QUALITY SEAM INSPECTION FOR LASER BRAZING IN THE AUTOMOTIVE INDUSTRY WITH OPTICAL SENSORS

Introduction

The arrival of laser brazing technology unlocked new levels of productivity in the automotive manufacturing industry. While automakers continue to increase their manufacturing output of safety-relevant parts with laser brazing, automated control schemes have proven indispensible for maintaining quality levels. The integration into laser brazing production lines of optical sensor technology, replete with customizable monitoring software, has proven superior to manual controls and tactile sensors, especially at higher throughputs. This whitepaper serves to outline the benefits of optical sensor technology, illustrated by quality improvements achieved by top automotive companies.

Background: What is Laser Brazing?

First introduced in the mid-1990s, laser brazing has become a prevalent joining process for visible and non-visible seams in the automotive industry in the U.S., Europe, and beyond. The technology gained prominence in 2001, when diode lasers first served to create seams in the tailgate of Audi's A3 model. While brazing speeds initially revolved around 2.4 meters per minute, the number has almost doubled today. Laser brazing has emerged as a standard for welding surfaces in safety-relevant automotive components; including trunk lid, side panel, chassis basis, water channel, and roof seams. Prominent automotive manufacturers such as Volkswagen, Audi, BMW, Honda, Porsche, Volvo, Fiat have expanded the usage of laser brazing in their production lines over the past years.

The technology relies on a robot-operated laser to heat a filler material above its melting point, which is then distributed via capillary action between two or more metal surfaces, creating a tight bond. Temperature levels for brazing exceed 450 °C, below this mark the process is known as "soldering". Laser brazing has become a standard for creating precision T-joints, flange seams, fillet seams, and I-seams for automotive applications.

The advantages of brazing over alternative joining techniques such as spot welding or laser welding are manifold: Laser brazing creates clean, aesthetically advanced joints that often eliminate the need for concealing marks with plastic strips. Joints created by brazing require no clean-up or additional finishing, and components are ready to move to the next production phase seamlessly (e.g. painting). In assembled vehicles, automotive components created with laser brazing offer high car body stiffness.

Rapid Growth Market

From a market perspective, laser welding has seen considerable growth in recent years. Third-party analysts *Strategies Unlimited* estimated revenues of the industrial lasers market at $1.89 billion in 2015. Within this market, laser-powered metal welding constituted a $444.6 million segment in 2015, up 17% from $380.8 million in 2014.[1] According to analyst firm *GrandView Research*, the automotive segment accounted for nearly 15% of the demand for industrial laser solutions in 2014.[2]

Major growth drivers include declining price points for industrial lasers and increased production throughputs achieved with laser brazing. Current production lines exceed speeds of 4 meters per minute; almost double the pace of early 2000s laser brazing technology. Adoption among automotive companies is on the rise, as several thousand laser brazing processes are installed worldwide.

Success stories include a recently documented productivity increase in the manufacture of the Ford Mustang vehicle: Since integrating laser brazing into the production line, the company was able to shorten the weld time of body-side outer assembly welds by five times. Ford now only requires 22 seconds – down from 111 seconds – for creating 79 welds. The technology also reduces the number of welding robots from twelve to four, while the entire process can be completed in one station cycle instead of three; all at reduced plant floor space.[3]

Challenge: Quality Control at Industrial Speeds

As laser brazing continues to increase line speeds in automated manufacturing, the need for equally fast-paced quality control has become a key challenge. Automakers investing in laser brazing technology want to make zero compromise on manufacturing quality. Therefore, current guidelines in automotive manufacturing require seamless quality monitoring of laser-brazed joints to be included right at the planning stages of new production lines. These rigid safety requirements tilt the scales in favor of "online" monitoring solutions; and more precisely, optical sensors.

Prevalent quality control methods are divided into *offline* and *online* methods. *Offline* methods include manual and visual controls by personnel. Manual checks sometimes also include sensors, but remains a time-intensive process with two downsides: Each new auto part requires re-teaching of the sensor, while alternately mounting the sensor and laser head on the same socket proves time-consuming. A prominent *online* seam control method relies on tactile sensors mounted alongside the laser, using 2D-filler wire to sense the weld; with the major disadvantage of requiring an edge to achieve a precise measurement.

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[1] David Belforte, *"2015 industrial laser market outperforms global manufacturing instability".* Published By Industrial Laser Solutions (2015). Retrieved at: http://www.industrial-lasers.com/articles/print/volume-31/issue-1/features/2015-industrial-laser-market-outperforms-global-manufacturing-instability.html

[2] Grand View Research, *"Laser Processing Market Analysis By Product (Gas, Solid-state, Fiber), By Process (Material Processing, Marking, Micro-Processing), By Application (Automotive, Aerospace, Medical), And Segment Forecasts, 2014 – 2025".* Published: March 2017, Report ID: 978-1-68038-272-3.

[3] Matthew Gilloon and Christine Gross, *"Remote laser welding boosts production of new Ford Mustang Technology enables efficiencies in time, space, and productivity".* Published By Industrial Laser Solutions (2015). Retrieved at: http://www.industrial-lasers.com/articles/print/volume-32/issue-1/features/remote-laser-welding-boosts-production-of-new-ford-mustang.html

Optical sensors, on the other hand, offer the most robust *online* solution, as they can be mounted next to the laser while requiring no physical contact with the work surface. Engineered to match the process speeds commonly found in automotive laser brazing, optical sensors deliver high image resolutions at frame rates up to 30,000 frames per second, while adjusting freely to each type of part being monitored. This not only allows for seamless integration of quality controls into the process – and no downtime for adjustments, re-teaching, etc. – but also yields a wealth of actionable process data in combination with the sensors' driver software.

plasmo profileobserver: Quality-Control for Industry-Scale Laser Brazing

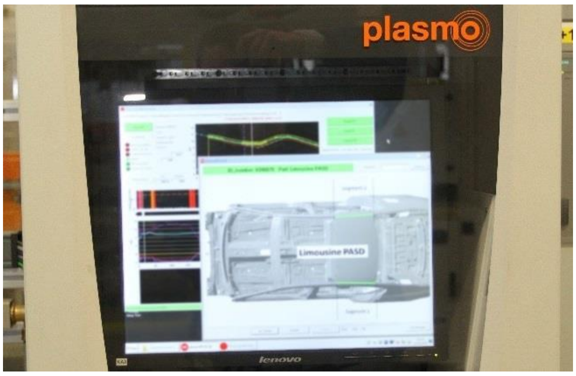
As a fully customizable plug-and-play solution, the *plasmo profileobserver* optical sensor easily integrates into serial production processes. Using a powerful CMOS-sensor, the solution captures high-resolution images at up to 30,000 images per second. Mounted directly on the laser head, the inline system recognizes, captures, analyzes and documents laser-brazed seams as well as geometry and surface. Meanwhile, the sensor maintains a safe distance to the welding surface – operating entirely contactless – while delivering resolutions up to 10µm even in rugged industrial environments and despite interference from dust or residue.

The *plasmo profileobserver* is built to match the automotive industry's high process speeds at fast tact intervals, while meeting the latest guidelines for 100% fault detection in the automated production of safety-relevant components. The system's main strength lies in the seamless integration between easy-to-use software and real-time monitoring according to customer specifications. Requiring little to no personnel training, the system can be programmed with fault types and individual tolerances according to internal and external standards. In automotive applications, it detects the following defects: Elevated or collapsed seam profiles, tears, splattering, as well as deviations in seam width and seam position. At the same time, the system can adapt to changing surface structures in a robust manner.

Directly and in real time, the camera-based sensor transmits optical data to the PC via a GigE-Bus connection. Measurements are recorded in precise detail – with coordinates down to the individual seam – allowing for 100% quality control. Automatically, the system alerts personnel to deviations as soon as they occur, therefore providing the basis for a proactive response to larger issues (including line stops or recalibration to avoid defects). The system also collects detailed process data, including data points such as weld length, seam position and width, as well as gap position. These insights can be rendered in 2D or 3D, greyscale and color, with various graph options. Data can be exported into statistics modules and computed into trends, which provide the basis for process optimization and adjustment initiatives.

By ensuring that only flawless parts may proceed downstream in the production line, the *plasmo profileobserver* avoids later reclamation, brings down manufacturing cost, and maintains highest quality levels. plasmo specialists work closely with manufacturers to select the right sensor and installation set-up to match their processes. As a major achievement, many clients have been able to monitor a process that used to require two optical sensor systems or more with just a single *plasmo profileobserver*. What's more, several customers have expanded their orders and equipped entire production lines with the technology.

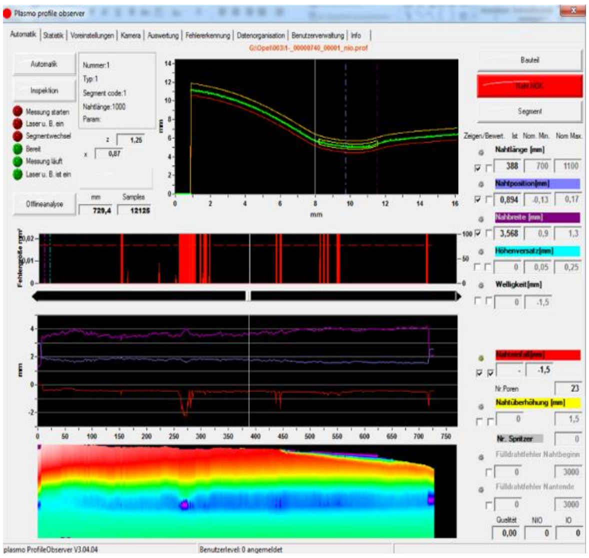
Case: Volkswagen Trusts plasmo profileobserver in Passat B8 Production



Europe's largest automotive manufacturer, the Volkswagen Group, operates a production plant in the town of Emden, North of the town of Bremen. At a size of 4.1 million square meters, the plant employs 9700 workers with an output of 264,000 vehicles.[4] For monitoring the seam quality during the Passat B8 model's serial production, Volkswagen opted for the *plasmo profileobserver compact* model. The system is in charge of monitoring the laser brazed welds on the car's critical water channel, trunk lid, and roof seams.

For Volkswagen, the main challenge consisted of finding a system that would spot the most miniscule deviations at the level of individual weld pores. The ultimate goal is to ensure that all parts passed downstream for further processing are in line with the company's high quality standards at 100% pore control. At the same time, the solution needed to provide real-time feedback and alerts in a customizable, maintenance-free package.

Results: As early as the implementation stages, the *plasmo profileobserver* compact already proved an asset by allowing for rapid onboarding with minimal personnel training. Once it was operative, the system's exact and responsive fault detection allowed Volkswagen to make a massive change to its production set-up: Whereas quality monitoring had previously required more than one optical sensor per laser brazing station, the Emden facility now ensures quality control with a single *plasmo profileobserver* per station. By integrating seamlessly into serial production – and providing accurate data during the process instead of costly post-inspection – the system proved a good match for the job. In the months after implementation, the customer also equipped its other workstations with *plasmo profileobservers*; a clear mark of success.



Conclusion

As more and more automakers adopt laser brazing into their automated parts manufacturing processes, industry guidelines at the highest level call for mandatory quality control monitoring of weld seams. Preferably, manufacturers want these sensors integrated in real-time at the process level. In combination with today's state-of-the-art laser brazing set-ups, advanced optical sensors such as the *plasmo profileobserver* have proven robust and scalable solutions for the automotive industry. Presenting highly customizable plug-and-play additions to existing or new laser brazing lines, optical sensors deliver results instantly while production is ongoing; not after the fact.

Optical sensors capture high-resolution images at high frequencies, automatically alerting personnel in case of any deviations. Thanks to constant evolution in sensor technology, a single state-of-the-art optical sensor can now handle the workload of what previously required several units. And by maintaining a comprehensive backlog of tolerances and key data points, solutions such as the *plasmo*

[4] Source: Volkswagen, December 2015.

profileobserver provide actionable intelligence for future process optimizations, as the automotive industry continues to invest in laser brazing technology.

To learn more about the plasmo profileobserver and plasmo solutions for the automotive segment, visit plasmosales@nlight.net