Innovative laser technology in electric car manufacturing

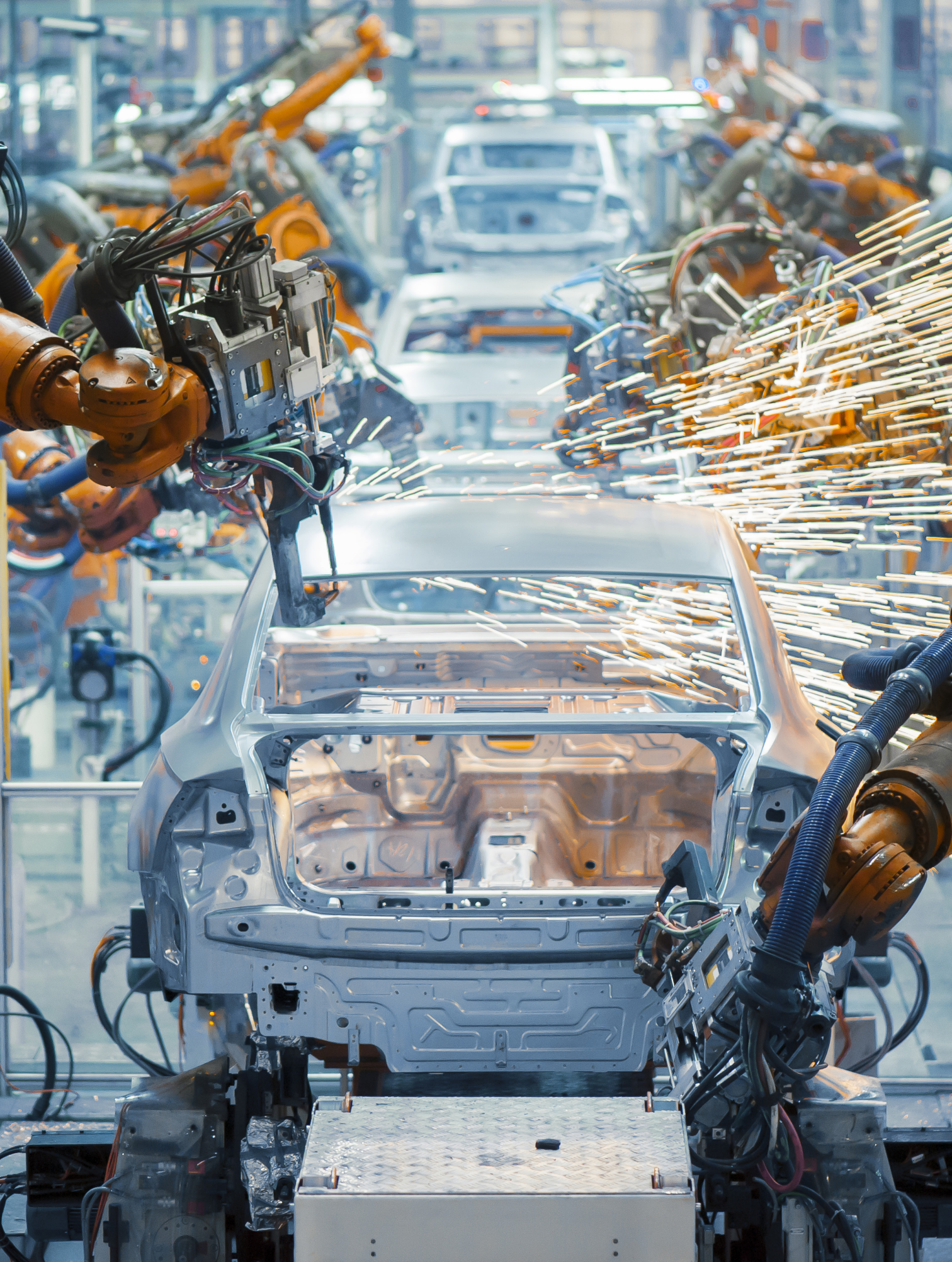
Compared to petrol and diesel powered vehicles, electric car technology (*emobility*) is in its infancy (for example, in performance and range) and is, therefore, technically much more dynamic. This means that the metal parts and the metals themselves are being applied in new ways and/or being pushed to new limits. But, at the same time, vehicle manufacturers and lower-tier suppliers are only willing to adopt manufacturing technologies that are scalable and highly profitable. All these reasons favour lasers over many other methods for welding, cutting, hardening, wire welding and other applications, since lasers offer non-contact, wear-free, consistent and high-speed processing. However, the demands for delivery of advanced functionality components often exceed conventional laser processing. In this article, we analyse two innovations in laser welding specifically aimed at automotive electric mobility components.

ALUMINIUM BATTERY COVER WELDING

A key stage in the production of lithium ion batteries used in electric vehicles is the welding of battery boxes. It is essential that this weld is totally hermetic during the entire useful life of the component. In particular, this seal must prevent moisture infiltration because water reacts strongly with lithium, creating gas and pressure that could destroy the device. In addition, the welding process itself should not cause splashing, since metal particles (as well as moisture) can create internal leakage currents that could short-circuit the battery. Finally, and from the mechanical point of view, the welding must be strong enough to withstand the vibrations from the road surface, or even the shock from a collision.

The sealing of the aluminium battery box has traditionally been done with laser conduction welding because the battery walls are thin (<1 mm). However, using conductive welding it is difficult to achieve the necessary penetration to produce a sufficiently strong weld with low enough porosity to avoid moisture intrusion. However, the use of higher laser powers to achieve a deeper penetration weld (by *key-hole*) carries the risk of creating pores, which can lead to low weld strength, and it practically always causes splashes.

Extensive development work at Coherent | ROFIN has demonstrated that a solution for high velocity metal welding without splashes can be achieved by modifying the intensity profile of the laser focal point on the workpiece so that it moves significantly away from the traditional single-peak Gaussian distribution. In particular, this research



has shown that the proper approach to the problem is to use a Gaussian central distribution point, surrounded by another concentric ring of laser light.

This unusual configuration is achieved using the adjustable ring mode fibre laser (FL-ARM) from Coherent's HighLight series. The beam transport fibre of this laser includes a conventional circular core surrounded by another fibre core of annular cross section.

Coherent supplies FL-ARM systems with output powers ranging from 2.5 kW to 10 kW. The power in the centre and the ring can be adjusted independently, on demand, within a range of 1% to 100% of the nominal maximum output. The core and ring beams can even be independently modulated, at repetition rates of up to 5 kHz.

With this configuration, there is a virtually limitless number of possible combinations in terms of the power ratio of the inner beam to the outer beam. However, all of these can be broadly grouped in the configurations shown in Figure 1. These basic patterns can be varied to offer a wide range of processing characteristics to optimally serve a diverse set of applications.

For fibre laser welding of aluminium, one challenge has been that the material has a relatively low absorption in the near infrared. Small unpredictable variations in absorption cause the depth of penetration to vary, resulting in uneven welding.

To address this, and to provide sufficiently precise control as required by the *key-hole* welding of the aluminium battery boxes, the FL-ARM beam is configured with power in both the centre and the ring. Using this particular power configuration, the leading edge of the ring beam raises the temperature of the aluminium enough to increase its absorption at the laser wavelength. Subsequently, the laser beam of the nucleus creates the *key-hole*, which is now very stable due to preheating. The back edge of the ring keeps the fusion pool open long enough to allow the gas to escape. Because the *key-hole* is stable and the material does not solidify so quickly, the whole process is more consistent and the process window is larger. The final result is a uniform and constant penetration of the material and welds of higher quality, without splashes or porosity.

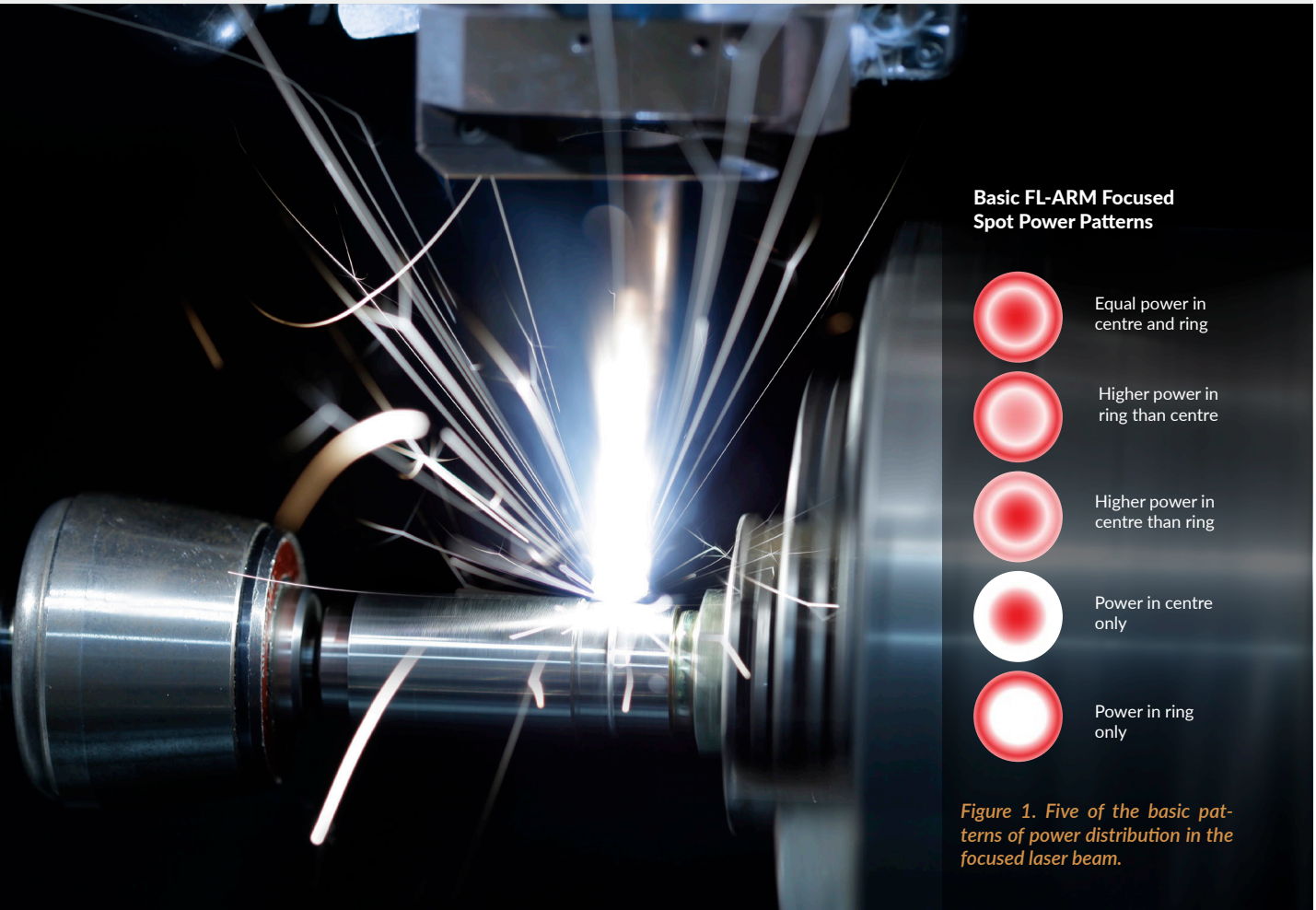


Figure 1. Five of the basic patterns of power distribution in the focused laser beam.

WELDING THE 'PINS' IN THE ELECTRIC MOTOR

Another demanding challenge in the production of the electric car is the welding of copper coil pins in the stator of an electric motor. These rigid pins (called 'hairpins' due to their 'u' shape) replace the copper wire windings that are traditionally used in an electric motor. Because they are much stiffer than cables, their orientation in the motor can be controlled more precisely, which ultimately results in better heat management and higher motor performance.

In the assembly process, the individual pins are first loaded into the stator slots. Then, the ends of the adjacent pins are welded together to electrically connect them. When the entire engine is finished, all the pins will act as a single long, twisted conductor, like the windings of a conventional electric motor.

The two key imperatives of this process are that the weld maintains the correct mechanical alignment of the pins and that it does not produce any defect (inclusions). The alignment of the pins is important because the exact shape of the winding directly affects the efficiency of the motor. Defects must be avoided because they increase the resistance of the final winding, which reduces its electrical efficiency and can also decrease the mechanical strength of the assembly.

Coherent | ROFIN has developed a method based on fibre laser to perform pin welding that achieves all these objectives. The first key element of this process, which is based on a standard fibre laser from the HighLightTM series, involves the use of so-called 'beam oscillation'. In this case, the size of the beam focused on the work surface is deliberately smaller than the total area to be welded. However, the position of the place is quickly scanned (oscillation) to cover the entire area.

As with the FL-ARM laser, the advantage of beam oscillation is that it allows more precise control over the temperature dynamics of the fusion pool. By moving the beam quickly and repeatedly over the part, and not allowing it to stop anywhere, it essentially preheats the part in a very controlled manner, instead of discharging all the power at once. All this stabilizes the melting bath, reducing splashes, defects and the porosity of the weld compared to traditional methods of laser welding.

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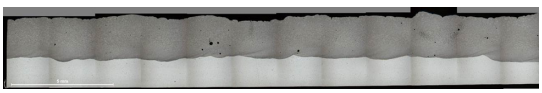

Figure 2. Cross section of a weld of two pieces of aluminium of the Series 5000 of 1.6 mm thickness that shows deep penetration without pores or splashes. Figure 3. Longitudinal cross section along a 20 mm weld bead showing uniform penetration. Figure 4. Unprocessed copper stator.

Coherent | ROFIN also offers practical tools related to processes that improve laser welding results in a production environment. The company can supply a laser welding subsystem that includes an artificial vision system to control the relative position of the focused laser beam and the tips of the pins.

You can watch videos of these processes at https://www.youtube.com/watch?v=csUUZouasKU

In conclusion, developing and implementing a successful laser production process involves exploring a portfolio of parameters, configurations and techniques that will ultimately offer the best welding results. Coherent | ROFIN has both the experience and the resources to perform the development work required to identify these various elements. In addition, Coherent | ROFIN can integrate all the required functionality (beam oscillation, FL-ARM adjustable mode profiles, process monitoring, etc.) into a single subsystem, which is controlled through a graphical user interface (GUI). The ability to acquire a complete and integrated laser welding system, instead of using part assembly, eliminates much of the uncertainty that can occur when an integrator assembles a system and finds that several elements do not work together successfully.

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