Energy Efficiency and Conservation Authority
Te Tari Tiaki Pūngao

Technical Information Document

Direct Process Heating
Induction Heating Technologies

Technical Information Document 2019

New Zealand Government

Introduction

Electric induction heating provides a fast, clean, and energy efficient heating solution for processing of electrically conductive materials. Induction heating is fully controllable allowing consistent, repeatable high-quality outputs to be achieved.

Induction technology is used to heat, weld or bond other conductive materials. It can be used to case harden, anneal, braze, harden, soften, temper and extrude metals. Induction can be used for heating ferrous and non-ferrous (mainly aluminium, copper, precious and alloy) metals. Coatings applied to conductive materials can be dried or cured using electric induction. Shrink fitting, stress relieving and forming of metals are other common uses for induction heating.

In the food industry, induction technology is commonly used to provide efficient and highly controllable heating of cooking vessels. Induction heated plates and kilns have been used to heat, dry and cook non-conductive materials such as grains and aggregates.

EECA commissioned Strata Energy Consulting and Efficient Energy International to produce this document which is one of a series on electrical heating.

Technical features

How induction heating works

Induction heating can be compared to an electrical transformer where the magnetic field in a primary winding interacts magnetically with, and induces an electrical current to flow in, the secondary winding. In induction heating, a primary winding (called the inductor) induces an electrical current to flow in the target material to be heated. The electrical resistance of the target material causes heat to be generated when electrical current flows within it.

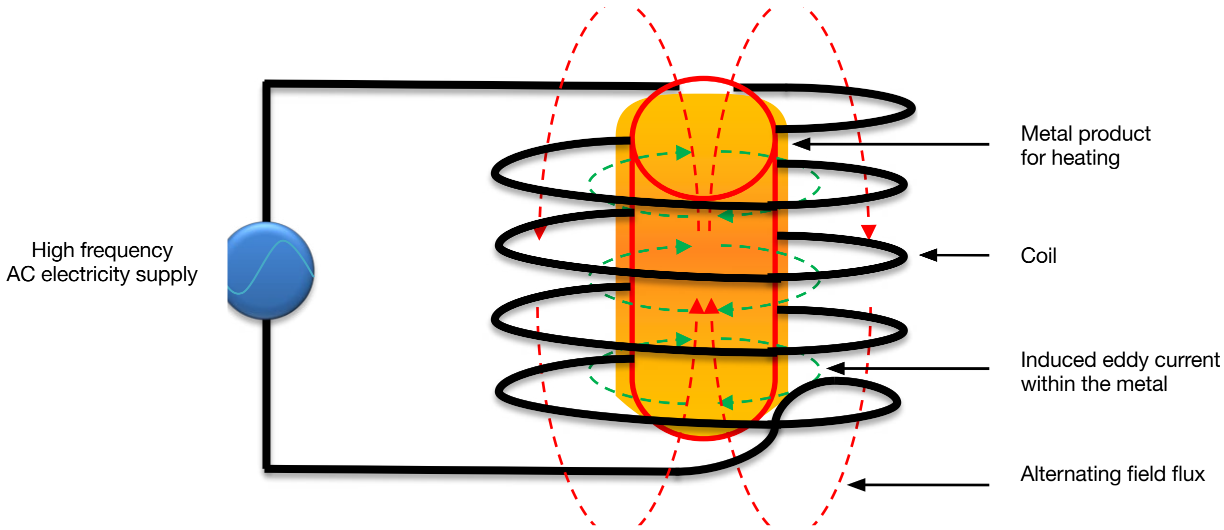


Figure 1. The components of an induction heater
Source: Strata Energy Consulting

A frequency converter changes the electricity supply frequency into frequencies that match specific heating applications. An induction coil (inductor) generates the primary magnetic field at the selected frequency. Moving the target material close to the inductor causes it to heat as electrical 'eddy' currents flow within it.

The converter output power, shape of the induction coil, and the characteristics of the target material determine the heat pattern that occurs within the target material. The frequency of electricity applied at the inductor determines the depth of heat penetration into the target material (the lower frequencies produce deeper penetration).

The inductor's design is important to the induction heating process and the overall efficiency. A wide range of off-the-shelf coils are available from manufacturers. Bespoke coil design and manufacture services are available for specific situations.

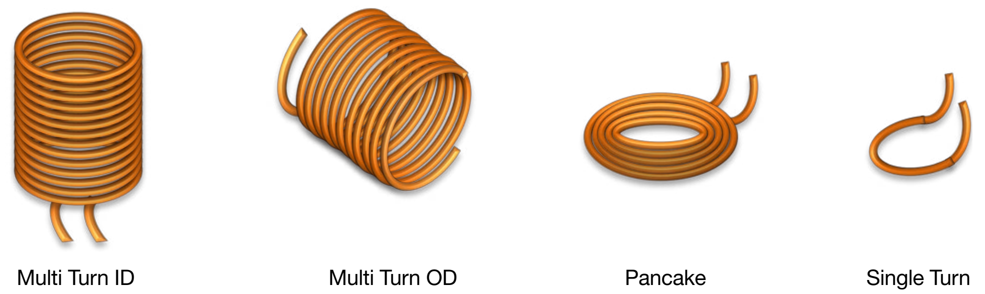


Figure 2. Examples of coil design
Source: Strata Energy Consulting

Examples of induction heating applications

Induction hardening

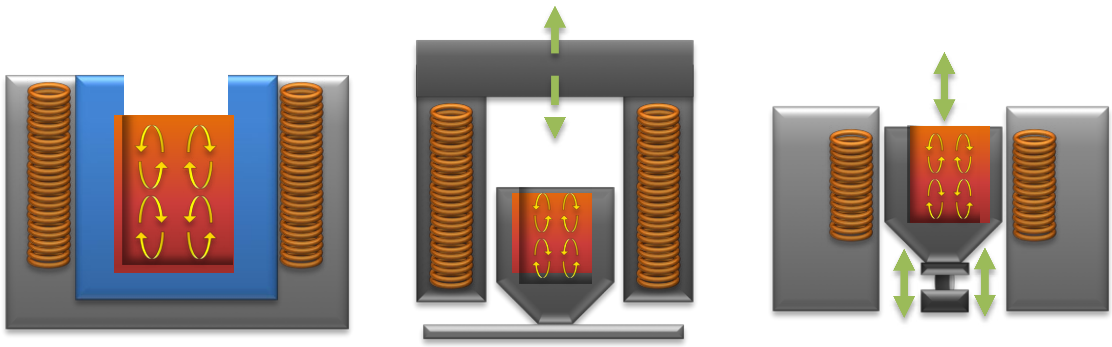
Induction heating technology is ideal for hardening metal through heat treatment because heating can be completed in a few seconds rather than hours using conventional furnaces. The fast heating and compact design allow induction heating equipment to be easily integrated into production processes.

Induction case hardening heats the surface of the metal component. Quenching is then applied to harden the surface of the product. Other heat treatments undertaken using induction technology include: tempering, normalising, stress relieving, carbonitriding, and annealing.

Metal melting

Coreless Induction heating is commonly used to melt and hold ferrous and non-ferrous metals. The simple construction allows easy emptying and restart. High melting rates are generally possible. For aluminium, the use of salt fluxes can be avoided, removing the need to clean flues.

Examples of coreless induction furnace configurations are provided in Figure 3.



Conventional
Melt is poured

Lift Coil
Coils are moved

Push Out
Crucible is moved

Figure 3. Coreless induction Furnace Examples
Source: Strata Energy Consulting

Notes: Coreless induction furnaces are suitable for melting metals such as aluminium and copper alloys.

Channel-type induction furnaces can be used where liquid metal must be held, stored, superheated or poured in large quantities. The coil induces electrical current in the metal located in the channel. As the metal becomes molten it circulates through convection currents into the holding furnace. Continuous circulation maintains molten metal through the furnace.

Benefits obtainable from channel induction furnaces include high efficiency and good mixing of the metals which is particularly important for alloy production.

Channel induction furnaces can be used to process scrap metals, store molten metal and for continuous casting and die-casting. The furnaces are also used for galvanising within the furnace.

Induction welding and bonding

Due to the fast processing speeds achievable with induction technologies, it can be used for welding automated production processes. An example of an automated process is pipe manufacturing where induction can be used for welding pipe seams. In welding applications, electrical currents are induced along the seam to produce a high temperature weld.

Induction welding techniques can also be applied to plastics that are doped with ferromagnetic ceramics or metallic particles. Plastic can also be embedded with electrically conductive fibre (such as metal or carbon). These materials are called susceptors. Electrical currents are induced in the susceptor and the heat generated is transferred to the plastic through thermal conduction. These techniques are used in automotive and aerospace industries.

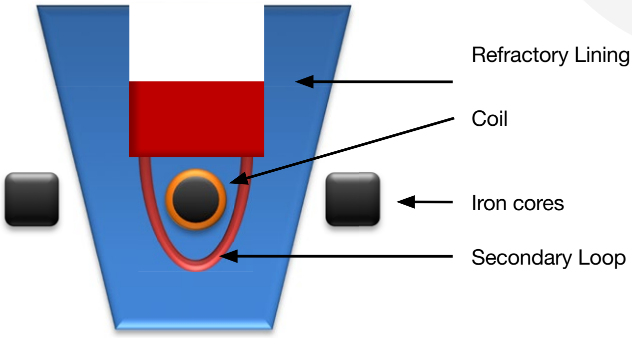


Figure 4. Channel Induction Furnace

Notes: Channel furnaces are suitable for a broad range of uses including zinc melting.

Manufacturers, suppliers and sources of further information

New Zealand suppliers

A small number of New Zealand based companies supply induction equipment for specific application.

International suppliers

Manufacturers of induction equipment operate internationally with the major manufacturers operating global networks.

CN Heating
http://www.cn-heating.com/products/induction-heating-furnace/

EFD Induction
http://www.efd-induction.com/en/Applications.aspx

Induction Heat
http://inductoheat.com/induction-heating/

GH Induction
http://www.ghinduction.com

Radyne
http://radyne.com/what-is-induction/induction-heating-basics/

Heattek
https://www.heattek.com

Ultraflex Power
https://ultraflexpower.com/about-ultraflex

Otto Junker
http://www.otto-junker.de/en/products-technologies/furnaces-for-cast-iron-steel/channel-type-induction-holding-furnaces/

Benefits

Reduced costs

Production yields go up. Swift heat cycles, precise delivery and accurate repeatability minimise waste and scrap. Energy costs go down because you heat only what you need to heat (there are no costly heat losses as with conventional ovens).

Increased throughput

Integrating induction heating into the production line improves production efficiency. Lead times are cut and throughput speeds up. The heating process itself is faster than with open-flame and oven alternatives. Accurate repeatability means increased speed by getting it right the first time.

Quality improvement

The ability to apply pre-set temperatures to pre-set parts of individual workpieces leads to an improvement in quality. Also, because induction coils are tailor-made for specific work-pieces, you know the delivered heat pattern in advance.

Precise heat delivery means any adjoining components and/or materials remain unharmed during the heating process.

Safe

No gas. No open flames. No noticeable increase in ambient temperature. No excessive floor space occupied by ovens; and because induction heating means no hazardous gas and open flames, you can negotiate lower insurance premiums.

Highly Responsive

The heat produced from a frequency converter is instant. It takes less than one second to achieve a uniform surface temperature of 1,000°C on small metal components.

Challenges

Capital costs

Capital costs for induction heating applications can become an initial issue until comparison is made with other options. It is important to value the additional benefits provided by electric induction as this is generally significant.

Energy costs

Electricity costs are higher than natural gas. This can be seen as an initial issue for induction heating. When the energy conversion efficiency of induction and the significant reduction in heat losses are considered, running cost issues may be overcome.

Potential Capacity Requirements

Induction heating will require adequate capacity of electricity supply to be available. For larger units this can be costly if supply transformers, switchgear and cables require upgrading.

Maintenance and servicing

Induction heating equipment generally requires minimal servicing when compared to gas options. Service contracts are generally available from suppliers to undertake servicing and maintenance work.

Availability of equipment

There are many world-wide manufacturers and suppliers of induction heating equipment. Obtaining delivery and installation in New Zealand can be a challenge and potential costs and extended delivery periods should be included in investment decisions.

Application Note

Direct induction heating technologies are suited for use in a broad range of applications including:

induction annealing, bonding, brazing, forging, hardening, melting, preheating, post-heating, tempering and welding, cable and wire heating, coating removal.

Common applications include:

heat treatment of metal frames and platforms, heat treatment for agricultural machinery, soldering and brazing of tips of batteries, terminals and contacts, heat treatment of gears bearings, pulleys and wheels, heat treatment of tools, drills, cutting equipment, pipe welding, annealing and normalizing, hardening and tempering.

Induction metal hardening machines are widely used for surface hardening and tempering of mechanical parts and tools, for example for shafts, gears, axles and valves.

Selecting Equipment

Selecting the right frequency

The choice of frequency is crucial when using induction heating, as frequency determines the heat's penetration depth. Expert advice should be sought to determine the appropriate frequency, or range of frequencies, for each application.

Detailed technical appraisal of each situation is needed to determine both the estimate of the possible benefits and the optimum positioning of the equipment.

Below is the type of information to have ready when making an enquiry:

1. You will need to know the:
   a. type of product material to be heated e.g. steel, copper, brass, etc.
   b. workpiece dimensions.
   c. desired production rate.
2. Description of the product or range of products.
3. Description of the production process:
   a. continuous flow or batch.
   b. product throughput: weight, volume, size etc.
   c. input and output requirements e.g. start and finish temperature.
   d. tolerable temperature range.
   e. any special features.
4. Reasons for investigating induction heating.
5. Existing heating method and its costs (if applicable).
6. Current process constraints or quality issues.
7. Benefits required to be delivered.

Indicative costs of direct induction heating

Capital purchase costs

Due to the broad range of induction equipment, processes and applications it is not possible to provide meaningful indicative capital costs for purchasing equipment for all applications. The following are examples of purchase costs for a selection of induction heating equipment.

Coreless induction furnace

A price of $1,500 /kW can be used to provide an initial indication of the purchase cost. This cost includes an allowance for power supplies, furnace, auxiliaries and installation. This is a rule of thumb guide only to indicate the potential order of capital cost. Decisions to invest should not be made on the basis of this value.

Channel induction furnace

A price of $1,000 /kW can be used to provide an initial indication of the purchase cost and a furnace capacity loading of 100 kW/tonne/hr. This is a rule of thumb guide only to indicate the potential order of capital cost. Decisions to invest should not be made on the basis of this value.

Induction heat treatment

The equipment capital cost depends on the frequency needed to obtain the treatment's required penetration and temperature. The cost of material handling gear also needs considering and this can be a material cost. Because of the wide variations in configuration, it is not possible to provide a price guide. It is advisable to obtain advice and prices from several equipment suppliers as costs can be variable. Also see the links to suggested case studies.

Induction welding of pipe seams

A wide range of pipe welding equipment is available internationally. The capital and installation cost will depend on the specific application, the frequency required and the speed of welding process. Smaller production units can be in the tens of thousands of dollars with larger units in the millions.

Calculating energy costs

Due to the broad range of induction heating equipment and their applications, determining operating costs can be complex. However, an initial estimate can be calculated by determining the following:

- The energy required to heat/melt the product
- The speed at which the metal is to be heated
- The duration of any handling and holding time
- An estimate of the overall production efficiency (including the energy to heat conversion of the induction equipment and any heat losses during the heating process) (%) - for induction heating, the efficiency is typically around 70%.

An indication of the KVA capacity of induction equipment required can be determined by multiplying the area to be heated by the power density of the metal (W/mm^2) and making an adjustment for power factor and the overall efficiency of energy conversion. Manufacturers and suppliers will be able to assist with determining the capacity of equipment for specific applications.

An indication of the energy used to heat or melt metal can be calculated from the capacity rating of the induction equipment, the heating time required, and the overall efficiency of the heating process.

kWh = (kW capacity x (time to heat/melt + handling time)) / % efficiency.

Heating and handling time needs to be in hours = seconds/3,600.

For comparison with alternative options such as gas furnaces and electric resistance furnaces, the heating times will increase (as induction is faster) and the overall efficiency may be less (if heat losses are greater). Again, the estimate is application specific and dependent of the equipment selected. Manufacturer and supplier advice should be sought.

Impact on CO_2 emissions

Electric induction heating will not directly produce any GHG emissions, but the electricity used to produce the heat may have been generated from non-renewable sources that GHG. In New Zealand, the proportion of non-renewable generation is low, therefore the GHG impact of electric induction heating will be much lower than for gas or other fossil fuel ovens.

Climate change gas rule of thumb comparison:

Electricity

CO_2 = kWh consumed x 0.1

For every 100 kWh of electricity used 10 kg of CO_2 is emitted.

Gas

CO_2 = kWh consumed x 0.216

For every 100 kWh of gas used 21 kg of CO_2 is emitted.

In summary, electric induction will generally use less energy than an equivalent gas furnace, and because electricity emits approximately half the CO_2, electricity will reduce CO_2 emissions by at least 50%.

Case studies

Case studies on various applications of induction heating are available from:

Case Study: GH Group

one of the largest experienced induction heating companies in the world with headquarters in Valencia, Spain. The website provides several case studies of applied induction heating in manufacturing industries.

http://www.ghinduction.com/1-machine-tools-3/

Case Study: Comdel RF power technology

Produces power and frequency conversion equipment used in induction heating applications. The website provides a case study example of a metal hardening manufacturer and marketer of replacement parts, equipment, and accessories for the forestry industries.

http://www.comdel.com/case-study-induction-heating

Case Study: Ultraflex Power Technologies

produce induction heating equipment for a broad range of applications. The website provides many case studies for a wide range of applications. Many applications are relatively small scale and likely to be applicable to New Zealand engineering and manufacturing businesses. For example this 400 W induction coil is used to shrink fit Teflon insulation onto a wire by heating a stainless steel pipe as a susceptor using induction.

Ultraflex Power Technologies applied induction technology for the preheating 10 mm quartz glass tube up to over 800°C using a graphite susceptor. The heating occurs in under 100 seconds allowing the quartz glass to be hot formed. A 5kW induction unit has been used for this application.

For more case studies and information visit:
ultraflexpower.com
https://ultraflexpower.com/induction-heating-applications/melting-of-metal/

Induction Coil
Source: Ultraflex Power Technologies

Hot formed quartz glass using a graphite susceptor
Source: Ultraflex Power Technologies

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