Multiple Challenges in Vehicle Electrification: Batteries and Beyond

Introduction

Manufacturing engineers today face significant challenges in developing robust processes to support electromobility. While vehicle electrification was once considered a topic related primarily to manufacturing and assembly of batteries, a recent review of automotive trends by EWI indicates that nearly every aspect of the vehicle is affected. Today, more pumps and motors are required to support subsystems of electric or hybrid-electric vehicles, thus increasing the number of wire harnesses and cables (Figure 1). This, in turn, multiplies the number of essential connections and adds weight. New materials, material chemistries, and design changes to conventional practices are required to address lightweighting.

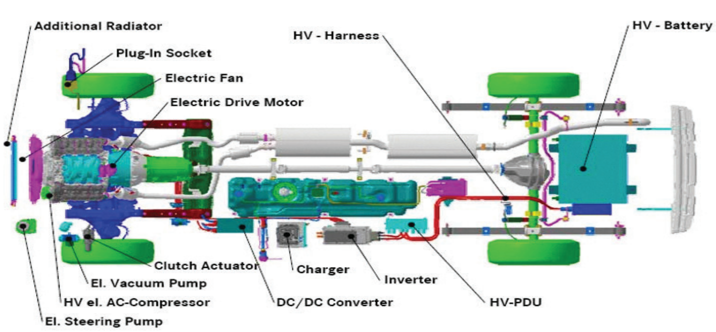

Figure 1. Diagram of a hybrid electric car.

An analysis of the challenges of vehicle electrification has demonstrated the importance of materials joining for its success. Its widespread adoption will require the development of unconventional fixture designs, tool materials, process development, and real-time quality monitoring. To help manufacturers get new concepts into production faster and cheaper, EWI has established a dedicated research program to address these challenges.

Manufacturing High-Performance Batteries

The two key concerns in battery manufacturing are 1) to reliably join multi-layer anodes and cathodes to a connection tab, and 2) to connect weld groups of tabs to a buss-bar. Laser welding and ultrasonic welding are the two primary technologies used to make these metal joints.

Laser welding is a process that can make small, precise welds quickly with little-to-no deformation. However, special attention must be given to certain factors to produce reliable bonds. Joint fixturing and alignment is one of the most crucial factors affecting weld quality due to the spot size of the beam. Alloy selection can play a critical role as well by requiring the use of filler materials and/or shielding gasses. Laser welding can also be very costly due to the equipment and safety systems required.

Ultrasonic welding is a very fast, solid-state welding process that generates friction and heat by oscillating materials against each other. Transmission of the ultrasonic motion to the interface is key to making high-quality welds. Industry has adopted an aggressive diamond-point knurl pattern to grip the materials and transfer motion. EWI has seen, however, that these knurl designs often pierce the layers and result in a reduction in weld strength. This disruption of the base material can produce small burrs or debris which remain in the cell.

To investigate the impact of knurl design on welding multi-layer thin foils, a comparison study was performed evaluating weld strength of diamond-point geometry versus a design focused on minimizing the amount of material deformation. Multiple knurl design variables (pad height, spacing, and angle) were tested for their influence on tensile strength and material damage. The images in Figure 2 are a visual representation of the differences in the knurl shape.

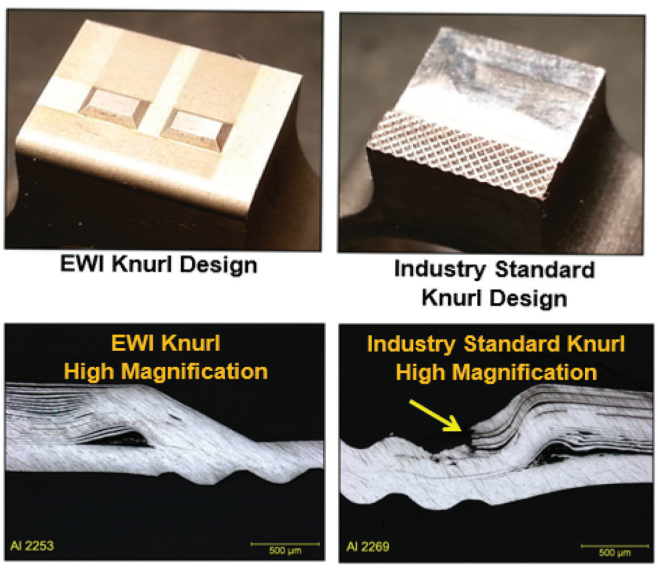

Figure 2. EWI knurl design and industry standard knurl design comparison with cross-section magnifications.

After down-selecting the best performing factors, the new knurl design was compared to the standard. The comparison study demonstrated an improvement of 5.5 kgf over the standard design. It also showed good correlation to reduced material damage around the perimeter of the knurl perimeter, which can be seen below in the cross sections. Knurl pattern design is not a case of one-size-fits-all.

Another attribute that can influence weld quality is material selection. Traditionally, tool steels and sintered powder metals have been used for their ability to make tens of thousands of welds. But as these tools wear, they begin to change the distribution of forces during welding and can negatively affect weld quality. EWI has demonstrated that this can be addressed by fabricating knurl patterns or tools out of nickel-based alloys or high-performance steels used in the aerospace industry.

Manufacturing Wire Harnesses and Cables

Wire harnesses and cables largely rely on mechanical crimping designs to attach a terminal or lug to connect numerous power distribution points. Material and joint configurations, however, are drastically changing. Higher voltages and currents are mandating higher strand count. Higher strand count and more cables create more weight. To make parts lighter, new materials like aluminum are being used. Using an alternative metal introduces dissimilar materials joining challenges.

Laser, ultrasonic, and resistance welding technologies are all attractive for their process feedback capabilities. Identifying the best process, however, requires that special attention is given to the materials and their size. Some examples of more challenging applications include welding of 3/0 and larger cables to flat lugs, welding of tin-plated copper lugs, welding aluminum cables, and welding large cables into barrel connectors.

Weld Quality Monitoring

Of the trends identified in EWI's analysis of vehicle electrification initiatives, weld quality monitoring is the most pressing issue that has not been well addressed. For decades manufacturers have relied upon the capability of equipment to provide closed-loop feedback from the system controller. That, however, very rarely translates to what occurs at the weld in the form of heat generation, forces, and/or motion. Through multiple programs, EWI has worked to develop improved weld quality monitoring systems by incorporating sensors into the joining process.

Successful ultrasonic metal welds require intense mechanical vibrations at the interface while applying moderate force. This process is critical to achieving the appropriate heat profiles for making welds. The use of shear and normal force sensors, accelerometers, and infrared sensors are all tools that have been locally applied to collect data during the welding process. Data collection of the type shown in Figure 3, along with manufacturing equipment's closed-loop feedback data, can be combined with specialty algorithms to determine a parameter's statistical significance relevant to bond quality.

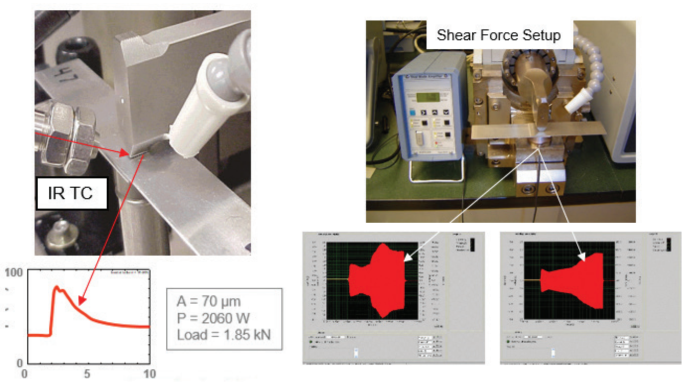

Figure 3. Localized temperature and force measurements of an ultrasonic weld.

Get Started

The challenges discussed here highlight the demand for materials joining solutions in support of vehicle electrification. EWI is actively developing new methods and technologies to advance these initiatives. To learn more about EWI's vehicle electrification program, contact us at:

614.688.5152 (or) info@ewi.org

For more information regarding our capabilities and services, visit EWI.org

EWI.ORG→