

INDUCTORS WITH MAGNETIC FLUX CONTROLLERS FOR NEW INDUCTION BRAZING INSTALLATIONS

Dr. V. Nemkov⁽¹⁾ and Dr. V. Vologdin⁽²⁾

⁽¹⁾ Centre for Induction Technology, Inc., 1388 Atlantic Blvd,
Auburn Hills, MI 458386, USA,

⁽²⁾ FREAL, Ltd., Vologdin High Frequency Currents Institute, Sankt Petersburg,
Russia

ABSTRACT. Induction brazing is one of traditional applications of induction technique. Many innovative solutions and method were developed during last ten years including new fluxes, filler metals, atmosphere etc. Induction technique responded to new challenges with new miniaturized power supplies, portable and hand-hold transformers and sophisticated control systems. In induction coils there are also new solutions and application of concentrators from MagnetoDielectric Materials (MDM) is one of the most important. The presentation contains a description of several innovative induction brazing applications, specially designed coils with magnetic flux controllers and whole brazing installations. Presentation is based on theoretical studies, computer simulation, laboratory tests and industrial implementation of processes and equipment.

INTRODUCTION

To respond to the modern market demand in induction brazing technologies, new materials were developed by many companies in – filler metals, fluxes, brazing and soldering pastes. New amorphous filler metals were developed for assemblies with tight joints as well as laminated filler metals for reduction of residual stresses in the joints. New filler metals and processes were proposed for fluxless brazing. Induction equipment manufacturers should match these achievements with more accurate and controllable heating while using production friendly equipment. Big improvements in induction brazing technique were made recently due to small transistor generators, hand-hold transformers and induction coils with MDM magnetic flux concentrators or controllers.

The largest consumer of induction brazing installations is a tool manufacturing industry, where induction technology is widely used for brazing of hard plates or inserts to different tools – cutters, drill bits, crowns of boring tools, etc. Company FREAL, Ltd. developed a family of transistorized power suppliers with rated powers 10kW, 30 kW and 50 kW and frequencies ranging from 50 to 100 kHz for different installations of induction tool brazing including diamond instruments.

Another large group of induction brazing customers is manufacturers of heat exchangers for cars, appliances and other machines and devices. Mass production of heat exchangers and pipe line elements from aluminum, copper and brass requires good uniformity and repeatability of heating and temperature control for high quality of joints. In car industry significant unification of aluminum heat exchangers was reached due to their connection to assembling pipes using induction brazing. Very good results were achieved by application of MDM controllers to brazing coils. Magnetic flux controllers allow the designer to distribute properly heat sources in induction system in order to achieve the best brazing results. Brazing systems have usually a complex geometry and it is difficult to foresee the results of the coil design change.

2D and 3D computer simulation is a powerful tool for brazing coil design. Centre for Induction Technology has good experience in optimization of coils for brazing of aluminum pipes to heat exchanger tubes (nipples). Even electromagnetic only 3D simulation provides

very valuable information on power distribution in brazing joint components and parameter sensitivity to the part positioning inside the inductor. Laboratory tests and industrial application confirmed the effectiveness of this design approach.

Use of MDM controllers was successful in induction brazing of heavy copper joints in production of big electrical motors, turbo generators, high-current copper busswork, super strong electromagnet conductors and so on. New inductors were designed for induction brazing installations in aircraft industry including clamshell inductors with MDM concentrators. New developments provide superior quality of brazing joints on pipelines, which are widely used in jet engine production.

NEW INDUCTION BRAZING COILS AND INSTALLATIONS

Brazing of aluminum heat exchangers

There are many types of heat exchangers used in home appliances, vehicles and other areas. In cars evaporators, condensers, radiators, oil coolers and heat cores are used for cooling, heating and air conditioning. The majority of heat exchangers in cars are made of aluminum. According to modern technology the whole heat exchanger body is brazed in big resistance furnace. Then different pipes must be brazed to heat exchanger in order to adapt it to a particular car system configuration. Brazing of tubes and other components to heat exchangers components is one of the most important industrial applications of induction brazing technique.

Aluminum brazing is a technology very sensitive to temperature distribution in joint area because of brazing and melting temperatures are close one to another. Underheating or

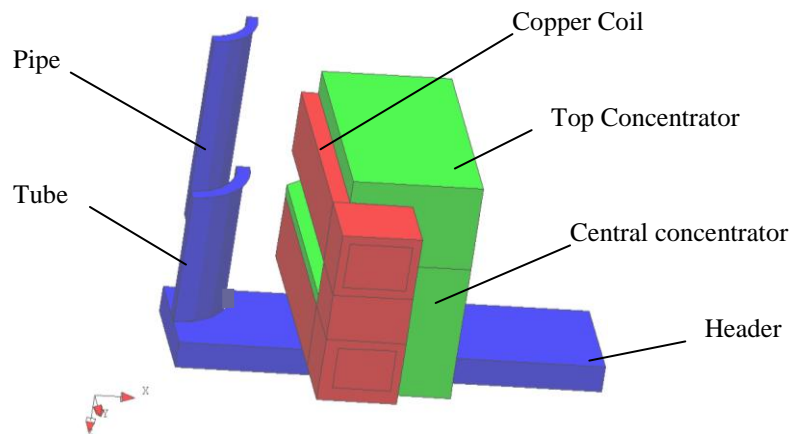


Figure 1. Geometry used for 3-D electromagnetic computer simulation

overheating may result in irreparable or hidden defects. Centre for Induction Technology conducted analysis of existing installations of one of major heat exchanger manufacturer and proposed a new solution. The situation was additionally complicated because it was necessary to use existing brazing machines where horse-shoe inductors moved into the brazing area from one side only. Electromagnetic field in such systems is essentially 3D and it was difficult to predict a priori distribution of magnetic field, power sources and temperature.

Intensive 3D simulation with a program Flux 3D has been done (computer simulation was made by Eng. R. Goldstein). One quarter of geometry used for simulation is shown on figure 1. Computer simulation of existing coils allowed us to reveal their drawbacks and new coil design with horizontal cross-over was proposed and its dimensions optimized [1]. Magnetic flux controllers play a critical role in new design (figure 2). Varying concentrators it was possible to achieve optimal distribution of

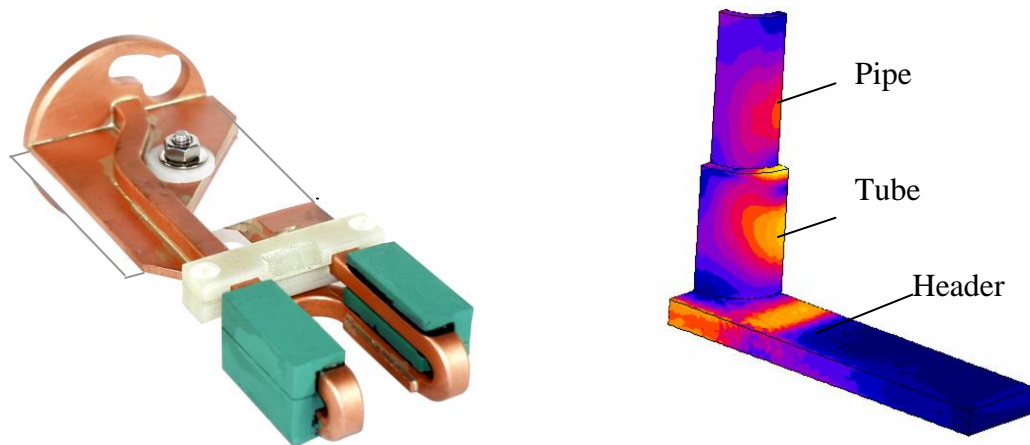


Figure 2. Optimized induction coil with Fluxtrol concentrator (left) and induced current density (right) in a quarter of the joint area

power between heat exchanger header, tube and pipe (figure 2) for several different types of joints using the same copper work.

Practical implementation of new inductors showed high quality of joints and reliable coil performance despite of very high intensities of magnetic field and current loads. In these applications programmed power was delivered by EFD power supplies (frequency 12-15 kHz). Fluxtrol concentrators had good lifetime even when very thin layers of material (1.5 – 2 mm) were used between the coil bottom and heat exchanger header.

Brazing of reverse bents to heat exchangers

Another application was brazing of copper jumpers (reverse bents) to copper nipples of heat exchangers. The main problem in this case was that just under the brazing joint there was the first radiator sheet made of tinned iron. Initial attempts of induction brazing resulted in fast overheating of this sheet. An inductor with a concentrator made from Fluxtrol 50 was designed. An L-shaped concentrator shielded the radiator sheet from magnetic field and concentrated power in the joint area (figure 3). Due to a new design there was no heating of adjacent reverse bents and radiator sheet. An installation consists of transistor generator VGT3-10/66 (10 kW, 66 kHz) (figure 4) and heat station BNK-6 manufactured by Freal.



Figure 3. Brazing of reverse bent



Figure 4. Transistor generator 10 kW, 66 kHz

Generators have manual and automatic control of power level. Digital timer has a time range from 0.1 to 100 sec with a setup step of 0.1 sec. Parameters of two power supplies are shown in Table.

Table. Parameters of transistor power supplies VGT3-10/66 and VChI1-25/66

| Parameter | Power supply | |
|--|-----------------|---------------------|
| | VGT3-10/66 | VChI 1-25/66 |
| Continuos power , kW | 10 | 25 |
| Rated frequency, kHz | 66 | 66 |
| Output voltage, V | 250 | 500 |
| Efficiency at rated power, % | 94 | 94 |
| Dimensions of generator (L x D x H), mm | 440 x 270 x 310 | 440 x 270 x 560 |
| Mass of generator, kg | 12 | 25 |
| Dimensions of heat station (L x D x H), mm | 400 x 400 x 400 | 450 x 400 x 500 |
| Mass of heat station, kg | 18 | 22 |
| Mains voltage | 380 V, 50/60 Hz | 3 x 380 V, 50/60 Hz |

Semi-automatic installation for brazing milling cutters

An installation serves for brazing hard plates to milling cutters (figure 5). Induction coil has a concentrator made of Fluxtrol 50 material. Concentrator improves coil efficiency and power factor and what is the most important, allows to control smoothly power distribution and therefore temperature in brazing area. An installation can work with programmed power delivery during the heating time with temperature stabilization at brazing point using feedback from pyrometer. Power supply frequency is 66 kHz.

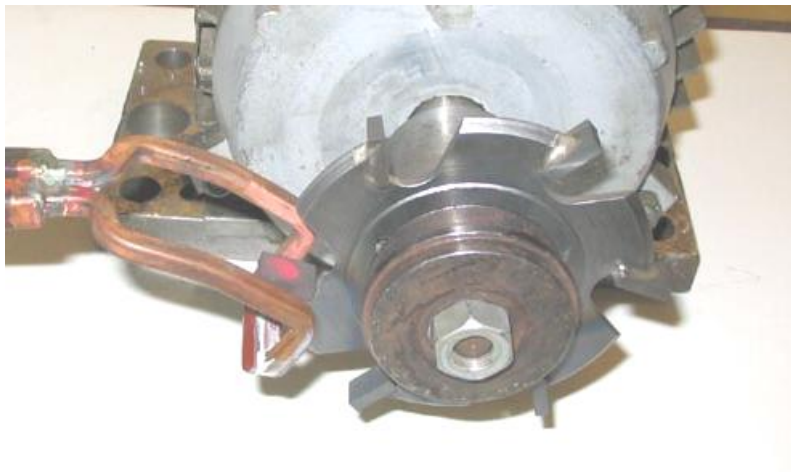


Figure 5. Induction brazing of milling cutter using inductor with Fluxtrol 50 concentrator. Light spot in the centre of brazing plate is from the pyrometer laser pointer.

Brazing of heavy copper busbars

Induction brazing is the most reliable technique for brazing of super-high magnet coils, used in nuclear energy. These coils are made of copper strips, more than 4 meters long with cross-section of 2700 mm² and even more. More than 500 brazing joints must be made in order to manufacture one coil, which has a form of a flat rectangular spiral. Reliable brazing joint may be achieved only under several conditions:

- Small technological gaps between the joining parts;
- Uniform temperature in the whole brazing area;
- Short heating time preventing oxidation.

Because of high thermal conductivity of pure copper, power density must be high. After thermal and electromagnetic simulation special induction installation was designed for Efremov Institute of ElectroPhysical Apparatuses (NII-EFA, St. Petersburg, Russia). An installation consists of solid-state power supply 100 kW, 10 kHz, capacitor battery, movable matching transformer, work table and a set of brazing inductors. Matching transformer with magnetic core made from amorphous strip was installed on a special 3-coordinate frame and connected to capacitor battery with water-cooled cables.

This installation allows brazing of 5 different types of joints using 10 inductors, 8 of which have magnetic flux controllers made of Fluxtrol A magnetodielectric material. Application of magnetic controllers makes possible to achieve required distribution of power between the brazing parts simultaneously improving coil efficiency and power factor. A typical brazing setup may be seen on figure 6. A rectangular inductor with concentrator provides heating of a main long busbar while additional inductor connected in parallel to the same transformer, heats short section of the joint. Copper brazing requires relatively high temperature and very high specific power densities resulting in high flux density in the concentrator. All concentrator worked reliably without overheating. The concentrator was made from separate plates glued to the coil tubing with a special copper-filled epoxy compound, which provided good heat transfer from the concentrator.

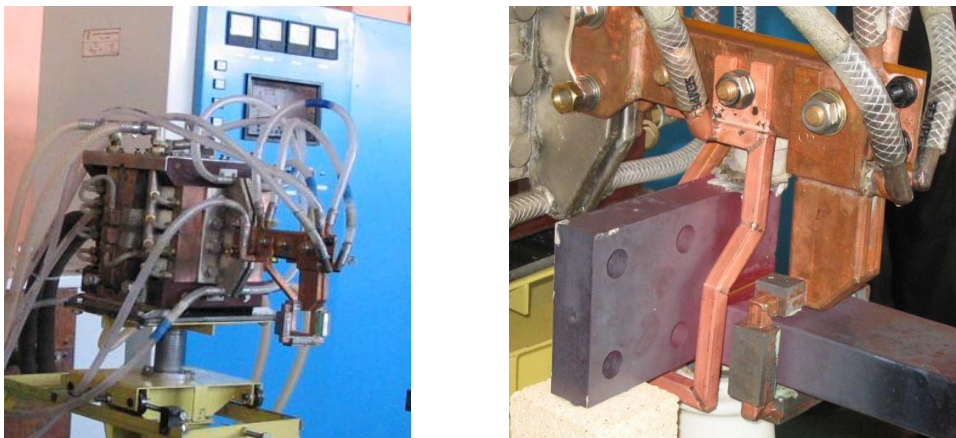


Figure 6. Movable transformer set with attached induction coils (left) and induction brazing process (right)

The installation is very convenient in operation and no changing of transformer ratio or battery capacitance required when brazing all the joints. Utilization of inductors with magnetic flux controllers allowed the user to reduce heating time more than two times and achieve excellent joint quality. Tests of brazed samples showed that yield strength was much higher than control value of 180 N/mm².

Several other induction coils with MDM concentrators have been developed and successfully used in practice. Some of the coil designs were patented.

CONCLUSIONS

There is a variety of small and light power supplies that may be used for induction brazing applications. These power supplies have intelligent control systems and programmed power delivery.

Induction coils design is of critical importance for high-quality brazing especially in the case of aluminum brazing.

Application of magnetic flux controllers improves brazing quality and efficiency of the whole installation. In many cases high quality of brazing joint can not be achieved without flux controllers.

Magnetodielectric materials of Fluxtrol and Ferrotron types proved to be an optimal material for magnetic flux controllers in brazing applications.

REFERENCES

[1] Goldstein, R., Nemkov, V., Ruffini, R. Computer-Assisted Induction Aluminum Brazing. *J. Industrial Heating*, Nov. 2003