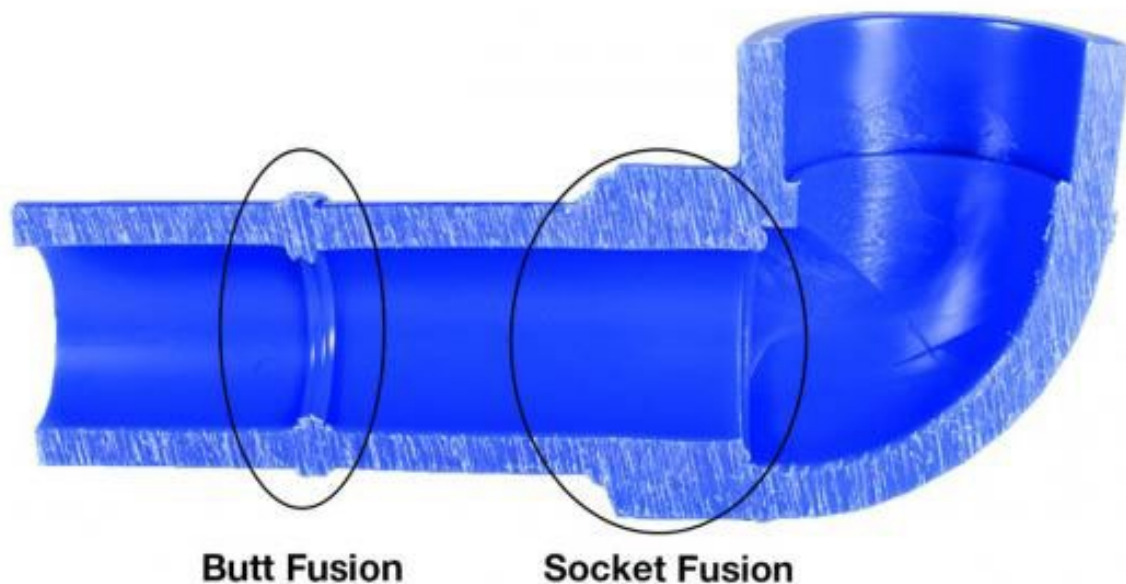


TYPICAL CAUSES OF FAILURES OF PLASTIC PIPE WELDED JOINTS

By PPN Editor

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Plastic welding, a pivotal process in various industries ranging from plumbing to infrastructure, relies on the unique properties of thermoplastic polymers. Unlike thermosets, thermoplastics can be softened and hardened repeatedly without undergoing permanent changes, making them ideal candidates for hot-melt or thermal welding techniques. This article delves into the technical aspects of plastic welding, exploring methodologies, considerations, and factors crucial for successful outcomes.

Understanding Thermoplastic Welding

Plastic welding exclusively involves thermoplastic polymers, which soften at elevated temperatures and solidify at ambient conditions. The essence of a successful weld lies in achieving interpenetration and integration of polymer chains between two surfaces. This entails heating the plastics to a molten state, pressing them together, and allowing them to cool and solidify, thereby eliminating any boundary between the parts.

Key Considerations for Successful Welding

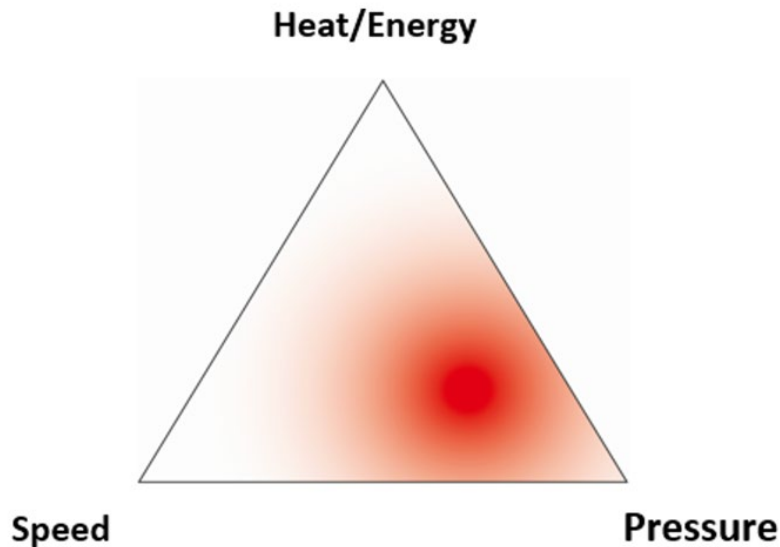
Achieving a successful plastic weld necessitates meticulous planning and adherence to fundamental principles:

1. **Weldability:** The inherent weldability of thermoplastic materials varies, with some types exhibiting better compatibility than others which is a function of density and melt flow index.
2. **Material Selection:** Similar types of plastic should be used to ensure successful blending, as dissimilar polymers typically do not meld well.
3. **Surface Preparation:** Contaminants like dust, oil, and moisture inhibit the blending process, necessitating thorough surface cleaning. Oxidized or degraded surfaces require removal before welding.
4. **Welding Environment:** Access to parts and ambient conditions significantly impact welding outcomes. Factors such as temperature, humidity, and wind influence parameters like heating and cooling times.

Factors Influencing Weld Quality

Once the materials, technique, and environmental factors are addressed, three primary factors influence weld quality:

1. **Time:** Sufficient time must be allotted for heating, interpenetration of the molecules, and cooling phases to ensure proper fusion.
2. **Temperature:** Maintaining an optimal temperature range is crucial; excessive heat can lead to excessive material flow or degradation, while insufficient heat compromises fusion.
3. **Pressure:** Appropriate pressure facilitates surface mixing without causing material displacement or part damage. Sufficient pressure must be applied between the parts to promote mixing of the surfaces, but not so much as to either force the material away from the working area, or to deform the pipe or fittings.



The above illustrates the 'sweet spot' for welding parameters to optimize weld quality. The zone where the red color is most intense, indicates the point at which the three welding parameters are closest to being in the correct proportion or optimum balance. All three parameters are inter-dependent upon each other and any change in one will influence the other. The further one or more of the parameters moves outside of this ideal zone, then the weld strength will be weaker than optimum. Different thermoplastics have different welding characteristics meaning that this balance will be different for each type of thermoplastic being welded.

Failures of plastic welded joints can be broadly categorised in the following five (5) categories:

1. Surface Oxidation
2. Cracks and cavities
3. Inclusions and Contamination
4. Deformation
5. Joint separations

Surface Oxidation

PE pipe is produced by feeding granules of raw polyethylene into an extruder which heats and melts the granules as they are conveyed toward the extruder's exit. The molten PE exits the extruder through a circular die which forms the

pipe's shape. As the pipe leaves the extruder, oxygen in the atmosphere reacts with the hot pipe surface causing a thin layer of oxidation to develop.

This oxidised plastic must be removed prior to welding because it acts as a barrier between the fitting and pipe surfaces during the welding process. Weld surfaces containing regions of oxidised plastic may pass short term pressure tests, but under long term stress the oxidised material can undermine the weld and lead to premature weld failure.

Hand scrapers used to be the common tool for peeling the oxidised material from pipe surfaces, however lab tests show they often remove too little oxidised plastic. Some test labs believe up to 70% of weld failures are caused by insufficient removal of oxidised plastic from pipe surfaces. This is why hand scrapers have long been prohibited in the Plastic Industry Pipe Association (PIPA) Electrofusion Installation Guideline POP001. Mechanical peeling tools are the most reliable way to remove the correct depth of oxidised plastic across the whole weld zone.

Cracks and Cavities

These can be caused by degradation of the polymer material; for example, by either exposure to heat, during or after the welding process, or by chemical exposure, such as from a solvent-welding technique. Such exposure might not cause immediate failure, but it might initiate a process of either slow crack growth, or one in which the generic properties and integrity of the plastic pipe deteriorate over time. If plastic pipework fails in this way, at or close to a welded joint, then one of the challenges for a forensic engineer is to determine whether the damage was caused or initiated either during the welding process, or afterwards, while the pipe was in service. Slow crack growth is a relatively common failure mode in plastic pipework which is the mechanism underlying environmental stress cracking (ESC).

Inclusions

This refers to 'foreign objects' that become trapped within the weld material, while the plastic is softened. They are most commonly a result of poor surface cleaning and preparation, or can also be due to an unclean environment during the welding process. For example, it would be very difficult to avoid sand particle or clay dust contamination if plastic welding was being conducted outside, without significant protection.

Foreign particles can act as stress concentration and/or crack starter points, so if the pipework is exposed to a stress whilst in service, it can promote a

mechanical (overload)-type failure. The presence of foreign particles will also reduce the overall strength and quality of a welded joint, so a diligent technician should take care to keep the welding zone as clean as possible. Another type of inclusion can be a ‘bubble’ of gas or air that becomes trapped in the weld material. This has a similar effect to a foreign particle, both by acting as a potential crack starting point, and also by reducing the overall strength of the weld.

Deformation

Deformation failures in plastic welded joints encompass two primary scenarios. Firstly, joints can overheat during the welding process, causing the bonding surfaces and sometimes the bulk material of the pipe to soften and deform. Secondly, improper alignment of components during welding can result in incorrect angles or positions, or failure to insert the pipe fully into the fitting. While deformation failures may not always lead to catastrophic consequences, they can disrupt liquid flow through the pipework or pose challenges during fitting and application.

Joint Separations

Joint separations are among the more common failure types in plastic pipework, including those joined by welding. These separations often stem from errors during the welding process, preventing the formation of a full-strength weld. Underheating of polymer surfaces, inadequate contact with heating tools, or premature removal from heat sources can compromise weld strength. In cases of insufficient heating, the bond strength is significantly lower due to incomplete blending of polymer surfaces.

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