WeldComputer

The Technology Leader in Resistance Welding

MADE IN THE U.S.A.

Adaptive Controls: Effectively Addressing Workpiece Variation Challenges in Resistance Welding

By Robert K. Cohen

Executive Summary

Ubiquitous in manufacturing, welding is used to build much of what we rely on every day. Consider the cars, airplanes, trains and buses we use for transportation; the appliances in our kitchen including the lowly bread toaster; medical devices such as surgical tools and pacemakers; and the satellites we launch into space.

One prevalent type of welding used to manufacture these and many other items is resistance welding. Established more than 130 years, the technique has evolved into an automated process known for its high production rate of joining different metals together without the need for additional material, such as filler metals.

Still, resistance welding has its challenges, which can have potentially dire consequences if not fully and accurately addressed. Faulty welding is notoriously commonplace in automobile manufacturing, for instance. Poor welding practices have been blamed in some cases for the well-known lethal explosions of airbag inflators. Other examples include improper welding that jeopardized vehicle body strength, impacted steering reliability, or resulted in unreliable seat belts (Refs. 1-6).

This paper will focus specifically on addressing one of the key challenges of resistance welding—workpiece variation. That is, the interface between workpieces and the electrode-to-workpiece interactions for heat generation that serve as the basis of resistance welding.

We will describe how resistance welding works and the most common types used. We'll talk about some of the challenges and what the conventional solutions have been. The paper will also detail the capabilities of adaptive controls, the most advanced tools available, and how this latest technology is benefiting manufacturing and other industries.

Resistance welding is a prevalent type of welding that is used in the manufacturing of many items found in kitchens.

RESISTANCE WELDING BASICS

Electric resistance welding, a largely automated welding method in industry, is widely used to permanently affix metal components in the manufacture of everything from steel pipes, automobile doors, appliances and surgical tools to missiles, satellites and aircraft.

Electrodes, attached on either side of the welding head, hold two workpieces in place, and pressure is applied as the electric current passes through. The electrical resistance of the workpiece materials as the current flows through them generates heat at their interface and within the material. When the right amount of heat is produced, the pieces adhere at the joint. Typical metals used in resistance welding include steel and stainless steel, nickel alloys, aluminum alloys and titanium. The key to producing consistent welds lies largely in the ability to precisely control the concentration of heat, or heat density, within the joining materials.

There are four main types of resistance welding:

Spot welding is typically used to join sheets of metal. The components are welded together at different spots, or locations. The material of each piece between the electrodes melts, forming a molten nugget that then solidifies before the operator moves the workpieces to the next location for the next weld.

Seam welding is a variation of spot welding. In this case, the electrodes take the form of rolling wheels. The distance between spots can be most easily controlled by rolling the desired distance and then making a spot weld. This can be more efficient than using a spot welder to do the same thing because the wheels can simply roll to the next position.

Projection welding works by concentrating the electrical current on the dimples, ridges or other embossments on the surface of one of the two workpieces. When these embossments, or "projections," heat up, under the applied force of the electrodes, they collapse and form weld nuggets. The nuggets then cool down and solidify to hold the parts together. This welding technique is typically used to connect studs, nuts or brackets on individual metal sheets or to join two metal plates. It is also frequently used to join bars, such as in fencing and grating (Ref. 8).

Flash/butt welding is for welding butt joints via a flashing action generated by high current density at small contact points between the workpieces. This process is applied in many industries to weld rebar, bandsaw blades, railroad tracks and tubing. It's also used for joining electrical contacts such as copper to aluminum. In addition, the aeronautical industry uses

Adaptive Controls: Effectively Addressing Workpiece Variation Challenges in Resistance Welding, p. 2

flash/butt welding to join rings for jet engines that are made of temperature-resistance metals and to weld together landing gear (Ref. 9).

WORKPIECE VARIATION CHALLENGES

Advancements in automation have increased the quality, efficiency and consistency in resistance welding while reducing overall industry costs. Still, there are any number of daily issues that must be addressed in a typical manufacturing environment. One of the biggest challenges is addressing workpiece variations. These variations relate to workpiece thickness, how the sheet metal or other parts fit together, and the size of the welds that are influenced by the weld nuggets' proximity to one another on the adjoining materials.

Workpiece variations are typically due to differences in material surface resistance as a result of (1) shunting, (2) material contamination and variation and (3) poor part fit-up.

Shunting

A common problem in spot welding is shunting, which affects the size and consistency of consecutive welds. Shunting happens when the welds are placed closely together. As a result, part of the current is diverted through the path created from the existing weld, which causes a reduction of current, and thus heat, at the site of the weld being produced. This results in an undersized weld.

Material Surface Contamination and Variation

The buildup of surface contamination from oxidation on metals such as aluminum, steel and nickel is commonplace and can have detrimental effects on the welding process if not appropriately addressed. Surface contaminants generally increase the resistance of the workpiece material. The properties of the same materials can also change from lot to lot.

Surface contaminants generally increase the resistance of the workpiece material. When this type of variability occurs, conventional controls that regulate the current can actually create more variability than if no regulation by the control were performed at all. This is because, under these circumstances, the regulating action of the control becomes the reason for generating excessive heat. Instead of reducing the variability, the regulating action of the control overheats the part, potentially resulting in expulsion of molten material and electrode damage.

Poor Fit-Up

Poor fit-up is also another common workpiece variation problem. When welding two pieces of metal, generally the parts are aligned between the two electrodes so that they are flush against one another. But when a workpiece is bowed or otherwise warped, the current doesn't flow properly through the components, which can result in no weld, an undersized weld, and often, expulsion as well.

STANDARD QUALITY CONTROL PROCEDURES

Attempts to minimize workpiece variations are usually achieved through careful material preparation and inspection. Weld variations are controlled usually through manual operator heat adjustments. Still, evaluation standards need to be implemented throughout the process.

Destructive Testing

Traditionally, periodic destructive testing has been the primary method of evaluating weld quality. Destructive tests identify if a change has occurred in the weld machine setup. However, because each weld cannot be subjected to destructive scrutiny, unacceptable welds can be produced and escape detection.

Destructive tests can also be costly and a time-consuming process. For instance, some companies have spent up to 25 percent of production time destroying samples in the attempt to verify the production of satisfactory welds, eating up valuable time and producing undue waste.

Destructive testing is actually a blind approach that does not address or correct the root causes of undersize welds, excessive heating, expulsion or material surface contamination. In addition, the bad welds themselves can be random. For example, shunting might take place on one weld but not another, so it's nearly impossible to know when unacceptable random welds are produced, making destructive testing all the more ineffective.

Monitoring Systems

Some controls employ monitoring systems to measure welding response variables such as nugget expansion and welding current. On these monitoring systems, technicians can often set upper and lower limit values for expansion and current. If a response is generated outside of the established limits after the weld has been produced, the operator is notified, and the weld is rejected.

Monitoring systems that effectively monitor enough variables can detect and prevent problem welds from leaving the factory. A high rejection rate, damage to parts and collateral damage can still take place, however, and such systems don't improve the consistency of the welds that are not rejected.

The problem with monitoring systems that employ standard heat controls is that the operator many times is unable to determine the cause of a weld variation and therefore cannot reliably use the information to determine what corrective action, if any, can be taken. Without knowing the sources of the variations, quality control and maintenance personnel may perform inappropriate corrective procedures. In short, these control systems do not improve the consistency of any of the welds produced.

THE LATEST SOLUTIONS AND TOOLS: ADAPTIVE CONTROLS

To more effectively address the wide range of workpiece variations discussed so far, multiple variables must be monitored at the same time. This is achieved through adaptive controls, the latest technology that industry and government have been turning to over the last 30 years for more detailed and flexible monitoring and to eliminate the need for destructive testing altogether.

Adaptive Controls: Effectively Addressing Workpiece Variation Challenges in Resistance Welding, p. 3

Adaptive controls developed by WeldComputer automatically adjust to the conditions of each weld. They automatically detect unwanted conditions, employ the appropriate decision-making process, and then take the appropriate action to correct and/or compensate for the condition(s) as each weld is produced.

This process prevents problem welds from occurring in the first place by increasing the consistency of all welds produced. And if the parts fit-up is so poor that corrective action is not possible, the adaptive control aborts the process, alerts the operator and identifies the condition.

The adaptive weld schedule to facilitate this identification and decision-making process is designed to operate at high production rates and result in no production delay.

Adjusting for Workpiece Variation

Adaptive controls, for example, can detect material coating and surface resistance variations that would affect the weld result, then take the appropriate corrective action to prevent problem welds from being made in the first place.

If a higher-than-normal workpiece resistance is detected (indicative of surface contamination), the adaptive controls immediately lower the level of heat, just enough to burn off the surface contamination in a controlled fashion. Once the contamination is reduced to acceptable levels, the weld is completed to its original specifications.

The same adaptive control features can address poor fit-up issues as well. The adaptive control detects that the workpieces don't fit together. It then deliberately reduces the heat to soften the parts enough to get them to fit flush together before increasing the heat to complete the weld. If conditioning for a flush surface and a reduction in workpiece resistance to an acceptable level cannot be achieved, the control aborts the weld and produces a record of the condition.

Adaptive controls also effectively compensate for shunt conditions and flattening electrodes. As the weld forms, if a lower than normal rate of thermal expansion is detected, the control responds by automatically increasing the weld heat by the amount needed to compensate for the condition.

Case Study

NASA Langley Research Center successfully employed a WeldComputer® adaptive control unit to address the inherent oxidation buildup on aluminum-lithium alloys. The Center, which was conducting experimental welding on the alloys for the fuel casing on the Space Shuttle, could not control the welds produced by its existing aerospace-quality welding system.

Aluminum-lithium alloys are much lighter than more conventional aluminum-based alloys and therefore ideal for aircraft applications (Ref. 7). The alloys also tend to oxidize quickly, with the surface conditions changing in just a few hours after cleaning. But instead of rendering the alloys unusable, the engineering team was able to use WeldComputer® adaptive controls to produce consistent welds during a two-week period before the material had to be cleaned again.

CONCLUSION

Resistance welding is a manufacturing process used in many industries. Conventional feedback control systems can be effective when the welding operation is dominated by one source of variability. However, they can't detect specific problems that lead to bad welds.

This is because they employ the same feedback algorithm, often responsive to just a single variable. So, while they may improve the consistency under certain circumstances, they are susceptible to making adjustments that could actually cause more variability than if no adjustments were made, and in some instances, they can damage the workpieces and electrodes. Destructive testing is still the primary standard used to detect defects, but the process is inefficient, costly and time consuming. Such testing also doesn't detect a problem with any weld that's not destroyed.

It takes hundreds of decisions every millisecond to instantly detect a multiplicity of different process conditions that can affect weld quality. Only a multivariable adaptive control with such capabilities can react fast enough to take the appropriate corrective actions needed to control the consistency of each and every weld and reduce the incidence of bad welds.

Proper deployment of monitoring and adaptive controls now allows manufacturers to achieve quality assurance standards far beyond what has traditionally been accepted with conventional controls. This reduces manufacturers' dependence on other competing joining processes that cost more and also have slower throughput and lower energy efficiency.

Ultimately, adaptive controls enable manufacturers to:

- Reduce reliance on destructive testing
- Prevent random problem welds from passing through production undetected
- Automatically take corrective preconditioning and compensating actions to prevent the production of out-of-spec welds

The end result is to prevent the occurrence of a bad weld in the first place and to increase the consistency of all welds produced.

ABOUT WELDCOMPUTER

As the leading expert and a pioneer in intelligent weld controls, WeldComputer offers a broad range of high-performance welding control and monitoring solutions, from basic consistent heat control to the most sophisticated adaptive applications. WeldComputer systems analyze and address the key challenges of resistance welding operations to consistently produce high-quality welds, quickly detect bad welds during the production stage and prevent bad welds from occurring in the first place.

To learn more about the latest technologies in adaptive controls, contact Weld Computer:

Email: info@weldcomputer.com
Phone: (800) 553-9353 or (518) 283-2897
Website: https://www.weldcomputer.com

Adaptive Controls: Effectively Addressing Workpiece Variation Challenges in Resistance Welding, p. 4

ROBERT K. COHEN is CEO of WeldComputer Corp.
He is also a member of the D17D Subcommittee on Resistance Welding in the Aircraft and Aerospace Industries and the AWS C1 Committee on Resistance Welding.

References

1. Bernstein, J; Klayman, G; and Kubota, Y. Oct. 14, 2014. "Exclusive: Takata Engineers Struggled to Maintain Air Bag Quality, Documents Reveal," Reuters. Electronic resource retrieved: https://www.reuters.com/article/us-takata-airbags/exclusive-takata-engineers-struggled-to-maintain-air-bag-quality-documents-reveal-idUSKCN0I701B20141018

2. Barry, K. July 12, 2019. "Some Subaru Owners Could Get New Cars After Recall," Consumer Reports. Electronic resource retrieved: https://www.consumerreports.org/car-recalls-defects/some-subaru-legacy-outback-owners-could-get-new-cars-after-recall/

3. Krok, A. July 17, 2019. "Subaru's new recall for 2019 Legacy and Outback puts the focus back on welds,"Road Show, CNET. Electronic resource retrieved: https://www.cnet.com/roadshow/news/subaru-recall-2019-legacy-outback-welds/

4. LiveMint July 6, 2018. "5,397 Ford EcoSport cars recalled to fix welding issue, seat recliner locks. "Electronic resource retrieved: https://www.livemint.com/Auto/mRI5O27X23ampBPOH1NhNL/5397-Ford-EcoSport-cars-recalled-to-fix-welding-issue-seat.html

5. Chin, C Oct. 1, 2019. "BMW Recalls 2020 Toyota Supra for Seat Belt-Related Malfunction," TheDrive.com, Action Media Inc. Electronic resource retrieved https://www.thedrive.com/news/30114/bmw-recalls-2020-toyota-supra-for-seat-belt-related-malfunction

6. Read, R. Sept. 11, 2015. "Ram pickup recall: over 1.3 million trucks with airbag, welding woes," Christian Science Monitor. Electronic resource retrieved: https://www.csmonitor.com/Business/In-Gear/2015/0911/Ram-pickup-recall-over-1.3-million-trucks-with-airbag-welding-woes

7. Djukanovic, G. Sep. 5, 2017. "Aluminum-Lithium Alloys Fight Back," Aluminum Insider. Electronic resource retrieved: https://aluminiuminsider.com/aluminium-lithium-alloys-fight-back/

8. HowToResisanceWeld.org. "Is cross wire welding a projection weld?" Resistance Welding Manufacturers Association. Electronic resource retrieved: https://www.howtoresistanceweld.info/projection-welding/is-cross-wire-welding-a-projection-weld.html

9. Total Materia April, 2007. "Welding of Aeronautical Components." Electronic resource retrieved: https://www.totalmateria.com/page.aspx?ID=CheckArticle&site=ktn&NM=168