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The Weld Nugget™

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Know when to hold 'em

Welding, soldering, and brazing process are primarily characterized by energy supplied to the joint area to produce heat in order to soften or melt the parts to be joined along with filler alloy, if present. However, the act of heating is not when the bond develops strength. In fact, the joint is very weak when the components are molten or soft. The weld/solder/braze develops strength as it cools to room temperature. The process of cooling after the heat source has been turned off is quite important but an often-overlooked part of the welding process. In some processes, the parts should be allowed to move to reduce residual stresses, and in some systems, parts should be held securely to avoid defects. As country music star Kenny Rogers has said in his famous song The Gambler - "You got to know when to hold them, know when to walk away."

Soldering is a joining process that involves melting, wetting, and flowing of the solder alloy such that it forms an electrical connection between the two parts to be soldered together. Process may require the solder to fill gaps between the two parts, or form a meniscus that bridges the two parts; almost looks like a fillet weld. Solder alloys are usually mixtures of two or more metals such that the mixture will melt at a temperature lower than the melting point of its constituents; the specific ratio that has the lowest melting point is known as the eutectic composition. Eutectic alloys will melt and freeze practically instantaneously at a single temperature and are not affected by minor movement of the parts during cooling. However, there are applications where the solder composition is intentionally selected to be non-eutectic such that the solder alloy has a melting range and is within the pasty region (Figure 1). In this range of temperature above the solidus and below liquidus, the non-eutectic solder is a viscous paste that is able to bridge larger gaps which a eutectic solder would not have been able to fill. As the non-eutectic solder cools below liquidus, some constituents start to solidify and the amount of liquid solder keeps decreasing till the solidus temperature is reached where solder is now completely solid. The solder joint is most at risk in this pasty range. If, in this viscous temperature range, the parts being soldered are moved, then the remaining smaller amount of liquid solder is unable to smoothly bridge the gaps, resulting in a dull grainy appearance. Depending on the amount of movement, the solder joint may also end up having a crack, or be separated completely. Such a defect is usually referred to as a dry joint. Ensuring that the parts do not have any movement or shaking during cooling is critical for joining success in non-eutectic solders.

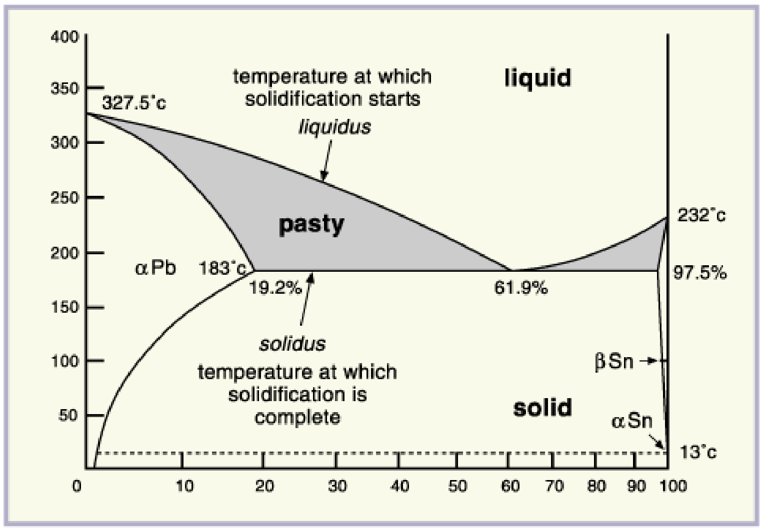

Figure 1. Tin-lead phase diagram showing non-eutectic pasty regions where the alloys have a solidification temperature range and do not freeze instantly as at the eutectic composition of 61.9%.

Post-heating hold time is also a critical element of process control in resistance welding. At the end of the resistance welding pulse, the weld zone is still soft, and in some situations it is molten (Weld Nugget: Spring 2021); the weld can separate if the weld pressure is released prematurely. For the weld to develop consistent strength, the parts should be held in place under action of the welding force after the current has stopped flowing. Hold time allows the weld to cool down to a low enough temperature to ensure weld has developed sufficient strength where it can be handled without any risks to weld quality.

On the other hand, an arc weld may have the opposite reaction. As the weld cools, the solidifying molten metal contracts substantially more than the base materials and can result in significant residual stresses in the weld. Such stresses can lead to cracking in the presence of any defects, phase segregations, or presence of brittle phases in the weld. One of the strategies used to reduce residual stresses, is to allow one of the parts to have some degree of freedom (Figure 2) such that cooling contraction will pull the two parts toward each other, thus producing a joint with relatively lower levels of stress. One of the downsides of allowing such mobility is potential for distortion.

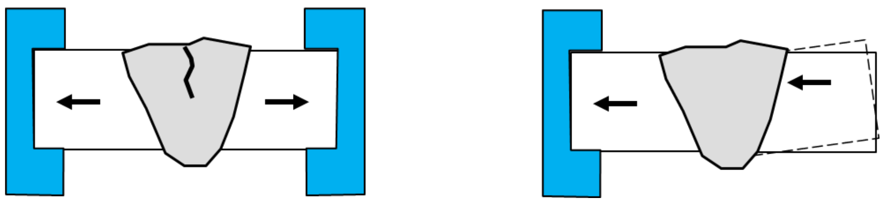

Figure 2. Schematic on left shows two parts being welded with heavy restraint resulting in residual stress in the weld which can lead to cracking. Schematic on the right shows a weld with some degree of freedom to move and relieve contraction stresses.

Personnel who are new to the field of welding/soldering/brazing get tripped by these subtle but important aspects that are not obvious at first glance. For most participants, the main activity seems to happen when the parts are being heated or supplied with energy in some form. But strangely enough, it is the process of cooling that is often more critical in determining weld quality. So, if you are responsible for developing a robust welding process and want to come up aces, make sure you know when to hold 'em.

If you have any questions about the contents of this newsletter or any other question about welding, please contact us at WJM Technologies, www.welding-consultant.com.