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Hot Application
Hot Crimping for EV

THIS ISSUE

The Challenge

EV manufacturers need to join multiple, insulated wires in a terminal sleeve, creating a solid electrical and mechanical connection for energy distribution. Traditional "cold crimping" is not an option because the insulation needs to be removed to make good electrical contact, and while this can be done mechanically or chemically, it introduces an additional manufacturing step, increasing both time and cost.

Solution:

Hot crimping first removes insulation, then fuses the wires and a sleeve into one, neat, connection-ready package that exhibits high tensile strength and maintains excellent electrical conductivity over time.

EV Manufacturing

EV manufacturers are tasked with building increasingly powerful, efficient cars, and their success depends, in part, on their ability to make and maintain robust electrical connections. Some of the issues engineers encounter in designing and assembling EVs include: thermal management, contact resistance, connector dimensions, mechanical stress load, product lifespan, and the need for cost reduction.

A previous publication addressed these kinds of challenges using wire compacting, a process in which stranded wire is gathered, compacted and welded into a desired shape in order to better facilitate attachment to other components. But the technology is not suited to the insulated magnet wire utilized in these terminal connections. Hot crimping – aka wire fusing - however, can help design and manufacturing engineers achieve these goals.

Magnet Wire

Magnet wire (sometimes referred to as enameled wire) is a copper or aluminium wire coated with a very thin layer of insulation. It is used in the construction of transformers, inductors, motors, generators, and other applications that require tight coils of insulated wire.

Some EV motors are manufactured using distributed windings of round copper magnet wire, and others utilize "hairpin windings" of flat copper magnet wire

wound in coils. When current is passed through the windings, an electromagnetic field is created, and the rotor rotates. A conductive terminal, usually coated with tin, nickel or silver, is attached to the free end of the wire so it can be connected to a source of electrical power. Remember that the magnet wire is *also* coated, usually with a polymer like Polyamide-imides (PAI), Polyether ether ketone (PEEK), or Polyamide-imides with polyimide foil (PAI+FEP); thickness varies between 50-200 µm. Removal of this coating is key to the success of the electrical connection.

Crimping

The motor winding terminations all need to be gathered and attached to a terminal in order to distribute power to the vehicle. How is this done?

Cold crimping

Cold crimping is a process that makes a connection to the cable shoe or terminal using pure mechanical force, resulting in a simple, robust joint. When the wire/cables are not coated, this is a perfect low-cost solution for terminals. For EV manufacturers with magnet wire, however, disadvantages to the process include:

- The need to manually or chemically remove insulation via wire stripping
- Deterioration of electrical contact due to stress relaxation over time
- Cavity corrosion caused by organic residues at the contact interface due to incorrect cleaning, crimping, or outgassing from surrounding plastics like the wire insulator

Hot crimping

Hot crimping is a metal joining technology that differs from cold crimping because it utilizes both current and mechanical pressure to join electrically conductive wires. It also differs from wire compacting in that it uses a conductive metal sleeve (aka shoe or terminal) to gather the wires together, pass the current, and generate heat, fusing the wires into one, solid, compacted, metal part. The heating causes the metal to anneal, and mechanical stress in the joint is relaxed which, in turn, minimizes stress on the copper in both the wire and terminal after the joining process. The joint is formed by diffusion welding, named because the copper wires and connector fuse together at near-to-melting temperature. The result is highly conductive electrical connection with nearly zero contact resistance and free from any significant voltage drop. Furthermore, because it is now one, solid piece of metal, the new hot-crimped joint has very high tensile strength that won't weaken over time due to vibration or temperature.

The intense heat generated by hot crimping also vaporizes the insulation, eliminating the need for an additional stripping step and increasing productivity. No metal is removed, which ensures maximum strength.

Is hot crimping a good fit?

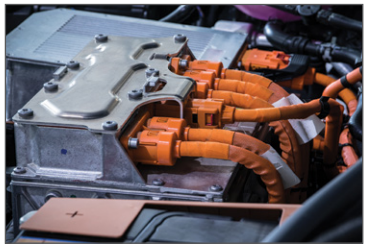
Hot crimping is an ideal solution for joining standard magnet wires, high-frequency magnet wire (above 10 kHz), and uninsulated copper wires. Hot crimping can be used for individual magnet wires as thin as 30 AWG (0.05 mm^2), or a wire bundle as thick as 400 mm^2 (stranded or braided). The low electrical resistance of the resultant joint will in turn, lead to lower temperatures for the parts in operation, and increase both the reliability and the electrical efficiency of the parts compared to conventional joining technologies.

Hot Crimping Applications

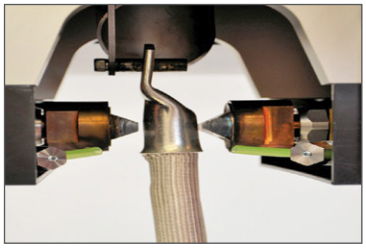
Hot Crimping has seen tremendous growth in the automotive market due to the electrification of the powertrain. Applications of hot crimping in EV manufacturing include:

- High current connections from the battery to the inverter
- High current connections from the inverter to the electrical motor
- Internal components

Battery to the inverter



Inverter to the electrical motor



Hot Crimping as a joining technology

A COMPARISON OF TECHNOLOGIES

	Wire Hot Crimping	Wire Compacting
Material	Copper or Aluminum	Copper
Wire Insulation/Coating	Various	None/tin/silver
Size	Up to 400 mm^2	Up to 120 mm^2
When to use	Cable elements are individually insulated and insulation needs to be removed to make a connection	• Compact connection with direct contact to deliver current • Cable elements are not insulated • Adding a cable shoe or sleeve makes the part too large and/or heavy
Typical Equipment	DC inverter, pincer weld head	AC weld control, DC inverter control, high force weld head/bus cooling