Plastic welding

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Plastic welding : welding for semi-finished plastic materials is described in ISO 472 [1] as a process of uniting softened surfaces of materials, generally with the aid of heat (except solvent welding). Welding of thermoplastics is accomplished in three sequential stages, namely surface preparation, application of heat and pressure, and cooling. Numerous welding methods have been developed for the joining of semifinished plastic materials. Based on the mechanism of heat generation at the welding interface, welding methods for thermoplastics can be classified as external and internal heating methods,[2] as shown in Fig 1.

On the other hand, production of a good quality weld can not only depend on the welding methods, but also weldability of base materials. Therefore, the evaluation of weldability is of critical importance before welding operation (see Rheological Weldability) for plastics.

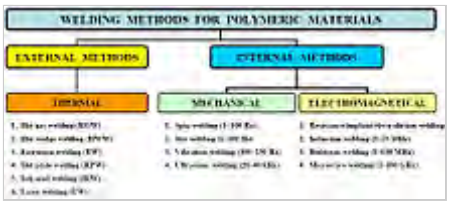

Fig. 1. Classification of welding methods for semi-finished polymeric materials.[2][3]

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Welding techniques

A number of techniques are used for welding of semi-finished plastic products as given below:

Hot gas welding

Hot gas welding, also known as *hot air welding*, is a plastic welding technique using heat. 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.)

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

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.

Welding rod

A plastic welding rod, also known as a *thermoplastic welding rod*, is a rod with circular or triangular cross-section used to bind two pieces of plastic together. They are available in a wide range of colors to match the base material's color. Spooled plastic welding rod is known as "spline".

An important aspect of plastic welding rod design and manufacture is the porosity of the material. A high porosity will lead to air bubbles (known as *voids*) in the rods, which decrease the quality of the welding. The highest quality of plastic welding rods are therefore those with zero porosity, which are called *voidless*.

Heat sealing

Heat sealing is the process of sealing one thermoplastic to another similar thermoplastic using heat and pressure. The direct contact method of heat sealing utilizes a constantly heated die or sealing bar to apply heat to a specific contact area or path to seal or weld the thermoplastics together. Heat sealing is used for many applications, including heat seal connectors, thermally activated adhesives and film or foil sealing. Common applications for the heat sealing process: Heat seal connectors are used to join LCDs to PCBs in many consumer electronics, as well as in medical and telecommunication devices. Heat sealing of products with thermal adhesives is used to hold clear display screens onto consumer electronic products and for other sealed thermo-plastic assemblies or devices where heat staking or ultrasonic welding is not an option due to part design requirements or other assembly considerations. Heat sealing also is used in the manufacturing of bloodtest film and filter media for the blood, virus and many other test strip devices used in the medical field today. Laminate foils and films often are heat sealed over the top of thermoplastic medical trays, Microtiter (microwell) plates, bottles and containers to seal and/or prevent contamination for medical test devices, sample collection trays and containers used for food products.[4] Medical and the Food Industries manufacturing Bag or flexible containers use heat sealing for either perimeter welding of the plastic material of the bags and/or for sealing ports and tubes into the bags. A variety of heat sealers are available to join thermoplastic materials such as plastic films: Hot bar sealer, Impulse sealer, etc.

Freehand welding

With freehand welding, the jet of hot air (or inert gas) from the welder is played on the weld area and the tip of the weld rod at the same time. As the rod softens, it is pushed into the joint and fuses to the parts. This process is slower than most others, but it can be used in almost any situation.

Speed tip welding

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. These welding techniques have been improved over time and have been utilized for over 50 years by professional plastic fabricators and repairers internationally. Speed tip welding method is a much faster welding technique and with practice can be used in tight corners. A version of the speed tip "gun" is essentially a soldering iron with a broad, flat tip that can be used to melt the weld joint and filler material to create a bond.

Extrusion welding

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. 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.

Contact welding

This is the same as spot welding except that heat is supplied with thermal conduction of the pincher tips instead of electrical conduction. Two plastic parts are brought together where heated tips pinch them, melting and joining the parts in the process.

Hot plate welding

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.

Hot-plate welding equipment is typically controlled pneumatically, hydraulically, or electrically with servo motors.

This process is used to weld automotive under hood components, automotive interior trim components, medical filtration devices, consumer appliance components, and other car interior components.

High frequency welding

Certain plastics with chemical dipoles, such as PVC, polyamides (PA) and acetates can be heated with high frequency electromagnetic waves. High frequency welding uses this property to soften the plastics for joining. The heating can be localized, and the process can be continuous. Also known as Dielectric Sealing, R.F. (Radio Frequency) Heat Sealing.

Radio frequency welding is a very mature technology that has been around since the 1940s. 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 27.120 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. RF welding is fast. 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, RF is most often used to weld PVC and polyurethane (PU) coated fabrics. This is a very consistent method of welding.

The most common materials used in RF welding are PVC and polyurethane. It is also possible to weld other polymers such as Nylon, PET, PEVA, EVA and some ABS plastics. Exercise caution when welding urethane as it has been known to give off cyanide gasses when melting.

Induction welding

When an electrical insulator, like a plastic, is embedded with a material having high electrical conductivity, like metals or carbon fibers, induction welding can be performed. The welding apparatus contains an induction coil that is energised with a radio-frequency electric current. This generates an electromagnetic field that acts on either an electrically conductive or a ferromagnetic workpiece. In an electrically conductive workpiece, the main heating effect is resistive heating, which is due to induced currents called eddy currents. Induction welding of carbon fiber reinforced thermoplastic materials is a technology commonly used in for instance the aerospace industry.[5]

In a ferromagnetic workpiece, plastics can be induction-welded by formulating them with metallic or ferromagnetic compounds, called susceptors. These susceptors absorb electromagnetic energy from an induction coil, become hot, and lose their heat energy to the surrounding material by thermal conduction.

Injection welding

Injection welding is similar/identical to extrusion welding, except, using certain tips on the handheld welder, one can insert the tip into plastic defect holes of various sizes and patch them from the inside out. The advantage is that no access is needed to the rear of the defect hole. The alternative is a patch, except that the patch can not be sanded flush with the original surrounding plastic to the same thickness. PE and PP are most suitable for this type of process. The Drader injectiweld is an example of such tool.

Ultrasonic welding

In ultrasonic welding, high frequency (15 kHz to 40 kHz) low amplitude vibration is used to create heat by way of friction between the materials to be joined. The interface of the two parts is specially designed to concentrate the energy for the maximum weld strength. Ultrasonic can be used on almost all plastic material. It is the fastest heat sealing technology available.

Friction welding

In friction welding, the two parts to be assembled are rubbed together at a lower frequency (typically 100–300 Hz) and higher amplitude (typically 1 to 2 mm (0.039 to 0.079 in)) than ultrasonic welding. The friction caused by the motion combined with the clamping pressure between the two parts creates the heat which begins to melt the contact areas between the two parts. At this point, the plasticized materials begin to form layers that intertwine with one another, which therefore results in a strong weld. At the completion of the vibration motion, the parts remain held together until the weld joint cools and the melted plastic re-solidifies. The friction movement can be linear or orbital, and the joint design of the two parts has to allow this movement.

Spin welding

Spin welding is a particular form of frictional welding. With this process, one component with a round weld joint is held stationary, while a mating component is rotated at high speed and pressed against the stationary component. The rotational friction between the two components generates heat. Once the joining surfaces reach a semi-molten state, the spinning component is stopped abruptly. Force on the two components is maintained until the weld joint cools and re-solidifies. This is a common way of producing low- and medium-duty plastic wheels, e.g., for toys, shopping carts, recycling bins, etc. This process is also used to weld various port openings into automotive under hood components.

Laser welding

This technique requires one part to be transmissive to a laser beam and either the other part absorptive or a coating at the interface to be absorptive to the beam. The two parts are put under pressure while the laser beam moves along the joining line. The beam passes through the first part and is absorbed by the other one or the coating to generate enough heat to soften the interface creating a permanent weld.

Semiconductor diode lasers are typically used in plastic welding. Wavelengths in the range of 808 nm to 980 nm can be used to join various plastic material combinations. Power levels from less than 1W to 100W are needed depending on the materials, thickness and desired process speed.

Diode laser systems have the following advantages in joining of plastic materials:

- Cleaner than adhesive bonding
- No micro-nozzles to get clogged
- No liquid or fumes to affect surface finish
- No consumables
- Higher throughput
- Can access work-piece in challenging geometry
- High level of process control

Requirements for high strength joints include:

- Adequate transmission through upper layer
- Absorption by lower layer
- Material compatibility – wetting
- Good joint design – clamping pressure, joint area
- Lower power density

A sample list of materials that can be joined include:

- Polypropylene
- Polycarbonate
- Acrylic
- Nylon
- ABS

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 cellular phone parts.

Transparent Laser Plastic Welding

New fiber laser technology allows for the output of higher laser wavelengths, with the best results typically around 2,000 nm, significantly higher than the average 808 nm to 1064 nm diode laser used for traditional laser plastic welding. Because these higher wavelengths are more readily absorbed by thermoplastics than the infra-red radiation of traditional plastic welding, it is possible to weld two clear polymers without any colorants or absorbing additives. Common Applications will mostly fall in the medical industry for devices like catheters and microfluidic devices. The heavy use of transparent plastics, especially flexible polymers like TPU, TPE and PVC, in the medical device industry makes transparent laser welding a natural fit. Also, the process requires no laser absorbing additives or colorants making testing and meeting biocompatibility requirements significantly easier.

Solvent welding

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.

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

Dichloromethane (methylene chloride), which is obtainable in paint stripper, can solvent weld polycarbonate and polymethylmethacrylate. Dichloromethane chemically welds certain plastics; for example, it is used to seal the casing of electric meters. It is also a component – along with tetrahydrofuran – of the solvent used to weld plumbing.

See also

- Heat sealer
- Heat seal
- Plastic cement
- Rheological Weldability for semi-finished polymer parts
- Thermoplastic staking
- Electrofusion

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