
Plastic Welding: Important Facts and Developments

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Abstract: This paper provides an introduction to some important facts and developments in the plastic welding field for assisting the developments in future in plastic welding. Plastic manufactured part are regularly used in many industries. The parts made of polymeric materials and polymeric composites fulfilled very demanding criteria now-a-days. Plastics have good corrosion resistance, excellent strength to weight ratio and ability to take good finish. Plastics can be categorized as thermosets and thermoplastics. Only the thermoplastic is weld able among these two. A chemical reaction occurs during processing and curing in case of thermo sets resin, that is, as a result of irreversible cross-linking reaction in the mold. Both molded thermosets and vulcanized elastomer components cannot be reshaped by applying heat, because of the irreversible reaction that occurs. And thus in this case joining can be obtained by mechanical fastening and adhesive bonding only. In this paper few selected welding processes are discussed like hot gas welding, friction welding, hot plate welding, etc. Various important Poly Vinyl Chloride welding parameters such as welding techniques, welding temperature, welding speed, equipments requirements have also been discussed. Recent developments in this field are also discussed.

Keywords: Poly Vinyl Chloride, P.V.C. Welding, Friction Welding, Hot Air Technique

1. Introduction

Plastics are used in day to day life for manufacturing of toys, utensils and complicated part such as heart valve for medical use etc. Plastic parts are frequently used in many industries [2]. Plastics have ability to take good finish, excellent strength to weight ratio and good corrosion resistance. There are two types of plastics, thermosets and thermoplastics out of which only thermoplastic is able to be welded. A chemical reaction occurs during processing and curing in case of thermosets resin, that is, as a result of irreversible cross-linking reaction in the mold. [3]. Molded thermosets components cannot be reshaped by applying heat, because of the irreversible reaction that occur [3]. And thus in this case joining can be obtained by mechanical fastening and adhesive bonding only. But, thermoplastics are able to be softened and remolded by means of heating, and can fusion welded. Therefore thermoplastics are able to be welded by following three methods (a) Thermal, (b) Friction (c) Electromagnetic. Further the types of Thermal plastic welding are (a) Hot air technique (b) Hot tool method (c) Laser beam heating (d) Infrared heating. PVC plastics are

different from other geomembrane like HDPE, LLDPE, and FPP because it is primarily amorphous while others are semi-crystalline [6]. When PVC is heated it will soften [5, 6], that allow alimited amount of chain entanglements to assure a strong bond.

2. Hot Tool Welding

Hot tool welding is a technique in which surfaces to be joined by direct contact with a heated metallic tool. When it is required to join the pipes, the surfaces to be joined are flat hence the tool is a hot plate. However in many applications, such as in automotive rear light and headlamps, because of doubly curved joined interface it require complex tool that allow the hot surface to match the contours of the joint interface.

3. Hot Gas Welding

When the external heating method is applied the technique is called hot air technique. In the process of welding the welding rod and a weld groove are simultaneously heated

with a hot gas stream until they soften sufficiently to fuse together; and then the welding rod is pressed into the weld groove to complete welding process. A stream of hot air is directed toward the filler and the joint area using a hot air torch. A filler rod of a similar composition as the polymer being joined is gently pushed into the gap between the substrates (Fig1). The round cross-section filler rod is used, but it is also available in oval, triangular and rectangular cross section [7]. During welding, the hot air temperature can range from 200 to 600°C, depending upon polymer being joined [3]. The table 2 shows a list of plastic welding temperature [10] for different type of plastics. The melting temperature of PVC is not well-defined, owing to the large distribution in crystalline particle size [8] this results broad melting range. Hot gas welding can be used for most thermoplastics but PVC is the major material being assembled by this technique [5]. Apart from PVC, there are some more plastic which can be welded by this techniques are polyethylene, polypropylene, acrylics, polystyrene, and polycarbonate [14].

Table 1. Process parameter for hot gas welding [7] [14].

Process parameters	Description
• Temperature	Temperature of hot gas
• Gas	Composition of hot gas(air, carbon dioxide, hydrogen, oxygen or nitrogen)
• Angle	Include angle between weldment and rod, angle between gas nozzle and weldment.
• Travel Speed	Rate at which weld is being deposited
• Weld force	Amount of force applied to the filler rod
• Filler rod	Composition of filler rod
• Gap distance	Distance between gas nozzle and workpiece
• Weld joint	butt joint and double strap fillet joint.
• Pressure of hot air/gas	Pressure of gas at which it coming out from nozzle
• shoe	Design and size of welding nozzle

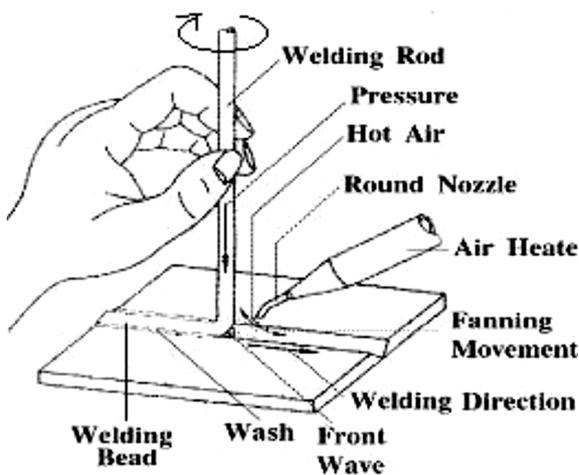


Fig. 1. Schematic of hot-gas welding, showing the correct position of torch and filler rod for different thermo-plastic [14].

4. Welding Procedure in Hot Gas Technique

The hot air gun is used for hot air welding. The gun

consists of a main body which contain heating element. This is anon contact soldering for high requirements. The air mass flow and the temperature can be adjusted in a prescribed range; the basic element of hot air gun is shown in the figure 2. The nozzles can be easily replaced so that each component is soldered by using the suitable nozzle, air and temperature setting [11].

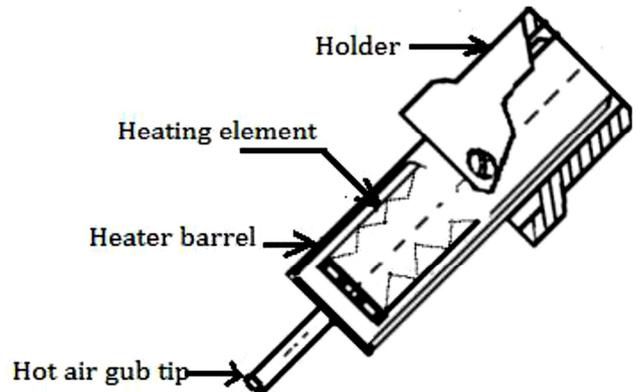


Fig. 2. Basic elements of hot air gun [11].

The melting temperature of PVC is not well-defined, owing to the large distribution in crystalline particle size [8] this results broad melting range. Most thermoplastic can be joined via hot gas welding but PVC is the major material being assembled by this technique [5]. Apart from PVC, there are some more plastic which can be welded by this techniques are polyethylene, polypropylene, acrylics, polystyrene, and polycarbonate.

Table 2. Different type of plastics with welding temperature.

Plastics	Welding Temperature
Acrylonitrile Butadiene Styrene	350°C
Acrylic	350°C
Hard PVC	220-300°C
Hypalon	600°C
Polyethylene (Hard)	250-280°C
Polyethylene (Soft)	270-300°C
Polysisobutylene	600°C

In figure 3 the graph is shown between Gap distance between torch and the job versus temperature of hot air with application of different pressures.

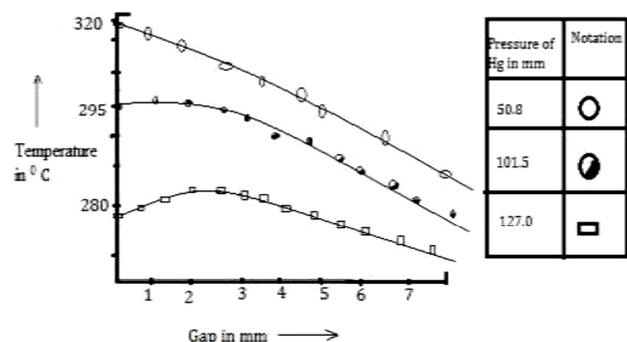


Fig. 3. Gap distance between torch and the job versus temperature of hot air [1] [14].

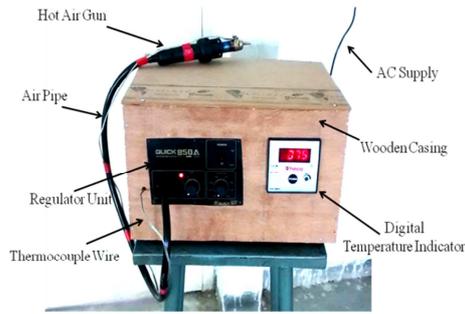


Fig. 4. Experimental setup for research work [15].

Md Shakibul Haque et.al. develop a experimental setup and performed experiments and find that The poly vinyl chloride can be successfully welded by using their fabricated setup in workshop. Their setup is user-friendly because of easy controlling of air flow, air temperature, welding speed, less weight and portable. and eco- friendly also because of no harmful fumes, gases, radiations and flames are generated [15].

Md Shakibul Haque et.al. has been carried out the work to study the effect of welding parameters on hardness of butt welds, made on poly vinyl chloride sample using hot air technique. These parameters are Temperature, welding speed and airflow. They are varied at two levels higher and lower. From their study conclusion is drawn that the better hardness of the welded joint is obtained at higher level of temperature [16].

Md Shakibul Haque et.al. has been worked on the study of the effect of input welding parameters on Tensile strength of butt welds, made on poly vinyl chloride sample using hot air technique. The parameters, Temperature, welding speed and airflow are varied at two levels higher and lower. From these study it is found that the better tensile strength of the welded joint is obtained at higher level of temperature. Better weld factor was obtained i.e. from 0.46 to 0.69. Better result of tensile strength was obtained maximum of 11.25MPa [17].

Hoomam Ahamad et al. carried the review for plastic welding, it can be concluded that there is huge scope for research in order to investigate the parameters responsible for high quality welding of plastic. Nitrogen gas and other inert gases can be used in order to prevent oxidation. Proper jigs and fixtures as well as roller can be used to increase the welding pressure applied on welding rod for proper fusion [18].

5. Hot Plate Welding

Hot plate welding is one of the simplest welding techniques making it highly reliable and common place in industry. The process works by bringing the faying surfaces to be joined in contact with a heated tool. The tool can have relatively complex geometries to allow the welding of complex interfaces. In addition, the tool is often coated with a non-stick material (often PTFE, product name: Teflon) to act as a release agent. In the initial phase (matching phase), pressure is applied to promote squeeze flow of the faying surfaces to assure that the faying surfaces are well defined

and all part irregularities are removed. Once sufficient matching displacement is achieved, the pressure is removed by mechanical stops or pressure regulators, so that a relatively thick melt layer is developed. After a pre-selected heating time, the parts are retracted from the tool, the tool is quickly displaced away from the parts and the parts are brought together to allow the two molten interfaces to weld. Again, the amount of displacement during the cooling phase may be limited by mechanical stops to prevent excessive squeeze out which would force the majority of melt out of the weld zone leaving a cold weld [7].

6. Recent Developments

6.1. Ultrasonic Welding

Ultrasonic welding is a very popular technique for fusion bonding of thermoplastics and thermoplastic composites. Welding is accomplished by applying low amplitude (1 to 250 μm) high frequency (10 to 70 kHz) mechanical vibration to parts. This results in cyclical deformation of the parts, primarily at the faying surfaces (joining surfaces) and surface asperities. The cyclical energy is converted into heat – within the thermoplastic – through intermolecular friction. This is similar to the heating that occurs in a metal wire that is bent back and forth repeatedly, or in general, to the effect occurring when materials are subjected to cyclical loading. The heat, which is highest at the surfaces (because asperities are straining more than the bulk), is sufficient to melt the thermoplastic and to fuse the parts. Usually, a man-made asperity in the form of a triangular protrusion is molded into one of the parts to improve the consistency of heating and welding. This protrusion, which is also called an energy director or concentrator, experiences the highest levels of cyclical strain producing the greatest level of heating. Therefore, the energy director melts and flows to join the parts. There is a wide range of joint designs that concentrate the energy at the faying surfaces, including shear joints, mesh joints, knife edge joints among others that can be used in conjunction with roughened surfaces to enhance welding. It is beyond the scope of this paper to review these alternative joint designs [7].

6.2. Friction Welding

Four main variations of friction welding are linear, orbital, spin and angular welding. Orbital and linear welding are similar in that they are amenable to a wide range of geometries, while in contrast, angular and spin welding are primarily suitable for circular weld geometries. All four processes rely on relative motion between the two parts that are to be joined, which results in frictional heating. The only major difference between these processes is the geometry of the relative motion. It is important to note that in all cases, the angular velocity of the displacement is in radians/s [12]. In addition, in the case of angular welding the angle of rotation is defined in radians. With the velocities, it is possible to estimate power dissipation based on the

fundamental assumption that power is equal to velocity multiplied by friction force as detailed in Grewell, D at all work [13]. Linear vibration welding allows welding of surfaces that are able to be moved in one direction. However, with linear vibration welding there is the risk that relatively weak welds can result with walls that are aligned transversely to the vibration direction. This is due to that fact that without proper support, either internally with stiffening ribs or externally with built-in features in the fixtures, the walls can deflect and reduce the relative motion of the interfaces. Orbital welding, produces a relatively constant velocity because of its elliptical or circular motion [13] assuming the amplitudes in both directions are equal. This constant velocity dissipates more energy at the joint for a given weld time and amplitude compared with linear vibration.

7. Advantages

The major use of Plastic welding are to repair polyolefin tank, container and welding of Polyvinylchloride, ABS, PE and PP pipe section [3] Apart from this it is also used to repair of bumper in automotive industry, construction, sealing and packaging of material etc.

8. Conclusion

In the present paper the different techniques of welding of plastics is reviewed with the help of available relevant literature. As this is the period of plastic age, joining of plastics is a challenge to young researchers and scholars working in the area of welding technology. Although there are several methods that are reported to join two plastic pieces but hot air gun technique is most reliable and technologically beneficial from research as well as production point of view and more work is required in this area in order to understand effect of different process parameters on the main response parameters. So, after this review there is a need to take initiative for the experiments for making the results more favorable. Further response parameters such as tensile test, hardness test and grain size can be analyzed.

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Biography



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