Curing Aluminium Car Moulding with Induction Heat

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Automotive manufacturers are constantly searching for cost-effective production technologies. Process heating is no exception. Ameritherm has developed specialised induction heating solutions for curing adhesives on aluminium trim mouldings. This provides uniform quality for continuous flow production and is easily incorporated into existing lines. The temperature and process control that it provides are vital for today's manufacturing environment.

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Curing adhesives on automotive trim mouldings at high speeds presents unique sets of challenges for process heating systems. Heating of the adhesives along with the removal of volatiles must be done in a uniform manner while compensating for variations in the mouldings, coatings and the environment. The various heating solutions available to the industry will be described in the following, including the use of induction heating in the manufacturing of over-moulded trims. Because it has been used as a method of process heating for many years, induction heating is now designed into solutions that yield significant improvements in uniformity and process line speeds. Induction heating is finding increased acceptance for use in today's lean manufacturing processes worldwide.

A trim is a thin structural metal web that is specifically shaped to meet the strict specifications of the end product for sealing and weatherproofing. Aluminium is replacing steel in a growing number of applications. The reduced weight of the aluminium core in the trim allows for lighter and more efficient designs. Typical metal thicknesses vary from 0.5 mm to 1.5 mm. The metal trim is over-moulded with rubber or plastic. Processing speeds of 7.5 to 20 metres per minute are common in manufacturing. The bond between the metal and the rubber or the plastic may be enhanced with the use of a thermoplastic adhesive. Heating of the metal is typically done before the metal passes through an extruder. The heat in the metal allows the adhesive to soften and forms a strong bond between the metal and the extruded rubber on its surface.

For maximum quality and efficiency, each curing application requires an individualised system that is custom designed to meet:

- the needs of the various materials
- increased demands for higher production speeds
- the complex geometry of the trim
- the ability to combine multiple processing operations
- strict environmental standards
- economic concerns

Methods of Heating

Radiant heat is probably the oldest and the most common form of heat employed for metal trim production. Flame heating does not lend itself to the heating of the adhesive on the trim material, unless the produced heat is stored in a furnace. The transfer of heat by convection and radiation in a furnace is slow. Resistance heating is another form of heating metal and is by far the most efficient form. It relies on the electric current passing directly through the material being heated. This implies that there is always mechanical contact between the trim and the source of heat. The contact is typically accomplished through carbon blocks that carry high currents. The contact resistance be-

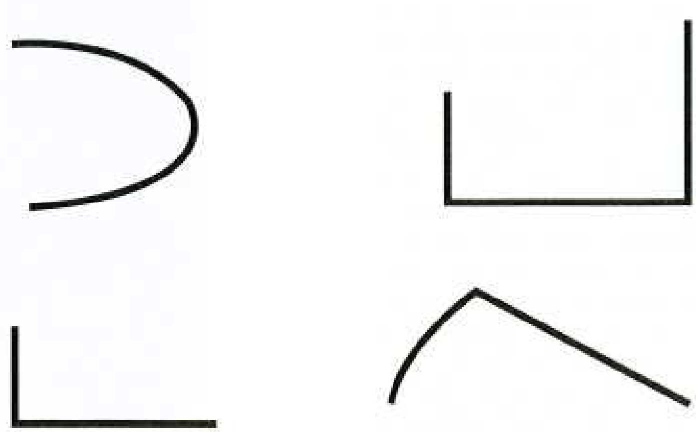

Figure 1: Different geometries of metal trim cores.

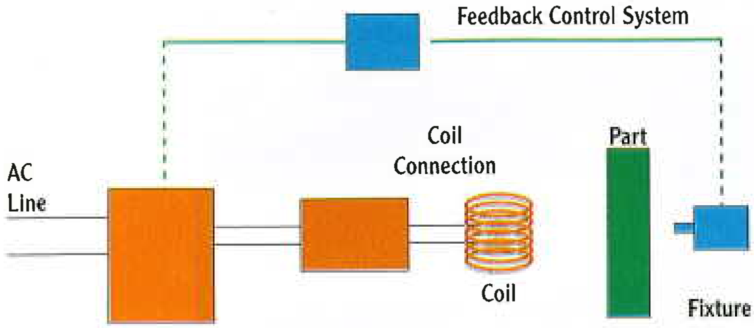

Figure 2: Typical Induction heating system.

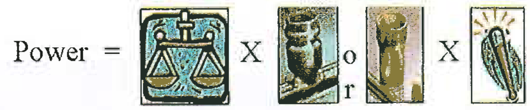

Figure 3: Power required to heat a material is mass times specific heat times change in temperature required.

tween the carbon and the metal trim cannot always be guaranteed, and therefore it does not work well in this application. Induction heating is slowly but steadily being utilised and gaining acceptance as the premier form of heating for moulding. It is used in a broad range of applications and processes and may be integrated into existing production lines.

The advantages of induction heating as a process heating solution include:

- Reduction of product waste during line starts and stops due to rapid heat up and cool down cycles
- Minimisation of trapped volatiles and gases because heat is produced in the metal as opposed to being transmitted through the thermoplastic adhesive
- State-of-the-art control features, with minimal maintenance of heating units
- Increased production line speeds
- Maximised energy efficiency

When combined, these advantages produce a quick return on investment of the equipment purchased.

Induction Heating Basics

Induction heating employs magnetic fields to induce eddy currents into the moulding as it moves through an induction coil. When an electrical current alternates in a work coil, it produces an alternating magnetic field in and around the work coil. If an electrically conductive part is placed within the magnetic field,

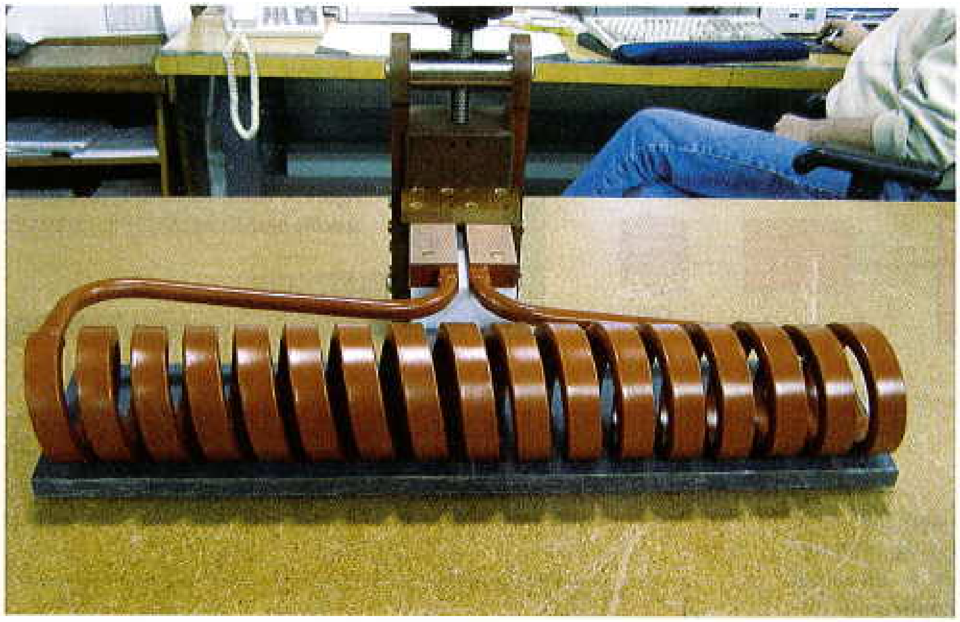

Figure 4: Picture of a series induction coil.

All conductive materials heat up in a magnetic field due to eddy current heating

a current is developed in that part. The work coil may be considered as the primary winding of a transformer and the workpiece as a short-circuit secondary winding. The induced current in the part flows against the resistivity of the material and generates heat. All conductive materials heat up in a magnetic field due to eddy current heating. A typical induction heating system includes an AC power supply, a remote workhead and a water-cooled copper coil. The coil size and shape are dependent on the size and geometry of the component being heated, Figure 2. An optional temperature-measuring system can be easily integrated into the system to provide temperature feedback to the power supply for precise temperature control of the metal. The coil is designed to deliver the most efficient heat to the metal, and is dependent on the speed at which the part travels through the coil in addition to the shape and magnetic properties of the part. When the workpiece is placed in the coil, the magnetic field induces eddy currents in the workpiece, generating precise amounts of clean, localised heat without any physical contact with the workpiece.

The different variables to be considered when selecting an induction heating system are operating frequency, power supply sizing and coil design.

Operating Frequency

Induction heating energy produced in the metal as a result of the induced eddy currents is produced within a certain distance from the surface. This depth of penetration of heat is called the 'skin depth'. The density of heat energy produced is greatest on the surface and drops off exponentially at the skin depth. There is a relationship between the frequency of the alternating current and the depth of penetration in the workpiece. Low frequencies of 5 to 30 kHz are effective for thicker materials, delivering deeper heat penetration, while higher frequencies greater than 50 kHz are effective for heating smaller or thinner parts or heating the surface of parts. Higher frequencies also have a higher efficiency of heat transfer into the parts. A good analogy is the act of rubbing your hands together for warmth. The faster you rub your hands together (representing a higher frequency), with the same amount of contact pressure, the more warmth you produce. In terms of aluminium and steel trim, steel heats more efficiently than aluminium trim. Magnetic materials are easier to heat than non-magnetic materials, due to the added effects of hysteresis heating. Magnetic materials naturally resist the rapidly changing magnetic fields within the induction coil. The resulting friction produces its own additional heat – hysteresis heating – in addition

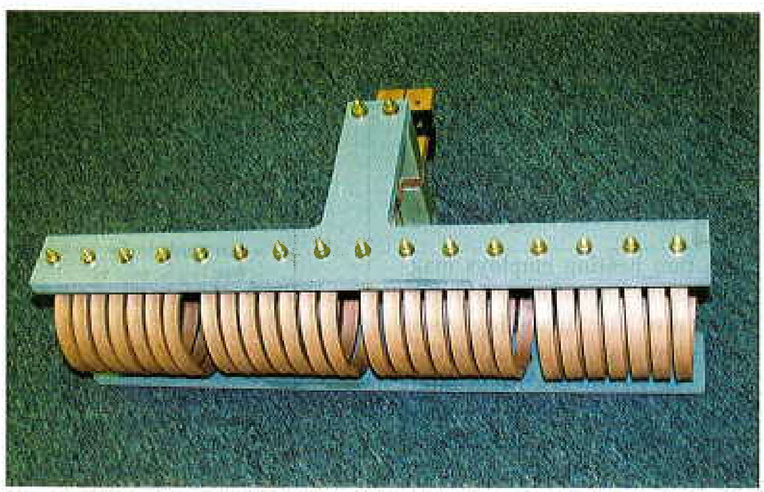

Figure 5: Series parallel induction coil (front view).

to eddy current heating. Steel trim is easier to heat than aluminium trim when using induction heating. With recent advancements in induction workhead design, aluminium can now be easily heated quickly.

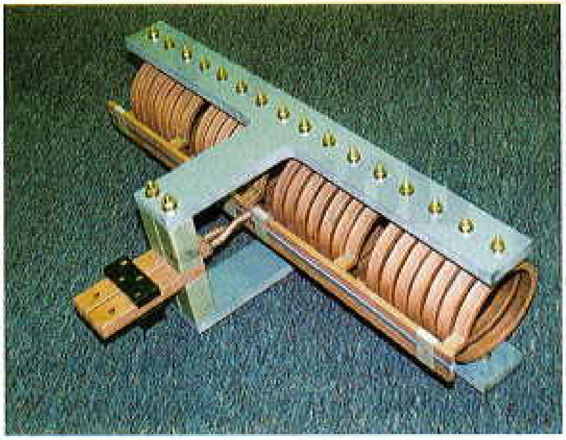

Figure 6: Series parallel induction coil (rear view) with a quick-change adapter.

Power Level Required

Several variables must be considered to determine the amount of heat energy required for heating a particular trim material. The mass flow rate, the specific heat of the material being heated and the rise in temperature required determine the amount of energy required in the material to raise its temperature from ambient to the desired final temperature. In addition, thermal losses due to conduction of heat into workpiece fixturing, and convection losses must also be considered.

Efficient Coil Design

The induction coil, typically made of copper tubing, is normally cooled with water. The shape of the copper tube is dependent on the current and water flow required for the application and can vary from round to rectangular. The size and type of the coil – single or multiple turn, helical, round or square, internal or external – is selected based on the properties of the metal trim being heated and the processing speeds required. The coil is designed to deliver energy at the best coupling efficiency. Coupling refers to the proportional relationship between the distance between the workpiece and the coil. Close coupling generally increases the flow of current and therefore increases the amount of heat produced in the workpiece. With a good coil design, the proper heat pattern is achieved and the efficiency of the induction heating power supply is maximised. A typical coil design for trim heating is shown below. Each coil needs a non-conductive liner inside to electrically insulate the trim from the coil as it travels through the coil. Glass, ceramic or plastic is generally used as an insulating tube material.

Induction heating provides fast, reliable, repeatable, non-contact, energy-efficient heat for curing automotive trim. Its small overall footprint including a small remote workhead provides for greater manoeuvrability in an automated or manual system. The bigger power supply unit may be located up to 50 metres away from the production line. The flexibility of the system allows it to be easily incorporated into any new or existing production set-up. Line changes in metals from steel to aluminium are easily incorporated with minimal changes in hardware. This results in quick changeovers in today's just-in-time work environments. The use of induction in process heating makes it an indispensable tool for automotive manufacturing processes.

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