Performance Analysis of Induction Heating Geyser

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Abstract: ***In this paper we proposed the method to heat the fluid using induction heating (IH) instantly. Different methods for fluid heating are discussed. Other parameters required to heat the fluid for various methods are also observed and compared with respect to time, power, efficiency, cost, etc. Two types of load coil using mild steel and stainless steel are fabricated. These load coils will carry the fluid (water in this case) which is to be heated. Electrical power of 1308 watt is applied to the IH circuit. The flow of water is varied between 0.5Lpm to 3Lpm. The experimental results show that the heat absorbed by water using this application is 1.2^{0}C to 11^{0}C more than traditional systems. According to survey this application can be very useful at bathrooms, kitchens, hospitals, hotels, industries and many more.***

Keywords: eddy current, fluid, heating, induction

1. Introduction

It is observed that since from the 18th century world utilizing liquid petroleum gas (LPG) for various types of heating process. The gas is stored into the cylinders and regulated valve is placed at the outlet to control the flow of gas. The gas is carried by pipe from cylinder to the burner (stove) where burning of gas takes place and this heat is absorbed by various applications which are to be heated. Mostly the gas carried out using flexible pipe. In recent years LPG geysers are also got popular for taking instant hot water for bathing [1]. Due to the burning of gas they cause pollution and can also be hazardous if the gas flow becomes faulty, leading to leaks as a result of ageing of the gas pipe especially in industries where chemical processes are continuously going on, resulting in life threatening calamities. LPG systems are also called slow killer as they omit carbon monoxide while in operation. These system gives efficiency up to 70% [1, 2].

Immersion heater is also one way to produce heat. It gives the efficiency of about 59% to 74% [2]. In such appliances resistive wire is wounded to form coil and is energized by electric supply. Later on immersion geysers comes in picture. At the beginning immersion coils are open circuit and comes in direct contact with the fluid. In such system there may be the risk of getting electric shock. As time goes these coils are placed in to the enclosed pipe with magnesium oxide powder around the coil so that to prevent coil from getting direct contact with fluid. Due to ageing effect these pipe get bust and same previous conditions are occur [2, 3].

Improved efficiency along with minimum power consumption is the need of today's world. The IH technique has attained considerable growth in its original system. Today, this technology has become very comfortable in controlling the power. The IH principle has been employed in industries for several years [4, 5]. The technique is applied to heat numerous magnetic materials. Sometimes, it is also included in the process of melting metals. Some of the applications of IH are forging, welding, bending, rolling, melting and surface hardening, medical use etc. [6, 7].

Advantages of IH

- **Fast heating:** Induction heating technology directly heats the induction target, reducing wastage of heat energy which significantly reduces the time for heating thanks to high power densities without any thermal inertia [7].
- **Efficiency**: The latest designs of the coil and the power converter allow obtaining efficiency values higher than 90%, significantly improving conventional heating techniques. Moreover, since only the induction target is heated, the heat loss through the ambient and surrounding elements is minimized and high temperatures can be obtained [8].
- **Controlled heating**: The power & frequency applied to the induction heating system and the area to be heated can be accurately controlled through the appropriate design of the coil, the power converter and its control. As a consequence, advanced features such as local heating, predefined temperature profiles, etc can be implemented [8].
- **Cleanliness and safety**: Since induction heating heats the induction target directly, the temperature of the surroundings of the heating area is lower, passing up burning of other materials, such as spilled food in the case of domestic induction heating [8,9].

Furthermore, there is no pollution like that generated from fossil fuel furnaces. Induction heating offers rapid and uniform heating. It also provides precise heat control and high efficiency in heating. These advantages, and the progress in induction heating technology achieved in recent years, have boosted applications of induction heating that can be classified into industrial, domestic and medical applications. The main technologies that have enabled this progress are power electronics, modulation, control algorithms, and magnetic component design. Taking the advantages of IH into account; the employment of the IH principle for fluid heating appears practical. Here successful adoption of IH principal for getting instant hot water is introduced.

2. IH Principal

The IH technique is a contactless heating technique. The technique is divided into three major aspects: a) electromagnetic coil in combination with b) driver circuit and c) microcontroller based controlling unit. Operator can program the circuit to achieve the desired temperature using the controlling unit. The electromagnetic waves generated with the IH system can link only with magnetic materials. Hence, the user has to apply this principle only for magnetic materials such as iron, steel, nickel, manganese, cobalt, and so on.Fig.1 demonstrates the operating principle of an IH system. When the inductor (IH coil) is energized, it develops the alternating flux around the IH coil [9 - 11]. The amount of the magnetic flux generated depends on the frequency and the power applied to the IH coil. The alternating flux induces eddy currents in the target as shown in Fig. 1. Due to the nature of load, eddy currents induced in it get short-circuited. This process develops heat in the target using Joule's effect. As a result, the metal piece is heated due to eddy current and magnetic hysteresis losses [9–13].

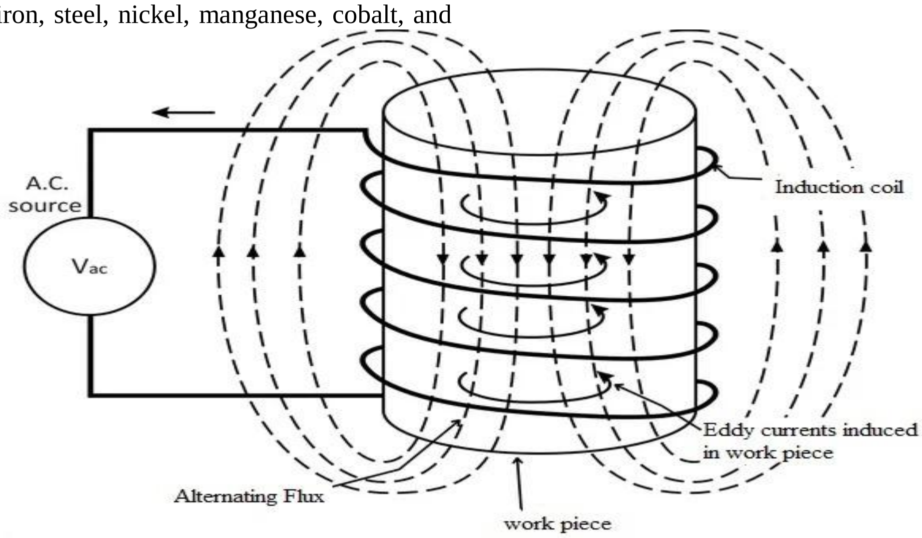

Figure 1: Working Principle of Induction Heating

This phenomenon is the main heating source in the IH process. In addition to this, magnetic hysteresis creates an additional heating component in ferromagnetic materials. The typical operating frequency of these systems ranges from line frequency to few MHz, and the operating voltage ranges from several volts to several thousands of volts [12, 13].

3. Experimental Setup and Methodology

This application is built on a 4-bit microcontroller. The power manipulation capacity of this circuit is 2000W, with a supply voltage of 230v/50 Hz AC. Power control is divided in eight stages ranging from 800W to 2000W and user can program as per the requirement. The induction generating coil is made up of copper lead with multi-strand technology. Fig. 2 illustrates the interfacing diagram of the experiment.

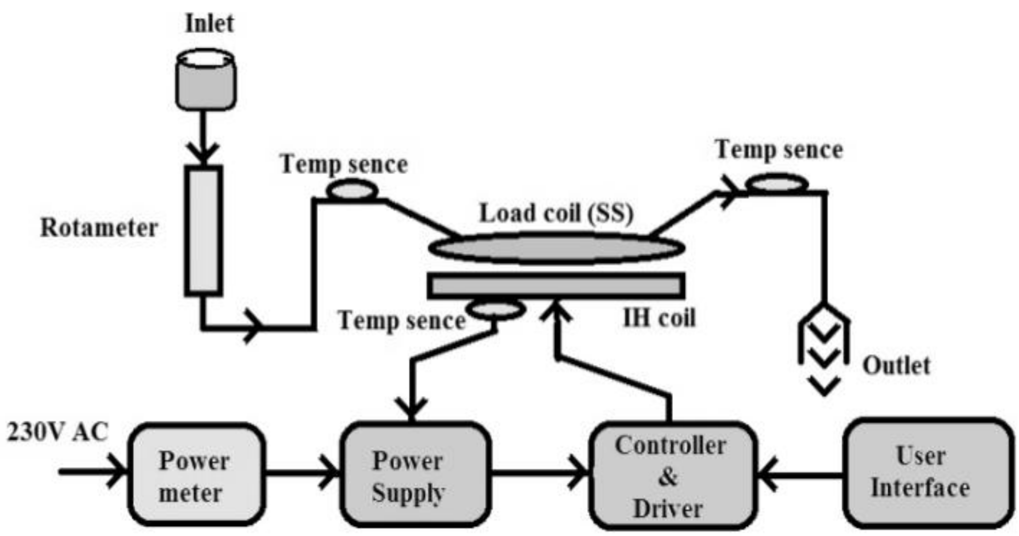

Figure 2: Block Schematic of a System

The IH coil has 45 turns of 30 strands to handle maximum power. The thickness of each strand is 32 AWG. The arrangement of IH coil and load coil is modified as per the requisite for easy handling and better operation. In addition to the IH system, the rotameter is inserted at the inlet terminal to control the flow of liquid and the temperature meter is also inserted at input and output flow to monitor the temperature of water in degree centigrade. To measure the power consumption throughout the experiment, the digital display panel power meter is also wired with the unit [13–19].

To obtain maximum efficiency throughout the experiment, two segments of load coils are designed. Fig. 3 shows the experimental load coil construction. The first coil is made up of mild steel (MS) material. The 8mm hollow MS pipe is spirally twisted as shown in the diagram. Each turn is neatly welded with MS material to form an electrically closed loop so that maximum EMF will be short-circuited in the coil. The MS pipe has a length of 11.5' (3.35 meters). The outer diameter of the complete coil is around 9 inches.

a b

Figure 3: Construction of Load Coils a) MS load coil b) SS load coil

The second load coil is made up of stainless steel (SS) material. Due to the plane material, the two surfaces are sealed at the ends only. The load has a circular shape with an inner diameter of 8 inches, and the separation of both surfaces is 8mm internally. The thickness of the plate is 0.5mm.

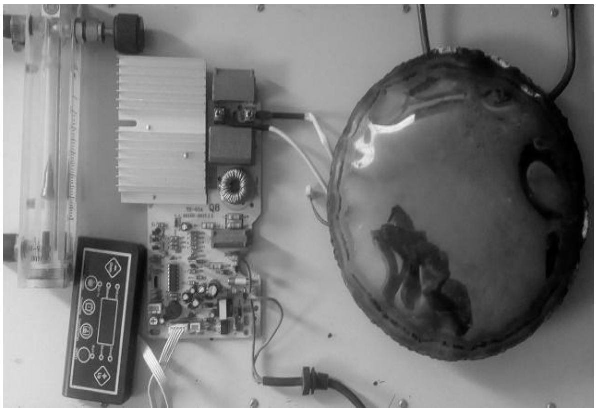

Figure 4: Practical setup

Fig. 4 shows the practical setup for SS load coil. Heat absorption, also known as heat transfer or heat exchange, is an endothermic process described by the second law of thermodynamics. The law states that thermal energy transitions from a hotter mass to a cooler mass to reach thermodynamic equilibrium. Once both objects reach thermodynamic equilibrium or the same temperatures, the heat transfer between the two objects will equal zero. When an object is at a different temperature than its surroundings or when it comes in contact with another object, the cooler object will absorb the warmer object's heat. Longer an object is exposed to a heat source; more the heat will be absorbed. Different substances have different capacities for absorbing heat [20-23]. For MS load coil and SS load coil; the procedure to measure temperature is the same. The flow of water varied in the steps, with the help of the rotameter, and simultaneously, the input and output temperature are noted. The inlet terminal is connected to an overhead water tank. By means of a variable rotameter, the flow of inlet water is controlled, ranging from 0.5 LPM to 3 LPM maximum.

4. Results and Discussion

Table 1 shows the observations for the MS and SS load coil. It also shows the observations for the immersion geyser technique. Power is kept constant at 1308Watt. From the observations it is noted that for the flow of 1 LPM of water, the total rise in temperature is 30^0C for the SS load coil, whereas it is 29^oC for the MS load coil. The total increase in temperature is from 0.4^0C to 1.3^oC in the SS coil rather than the MS coil. The observations for the immersion geyser are made with reference to the system developed by Jamie Bristol, which attempts to achieve a total rise in temperature [24].

Table 1: Rise in temperature for IH and Immersion Technique

LPM	Rise in Temperature (^{0}C) M. S. Coil	Rise in Temperature (^{0}C) S.S. Coil	Rise in temperature (^{0}C) Immersion Geyser
0.5	36	36.4	37
0.75	34	34.9	25
1	29	30	19
0.25	24.6	25.8	15
0.5	23.4	24.6	12.5
0.75	22.5	23.8	10.6
2	19	19.3	9.3
2.25	17.9	18.5	8.3
2.5	17	17.8	7.45
2.75	15.8	16.4	6.75
3	13	13.8	6.2

The first column indicates the flow of water in LPM. The second column shows the total rise in temperature for the MS load coil consequently the next column defines the total rise in temperature for the SS load coil. The last column indicates the observations for the immersion geyser.

4.1. LPM Vs Total Rise in Temperature

The graphical analysis exhibits a total increase in temperature Vs flow of water in LPM. Initially, for the low flow rate (0.5 LPM), the total rise in temperature is about the same having 2-degree centigrade difference. However, as the flow rate increases, the IH technology provides better results and also provides a considerable increase in temperature.

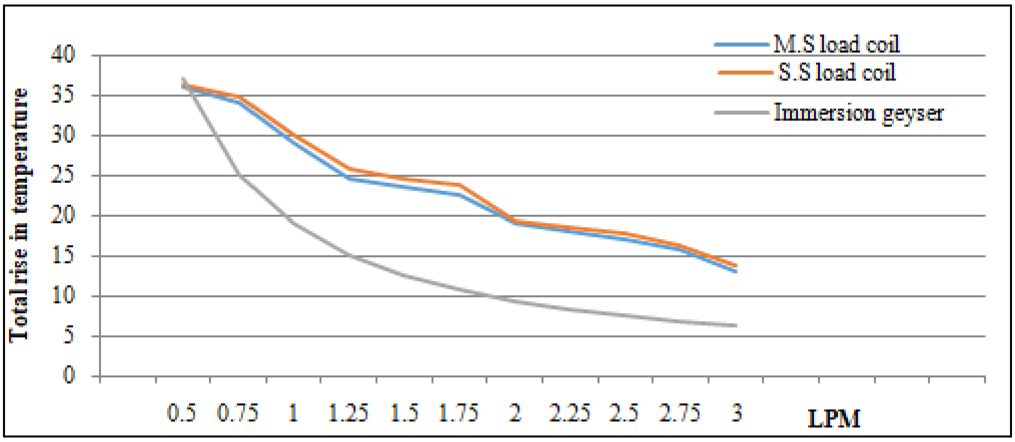

Figure 5: Plot between Flow Rate and Rise in Temperature from Aforementioned Observations

Change of temperature with respect to flow is more for IH technology. As compare to IH technique, immersion geyser technology provides typically less temperature gain in fluid. One thing that is observed again is that the temperature gain of the SS coil is highest among all others.

4.2 Heat Absorption

A material such as SS absorbs more heat and transfers it to the fluid, as compared to MS material. In terms of the immersion geyser, the filament gets heated first, and then the surrounding metal tube is heated. The electrical insulator is placed between the filament and outer tube. Due to the fact that indirect heat is induced in the outer coil, the heat absorption appears less as compare to IH. Also, in terms of the Gas geyser, the heat is produced at the burner. This heat is absorbed by the metal fins, and again, it absorbed by the copper tubing, and then, it transfers to the liquid flowing through it. As direct heat is not transferred to the copper coil, the heat absorption is much lesser in the LPG technique as well as in the immersion geyser also. From Table 1, it is noted that up to the flow of 2.5 LPM, the IH system performs excellently. Further ratio decreases but is still in consideration [2].

4.3 Power Requirement

The power required in IH is considerably low. In terms of the immersion geyser, the power loss is due to the resistance of the coil. If LPG geysers are taken into account, the required volume of gas is more as compared to the aforementioned methods. It is observed that there is a constant power of 1300W for the IH system. The immersion system requires more power if the user requires the same temperature within the same time required for the IH system. When power is kept constant, it requires more time to achieve same temperature as in IH. The range of increase in temperature is 6^0C to 11^0C in IH. The temperature in an LPG-operated geyser can be increased by increasing the gas flow, which is more expensive than in IH.

4.4 Efficiency

According to the research conducted by the energy-ex of non-conventional power devices Pvt. Ltd. Panaji, Goa, India, the parameters of various devices are a) efficiency, b) time required to boil 2 liters of water and c) power applied are observed. The observations from table 2 clearly show that the IH system provides better efficiency than any other method that depends on either gas or electricity.

Table 2: Efficiency chart for various methods

Type	Efficiency	Time	Energy	Power
Induction stove	90%	4 minutes	745KJ/s	3.1KW
Electric Coil	55%	9 minutes	1220 KJ/s	2.3KW
Gas	40%	8 minutes	1700KJ/s	3.54KW

The results given above are the open pot applications for the IH system. Here, the efficiency ranges from 88% to 94% for the water flow of 0.5 LMP to 4 LPM.

4.5 Emission

Compared to nature-friendly equipment, the immersion geyser and IH geyser have no emission. But, the same is not considerable in the case of an LPG geyser, due to the burning of fossil fuels. Sometimes, in atmospheric conditions, these geysers emit more smoke. In such cases, suffocation takes places if ventilation is not maintained properly.

4.6 Safety

The manner in which your system will become more eco-friendly and safe, one cannot neglect the possibility of an electric shock for immersion geyser, because the heating coil is fitted inside the metal tube with an insulator. In working conditions, these tubes may bust and the coil directly comes to contact with the fluid, which cause an electric shock. An LPG geyser has a pipe with gas flowing through made up of rubber. After a periodic interval, it gets damaged and simultaneously, if the ignition process in the geyser is occurring, then in such situations, a fire hazard may take place. In industries where it this occurs in large amounts, the hazard may become a serious case. In contrast, IH technology is contactless heating technology. The associated fluid does not come in contact with the electric circuitry and it also does not emit harmful gases. Hence, there is no possibility of a hazard and it is completely safe.

4.7 Time required

By taking into account all the aforementioned results, it is implied that the total time required to heat the fluid using IH technique is less as compared to earlier methods.

4.8 Power loss

Table2 in terms of fuel conversion implies that the power loss in an LPG gas geyser is 60%, whereas, in the immersion geyser, it is closer to 26%. Furthermore, in IH method, the total power loss is in between 6% to 12%. This is the minimum figure as compared to traditional methods.

4.9 Cost

By considering today's market trends, the cost of any system must satisfy all its required constraints. The cost for an LPG gas geyser is within the range of Rs. 3000=00 to 6500=00 in Indian Rupees, whereas the immersion geyser costs within the range of Rs. 3500=00 to 7000=00. In accordance with available equipment, the IH geyser will be priced from Rs. 3000=00 to 5000=00. For large volume applications, the cost of the IH technique will be less.

5. Conclusion

It is observed that the average temperature increases from 6^0C to 11^0C in IH technology as compared to immersion heating technology, whereas the same increases from 0.8^0C to 1.2^0C in the SS load coil than MS load coil. In the case of the flow ranging from 0.5 LPM to 4 LPM, the rise in temperature is from 36.4^0C to 13.8^0C using IH technology. From the history and the current observations based on IH, it is seen that it has delivered better efficiency within the range of 88% to 92%, which is 17% to 25% more than the traditional methods. The system has a power loss ranging from about 8% to 12%. Hence, the IH technique for a geyser can be a better power saving application than the immersion geyser technique and obviously the LPG technique. This application can be adopted for geysers in bathrooms, kitchens, hospitals, restaurants and in many more places where the instant hot fluid is required. IH technique may also apply to heat slurries of various ready-to-eat preparations while transferring them from one place to another, hence no need to wait. Such technique has numerous applications like hot oil baths, and so on.

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