Reinventing laser processing for EVs

The ARM fiber laser and the SmartWeld+ processing head meet the most demanding EV battery manufacturing challenges

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The demand for electric vehicles (EVs) has put automakers in a race to reach new levels of manufacturing precision. Of course, the trend towards higher precision manufacturing has been in place for several decades as cars have become increasingly complex and sophisticated. Lasers have played a key role in this transformation all along.

Today lasers are routinely used for demanding processes like drilling small, precisely shaped holes for fuel injector nozzles, welding advanced steel alloys, and automatic transmission gear welding. Often, new methods were required to perform these processes. But in some cases, none of the existing laser-based systems could meet the requirements, and entirely new technology was needed.

This is exactly the case for some of the most demanding EV manufacturing tasks now coming on-line – especially those involved in making the batteries themselves. This is because several of these steps require processing very thin and heat-sensitive materials. And these processes must be performed fast enough, and with sufficiently high yield, to be economically feasible. No laser-based tools could meet all these needs before now.

Fig. 1 Example of foil stack with more than 120 aluminum foils for a prismatic battery cell

Source all figures: Coherent

Coherent is the first laser subsystem manufacturer to develop a new generation of products specifically designed to satisfy the requirements of the most challenging EV battery assembly operations, surpassing traditional remote welding systems. Specifically, its ARM fiber laser in combination with the SmartWeld+ processing head is now able to offer a new laser weld process and deliver better results in one of the most critical tasks involved when assembling pouch and prismatic battery cells. This is supplemented by real-time in-process monitoring of the Coherent SmartSense+ system to detect defects and issues.

Foil to tab welding

A standout application example is the stack of thin aluminum and copper foils – the electrode foil stack – that needs to be welded to the battery 'tab'. The tab is the conductive terminal that extends from the electrode materials to outside the battery.

Each cell manufacturer implements these processes in a different way. The most common method starts by tacking the assembled foil stack together using ultrasonic welding – usually called stack or prewelding. This holds the foil stack together well enough to make them sufficiently mechanically stable for subsequent handling. But it is not meant to be the final weld of the assembly.

The edges of the foil stack are then trimmed with a mechanical blade. Trimming the stack serves several important functions. It provides a uniform edge that is free of irregularities and dimensionally accurate. This will make battery assembly easier and more consistent.

After prewelding and trimming, the foil stack is robust enough to be moved, if necessary. Typically, for the next step it is transferred to another tool where it is welded to the tab. The various cell manufacturers utilize usually ultrasonic welding or sometimes laser welding for this step.

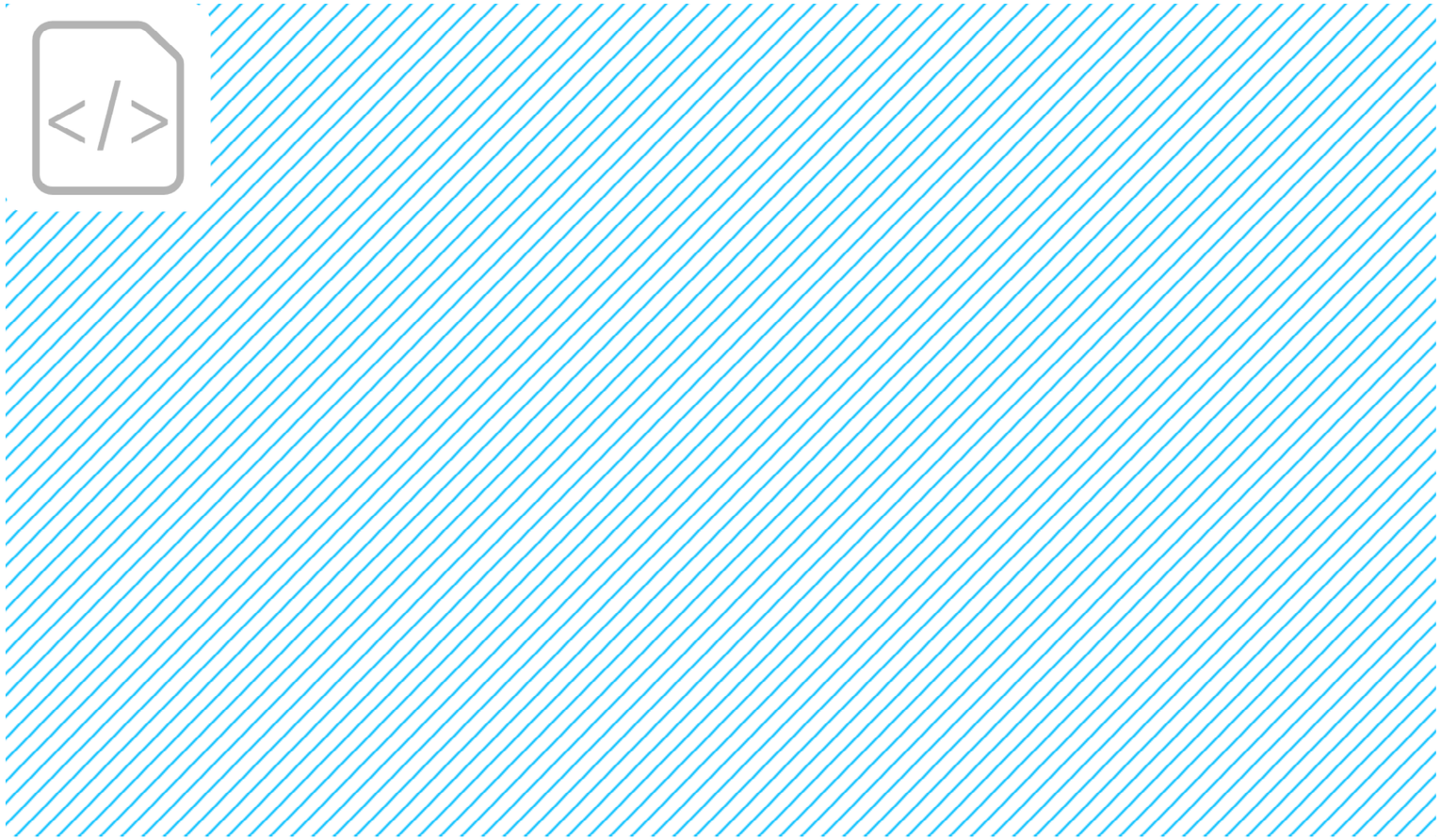


Fig. 2 Video showing the new foil-to-tab welding process with Coherent FL-ARM laser and SmartWeld+ processing head

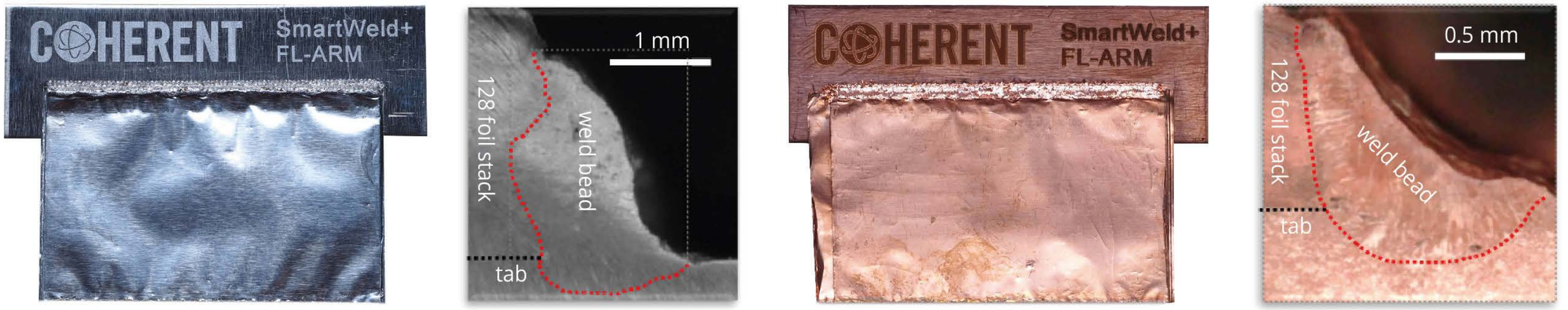
Unfortunately, there are some drawbacks with the ultrasonic approach. First, ultrasonic welding does not always produce a strong enough bond, and most importantly, a bond that penetrates all the way through to the tab.

Most common ultrasonic welding equipment used is usually limited in the total number of foils that can be welded in one process step. This is significant because battery energy storage capacity increases with the number of foils. It is therefore important to battery manufacturers to have the freedom to increase the foil count.

Ultrasonic welding also presents practical limitations. The tools required for it wear rapidly in high volume production, necessitating frequent maintenance and regular replacement. This causes production downtime.

Both ultrasonic welding and laser welding have been problematic for foil-to-tab joining, as well. Again, for most ultrasonic welding there is a limitation on the penetration depth and, therefore, the number of foils.

Foil-to-tab welds can suffer from cracking and 'micronecking'. This refers to a localized region where the foil has become thinner due to the process. This typically happens because tensile stresses created during the ultrasonic welding process stretch the material. But the foil isn't ductile enough to deform uniformly across its entire width in response to this stress.



128 aluminum foil stack to tab | cross-sectional view | 128 aluminum foil stack to tab | cross-sectional view

Fig. 3 Examples of foil stacks for pouch cells out of aluminum and copper

Necking is a serious problem because it creates a mechanically weaker zone in the material that can subsequently break or deform further. The reduction in cross-sectional area of the foil also increases its electrical resistance, which can alter battery charging and discharging characteristics.

An innovative approach

Overcoming the limitations of ultrasonic and traditional fiber laser welding in these applications requires a high degree of control over how laser power is delivered to the process – both, in how power is distributed spatially and how it varies over time. The level of control required exceeds what can be accomplished with traditional remote laser scanning systems, which are primarily designed for welding larger, thicker parts, such as auto body or powertrain components.

Coherent SmartWeld+ was specifically engineered to provide this high level of control and outstanding precision. And it reaches its full potential when paired with the adjustable ring mode (ARM) fiber laser when welding these thin and high reflective copper and aluminum foils. This is because SmartWeld+ implements a wide variety of 'beam wobble' (rapid oscillation) patterns, which distribute the laser energy over an area much larger than the focused laser spot, with the power varied spatially as needed. And the power distribution between the two independent ARM beams itself can be dynamically varied to further fine-tune the overall way the laser energy is deposited on the work surface.

The other significant key characteristic required for this application is, that this combination is extremely fast. SmartWeld+ utilizes small, low-inertia mirrors. These cover a smaller field of view but move much faster (as much as 10×) than traditional laser welding scanner heads. Added to this, the ARM laser can be rapidly modulated – both center and ring beam independently. And this modulation can be synchronized very accurately with scan mirror motion. Together, this gives a degree of spatial and temporal control over laser power delivery that has never been available before.

Improved battery cell welding

This speed advantage of the SmartWeld+ can be used to benefit the foil-to-tab welding in a way, where the prewelding and main welding operations can now be combined into a single process step, giving the manufacturer the freedom to design the process according to his production requirements.

Coherent

Coherent Corp. is a global leader in materials, networking, and lasers for the industrial, communications, electronics, and instrumentation markets. The company was founded in 1971 and is headquartered in Saxonburg, Pennsylvania, USA. Today, the company operates in more than twenty countries around the world and empowers market innovators to define the future through breakthrough technologies, from materials to systems.

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The Coherent Labs applications team has developed an innovative, patented solution that involves focusing the laser beam on to the edge of the foil stack from a certain angle – rather than directly overhead. Then SmartWeld+ rapidly oscillates the beam to cover the entire thickness of the foil stack, welding it to the top side of the tab. Overall laser power and power distribution in the ARM beam is varied in synchrony with this beam motion.

Performing the weld at an angle turns out to be key to minimizing micronecking. This is because it allows the SmartWeld+ and ARM fiber laser to apply the heat to the stack in a way that minimizes thermally induced stress. As a result, the foils do not pull on themselves when shrinking during cooling, which is what otherwise causes the micronecking, especially with aluminum foils.

The independent modulation of the ARM beam also produces a better weld joint. Specifically, it provides the control necessary to stabilize the weld 'keyhole' resulting in reduced spatter and porosity, and lower defects. The weld joint itself has excellent mechanical strength, which translates into good electrical conductivity. Additionally, laser welding does not produce metal dust, which often is an issue with ultrasonic welding.

Besides improving weld quality, the other benefit of the laser edge weld approach is that it can be used on virtually any thickness stack. This allows battery makers to increase the number of foils to increase cell capacity, if desired.

Partnering for success

Meeting the challenges of EV and battery manufacturing often requires novel and innovative solutions. Traditional tools which have performed well in the past for other uses sometimes do not possess the capabilities needed for these highly exacting processes. The key to success lies in first understanding the unique challenges faced by each application. Coherent offers the technical expertise and commitment to partner with manufacturers to identify and characterize the critical parameters that determine success. For example, in battery foil-to-tab welding, the phenomenon of 'micronecking' was not widely recognized in the industry. The information in the public domain was non-existent as battery manufacturers would not release such information publicly. Our team identified this defect and developed a solution to minimize it for mass production. ■

Thomas Hofmeister

Thomas Hofmeister has been working in the Automotive Industry for almost 25 years, after receiving his master's degree in automotive engineering from the University in Munich. He was mainly working in robot automated production for various companies and went from mechanical design and process planning to key account management of production lines. In 2019 he joined Coherent as a business development manager transport and energy storage of the laser segment for the EMEA region.

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