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The Weld Nugget™

a newsletter to inform, entertain, and educate

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Resistance Welding – A Pressure Cooker

Resistance welding is a unique process that is able to produce a bond at the interface between two parts to be welded while maintaining the external surfaces relatively undisturbed. Bond formed can be a solder joint (reflow solder), a solid-state bond (where parts do not melt), and the conventional fusion bond where a nugget forms at the interface. Question that often confounds users is that if the weld does form a fusion nugget, why don't we see any signs of molten metal? Answer is that a combination of welding pressure, electrode tip size, and heat balance form a pressure cooker that traps the molten metal safely inside.

<u>(Note: The following discussion is only applicable for welds that form a fusion nugget; not applicable for welds that form a solid-state bond or solder/braze joints).</u>

In resistance welding, the parts to be welded are pinched between electrode tips which apply force prior to flow of welding current. Force applied should be sufficient to produce intimate contact between electrodes and parts to be welded, and at the same time should not be so high as to severely indent external surfaces during welding. Once the intended force is reached, a signal is given to the power supply to start sending current. Depending on type of power supply used, current flows alternately in both directions (AC) or in a single direction (DC, Inverter, Capacitor Discharge). In any case, as the current starts flowing, it encounters resistance at the interfaces and in the bulk, resulting in heat generation. A unique aspect of the electrodes is that in addition to providing pressure and current, they also act as a heat sink, carrying heat away from the external surface. Additionally, the parts themselves act as a heat sink. In a properly designed welding process, this balance between heat generation and heat loss leads to a strong temperature gradient with a peak at the center of the weld.

As additional current flows, temperature continues to rise and ultimately exceeds the melting point of the metal leading to formation of weld puddle at the center. With further increase in energy supplied, this zone starts to grow. Size and shape of the fusion zone formed depends on rate of energy delivery and rate of heat loss. Under normal circumstances, the nugget takes a familiar oblong shape with height and diameter designed to meet quality requirements.

As the molten metal has a higher volume than solid metal, the molten metal starts to exert pressure against the welding force and tries to separate the two parts being welded. The weld is now in the phase of a tug-of-war between welding force acting through the un-melted part surrounding the fusion zone trying to keep the parts together, and fusion volume trying to force them apart. This pressure cooker that forms at the weld is shown in Figure 1. Tip size is chosen to be slightly bigger than the expected nugget size so that there will be sufficient solid metal around the fusion nugget through which pressure can be exerted to contain the fused metal. As an example, when welding 1mm (0.040”) stainless steel sheets, the expected nugget size would be 4 mm (~0.160”), and the recommended tip size would be 5 mm (~0.200”).

As with all manufacturing processes, and especially with welding, things don’t always go according to plan. If the weld time is excessive, the fusion nugget can grow in an uncontrolled manner and end up having a diameter larger than that can be contained by the pressure cooker. In such situations, the molten metal can be seen spitting out from between the sheets resulting weld flash, as shown in Figure 2. And if the rate of weld heating is too high, the nugget height can grow rapidly and extend either close to or all the way to the external surfaces. In such an event, the electrodes can produce excessive indentation on the external surface, or molten metal can react with the electrode and produce electrode sticking along with molten metal spit out from the external surface.

A welding engineer would be wise to carefully evaluate weld sections during development of a fusion weld to make sure that the fusion zone is large enough to meet specifications, yet properly contained to ensure that the process does not produce fire-works during operation.

Weld spatter will not only damage fixtures/automation, it can also get dislodged during follow-on operations such as painting, and lead to some embarrassing conversations with quality personnel.

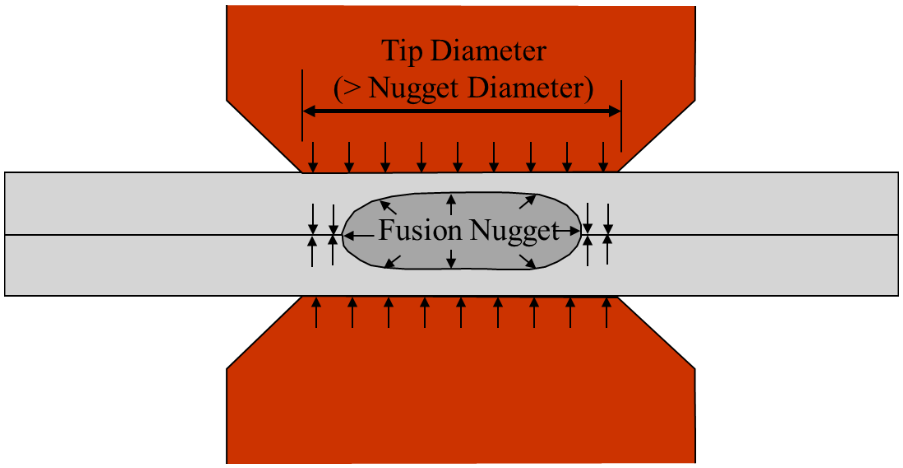

Figure 1. Schematic shows fusion nugget exerting outward pressure on surrounding solid material; while welding force is exerting enough pressure to contain the molten metal and prevent it from escaping.

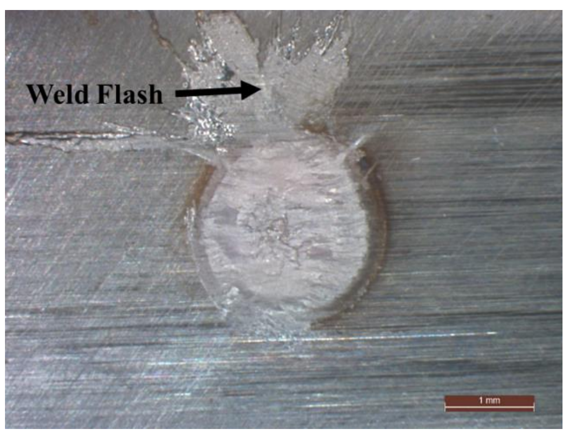

Figure 2. Photo of weld interface after testing shows weld flash that was trapped between the two sheets being welded.

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.
