Thermal Analysis of Induction Coil Heater

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Abstract- *'Thermal analysis of induction coil heater ' was industrial project based on casting industry this project will give more productive and cost effective and time savings then conventional machines working now days our team is on internship on indo shell cast India pvt .ltd manufacturing s .g .iron and grey iron castings using shell moulding process company since 1987 July 21 . Our project based on shell moulding process in shell moulding we want to create shell of castings. Process of creating a shell contains phenol formaldehyde resins (pf) or phenolic resins (also infrequently called phenolates) are synthetic polymers and fine silica sand and casting power. Fine silica sand that is covered in a thin (3– 6%) thermosetting phenol formaldehyde resin dumped, blown, or shot onto a hot pattern. The pattern is usually made from cast iron and is heated to 230 to 260 °c (450 to 600 °f) this heating process take 3.6 minutes to heat the shell on conventional machines. In this research a modelling, design and analysis of the most suitable temperature for heating plate by using induction coil. Ansys fluent computer package is used for this purpose. The simulation determines the heat required to melting process through electromagnetic field distribution inside the work coil by the required excitation current. Then the optimal work coil is determined. Also, it is used to determine the required magnitude of the load resonant circuit capacitance to achieve this frequency. The simulation describes the temperature over the plates by amount of current which is required to achieve melting process.*

Keywords- induction coil heater.phenol formaldehyde resins,Ansys fluent,electromagnetic field distribution

I. INTRODUCTION

Induction heating is a process which is used to bond, harden or soften metals or other conductive materials. For many modern manufacturing processes, induction heating offers an attractive combination of speed, consistency and control. 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 wartime requirements for a fast, reliable process to harden metal engine parts. 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, all solid-state induction power supplies. 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 7 Flame, the inductor does not get hot, and there is no product contamination. When properly set up, the process becomes very repeatable and controllable.

II. REVIEW OF LITERATURE

KHAING MOE Induction Heating (IH) systems using electromagnetic induction are developed in many industrial applications. Many industries have benefited from this new breakthrough by implementing induction heating for melting, hardening, and heating. Induction heating cooker is based on high frequency induction heating, electrical and electronic technologies. From the electronic point of view, induction heating cooker is composed of four parts. They are rectifier, filter, high frequency inverter, and resonant load. The purpose of this research is mainly objected to develop an induction heating cooker. The rectifier module is considered as fullbridge rectifier. The second portion of the system is a capacitive filter. The ripple components are minimized by this filter. The third is a high frequency converter to convert the constant DC to high frequency AC by switching the devices alternately. Insulated Gate Bipolar Transistor (IGBT) will be used as a power source, and can be driven by the prides signals from the pulse transformer circuit. In the resonant load, the power consumption is about 500W. The merits of this research work are that IH cookers can be developed because of having less energy consumption Vimal R. Nahum, Kevin M. Vyas, Niraj C. Mehta This paper presents results of finite element analysis of induction heating problems considering temperature dependence of material characteristics. In this analysis, we have used the three-dimensional finite element method in order to correctly express induction heating coil's shapes and to make clear its effects on temperature distributions. The heat conducting problem and the eddy current problem are coupled, and solved by using the step-by-step calculations. 18 O. Lucia Induction heating technology is nowadays the heating technology of choice in many industrial, domestic, and medical applications dueto its advantages regarding efficiency, fast heating, safety, cleanness, and accurate control. Advances in key technologies, i.e., power electronics, control techniques, and magnetic component design, have allowed the development of highly reliable and cost-effective systems, making this technology readily available and ubiquitous. This paper reviews induction heating technology summarizing the main milestones in its development, and analyzing the current state-of-art of induction heating systems in industrial, domestic and medical applications, paying special attention to the key enabling technologies involved. Finally, an overview of future research trends and challenges is given, highlighting the promising future of induction heating technology William P. KornrumpfJohn D. Harnden, Jr. Solid state induction surface cooking units for domestic electric ranges and other cooking appliances are defined with respect to the operating parameters and functional components of complete induction heating systems suited for this use. The surface cooking units are designed for reliable, convenient, and safe operation, and for circuit packaging using hybrid and monolithic integrated circuits. Wide range power control of the inverter power circuits is needed for general cooking but is obtained within a limited ultrasonic operating range of the power semiconductors. The inter dependent electrical and magnetic characteristics utilized in solid state induction cooking are related to the achievement of such desirable user features as the cool cooking surface, fast utensil warm-up, responsive heating, and unrestrained utensil mobility. In addition to cooking by changing the relative heating level, cooking is performed by setting the desired utensil temperature and by setting the desired utensil power level. 19 David L. Bowers, Wauwatosa, Wis.; Donald S. Heidtmann, Louisville, Ky., John D. Harnden, Jr., Schenectady, N.Y. A cooking appliance for inductively heating a cooking utensil comprises a flat induction heating coil mounted beneath a nonmetallic support with a substantially unbroken utensil supporting surface. The induction heating coil is driven with an ultrasonic frequency wave generated by a static power conversion circuit typically formed of a rectifier and an inverter. The inverter is a series capacitor commutated sine wave inverter with a variable output frequency, variable input voltage, or variable commutating components to adjust the utensil heating level. The inverter is also controlled in on-off mode by a utensil temperature Sensor. Raymond M. Tucker; Clarence L. Dyer; Gregory P. Maman an induction heating system is provided and includes a plurality of induction heating coils Touch control pads are provided together with circuitry for generating energization control signals. Circuitry is provided for electrically energizing the induction heating coils An electronic digital processor is responsive to the energization control signals for generating energization signals for actuating and controlling the energization circuitry to thereby vary the energization of the plurality of induction heating coils .Circuitry is provided for maintaining touch control pads (operable when an opera tor is in contact with a pan disposed adjacent the plurality of induction heating coils . John D. Harnden, Jr.; William P. Kornrumpf An ultrasonic frequency induction surface cooking unit heats aluminum foil and other thin metal utensils placed on the cool cooking surface. For optimum heating the 20 aluminum foil has a thickness of 0.5 mils. A uniform heating distribution is obtained by preferably using a rectangular induction heating coil with several series-connected elongated coil sections, or by varying the metal thickness to graduate the energy acceptance. Frozen convenience foods can be defrosted in this manner, and the aluminum foil can be wrapped about the food and shaped by the user into disposable utensils using a set of molds. Disposable foil cooking obviates the clean-up and storage problems of pots and pans.

III. PROBLEM IDENTIFICATION

To modify the existing 25 years old 15 kW high vacuum-high temperatures intering induction furnace at H2 laboratory. The induction heater was not functioning for a long time. Because of the non-availability of technical assistance from the German manufacturer LAYBOLD and drawings, it was a hard to trace the problem. Further more mistakes were found in those drawings on examination. By continuous effort from CIS team, the problem was rectified and few copper samples were melted successfully. But again the furnace failed. By tracing it was found that GTO in the inverter section had failed. The GTO is from AEG make which is obsolete in the market. Since the vacuum chamber and its relevant circuits, LC unit, converter section and other components are in good condition, it has been decided to replace the existing inverter with newly designed compatible inverter using advanced transistors like MOSFETs and IGBTs instead of GTOs

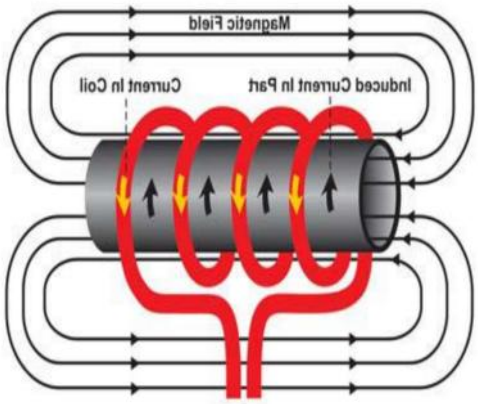
IV. SOLUTION

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. In a basic induction heating setup shown at above right, a solid-state RF power supply sends an AC current through an inductor (often a copper coil), and the part to be heated (the work piece) is placed inside the inductor. The inductor serves as the transformer primary and the part to be heated becomes a short circuit secondary. When a metal part is placed within the inductor and enters the magnetic field, circulating eddy currents are induced These eddy currents flow against the electrical resistivity of the metal, generating precise and localized heat without any direct contact between the 22 part and the inductor. This heating occurs with both magnetic and nonmagnetic 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. Secondarily, additional heat is produced within magnetic parts through hysteresis – internal friction that is created when magnetic parts pass through the inductor. Magnetic materials naturally offer electrical resistance to the rapidly changing magnetic fields within the inductor. This resistance produces internal friction which in turn produces heat. In the process of heating the material, there is therefore no contact between the inductor 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.It is within the inductor that the varying magnetic field required for induction heating is developed through the flow of alternating current. So inductor design is one of the most important aspects of the overall system. A welldesigned inductor 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

V. DESIGN DESCRIPTION

The inductor is similar to a transformer primary, and the workpiece is equivalent to the transformer secondary (Fig.4.1). Therefore, several of the characteristics of transformers are useful in the development of guidelines for coil design. One of the most important features of transformers is the fact that the efficiency of coupling between the windings is inversely proportional to the square of the distance between them

In addition, the current in the primary of the transformer, multiplied by the number of primary turns, is equal to the current in the secondary, multiplied by the number of secondary turns. Because of these relationships, there are several conditions that should be kept in mind when designing any coil for induction heating: 28 1) The coil should be coupled to the part as closely as feasible for maximum energy transfer. It is desirable that the largest possible number of magnetic flux lines intersect the workpiece at the area to be heated. The denser the flux at this point, the higher will be the current generated in the part. 2) The greatest number of flux lines in a solenoid coil are toward the center of the coil. The flux lines are concentrated inside the coil, providing the maximum heating rate there. 3) Because the flux is most concentrated close to the coil turns themselves and decreases farther from them, the geometric center of the coil is a weak flux path. Thus, if a part were to be placed off center in a coil, the area closer to the coil turns would intersect a greater number of flux lines and would therefore be heated at a higher rate, whereas the area of the part with less coupling would be heated at a lower rate; the resulting pattern is shown schematically in Fig. 2. This effect is more pronounced in high-frequency induction heating. 4) At the point where the leads and coil join, the magnetic field is weaker; therefore, the magnetic center of the inductor is not necessarily the geometric center. This effect is most apparent in single-turn coils. As the number of coils turns increases and the flux from each turn is added to that from the previous turns, this condition becomes less important. Due to the impracticability of always centering the part in the work coil, the part should be offset slightly toward this area. In addition, the part should be rotated, if practical, to provide uniform exposure. 29 5) The coil must be designed to prevent cancellation of the magnetic field. The coil on the left in Fig. 3 has no inductance because the opposite sides of the inductor are too close to each other. Putting a loop in the inductor (coil at center) will provide some inductance. The coil will then heat a conducting material inserted in the opening. The design at the right provides added inductance and is more representative of good coil design. Because of the above principles, some coils can transfer power more readily to a load because of their ability to concentrate magnetic flux in the area to be heated. For example, three coils that provide a range of heating behaviors are: • a helical solenoid, with the part or area to be heated located within the coil and, thus, in the area of greatest magnetic flux; from only one surface intersects the workpiece; • an internal coil for bore heating, in which case only the flux on the outside of the coil is utilized. In general, helical coils used to heat round workpieces have the highest values of coil efficiency and internal coils have the lowest values (Table I). Coil efficiency is that part of the energy delivered to the coil that is transferred to the workpiece. This should not be confused with overall system efficiency. Besides coil efficiency, heating pattern, part motion relative to the coil, and production rate are also important. Because the heating pattern reflects the coil geometry, inductor shape is probably the most important of these factors. Quite often, the method by which the part is moved into or out of the coil can necessitate large modifications of the optimum design. The type of power supply and the production rate must also be kept in mind. If one part is needed every 30 seconds but a 50-second heating time is required, it will be necessary to heat parts in multiples to 30 meet the desired production rate.



VI. INTRODUCTIONS TO CATIA

CATIA which stands for computer aided three dimensional interactive applications is the most powerful and widely used CAD (computer aided design) software of its kind in the world. CATIA is owned/developed by Dassault system of France and until 2010, was marketed worldwide by IBM. The Following general methodologies and best practices can be followed in the modeling of components in CATIA. The Below methodologies and Best practices followed will help in capturing the design intent of the Feature that is to be Modeled and will make the design robust and easy to navigate through.

- Specification tree structuring
- Renaming appropriate features & bodies in specification tree
- Handling input data & foreign bodies
- Dimensioning & constraining in sketches
- Parameters and relations.

CAD MODEL

Using Rib option coil has design

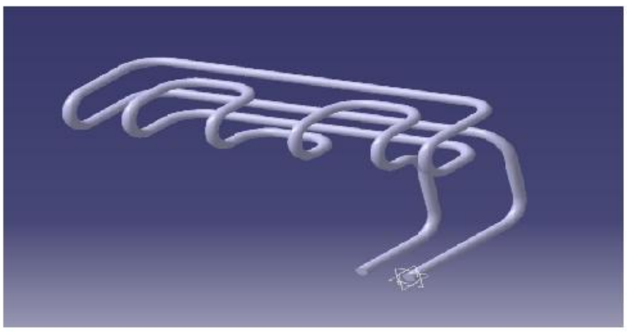


Fig 5.1 Induction coil 3D model

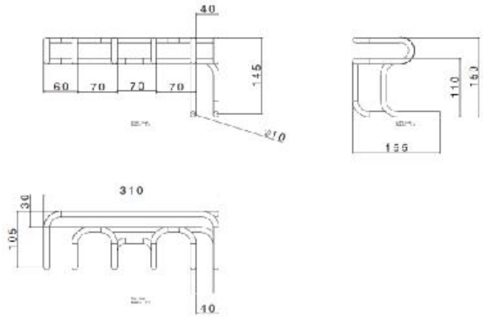


Fig 5.2 Coil Detailing

Diameter of 10mm Steel Ball Had Designed In That above Plate

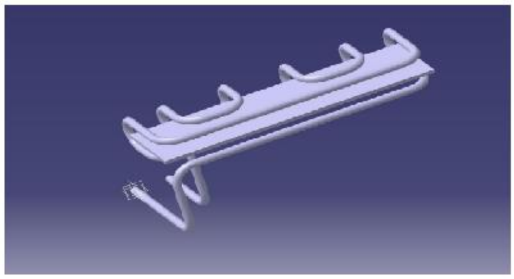


Fig 5.3. steel plate above surface

Analysis procedure

The flow through rocket nozzle is analyzed by Fluid-Flow Analysis (Fluent). Open ANSYS Workbench to do a simulation in ANSYS Workbench! Open ANSYS Workbench by going to Start > ANSYS > Workbench. This will open the startup screen as shown in figure 4.1. After opening this window, we will find all the analysis systems on left side, as it is discussed before we are going to make analysis with Fluent. To make analysis in Fluid – Flow Analysis (Fluent) click on fluent on left side, hold it and drag it to right side empty space. After dragging the fluent the fluent workbench is visible on the empty space as shown in figure 5.1

Figure 8.1. Fluent work bench

ANSYS Design Modeler software is specifically designed for the creation and preparation of geometry for simulation. It's easy-to-use, fully parametric environment with direct, bidirectional links to all leading CAD packages acts as the geometry portal for all ANSYS products to provide a consistent geometry source for all engineering simulations

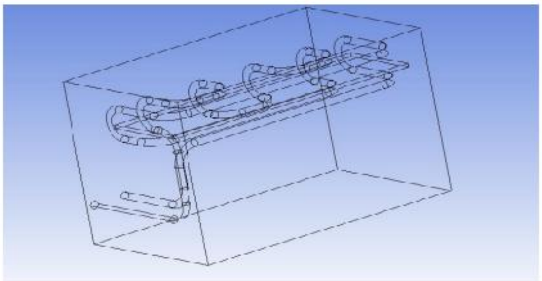
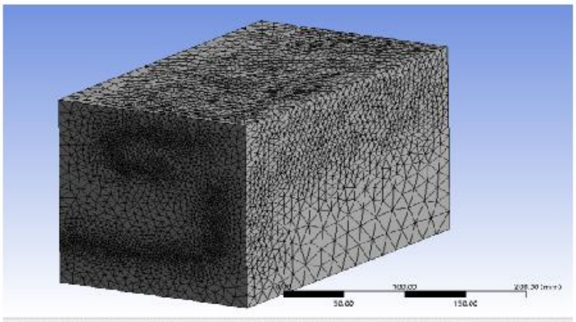


Fig 8.2. Imported geometry

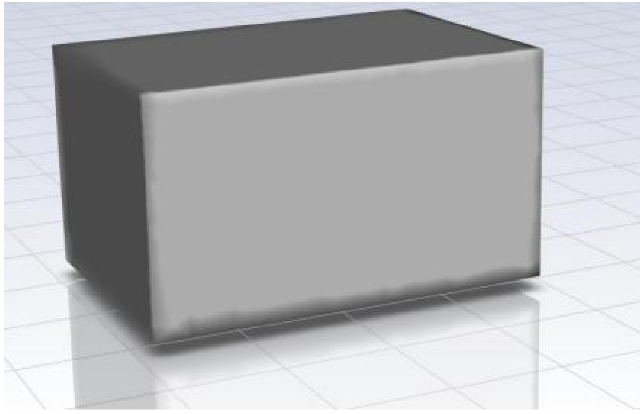
8.2 MESH

Meshing is the process of dividing the whole component into number of elements so that whenever the load is applied on the component it distributes the load uniformly. To start meshing double click on mesh option that is below the geometry option as shown in the figure 8.8. After opening the meshing, you will find project tree in which there is an option called mesh. Click on the mesh so that you will find details of mesh at the bottom as



SETUP

This is the most important step to make the simulation, in this step properties of fluid, boundary conditions and the calculation part takes place. Now go to the first window and double click on setup so that another window where we can input above discussed properties



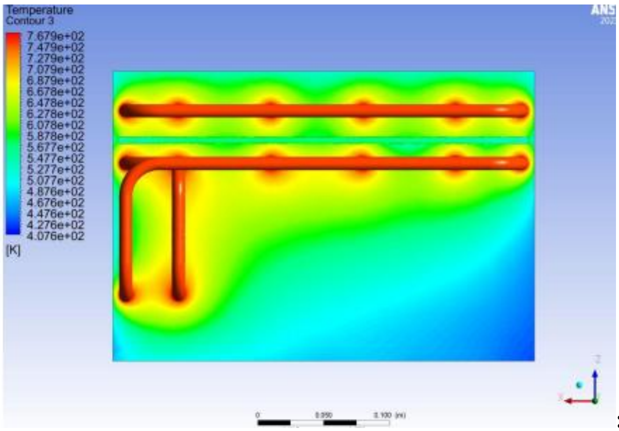
Radiative Transfer Equation

The radiative transfer equation (RTE) for an absorbing, emitting, and scattering medium at position in the direction isis the optical thickness or opacity of the medium. The refractive index is important when considering radiation in semi-transparent media. Figure 5.3.1 illustrates the process of radiative heat transfer. Fig 7.1. Radiative Heat Transfer The DTRM and the P-1, Rosela--nd, and DO radiation models require the absorption coefficient as input. and the scattering coefficient can be constants, and can also be a function of local concentrations of H2O and CO path length, and total pressure. ANSYS FLUENT provides the weighted-sum-of-gray-gases model (WSGGM) for computation of a variable absorption coefficient. See Section 5.3.8 for details. The discrete ordinates implementation can model radiation in semi-transparent media. The refractive index of the medium must be provided as a part of the calculation for this type of problem. The Roseland model also requires you to enter a refractive index, or use the default value of .

$$\frac{dI(\vec{r},\vec{s})}{ds} + (a+\sigma_s)I(\vec{r},\vec{s}) = an^2\frac{\sigma T^4}{\pi} + \frac{\sigma_s}{4\pi}\int_0^{4\pi} I(\vec{r},\vec{s}\,')\,\Phi(\vec{s}\cdot\vec{s}\,') \qquad (5.3\text{-}1)$$

where	$\vec{r}$	=	position vector
	$\vec{s}$	=	direction vector
	$\vec{s}\,'$	=	scattering direction vector
	s	=	path length
	a	=	absorption coefficient
	n	=	refractive index
	σ_s	=	scattering coefficient
	σ	=	Stefan-Boltzmann constant (5.669×10^{-8} W/m ^{2}-K ^{4})
	I	=	radiation intensity, which depends on position ($\vec{r}$) and direction ($\vec{s}$)
	T	=	local temperature
	Φ	=	phase function
	Ω'	=	solid angle

Ansys result:



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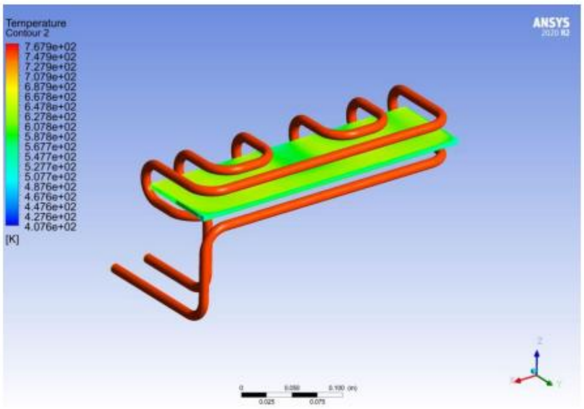
Result and discussion



VII. CONCLUSIONS

The analysis using ANSYS fluent helps to find the induction heating load parameters the ansys fluent simulation shows a behaviour in which the resistance of the work piece increasing as temperature increases during heating process. With reference result chapter V, as the work piece temperature increases with time and the penetration depth increases with temperature, the cross-sectional area of the work piece

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