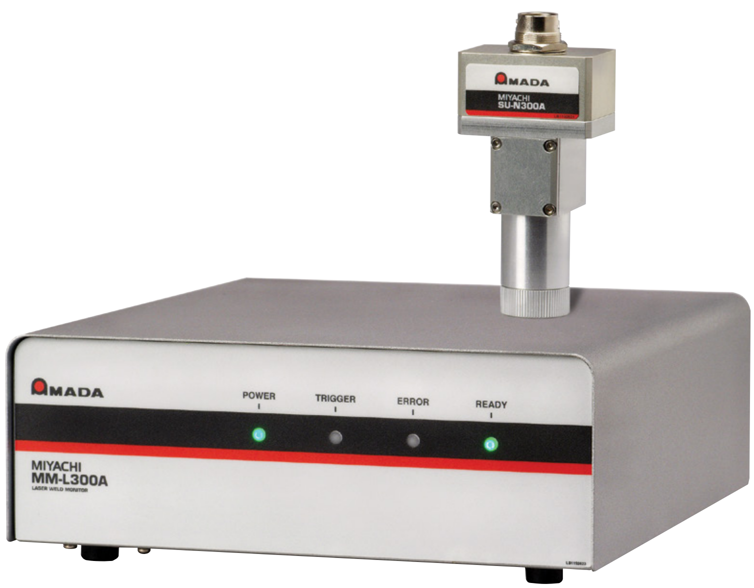
Process Monitoring Systems Usher in the Future of Laser Weld Quality Control

Real-Time Error Detection Increases Quality, Throughput and Traceability



AMADA WELD TECH's MM-L300A laser weld monitor.

In today's economy, the old adage "time is money" seems more apt than ever. Being able to repeatedly produce high-quality products can determine a company's success within the manufacturing sector. Having to scrap a product due to poor quality welding, for example, incurs significant costs in both time and money. Recalling a product can be even more costly and can damage a company's reputation. Catching weld errors as they occur, instead of reacting to defects downstream, ensures seamless laser weld quality control. In recent years, a number of weld monitors have been developed with the goal to increase yield, improve quality, save labor, and increase savings. These monitors can help a manufacturer continuously meet the demands within the market.

LASER WELD MONITORING BASICS

Laser welding is a manufacturing process that uses the output energy from a laser to heat and melt two parts that are then joined together in a fusion bond as they re-solidify. A number of factors – such as material and plating selection, equipment capability, and process settings- determine whether the process has the potential to be successful.

Weld success criteria depends on the purpose of the weld and surrounding environmental elements. A successful weld can be defined by how well the parts hold together (tensile strength), how well the weld seals a package (hermeticity), conductivity, or other tests. While some tests are non-destructive, many require destroying the parts to determine quality.

But how does one know if the welding process was successful?

Typically, a design of experiments (DoE) study is performed to determine the range of output based on the variation of input parameters. The result is then used to set boundaries around the measurable input parameters to infer whether the process is successful. After implementation, the welds are periodically checked via testing to confirm success. While this increases likelihood of success and certain inferences can be made for adjacent welds, it does not provide 100 percent certainty.

The interaction of the laser with material produces a visible and audible event. An experienced welding engineer or operator might instinctively "know" whether it was a good or a bad weld. He/she looks at the height or brightness of the plume or listens for the sound of the weld and can visually inspect the weld afterward. Quality control may take a few samples to destructively test whether it was a good or bad weld.

However, this type of monitoring misses a lot of available measurements and is not scientific or traceable, which is why products designed to measure during the weld process are entering the market.

With the advent of laser process monitors, we now have a way to observe the process while it's happening to determine success. During the weld, there are a number of measurements that can be recorded to provide information about the weld. This includes information about the laser radiation, the heating process, and weld penetration. Different radiation wavelengths can be collected and different frequencies of sound can be collected.

One method is to measure the thermal characteristics during the welding process. The material is locally heated and will emit radiation that is temperature dependent. This signal can be detected and recorded versus time.

Similar to a night vision scope, which can extend the spectral range and intensity range viewers can observe, some laser welding monitors use thermal imaging to collect radiation from the weld zone. The 1300-2500 nm range corresponds to the melting point of common metal materials.

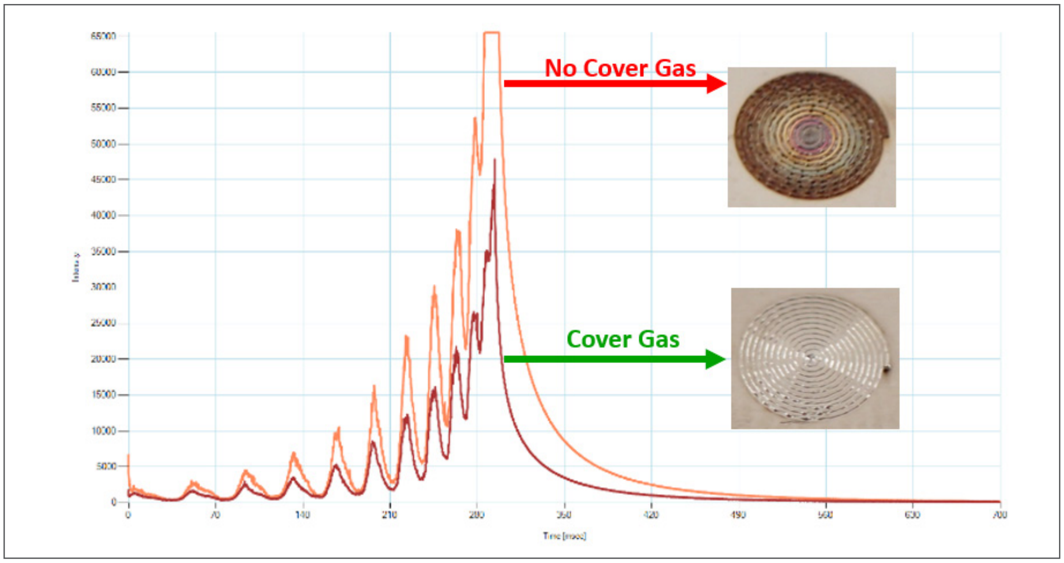


Fig. 1 – The thermal-time signature of spiral weld is plotted as signal [arb. Units] versus time [ms], as recorded by MM-L300A. Two spiral welds on steel were recorded – one performed with cover gas in weld zone and the second without. The inset pictures show the visual appearance after welding for each condition.

Each weld will have a unique temperature – time profile. Once this waveform is defined through multiple measurements, it is possible to set upper and lower limits for variation and comparative measurements can be made.

Temperature increases as the laser pumps energy into the part. The increase in temperature depends on the material, part geometry, and weld parameters. Once the laser stops emitting, the temperature decrease manifests itself as a visible cooling pattern. A monitoring system enables the user to monitor the whole wave form of a weld versus time. Accounting for certain known variations, boundaries are set up around that profile. When the monitoring system records that the profile heated up too slowly or too quickly, or cooled too slowly or too quickly, issues with a weld are revealed.

COMMON PROBLEMS IN PRODUCTION

A common fallacy is the belief that once the weld parameters are dialed in, it will always be successful. However, a number of things can go wrong during manufacturing, which can originate from material, process, or equipment variations. Some common examples include:

- Damaged parts from mishandling
- Improper loading of part(s)
- Parts being out of focus
- Insufficient cover gas
- Laser power may be low
- Change in material composition or plating
- Gap between materials

DETECTING PRODUCTION ISSUES

Each of these scenarios can detrimentally affect the weld quality. The goal is to catch and address these issues early. The more production that occurs with faulty parameters, the greater the chance that a production recall could occur. AMADA WELD TECH's MM-L300A, which measures the process in real time, can prevent costly errors from becoming a reality.

A high-resolution welding monitor, such as AMADA WELD TECH's compact MM-L300A, is ideal for detecting these production errors in laser welding technologies for spot or seam welds. In addition to detection of gaps between parts and incorrect focus, the high-precision MM-L300A also detects missing parts, over-penetration, and cover gas absence in order to provide operators real-time feedback on laser weld quality.

As described earlier, the MM-L300A determines weld success by detecting and recording a thermal signal from the area of laser interaction and provides the user an output waveform around which maximum/minimum or envelope limits can be set. Once these are in place, the unit compares a new weld waveform in real time to identify a weld that is good or not. These qualities make this high-resolution monitor ideal for process development and quality control laser welding applications.

Other errors that can be detected include incorrect positioning or bent pins, which might not always be catchable by visual inspection alone. The smaller and thinner materials are, the more likely they are to get bent or positioned incorrectly. Thus, monitoring is a major asset to the micro-welding sector, as monitoring systems can capture very fine defects that might be too minute for visual inspection to detect.

Without real-time process monitoring, users cannot see errors until after welding has completed and quality inspection has begun. The amount of parts a manufacturer may have to discard depends on how often the weld is being checked. For example, if welds are only monitored at the end of the day, a company has reason to suspect the quality of all welds made that day may be compromised if any inconsistency is detected. As such, more welds than fewer have to be inspected to ensure consistent weld quality efficiently.

LASER WELD MONITORING BENEFITS

There are a number of benefits to real-time monitoring a weld. This includes: failure detection, increased product throughput, and traceability. This ability streamlines production and quality assurance, and is a great asset to a company.

FAILURE DETECTION

First and foremost, the function of a laser weld monitor is to measure the signal and compare it to a known good reference. This is a first line of defense that can indicate whether a weld was successful or not. The earlier this is caught, the greater the cost savings.

INCREASED THROUGHPUT

Laser weld monitoring can reveal weld errors as they occur, instead of after production. This can increase throughput and lower scrap.

In production, it is necessary to test a number of samples to ensure quality. This might be done every day or potentially more frequent. If one of the weld tests failed, the lot of parts may need to be scrapped.

By measuring the thermal time waveform as the weld occurs and comparing to a known good reference, instantaneous detection of errors can be made for each and every part. If something goes wrong, then a signal can be sent and the offending part can be separated out and flag to hold production until the issue is resolved and production of good parts can continue.

Additionally, being able to tell whether a weld is going to be good or not as the welding process takes place greatly enhances production line efficiency. Relying on a high-precision monitoring system reduces the number of additional cross sections and destructive testing a manufacturer must do to ensure a weld is good quality.

TRACEABILITY

In addition, monitoring provides the opportunity to record measurements for 100 percent traceability.

In today's networked world, data and data analysis are becoming increasingly essential in the manufacturing sector. Laser weld monitoring systems provide an extra layer in which data can be collected and stored, whether locally or on a network, that can then be accessed later for tracking, tracing, and analyzing purposes. The data becomes invaluable if there is ever a product recall and there is a need to source the root cause.

IMPLEMENTING INTO A PRODUCTION ENVIRONMENT

Implementing a monitor into a welding production line can significantly increase a manufacturer's return on investment. High-precision monitoring systems such as the MM-L300A can help customers understand and target problems in order to get successful welds each time to achieve improved yield. This is crucial for medical device manufacturing, as much processing often goes into a particular part before it is welded. Each of these medical parts can cost tens of thousands of dollars or more. Having to discard welds that are not good wastes the time it took the manufacturer up to that point and the value of the product itself.

The MM-L300A is easy to integrate into a laser welding workstation. The sensor can be mounted in both on-axis (through a focus head) or off axis configurations to monitor the signal. The unit offers Ethernet and RS-232 output signals that can be connected to a PLC and or a network.

A MONITOR FOR MICRO-WELDING

In the micro-welding world, because the parts are small, the heat input (laser pulses) are typically a few milliseconds or faster. In order to properly measure the weld during the laser pulse, the sampling rate must be faster, so that multiple recordings can be made during the weld.

For accurately determining weld quality, precision is paramount. A high-precision monitoring system that samples the signal more quickly allows the user to see very fine distinctions in the weld that would not be otherwise observable. A monitoring system that samples every microsecond instead of every millisecond enables the user to view with precision the fine details of the weld, including any anomaly occurring between the two measured points of a slower monitor. The MM-L300A provides high temporal resolution – down to one microsecond – and enables precision monitoring, thanks to its SU-N300A dedicated thermal sensor.

Increased monitoring system precision is ideal for many micro-welding applications, including manufacturing for the automotive and medical device manufacturing sectors. Both of these industries require traceability and reliable results from part to part. Knowing each and every weld is going to be successful is a key factor driving the increased implementation of monitoring systems into existing manufacturing configurations.