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Ensuring Quality in Automated Welding Cells

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Spot Welding & Quality

Spot welding is one of the most common forms of resistance welding. It is used to manufacture many types of products, and often the welding process is automated using robots with attached spot welding equipment.

As for all manufacturing processes, it is imperative that product quality is maintained at a high level. This has never been more critical than in today's age of zero-defects and increased pressure to improve productivity. When a process is out-of-control, lack of quality increases two main costs: quality control costs and quality spill costs. See Table 1 for examples of the costs of quality.

A common problem related to these costs of quality is that they are often hidden, overlooked, or known but hard to resolve. In the worst case (and most common case) these costs of quality are simply accepted. Does that sound absurd? Yes, but it's true. Market research revealed two items of significance; 1) most companies experience these costs and 2) these companies would take steps to prevent or reduce these costs if they could.

Table 1 - The Cost of Quality

Quality Control Costs	Quality Spill Costs
Rework	Liability Risk
Scrap	Containment
Expedited Delivery	Rework
Unplanned Overtime	Prevention Steps
Unplanned Downtime	Reputation
Visual Inspection	

Process Features

To understand how to prevent these costs, we must first have a good understanding of the spot welding process and the current best practices.

The amount of heat (energy) delivered to the spot governs the quality of the weld. The amount of energy is chosen to match the sheet's material properties, its thickness, and type of electrodes. Applying too little energy won't melt the metal or will make a poor weld. Applying too much energy will melt too much metal and make a hole rather than a weld. The amount of heat is determined by the resistance between the electrodes and the amplitude and duration of the current, as shown in Equation I below.

$Q=I^2Rt$ (Equation I)

I = Current (Amps) R = Resistance (Ohms) t = time (seconds)

The amplitude and duration of the current delivered is typically controlled by the weld controller (timer). The resistance of the weld circuit is the most difficult factor to monitor and control. There are six primary sources of resistance in spot welds as depicted in Figure 1.

Three of the six critical factors of resistance are related to the welding electrodes. Moreover, your manufacturing process already has robust controls on the other three factors (dimensions and material properties of the welding materials.) What does all this mean? This means that electrode condition is at least as important as any other factor of the spot welding process.

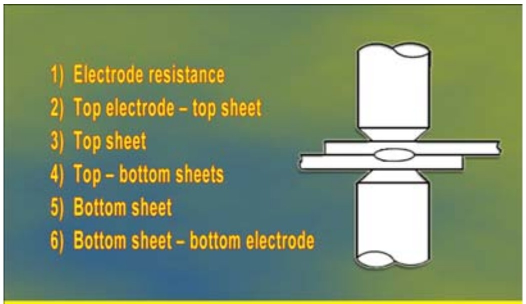


Figure 1 – Primary Resistance Sources

So what are the critical characteristics of weld tips?

- ***Type*** *– Many different types or styles of tips exist.*
- ***Face Diameter*** *– This dimension is critical for consistent current density at the weld.*
- ***Face Condition*** *– Poorly dressed or damaged tips do not produce consistent welds.*
- ***Face Position*** *– With offset or D-nose tips, position is critical.*

Current Best Practices

There are many actions that companies take to reduce the risks associated with weld tips. One of the most common is the presence of redundant welds. Because the spot welding process is often difficult to manage, many OEMs design extra welds to ensure the products meet specification. Many companies institute policies that require frequent tip changes and convenient tips changes. These policies often create unnecessary downtime and the copper costs for these manufacturers are typically very high. Some companies use long current stepper profiles in an attempt to create the proper current density at the contact surface. This method may be effective at times; however the expectation of uniform and predictable tip wear is often unreasonable. Other firms perform end of life tip inspections to monitor tip wear, after the fact. Another common post-process inspection is frequent destructive testing. Both of these reactions require labor and the latter produces unnecessary scrap. What do all of these best practices have in common? They all add significant fixed and variable costs to the spot welding process, and they are all reactive. Does your company perform any of these best practices?

A truly best practice should require a justifiable expenditure and minimal ongoing labor costs. The solution should also provide forward looking, proactive information. One current best practice, tip dressing, is a step in this direction. Tip dressing is designed to re-machine the tips to original size and shape specifications. In an automated work cell, this produces minimal downtime while ensuring that the tip condition is appropriate. To date, tip dressing has been the best practice for managing spot welding tips. However, because dressing used tips is not always as easy as it sounds, it often offers a false sense of security related to the condition of tips. Consider the example of turning a part on a lathe that will be joined with its mating component at the assembly line. Can you imagine cutting this part and sending it to the line without first inspecting the critical dimension? Obviously not. Well cutting material from a used welding tip and then immediately welding is analogous to this example. Therefore, a method of inspecting dressed tips is necessary to have a truly robust best practice.

Investigating tip inspection methods is not necessarily breaking new ground. In recent years multiple types of sensors have been tested for this purpose. Reflectivity and fiber optic sensors are two methods of inspection that have been tried, but have not been adopted because of their shortcomings. These sensors provide partial information, but not enough to determine whether a tip is fit for use. For example, a reflectivity measurement is a relative inspection based on tip condition. Nearly identical reflectively results could come from a proper formed round face and an oversized round face with some embedded impurities. Obviously these are not robust solutions.

Best Practice Developments

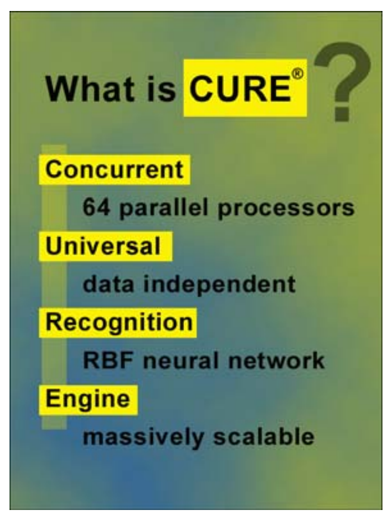
A more robust solution would be able to ensure that the electrode's face is the proper shape (circular), proper size (diameter), and adequate (subjective) condition. Certainly a visual inspection could perform this analysis. Traditional vision systems have been tested for this application, but have not performed as well as intended. These vision systems are incapable of managing the subjective nature of the good/bad tip decision, and they also struggle with the varying environmental conditions (lighting, debris, etc.) of the work cells.

As a result of these experiments, it was concluded that a complete solution to the tip inspection problem must include a method of managing the subjectivity and variance in the environmental conditions. These conclusions led to the inclusion of a neural network based technology, CURE, in the weld tip inspection product. A CURE enabled vision system was designed and tested and the results show that it effectively manages the environment and subjective concerns. This product is known as WTS, or Weld Tip System.

The WTS Solution

WTS includes custom lenses and filters' and requires no programming or toolkits. All it needs is examples of acceptable tips, and it learns automatically. It truly mimics the functionality of the human brain by learning patterns, storing the patterns as knowledge, later recognizing the patterns, and then acting accordingly.

This process intelligence tool converts sensor and image data of weld tips into actionable quality assurance information. The WTS system status can be used by a cell controller to take the appropriate action. For instance, suppose that WTS fails a set of tips immediately following a dressing operation. This fail signal can be used to send the tips back to the dresser, and then WTS can perform another inspection. If the dressing fails three times in a row, then operator intervention is likely required.

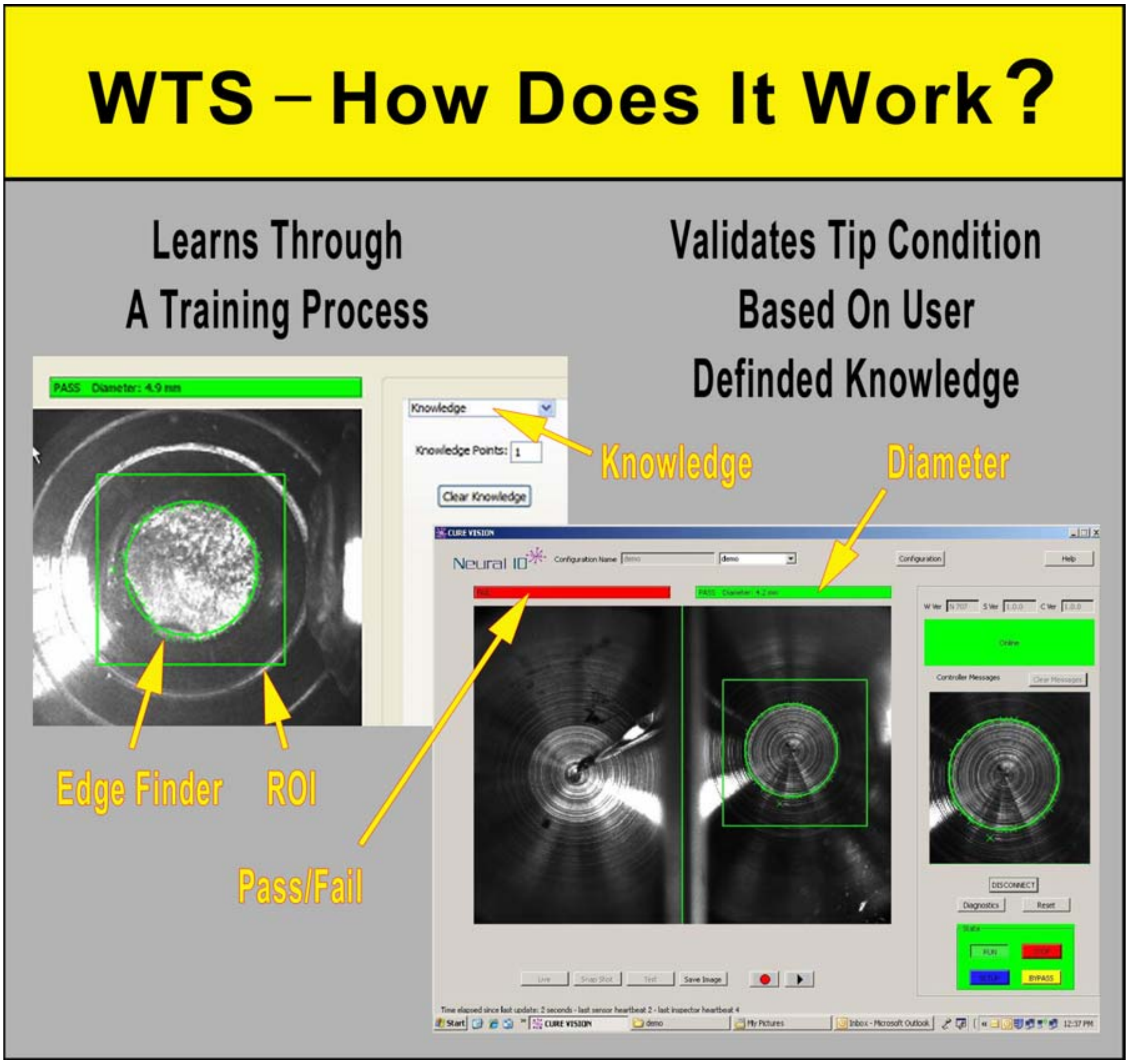


Another nice feature of WTS is that it can store inspection images and the appropriate corresponding inspection result data. This is used for two main purposes. First, these saved images can be used to perform offline training which is an efficient method of starting up the WTS system. Another benefit of these images is for benchmarking and traceability.

Note: For an illustration and description of how WTS works. Learning, inspection, etc. See the end of this document.

Best Practice Quality Management with WTS

WTS allows spot welding process managers to take their best practices to a new level. Now electrodes can be replaced more efficiently, current stepper profiles can be utilized with more confidence, tear-down frequencies and redundant welds can be reduced, and other forms of end-of-life inspection can be eliminated. WTS provides security for automatic robotic weld cells, especially when automatic tip dressers are utilized. Using these new best practices can decrease weld cell variability and increase profitability.



If you would like to learn more about inspecting weld tips, your next step is to send an email to wts@orbitform.com, or simply log on to our website at www.orbitform.com.