PROCESS MONITORING IN LASER WELDING OF AIRBAG INFLATORS: QUALITY AND PRODUCTIVITY CONCERNS

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Abstract

The present paper discusses the implementation of laser weld process monitoring at a manufacturing site for airbag inflator modules. Emphasis is put on how quality control was handled in the past, why the plant saw the need to change and how the weld process monitoring effects production from a quality and productivity standpoint at the current time. The functionality of the weld process monitor is explained and its application results are shown.

Introduction

Laser material processing is nowadays a commodity in many manufacturing processes. The high degrees of automation and demand for flexibility call for a versatile tool such as the laser. In the industry of airbag inflator modules, manufacturers are using high power Solid State Lasers (Nd:YAG, Fibre) or CO_2 lasers.

The highly automated manufacturing drives the need for an increased automation in process and quality control. This not only saves time and resources but also helps with customer satisfaction.

To date, companies still rely on destructive testing. While it is a useful reference and easy to implement with low initial investment; it does not give 100% quality control. It is labor and time intensive, and subjective to the operator. There is a high cost for the destroyed material and recalls if a failure is detected.

When customers do not have incoming inspection they rely on a high degree of quality control from their suppliers. A failure in subsequent processing or finished good can have severe consequences for the supplier.

Most important requirements to the welds are strength and hermetic sealing. Laser welds by nature have superior hardness and strength. Still, certain geometry measures need to be assured (Fig. 1).

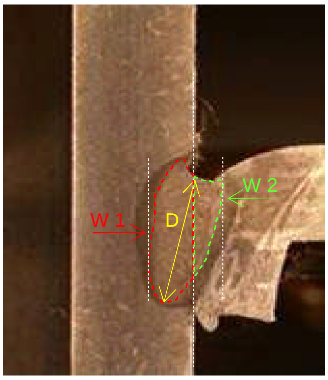


Fig. 1: weld nugget with geometrical requirements

Previous Quality Control and its Limits

In the past weld quality inspection was done by weld cross sections of selective parts and a Helium leak test at the end of the assembly line. In addition, a brief visual inspection of the appearance of the weld by the line operator was encouraged, but it was not objective and not in the operators interest of producing many parts per shift.

Cross section testing was done at a pre-determined frequency, e.g. every 300 parts. Only two or four inspection points could be selected for this task (Fig. 2). A dedicated operator was taken aside and the whole line was stopped. If the tested part failed, a corrective action was necessary resulting in more production downtime.

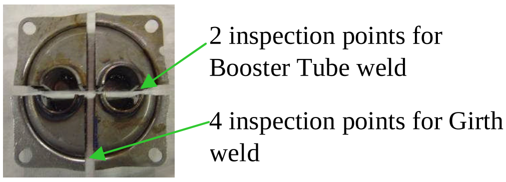


Fig. 2: cross sections of welds

Implementing Weld Process Monitoring

The necessity to implement some kind of automated process control lies within the part's function itself. A part that enhances the safety and protects lives in a car cannot fail in operation. Therefore full functionality of each produced part needs to be guaranteed.

The process monitoring system PD2000 was chosen for this monitoring task. It uses CMOS technology which is a preferred choice because of its logarithmic response and the ability to select only a Region Of Interest (ROI). As seen in Fig. 3, the camera is mounted coaxially to the laser beam allowing for a three dimensional monitoring solution.

Details about the basics of this system can be found in [1], [2].

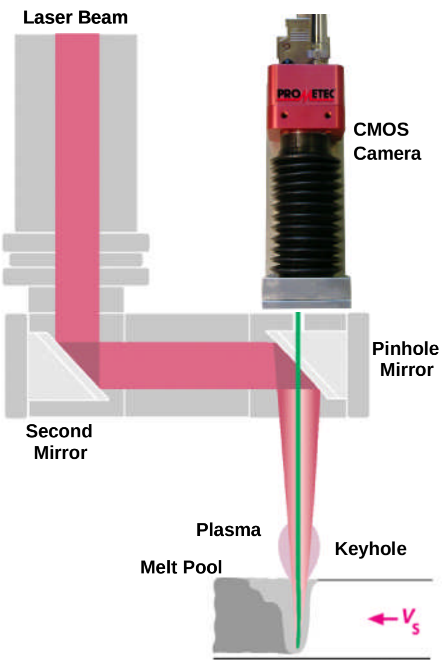


Fig. 3: Setup of a Camera based Inline Weld Process Monitoring on a CO_2 laser

Fig. 4 shows the principle of the monitoring task. The system processes images in real time (>1kHz) and evaluates them for different weld faults such as holes, gap, lack of penetration, offset just to mention a few. This is done through mathematical algorithms. For example, changes in image intensity, geometry and position are analysed and then compared to a known standard. Limits are set in a way to accommodate the quality requirements. They can be as simple as "upper" or "lower" limit or can follow a signal curve that is typical for an application.

The monitoring system is commonly (but not limited to) communicating with the PLC through field bus in a hand shake mode. While the PLC dictates the type of part (PD2000 will choose from an established library) and the start and end of monitoring; it also sends part identifications to the monitoring system. This is being saved together with the monitoring result of each weld for later tracking purpose. On the other hand, the PLC receives information from the monitoring system about the weld result. It can distinguish between the types of faults or the faulted weld number. Alarms are triggered immediately when the fault occurs but also additional when the part is finished as an accumulated alarm. Based on the result, the PLC makes a decision about the future of a part. E.g. if a part is evaluated as "NOK" it will go into a trash bin and cannot be reused again because the part tracking number is linked to the monitoring result.

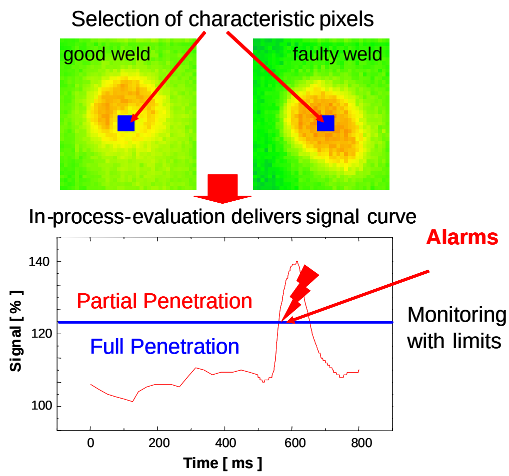


Fig 4: Principle of Monitoring with PD2000

Application Results

It is most important to monitor a certain degree of penetration and the position of the weld to assure that both piece parts are adequately bonded to each other. A change in penetration can be seen by a change in keyhole intensity for this application (Fig. 5). If the laser position is offset relative to the middle of the joint, while the camera keeps its coaxial position to the laser beam, the keyhole will deflect in a certain direction and change its geometry as can be seen in Fig. 6.

Weld instabilities such as holes, humping or gap can be monitored in a similar way as penetration by specific pixel intensity analyses.

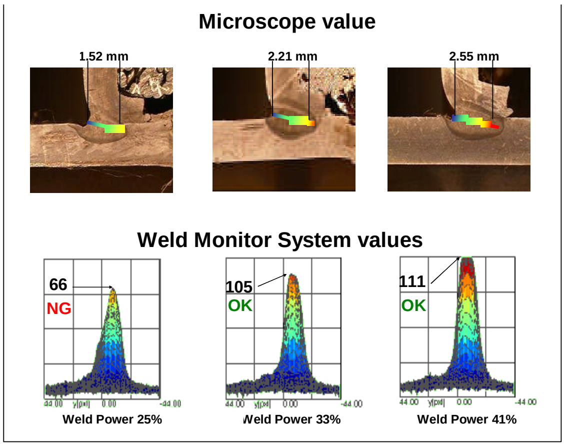


Fig. 5: Visualization of penetration in 3D display of monitoring system as function of laser power.

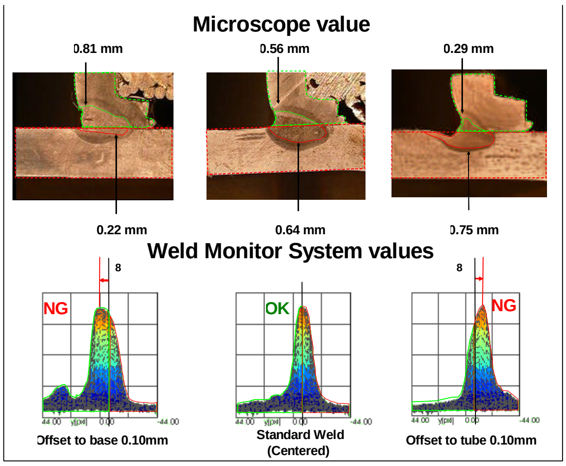


Fig. 6: Visualization of weld offset in 3D Display of monitoring system.

The following Fig. 7 shows a study about the relationship between penetration depth, determined by cross sections and signal amplitude of the process monitor at the particular spot of the cross section. Different laser power levels were programmed to receive a variation in penetration depth.

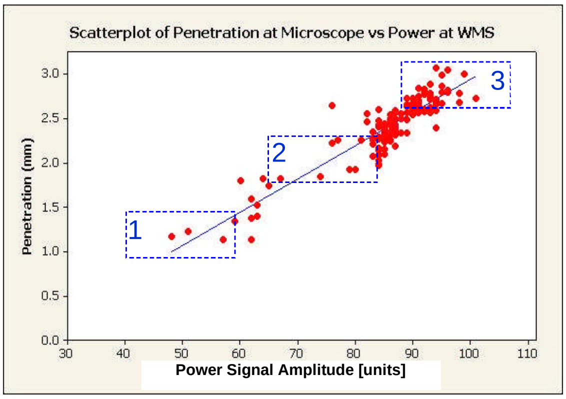
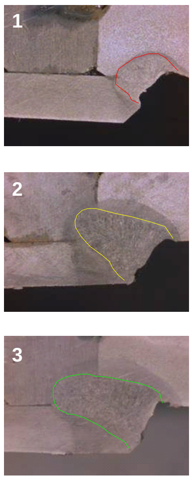


Fig. 7: Example of data plot and examples of cross sections (below)



With the selected evaluation methods, a strong linear relationship between penetration and signal height was found. This is confirmed through calculation of the Pearson coefficient (Pearson product-moment correlation coefficient) which equaled 0.8. This coefficient indicates the strength and direction of a linear relationship between two random variables. The closer it is to either -1 or 1, the stronger the correlation between the variables.

Quality and Productivity

The implementation of automated weld process monitoring has influenced the quality of the production and product as well as the productivity in direct and indirect ways.

Instead of 2 or 4 inspections points, the monitoring systems monitor up to 3500 points per weld, which basically means that information about the complete weld is available. Not only every 300th but each single part is now under control eliminating the subjectivity of the operator. A rejected part lands automatically in the scrap bin and all data are stored electronically.

With the introduction of the weld monitoring system, a new concept of quality control has been developed. The consequence is a reduction in destructive testing Personnel resources become free. When in the past, one quality inspector per shift per line was necessary; now one person can do the job for all lines.

At the end of the assembly line, there is a finished part "ready to ship". The finished good doesn't need to undergo a routine final inspection by destructive testing of a predetermined number of parts. Merely a check of the graphs and variations from the process monitoring results is being done before shipping with a few cross sections only being done when suggested by the graphs.

The following figure shows how the implementation of the weld monitor has helped to reduce the scrap of finished goods considerably.

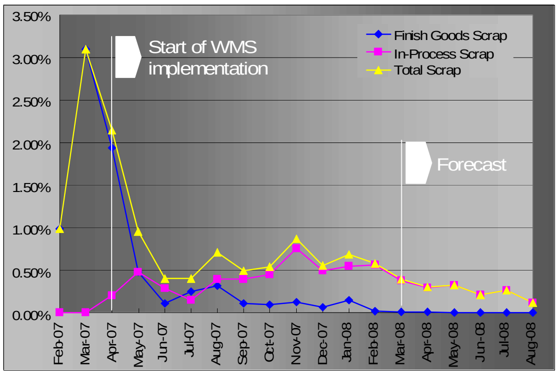


Fig. 8: Scrap rate before and after implementation of Weld Monitoring System

Where there was no "In-Process" scrap before, the process monitor now rejects welds that don't conform with the quality requirements.

The parts are identified as scrap at a much earlier state of production, i.e. at a lower level of added value.

The analysis of the image also helps to better understand the process. Trends showing in the signal levels induce proactive parameter adjustments before welds are rejected. Through theses proactive measures, continuous improvements in the area of laser and machine maintenance and an increase in quality of incoming parts, production can achieve the goal of a further 50% in-process scrap reduction as forecasted in Fig. 8.

A Plug and Play Solution?

Experience showed that equipment for process control is not a "plug & play & walk away" solution. It was found to be important that the engineers took ownership of the project. The equipment provider does have the expertise in the monitoring system but not in the production. Both sides are complex. Because the engineers take an effort to fully understand the functionality, they are able to make most use of the equipment's capabilities.

While operators have limited responsibilities and access to the monitoring system, it is still important that they understand and trust the system and see it as useful help in the production process. This was not given from day one but took some effort such as optimizing the monitoring system to the given application.

Implementing process monitoring benefits both parties mutually; the customer and the vendor. While the customer needs extended support during and after the installation, he will be able to be more and more pro-active after time and take ownership. The vendor on the other side will learn from the customer about specific needs. This will help the vendor to continuously improve the product.

References

[1] Beersiek, J. (2002) New Aspects of Monitoring with a CMOS camera for Laser Materials Processing

ICALEO 2002

[2] Beersiek J. (2001) A CMOS camera as a tool for process analysis not only for laser beam welding

ICALEO 2001, Section F206