Eight Questions and Answers about Hot Crimping vs. Wire Compacting Using Resistance Welding Technology

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Manufacturers — especially those in the automotive sector — utilize stranded wires for their flexibility and durability, but the wires present a challenge in making robust interconnects.

Stranded wires tend to fray and splay when pressed without confinement, which may create hazardous short circuits. Additionally, connections can be inconsistent because each wire is pressed differently. Mechanically crimped wire tends to have higher resistance and can lead to overheating of the joint. By gathering and compacting the ends either directly or in a terminal sleeve, manufacturers can create a single, solid electrical and mechanical connection for efficient energy distribution and robust performance. In addition, compacting of stranded wires eliminates the need for terminal lugs and thus will reduce vehicle weight; it also has lower resistance and provides a more robust connection.

Q: WHAT IS THE DIFFERENCE BETWEEN HOT CRIMPING AND WIRE COMPACTING?

A: On the surface, hot crimping and wire compacting are similar technologies used to achieve the same end goal. However, some subtle differences dictate when and why one process would be used over the other. Let's first look at the basic definitions:

Hot crimping is a manufacturing process that uses electrical current and mechanical force to form a robust electro-mechanical connection. A sleeve is placed on the end of the wires, gathering them into a neat package. Then, an electrical current is applied to simultaneously remove insulation and fuse the wires and sleeve into a neat, connection-ready package that exhibits high tensile strength and maintains excellent electrical conductivity over time.

Wire compacting is like hot crimping in that it uses current and mechanical force to create a solid cuboid shape encapsulating the stranded wires. The difference is that it works without the addition of a sleeve, and the wires need to be stripped of any insulation before fusing. The resultant compacted wires form a solid welded volume that facilitates connections to other components.

Q: WHAT CHALLENGES DO MANUFACTURERS FACE WITH STRANDED WIRE, AND HOW DO HOT CRIMPING AND WIRE COMPACTING HELP?

A: Manufacturers utilizing stranded wire face four primary challenges: contact resistance, mechanical stress load, product lifespan, and cost.

1) **Contact resistance —** Mechanically crimped stranded wires have a higher resistance than compacted or hot crimped stranded wires. As contact resistance increases, current flow is reduced, generating heat at the interface. Exposure to this heat weakens cables over time. Therefore, the longevity of the electrical system is directly proportional to its cumulative heat exposure. Hot crimping and wire compacting produce a connector that possesses reduced contact resistance, which, in turn, helps reduce the overall temperature of the electrical system.

2) **Mechanical stress load —** Stresses due to vibrations and G-forces can cause degradation or failure in conductivity. Hot crimping and wire compacting result in more-robust connections, reducing potential problems due to mechanical stress load.

3) **Product lifespan —** The cycle of localized heating and cooling of the weld joint causes minute expansion and contraction of the material, which, as the material relaxes during cooling, often fails to return to its original crimped dimensions, thus reducing the part's lifespan. The reduced contact resistance of a compacted joint results in lower temperatures, less thermal cycling, and, ultimately, improved product lifespan.

4) **Cost —** Every manufacturer in every industry seeks to make more and better products at a lower cost per unit. Hot crimping and wire compacting reduce the need for complicated assemblies that require additional processing steps, like organizing frayed wires. This also reduces cycle time and increases throughput, saving money.

Q: HOW DO I DETERMINE WHETHER TO SELECT HOT CRIMPING OR WIRE COMPACTING FOR MY APPLICATION?

A: Several considerations must be made when selecting the right technology, including material, insulation, connection size, and final product design. The following two questions and answers provide further insight and general guidance on selecting one or the other. As this is often a multifaceted decision, it is recommended that you discuss it with your trusted partners.

Q: WHAT INFLUENCE DO MATERIAL AND PROCESS HAVE ON THE SELECTION?

A: Hot crimping is ideal for joining standard magnet wires, high-frequency magnet wires (above 10 kHz), and uninsulated copper wires. Because the crimping process essentially encapsulates the wires, the material choice is more forgiving than wire compacting.

Wire compacting is particularly well-suited for copper wire, with or without a tin or silver coating. It is also a good fit for twisted pairs and multiple sheathed cables. It is not well suited to aluminum because the thin oxide layer that naturally occurs on the aluminum inhibits strong welds. Compacting is also unsuited for copper wires with nickel plating or a nickel barrier layer; the different melting points of the base material and coating make it difficult to get stable process results.

Hot crimping is ideal for applications where the cable elements are individually insulated, and that insulation needs to be removed to make a connection. Conversely, compacting is better suited to applications where the compacted connection requires direct contact to deliver current and the individual cable elements are not insulated.

Q: HOW DOES SIZE AFFECT THE SELECTION PROCESS?

A: 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).

Wire compacting can handle a wide range of wire sizes, from 0.25 mm^2 (26 AWG) to 120 mm^2 (4/0).

Q: WHAT ARE SOME TYPICAL APPLICATIONS OF EACH TECHNOLOGY?

A: Applications of hot crimping in electrical vehicle (EV) manufacturing include the following:

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

Applications of wire compacting in EV manufacturing include the following:

- Sensors (safety belts, temperature, etc.)
- Electrical distribution from batteries
- Airbag initiators
- Y and T connections

Q: WHAT OTHER CRITERIA SHOULD I CONSIDER WHEN SELECTING COMPACTING OR HOT CRIMPING?

A: Other criteria include the part requirements — particularly weight, as adding a cable shoe or sleeve would make the part too large and/or heavy.

In addition, manufacturing criteria, such as throughput and available facilities, should also be considered.

Q: WHAT EQUIPMENT IS TYPICALLY USED FOR WIRE COMPACTING AND HOT CRIMPING?

A: For wire compacting, an alternating current (AC) or direct current (DC) inverter weld control and high-force weld head with bus cooling are typically used. For hot crimping, a DC inverter paired with a pincer weld head is standard.