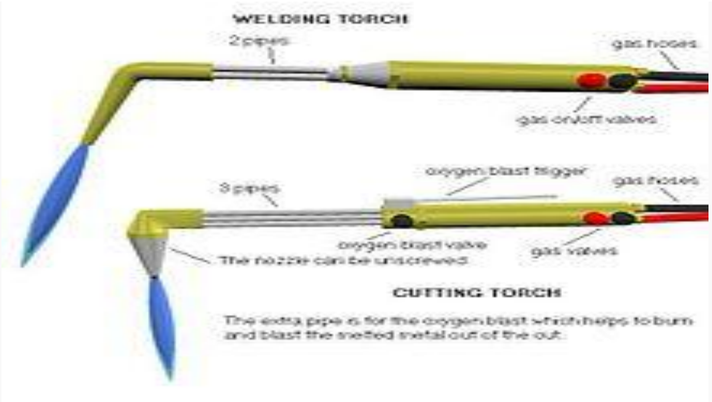
The flashback arrestor (not to be confused with a check valve) prevents the shock waves from downstream coming back up the hoses and entering the cylinder (possibly rupturing it), as there are quantities of fuel/oxygen mixtures inside parts of the equipment (specifically within the mixer and blowpipe/nozzle) that may explode if the equipment is incorrectly shut down; and acetylene decomposes at excessive pressures or temperatures. The flashback arrestor will remain switched off until someone resets it, in case the pressure wave created a leak downstream of the arrestor.

Check valve

A check valve lets gas flow in one direction only. Not to be confused with a flashback arrestor, a check valve is not designed to block a shock wave. The pressure wave could occur while the ball is so far from the inlet that the pressure wave gets past before the ball reaches its off position. A check valve is usually a chamber containing a ball that is pressed against one end by a spring: gas flow one way pushes the ball out of the way, and no flow or flow the other way lets the spring push the ball into the inlet, blocking it.

Torch

The torch is the part that the welder holds and manipulates to make the weld. It has a connection and valve for the fuel gas and a connection and valve for the oxygen, a handle for the welder to grasp, a mixing chamber (set at an angle) where the fuel gas and oxygen mix, with a tip where the flame forms.



Welding torch

A welding torch head is used to weld metals. It can be identified by having only one or two pipes running to the nozzle and no oxygen-blast trigger and two valve knobs at the bottom of the handle letting the operator adjust the oxygen flow and fuel flow.

Fuels

Oxy-fuel processes may use a variety of fuel gases, the most common being acetylene. Other gases that may be used are propylene, liquified petroleum gas (LPG), propane, natural gas, hydrogen, and MAPP gas. Many brands use different kinds of gases in their mixes.

Acetylene

Acetylene is the primary fuel for oxy-fuel welding and is the fuel of choice for repair work and general cutting and welding. Acetylene gas is shipped in special cylinders designed to keep the gas dissolved. The cylinders are packed with porous materials (e.g. kapok fibre, diatomaceous earth, or (formerly) asbestos), then filled to around 50% capacity with acetone, as acetylene is acetone soluble. This method is necessary because above 207 kPa (30 lbf/in²) (absolute pressure) acetylene is unstable and may explode.

There is about 1700 kPa (250 psi) pressure in the tank when full. Acetylene when combined with oxygen burns at 3200 °C to 3500 °C (5800 °F to 6300 °F), highest among commonly used gaseous fuels. As a fuel acetylene's primary disadvantage, in comparison to other fuels, is high cost.

As acetylene is unstable at a pressure roughly equivalent to 33 feet/10 meters underwater, water submerged cutting and welding is reserved for hydrogen rather than acetylene.

Gasoline

Oxy-gasoline, also known as oxy-petrol, torches have been found to perform very well, especially where bottled gas fuel is not available or difficult to transport to the worksite. Tests showed that an oxy-gasoline torch can cut steel plate up to 0.5 in (13 mm) thick at the same rate as oxy-acetylene. In plate thicknesses greater than 0.5 (13mm) inch the cutting rate was better than oxy-acetylene; at 4.5 in (110 mm) it was three times faster.

The gasoline is fed either from a pressurised tank (whose pressure can be hand-pumped or fed from a gas cylinder).[6] OR from a non pressurised tank with the fuel being drawn into the torch by venturi action by the pressurised oxygen flow. Another low cost approach commonly used by jewelry makers in Asia is using air bubbled through a gasoline container by a foot-operated air pump, and burning the fuel-air mixture in a specialized welding torch.

Types of flame

The welder can adjust the oxy-acetylene flame to be carbonizing (aka reducing), neutral, or oxidizing. Adjustment is made by adding more or less oxygen to the acetylene flame. The neutral flame is the flame most generally used when welding or cutting. The welder uses the neutral flame as the starting point for all other flame adjustments because it is so easily defined. This flame is attained when welders, as they slowly open the oxygen valve on the torch body, first see only two flame zones. At that point, the acetylene is being completely burned in the welding oxygen and surrounding air.[2] The flame is chemically neutral. The two parts of this flame are the light blue inner cone and the darker blue to colorless outer cone. The inner cone is where the acetylene and the oxygen combine. The tip of this inner cone is the hottest part of the flame. It is approximately 6,000 °F (3,300 °C) and provides enough heat to easily melt steel.[2] In the inner cone the acetylene breaks down and partly burns to hydrogen and carbon monoxide, which in the outer cone combine with more oxygen from the surrounding air and burn.

An excess of acetylene creates a carbonizing flame. This flame is characterized by three flame zones; the hot inner cone, a white-hot "acetylene feather", and the blue-colored outer cone. This is the type of flame observed when oxygen is first added to the burning acetylene. The feather is adjusted and made ever smaller by adding increasing amounts of oxygen to the flame. A welding feather is measured as 2X or 3X, with X being the length of the inner flame cone. The unburned carbon insulates the flame and drops the temperature to approximately 5,000 °F (2,800 °C). The reducing flame is typically used for hardfacing operations or backhand pipe welding techniques. The feather is caused by incomplete combustion of the acetylene to cause an excess of carbon in the flame. Some of this carbon is dissolved by the molten metal to carbonize it. The carbonizing flame will tend to remove the oxygen from iron oxides which may be present, a fact which has caused the flame to be known as a "reducing flame".[2]

The oxidizing flame is the third possible flame adjustment. It occurs when the ratio of oxygen to acetylene required for a neutral flame has been changed to give an excess of oxygen. This flame type is observed when welders add more oxygen to the neutral flame. This flame is hotter than the other two flames because the combustible gases will not have to search so far to find the necessary amount of oxygen, nor heat up as much thermally inert carbon.[2] It is called an oxidizing flame because of its effect on metal. This flame adjustment is generally not preferred. The oxidizing flame creates undesirable oxides to the structural and mechanical detriment of most metals. In an oxidizing flame, the inner cone acquires a purplish tinge, gets pinched and smaller at the tip, and the sound of the flame gets harsh. A slightly oxidizing flame is used in braze-welding and bronze-surfacing while a more strongly oxidizing flame is used in fusion welding certain brasses and bronzes[2]

The size of the flame can be adjusted to a limited extent by the valves on the torch and by the regulator settings, but in the main it depends on the size of the orifice in the tip. In fact, the tip should be chosen first according to the job at hand, and then the regulators set accordingly.

Oxyacetylene welding/cutting is not difficult, but there are a good number of subtle safety points that should be learned such as:

- More than 1/7 the capacity of the cylinder should not be used per hour. This causes the acetone inside the acetylene cylinder to come out of the cylinder and contaminate the hose and possibly the torch.
- Acetylene is dangerous above 1 atm (15 psi) pressure. It is unstable and explosively decomposes.
- Proper ventilation when welding will help to avoid large chemical exposure.

Flashback

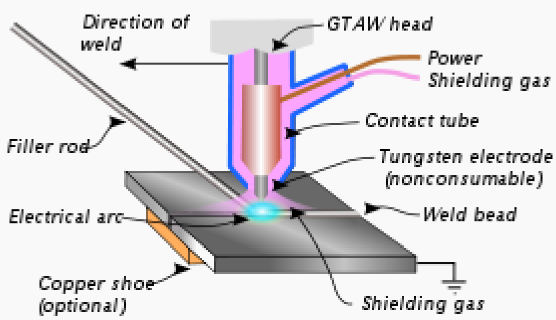
Flashback is the condition of the flame propagating down the hoses of an oxy-fuel welding and cutting system. To prevent such a situation a flashback arrestor is usually employed.[14] The flame burns backwards into the hose, causing a popping or squealing noise. It can cause an explosion in the hose with the potential to injure or kill the operator. Using a lower pressure than recommended can cause a flashback.

Gas tungsten arc welding

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma.

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such asshielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.[1]

Operation



Manual gas tungsten arc welding is often considered the most difficult of all the welding processes commonly used in industry. Because the welder must maintain a short arc length, great care and skill are required to prevent contact between the electrode and the workpiece. Similar to torch welding, GTAW normally requires two hands, since most applications require that the welder manually feed a filler metal into the weld area with one hand while manipulating the welding torch in the other. However, some welds combining thin materials (known as autogenous or fusion welds) can be accomplished without filler metal; most notably edge, corner, and butt joints.

To strike the welding arc, a high frequency generator (similar to a Tesla coil) provides an electric spark; this spark is a conductive path for the welding current through the shielding gas and allows the arc to be initiated while the electrode and the workpiece are separated, typically about 1.5–3 mm (0.06–0.12 in) apart. This high voltage, high frequency burst can be damaging to some vehicle electrical systems and electronics, because induced voltages on vehicle wiring can also cause small conductive sparks in the vehicle wiring or within semiconductor packaging. Vehicle 12V power may conduct across these ionized paths, driven by the high-current 12V vehicle battery. These currents can be sufficiently destructive as to disable the vehicle; thus the warning to disconnect the vehicle battery power from both +12 and ground before using welding equipment on vehicles.

An alternate way to initiate the arc is the "scratch start". Scratching the electrode against the work with the power on also serves to strike an arc, in the same way as SMAW ("stick") arc welding. However, scratch starting can cause contamination of the weld and electrode. Some GTAW equipment is capable of a mode called "touch start" or "lift arc"; here the equipment reduces the voltage on the electrode to only a few volts, with a current limit of one or two amps (well below the limit that causes metal to transfer and contamination of the weld or electrode). When the GTAW equipment detects that the electrode has left the surface and a spark is present, it immediately (within microseconds) increases power, converting the spark to a full arc.

Once the arc is struck, the welder moves the torch in a small circle to create a welding pool, the size of which depends on the size of the electrode and the amount of current. While maintaining a constant separation between the electrode and the workpiece, the operator then moves the torch back slightly and tilts it backward about 10–15 degrees from vertical. Filler metal is added manually to the front end of the weld pool as it is needed.

Welders often develop a technique of rapidly alternating between moving the torch forward (to advance the weld pool) and adding filler metal. The filler rod is withdrawn from the weld pool each time the electrode advances, but it is never removed from the gas shield to prevent oxidation of its surface and contamination of the weld. Filler rods composed of metals with low melting temperature, such as aluminum, require that the operator maintain some distance from the arc while staying inside the gas shield. If held too close to the arc, the filler rod can melt before it makes contact with the weld puddle. As the weld nears completion, the arc current is often gradually reduced to allow the weld crater to solidify and prevent the formation of crater cracks at the end of the weld.

Applications

While the aerospace industry is one of the primary users of gas tungsten arc welding, the process is used in a number of other areas. Many industries use GTAW for welding thin workpieces, especially nonferrous metals. It is used extensively in the manufacture of space vehicles, and is also frequently employed to weld small-diameter, thin-wall tubing such as those used in the bicycle industry. In addition, GTAW is often used to make root or first pass welds for piping of various sizes. In maintenance and repair work, the process is commonly used to repair tools and dies, especially components made of aluminum and magnesium.[13] Because the weld metal is not transferred directly across the electric arc like most open arc welding processes, a vast assortment of welding filler metal is available to the welding engineer. In fact, no other welding process permits the welding of so many alloys in so many product configurations. Filler metal alloys, such as elemental aluminum and chromium, can be lost through the electric arc from volatilization. This loss does not occur with the GTAW process. Because the resulting welds have the same chemical integrity as the original base metal or match the base metals more closely, GTAW welds are highly resistant to corrosion and cracking over long time periods, GTAW is the welding procedure of choice for critical welding operations like sealing spent nuclear fuelcanisters before burial.

Quality

Gas tungsten arc welding, because it affords greater control over the weld area than other welding processes, can produce high-quality welds when performed by skilled operators. Maximum weld quality is assured by maintaining cleanliness—all equipment and materials used must be free from oil, moisture, dirt and other impurities, as these cause weld porosity and consequently a decrease in weld strength and quality. To remove oil and grease, alcohol or similar commercial solvents may be used, while a stainless steel wire brush or chemical process can remove oxides from the surfaces of metals like aluminum. Rust on steels can be removed by first grit blasting the surface and then using a wire brush to remove any embedded grit. These steps are especially important when negative polarity direct current is used, because such a power supply provides no cleaning during the welding process, unlike positive polarity direct current or alternating current.[15] To maintain a clean weld pool during welding, the shielding gas flow should be sufficient and consistent so that the gas covers the weld and blocks impurities in the atmosphere. GTAW in windy or drafty environments increases the amount of shielding gas necessary to protect the weld, increasing the cost and making the process unpopular outdoors.[16]

The level of heat input also affects weld quality. Low heat input, caused by low welding current or high welding speed, can limit penetration and cause the weld bead to lift away from the surface being welded. If there is too much heat input, however, the weld bead grows in width while the likelihood of excessive penetration and spatter increase. Additionally, if the welding torch is too far from the workpiece the shielding gas becomes ineffective causing porosity within the weld. This results in a weld with pinholes, which is weaker than a typical weld.[16]

Equipment

The equipment required for the gas tungsten arc welding operation includes a welding torch utilizing a non-consumable tungsten electrode, a constant-current welding power supply, and a shielding gas source.

Welding torch

GTAW welding torches are designed for either automatic or manual operation and are equipped with cooling systems using air or water. The automatic and manual torches are similar in construction, but the manual torch has a handle while the automatic torch normally comes with a mounting rack. The angle between the centerline of the handle and the centerline of the tungsten electrode, known as the head angle, can be varied on some manual torches according to the preference of the operator. Air cooling systems are most often used for low-current operations (up to about 200 A), while water cooling is required for high-current welding (up to about 600 A). The torches are connected with cables to the power supply and with hoses to the shielding gas source and where used, the water supply.

The internal metal parts of a torch are made of hard alloys of copper or brass in order to transmit current and heat effectively. The tungsten electrode must be held firmly in the center of the torch with an appropriately sized collet, and ports around the electrode provide a constant flow of shielding gas. Collets are sized according to the diameter of the tungsten electrode they hold. The body of the torch is made of heat-resistant, insulating plastics covering the metal components, providing insulation from heat and electricity to protect the welder.

The size of the welding torch nozzle depends on the amount of shielded area desired. The size of the gas nozzle will depend upon the diameter of the electrode, the joint configuration, and the availability of access to the joint by the welder. The inside diameter of the nozzle is preferably at least three times the diameter of the electrode, but there are no hard rules

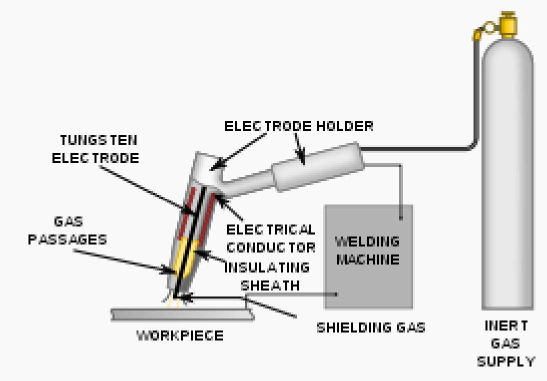
Power supply

Gas tungsten arc welding uses a constant current power source, meaning that the current (and thus the heat) remains relatively constant, even if the arc distance and voltage change. This is important because most applications of GTAW are manual or semiautomatic, requiring that an operator hold the torch. Maintaining a suitably steady arc distance is difficult if a constant voltage power source is used instead, since it can cause dramatic heat variations and make welding more difficult.

The preferred polarity of the GTAW system depends largely on the type of metal being welded. Direct current with a negatively charged electrode (DCEN) is often employed when welding steels, nickel, titanium, and other metals. It can also be used in automatic GTAW of aluminum or magnesium when helium is used as a shielding gas.[19] The negatively charged electrode generates heat by emitting electrons which travel across the arc, causing thermal ionization of the shielding gas and increasing the temperature of the base material. The ionized shielding gas flows toward the electrode, not the base material, and this can allow oxides to build on the surface of the weld.[19] Direct current with a positively charged electrode (DCEP) is less common, and is used primarily for shallow welds since less heat is generated in the base material. Instead of flowing from the electrode to the base material, as in DCEN, electrons go the other direction, causing the electrode to reach very high temperatures.[19] To help it maintain its shape and prevent softening, a larger electrode is often used. As the electrons flow toward the electrode, ionized shielding gas flows back toward the base material, cleaning the weld by removing oxides and other impurities and thereby improving its quality and appearance.

Alternating current, commonly used when welding aluminum and magnesium manually or semi-automatically, combines the two direct currents by making the electrode and base material alternate between positive and negative charge. This causes the electron flow to switch directions constantly, preventing the tungsten electrode from overheating while maintaining the heat in the base material.[19] Surface oxides are still removed during the electrode-positive portion of the cycle and the base metal is heated more deeply during the electrode-negative portion of the cycle. Some power supplies enable operators to use an unbalanced alternating current wave by modifying the exact percentage of time that the current spends in each state of polarity, giving them more control over the amount of heat and cleaning action supplied by the power source.[19] In addition, operators must be wary of rectification, in which the arc fails to reignite as it passes from straight polarity (negative electrode) to reverse polarity (positive electrode). To remedy the problem, asquare wave power supply can be used, as can high-frequency voltage to encourage ignition.

Shielding gas



As with other welding processes such as gas metal arc welding, shielding gases are necessary in GTAW to protect the welding area from atmospheric gases such as nitrogen and oxygen, which can cause fusion defects, porosity, and weld metal embrittlement if they come in contact with the electrode, the arc, or the welding metal. The gas also transfers heat from the tungsten electrode to the metal, and it helps start and maintain a stable arc.

The selection of a shielding gas depends on several factors, including the type of material being welded, joint design, and desired final weld appearance. Argon is the most commonly used shielding gas for GTAW, since it helps prevent defects due to a varying arc length. When used with alternating current, the use of argon results in high weld quality and good appearance. Another common shielding gas, helium, is most often used to increase the weld penetration in a joint, to increase the welding speed, and to weld metals with high heat conductivity, such as copper and aluminum. A significant disadvantage is the difficulty of striking an arc with helium gas, and the decreased weld quality associated with a varying arc length.

Argon-helium mixtures are also frequently utilized in GTAW, since they can increase control of the heat input while maintaining the benefits of using argon. Normally, the mixtures are made with primarily helium (often about 75% or higher) and a balance of argon. These mixtures increase the speed and quality of the AC welding of aluminum, and also make it easier to strike an arc. Another shielding gas mixture, argon-hydrogen, is used in the mechanized welding of light gauge stainless steel, but because hydrogen can cause porosity, its uses are limited.[24] Similarly, nitrogen can sometimes be added to argon to help stabilize the austenitein austentitic stainless steels and increase penetration when welding copper. Due to porosity problems in ferritic steels and limited benefits, however, it is not a popular shielding gas additive.

Welding jigs and fixtures Purpose
1.To minimize distortion caused by heat of welding
2.To permit welding in more convenient position
3.To increase welding efficiency and productivity.
4. Minimise fitting up problem.

Welding Jigs.
Welding jigs are specialized devices which enable the components to be easily and rapidly setup and held. Jigs are stationery while fixtures rotate usually on trunions about vertical and horizontal axis. It should be
1. Rigid and strong to stand without deforming.
2. Simple to operate, yet it must be accurate.
3. Designed such that it is not possible to put the work in it in the wrong way.
4. Faced with wear resistant material to stand continual wear.

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal. Soldering differs from welding in that soldering does not involve melting the work pieces. In brazing, the filler metal melts at a higher temperature, but the work piece metal does not melt. In the past, nearly all solders contained lead, but environmental concerns have increasingly dictated use of lead-free alloys for electronics and plumbing purposes.

Applications

Soldering is used in plumbing, electronics, and metalwork from flashing to jewelry.

Soldering provides reasonably permanent but reversible connections between copper pipes in plumbing systems as well as joints in sheet metal objects such as food cans, roof flashing, rain gutters and automobile radiators.

Jewelry components, machine tools and some refrigeration and plumbing components are often assembled and repaired by the higher temperature silver soldering process. Small mechanical parts are often soldered or brazed as well. Soldering is also used to join lead came and copper foil in stained glass work. It can also be used as a semi-permanent patch for a leak in a container or cooking vessel.

Electronic soldering connects electrical wiring and electronic components to printed circuit boards

Nondestructive testing

Nondestructive testing or Non-destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage.[1] The terms Nondestructive examination (NDE), Nondestructive inspection (NDI), and Nondestructive evaluation(NDE) are also commonly used to describe this technology.[2] Because NDT does not permanently alter the article being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. Common NDT methods include ultrasonic, magnetic-particle, liquid penetrant, radiographic, remote visual inspection (RVI), eddy-current testing,[1] and low coherence interferometry.[3][4] NDT is commonly used in forensic engineering, mechanical engineering, electrical engineering, civil engineering, systems engineering, aeronautical engineering, medicine, and art

Dye penetrant inspection (DPI), also called liquid penetrant inspection (LPI) or penetrant testing (PT), is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics). The penetrant may be applied to all non-ferrous materials and ferrous materials, although for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. LPI is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service components.

Inspection steps

Below are the main steps of Liquid Penetrant Inspection:

1. Pre-cleaning:

The test surface is cleaned to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Cleaning methods may include solvents, alkaline cleaning steps, vapor degreasing, or media blasting. The end goal of this step is a clean surface where any defects present are open to the surface, dry, and free of contamination. Note that if media blasting is used, it may "work over" small discontinuities in the part, and an etching bath is recommended as a post-blasting treatment.

2. Application of Penetrant:

The penetrant is then applied to the surface of the item being tested. The penetrant is allowed "dwell time" to soak into any flaws (generally 5 to 30 minutes). The dwell time mainly depends upon the penetrant being used, material being tested and the size of flaws sought. As expected, smaller flaws require a longer penetration time. Due to their incompatible nature one must be careful not to apply solvent-based penetrant to a surface which is to be inspected with a water-washable penetrant.

3. Excess Penetrant Removal:

The excess penetrant is then removed from the surface. The removal method is controlled by the type of penetrant used. Water-washable, solvent-removable, lipophilic post-emulsifiable, or hydrophilic post-emulsifiable are the common choices. Emulsifiersrepresent the highest sensitivity level, and chemically interact with the oily penetrant to make it removable with a water spray. When using solvent remover and lint-free cloth it is important to not spray the solvent on the test surface directly, because this can remove the penetrant from the flaws. If excess penetrant is not properly removed, once the developer is applied, it may leave a background in the developed area that can mask indications or defects. In addition, this may also produce false indications severely hindering your ability to do a proper inspection.

4. Application of Developer:

After excess penetrant has been removed a white developer is applied to the sample. Several developer types are available, including: non-aqueous wet developer, dry powder, water suspendable, and water soluble. Choice of developer is governed by penetrant compatibility (one can't use water-soluble or suspendable developer with water-washable penetrant), and by inspection conditions. When using non-aqueous wet developer (NAWD) or dry powder, the sample must be dried prior to application, while soluble and suspendable developers are applied with the part still wet from the previous step. NAWD is commercially available in aerosol spray cans, and may employ acetone, isopropyl alcohol, or a propellant that is a combination of the two. Developer should form a semi-transparent, even coating on the surface.

The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out. Any areas that bleed-out can indicate the location, orientation and possible types of defects on the surface. Interpreting the results and characterizing defects from the indications found may require some training and/or experience [the indication size is not the actual size of the defect]

5. Inspection:

The inspector will use visible light with adequate intensity (100 foot-candles or 1100 lux is typical) for visible dye penetrant. Ultraviolet (UV-A) radiation of adequate intensity (1,000 micro-watts per centimeter squared is common), along with low ambient light levels (less than 2 foot-candles) for fluorescent penetrant examinations. Inspection of the test surface should take place after 10 to 30 minute development time, depends of product kind. This time delay allows the blotting action to occur. The inspector may observe the sample for indication formation when using visible dye. It is also good practice to observe indications as they form because the characteristics of the bleed out are a significant part of interpretation characterization of flaws.

6. Post Cleaning:

The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

Magnetic particle Inspection (MPI) is a non-destructive testing (NDT) process for detecting surface and slightly subsurface discontinuities in ferromagnetic materials such asiron, nickel, cobalt, and some of their alloys. The process puts a magnetic field into the part. The piece can be magnetized by direct or indirect magnetization. Direct magnetization occurs when the electric current is passed through the test object and a magnetic field is formed in the material. Indirect magnetization occurs when no electric current is passed through the test object, but a magnetic field is applied from an outside source. The magnetic lines of force are perpendicular to the direction of the electric current which may be either alternating current (AC) or some form of direct current (DC) (rectified AC).

In **ultrasonic testing (UT),** very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz and occasionally up to 50 MHz are transmitted into materials to detect internal flaws or to characterize materials. A common example is ultrasonic thickness measurement, which tests the thickness of the test object, for example, to monitor pipe work corrosion.

Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is a form of non-destructive testing used in many industries including aerospace, automotive and other transportation sectors.

In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant (such as oil) or by water, as in immersion testing. However, when ultrasonic testing is conducted with an Electromagnetic Acoustic Transducer (EMAT) the use of couplant is not required.

There are two methods of receiving the ultrasound waveform: reflection and attenuation. In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the "sound" is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object. The diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection. In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium. Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence. Using the couplant increases the efficiency of the process by reducing the losses in the ultrasonic wave energy due to separation between the surfaces.

Advantages

1. High penetrating power, which allows the detection of flaws deep in the part.
2. High sensitivity, permitting the detection of extremely small flaws.
3. Only one surface needs to be accessible.
4. Greater accuracy than other nondestructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces.
5. Some capability of estimating the size, orientation, shape and nature of defects.
6. Non hazardous to operations or to nearby personnel and has no effect on equipment and materials in the vicinity.
7. Capable of portable or highly automated operation.

Disadvantages

1. Manual operation requires careful attention by experienced technicians. The transducers alert to both normal structure of some materials, tolerable anomalies of other specimens (both termed “noise”) and to faults therein severe enough to compromise specimen integrity. These signals must be distinguished by a skilled technician, possibly, after follow up with other nondestructive testing methods.[1]
2. Extensive technical knowledge is required for the development of inspection procedures.
3. Parts that are rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect.
4. Surface must be prepared by cleaning and removing loose scale, paint, etc., although paint that is properly bonded to a surface need not be removed.
5. Couplants are needed to provide effective transfer of ultrasonic wave energy between transducers and parts being inspected unless a non-contact technique is used. Non-contact techniques include Laser and Electro Magnetic Acoustic Transducers (EMAT).
6. Inspected items must be water resistant, when using water based couplants that do not contain rust inhibitors.

Electromagnetic Testing (ET), as a form of nondestructive testing, is the process of inducing electric currents or magnetic fields or both inside a test object and observing theelectromagnetic response. If the test is set up properly, a defect inside the test object creates a measurable response.

The term "Electromagnetic Testing" is often intended to mean simply Eddy-Current Testing (ECT). However with an expanding number of electromagnetic and magnetic test methods, "Electromagnetic Testing" is more often used to mean the whole class of electromagnetic test methods, of which Eddy-Current Testing