Hot gas welding of plastics: Part 1 - The basics

Process background

Hot gas welding is a fabrication process for thermoplastic materials. The process, invented in the mid 20 th century, uses a stream of heated gas, usually air, to heat and melt both the thermoplastic substrate material and the thermoplastic welding rod. The substrate and the rod fuse to produce a weld (*Figs. 1 and 2*).

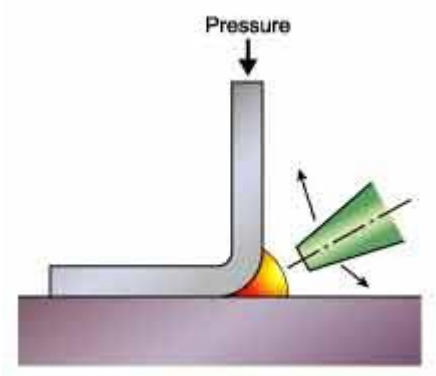

Fig.1. Hot gas hand welding nozzle motion and rod angle

Fig.2. Hot gas hand welding

To ensure welding takes place, adequate temperature and pressure must be applied to the rod, along with the use of the correct welding speed and gun position. The weld quality, since this is a purely manual technique, is dependent on the skill of the welder. Typical applications include chemical storage vessels, ventilation ducting and repair of plastic mouldings such as car bumpers.

Welding materials

There are two groups of plastic materials; thermoplastics and thermosets. The hot gas welding technique is only applicable to those plastic materials that can be heated and melted repeatedly, namely thermoplastics. When a thermoplastic is heated, the molecular chains become mobile within the material and allow it to melt and flow. Thermosets are a group of plastic materials in which the molecular chains form cross-links. These cross-links, formed by a chemical reaction, prevent the molecular chains becoming mobile when heat is applied. Although many thermoplastics can be welded by this process, the most common are polypropylene, polyethylene, PVC and some fluoropolymers such as PVDF, FEP and PFA.

Extruded rod and sheet are the most commonly used raw materials for the manufacture of fabricated plastic products. It is of utmost importance when fabricating plastics that the welding rod and the sheet are of identical material and chemical type. For example, although it is possible to weld polypropylene homopolymer to polypropylene random block copolymer, the strength of the weld will be reduced significantly. It is also important to check the quality of the welding rod prior to use, since air bubbles within the rod can form during the extrusion process. These will lead to voids in the weld. Welding rods will typically be either three or four millimetres in diameter.

Welding equipment

The equipment used for hot gas welding consists of an air supply, a handle with sturdy grip, a heating chamber with temperature control to produce the hot gas and a nozzle where the heated gas leaves the welding gun in order to heat the plastic rod and substrate. (*Fig.3*)

Fig.3. Hot gas welding gun

A fan, either incorporated into the welding gun handle or positioned remotely and connected to the gun, provides the air supply. It is also possible to use compressed gas from bottles, for example, air or nitrogen. Whichever gas supply is used, it is important that it is clean and dry, since dirt and moisture will contaminate the weld. The gun temperature is set via a dial on the handle, with some welding guns showing the temperature of the air stream on a digital read-out also on the handle. It is good practice to measure the gas temperature consistently using a digital thermometer, for example, with the thermocouple tip placed 5mm inside the welding gun nozzle. The front end of the welding gun allows interchangeable welding nozzles to be fitted depending on the type of welding needed.

Three nozzle types are most commonly used, the tacking nozzle, the round nozzle and the high-speed nozzle (*Fig.4*).

Fig.4. Plastic welding nozzles (left to right) tacking nozzle, round nozzle, high speed nozzle

The tacking nozzle, as the name suggests, is used to tack the materials together before welding. The round nozzle allows the welder to heat the rod and substrate without physical contact with either and is useful for welding in areas with difficult access.

This is less commonly used than the high-speed welding nozzle where the toe of the nozzle contacts the welding rod and allows the welder to put pressure on both the rod and the substrate material whilst welding. Along with correct temperature, the pressure ensures that there is adequate fusion between the welding rod and the substrate material. In addition to the welding gun, several tools are needed. These are a coarse tooth file, router and hand grinder for edge preparation, a scraper for removal of the material surface around the weld and a wire brush for cleaning the nozzle. Also, wire cutters are required for cutting the welding rod and a jigsaw for cutting the substrate materials.

Welding parameters

There are four main welding parameters in the hot gas welding process: temperature, pressure, welding speed and gun position. Since the process is manual, it is important that the welder has a good understanding of the need to ensure that all four of these parameters are correct and controlled during the welding operation. Temperature is the most important of the four parameters, since the temperature at the interface between the rod and the substrate is not only controlled by the setting on the gun, but also by the gun travel speed and the gun position with respect to the substrate. Typically, the temperature for welding is set between 80 and 100°C above the melting point of the material being welded. The gun travel speed is normally between 0.1 and 0.3m/min, again, depending upon the material being welded. The welding pressure is applied via the toe of the welding nozzle and is achieved by holding the welding gun grip firmly and pushing down into the weld. For round nozzle welding, pressure is applied manually from the welding rod. The correct welding pressure is easier to achieve using welding guns with the fan separate to the gun since a firmer grip around the handle can be achieved. The force applied to the welding rod would typically be between 15 and 30N. Practical welding details are given in Hot gas welding of plastics: Part 2 - welding techniques

Weld quality

As a manual process, weld quality is dependent on skill. There is no recognised non-destructive technique, that conclusively shows the presence of defects in plastic welds that could lead to weld failure. Therefore, it is recommended that good quality welder training is received and that welder certification is adopted.

The European Standard (EN13067) sets out the criteria for plastic welder approval. It details a scheme where the welder undergoes both a theoretical and a practical test and the welder, upon successful completion, is awarded a certificate of approval in the specific material categories taken in the test. Certification lasts for two years with a further two years prolongation, effectively giving the welder an approval certificate for four years before requiring a full retest.