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A new approach to working coil design for a high frequency full bridge series resonant inverter fitted contactless induction heater

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Abstract. High frequency full bridge series resonant inverters have become increasingly popular among power supply designers. One of the most important parameter for a High Frequency Full Bridge Series Resonant Inverter is optimal coil design. The optimal coil designing procedure is not a easy task.. This paper deals with the New Approach to Optimal Design Procedure for a Real-time High Frequency Full Bridge Series Resonant Inverter in Induction Heating Equipment devices. A new design to experimental modelling of the physical properties and a practical power input simulation process for the non-sinusoidal input waveform is accepted. The design sensitivity analysis with Levenberg-Marquardt technique is used for the optimal design process. The proposed technique is applied to an Induction Heating Equipment devices model and the result is verified by real-time experiment. The main advantages of this design technique is to achieve more accurate temperature control with a huge amount of power saving.

Keywords: induction heating; optimal design; COMSOL; full bridge inverter; resonant

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Where ρ_0 the resistivity at the reference temperature is T_0=293K, α is the temperature coefficient of the resistivity and T is the actual temperature in the domain.

The time average of the inductive heating over one period, is given by

$$Q = \frac{1}{2\sigma}|E|^2 \tag{4}$$

The coil inductor is cooled by a turbulent water flow in an internal cooling channel. This is matched by a combination of a high effective thermal conductivity and a homogenized out-of-plane convective loss term

$$Q_C = \frac{\frac{dM}{dt} C_\rho (T_{in} - T)}{2\pi r A} \tag{5}$$

Where

$\frac{dM}{dt}$ =The Water Mass Flow

T_{in}=The Water Inlet Temperature

r=The Radial Coordinate

A=The Cross Section Area of the Cooling Channel.

3. Orbital stability analysis of coil design system

Considered the system defined by the following equation

$$\begin{aligned} x_1 &= x_1 g(r) - x_2 \\ x_2 &= x_1 + x_2 g(r) \end{aligned} \tag{6}$$

Where $\begin{aligned} g(r) &= r^2 (A - r) \\ r &= \sqrt{x_1^{\,2} + x_2^{\,2}} \end{aligned}$

This system has a unique closed trajectory i.e., a limit cycle.

$$\begin{aligned} C : x^0(t) &= \begin{pmatrix} A & \cos t \\ A & \sin t \end{pmatrix} \\ x^0(t) &= x^0(t - 2\pi) \end{aligned} \tag{7}$$

It represents an oscillator stabilized at an amplitude A>0; and its equation of first variation about $x^0(t)$ are

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} -A^3 \cos^2 t & \left(-1 - A^3 \sin t \cos t\right) \\ \left(1 - A^3 \sin t \cos t\right) & -A^3 \sin^2 t \end{pmatrix} \begin{pmatrix} y_1 \\ y_2 \end{pmatrix} \tag{8}$$

$$-\frac{d^2u}{dx^2} = 2 \quad \text{for } 0 < x < 1 \tag{15}$$

With $\mu(0)=\mu(1)=0$
The exact solution is

$$\mu(x) = \mu(1-x) \tag{16}$$

While the finite element solutions are for $N = 2$

$$\mu_h = \begin{cases} h^2\left(\frac{x}{h}\right) & \text{for } 0 \le x \le h \\ h^2\left(2-\frac{x}{h}\right) & \text{for } h \le x \le 2h \end{cases} \tag{17}$$

$N = 3$

$$\mu_h = \begin{cases} 2h^2\left(\frac{x}{h}\right) & \text{for } 0 \le x \le h \\ 2h^2\left(2-\frac{x}{h}\right)+2h^2\left(\frac{x}{h}-1\right) & \text{for } h \le x \le 2h \\ 2h^2\left(3-\frac{x}{h}\right) & \text{for } 2h \le x \le 3h \end{cases} \tag{18}$$

$N = 4$

$$\mu_h = \begin{cases} 3h^2\left(\frac{x}{h}\right) & \text{for } 0 \le x \le h \\ 3h^2\left(2-\frac{x}{h}\right)+4h^2\left(\frac{x}{h}-1\right) & \text{for } h \le x \le 2h \\ 4h^2\left(4-\frac{x}{h}\right)+3h^2\left(\frac{x}{h}-2\right) & \text{for } 2h \le x \le 3h \\ 3h^2\left(4-\frac{x}{h}\right) & \text{for } 3h \le x \le 4h \end{cases} \tag{19}$$

For the two-element case $h = 0.5$, the errors are given by

$$\begin{aligned} \left\|\mu-\mu_h\right\|_0^2 &= \int_0^h \left(x-x^2-hx\right)^2 dx + \left(x-x^2-2h^2+hx\right)^2 dx = 0.002083 \\ \left\|\frac{d\mu}{dx}-\frac{d\mu_h}{dx}\right\|_0^2 &= \int_0^h \left(1-2x-h^2\right)^2 dx + \left(1-2x+h^2\right)^2 dx = 0.08333 \end{aligned} \tag{20}$$

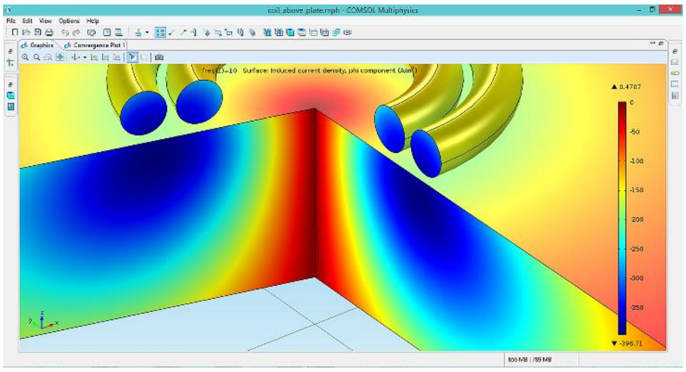

Fig. 3 The design parameters in the optimal design process(3D)

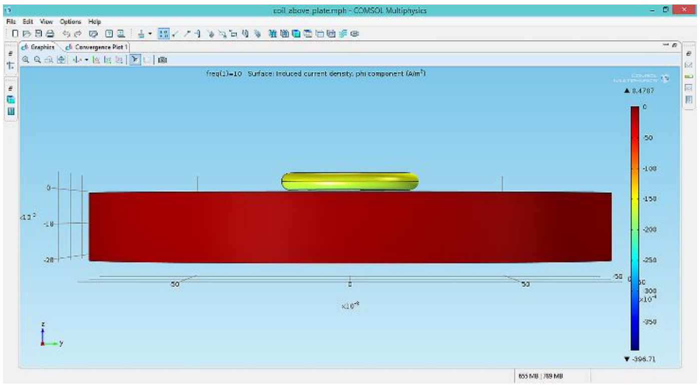

Fig. 4 The design parameters in the optimal design process (2D)

Table 2 Error in the energy conservation

Description	Expression
Supply Voltage	240 V
Wire Conductivity	5483.165792 S/n
Wire Radius in Coil	0.05 mm
Frequency	55 Khz
Turns in coil	40
Time for Stationary Solution	1 sec

6. The practical power input simulation results and analysis

In the real-time analysis of the eddy current system the input current was time harmonic sinusoidal wave but the actual power input of the cooker is an envelope waveform as shown in Fig. 1.

7. Optimal design procedure for a real-time high frequency full bridge series resonant inverter in induction heating equipment devices

The Optimal Design model for a Real-time High Frequency Full Bridge Series Resonant Inverter in Induction Heating equipment devices is shown in Fig. 2. The design parameters of the induction heating equipment devices considered here are the width and location of the gap between exciting coils mainly is shown in Fig. 3. The size of the central hole and the end diameter are fixed in the design. The design parameters in the optimal design process is shown in Fig. 4. Table 1 give the results of error in the Conservation of Energy in the coil Design System and Table 2 give the error in the Optimal Design Procedure for a Real-Time High Frequency Full Bridge Series Resonant Inverter in Induction Heating Equipment Devices and Fig. 4 shown the design parameters in the optimal design process (2D).

8. Conclusions

An optimal design procedure for a Real-Time High Frequency Full Bridge Series Resonant Inverter in Induction Heating Equipment device is proposed. Temperature distribution of the pan after optimization is modelled through an experiment. Also, non-sinusoidal exciting current is taken into account by the inverter simulation program and the actual power input waveform of the induction cooker is to be considered. The temperature distribution of the system is computed by finite element method and compared with experimental determinations. The Levenberg-Marquardt technique is used for the optimal design with real-time limitations. The new experimental and simulation data are similar, proving the validity of the proposed technique.

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