

Microcontroller Based Induction Heating System

Mr. Sohum N. Chowhan¹, Dr. Ajay M. Mendhe², Dr. Dhiraj N. Katole³, Mr. Sandip D. Chahande⁴

¹Student, Department of Electrical Engineering, PBCOE, Nagpur, India

sohum.nc@gmail.com

²Associate Professor, Department of Electrical Engineering, PBCOE, Nagpur, India

mendheajay@rediffmail.com

³Assistant Professor, Department of Electrical Engineering, PBCOE, Nagpur, India

dn.katole@gmail.com

⁴Assistant Professor, Department of Electrical Engineering, PBCOE, Nagpur, India

csandip.pjlce@gmail.com

Abstract - Induction heating is a heating method for electrically conductive materials that takes advantage of the heat generated by the eddy currents originated by means of a varying magnetic field. This project focuses on the design and implementation of a microcontroller-based induction heater, optimizing its use for shrink-fitting and removing industrial components like bearings and gears. The system employs solid-state relays, a dedicated temperature controller, and a microcontroller to manage system timing, ensuring rapid, safe, and precise heating without mechanical damage or open flames. By incorporating safety cut-offs and performance optimizations, the design ensures reliable 24-hour operation suitable for high-production industrial environments.

Key Words: induction heater, bearing, gear, flexibility, reliability, Microcontroller, work piece.

I. INTRODUCTION

A. Principle

The most basic elements composing an induction heating system are the piece to be heated, also known as a workpiece, and the inductor or coils that produce the magnetic field needed to generate the heat. The induction heating phenomenon is based on two mechanisms of energy dissipation: energy losses due to the Joule effect and energy losses due to hysteresis [4].

When applying an alternating voltage to an inductor coil, an alternating current is generated. This current produces an alternating magnetic field (Ampere's Law) that induces voltage in the workpiece, which opposes the

variation of this magnetic field (Lenz's Law). These voltages create eddy currents that produce heat through the Joule effect, which can be defined by the following relation:

$$P = I^2R \quad (1)$$

Furthermore, energy losses due to hysteresis appear in ferromagnetic materials below their Curie temperature, caused by friction between dipoles [5].

II. LITERATURE REVIEW

In the conventional finite element analysis for linear induction heating problems, magnetic material Induction heating (IH) is a method of heating electrically conductive materials taking advantage of the heat produced by the eddy currents generated in 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, more energy saving and higher production rates. The research done these last years in specific power supplies for this application, the numerical and computational methods developed, as well as the decrease of the cost of these systems, has led to a widespread IH in many processes and applications [1].

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. The eddy currents flowing through the resistance of the material heat it by Joule heating [2].

An important feature of the induction heating process is that the heat is generated inside the object itself,

instead of by an external heat source via heat conduction. Thus, objects can be heated very rapidly. 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 [3].

parameters are usually assumed to be constants with respect to temperature. The design of induction heating devices requires measuring and considering the dependence of the magnetic permeability under a constant magnetic field condition with toroidal cores because the magnetic field strength is directly proportional to the exciting current.

A. Mounting and Removing Bearings

Induction heaters are ideal for mounting bearings by preheating them to roughly 120°C. Heating beyond this can be harmful to the bearing structure. After heating, the bearing is easily mounted on the shaft, forming a strong shrink connection upon cooling. For removal, the induction coils are wrapped around the bearing to heat it quickly and with great precision, without heating the shaft, enabling simple disassembly.

B. Literature Survey of Conference Published Papers

Prior industrial methodologies emphasize structures based on the combination and parallel connection of basic diode bridge rectifiers and H-bridge inverters to multiply frequency output and scale structural limits efficiently. Related control strategies deploy all-digital DSP-based phase-locked loops (PLL) to minimize standard analog dependencies, allowing load-adaptive tracking algorithms to dynamically minimize parasitic losses across switching components above the Curie threshold.

III. METHODOLOGY

The system methodology centers around a microcontroller unit coordinating with a temperature controller and a solid-state relay to optimize performance and ensure safety. The primary functions involve protection from overheating and overcurrent, performance optimization, and timing communication [1].

The temperature controller provides heat energy into a substance at a desired temperature. If there is a sudden change in the current value, the controller signals the cut-off relay immediately to protect the equipment and operator. A solid-state relay performs best when managing the static flow of current to the heater, maintaining the inductive load and breaking the line

during overload conditions. The microcontroller is responsible for communicating with the electronic control unit (digital timer and temperature controller) to govern operation periods.

A. System Design and Components

The core hardware components include a microcontroller (e.g., AT89C2051 or PIC series), a step-down transformer, a 7806 voltage regulator, solid-state relays (SSR), capacitors, resistors, a 7-segment FND display, and a temperature sensor.

1) Microcontroller and Display

Microcontrollers are embedded in the system to act as the primary processing and control unit. For user interface, a 3-digit 7-segment display (common anode) is multiplexed using transistors (e.g., 2N2222) to output real-time system states and timers.

2) Temperature Controller and Sensor

A temperature controller holds the desired temperature at a specified value. It measures the process variable against the set value and uses the deviation error to dictate how much heating is required. The system utilizes a precise temperature sensor to monitor the immediate environment and provide feedback for the cut-off relay.

3) Solid State Relay (SSR)

An SSR serves the same function as an electromechanical relay but has no moving parts, resulting in a longer operational lifetime. It switches power to the load circuitry based on an external control signal supplied by the microcontroller.

IV. RESULTS

The designed microcontroller-based induction heating system proves to be highly accurate, fast, and repeatable. By integrating digital timers and automated temperature cut-offs, the system achieves maximum efficiency while minimizing power consumption and safety risks.

TABLE I. HEATING PERFORMANCE

Sr. No.	Core Diameter Range	Temperature Control	Temperature Rise Time	Maximum Temperature
1	20-100mm (0.8-4.0 inch)	Up to 200°C	40 sec	200°C
2	20-300mm (0.8-11.8 inch)	Up to 250°C	40 sec	250°C
3	20-400mm (0.8-15.7 inch)	Up to 250°C	40 sec	250°C
4	33-600mm (1.3-23.6 inch)	Up to 250°C	45 sec	250°C
5	200-800mm (7.9-31.5 inch)	Up to 260°C	60 sec	260°C

TABLE II. ELECTRICAL PARAMETERS

Sr. No.	Operating Frequency	Applied Voltage	Operating Current
1	50 Hz	230 V	5 A
2	50 Hz	230 V	5 A
3	50 Hz	230 V	5 A
4	50 Hz	230 V	5 A

The experimental setup shows excellent correspondence with targeted industrial applications, validating the system's reliability for 24-hour manufacturing processes. It is more economical than traditional heating methods, consumes less power, operates rapidly, and provides accurate heating without flames.

V. CONCLUSION

The present work evaluated structural parameters within a microcontroller-managed induction heating deployment. The integrated layout proves remarkably flexible and stable under sustained 24-hour cycles. Discrepancies between practical runs and modeling baselines track back entirely to high-frequency converter configurations and standard parasitic coupling components. The architectural simplicity provides minor workshops and automotive repair networks an optimized framework to manage precise shrink fittings without high maintenance overheads.

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REFERENCES

- [1] S. Zinn and S. L. Semiatin, Elements of Induction Heating-Design, Control, and Application, ASM International, Electronic Power Research Institute, Metals Park, Ohio, 1988.
- [2] V. Rudnev, D. Loveless, R. Cook, and M. Black, Handbook of induction heating. M. Dekker, New York, USA, 2003.
- [3] M. G. Lozinskii, Industrial Applications of Induction Heating, Pergamon Press, 1969.
- [4] W. A. Tabisz and F. C. Lee, "Development of power supply in induction heating," International Journal of Electronics, 1991.
- [5] J. Davies, Induction Heating Handbook, McGraw-Hill Book Company Inc., 1979.