An Extensive Literature Review Showing Relation Between Process Parameter And Mechanical Properties of Welded Hard PVC by Hot Air Technique

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ABSTRACT: This paper is procured in the field of polymer joining (welding) to assist relation between process parameter and quality of welded structure of hard PVC. Effect of different parameters during welding, such as air medium, filler rod, weld force, pressure of hot air gas etc. has been studied and also various outlines and applications are also being discussed.

Keywords: Polyvinylchloride (P.V.C). Welding, hot air technique, Nitrogen, Heeling, heating element, modulus density.

1. INTRODUCTION:

In many industry fields plastic parts are applied more and more frequently. Very demanding criteria must now be fulfilled by parts made of polymeric materials and polymeric composites. In many cases it is not possible to manufacture such parts as single elements. Usually they are assembled from two or more semi products. When leak proof and tough joints are needed common method used to join parts made of thermoplastic polymers is welding technology [5]. The use of polymeric material is nowadays increasingly in a many important applications including packaging, building appliance, electronics, automotive, aerospace [12]. Also used for manufacturing of toys, to utensil to complicated part such as heart valve etc. [3].

Polymeric materials have many advantages including, high specific strength (strength/density ratio), high specific modulus (modulus density ratio), design flexibility, reduced manufacturing costs, excellent corrosion, solvent and environment resistance, thermal and electrical insulation, durability etc. [12, 3]. Plastic offers the structural strength of steel by virtue of its greater elasticity [9]. Plastics can be fabricated by welding and are categorised as thermosets and thermoplastics. Thermoplastics are the only weld able plastics as they maintain their molecular structure even after repeated heating [1]. The common thermoplastics are; acrylics, fluorocarbons, shellac, asphalt, nylon, polyethylene, polyvinyles, and protein substances. Among above the rigid Polyvinyl chloride has sufficient resistance against corrosion, strong acids, alkalies and organic solvent. It is therefore the most common thermoplastic in use these days [1, 4].

2. FUNDAMENTAL WELDING STEPS AND PROCEDUR IN COMMON USE:

The most of the welding processes have in common five distinct steps. The basic welding steps are:

I	Surface preparation
II	Heating
III	Pressing
IV	Intermolecular diffusion
V	Cooling

2.1 Surface preparation

A good homogeneous weld requires proper preparation of the material [16]. Mild soap and lukewarm water is generally used to remove the dirt and methyl ethyl ketone is used to remove oil and grease [14]. These foreign material may entrapped in weld bead which may leads to poor weld bead.

2.2 Heating

A stream of hot air or gas (nitrogen, air, carbon dioxide, hydrogen, or oxygen) is directed toward the filler and the joint area using a torch. A filler rod or tap (of a similar composition as the polymer being joined) is gently pushed into the gap between the substrates. The gas temperature can range from 200 to 600^0 C [3].

2.3 Pressing

Pressure must be applied on filler rod to form close contact between the joining parts [12]. The welding pressure is applied on the partially molten rod and ensures penetration into the weld groove [7].

2.4 Intermolecular diffusion

Once the interfaces conform to each other, they heal together by diffusion and entanglement of molecules. Healing of the interfaces is basically the diffusion of the polymer chains across the interface from one side to the other. This mechanism is depicted in *fig.3* at various times and degrees of healing. Under ideal conditions at complete healing, polymer chains at each side of the interface migrate cross the interface so that it essentially becomes indistinguishable from the bulk material [10].

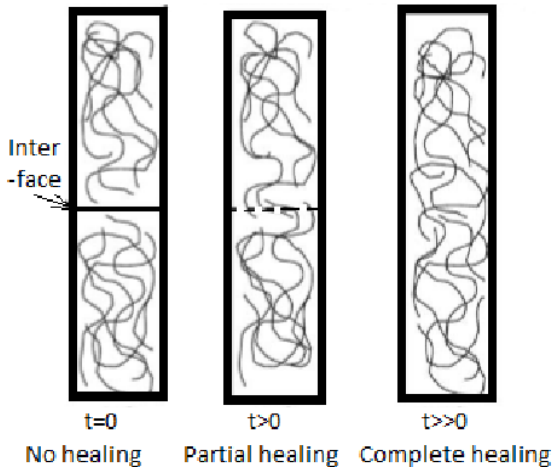


Fig. 3 *Details of intermolecular healing of the interface over time.*

2.5 Cooling

The final stage in the welding process is the cooling and re-solidification of the polymer at the joint. During the final step, semi-crystalline matrices re-crystalize to obtain their final micro structure. Amorphous plastics retain any orientation. In addition, thermally induced residual stresses and distortion remain "frozen" in the parts [12].

3. HOT AIR TECHNIQUE AND HEATING ELEMENT SOURCE:

Hot gas welding is a technique which basically consists of using a stream of hot gas to soften both filler rod and parent metal. The filler rod becomes tacky on its surface of the material to be welded. The tacky surface bond together under pressure of shoe *(fig.4)* [14].

For hot air technique welding hot air gun is used. The gun consists of a main body which contain heating element. This is a non-contact soldering for high requirements. The air volume and the temperature can be set or adjusted in a wide range; the nozzles can be easily replaced so that each component is soldered by using the suitable nozzle, air and temperature setting [3]. The gas temperature can range from 200 to 600^{0}C, depending upon polymer being joined [3]. Here is a list of plastic welding temperature (in centigrade) for different type of plastics [13]

ABS 350ºC
Acrylic 350ºC
Hard PVC 220 - 300ºC
Hypalon 600ºC
Polycarbonate 350ºC
Polyethylene (Hard) 250 - 280ºC
Polyethylene (Soft) 270-300ºC
Polyisobutylene 600ºC
Polypropylene 300ºC
Polyvinylidene Fluoride 350ºC [13]

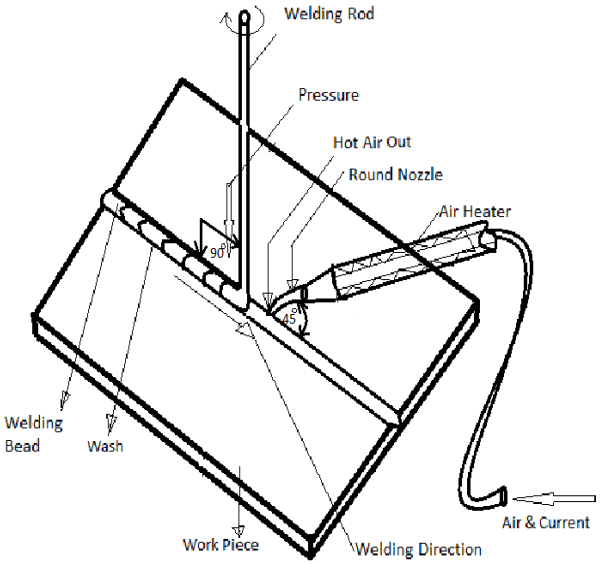


Fig. 4 *systematics of hot gas welding [3, 1].*

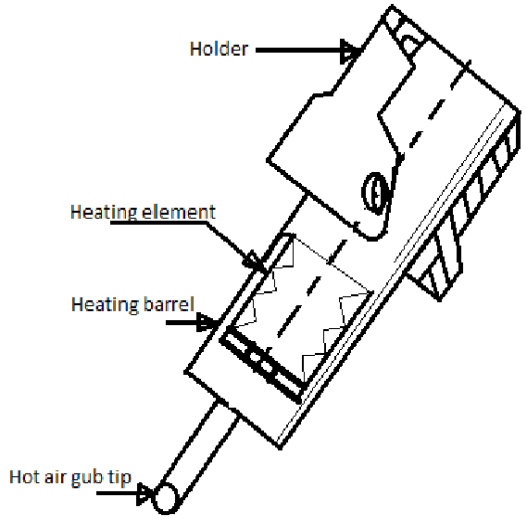


Fig. 5 *heating element source [3].*

Table 2. Technical data of heating element [3]

Power input	230V/50Hz
Power consumption	550 W
Temperature	100^0C – 480^0C (rotary knob adjustment)

4. WELDING MATERIAL AND PROCESS PARAMETERS:

The plastics becoming important material to manufacture the components for various category of load carrying application [2]. There are also various thermoplastics which are weld able like ABS, Acrylic, Hypalon, Polycarbonate, Polyethylene (Hard), Polyethylene (Soft), Polyisobutylene, Polypropylene, Polyvinylidene etc. [13]. But Polyvinyl chloride (P.V.C) is the main material which is being welded and insoluble in most of the organic solvents [1]. PVC is the major material being assembled by this technique [8]. Most vehicles built today as well as many other modern products have components made from plastic. For example in automobile and trucks , bumpers grilles , spoilers, and even complete body panels enable designers to enhance aerodynamic styling and cosmetic appeal while retaining impact resistance and eliminating corrosion. So, a plastic component can be quickly restored to an "as new" condition without the need for fillers or special treatments. The combination of welding and the recommended repaint procedures will show no trace of a repair that should last the life of the vehicle [13].

Table 1. Process parameter for hot gas welding [10]

Process parameters	Description
1. Temperature	Temperature of hot gas (N_2)
2. Gas	Composition of hot gas(air carbon dioxide, hydrogen, oxygen or nitrogen)
3. Angle	Include angle between weldment and rod, angle between gas nozzle and weldment.
4. Travel speed	Rate at which weld is being deposited
5. Weld force	Amount of force applied to the filler rod
6. Filler rod	Composition of filler rod
7. Gap distance	Distance between gas nozzle and workpiece
8. Weld joint	Butt joint and double strap fillet joint.
9. Pressure of hot air/gas	Pressure of gas at which it coming out from nozzle
10. shoe	Design and size of welding nozzle

Effect of welding parameters on tensile strength of weld bead:

1. **Effect of Temperature of hot air:** Air temperature depends on the type of polymer being joined, and which determines the heating elements, nozzle dimension and gas/air flow rates that are used [3].The melting temperature of Hard polyvinyl chloride PVC (in centigrade, when welded at 20 ^{0}C) is 220 - 300ºC [13]. And it is less important during heating if the temperature difference, not greater than 10^0c, between the plastic surfaces [5].

2. **Effective gas:** Generally gas used for welding is air or N [10]. In hot gas (air) welding, the heat transfer medium is a heated gas, in general clean air. In the infancy of plastic welding, the use of Nitrogen proved most successful in preventing material contamination and oxidation [16]. While direct flame chars the material (PVC) and therefore, hot gas is used for welding purpose [1]. With today's material quality and equipment technology, Nitrogen is becoming more and more a relic of the past [16].
3. **Effect of angle:** Generally angle between the filler rod and weldment is taken as 90^0 and between gas nozzle and weldment is 45^0 [1]. The necessary pressure on the welding rod is hand

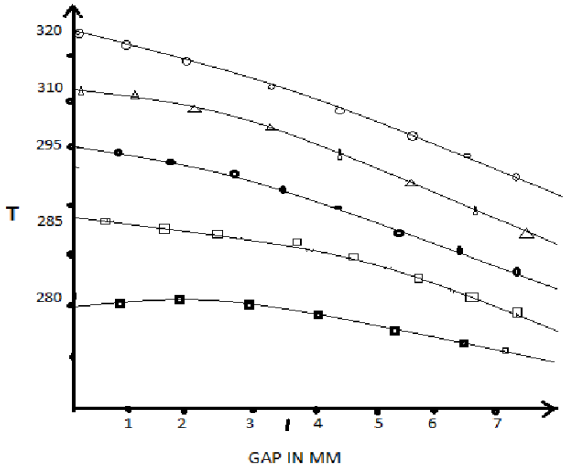
applied by pushing down on it vertically at a 90° angle [16].

4. **Effect of travel speed: [4]**

$$\text{Travel speed} = \frac{\text{distance traveled}}{\textit{time taken to cover dist.}}$$

As far as hot gas (air) hand welding is concerned, more than 90% of the structural welds are high speed welded [16].

5. **Effect of weld force:** Best result attains when welding force applied on the weld in the range of 10-20 N when welding shoe is employed, however, it is approximately 5 N [7**].** In a weld, exerting pressure on the molten material helps ensure through mixing of the material across the interface. Insufficient welding pressure leads to reduce weldability at the interface [15].
6. **Effect of filler rod:** The composition of filler rod is must be similar to the polymer being welded [6]. The filler rod has a round cross-section, but it is also available in oval, triangular and rectangular cross-section [3]. But, standard profiles are round and triangular [16]. Plastic welding rod does not become completely molten, it may appear much the same before and after welding. One accustomed to welding metal a plastic weld may see the weld as appearing incomplete. The reason is that only the outer surface of the rod has become molten while the inner core has remained hard [13].
7. **Effect of gap distance:** The gap distance between the nozzle tip and the parent platesurface was varied from almost 0 to 7 mm at varying gas (gas) pressure, and temperature as shown below [1].



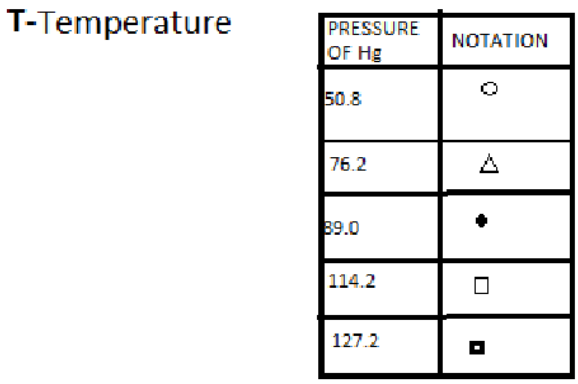


Fig .1 *gap distance between torch and the job versus temperature of hot air [3]*

8. **Effect of weld joint:** It is shown that double V-welds contains higher values of welding energy than single V-welds. This means that strength of double V-welds can be higher than single V-welds [7].

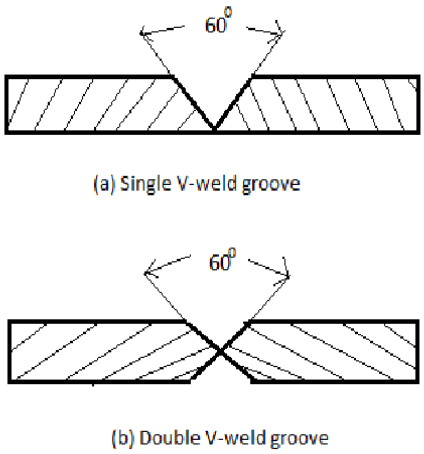


Fig 2 geometries of weld grove. (a) Single V-weld grooves. (b) Double V- weld groove [7].

9. **Pressure of hot air/gas**: Pressure can be varied from 1.4 – 2.8 MPa when shoe is employed. However it is approximately 0.7 MPa [3].

5. APPLICATIONS AND LIMITATIONS

Plastic welding is used to repair polyolefin tank, container and welding of PVC, ABS, PE and PP pipe section [3]. Apart from this it is also used in automotive industry (repair of bumper) construction, sealing, packaging of material, electronics and aerospace etc. [12]. The one of the main disadvantage is that the operator must be well skilled and trained otherwise it make the joint of very less strength or more defective as it should.

6. CONCLUSION

The welding action is an adhesive action [1] and the joint made is still weaker than the parent material. It is also being revealed that under ideal conditions at complete healing, polymer chains at each side of the interface migrate cross the interface so that it essentially becomes indistinguishable from the bulk material [10]. So, there is a need for further investigation of increasing the strength of weld bead rather by changing the parameters or the air medium (N_2).

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BIOGRAPHY

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