Wiring Harness Technology Comes of Age

By: Peter Els

In 2013 the global automotive wiring harness market increased by a modest 2.3 percent to USD 40.3 billion, and is expected to grow to just USD 41 billion in 2014. However this is not a true reflection of the industry: Two Japanese manufacturers account for 50% of the market, and with the Japanese Yen devaluating by 24% in 2013, the market experienced a significant decline when measured in U.S. dollars. Also, due to the decline in copper prices and several lawsuits for wiring harness price manipulation, manufacturers were forced to reduce prices.

What is not clearly highlighted in these financial reports is the impact of technology and the changing electric and electronic distribution architecture on the cost and design of wiring harnesses.

Faced with ever increasing demands for higher power transmission density, increased data transfer rates and reduced weight and cost, manufacturers are evaluating several technologies and materials to meet the challenges.

French cable and optical fiber manufacturer ACOME has focused on reducing harness weight while maintaining cable conductivity by combining two complementary approaches:

- A thermal approach to reduce the temperature of the copper wire, thereby reducing resistance. This is accomplished by using reticulated polyethylene insulation
- Producing new alloys and metallic materials, which has led to a reduction of cross sectional area from 0.22 mm² to 0.13 mm² and soon 0.08 mm², while preserving the mechanical properties of traditional copper wire

By alloying magnesium with copper (CuMg) ACOME have managed to increase the tensile strength of the wire, thereby allowing thinner and lighter cables to be used in harnesses.

Adopting a different approach, ACOME have also been able to increase the tensile strength of traditional copper wire through modifying the internal microscopic structure, resulting in wire with a cross section of 0.22 mm² that is still capable of resisting current terminal pull-off forces.

Notwithstanding these impressive results the possible weight savings of up to 2kg on a 15kg harness, has led to renewed interest in aluminium as an automotive wiring harness material.

Aluminum as a replacement for Copper

Professor Udo Lindemann, a researcher at the Institute of Product Development at the TU Munich, firmly believes aluminium will be widely used in future electric vehicles. "We expect the high-voltage on-board systems of most electric vehicles to be based on aluminium by 2020. Aluminium will also find its way into low-voltage on-board systems, because the price of copper will rise significantly with increasing demand." Copper at the moment is more than 7 times the price of aluminium per kilogram.

Cu features		Al features	
when Cu IACS conductibility is	100	Al IACS conductibility is	62
when Cu wire section is	100	for same electrical function Al wire is	161
when Cu density is	8,9	Al density is	2,7
when Cu wire weight is	100	for same electrical function Al wire is	49
when Cu wire outer diameter	100	for same electrical function Al wire is	125
when Cu tensile strengh is	100	Al tensile strengh is	50
when Cu wire tensile strenght	100	for same electrical function Al wire is	81

Image credit: www.sae.org

At about half the weight of copper, for the same electrical conductivity, aluminium's weight saving potential is significant. Nonetheless there are several challenges to be

overcome before aluminium replaces copper in the manufacture of automotive harnesses.

When compared to copper, aluminium's lower tensile strength imposes restrictions on traditional crimping as well as routing in the vehicle.

Recognizing these challenges Japanese harness manufacturer, Sumitomo, spent many months developing an aluminium alloy which could achieve a tensile strength of 110 MPa or more and conductivity of at least 58% International Annealed Copper Standard (IACS); assuming that the 0.5 mm copper wire generally used in low-voltage power cables was replaced with 0.75 mm aluminium wire.

Commercially pure aluminum (Ex. AA1060: Purity 99.6%) has good conductivity (62%IACS), but the tensile strength after annealing is pretty low (70 MPa). Therefore, the strength had to be improved by forming an aluminum alloy that would be suitable for automotive cabling.

Sumitomo finally settled on aluminium alloyed with 1.05 mass% Fe and 0.15 mass% Mg which achieved a tensile strength of 120 MPa and conductivity of 60% IACS.

However with aluminium's absolute conductivity about 40% lower than that of copper, the cross-sectional area has to be increased by 61%, and the outer diameter of the equivalent aluminium cable increased by 25%. This poses packaging problems, especially when faced with ever increasing power transmission demands.

Preformed wiring harnesses

A possible solution to packaging constraints could be the adoption of a preformed harness, such as that unveiled by cable manufacturer, Leoni. At a 2013 SAE International World Congress session on wiring Leoni's Matthias Groetsch showed both 2 – and 3 – D preformed harnesses, the former available with a heat protection mat.

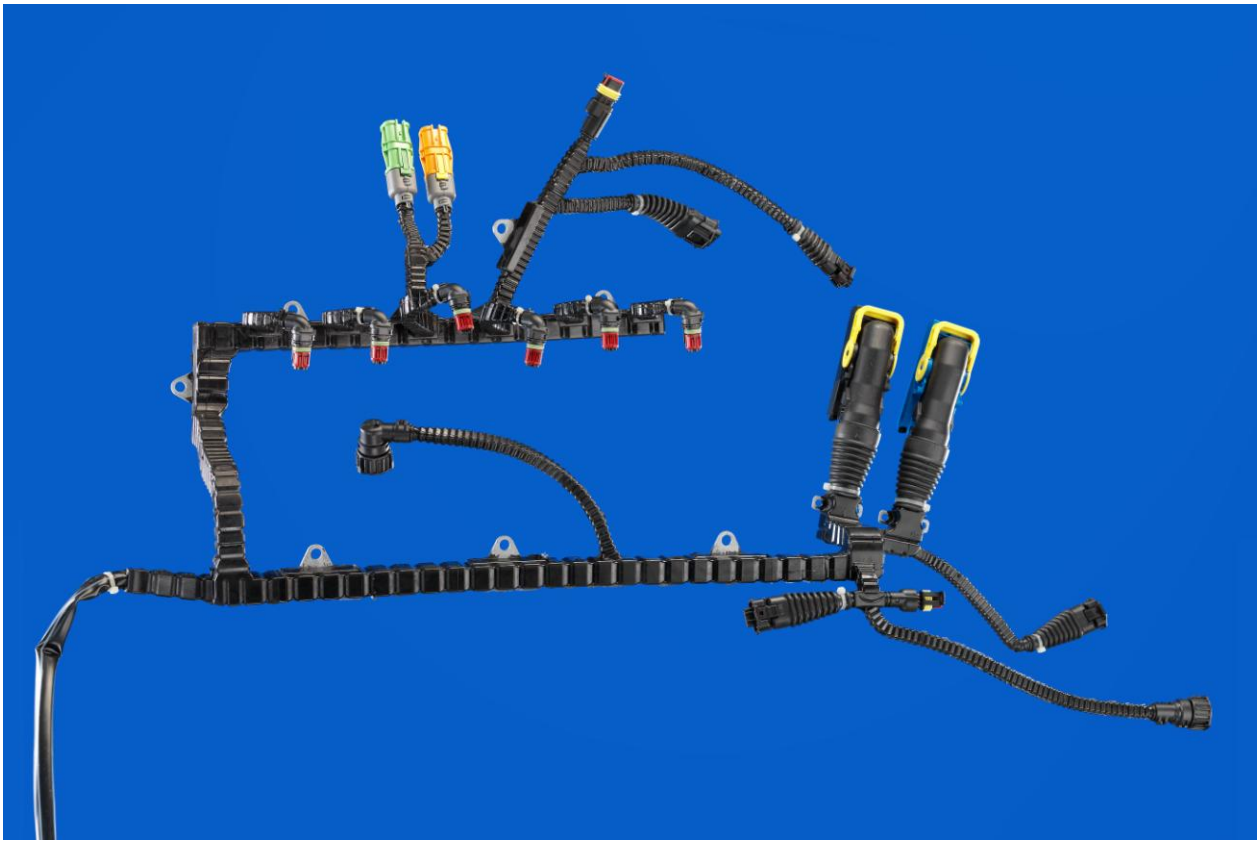

Image credit: www.leoni.com

The preformed harness requires no in-vehicle manipulation of the cabling to fit the contours of the vehicle, thereby simplifying fitment of the bulkier aluminium cables.

Leoni's preformed harnesses, which are foam-filled up to the electrical contacts to eliminate any internal wiring movement, also use polyurethane conduit: Thus making the harnesses thermally stable in a range of -40° to +120°C.

Aluminium cables also face challenges with regards to crimping. These challenges come in the form of galvinitic corrosion and aluminium’s rapid oxidization which further reduces conductivity.

Mitigating the corrosion issue, particularly when an aluminum wire is mated to a copper terminal, requires a well-sealed joint. The solutions vary according to the environment, with the simplest a shrink seal around the joint that is both ultrasonic welded and crimped. This approach is also well suited to automation.

To speed up and optimize harness design manufacturers have turned to sophisticated development and simulation software, such as engineering company, Zuken's, newly released E3.EDM (Engineering Data Management) tool. The software is based on the E3.series and uses the CIM DATABASE EDM platform from Contact Software in Munich to provide data and process management for wire, harness, cable and control system design.

Using the native data simplifies the workflow and design processes in key areas and allows harness designs to be more efficient. This helps reduce the harness weight and optimise cross sectional area and packaging.

As carmakers start using Ethernet networks and more advanced applications, such as uncompressed high-definition video, data rates of over 100Mb/s will become the norm. It won't be across all the nodes in the network, and according to Ali Abaye, director of Ethernet automotive products at Broadcom, is unlikely to be in production before 2018.

Developments in improving data transfer rates

In the automotive sector weight, flexibility and reliability are key. To meet these requirements a technology called BroadR-Reach is being developed, proving that Ethernet traffic can be run over one pair cables. Although in the early stages of development, tests have been conducted transmitting 10 GB/s over unshielded twisted-pair cables.

Not only does this technology improve data transmission rates, but it also reduces the number of cables required, in the harness.

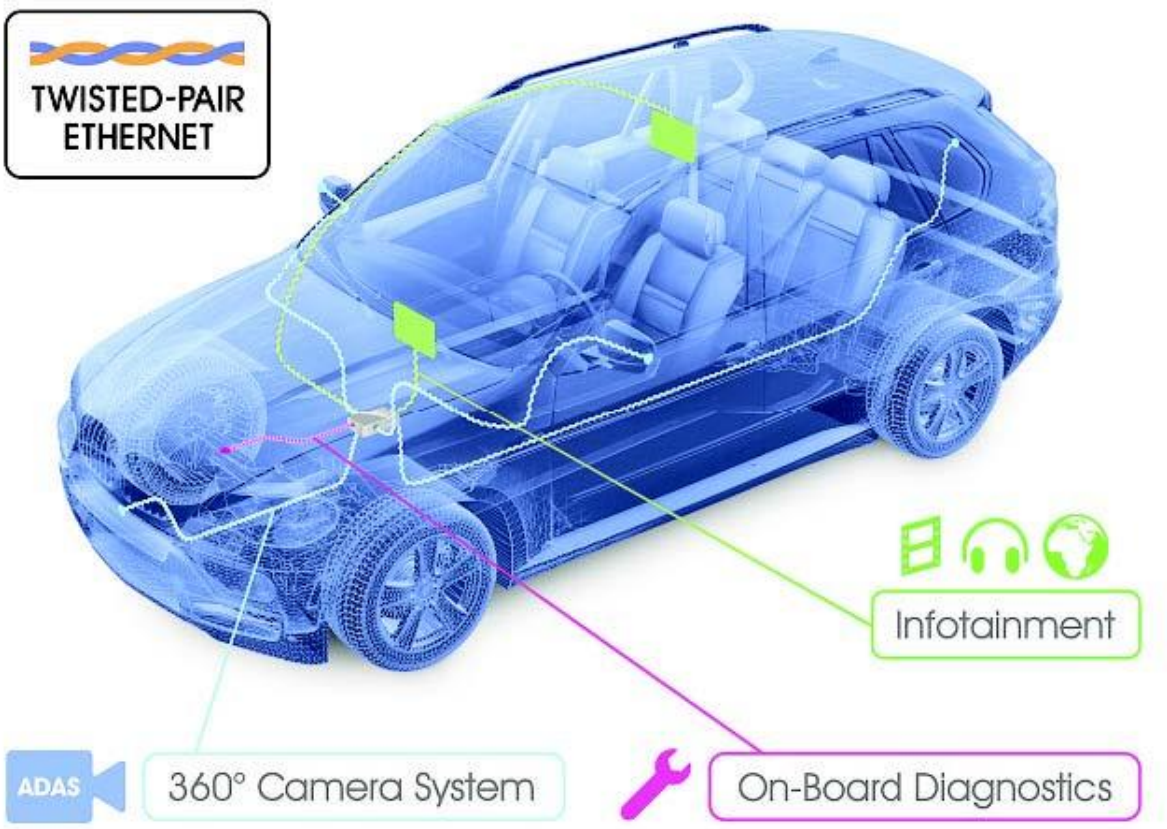

Image credit: The Industrial Ethernet Book

As an alternative cabling solution for high speed data transmission, coaxial cable is already being used in infotainment applications. With coaxial cable high data rates of around 1 to 3 gigabits can be achieved, but these cables are prone to damage during fitment, which has limited their use in the automotive industry.

Another technology that has seen widespread use in infotainment systems is fibre optic, which Ali Abaye claims could achieve transmission rates of up to 100Gb/s, while also satisfying the most stringent EMC requirements.

Commonly used in Media Systems Oriented Transport (MOST) plastic optical fibre (POF) has proven robust in operation, even though somewhat limited in bandwidth. This limitation has led to several research projects focusing on glass fibre which enables higher data rates.

New technologies that may shape the future of wiring harnesses

One project that's yielding some amazing results was setup at the University of Southampton and achieved data transmission at 99.7% the speed of light, equating to an incredible 73.7 terabits per second.

Because light passes through air a lot faster than it does through glass, this new glass fiber cable is hollow. Using an ultra-thin "photonic-bandgap rim" the fibres remain hollow while still being able to be bent. With a recorded loss of 3.5 dB per 1000m, the application for short-distance transfer is promising. Nevertheless with all the unknowns it's unlikely this will be seen in automotive applications in the near future.

Futuristic research is not confined to optic fibres: At about 100 times the strength of steel, only one sixth the weight and with impressive electrical conductive properties, carbon nanotubes (CNTs) have been the subject of many studies since their discovery in 1991. To date, the problem has been to apply the impressive nano scale properties to real-world applications on the macro scale. Researchers have now unveiled a new CNT fiber that conducts heat and electricity like a metal wire, is as strong as carbon fiber, and as flexible as textile thread.

In 2013, building on ten years of research, a team, consisting of scientists from Rice University, Dutch firm Teijin Aramid, the Air Force Research Laboratory (AFRL) and the Technicon-Israel Institute of Technology, revealed a "wet-spinning" chemical process to create CNT. Raw nanotubes are dissolved in chlorosulfonic acid, before being propelled through tiny holes to form long strands. These strands, with trillions of tightly packed carbon nanotubes all aligned in the same direction, are then spun into a macroscopic thread. Initial results indicate that these strands have the highest conductivity ever reported for a macroscopic CNT fiber.

"We finally have a nanotube fiber with properties that don't exist in any other material," said lead researcher Matteo Pasquali, professor of chemical and biomolecular engineering and chemistry at Rice. "It looks like black cotton thread but behaves like both metal wires and strong carbon fibers."

"The new CNT fibers have a thermal conductivity approaching that of the best graphite fibers but with 10 times greater electrical conductivity," adds study co-author Marcin Otto, business development manager at Teijin Aramid. "Graphite fibers are also brittle, while the new CNT fibers are as flexible and tough as a textile thread. We expect this combination of properties will lead to new products with

unique capabilities for the aerospace, automotive, medical and smart-clothing markets."

Pasquali says the specific electrical conductivity of the fibers is on a par with copper, gold and aluminum wires, but is much stronger, which gives them advantages over metal wires for data and low-power applications.

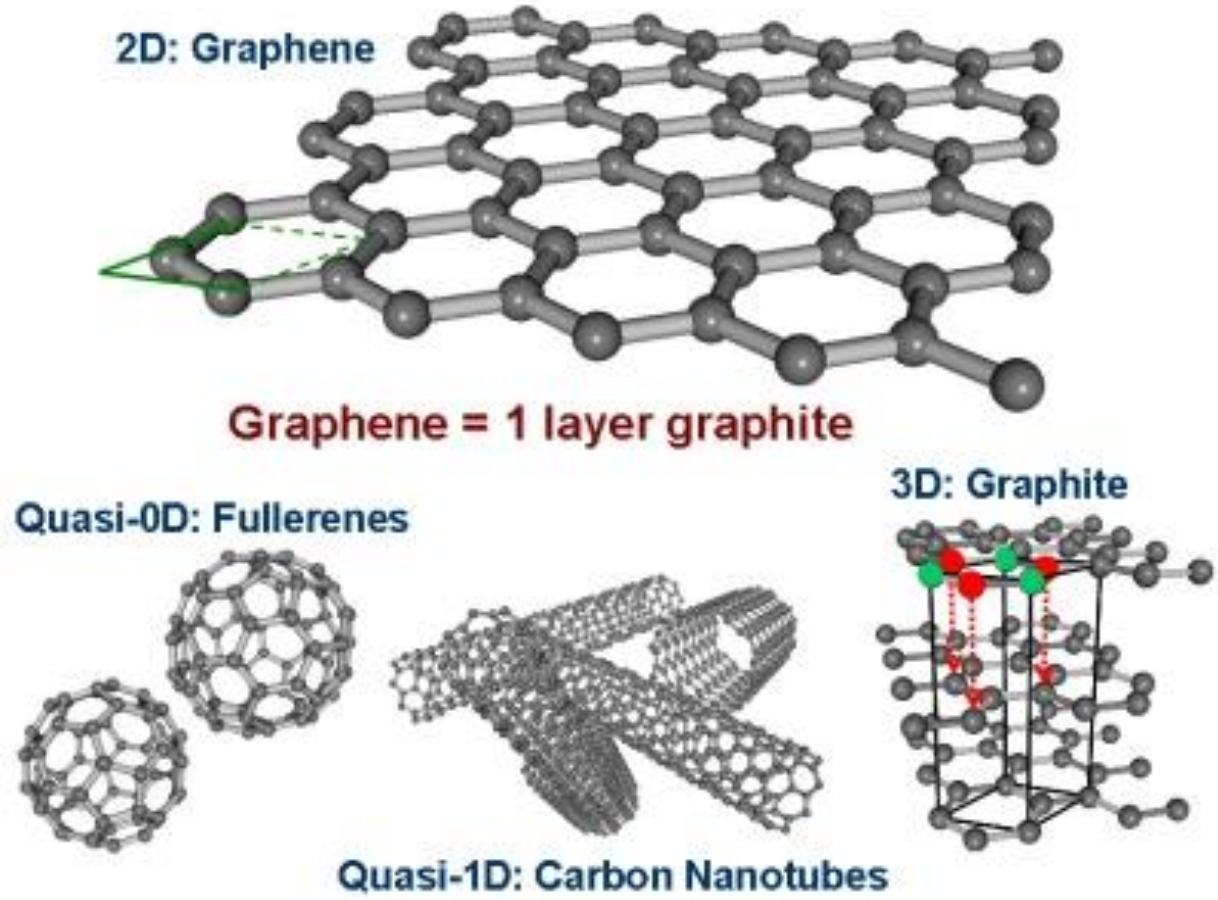

Image credit **：*www.graphene.nat.uni-erlangen.de***

The advantages of the new "super" material, graphene, are already being investigated in electronic applications such as 3 D printed circuit boards, and flexible electronic circuits, but grapheme may at some point in time also find it's way into wiring harnesses.

Inventors Ki II Kim, Young K. Kim and Sang-Woo Kim have applied for a patent (US 2013/0140058A1 Published Jun. 06/ 2013) for the manufacture of graphene electrical wire.

Although details are not available the patent describes a graphene electrical wire which has a metal coated polymer core with a graphene layer on the outer surface of the metal.

This graphene layer can be synthesized by chemical vapor deposition or large scale graphene synthesis.

The inventors claim that by using graphene, which has 100 times the current density of copper, high heat conductivity and chemical resistance, it is possible to manufacture electrical cable which is thin but has a high electrical conductivity.

Conclusion

Carmakers often adopt technologies that have been developed in other industries, and the same is true for electric and electronic distribution systems. With computer technology and networks making quantum leaps in data transfer technology we can expect the auto industry to adopt technology such as the Ethernet and twin twisted wire within a short space of time.

When it comes to power transmission, aluminium may present a short to medium term solution, but with the exciting developments in fibre and graphene technologies we may one day see a very different looking wiring harness in our vehicles.

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About the Author

After qualifying as an Automotive Engineer, Peter has spent 40 years in the South African Automotive industry. Having started his career with Nissan's product development division, automotive technology and engineering remain his passion.