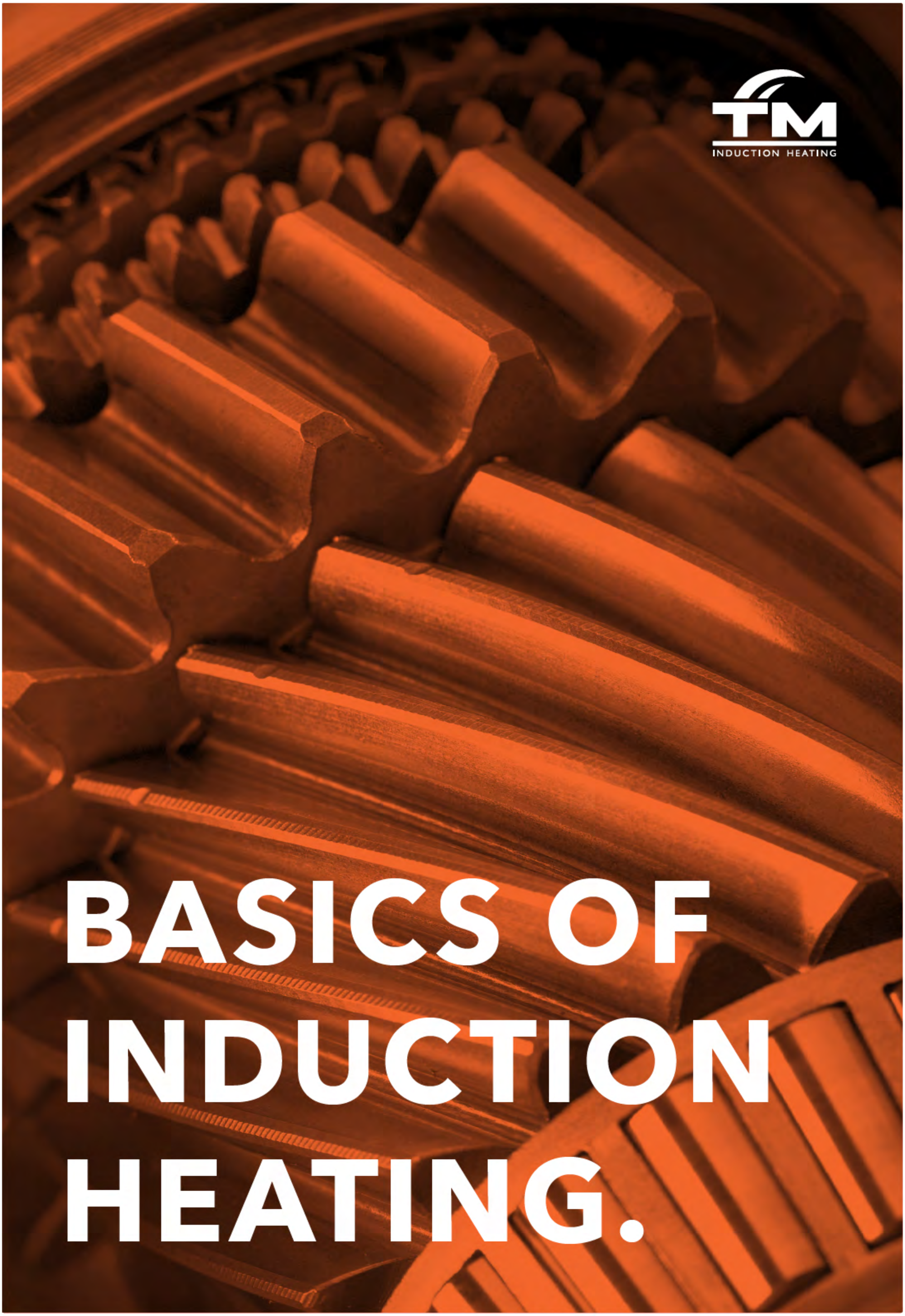


TM INDUCTION HEATING

BASICS OF INDUCTION HEATING.

PRINCIPLE

Induction heating is a physical phenomenon in the area of electromagnetism. It involves the heating of an electrically conducting object (a metal or a material such as carbon or graphite) by electromagnetic induction. An oscillating magnetic field in an electromagnet, the primary coil, induces so-called eddy currents in a short-circuited secondary circuit. This circuit is the workpiece, i.e. the object to be heated. The eddy currents generate heat against the electrical resistivity of the material. In case the material is magnetic, there is a second effect: magnetic hysteresis losses also produce heat in the object. The amount of heat generated depends on the electric power used to create the oscillating magnetic field, the dimensions and geometry of the workpiece and its material properties, and the coupling between the workpiece and the primary coil that generates the electromagnetic field.

APPLICATION

Induction heating can have numerous applications, primarily related to the amount of power induced in the workpiece(s). Examples of high power applications are induction melting, welding, soldering and brazing. Lower power applications include heat treatment such as hardening, and shrink-fitting. The technique can also be used for bonding metal to glass or plastic or for indirect heating, such as in cooking, injection moulding of plastics or sealing of packagings.

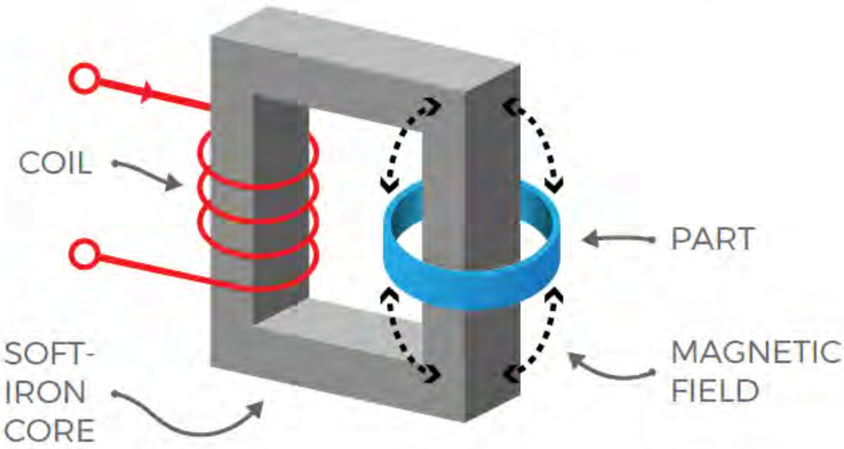
Heat treatment can be applied to such metal products as bearings, gears, bushings, pulleys, couplings, etc. Two procedures can be distinguished:

- **Low frequency induction heating (50 or 60 Hz)**
  This is the most cost-effective solution, based on using the utility frequency. It offers a relatively deep heat penetration, providing a gradual and uniform heating of the workpiece.
- **Mid frequency induction heating (5-500 kHz)**
  This is the solution for high power, localised (sub-surface) heat treatment. At higher frequency the heat penetration will be less deep.

The figures shown on this page present the two mentioned induction configurations.

Figure 1 - a mutual soft-iron core transmits the alternating magnetic field generated by the primary coil (with a large number of windings) to the part under treatment, which acts as a short-circuited, single-winding secondary coil. As the voltage ratio is equal to the ratio of

Fig. 1



the number of windings, while electromagnetic energy is preserved, the secondary coil will provide a low voltage at a high amperage and, hence, generate a lot of heat.

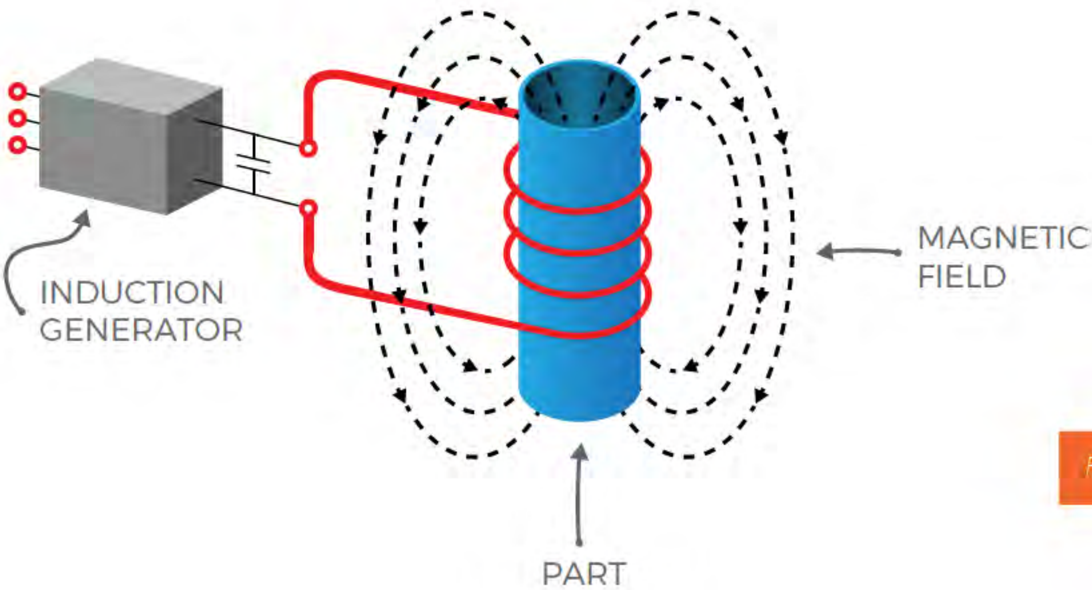


Fig. 2

Figure 2 - the primary coil encloses the workpiece and directly subjects it to the alternating magnetic field.

ADVANTAGES

The essential feature of the induction heating process is that the heat is generated inside the workpiece. No external heat transfer through either conduction or convection is required. The energy is transferred by means of an electromagnetic field, hence there is no contact. For the heating of metal objects the technique of induction heating offers a number of advantages compared to other (conventional) technologies such as flame/torch/furnace/oil bath heating:

- **High speed**
  Applying power leads to immediate heating, without any start-up time causing a delay in the process.
- **High efficiency**
  The heat is generated directly inside the workpiece, without the need for external heat transfer, which keeps energy losses low. The non-productive heating up or cooling down of any equipment is eliminated. When no workpieces have to be processed, the primary current is switched off immediately.
- **High cleanliness**
  There is no contact between the heating source (the primary coil) and the workpiece, which prevents corrosion, contamination by residues, or degradation, for example by a flame.
- **High safety**
  Induction heating can be designed as an intrinsically safe process. There is no external heat source that requires special safety precautions. No oxygen is consumed from the environment, neither are any fumes emitted.
- **Easy control**
  Induction heating is all-electric, which makes it a highly deterministic process. It allows for easy (remote) control including sensor integration and data logging.
- **Consistent quality**
  User-friendly process control can ensure consistent quality of all workpieces. Heating over a specified, well-controlled trajectory will yield stress-free products.
- **Easy integration in production**
  Induction heating equipment requires a modest footprint and provides easy access for the exchange of workpieces. Therefore, the process can be easily integrated in production lines. Moreover, no special precautions such as for operator safety or fume extraction are required.

PROCESS PARAMETERS

The induction heating process can be characterised by a number of process parameters that are related to the exact nature of the product to be heated. These parameters include:

- **Frequency**
  The frequency primarily determines the penetration depth of the induction effect. The higher the frequency is, the shallower the heat penetration will be. So, low frequency is used for large objects, while higher frequencies can be used for smaller workpieces or products of which the treatment requires only shallow penetration (sub-surface heating).

- **Power**
  The electric power inserted in the primary coil determines the magnitude of the heating effect in the secondary coil, i.e. the workpiece. Usually, this parameter is treated as a variable depending on the amount of material to be heated and the temperature to be reached.

- **Temperature setpoint**
  The final temperature that has to be reached in the workpiece is determined by the effect that the treatment must achieve. This temperature can be specified as a single setpoint or as a trajectory that has to be followed to achieve a controlled heating process yielding stress-free products.

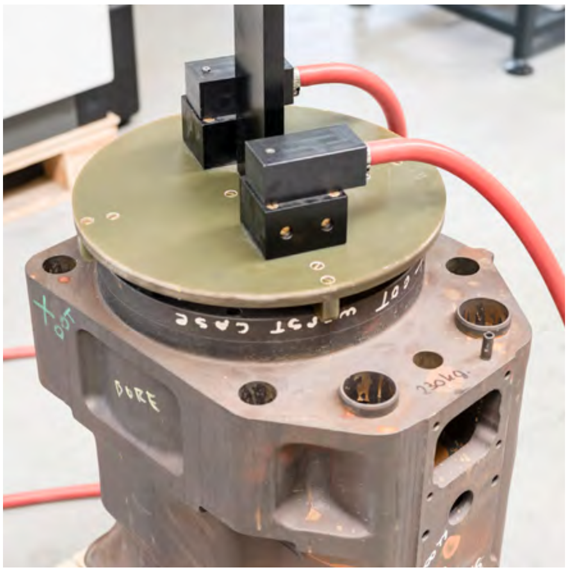


Fig. 3 *Application of a custom mid frequency coil, designed for restoring cylinders in the rolling stock industry.*

Fig. 4 *Interface showing configurable process parameters for a correct heating cycle.*

- **Coil/inductor geometry**
  The geometry of the primary coil, also called the inductor, can be designed to fit the geometry of the workpiece for an optimum induction effect. In any case, the exact coil geometry influences the effectiveness of the induction process.

- **Material properties**
  For induction to take place in a material, it should be electrically conducting. The exact value of its electrical resistivity determines the penetration depth of the induction effect and the amount of heat that is generated by the eddy currents. The material does not have to be magnetic, but if it is magnetic, then a second effect, magnetic hysteresis losses, will add to the heating.

EQUIPMENT

In principle, an induction heater consists of an electromagnet and an electronic oscillator (or the mains supply) that provides the alternating current for generating the magnetic field in the electromagnet, i.e. the primary coil. Industry-ready induction heating equipment also requires materials handling, power cabinet, process control, user interface, cooling, etc. Worldwide, a large number of equipment suppliers offer a wide variety of induction heating solutions. TM Induction Heating distinguishes itself with the cost-effective and innovative design of a range of highly efficient heaters. Typical features include:

- **Energy-efficient operation**
  Heaters can draw heavily on the mains supply when requiring a high current. This load results in a phase shift between current and voltage, described in terms of the power factor (cosφ) becoming smaller than 1. This means that not all input power can be used effectively as 'active power', and consequently the energy efficiency will drop. To compensate for this, a capacitance-based solution has been introduced. This power factor correction limits the phase shift, and hence the loss of active power.

Fig. 5 A completed heating cycle with a specified Delta-T, ensuring a safely heated workpiece.

- **Small footprint**
  In relation to workpiece dimensions, the heaters require a small footprint, which facilitates integration of the induction heating process in production lines.

- **Advanced temperature control**
  Besides a simple temperature setpoint two control modes for gradual heating are available, which can ensure that the products remain stress-free. In ramp heating the power input is gradually increased. The second, so-called Delta-T mode involves two temperature sensors which are used to monitor the temperature difference between the inside and outside of the product. The maximum allowable Delta-T can be specified.

- **User-friendliness**
  All systems are provided with a simple touchscreen interface, which commands multiple languages. The display not only presents the system status (settings, temperature, error number) but in case of an error also the relevant call-to-action.

- **Extensive communication options**
  Ethernet communication can be used for remote read-out and control of all equipment settings. A USB port is avaible for collecting the results from data logging, to facilitate product documentation and traceability.

- **Custom design**
  When required, custom advice and custom design can be provided regarding highly demanding functional specifications or the adoption of the customer's corporate design. Over the years, popular customer requirements have evolved into standard specifications.

TM INDUCTION HEATING

TM Induction Heating was founded in 1992 and has grown to become a leading supplier of induction heating equipment for the automotive, heavy-duty vehicle, railway, windpower, machine building, civil engineering, mining, process and other industries. TM Induction Heating provides its clients with all the benefits of a fast, efficient, contactless and safe heating process that can be easily integrated in production lines. The product portfolio includes low and mid frequency induction heating systems for heat treatment of bearings, gears, bushings, pulleys, couplings, etc.

TM Induction Heating delivers a comprehensive range of standard heaters as well as custom systems which are completely designed to client specification. Building on extensive experience, a worldwide sales & service network and its certified quality systems (ISO 9001:2008 and UL by TüV Rheinland, CE by Certification Experts), TM Induction Heating can offer clients around the globe the right solution to a large variety of industrial heating problems.

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