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Experimental Study of Helical Coil Induction Water Heater using Induction Cooker

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Abstract

This paper present a new phenomenon of heating of water flowing through helical coil using induction heating process is applied through induction cooker. The experimental setup is prepared according to proposed plan with helical coil configurations which is varying factor among the several has high heat transfer rate.Helical coil is designed as per limitations of induction cooker with some parameters and the values of water outlet temperature observed with variable flow rates of water during the experimental analysis is getting affected with the help of different helical coil configurations by changing number of turns with coil pitch, coil diameter and coil tube diameter maintainsconstant. The data obtained from experimentation is analyse to succeed highest heat transfer from induction cooker to water flowing through Helical coil with minimum time consumption, less pollution and safety aspect specially related to industrial applications.

Keywords*:* Induction Cooker, Helical coil, Induction Heating Process, Coil Pitch.

1. Introduction

Industry prerequisites of electricity and especially water at certain temperature of 85^0-90^0 for different processes to fulfill demands it required lot of electricity or fuel and also for hot water required at particular temperature using different techniques including Electric Heater, Gas Water Heater, Storage Heat Pump water heater, Heat Exchanger using burning of fuel etc. Due to degradable resources in environment it is necessary to find out alternative energy resources or use available resources effectively; so for water heating process it should aimed at having effective use over the supplied electricity, the new technique of water heating using induction heating process is being developed. Typical applications of induction heating are melting of metals, heating of metals for design, Brazing, Welding and all sorts of Surface Treatments.

The previous work done by Yuki Makimura,hideo tomita and shin-ichi Motegi (2010), on improvement of superheated steam generator by induction heating which is able to generate joule heat to metal effectively and this IH has been recently applied to small thermal power plants and home appliancesbecause of high thermal efficiency, safety , cleanliness and convenience for water heating . A green and renewable energy, high cost,

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thermal efficiency, safety and clean environmental are important issues that influenced the technology in home appliances recently such as in stove and water heating. Induction heating is a non-contact heating process and one of the new technologies in home appliance. There are some researches that discussed about induction heating process and implementation due to their clean and no pollution.Also previous work done by Nihar P Bara (2013), states the main advantages of using induction processes when compared to any other heating process (gas furnace) are among others, their fast heating rate, good reproducibility and low energy consumption and it is check with finite element analysis of induction furnace.

The previous work done byL. C. Meng, K.W.E. Cheng and K.W. Chan (2009) on heating performance improvement of the induction cooker studied magnetic field and heating performance with identifications of problems where it changes the induction coil with a Novel coil format is proposed. The conventional Induction heating has been extended to the catering industry as currently; the Induction Cooker draws more and more attentions as one of the popular kitchen appliances instead of ordinary stove plates andthese InductionCooker works with the suitable magnetic material pots such as Steel,Enameled Steel and Cast Iron etc. Instead of pot utilized in water heating process using Induction cooker for continuous hot water requirement; it is suggested that helical coil is being used for water flow through it which placed on Induction cooker where induction cooker acts as heat source to change the temperature of water. The previous work done by Ordoñez Flores Rafael, Reyes Castillo Fabiola and Carreño Hernández Carlos (2013) on water heater by magnetic induction shows new device that is proposed to heat the shower water as it obeys the excessive water wasting at start of knob of water, so it anticipates a water and gas saving. This water heater consumes less electrical energy than the resistance based boiler and it doesn't store hot water which signifies use of less energy than the gas based boilers. A review study done by N. D. Shirgire and P. Vishwanath Kumar (2013), on comparison of helical coil and straight tube heat exchanger heat transfer coefficient of helical coil is affected by geometry of heat exchanger. Helical coils offer advantageous over straight tubes due to their compactness and increased heat transfer coefficient.The effectiveness of heat exchanger greatly affected by hot water mass flow rate and cold water flow rate when cold water mass flow rate is constant and hot water mass flow rate increases the effectiveness decreases and increase in cold water mass flow rate for constant hot water mass flow rate resulted in increase in effectiveness hence flow rate of fluid plays vital role in experimenting with helical coil.

A review study by S.S. Pawar, V.K.Sunnapwar and B.A.Mujawar (2011), shows the heat transfer through helical coils for circular cross sections utilized either active (electric field, acoustic or surface vibrations etc.) or passive (Fluid additives or special surface geometries) techniques had been applied which can improve performance of heat exchanger in heat transfer. This shows that heat transfer in helical coil with circular cross section varied by altering basic geometry of the coil and different fluid types with different flow rates. The preceding work done byMofid Gorji Bandpy and Hasan Sajjadi (2010), accomplished about various aspect like coil diameter, coil tube diameter and coil step (coil pitch) of coil tube used in heat transfer process, considering coil step for coiled tube experimentally represented enhancement of coil step in a fixed tube diameter, shell side heat transfer coefficient increases. This also conclude shell side heat transfer coefficient raises with increases with heat flux rate of coil for fixed pipe diameter and heat transfer coefficient for coil inlet temperature increases with enhancement of coil step with fixed tube diameter at different mass flow rates. This shows coil step influence on heat transfer rate of coil for both laminar and turbulent flow. The previous work done by M.R. Salimpour (2008) on the experimental study shows that the shell-side heat transfer coefficients of the coils with larger pitches up to certain are higher than those for smaller pitches and the empirical correlation for constant temperature boundary condition is quite in agreement with the experimental data in low Dean number region. With experimental data indicates shortcoming of enhancement of coil pitch shows correspond to the lower values of helical number or loose-coiling conditions decreases the inner Nusselt number. These caused the heat transfer coefficients of coiled tubes are found closer to those of the straight pipes.

Helical coils are widely used in applications such as heat recovery system, chemical processing, food processing, nuclear reactors and high-temperature gas cooling reactors. Because of helical coils have a compact

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configuration, more heat transfer surface can be provided per unit of space than by the use of straight tubes, ease of manufacture and longer operating life. Hence helical coil is used instead of Spiral or Pancake Coil for heat exchange purpose. With the utilization of all these individual benefits of total system for helical coil water heater includes induction cooker and helical coil with measuring instruments which is developed to heat the water flows through it and is placed on Induction cooker. So there is continuous flow of water is maintained using rotameter attached in the system like in case of gas geysers.

2. Characteristics of Helical coil.

The schematic view of helical coil used as shown in figure 1. The pipe has outer diameter d_0. The coil has diameter of D (measured between the centresof the pipe), while the distance between the adjacent turns, called as pitch is P and the coil is diameter also called as pitch circle diameter (PCD). The ratio of pipe diameter to coil diameter (d_0/D) is called curvature ratio and number of turns of helical coil N.

Many researchers have identified the effect of all these parameters on the heat transfer rate to and from fluid flowing through helical coil by varying one or more parameter and keeping other constant. So in this present research work overall focus is given to number of turns of helical coil 'N' which three separate number of turns for helical coil selected arbitrary with N=3.25, N=4 and N=5 for experimental work keeping other parameters constant such as coil diameter D=109.5 mm, Pipe Diameter d_0= 9.5 mm and pitch of coil is 9.5 mm.

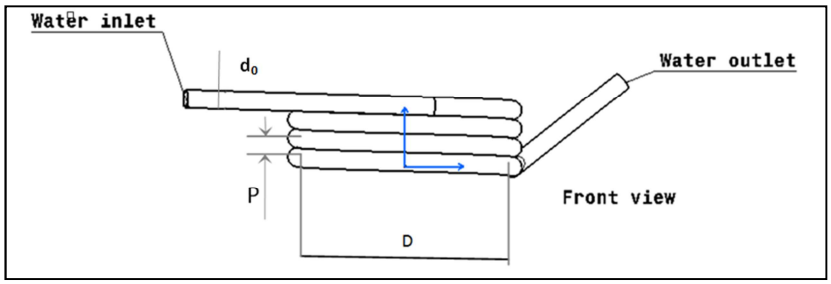

Figure 1: Basic Geometry of helical coil

So the previous work done by Ramchandra K. Patil, B.W. Shende and Prasanta K. Ghosh (1982) on design of helical coil heat exchanger where length of helical coil and volume occupied by coil is determined by analytical method as follows:

1. The length of coil L, needed to make N turns:

$$L = N\sqrt{((2 * \Pi * r)^2 + p^2} \quad (1)$$

Where N= number of turns of helical coil
r = Average radius of helical coil, taken from centerline of helix to the centerline of coil
P = Pitch spacing between consecutive coil turns measured from center to center

Hence for number of turns (N) as 3.25, 4 and 5 turns for designing of helical coil

Length of coil For N=3.25,

$$L = 3.25\sqrt{((2 * \Pi * 54.75)^2 + 9.5^2}$$

L = 1118.44 mm.

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Also extra length is added at inlet and outlet of helical coil for steady flow condition achieved for experimentation purposed as follows:

Extra length added to inlet of helical coil = 130 mm

Extra length added at outlet of coil varies with number of turn selected for experimentation purpose is as follows:

4. For N=3.25 Extra length added to outlet of helical coil = 75 mm
5. For N=4 Extra length added to outlet of helical coil = 95 mm
6. For N=5 Extra length added to outlet of helical coil = 120 mm

Length of coil with extra length L_{max} for N=3.25:-

$$L_{max} = L + 130 + 75 = 1118.44 + 130 + 74$$

$$L_{max} = 1322.44 \text{ mm} = 1.322 \text{ m.}$$

Similarly,
Length of coil for N=4 L_{max} = 1.601 m

Length of coil for N=5 L_{max} = 1.970 m

2. The volume occupied by coil, Vc:

$$Vc = \frac{(\Pi * d^2{}_0 * L \max)}{4} \qquad (2)$$

Volume occupied by helical coil For N=3.25

$$Vc = \frac{(\Pi * 9.5^2 * 1.322)}{4}$$

` $Vc = 374824.9903 \text{ mm}^3 = 3.748349\text{e-}4 \text{ m}^3$

Similarly,
Volume occupied by helical coil For N=4 is 1.1348e-4 m^3
Volume occupied by helical coil For N=5 is 1.39637e-7 m^3

3. Experimental Setup and Procedure

3.1 Experimental setup:-

It is necessary to evolve physical design of an experimental set up having provision of setting test points, adjusting test sequence, executing proposed experimental plan, provision for necessary experimentation for noting down the responses. The experimental set up is designed considering various physical aspects of its elements. The other sub system of the setup such as measuring instruments and environmental factors are considered. This generalized procedure of design of experimental set up however cannot be totally followed in the field of experimentation. This is because in the field of experimentation, we are carrying out the experimentation using the available ranges of the various independent variables to assess the value of the dependent variables. The experimental setup consists of Induction cooker, helical coil, Rotameter and thermocouple arrangement as shown in figure 2. The Bajaj Majesty ICX 6 induction cooker with rating 1600 w is used in test set up for this experimentation. Induction cooker is works at 1200 Watt as constant heat source

for heat transfer to water flow through helical coil which is work on induction heating process for experimentation while helical coil is placed at center of induction cooker. Water is flow through helical coil from top to bottom of coil and coil is subjected to induction heating process. These helical coil shown in figure is replaced with other coil has differs in number of turns.Water at atmospheric temperature is supplied from tap to inlet of helical coil through rotameter where flow rate is maintaining forten different levels for each helical coil and flow from rotameter to insulated pipe where thermocouple is fixed which shows temperature on display unit provided with it to measure inlet water temperature. Water from insulated pipe is supplied to helical coilis placed on induction cooker for heat supply after passing through helical coil outlet it is passes from insulated pipe after helical coil where again thermocouple is attached to measure outlet water temperature and this water is collected in bucket for different application in house hold applications. Also portable thermometer is also used to measure temperature of water outlet temperature is shown in figure 2.

The experimental set up is designed with the following instrumentation.

- Induction cooker arrangement
- Helical coil arrangement
- Rotameter and thermocouple arrangement

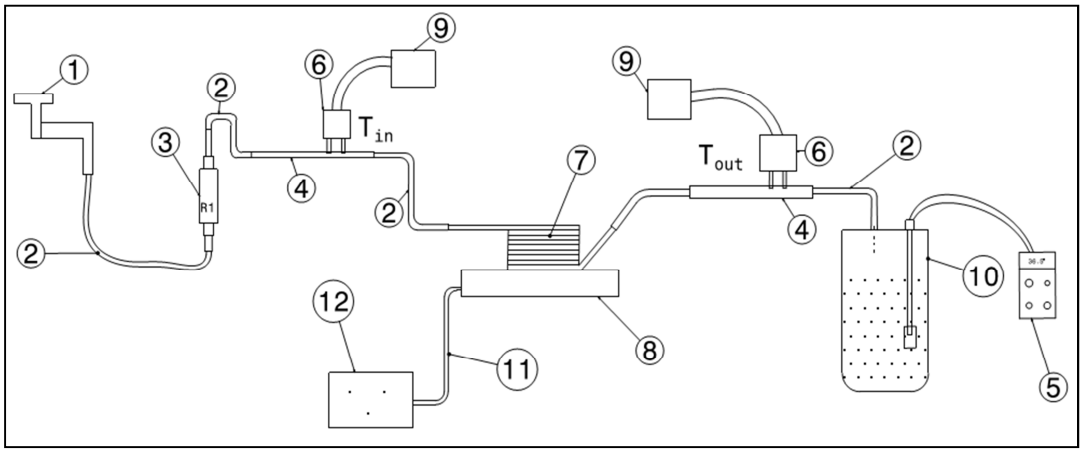

Figure: 2 Schematic View of Experimental setup

1. Water Tap
2. Flexible Pipe to continue water flow
3. Rotameter
4. Insulated Pipe for thermocouple
5. Portable thermometer
6. Thermocouple fixed at insulated pipe
7. Helical coil
8. Induction Cooker
9. Temperature Display unit
10. Plastic Bucket
11. Supply cable of induction cooker
12. Switch Board

3.2 Procedure for Test Run

Different Helical coils are used for performing the task of developing helical coil water heater using Induction cooker.Experiments are conducted for ten different water flow rates through the coil and for three different helical coil with N=3.25, N=4, N=5.The water flow rate in lph is noted down for different helical coils with number of turns 3.25, 4 and 5 in observation tables. As per the plan the flow rate is varied at ten levels. The readings for water inlet and outlet temperature for heat transfer analysis of helical coils are noted down.Measurements are taken only after the temperatures attainsteady values.During the courseof each set of experiments, the heat supply from induction cooker at 1200 w is kept constant, which ensures a constant heat transferin induction heating process.

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4. Results and discussion

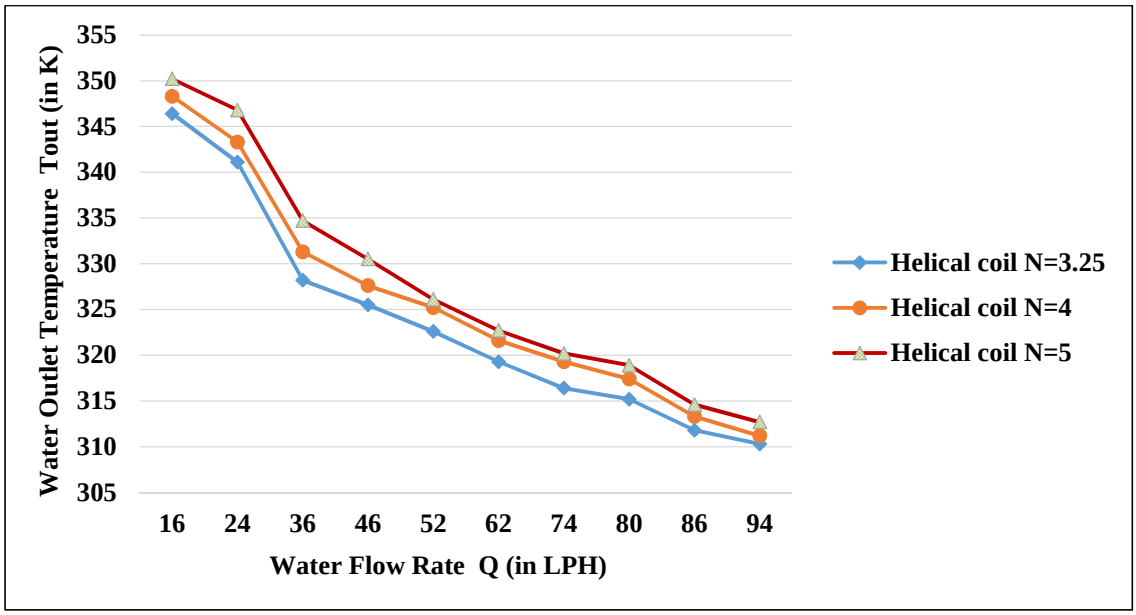

Figure 3: Variation in water outlet temperature Vs. water flow rate for different Helical N=3.25, N=4 and N=5

It is observed from the figure3 variations in water outlet temperature Vs. water flow rate for different Helical coil using number of turns N=3.25, N=4 and N=5. It is found that when one helical coil is selected at different water flow rate viz. 15 lph to 95 lph the water outlet temperature decreases with increase in water flow rates. During the change of Helical coil as number of turns increases form N=3.25 to N=5 value of water outlet temperature is also increased at same water flow rate. It also clarify from the results that as number of turns is increases which causes increase in length of pipe required to form helical coil indicates that higher the length of pipe used will increase the water outlet temperature of helical coil.

5. Conclusions

Helical coil water heater with the help of induction cooker is non-contactless, pollution free and safety setup is used to heat water up to certain temperature with variations in flow rates. It is concluded from experimentation as number of turns of helical coil is increases the water outlet temperature also increases at constant flow rates keeping other parameters constant.This experimentation set up is utilised in industry where hot water requirement is necessary for different process which leads to optimize helical coil design to get maximum output water temperature using induction cooker with least energy consumption due to faster process rate.

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A Brief Author Biography

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Atul A. Patil is Assistant Professor in GF's Godavari College of Engineering, Jalgaon, India. He received degree in BE Mechanical in 2002, Post-Graduation ME with specialization in Designin 2005 from Shivaji University, Kolhapur and submitted Ph.D. Thesis on Design and Development of Energy Efficient Exhaust System for Four Stroke Compression Ignition Engine to North Maharashtra University, special interest of field is related to heat transfer analysis using software simulation to validate with the experimental results.