Adapt and change

How adaptive control of resistance welding can cut production costs and improve product quality
Adaptive welding remains a small proportion of the UK’s welding market, but its ability to improve the quality of weld and drive cost out of the manufacturing process could offer many manufacturers an alternative to traditional methods.

As resistance spot welding users will know, the process is prone to weld disturbance, including shunting, caused by alternative current paths leading to a loss of energy, bad fitting of sheets and also variations of coating and sheet thickness.

Problems can also include deterioration of the condition of welding tips, inclusion of sealer and adhesives between the material, and problems attributable to wear of pneumatic cylinders, which creates a variation in weld force affecting weld condition. The issues surrounding resistance spot welding do not stop once the process is complete. Quality checking is problematic and rests on two methods.

Firstly, the ultrasonic inspection method which uses a hand-held probe device that emits ultrasonic waves to ascertain the size of the weld nugget. However, the manual nature of the job can mean that individual operators obtain different results from the same weld. Also the ultrasonic wave method is a highly skilled task which requires trained operators and a separate weld station, all of which adds cost to the process.

The setting of weld parameters is crucial in obtaining a ‘good’ weld. Too much energy creates weld ‘splash’, whilst too little can easily create a weld ‘failure’. Whilst disturbances during the weld can easily create a ‘splash’ the big fear for many users of resistance spot welding is going into the failure zone which, more often than not, will result in the recall of parts.

This white paper examines the ability of adaptive welding systems to eliminate many of the problems associated with spot welding, at the same time driving cost out of the manufacturing process and improving quality. Early adopters have embraced adaptive welding, but it remains a small proportion of the total market. My hope is that this white paper encourages further adoption of a system that has the potential to revolutionise welding methods.

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Global manufacturing is increasingly placing a premium on quality and durability of its products. Take the automotive sector for example, which is demanding that all its cars are produced with the highest levels of precision, with outstanding structural integrity to protect the vehicle’s value and the competitive strength of the manufacturer’s brand across the globe.

To help accomplish these goals, leading-edge manufacturers for example are investing heavily in advanced automation platforms that offer two fundamental advantages, namely the ability to manufacture in volume coupled with extremely detailed control of every key process - including use of latest generation digital platforms that capture and track a broad range of production data.

The widespread implementation of high-speed, automated MFDC (Medium Frequency Direct Current) Resistance Welding, particularly in automotive manufacturing, is one significant example of this kind of investment.

Robotic resistance welders provide a highly cost-effective and proven method of rapidly welding hundreds of parts per hour. To track and ensure the quality of these welds, components is widely conducted in all operations.

However, a key process improvement for high-speed welding is not yet broadly adopted — and it is one with the potential to revolutionise the quality, flexibility and productivity of welding platforms, namely in-process inspection and real-time adaptive control of resistance welding.

**Adaptive control advances welding performance**

Adaptive resistance welding control utilises cutting edge controls platforms to adjust, in real time, precise functional characteristics of the welding system so that every weld is performed within the tightest quality tolerances. This creates the framework to significantly reduce, or potentially replace ultrasonic weld inspection technology.

Typical manual ultrasonic inspection methods involve taking a sample part from the line and subjecting it to a manual, standalone inspection — as a representation of the quality of that particular welding process, during a given production run.

Whilst it is non-destructive, it is time consuming and has the potential to introduce repeated inconsistencies, based on a tester’s own opinion of what represents a good weld. Adaptive resistance welding control integrates the inspection of each weld, and the real-time control of how each weld is performed, to vastly improve the reliability of the welding process and simultaneously maintain the highest levels of welding throughput.

Adaptive welding systems provide one of the most advanced platforms for real-time control of welding. During automated welding, parameters such as current, voltage and resistance are monitored every millisecond, with these parameters constantly compared in real time against a previously established reference resistance curve that controls the quality of the process.
This reference resistance curve is generated through a mathematical calculation of previously captured stored current, voltage and resistance curves of known good welds. During a weld using adaptive control, actual values of current, voltage and resistance are compared to the reference values for a good weld.

The Bosch Rexroth PSQ (Process Quality Control) 6000 Adaptive Welding system for example, works together with the weld controllers constant current control system to automatically raise and lower the welding current and weld time in real time, to keep the actual welding parameter values as close as possible to those of the reference curve — with the anticipated result that the weld will have the equivalent quality.

**Inline, real-time weld correction**

Process control is the foundation for successful, cost-effective automation. Today’s high-speed controller technology can integrate complex data, such as high speed sampling data of current voltage and resistance, process those inputs against proven performance curves, and then adjust the performance of the automated production platform to prevent faults, errors or less-than-acceptable product from being created in the first place.

Adaptive resistance welding control demonstrates the value of this approach — substituting the time consuming process of pulling test components during a production run, manually testing weld quality and then correcting weld schedule data (current and time) to compensate.

A fully integrated solution saves time, improves weld quality, and ensures that 100 percent of all welds are inspected and their quality documented by the control system.

Rexroth’s adaptive welding platform measures the weld current and voltage across the weld, ideally as close to the electrodes as possible. Mathematical algorithms calculate resistance curves and energy balance. Data from the weld such as PSF (Process Stability Factor), UIP (Weld Quality Factor) and expulsion are stored and made available for monitoring and trend analysis.

The current is then adjusted to compensate for minute differences as welding proceeds. In special circumstances, sheet combinations with different thicknesses and coatings can be welded by a single program, for special process applications (i.e. manual gun applications).

This kind of control also enhances welding flexibility, which helps manufacturers be more responsive to fast-changing market needs. For example, Rexroth’s automated platform can store and operate multiple welding schedules, as well as change schedules much more quickly when demand for different components, body types or product changeovers have to be welded to meet sudden changes in demand.
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Repeatability of welding process
Every manufacturing process is subject to variations. With resistance welding, these include:

▶ Part fit-up
▶ Part thickness variations
▶ Misaligned electrodes
▶ Variations in coating materials or thickness
▶ Sealer
▶ Weld force variations
▶ Shunting
▶ Machine tooling degradation

All welding gun tips undergo wear. Much of the weld-testing regimen was developed precisely to assess how that wear is affecting weld quality, in order that it could be adjusted before weld quality impacts the component’s integrity. Rather than discovering the impact that these variations have on welding production, after dozens or even hundreds of components have been processed, adaptive resistance welding control automatically compensates to keep production and quality up to the levels required. As gun tips undergo wear, for example, adaptive welding has the ability to compensate for changes in their output, to ensure that the welds remain reliable.

This results in the significant reduction in the variability of welds, and an accompanying increase in weld reliability — a fundamental measure of the quality of welding processes, and ultimately the quality of the final product being manufactured.

A system such as the Rexroth PSQ 6000 also provides an information framework to assure manufacturers that the weld reliability is actually being achieved, since 100% of the welds are inspected in real-time, the platform captures a record of each weld, and any variations the controller made to ensure that the weld is within the established parameters. This is a significant improvement, from a process control perspective, from selecting and testing sample components and projecting the weld quality from the results of the sampling.

Another key benefit is that a warning or error message can be communicated when a process limit has been exceeded. The process can be halted until a technician or engineer intervenes to check the cause of the disturbance. The system also allows for the production of documentation from process data allowing for greater traceability of welded parts. The system displays all the process-critical parameters online in a diagram, enabling accurate visualisation of the process.

Improved safety and operational quality
Adaptive resistance welding control provides an important improvement in worker safety and operational quality through the reduction of welding expulsion. Many highly automated resistance welding operations, with multiple robots carrying out hundreds of welds a minute, generate a significant amount of expulsion because the process lacks real-time control. The result is the potential for a constant cascade of hot, dangerous sparks that can impact worker safety, leading to the need for enclosures and other expensive protective devices and procedures.

As the adaptive system allows the weld engineer to now 'see' what is happening during the welding process, it is far easier to identify 'hot' welds and make the necessary adjustments to the weld current. Once the weld parameters have been optimised correctly, the adaptive weld control modulates the current flow to the welding tools to such an extent that expulsion levels can be drastically reduced.

Instead of delivering a constant flow of power to the guns, which in certain instances and with certain materials is in excess of what is needed to complete the weld, the real-time feedback of conditions on the component's surface enables the PSQ 6000 controller to adjust the power flow to just the correct level to complete the weld without generating expulsion.

Not only does this increase worker safety, it reduces the dirt and contamination associated with constant expulsions in the welding workspace. Reducing particulates on the production line floor means a cleaner environment, with less need for maintenance and also eliminates contaminants that can interfere with sensitive electronic connections, sensors and other production line equipment.

In addition, some studies have shown that it is possible to reduce overall energy consumption by welding tools through adaptive control, since only the amount of energy needed to complete the weld is being delivered to the tool.
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Cost savings throughout welding process
The true value of any technology to improve automation is measured in how it can ultimately help a manufacturer generate savings through improved productivity and/or elimination or reduction of manufacturing costs. Adaptive resistance welding control offers multiple pathways to improving the total cost of ownership of welding systems. These include:

- Major reductions in testing costs — including labour, cost per part tested and scrapped, time for testing, documentation and testing materials
- Elimination of weld quality spills and quarantine requirements
- Reduced weld commissioning time
- Increased weld reliability leads to reduction in costs associated with poor part quality (rework of components, recalls, rebates, legal liability)
- Increased throughput from 100% weld inspection which translates into lower cost per part with higher levels of production
- Reduction in expulsion-related costs — better worker safety, cleaner workspace with less contaminants and better quality welds

Additional benefits also include a reduction in post-weld checks and a reduction in the number of test parts and time taken checking the weld condition. In turn, this reduces production time and cuts the number of personnel required at the manufacturing site.

While there are costs associated with adding adaptive control to resistance welding platforms, Rexroth developed a model for broadly comparing costs of a platform that used manual destructive testing versus use of adaptive welding control.

On a theoretical resistance welding platform of 14 robots welding 150 spots per part, generating approximately 800 parts per day in three shifts, the return on investment was significant. Even after factoring in the cost of the PSQ 6000’s components and programming, a manufacturer could expect to reduce the cost of testing and quality control for resistance welding by more than 30 per cent over six years, through reductions in labour costs, materials costs, scrapped test materials costs and time.

These savings do not include any savings associated with improved parts quality — and with adaptive control, 100 per cent of parts welded are tested and the quality of the welds documented.

Adaptive control essential to maximising value of resistance welding
The Rexroth Adaptive Resistance Welding solution is designed for today’s world-class manufacturers, those that are committed to investing in cutting edge automation technology that adds value to their vehicles by improving product quality, increasing productivity and enabling a sustained return on investment.

This platform includes the PSQ 6000 Adaptive Feedback control platform, a range of powerful authoring and analysis software tools, and a complete family of Bosch Rexroth weld controllers, transformers and other system components — a comprehensive solution that has been engineered for efficient integration and retrofitting into Rexroth’s resistance welding platforms.

Adaptive control of resistance welding can transform the contribution your Rexroth resistance welding system makes to your automotive manufacturing operations, helping reduce losses related to poorly made welds, increase welding throughput and elevate your control of automated welding processes to a whole new level.

In conclusion, adaptive welding can aid manufacturing processes by:

- 100% inspection and real-time control of welding processes enables high-quality, high throughput automated welding
- Reduction in the need to pull samples and conduct destructive weld tests
- Dramatically reduces resistance welding expulsion, increasing safety and reducing contamination
- Significant reduction in weld variability and a concomitant increase in weld reliability
- Documentation of weld quality can be automatically integrated into manufacturer’s quality tracking and control processes

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Conclusions

For the reasons outlined, there is a real momentum towards the conversion to resistance spot welding adaptive systems which have the ability to correct many of the weld disturbances, during the course of the welding process.

An adaptive welding system has the potential to offer far more control to a production process as it monitors the condition of the weld during the process every millisecond. This monitoring compensates for process disturbances by adjusting current and if applicable, weld time. These adjustments optimise the weld process to ensure the correct energy is applied to all of the welds, which in turn will mean that the correct size weld nugget is achieved. Early adopters have embraced adaptive welding as a method of ensuring good quality and driving cost out of the welding process, but it remains a small proportion of the total market.

However, it is becoming increasingly clear that relentless production cost pressures are moving the market in the direction of adaptive welding, particularly amongst users of MFDC welding who are able to retrofit an adaptive welding module into their existing Rexroth MFDC weld control. This method ensures that the cost of utilising an adaptive welding system is significantly reduced and there is less new technology to incorporate into existing processes.

Looking for support on your welding project?

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