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Wire Harness Assembly

More Challenges but New Solution With Ultrasonic Metal Welding

As featured in the
September/October 2010 issue

Serving the Electric Wire and Cable Processor
WIRING HARNESS NEWS®
Voice of the Industry
P.O. Box 527 • RICHMOND, ILLINOIS 60071

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Wire Harness on Assembly Board

One look at the automotive marketplace will tell you that things are changing and quickly. The first real production electric vehicles are on the horizon. Hybrid vehicles dot the landscape in various forms from the small hyper-efficient high mileage cars to very large passenger trucks. Every major automotive manufacturer offers some kind of hybrid vehicle. It was only a few years ago that the term "hybrid" began when the futuristic promise of zero emissions vehicles was just a dream. The future is fast approaching and wire harness manufacturers face unique new challenges.

Ultrasonic Metal Welding (UMW) has long been thought of as a young technology. UMW technology has faced continuous challenges while expanding its capabilities. Right now UMW faces its largest challenges yet, to provide welding solutions for current developments in renewable energy. For example; Hybrid vehicles and solar energy require larger splices and connections previously outside the capability of UMW.

The wire harness manufacturing industry has traditionally been the single largest user of UMW since the 1980's and will therefore be the focal point of this article. This industry now needs to develop products and processes at an accelerated rate to meet the challenges in the development of high voltage connections in harnesses. In the process, Ultrasonic metal welding capabilities and limits need to be redefined. This article defines the welding spectrum for UMW in relation to the latest applications development. In order to understand and appreciate the new challenges in UMW, we should define the technology and its application as accepted by the wire harness industry today.

Automotive wire harnesses contain more than 100 splices and grow with each model year. They are adding more features to cars and electronic features require more splices. The splices and wire terminations together make up a long and complex heavy harness that controls the entire electrical system throughout the vehicle.

Wire splicing has always been a major focus in the manufacturing of wire harnesses due to its labor intensity. Mechanical connection (crimping) was the first method introduced for wire splicing and it still has applications today. In some cases, the joints were dipped in solder. In the early 1970's some companies started to utilize Resistance Welding to join wires together. This process involves fusion (melting) of the material created by resistance to current through electrodes.

In the late 70's German Wire Harness manufacturers started to investigate the feasibility of using ultrasonic metal welding for splicing stranded wires. Soon after, American manufacturers adopted this largely unknown technology. Companies like Delphi Packard, United Technologies and Siemens spearheaded efforts to perfect this process because of the advantages it offered.

- Low temperature process does not affect material properties.

• Pure metallurgical bond for many non-ferrous materials.

• Ability to weld dissimilar materials.

• No consumable materials such as splice clips or solder.

• Environmentally friendly process.

• Consistent weld quality, mechanical and electrical properties.

• Fast cycle time.

• Operator safety with no fumes or chemicals such as lead.

Naturally, experts in ultrasonic metal welding became interested in developing reliable systems as high volume equipment was in demand if the process proved to meet industry requirements. Some automotive wire harness manufacturers implemented these newly developed Ultrasonic Splicers. However, the process was still in its infancy, and major breakthroughs in equipment and process soon followed. A brief history of the UMW wire splicing evolution:

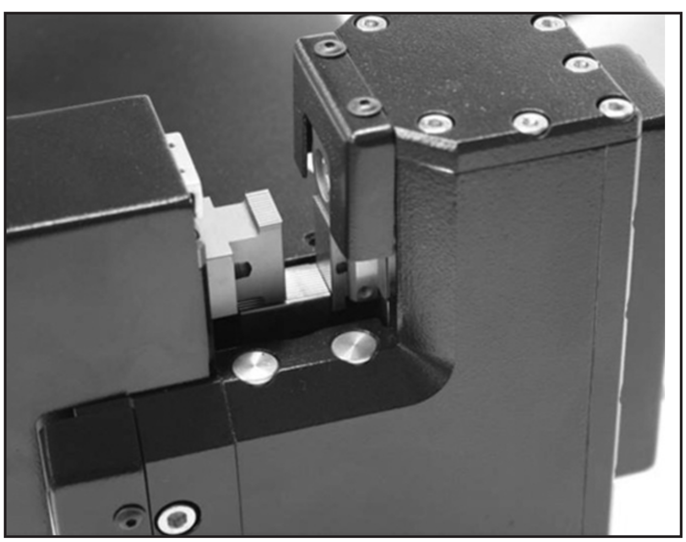
• Correlations were found between the dimensions of the weld nugget and the weld strength. The width and height of the weld are controlled by the machine. This remains one of the most important process controls today.

• Welding equipment became more compact and ergonomic. The machine became compact enough to be carried by hand.

• Universal tooling systems allowed many different splices to be made using the same equipment.

• The set up and tooling change-over was reduced to 15 minutes from over an hour.

• Tooling adjustments for each splice were made automatic.

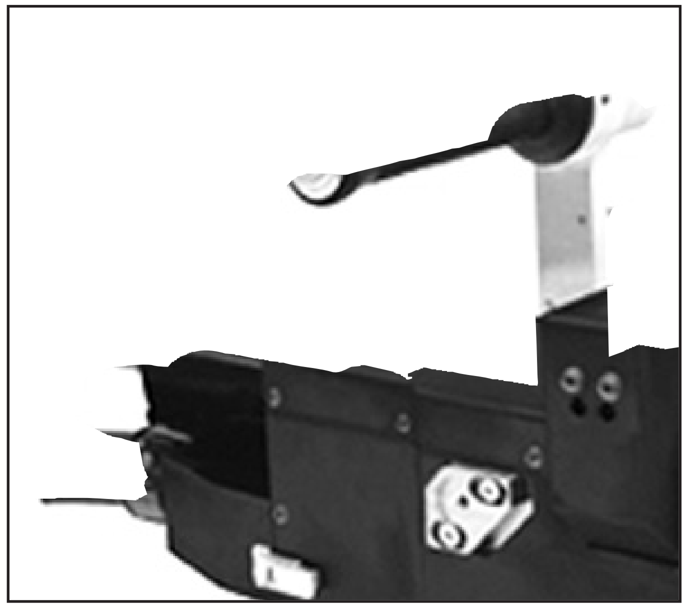


Tooling Configuration of Splicer

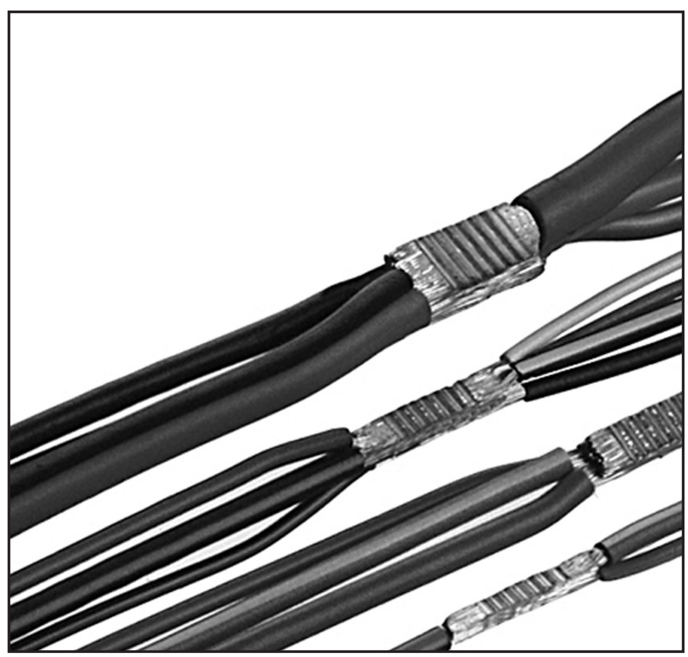
• Digital controllers provided methods for saving process parameters by name in files, instead of analog knobs and buttons. A bar code reader can be used to recall the process parameters for different splices in less than 5 seconds.

• Computer algorithms calculated process parameters based on wire size only.

• Ultrasonic energy generation development allowed more consistent process control regulating amplitude and frequency.

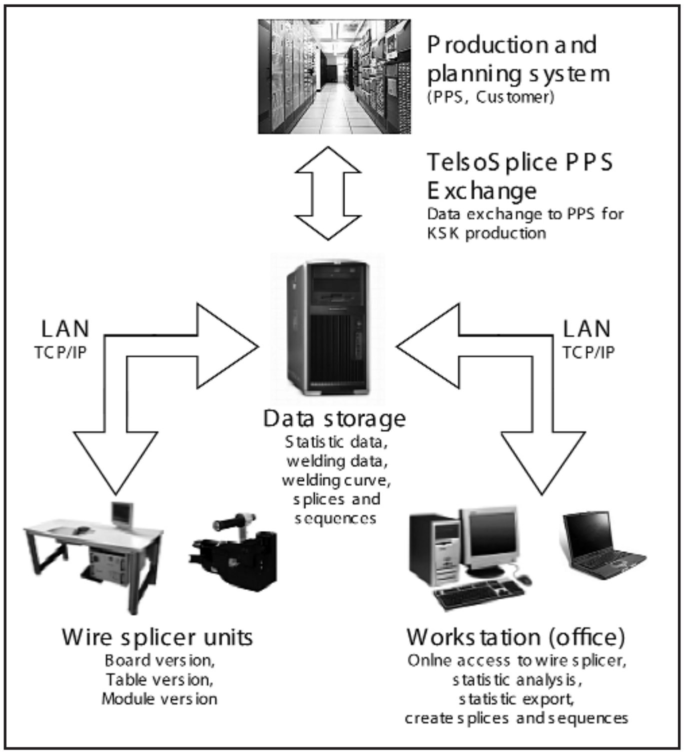


TelsoSplice Machine for Bench and Assembly Board



Typical Copper Wire Splices

Car makers slowly but surely started to utilize advances in UMW technology. Splicing harnesses on an assembly board using portable ultrasonic welders has been standard practice for over a decade. Today wire harness production plants use a network control specific harness fabrication. Orders are sent to assembly carousels and every single splice is made according to customer requirements, including 100% weld quality monitoring.



Networking Capability

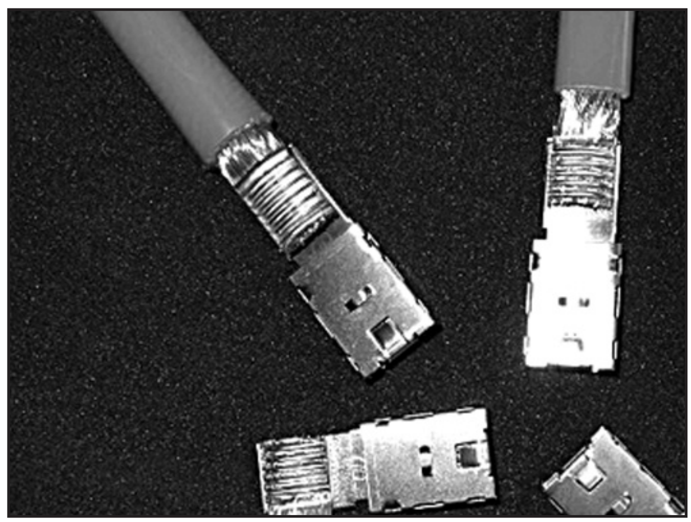
Current applications utilized up to recent times

Until the early 1990's, only splices of up to $15mm^2$ in total cross sectional area were allowed using ultrasonic welding by most carmakers. This was due to the power limitation of the ultrasonic generator, transducers, and welding modules. As the industry gained confidence in ultrasonic wire splicing, equipment manufacturers were faced with more challenges, including requirements for welding process control, better performing equipment and the capability to weld larger cross sections.

By the beginning of the 2000's Ultrasonic Metal Welding machines could weld larger splices, with precise control and proven quality. The wire harness industry was then ready to implement the technology further and apply it to wire terminations, welding FFC (Flexible Flat Cables), battery cable splices, and fuse elements. One popular application is the termination of multiple wires to eyelet terminals for ground connections. This was clearly for cost savings and quality improvements.

As application requirements changed and became more stringent, further advances in digital electronics were being utilized by ultrasonic equipment manufacturers. Innovation didn't stop there. Ingenuity had to be applied to the mechanics of the welders which historically have the largest impact on the quality and consistency of the weld.

Besides passenger cars, almost all moving vehicles from motorcycles, light and heavy trucks to construction, agricultural, emergency, recreation and since the late 1990's some military vehicles have utilized ultrasonic splice welding. The main reason is the superior quality and technology advantages that ultrasonic metal welding companies have created to meet the ever increasing OEM quality standards.



Typical Wire Termination Examples

APPLICATIONS COMMONLY UTILIZED UP TO RECENT TIMES			
Wire Welding	**AWG Size**	**mm^2**	**Ultrasonic Power Range Required**
Splices			
Wire Size	22-6	0.35 – 13.00	
Weld size in Splice		1.05 – 50.00	3 KW - 5 KW, 20 KHz
Terminations			
Wire Size	22-6	0.35- 13.00	
Weld size		5.00- 35.00	3 KW – 5 KW, 20 KHz

1. *0.35 mm^2 is the smallest wire used in splices and terminations*
2. *Most applications for terminations involve either multi-wire to eyelet terminal or single and larger cable*

The table above shows the UMW size spectrum for wire splicing and terminations, currently accepted and practiced in the wire harness manufacturing process.

New applications for wire harnesses

Aluminum Wires in Automobile Harnesses

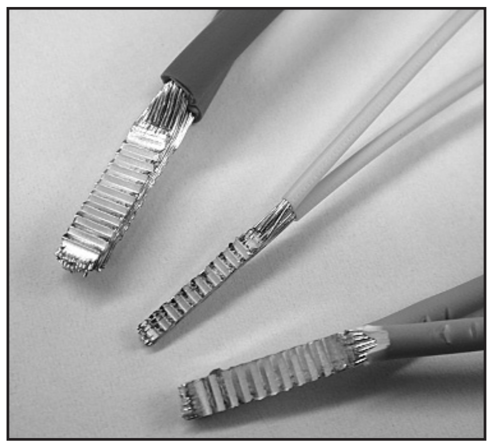
The Ultrasonic Metal Welding process has never been as popular as it is today, yet equipment manufacturers have never been challenged as they have in the last couple of years. Car companies have started to take interest in using Aluminum wires in place of traditional copper wires due to increased flexibility, lighter weight and lower cost. Now wire harness manufacturers need to evaluate aluminum wire splicing for their harnesses. It has taken some time to understand the application of aluminum wires due to several factors. Aluminum wire requires more cross sectional area than a traditional copper wire of the same current carrying capacity. Life cycle testing including environment and corrosion tests also must be passed.

When evaluating Ultrasonic Metal Welding for aluminum wires there were two major challenges.

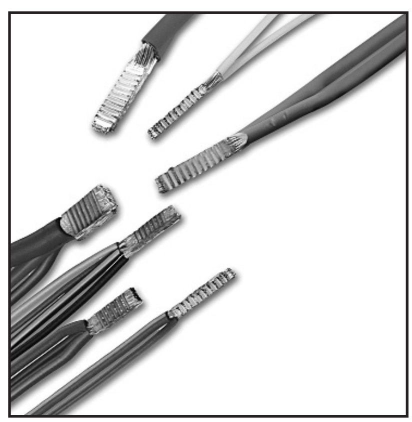
• The process parameters and weld dimensions had to be revisited.

• Tooling had to be developed to prevent strands from sticking of the working surface.

Those equipment manufacturers that invested time into the Al wire welding research have succeeded in delivering promising results. More aluminum wires will be slowly used in the harness of the future. However, the application of larger Aluminum cables for Hybrid electric cars is on the fast track with immediate demands for welding solutions. Due to the required cable size and flexibility, Aluminum cables are being considered more and more for high voltage connections.



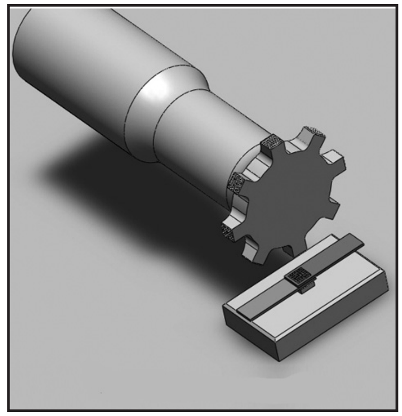
Aluminum Wire Splices



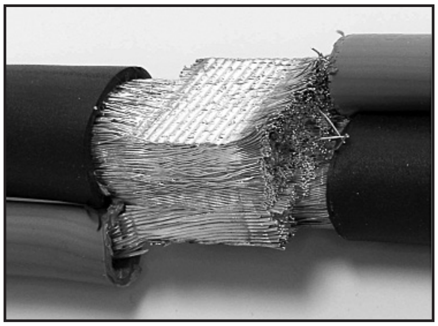
Al and Cu Wire Splices

Introduction of Hybrid and Electric Vehicles

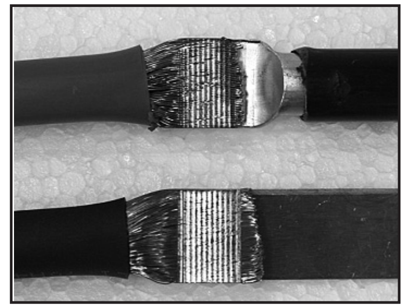
The dynamic changes brought on by hybrid vehicles are not only limited to battery manufacturers. It has introduced requirements for high power electrical wiring harnesses, connectors, and hybrid electrical centers. The high voltage/high current cable assemblies include high voltage connection systems for motors, inverters, battery packs, service plugs, battery bus bars, high voltage cables with EMI shielding, and HV junction boxes for gasoline electric hybrid and other vehicles utilizing electric drive technology.



Linear Welding Concept



Large Splice 172 mm^2



Larger welds with AKG

120 mm^2 Aluminum Cable Welded to Bus Bar

The evolution of high voltage/High current cable assembly connections for all aspects of Hybrid electrical cars has put terminal development on the fast track. Today every carmaker and their tier 1 suppliers for wiring harness assemblies have established their own hybrid /high voltage technical centers with ongoing development to meet the demands for electric cars. Ultrasonic metal welding is a crucial process for all aspects of these assemblies due to its ability to provide a bond with high current carrying characteristics. Therefore, certain standards and specifications are being prepared by individual companies. USCAR in Southfield, Michigan recently released their SAE 38 for Ultrasonic Wire Termination that covers larger Copper cables.

These new cable assembly designs require unique ultrasonic metal welding technologies with high power generators and robust machinery. The equipment necessary to accomplish these tasks must not only be capable of welding the much larger cross sections but also satisfy the new quality requirements specific to high voltage applications. The newly expanded spectrum of UMW equipment will drive the design and manufacturability of the harnesses for hybrid and electric cars.

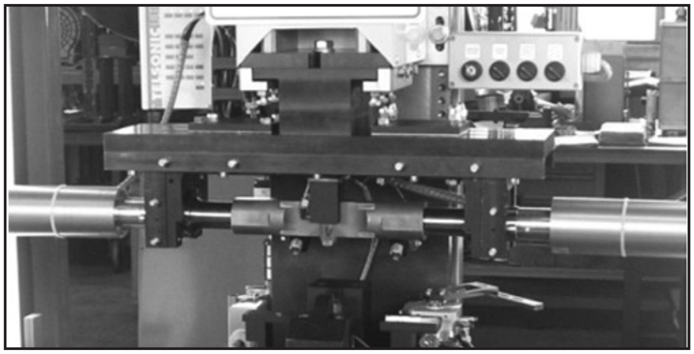
CHALLENGING APPLICATIONS BY THE INDUSTRY

Wire Welding	**mm^2**	**Ultrasonic Power Required**
Splices		
Wire Size - Copper	0.13 – 35.00	
Weld size in Splice -Copper	0.39 – 120.00	3 KW – 10 KW, 20 KHz
Wire Size- Aluminum	0.50 - 2.50	
Weld Size in Splice- Aluminum	1.00 – 5.00	3 KW – 10 KW, 20 KHz
Terminations		
Wire Size - Copper	5.00- 103.00	
Weld size - Copper	16.00- 120.00	3 KW – 10 KW, 20 KHz
Wire Size - Aluminum	19.00 – 120.00	
Weld Size – Aluminum	19.00 – 120.00	3 KW – 10 KW, 20 KHz
Splices and Terminations	120.00 – 200.00	**Torsional Welding -** Power Wheel

New Technologies in Ultrasonic Metal Welding

The table on the previous page shows the current UMW size requirements for wire splicing and terminations on high power electrical wiring harnesses.

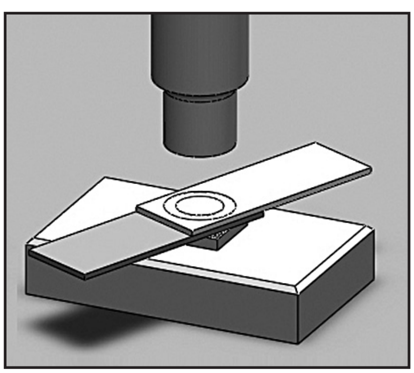
The highest power generator and welder in the market today is 10KW. SonicSolution Systems with its collaborative team at Telsonic have equipments that allow welding in the size range in the table above.The equipment are categorized as Linear and Torsional welding.



AKG Telsonic with 10KW Power

Linear Ultrasonic Welding

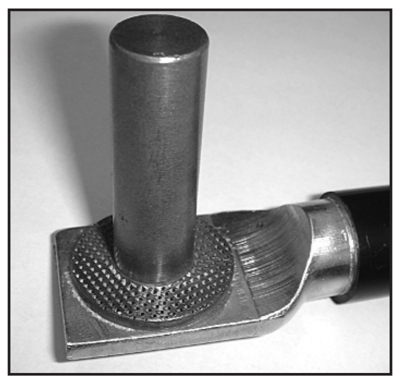
This is the most common way of applying the oscillations to the work pieces. In this approach, the substrate is supported rigidly on an anvil, and the superstrate is vibrated longitudinally against it, under a static force delivered in a normal direction. A typical linear welder uses a single converter, an optional booster and a half wave sonotrode/horn as the main components in the transducer assembly. This type of set-up is widely used when power limitations and or mechanical deflection are not a concern. The linear systems are easy to assemble and operate, and represent a low cost solution for a variety of joining applications. For larger welds (i.e. a wire splice with a cross section of 120mm²) the same linear approach is used, with the exception of two converters and a full wave sonotrode/horn. This type of transducer assembly utilizes two converters on the opposite sides of the horn. This allows for better amplitude distribution (mechanical displacement) to be applied to the work pieces. At the same time since the sonotrode/horn is supported on both sides while the static force is applied directly over the weld area, the deflection/bending of the transducer is practically eliminated. Welding with a full wave horn is more efficient, and only incrementally more complicated and costly. It is important to point out that this is still a more cost effective alternative to other joining techniques such as laser welding. Telsonic has developed special converters as well as ultrasonic generator with power output of 10kw+, which can drive a full wave length horn very efficiently with minimal energy loss under heavy loads.



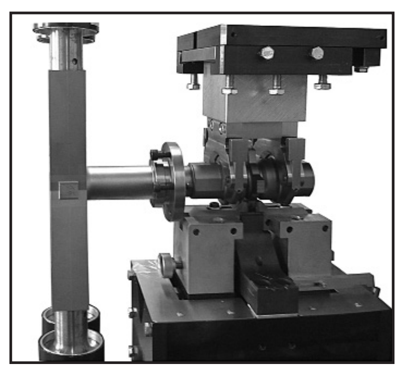
Torsional Welding Concept

Torsional Ultrasonic Welding

The Ultrasonic Torsional welding approach was originally conceived by Telsonic over 20 years ago for plastic welding applications. The main objective was to achieve a hermetic seal on round parts by applying the vibration in a horizontal plain (same as a linear welder) in combination with a twisting motion of the same frequency. The principal is that a single the converter will apply the oscillations to the horn in a perpendicular fashion, resulting in a dynamic motion that is still longitudinal but with a twist.



Stud Termination by Torsional Welding Process



Torsional Welding by Telsonic "Power Wheel"

In the last few years the Torsional welding technique which is still exclusively offered by Telsonic has found quite a few niches in the metal welding market. The original applications focus was mainly on non-ferrous metals with round shapes such as cylindrical batteries, airbag and seatbelt sensors. But in the recent past this approach has been very

Wire Termination by TSP Power Wheel

sucessful on conventional applications such as battery tab welding, wire splicing and terminations. By utilizing a high power generator and multiple converters, (i.e. "Power Wheel"), a new method of Torsional wire splicing and terminations has been developed for welds with cross sections as large as 200mmÇ. Due to the unique dynamics of the vibratory energy of a Torsional system, there is less stress on the material and depending on the geometry of the parts; the force and amplitude distribution is much more uniform across the weld area. Certain applications for high voltage connections that have historically utilized friction welding, can be done with the Torsional technique, using less power , and at lower temperatures. The resulting joint is much cleaner, not to mention better quality monitoring capabilities and a fraction of capital investment.

These new requirements and advances are truly a revolution in the wire harness industry. The exciting changes in the automotive industry seem like the science fiction of clean, quiet, electric vehicles that we read about as children. Yet, the biggest challenges lie ahead.

We are only scratching the surface of these new technologies. Hybrid cars are still a small percentage of overall vehicle sales, and purely electric cars are just making their debut this model year. In time, as battery technology advances these will become more prominent.

Let us not disregard other factors in wire harness design. Even the most common passenger vehicles now boast electronic gadgets once found only in top luxury vehicles. Steering wheels with a wide array of functions, displays for navigation and virtual gauges, heated seats, windows and mirrors, and an incredible array of dashboard options continue to expand the needs of vehicle wiring. The utilization of these instruments and devices often highlight the need for termination of ever smaller wire gauges. At the same time it challenges the terminal suppliers to produce connector solutions with a much wider range of capabilities while maintaining the flexibility of the design.

Ultrasonic welding has always been and will continue to be a critical part of the wire harness manufacturing. The ever expanding size of power cables and the increasing use of material such as Aluminum wires will require the development of new processes and techniques. There will be joining challenges and barriers to overcome, and it seems inevitable that the conventional approaches will need to give way to new promising technologies such as ultrasonic Torsional welding. Today's impossible will soon become tomorrow's normal procedure.

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