Edge effect of load in transverse flux induction heating systems

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Introduction

Induction heating in transverse flux can be economically effective for thin workpieces from aluminum, copper, gold, silver and other metals with low resistivity. One thing to note is that obtaining of temperature uniformity is very easy, because a strong edge effect of the load plays determining role in quality of heating. Multiple studies since the beginning of 1960s showed that it is a very serious problem for this type of heating.

Methods of calculation

Analytical method

The analytical solution of TFIH system (a) can be obtained, assuming that the
metallic strip is located between two large and flat poles of electromagnet
without poles and slots (b).

The induced current density is written in the following Fourier series

\[ \vec{j} = \sum_{n=1}^{\infty} \frac{2}{\pi a} \left( \frac{n \pi}{a} \right) \left( \psi_n \cos(mz) + \phi_n \sin(mz) \right) \frac{e^{-j \omega t}}{\mu_0} \]

The current densities will be the two-dimensional arrays of the complex values with fixed \( d \).

\[ \vec{j}_x = \psi_n \cos(mz) + \phi_n \sin(mz) \]

The specific power is calculated as

\[ p_s(y,z) = p_{s0} \left[ \left| \vec{j} \right|^2 - \left| \vec{j}_d \right|^2 \right] \]

Numerical method

Equation in numerical method of calculation for magnetic field in a rectangle
body has the form

\[ \frac{\partial H_x}{\partial y} + \frac{\partial H_y}{\partial z} = \sum_{n=1}^{\infty} \left( \frac{n \pi}{a} \right) \left( \psi_n \cos(mz) + \phi_n \sin(mz) \right) \frac{e^{-j \omega t}}{\mu_0} \]

New program of Transverse Flux Heating is inserted in ELTA 6.0 to make
simulation and predict temperature distribution in the width of thin strips.

Investigation of TFIH edge effect

Results of simulation

Strip parameters: thickness \( t = 2.5 \) mm, width \( d = 1200 \) mm, materials – copper, aluminum, stainless steel and ferromagnetic steel.

Parameters of E-type TFIH system: direct and back conductor – inductor width 90
mm, turns number 6 from copper tube, coupling gap 29 mm (total window opening
\( h = 60.5 \) mm), pole pitch \( r = 210 \) mm. Processing: continuous heating.

Distribution of power (left) and predicted temperature (right) along the width of aluminum strip 2.5 mm thickness.

Distribution of power (left) and predicted temperature (right) along the width of steel 1040 strip 2.5 mm thickness.

Conclusion

This study confirmed existing and provided new information about edge effects
of strips in TFIH system. New program Transverse Flux Heater based on
a structure of ELTA has been developed to investigate edge effect. This program can simulate distribution of specific power along the strip width. Knowledge of edge effect is very important for understanding behavior, simulation, and optimal
design of TFISH systems. Balancing proper selection of frequency and the coil
position or length allows the designer to provide the required temperature
distribution along the part.

More information may be found at:

www.nsgsoft.com  www.fluxtron.com

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