TECHNICAL DATA SHEET

MAXIM

Induction heating technology for repair applications

► DESCRIPTION

Company “GMI Aero” has investigated these last years the induction heating process for composite bonding especially in the field of repair.
These developments have always to be adapted according to specificities of the problems submitted. When heating blanket technology can be considered of a general application when heating for bonding , induction principle has to be adapted in terms of power, frequency, coil design according to nature of material to be assembled , surfaces, nature of resin just name some parameters. In this TDS we would like to give you the nature of the technology preceded by a recall chapter on induction principles. Then we suggest possible application and steps of a possible cooperation with a customer.

► THE PRINCIPLE OF INDUCTION HEATING

Induction is a non-contact process, which is an advantage when heating geometrically complex surfaces, thin or thick. By applying the induction process we will eliminate the need to design and manufacture a sensor and patching element that has to conform to complex geometrical profiles. This can be done with the use of an Induction Coil installed at a certain distance from a reference area. Moreover, induction technique allows control of the distribution of heat in order to apply it only to the composite patch and to control the depth of penetration of the heat in the metallic base (skin effect).

Induction heating occurs in ferromagnetic materials when they are exposed to a varying magnetic field. This is the result of the development of currents called Eddy Currents in the material. Heat generation is mainly the consequence of the Joule effect. In general, an induction system constitutes of a power generator, an induction coil, and a susceptor. To generate the eddy currents, a ferromagnetic material must be added to the couple composite - aluminium. This material is called a susceptor. Figure 1 illustrates the effect of induction heating.

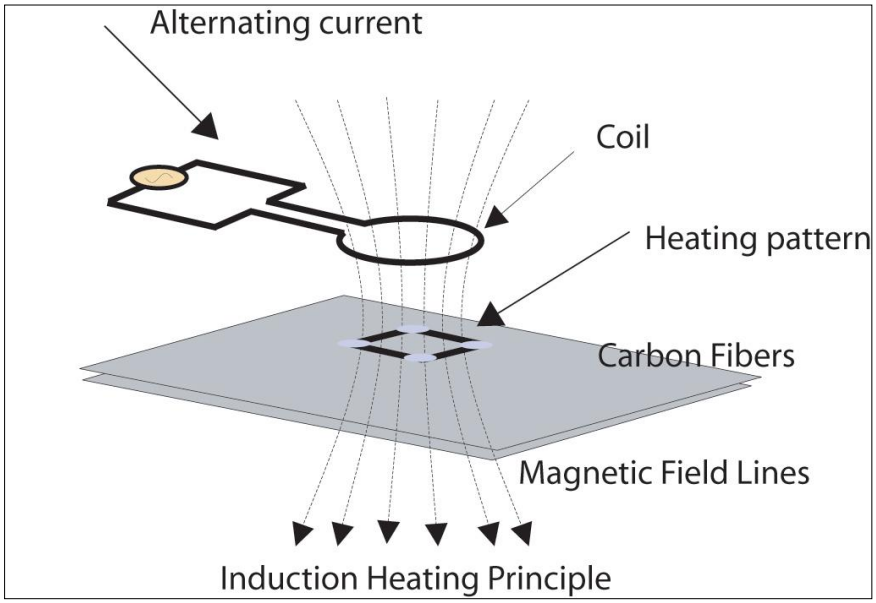


Figure1: Schematic of the induction heating process for curing of composites.

► EQUIPMENT REQUIRED TO INDUCTIVELY HEAT A REPAIR

The main equipment required to inductively heat a repair are:

a. The power generator

The power generator imposes an alternative voltage to the coil circuit. This voltage results in an alternative current that circulates in the closed loop circuit that constitutes the coil. This voltage has a predetermined power and frequency. These variables govern the heat generated inside the susceptor and are represented in terms of heat capacity and penetration depth in the material. Since the system has to generate energy to heat certain quantity of adhesive material up to a reasonable temperature (95 to 120 °C, sometimes 180 °C) while avoiding heating the aluminium base, these two characteristics (power and frequency) have to be optimised within the operation range. Finally, control of the penetration depth of the heat in the aluminium substrate can be achieved through adjustment of the frequency.

b. The coil

The coil is the second element of the system associated with the power generation because it produces the magnetic field, whose profile will command the distribution of the heat induced in the material. A major advantage of the induction heating technology is the coil-design flexibility. The size and shape of an induction coil can be “fit” or matched to the composite part that is to be heated, even for geometrically complex shapes. The coil must be adapted to the surface of interest before heating. It is one advantage of the induction heating process that allows adaptation of the coil to complex surface, shape and geometry. The temperature in the susceptor is dependent of the field distribution.

c. The susceptor

The susceptor is the key element of the system. The susceptor will transfer heat to the repair zone (area to be heated) by conduction. In this configuration, the susceptor must be close to the adhesive film. By nature the susceptor will be metallic and with a high magnetic coefficient, or the reinforcement carbon fibers or carbon nanotubes of the composites can be used.

► TECHNOLOGY DEVELOPED BY GMI AERO

Following several years of R&D, the GMI- MAXIM power supply and induction heating control system was developed by GMI. These developments have been done to investigate and practice:

a) carbon to metal repair by bonding;
b) investigate the use of doped resins;
c) prepare of surface for the following repair. Picture 2.

These works have developed a thorough knowledge of the induction processes applied in the field of composites and technology appropriate.

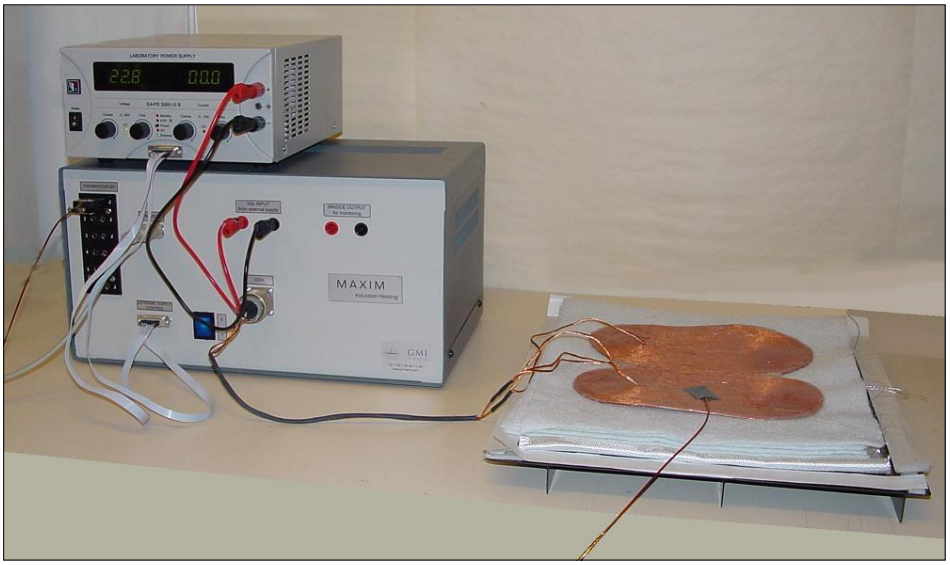


Figure 2: MAXIM power supply and induction heating control system developed by GMI

► ADVANTAGES OF INDUCTION HEATING COMPARED TO CONDUCTIVE HEATING OF REPAIRS

Induction heating is an excellent alternative methodology for heating repairs, as it presents certain advantages compared to conventional conductive heating, which among others include:
a. Minimization of residual stresses and, consequently, better structural behavior of the part, due to heating of significantly smaller areas.
b. Reduction of energy consumption per repair, which is very important in case of repairs of thermoplastics at elevated temperatures (e.g. 400^{o}C).

An example of potential composite to metal repair application using induction heating can be shown in the following Figure:

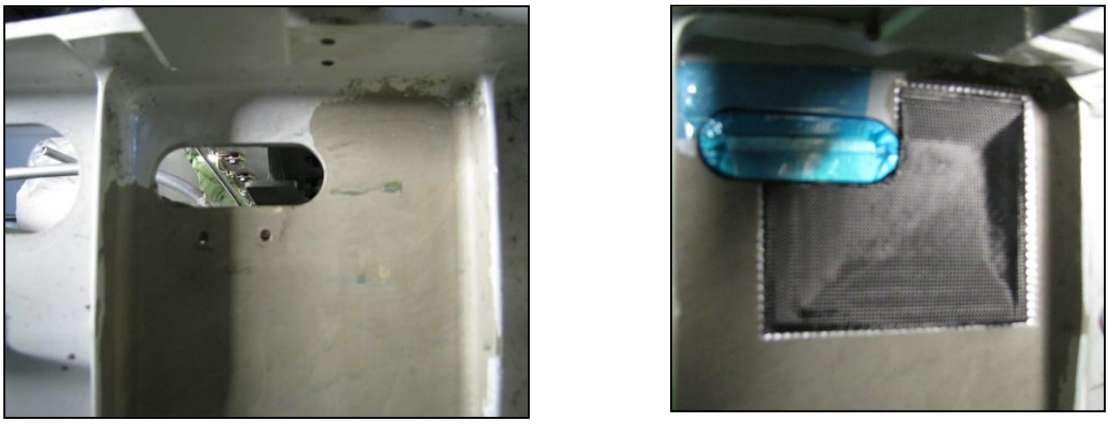
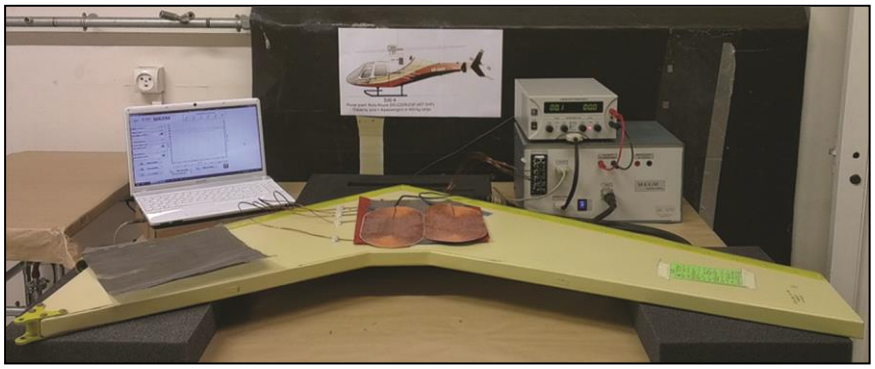


Figure 3: Repair of an ATR-72 aluminium floor beam using a bonded carbon patch, performed in situ by GMI Aero, in cooperation with the ATR company.

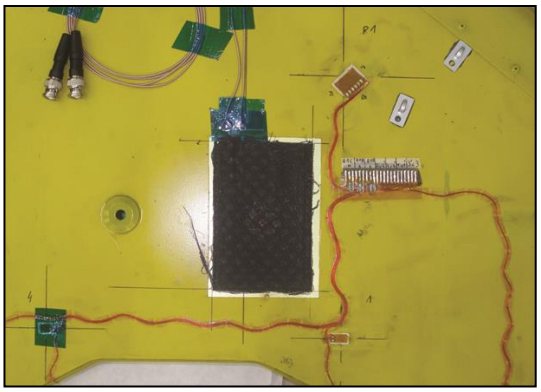
► INDUCTION HEATING REPAIR APPLICATIONS:

Given its versatility and efficiency, induction heating could therefore support composite repair application, for a great variety of cases, namely:

- Classical composite to composite repairs;
- Advanced composite repairs to metallic aircraft structures;
- Repair of thermoplastic composites.



► CONCLUSIONS FOR POSSIBLE COOPERATION



GMI has developed all the required equipment and methodology enabling induction heating of bonded composite repairs. In this context, GMI could further evolve developed technology in order to comply with specific application requirements, through a **tight cooperation** with the end-user. The main steps of such development process would potentially include:

a. Detailed survey and definition of final application requirements / specificities;

b. Optimization of the system, in order to tailor it to the specific application requirements;

c. Induction heating demonstration campaign and process feedback;

d. Writing of induction heating methodology application procedures (user's manual);

e. Training of technical personnel in the induction heating process.

► NOTES

Please contact us for more information for your specific requirements.