by Valery I. Rudnev • Inductoheat Group

Joining components by induction heating, Part II

Professor Induction welcomes comments, questions, and suggestions for future columns. Since 1993, Dr. Valery Rudnev has been on the staff of Inductoheat Group, where he currently serves as group director – science and technology. In the past, he was an associate professor at several universities, where he taught graduate and postgraduate courses.
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Induction joining applications include, but are not limited to, brazing, soldering, friction welding, bonding, and shrink fitting. The metals being joined can be similar or dissimilar.[1] In brazing, soldering, and friction welding, both of the components to be joined must be heated to approximately the same temperature; however, when bonding or shrink fitting, only one of the components might be heated.

Induction brazing and soldering were discussed in Part I (*HTP*, March/April 2005, p. 19–22). Part II, which follows, focuses on induction bonding and shrink fitting.

Shrink fitting by induction

Shrink fitting is a method of joining components without the use of a filler material. The expansion of metal during heating and its contraction during cooling are exploited to provide a mechanical bond between the two pieces.[1]

During shrink fitting, the external (or encircling) component is heated to temporarily expand it, which enables insertion of the other component. The assembly is then cooled to ambient temperature. The external component contracts, permanently locking the parts together. Shrink fitting is a reversible process — components can be disassembled by reheating. (If the parts were only press-fit together without heating, unacceptable deformation of the assembly could result.)

In most shrink fitting applications, the entire part must be heated rather than selected areas. This means that a low power density and relatively low frequency are used. The applied frequency typically ranges from as low as line frequency to 10 kHz, while the required temperature ranges from about 120 to 400°C (250 to 750°F), depending on the geometry of the components and their material (or materials) of construction. Single-turn or multiturn solenoid coils or "C"-core type inductors are the ones most commonly used (see column in *HTP* January/February 2005, p. 23).[1]

Note that not every assembly is a candidate for shrink fitting. The process is most often applied to cylindrical hollow parts such as ring gears and roller bearings. In the case of roller bearings, for example, shrink fitting is the most cost-effective assembly method. The outer race is heated and expands relative to the inner race. The ball bearings are then slipped into place and the assembled bearing is allowed to cool and contract.

Steering knuckles: Figures 1 and 2 show an eight-station, automatic induction shrink fitting system. The Inductoheat machine's rotary-indexing unit is driven by a hydraulic motor. C-core inductors powered by a line-frequency source heat truck steering knuckles to 345–370°C (650–700°F) in two stages. The preheat station heats

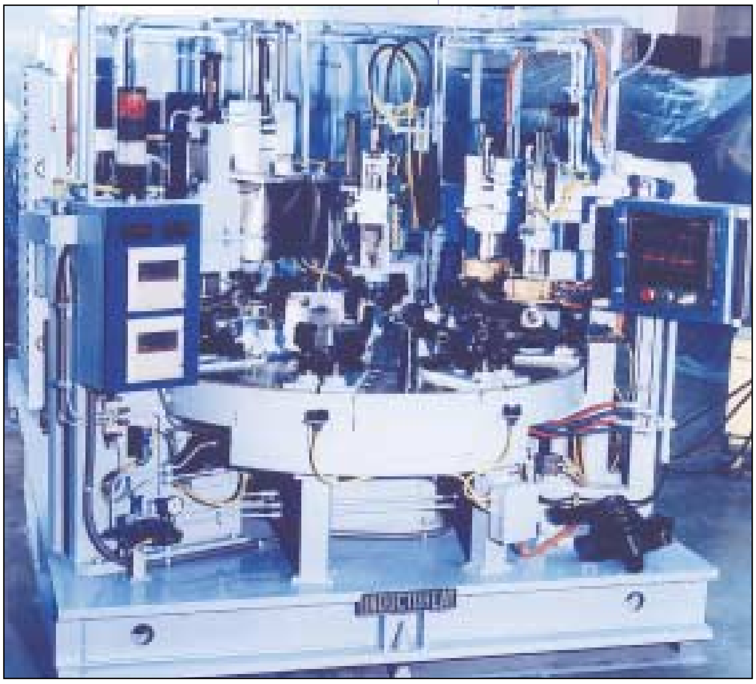

Fig. 1 — Eight-station shrink fitting machine is used to assemble truck steering knuckles. The Inductoheat system produces 30 knuckles per hour.

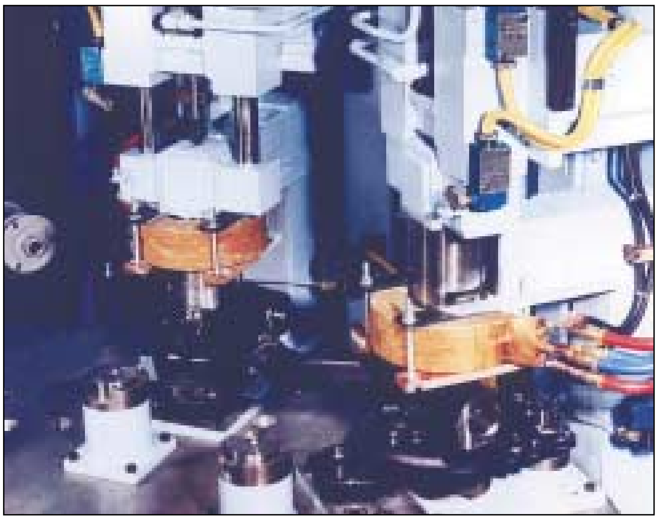

Fig. 2 — Preheat and final heat stations of the system for shrink-fit assembly of truck steering knuckles (see Fig. 1). A line-frequency source powers the C-core inductors.

Fig. 3 — An Inductoheat system for adhesive bonding a rubber gasket to a metal brake pedal support. The operation takes just 4 seconds, using a 2 kW, 30 kHz inverter.

the knuckle for a minimum of 40 seconds prior to final heating. The part "soaks" at temperature for approximately 30 seconds prior to insertion of the spindle. The assembly is then cooled with pressurized water to less than 95°C (200°F) before being removed from the machine. One assembled steering knuckle is produced every 120 seconds.

This shrink-fitting system is manually loaded and unloaded, and its indexing table is tooled to accommodate either right- or left-hand knuckles. An optical pyrometer monitors and controls part temperature throughout the cycle.

Bonding by induction

Compared with brazing and soldering, adhesive bonding is much more versatile because the components to be joined do not have to be metals. Plastics, ceramics, glasses, and other nonmetallic materials also can be bonded.[1]

The adhesive, which is applied prior to induction heating, is not electrically conductive, so it cannot be heated by induction. Therefore, at least one of the components to be joined should be electrically conductive. (If a multicomponent structure is being assembled, several of its components should be conductive.) The adhesive will be heated via thermal conduction from the electrically conductive, induction heated component in contact with it. (*Note:* In some bonding applications, pressure also must be applied to the components being joined.)

Most adhesives can be divided into two large groups: thermoplastic adhesives and thermosetting adhesives. Thermoplastic adhesives soften when heated and harden when cooled. Thermosetting adhesives form a bond due to a chemical reaction (polymerization). Induction heating is effective whether it's used to soften an adhesive or accelerate an adhesive polymerization process.

Bonding is among the low-temperature applications of induction heating. Because the maximum temperature is approximately 230°C (450°F), power requirements are usually relatively small. Many bonds are completed using a power of less than 10 kW and a frequency between 10 and 200 kHz. However, as for all induction heating applications, the optimal power and frequency are greatly affected by component size, shape, and material of construction, as well as the required heated mass.

Induction bonding is often performed on sheet metal or thin metal strips. Bonding of brass electrical connectors is a typical example. Two other examples follow.

Rubber to metal: This first case study involves joining of dissimilar materials: securing a rubber-like gasket to a metal automobile brake pedal support. Mechanical joining via fasteners such as rivets or clips was an option; however, fasteners add to costs and require additional manufacturing operations. Conventional gluing can be impractical and messy.

The bonding machine (Fig. 3) uses induction to "heat stake" the gasket to the pedal support. System components include a table structure which supports a 2 kW, 30 kHz power supply, an induction heating coil, a fixture for locating the brake pedal, a clamping device, and palm buttons to start the cycle. Production rate: 500 parts per hour.

The fixture is manually loaded and unloaded, which helps keep equipment capital cost down. In the bonding process, the operator loads a brake pedal (with preapplied adhesive) and gasket on their supports. This automatically locates them directly above the induction coil. The heating cycle begins by heating the pedal to approximately 205°C (400°F), which is sufficient to bond the gasket to the pedal. The entire process takes about 4 seconds and uses about 2 kW per cycle. Induction bonding was selected for this application primarily because it is very fast and the temperature can be accurately controlled, which is critical because rubber can deteriorate if heated to above a certain temperature.[1]

Hem flange bonding: Induction hem bonding systems offer a rapid and reliable partial cure of adhesives that provides a joint strength adequate to maintain dimensional stability of an assembly during material handling until final joining. Automotive industry applications include inner and outer door panels, deck lids, lift gates, and hoods.

Resistance spot welding is one way of final joining. A drawback to spot welding is the need to grind the weld nugget, which adds an operation. In addition, welding and grinding can damage any protective coating on the sheet metal, creating stress risers and sources for initiation of corrosion.

An alternative approach is to use two-part epoxy adhesives and an induction cure. An example is shown in Fig. 4, an induction system for hem bonding of automobile door panels. Main system components are a 100 kW, 10 kHz solid-state power supply, an induction coil assembly, and a modular fixture that enables the machine to be easily incorporated into new or existing panel assembly lines. The system can be designed for full-periphery or spot curing of panels. The door panel "nest" is machined from a heat-resistant material.[1]

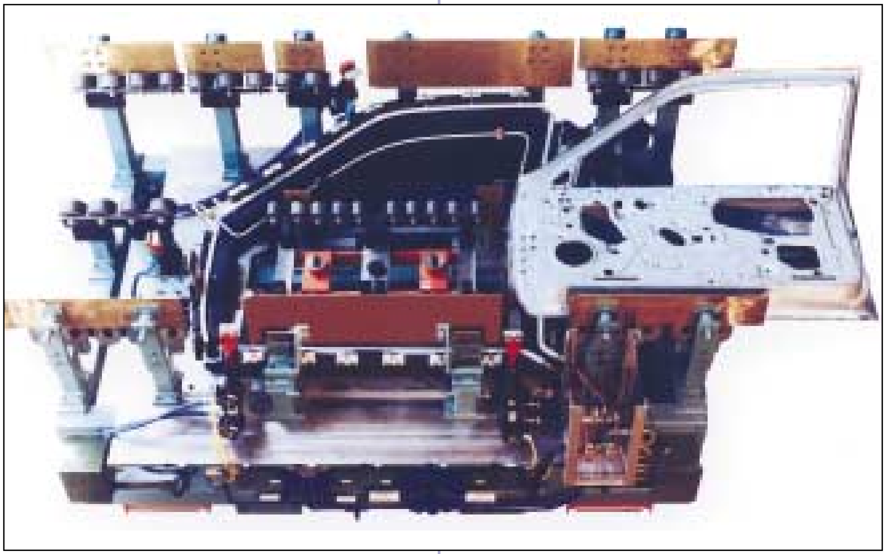

Fig. 4 — Fixture for full- or partial-periphery cure of adhesive hem bonds in automobile door panels. Note panel lifting mechanism. Photo courtesy Inductoheat.

Reference

1. *Handbook of Induction Heating,* by V. Rudnev, D. Loveless, R. Cook, and M. Black: Marcel Dekker Inc., New York, 2003, 800 p.