Smart Ultrasonic Welding

Unbeaten in flexibility, reliability, and performance, the electronic industry relies on more than 15 trillion wire bonds per year.
For large-area joints in EVs, this ultra-sonic process comes as Smart Welding.

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The first modern battery EVs (BEV) have been on the market for more than10 years. Today, the automotive dealerships and product pipelines of the EV manufacturers present a broad range of widely accepted electric cars. EVs being available in any class of passenger cars will be the big push for an increasing EV market share. This requires scalable high-volume production that drives the related technologies to the next level.

Different concepts and designs of the battery pack its related power electronics are in the field. They are proving their ability to persist under strong competition in cost and performance.This applies also to the chosen production technologies. While the big players appear to have made their strategic decisions, many small and medium-sized projects are flexible and curious enough to keep the race between interconnection technologies open. This enables them to build up wide process know-how and gain competive advantages by choosing the technologies which best fit their technical requirements. With this mindset and the plurality of target applications, the fastest adapting equipment suppliers will be the most successful.

As a responsible engineer you visit manufacturers of laser and/or ultrasonic welders, wire bonders and you will benchmark them to known technologies like bolting or resistance welding. Each of these technologies deliver good arguments like lowest cost per joint, shortest takt time, best traceability and quality control, lowest contact resistance or ease of application [1]. In the end, decisions may feel like compromises.

Avoiding Compromises Between Joining Technologies

Smart Welding now closes such a gap for applications joining a contact element to a base structure. As an ultrasonic joining method it does not require applied heat and provides high material flexibility. Additionally, Smart Welding merges the three main strengths of ultrasonic welding and wire bonding: High power (1) for large joints of traditional ultrasonic welding with the precise control (2) and speed (3) of wire bonding. The stability and efficiency of the underlying hard- and software benefit from decades of experience from the original technologies and their features.

Wire bonders can provide ultrasonic powers up to 200 W and welding forces up to 40 N. This is sufficient for joint areas of 1-3 mm². Effective contact area can easily be increased by adding wires. Large area joints are always necessary when massive connectors are required for their electrical and also thermal performance. Contact elements like copper terminals of power modules require up to 1000 N of weld force and 1.5 kW of ultrasonic power output. Such elements are applications for Smart Welding.

Precision Is the Key to Stable Results

The placement accuracy of wire bonding equipment of below 10 µm is well appreciated in the industry. Taking also the image recognition and the operator into account, placing accuracies on good products are still below 20 µm. In any application, such good positioning, together with image recognition, does compensate the X- and Y-placing tolerance of the contact element caused by the pre-positioning. This is a great benefit for a stable weld area size. In case of batteries, the cell balancing will not be distorted by alterning resistances due to high variance of weld areas.

And there is another advantage of a very dynamic motion control and a precise control of position and force: The process control is accordingly. Profiles of force, overtravel and ultrasonic power can be tailormade for the product and its conditions. The deformation is measured with micron accuracy and, together with the oscillation feedback, it can be traced how the joint forms and how the conditions (e.g. friction, vibrations) change.

Figure 1 Contacting Battery Cells with Copper Wire Bonding

Speed Alone Is Not the Key to Low Cost of Ownership

As Smart Welding equipment has highly dynamic motion control, it enables high travel speed. However, the major share of the process time is spent welding, rather than travelling. When focusing on the process time, other technologies might appear faster at first sight.

On the one hand, the processes are well comparable as both use the same motion system. On the other hand they are not, as the wire bonder provides the connector within the same process, while Smart Welding and other technologies require a corresponding pre-process. This is not represented in process times, but matters in assessing the complexity and cost of the whole production line.

This is just one example of why process time alone provides only a limited perspective. The production and automation concept, including loading and positioning processes, is crucial for judging speed in general and total cost of ownership.

Electromobility production lines demand stable quality, flexibility and full embeddance

Tracing the process data and the equipment variables to each single weld in real-time is a requirement to track failure modes and changing conditions during production. Doing this efficiently requires monitoring and a central server station, that handles the data and the equipment management. With such a system, additional production machines can be added to existing lines by plug&play as they synchronize to already existing machines. To reduce downtime in production, operators can clear production stoppers like image recognition errors from their work place or their mobile devices.

Figure 2 Smart Welded Terminal Smart Welded Terminal on Direct Bonded Copper (DBC – ceramic isolation between thick copper layers)

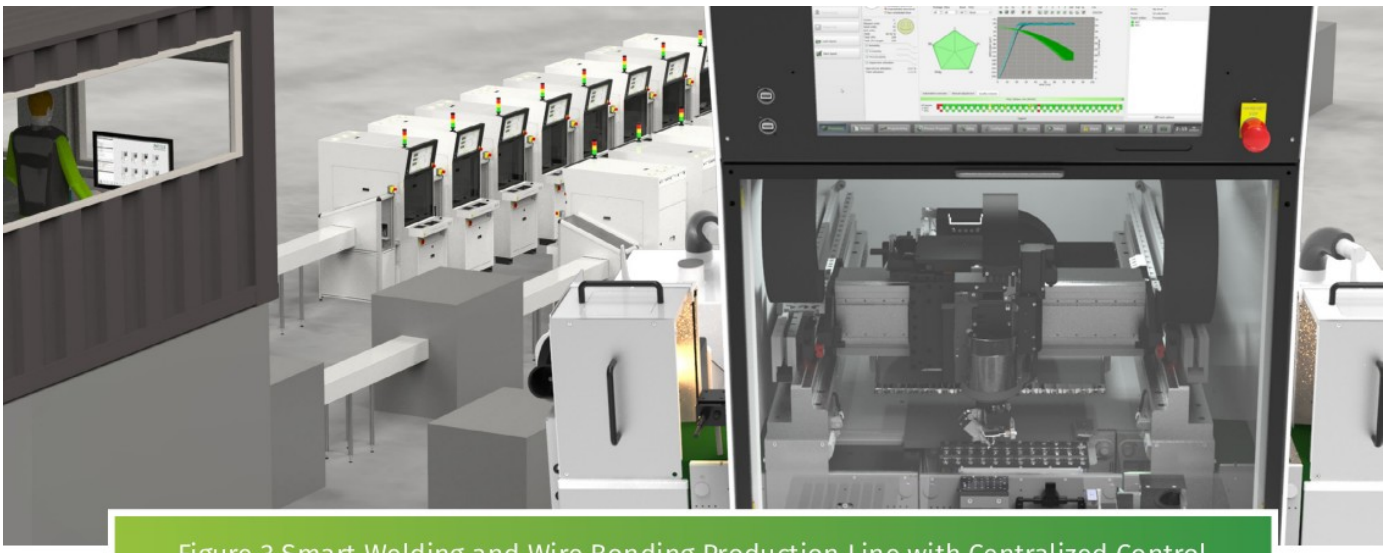

Figure 3 Smart Welding and Wire Bonding Production Line with Centralized Control

Understanding the Requirements of Future E-mobility Products

Both high voltage components and low voltage sensing connections are affected by an increasing degree of integration of battery packs. More and more compact designs limit space on pack and module level. Also power modules and battery management systems must be integrated properly, while still performing on the same or even higher levels. Smart Welding tool designs enable welds on the crimps of cylindrical cells or inside housings at close distances to the walls.

On the materials side, copper with its superior thermal and electrical properties is a desired joint material. In wire bonding, copper used to be a challenging process However, understanding the wear mechanisms and developing appropriate tools and processes now allows bonding tools to last for more than one million copper joints [3]. This is another benefit that wire bonding brings into Smart Welding processes – the readiness to cost-efficiently weld copper.

The Entry to Sustainable Benefits

Smart Welding is a new technology rooted in well-established and stable processes. It can provide a decisive competitive advantage to those who flexibly strive for best results and who do not accept limits set by other technologies. Developing processes in collaboration with equipment manufactures can be key to quick product launches and become the basis of fruitful partnerships.

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Further Literature

[1] Brökelmann, M; Holtkämper, S.; Hunstig, M.; Ultrasonic Bonding for Automotive Semiconductor and Battery Applications, MicroTech 2019 – Power in Packaging, 2019

[2] Hunstig, M.; Schaermann, W.; Brökelmann, M.; Holtkämper, S.; Siepe, D.; Hesse, H. J.: Smart Ultrasonic Welding in Power Electronics Packaging. CIPS 2020 – 11th International Conference on Integrated Power Electronics Systems, 2020

[3] Brökelmann, M.; Siepe, D.; Hunstig, M.; Guth, K.; Schnietz, M.: Wear optimized consumables for copper wire bonding in industrial mass production. CIPS 2016 – 9th International Conference on Integrated Power Electronics Systems, 2016

Figure 4 Smart Welding on Typical Substrate for Power Modules