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Induction Heating: Its Applications In Dairy Industry

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Induction heating is a non-contact heating process. It uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact, the heating process does not contaminate the food material being heated. It is also very efficient since the heat is actually generated inside the work-piece (sample). This can be contrasted with other heating methods where heat is generated in a flame or heating element, which is then applied to the work-piece. For these reasons Induction heating lends itself to some unique applications in food, dairy and other industry here heating in carried out.

Induction heating was first noted when it was found that heat was produced in transformer and motor windings. The basic principles of **induction heating** have been understood and applied to manufacturing since the 1920s. During World War II, the technology developed rapidly to meet urgent war time requirements for a fast, reliable process to heat the material. More recently, the focus on lean manufacturing techniques and emphasis on improved quality control have led to a rediscovery of induction technology, along with the development of precisely controlled.

What makes this heating method so unique?

In the most common heating methods, a torch or open flame is directly applied to the metal part. But with induction heating, heat is actually "induced" within the part itself by circulating electrical currents.

Induction heating relies on the unique characteristics of **radio frequency (RF) energy,** that portion of the electromagnetic spectrum below infrared and microwave energy. Since heat is transferred to the product via electromagnetic waves, the part never comes into direct contact with any flame, the coil itself does not get hot, and there is no product contamination. When properly set up, the process becomes very repeatable and controllable.

Induction heating allows the targeted heating of an applicable item for applications including surface hardening, furnace, cooking, steam generation, heat treatment, melting, brazing and soldering and heating to fit. Iron and its alloys respond best to induction heating, due to their ferromagnetic nature.

HOW INDUCTION HEATING WORKS

It helps to have a basic understanding of the principles of electricity. When an alternating electrical current is applied to the primary of a transformer, an alternating magnetic field is created. According to **Faraday's Law**, if the secondary of the transformer is located within the magnetic field, an electric current will be induced.

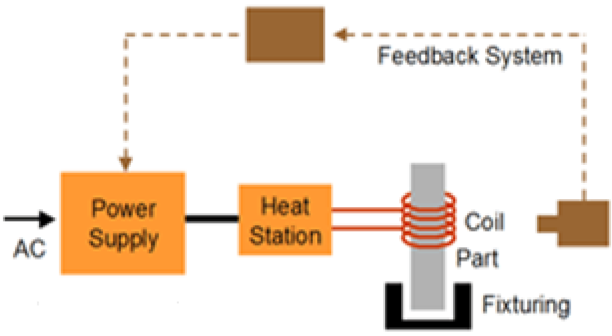

Fig 1:Typical Induction heating setup

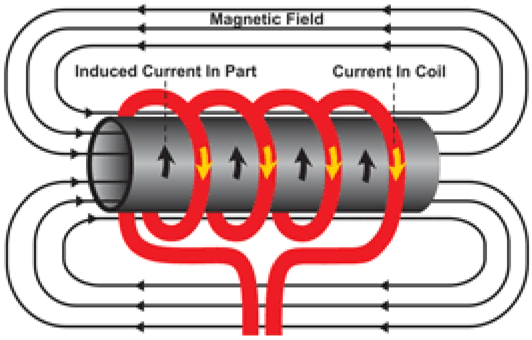

Fig 2: eddy current flow

In a basic induction heating setup shown (Fig 1), a solid state RF power supply sends an AC current through a copper coil (inductor), and the part to be heated (the workpiece or flow of liquid) is placed inside the coil. The coil serves as the transformer primary and the part to be heated becomes a short circuit secondary. When a metal part is placed within the induction coil and enters the magnetic field, circulating eddy currents are induced within the part.

As shown in the second diagram (Fig 2), these eddy currents flow against the electrical resistivity of the metal, generating precise and localized heat without any direct contact between the part and the coil. This heating occurs with both magnetic and non-magnetic parts, and is often referred to as the "**Joule effect**", referring to Joule's first law – a scientific formula expressing the relationship between heat produced by electrical current passed through a conductor. The losses produced by resistance are based upon the basic electrical formula: $P = i^2R$, where i is the amount of current, and R is the resistance. Because the amount of loss is proportional to the square of the current, doubling the current significantly increases the losses (or heat) produced.

Secondarily, additional heat is produced within magnetic parts through **hysteresis –** internal friction that is created when magnetic parts pass through the induction coil. Magnetic materials naturally offer electrical resistance to the rapidly changing magnetic fields within the coil. This resistance produces internal friction which in turn produces heat.

In the process of heating the material, there is therefore no contact between the coil and the part, and neither are there any combustion gases. The material to be heated can be located in a setting isolated from the power supply; submerged in a liquid, covered by isolated substances, in gaseous atmospheres or even in a vacuum.

IMPORTANT FACTORS TO CONSIDER

The efficiency of an induction heating system for a specific application depends on several factors: the characteristics of the part itself, the design of the induction coil, the capacity of the power supply, and the amount of temperature change required for the application.

1. The Characteristics of the Part

a) Metal or Plastic:-

First, induction heating works directly only with conductive materials, normally metals. Plastics and other non-conductive materials can often be heated indirectly by first heating a conductive metal susceptor which transfers heat to the non-conductive material.

b) Magnetic or Non-Magnetic

It is easier to heat magnetic materials. In addition to the heat induced by eddy currents, magnetic materials also produce heat through what is called the hysteresis effect. This effect ceases to occur at temperatures above the "**Curie**" point - the temperature at which a magnetic material loses its magnetic properties. The relative resistance of magnetic materials is rated on a “permeability” scale of 100 to 500; while non-magnetics have a permeability of 1, magnetic materials can have a permeability as high as 500.

c) Thick or Thin

With conductive materials, about 85% of the heating effect occurs on the surface or "skin" of the part; the heating intensity diminishes as the distance from the surface increases. So small or thin parts generally heat more quickly than large thick parts, especially if the larger parts need to be heated all the way through.

Research has shown a relationship between the frequency of the alternating current and the heating depth of penetration: the higher the frequency, the shallower the heating in the part. Frequencies of 100 to 400 kHz produce relatively high-energy heat, ideal for quickly heating small parts or the surface/skin of larger parts. For deep, penetrating heat, longer heating cycles at lower frequencies of 5 to 30 kHz have been shown to be most effective.

d) Resistivity

If you use the exact same induction process to heat two same size pieces of steel and copper, the results will be quite different. Why? Steel – along with carbon, tin and tungsten – has high electrical **resistivity**. Because these metals strongly resist the current flow, heat builds up quickly. Low resistivity metals such as copper, brass and aluminum take longer to heat. Resistivity increases with temperature, so a very hot piece of steel will be more receptive to induction heating than a cold piece.

2. Induction Coil Design

It is within the induction coil that the varying magnetic field required for induction heating is developed through the flow of alternating current. So **coil design** is one of the most important aspects of the overall system. A well-designed coil provides the proper heating pattern for your part and maximizes the efficiency of the induction heating power supply, while still allowing easy insertion and removal of the part.

3. Power Supply Capacity

The size of the induction power supply required for heating a particular part can be easily calculated. First, one must determine how much energy needs to be transferred to the work-piece. This depends on the mass of the material being heated, the specific heat of the material, and the rise in temperature required. Heat losses from **conduction**, **convection** and **radiation** should also be considered.

4. Degree of Temperature Change Required

Finally, the efficiency of induction heating for specific application depends on the amount of temperature change required. A wide range of temperature changes can be accommodated; as a rule of thumb, more induction heating power is generally utilized to increase the degree of temperature change.

CHARACTERISTICS OF INDUCTION HEATING

Process technical

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- ✓ Because of the high power density an induction installation can be compact and realise a quick heating.
- ✓ Induction offers the possibility to reach very high temperatures
- ✓ Induction heating can be applied very locally
- ✓ Induction installations are suited for automation

Energy consumption

- ✓ Induction installations generally have a good efficiency. However, the efficiency also
- ✓ Depends on the characteristics of the material to be heated.
- ✓ An important part of the heat losses can be recuperated

Area	Gas	Electricity
	BTU/hour	Induction/ hour
Small:	5,000	0.70 kW
Medium:	9,000	1.25 kW
Large:	12,000	1.70 kW
	18,000	2.10 kW

Quality

- ✓ Extreme purity is possible by working under vacuum or inert atmospheres
- ✓ The place of heating can be determined accurately
- ✓ The heating can be regulated precisely

Environment and working conditions

- ✓ No production of flue gasses

Limitations

- ✓ An induction installation usually implies a big investment that must be considered and compared to alternative heating techniques.
- ✓ Induction heating is preferably used for heating relatively simple shapes.

WHAT IS REQUIRED FOR INDUCTION HEATING?

In theory only 3 things are essential to implement induction heating:

1. A source of High Frequency electrical power,
2. A work coil to generate the alternating magnetic field,

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3. An electrically conductive work-piece to be heated,

Having said this, practical induction heating systems are usually a little more complex. For example, an impedance matching network is often required between the High Frequency source and the work coil in order to ensure good power transfer. Water cooling systems are also common in high power induction *heaters* to remove waste heat from the work coil, its matching network and the power electronics. Finally some control electronics is usually employed to control the intensity of the heating action, and time the heating cycle to ensure consistent results. The control electronics also protects the system from being damaged by a number of adverse operating conditions. However, the basic principle of operation of any induction heater remains the same as described earlier.

APPLICATIONS

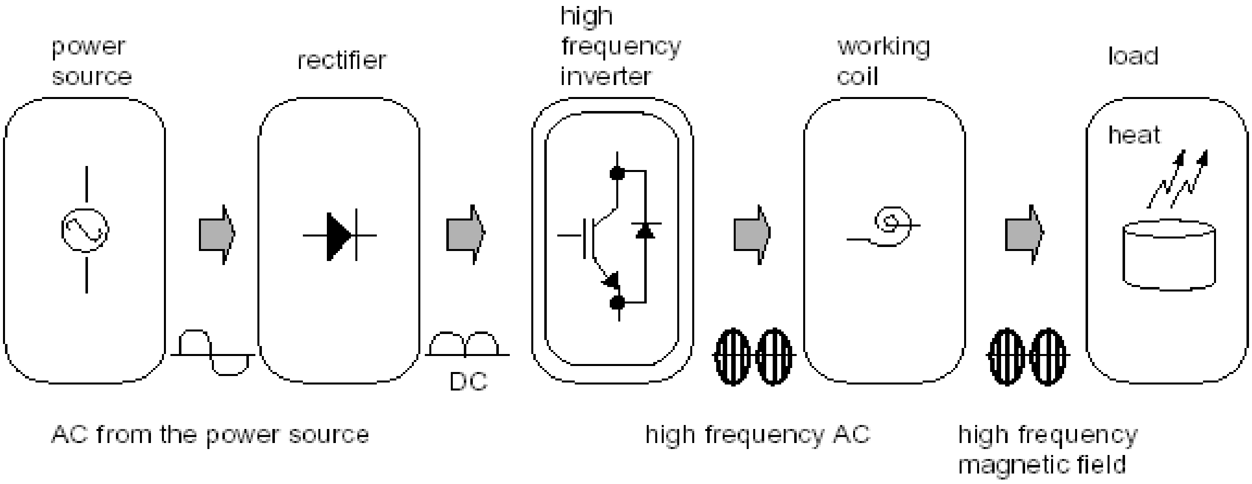
Induction heating allow the targeted heating of an applicable item for applications including surface hardening, melting, brazing and soldering, steam generation, induction sealing, induction cooking, heat treatment and heating to fit the joints etc., Iron and its alloys respond best to induction heating, due to their ferromagnetic nature. Eddy currents can, however, be generated in any conductor, and magnetic hysteresis can occur in any magnetic material. Induction heating has been used to heat liquid conductors (such as molten metals) and also gaseous conductors. Induction heating is often used to heat graphite crucibles (containing other materials) and is used extensively in the semiconductor industry for the heating of silicon and other semiconductors. Supply frequency (mains, 50/60 Hz) induction heating is used for many lower cost industrial applications as inverters are not required.

INDUCTION COOKING

In induction cooking, an induction coil in the cook-top heats the iron base of cookware. Copper bottomed pans, aluminium pans and other non-ferrous pans are generally unsuitable.

OPERATING THEORY OF AN IH RICE COOKER

This concept can be simplified as follows. First, convert the AC current coming from the power source to DC using a rectifier. Then, connect this DC current to a high frequency switching circuit to administer high frequency current to the heating coil. According to Ampere’s Law, a high frequency magnetic field is created around the heated coil. If a conductive object, e.g. the container of a rice cooker is put inside the magnetic field, then induced voltage and an eddy current are created on the skin depth of the container as a result of the skin effect and Faraday's Law. This generates heat energy on the surface of the container. Rice is cooked by using this heat energy.



The heat induced in the base is transferred to the food via conduction. Once the pan is removed from the cook-top, the energy transfer stops. The result is a flame-less method of cooking. Changing cooking temperatures is achieved quickly because there is no wait for the hob to heat up, only the pan. Less heat is lost into the air, resulting in a more efficient means of cooking. Also the induction cookers include efficiency, safety (the induction cook-top is not heated itself) and speed. Drawbacks include the fact that non-metallic cookware such as glass and ceramic cannot be used on an induction cook-top. Both installed and portable induction cookers are available.

STEAM GENERATION

Fossil fuels are burned as heat sources for large steamers**.** Is not economical large scale production of steam and also it is discharges huge amount of flue gases. Short interaction times to reach the required temperature. Several hundred degrees can achieve. Reduced thermal distortion and damage in the processing plant. Induction steam generator can be used in following industries Clothing, Dry-cleaning, Dairy and Food Processing, Baking, Dairying, Catering and Fur Industries and in Research Centers and Hospitals. Also for Industrial Process Heating, Steam Baths, Humidification, Heat Treatment Processes, Steam Cleaning, Soil Treatment, Rubber Industries, Chemical, Timber Treatment, & wherever Steam is required.

Steam Demand Growth can be met by adding additional generators to operate either in parallel or adjacent to individual process operations. This is a great energy saver and also reduces cost of your production. Generators do not require a boiler room or special foundations or local authorities' approvals, it can be installed anywhere adjacent to users of steam, so it produces a saving on pipe installation work, materials, maintenance. An induction steam generator as show bellow.

120kW Electric Steam Generator & Superheater 300°C

INDUCTION SEALING

Induction sealing, otherwise known as cap sealing, is a non-contact method of heating a metallic disk to hermetically seal the top of plastic and glass containers. This sealing process takes place after the container has been filled and capped.

The closure is supplied to the bottler with foil liner already inserted. Although there are various liners to choose from, a typical induction liner is multi-layered. The top layer is a paper pulp that is generally spot-glued to the cap. The next layer is wax that is used to bond a layer of aluminum foil to the pulp. The bottom layer is a polymer film laminated to the foil. After the cap or closure is applied, the container passes under an induction coil, which emits an oscillating electromagnetic field. As the container passes under the induction coil (sealing head) the conductive aluminum foil liner begins to heat. The heat melts the wax, which is absorbed into the pulp backing and releases the foil from the cap. The polymer film also heats and flows onto the lip of the container. When cooled, the polymer creates a bond with the container resulting in a hermetically sealed product. Neither the container nor its contents are affected, and this all happens in a matter of seconds.

There are a variety of reasons companies choose to use induction sealing:

- Tamper evidence
- Leak prevention
- Freshness Retention
- Pilferage protection
- Sustainability
- Production Speed

Efficiency

- Induction heating results in the highest energy efficiency.

Efficiency of Cooking Methods	
Cooking Method	**Efficiency**
Induction	90%
Halogen	58%
Electric	47%
Gas	40%

Advantages of induction heating

- Heating speed linked to the possibility of obtaining very high power density,
- The possibility to heat at very high temperatures with an efficiency practically independent of the temperature,
- Easy automation of equipment,
- Absence of thermal inertia (rapid start-up),
- Repeatability of operations carried out,
- Often extremely high heating efficiency,
- Absence of pollution from the source of heating (cold source),
- Good working conditions

Drawbacks

- Big investment cost
- High Frequency electrical power
- Induction heating is preferably used for heating relatively simple shapes.
- Non-ferrous cookware such as copper, aluminum and glass cannot be used on an induction cook-top.

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