

Induction Heating

Final Year Project – B.Tech (Electrical & Power Engineering)

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Abstract

Induction heating is an efficient heating method for electrically conductive materials. It uses eddy currents generated by a varying magnetic field. Since the discovery of electromagnetic induction by Michael Faraday in 1831, induction heating has been widely applied in industrial processes such as transformers, motors, generators, and metal heating. Modern induction heaters use solid-state converters with IGBT and MOSFET devices for high- frequency and medium-power applications. The proposed induction heater is designed primarily for bearing mounting but can also heat other metal workpieces such as gears, pulleys, bushings, and shrink rings. The system offers safe, efficient, and user-friendly operation with a reduced risk of incorrect mounting. A microcontroller- based control system improves the flexibility and reliability of the heating process. Continuous induction heating provides high production rates, reduced space requirements, and suitability for industrial applications operating continuously for long durations.

Keywords: *induction heater, bearing, gear, flexibility, reliability, microcontroller, workpiece*

Introduction

Induction heating (IH) is a method of heating electrically conductive materials that takes advantage of the heat produced by eddy currents generated within the material. It has many advantages compared to other heating systems (e.g., gas- and oil-fired furnaces), such as quicker heating, faster start-up, greater energy savings, and higher production rates. Research conducted in recent years into specific power supplies for this application, along with the development of numerical and computational methods and the decreasing cost of these systems, has led to the widespread adoption of induction heating in many processes and applications, such as cooking, automotive sealing, motor heating, paper making, tube and bar heating, and aluminum melting.

Since Michael Faraday discovered electromagnetic induction in 1831, this phenomenon has been widely studied in many applications, such as transformers and other magnetic designs. The basic electromagnetic phenomenon upon which an induction heater relies has been extensively described and discussed. An induction heater consists of an electromagnet and an electronic oscillator that passes a high-frequency alternating current (AC) through the electromagnet. The rapidly alternating magnetic field penetrates the object, generating electric currents inside the conductor called eddy currents. These eddy currents flowing through the resistance of the material heat it by Joule heating.

In ferromagnetic and ferrimagnetic materials such as iron, heat may also be generated by magnetic hysteresis losses. The frequency of the current used depends on the object size, material type, coupling between the work coil and the object to be heated, and the penetration depth. An important feature of the induction heating process is that heat is generated inside the object itself rather than by an external heat source via conduction. As a result, objects can be heated very rapidly. Furthermore, there is no need for any external contact, which is important where contamination is a concern.

Induction heating is used in many industrial processes, such as heat treatment in metallurgy, crystal growth, and zone refining in the semiconductor industry, and for melting refractory metals that require very high temperatures. It is also used in induction cooktops for heating containers of food — a process known as induction cooking. This

induction heater is designed to heat bearings that are mounted with an interference fit onto a shaft. The heat causes the bearing to expand, which eliminates the need to use force during installation. A temperature difference of approximately 90°C (194°F) between the bearing and the shaft is generally sufficient to enable installation.

1.1 Principle

The most basic elements of an induction heating system are the workpiece (the piece to be heated) and the inductor, or coil, that produces the magnetic field needed to generate heat. The inductor and the workpiece can take various shapes, and the workpiece is usually placed inside the coil to achieve better coupling. In this study, which is focused on the heating of round wire, the inductor used is a solenoid and the workpiece is a round wire. The induction heating phenomenon is based on two mechanisms of energy dissipation:

1) Energy Losses Due to the Joule Effect

When an alternating voltage is applied to an inductor coil, an alternating current is generated in the coil. This current produces an alternating magnetic field (Ampere's Law) that induces a voltage in the workpiece, which opposes the variation of the magnetic field (Lenz's Law). This voltage creates a current in the workpiece called eddy currents or Foucault currents, which have the same frequency but the opposite direction to the original current. These eddy currents produce heat in the workpiece by the Joule effect.

2) Energy Losses Due to Hysteresis

These losses are caused by friction between magnetic dipoles when ferromagnetic materials are magnetized alternately in opposite directions. They appear in ferromagnetic materials below their Curie temperature — the temperature at which materials become non-magnetic.

3.1 Methods of Induction Heating

Induction heating is accomplished using two primary methods. The first method is referred to as eddy current heating, which results from the I²R losses caused by the electrical resistivity of the workpiece material. The second method is referred to as hysteretic heating, in which energy is produced within a component by the alternating magnetic field generated by the coil, which continuously modifies the component's magnetic polarity. Hysteretic heating occurs in a component up to the Curie temperature, at which point the material's magnetic permeability decreases to 1 and hysteretic heating is significantly reduced. Eddy current heating then constitutes the remaining induction heating effect.

When the direction of an electrical current (AC) changes, the magnetic field it generates collapses and is regenerated in the reverse direction. When a second conductor is positioned within that alternating magnetic field, an alternating current is induced in it. The current transmitted through the second conductor and that through the first are proportional to each other and inversely proportional to the square of the distance between them.

When the wire in this model is replaced with a coil, the alternating current in the coil generates an electromagnetic field. When a workpiece to be heated is placed within this field, it acts as the second conductor and an alternating current is induced in it. The I²R losses arising from the electrical resistivity of the workpiece material cause heat to be generated within the workpiece. This effect is known as eddy current heating.

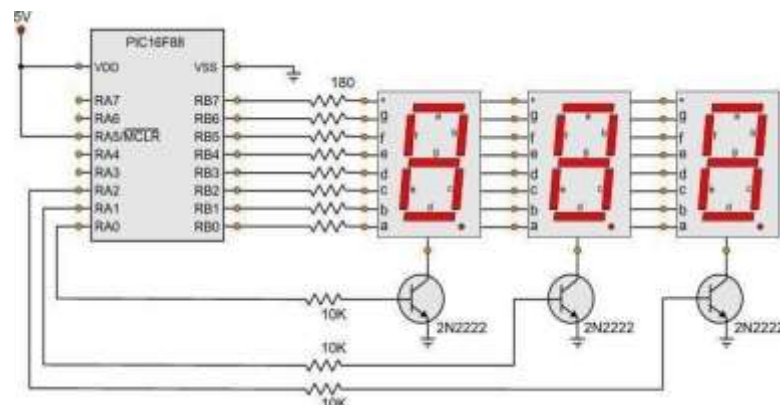
2. Controller Side

2.1 Microcontroller

Microcontrollers are used in automatically controlled products and devices. A microcontroller is a small, programmable controller that is equivalent to a single-chip computer. It is embedded in other systems to act as a processing and control unit.

A 7-segment display has a total of 10 pins and may be configured as either common anode or common cathode. Of the 10 pins, the two middle pins — pin numbers 3 and 8 — are the common anode and are internally shorted. Since interfacing a 7-segment display requires more than 12 pins, which exceeds the capacity of the standard 8051

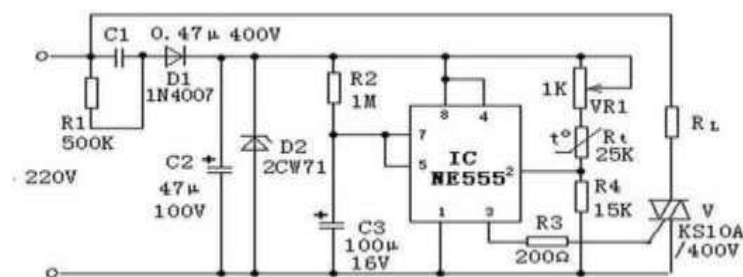
Microcontroller, the AT89C2051 was used instead. The interfacing of a 3- digit 7-segment display with the 8051 Microcontroller is shown in Figure 3.4. Transistor Q1 drives display 1, Transistor Q2 drives display 2, and Transistor Q3 drives display 3. According to the concept of multiplexing, data corresponding to digit 1 must be presented when display 1 is enabled. The program continuously displays '321' on the three 7-segment displays.



MICROCONTROLLER WITH 3 DIGIT DISPLAY

3.2 Temperature Controller

A temperature controller is a device used to maintain a desired temperature at a specified value. The simplest example of a temperature controller is commonly found in homes. For instance, hot water heaters use a thermostat to control the temperature of the water and maintain it at a set value.



TEMPERATURE CONTROL

3. Results

Table 1: Core Diameter vs. Temperature Performance

S.No	Core Diameter Range	Temperature Control	Time to Temperature	Max. Temperature
1	0–100 mm (0–3.9 in)	Up to 200°C	40 sec	200°C
2	0–300 mm (0–11.8 in)	Up to 250°C	40 sec	250°C
3	0–400 mm (0–15.7 in)	Up to 250°C	40 sec	250°C
4	0–600 mm (0–23.6 in)	Up to 250°C	45 sec	250°C
5	0–800 mm (0–31.5 in)	Up to 260°C	60 sec	260°C

Table 2: Operating Parameters

S.No	Operating Frequency	Applied Voltage	Operating Current
1	50 Hz	230 V	3.5 A
2	50 Hz	230 V	3.5 A
3	50 Hz	230 V	3.5 A
4	50 Hz	230 V	3.5 A

4. Conclusion

This paper has examined structures used in the field of induction heating. The system has been tested in real industrial applications, proving its reliability and flexibility. Experimental results using equipment designed and constructed by the authors have been presented. Although there are some divergences between the experimental and simulation results, these are mainly due to the complexity of the converter control system and the difficulty of determining the parasitic components. Nevertheless, the results obtained are sufficiently accurate and demonstrate a strong correspondence between experimentation and simulation.

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