Inventory of Existing Maintenance Technologies

GTAW Welding / TIG Welding

Description
Gas Tungsten Arc Welding (GTAW) is also referred to as TIG welding.
An arc between a non-consumable tungsten electrode and the metal is formed. To shield electrode and molten weld pool gas is fed through a torch. Filler wire can be added to the weld pool separately.

Field of application
High quality, precision welding.
Requires greater welder dexterity than MIG or stick welding.

Material
Metal

Time
Gas tungsten arc welding, after decades of development, was finally perfected in 1941.

Scope
Superior quality welds.
Welds can be made with or without filler metal.

Sources
http://www.weldingengineer.com/
http://www.millerwelds.com/resources/tech_tips/TIG_tips/
http://www.instructables.com/id/How-to-Weld-TIG/
http://www.weldguru.com/welding-history.html

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European Union The European Regional Development Fund

MIG Welding

Description
Gas Metal Arc Welding (GMAW) is also referred to as MIG (Metal Inert Gas) welding.
From a spool wire is continuously fed which makes it a semiautomatic welding process.
MIG welding is the process of using electricity to melt and join pieces of metal together. MIG welding is generally regarded as one of the easiest types of welding to learn.

Field of application
High deposition rate welding.
MIG usually is used in shops and factories, because out in the field, the wind displaces the shielding gas.
One has to be careful MIG welding in close quarters, because some of the shielding gases, such as argon, can displace the oxygen in the brain or collapse the lungs.
MIG can be used in the field. However, wind blocks, usually made of plastic sheets, must be built around the welder.
An example of automatic MIG is a robotic arm welding car frames at an auto assembly plant.

Material
Metal, non-ferrous materials

Time
Gas metal arc welding came up in 1948.

Scope
MIG welding is operated in semiautomatic, machine, and automatic modes. It is utilized particularly in high production welding operations.
All commercially important metals such as carbon steel, stainless steel, aluminum, and copper can be welded with this process in all positions by choosing the appropriate shielding gas, electrode, and welding conditions.

Sources

http://www.mig-welding.co.uk/
http://www.instructables.com/id/How-to-Weld---MIG-Welding/
http://www.thefabricator.com/article/arcwelding/mig-welding-the-basics-and-then-some
http://www.weldguru.com/welding-history.html

Flux Cored Welding

Description
Flux Cored Arc Welding (FCAW) is referred to as flux cored welding.
Like in MIG welding wire is continuously fed from a spool which also makes it a semiautomatic welding process. This adds the benefits of flux to the welding simplicity of MIG welding because it uses a wire which contains materials in its core that, when burned by the heat of the arc, produce shielding gases and fluxing agents to help produce a sound weld, without need for the external shielding gas.

Field of application
High deposition rate welding.
Often this type of welding is primarily performed on mild steel applications outdoors.

Material
Metal

Time
In 1957, the flux-cored arc welding process debuted, in which the self-shielded wire electrode could be used with automatic equipment, resulting in greatly increased welding speeds, and that same year, plasma arc welding was invented.

Scope
In general, this process is best for welding thicker materials with a single pass.

Sources
http://www.weldingengineer.com/1flux.htm
http://www.lincolnelectric.com/knowledge/articles/content/migvsfluxcored.asp
http://www.weldreality.com/flux%20cored%20weld%20questions.htm
http://www.weldguru.com/welding-history.html

Stick Welding

Description

Shielded Metal Arc Welding (SMAW) is frequently referred to as stick or covered electrode welding. The flux covering the electrode melts during welding. This forms the gas and slag to shield the arc and molten weld pool. The flux also provides a method of adding scavengers, deoxidizers, and alloying elements to the weld metal.

Field of application

Because of its versatility and simplicity, it is particularly dominant in the maintenance and repair industry, and is heavily used in the construction of steel structures and in industrial fabrication. In recent years its use has declined as flux-cored arc welding has expanded in the construction industry and gas metal arc welding has become more popular in industrial environments.

Time

In 1912 Strohmenger released a heavily coated electrode but high cost and complex production methods prevented these early electrodes from gaining popularity. In 1927 the development of an extrusion process reduced the cost of coating electrodes while allowing manufacturers to produce more complex coating mixtures designed for specific applications. In the 1950s manufacturers introduced iron powder into the flux coating, making it possible to increase the welding speed.

Scope

It can be used outdoors without special arrangements, has all-position welding capability, and is usable on a wide variety of materials.
Stick welding is among the most widely used welding processes accounting for over half of all welding in some countries.

Sources

http://www.weldingengineer.com/1stick.htm
http://en.wikipedia.org/wiki/Shielded_metal_arc_welding
http://www.millerwelds.com/resources/articles/index?page=articles16.html
http://www.lincolnelectric.com/stick-welders.asp

Submerged Arc Welding

Description

Submerged arc welding (SAW), also known as sub-arc, is a welding process that utilizes a continuously fed wire electrode and a blanket of fusible, granular material that is used for shielding the arc and molten metal. The arc is established between the work piece and wire electrode. An advantage is that it can be applied in all positions, flat, vertical, horizontal and overhead.

Field of application

Submerged Arc Welding (SAW) is primarily used to weld iron and steels. It is the preferred choice in steel fabrication. It is also a favoured process for rebuilding and hardfacing.

Material

Metal

Time

Submerged arc welding was invented in 1930 and continues to be popular today.

Scope

High quality welds, extremely high deposition rates possible.

Sources

http://www.weldingengineer.com/1saw.htm
http://www.lincolnelectric.com/submerged-arc-welding.asp
http://www.weldguru.com/welding-history.html

Resistance Welding

Description

Resistance Spot Welding (RSW) and Resistance Seam Welding (RSEW) are commonly used resistance welding processes. Resistance welding uses the application of electric current and mechanical pressure to create a weld between two pieces of metal. Weld electrodes conduct the electric current to the two pieces of metal as they are forged together.
The welding cycle must first develop sufficient heat to raise a small volume of metal to the molten state. This metal then cools while under pressure until it has adequate strength to hold the parts together.

Spot welding: The advantages of the method include efficient energy use, limited workpiece deformation, high production rates, easy automation, and no required filler materials. When high strength in shear is needed, spot welding is used in preference to more costly mechanical fastening, such as riveting. While the shear strength of each weld is high, the fact that the weld spots do not form a continuous seam means that the overall strength is often significantly lower than with other welding methods, limiting the usefulness of the process.

Seam welding: In contrast to spot welding seam welding allows the electrodes to stay in constant contact with the material to make long continuous welds. It is usually an automated process.

Field of application

Spot welding: It is used extensively in the automotive industry— cars can have several thousand spot welds. Spot welders can also be completely automated, and many of the industrial robots found on assembly lines are spot welders. A specialized process, called shot welding, can be used to spot weld stainless steel.

Seam welding: A common use of seam welding is during the manufacture of round or rectangular steel tubing.

Material

Metal

Time

Resistance welding was developed during the end of the 19th century, with the first patents going to Elihu Thompson in 1885.

Scope

High speed welding. Resistance welding applications are limited to relatively thin materials and the equipment cost can be high.

Sources

http://www.weldingengineer.com/1%20Resistance.htm,
http://en.wikipedia.org/wiki/Electric_resistance_welding,
http://www.matuschek.de/index_en.htm,
http://www.weldguru.com/welding-history.html

Electron Beam Welding

Description

Electron Beam Welding (EBW) is a fusion joining process that produces a weld by impinging a beam of high energy electrons to heat the weld joint. Electrons are elementary atomic particles characterized by a negative charge and an extremely small mass. Raising electrons to a high energy state by accelerating them to roughly 30 to 70 percent of the speed of light provides the energy to heat the weld.

Field of application

Almost all metals can be welded by the process, but the most commonly welded are stainless steels, superalloys, and reactive and refractory metals. The process is also widely used to perform welds of a variety of dissimilar metals combinations. However, attempting to weld plain carbon steel in a vacuum causes the metal to emit gases as it melts, so deoxidizers must be used to prevent weld porosity. Some of the uses of EB welding include making aerospace and automotive parts, as well as semiconductor parts and even jewellery.

Time

The year 1958 marks the breakthrough of electron beam welding, making deep and narrow welding possible through the concentrated heat source.

Scope

The electron beam is always generated in a high vacuum. The use of specially designed orifices separating a series of chambers at various levels of vacuum permits welding in medium and nonvacuum conditions. Although, high vacuum welding will provide maximum purity and high depth to width ratio welds.

Sources

http://www.weldingengineer.com/1%20Electron%20Beam.htm
http://en.wikipedia.org/wiki/Electron_beam_welding
http://www.weldguru.com/welding-history.html

Laser Beam Welding

Description
Laser beam welding (LBW) is a welding process which produces coalescence of materials with the heat obtained from the application of a concentrated coherent light beam impinging upon the surfaces to be joined.
The focused laser beam has the highest energy concentration of any known source of energy. The laser beam is a source of electromagnetic energy or light that can be projected without diverging and can be concentrated to a precise spot. The beam is coherent and of a single frequency.

Field of application
Especially useful in high-speed automated welding.

For plastics specific applications include sealing / welding / joining of: catheter bags, medical containers, automobile remote control keys, heart pacemaker casings, syringe tamper evident joints, headlight or tail-light assemblies, pump housings, and mobile phone parts.

Material
The laser beam has been used to weld carbon steels, high strength low alloy steels, aluminium, stainless steel, and titanium.
For plastics materials that can be joined include Polypropylene, Polycarbonate, Acrylic, and Nylon.

Time
Following the invention of the laser in 1960, laser beam welding debuted not before several decades later. The first applications of laser beam welding in industrial series production was in 1984.

Scope
The laser offers a source of concentrated energy for welding; however, there are only a few lasers in actual production use today. The high-powered laser is extremely expensive. Laser welding technology is still in its infancy so there will be improvements and the cost of equipment will be reduced. Recent use of fibre optic techniques to carry the laser beam to the point of welding may greatly expand the use of lasers in metal-working.

Sources
http://www.weldguru.com/Laser-Welding.html
http://www.weldguru.com/welding-history.html
http://www.isf.rwth-aachen.de/index.php?id=16&L=1

Soldering and Brazing

Description

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a relatively low melting point. Soft soldering is characterized by the melting point of the filler metal, which is below 400 °C (752 °F). The filler metal used in the process is called solder.

Soldering is distinguished from brazing by use of a lower melting-temperature filler metal; it is distinguished from welding by the base metals not being melted during the joining process. In a soldering process, heat is applied to the parts to be joined, causing the solder to melt and be drawn into the joint by capillary action and to bond to the materials to be joined by wetting action. After the metal cools, the resulting joints are not as strong as the base metal, but have adequate strength, electrical conductivity, and water-tightness for many uses.

Field of application

One of the most frequent applications of soldering is assembling electronic components to printed circuit boards (PCBs). Another common application is making permanent but reversible connections between copper pipes in plumbing systems. Joints in sheet metal objects such as food cans, roof flashing, rain gutters and automobile radiators have also historically been soldered, and occasionally still are. Jewellery components are assembled and repaired by soldering. Small mechanical parts are often soldered as well. Soldering is also used to join lead came and copper foil in stained glass work. Soldering can also be used as a semi-permanent patch for a leak in a container or vessel.

Material

Copper, silver, and gold are easy. Iron and nickel are found to be more difficult. Because of their thin, strong oxide films, stainless steel and aluminium are a little more difficult. Titanium, magnesium, cast irons, steels, ceramics, and graphite can be soldered but it involves a process similar to joining carbides. They are first plated with a suitable metallic element that induces interfacial bonding.
Some examples of solder types and their applications are tin-lead (general purpose), tin-zinc for joining aluminium, lead-silver for strength at higher than room temperature, cadmium-silver for strength at high temperatures, zinc-aluminium for aluminium and corrosion resistance, and tin-silver and tin-bismuth for electronics.

Time

Soldering is an ancient technique mentioned in the Bible and there is evidence that it was employed up to 5000 years ago in Mesopotamia.

Sources

http://www.uniweld.com/catalog/alloys/silver_brazing_alloys/intro.htm
http://en.wikipedia.org/wiki/Soldering

Oxy-Acetylene Welding

Description
Oxy-acetylene welding is simple in concept - two pieces of metal are brought together, and the touching edges are melted by the flame with or without the addition of filler rod.
Pure oxygen, instead of air (20% oxygen/80% nitrogen), 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, a propane/oxygen flame burns at about 2,500°C, and an acetylene/oxygen flame burns at about 3,500°C.
It is the only gas flame that is hot enough to melt all commercial metals.

Field of application
In recent years it has become less popular in industrial applications. However, it is still widely used for welding pipes and tubes, as well as repair work. It is also frequently well-suited, and favoured, for fabricating some types of metal-based artwork.
An oxy-acetylene welding outfit can also be used for oxygen cutting. This application has expanded in every decade since 1902.
The flame is used as a source of heat for many different tasks like bending or forming metals or loosening "frozen" nuts. Another widespread use for the heat of the oxy-acetylene flame is in the brazing of joints in copper tubing systems. There are several industrial applications of the flame – for example, flame-hardening and flame- de-scaling too.

Material
Metal

Time
Gas welding, using oxygen and hydrogen to produce a hot flame was used in fields like the making of jewellery dating back to the 1850's. However, the oxy-hydrogen flame is virtually useless for welding steel. Gas welding, to be broadly useful, had to await the discovery of the remarkable properties of the oxy-acetylene flame, and of a way to make acetylene at reasonable cost. These events took place in the 1890's.

Scope
Widely in use especially for maintenance and repair; an oxy-acetylene welding outfit can also be used for oxygen cutting and a variety of applications utilizing the heat of the flame.

Sources
http://www.stanford.edu/group/prl/documents/html/OAweld.htm
http://www.metalwebnews.com/howto/weld/weld.html
http://www.esabna.com/euweb/oxy_handbook/589oxy2_1.htm
http://en.wikipedia.org/wiki/Oxy-fuel_welding_and_cutting

Ultrasonic Welding

Description

Ultrasonic welding is an industrial technique whereby high-frequency ultrasonic acoustic vibrations are locally applied to workpieces being held together under pressure to create a solid-state weld. It is commonly used for plastics, and especially for joining dissimilar materials. In ultrasonic welding, there are no connective bolts, nails, soldering materials, or adhesives necessary to bind the materials together.

Field of application

Found in many industries including electrical and computer, automotive and aerospace, medical, and packaging.

Material

Plastics

Time

Developed in 1960 by Sonobond Ultrasonics

Sources

http://en.wikipedia.org/wiki/Ultrasonic_welding
http://ultrasonicwelding.org/
http://machinedesign.com/article/fundamentals-of-ultrasonic-plastic-welding-0203

Friction Welding

Description

Friction welding (FW) is a class of solid-state welding processes that generates heat through mechanical friction between a moving workpiece and a stationary component, with the addition of a lateral force called "upset" to plastically displace and fuse the materials. Technically, because no melt occurs, friction welding is not actually a welding process in the traditional sense, but a forging technique. However, due to the similarities between these techniques and traditional welding, the term has become common. Friction welding is used with metals and thermoplastics in a wide variety of aviation and automotive applications.

Friction welding techniques are generally melt-free. This has the advantage of avoiding grain growth in engineered materials such as high-strength heat-treated steels. Another advantage is that the motion tends to "clean" the surface between the materials being welded, which means they can be joined without as much prior preparation.

Friction welding provides a "full strength" bond with no additional weight.

Field of application

Friction welding allows dissimilar materials to be joined. This is particularly useful in the aerospace field, where it is used to join lightweight aluminium stock to high-strength steels.

Another common use for these sorts of bi-metal joints is in the nuclear industry, where copper-steel joints are common in the reactor cooling systems.

For instance, the technique can be used to join eyeglass frames to the pins in their hinges.

Material

metal:
spin welding, linear friction welding, friction surfacing

thermoplastic:
linear vibration welding, orbital friction welding

Time

In 1891 the first patent on the process was issued in the USA. More work progressed throughout Europe as more patents were issued from 1920 to 1944, and in the USSR in 1956.

Sources

http://www.azom.com/Details.asp?ArticleID=1170
http://en.wikipedia.org/wiki/Friction_welding
http://www.nctfrictionwelding.com/process.php

Solvent welding

Description

In solvent welding, a solvent is applied which can temporarily dissolve the polymer at room temperature. When this occurs, the polymer chains are free to move in the liquid and can mingle with other similarly dissolved chains in the other component. Given sufficient time, the solvent will permeate through the polymer and out into the environment, so that the chains lose their mobility. This leaves a solid mass of entangled polymer chains which constitutes a solvent weld.

Field of application

This technique is commonly used for connecting PVC and ABS pipe, as in household plumbing. The gluing together of plastic (polystyrene or ABS) models is also a solvent welding process.

Material

Plastics

Sources

http://www.twi.co.uk/content/ksrw002.html
http://en.wikipedia.org/wiki/Plastic_welding

Hot gas welding

Description

Hot gas welding, also known as hot air welding, is a plastic welding technique which is analogous to gas welding metals, though the specific techniques are different. A specially designed heat gun, called a hot air welder, produces a jet of hot air that softens both the parts to be joined and a plastic filler rod, all of which must be of the same or a very similar plastic. Welding PVC to acrylic is an exception to this rule. In the case of webs and films a filler rod may not be used. Two sheets of plastic are heated via a hot gas (or a heating element) and then rolled together. This is a quick welding process and can be performed continuously.

Field of application

Hot air/gas welding is a common fabrication technique for manufacturing smaller items such as chemical tanks, water tanks, heat exchangers, and plumbing fittings.

Material

Plastics

Time

1938

Sources

http://www.twi.co.uk/content/pjkhotgas.html
http://en.wikipedia.org/wiki/Plastic_welding
http://www.weldinghistory.org/whistoryfolder/welding/wh_1900-1950.html

Speed tip welding

Description

With speed welding, the plastic welder, similar to a soldering iron in appearance and wattage, is fitted with a feed tube for the plastic weld rod. The speed tip heats the rod and the substrate, while at the same time it presses the molten weld rod into position. A bead of softened plastic is laid into the joint, and the parts and weld rod fuse. With some types of plastic such as polypropylene, the melted welding rod must be "mixed" with the semi-melted base material being fabricated or repaired. Speed tip welding is a fast welding technique and with practice it can be used in tight corners.

Field of application

Plastic fabrication and repair

Material

Plastics

Time

1950s

Sources

http://en.wikipedia.org/wiki/Plastic_welding
http://www.ehow.com/how_5705346_speed-tip-weld-plastic.html

Extrusion welding

Description
Welding rod is drawn into a miniature hand held plastic extruder, plasticized, and forced out of the extruder against the parts being joined, which are softened with a jet of hot air to allow bonding to take place.

Field of application
Extrusion welding allows the application of bigger welds in a single weld pass. It is the preferred technique for joining material over 6 mm thick.
Extrusion welding is commonly used in apparatus engineering and in laying waterproofing membranes for ground water protection applications, using extruded sheet and profiles made of polyolefins. It has also been used to join corrosion-resistant steel pipe lined by a theroplastic layer, either in the shop or in the field, for use in the oil, gas, chemical, marine, and mining industries.

Material
Plastics

Sources
http://www.twi.co.uk/content/ksidf001.html
http://en.wikipedia.org/wiki/Plastic_welding
Handbook of plastics joining: a practical guide
Plastics Design Library (see the following link)
http://books.google.de/books?id=B-F5pXuj_M8C&pg=PA87&lpg=PA87&dq=extrusion+welding&source=bl&ots=I3MHobpIWc&sig=oTrUOSGLFnIsFxL_Cvi36oz1APo&hl=de&ei=hYxJTMfjBZSSOK6MoZUD&sa=X&oi=book_result&ct=result&resnum=2&ved=0CCQQ6AEwATgK#v=onepage&q=extrusion%20welding&f=false

Heat Welding

Description
Heat welding, also called fusion welding, is a welding process used to join two different pieces of a thermoplastic together. This process involves heating both pieces simultaneously and pressing them together. The two pieces then cool together and form a permanent bond. When done properly, the two pieces become indistinguishable from each other. Using dissimilar plastics can result in improper bonding.

Field of application
This process is commonly used in plastic pressure pipe systems to join a pipe and fitting together, or to join a length of pipe directly to another length of pipe. Generally, polyolefins such as polypropylene, polyethylene, and polybutylene are used for these applications. Heat fusion is not recommended for use with PVC because of issues with the pipe cracking.
Primarily used in commercial applications, a successful heat welded seam will provide the customer/end user with a floor free of voids and joints where pathogens and bacteria can collect or grow. For this reason resilient floors with heat welded seams are sometimes referred to as seamless floors and are frequently used in areas requiring an aseptic or clean environment such as surgical and clean room manufacturing rooms.

Material
Plastics

Sources
http://en.wikipedia.org/wiki/Butt_heat_fusion
http://www.asf.com.au/12heat.html
http://www.fcimag.com/Articles/Feature_Article/BNP_GUID_9-5-2006_A_10000000000000018182

Hot plate welding

Description

Related to contact welding, this technique is used to weld larger parts, or parts that have a complex weld joint geometry. The two parts to be welded are placed in the tooling attached to the two opposing platens of a press. A hot plate, with a shape that matches the weld joint geometry of the parts to be welded, is moved in position between the two parts. The two opposing platens move the parts into contact with the hot plate until the heat softens the interfaces to the melting point of the plastic. When this condition is achieved the hot plate is removed, and the parts are pressed together and held until the weld joint cools and re-solidifies to create a permanent bond.

Field of application

Hot plate welding is commonly used to weld two circular tubes end to end. It is applied in pipes, components of domestic electric devices (dishwashers, washing machines, vacuum cleaners) and automotive components (lights, fuel tanks, reservoirs, batteries).

Material

Plastics

Scope

Hot Plate Welding is widely used for the most challenging materials and large part assembly with high strength and hermetic requirements, or where parts have complex geometries, such as irregular shape, or curved or internal walls.

Sources

http://en.wikipedia.org/wiki/Plastic_welding
http://www.branson-plasticsjoin.com/hot_plate_systems.asp
http://www.forwardtech.com/PlasticAssembly/HotPlate/
http://plastics.inwiki.org/Hot_plate_welding

High Frequency Welding

Description

High frequency welding is also known as Radio frequency welding. Two pieces of material are placed on a table press that applies pressure to both surface areas. Dies are used to direct the welding process. When the press comes together, high frequency waves (usually 27.12 MHz) are passed through the small area between the die and the table where the weld takes place. This high frequency (radio frequency) field causes the molecules in certain materials to move and get hot, and the combination of this heat under pressure causes the weld to take the shape of the die.

Field of application

This type of welding is used to connect polymer films used in a variety of industries where a strong consistent leak-proof seal is required. In the fabrics industry, it is most often used to weld PVC and polyurethane (PU) coated fabrics.
It is in use for thin wall tubes and also for coated steels for applications such as car exhaust pipes as well as higher quality pipe in the oil and gas industry.

Material

Certain plastics with chemical dipoles, such as PVC, polyamides (PA) and acetates. The most common materials used in RF welding are PVC and polyurethane. It is also possible to weld other polymers such as nylon, PET, EVA and some ABS plastics.

Time

In use since the 1940s

Scope

The range of application includes diameters between about 12 and 660mm. Wall thicknesses from about 0.5 to 25mm can be welded but there are some practical limitations on extreme thickness to diameter ratios.

Sources

http://en.wikipedia.org/wiki/Plastic_welding
http://www.tis-gdv.de/tis_e/verpack/kunststo/schweiss/schweiss.htm
http://www.twi.co.uk/content/kssaw007.html