Mathematical modeling of temperature distribution in a ferromagnetic plate subjected to high-frequency induction heating

Bhushan B. Balpande[a] and Ganesh D. Kedar[b]

[a,b] Department of Mathematics, RTM Nagpur University, Nagpur-440033, Maharashtra, India

Abstract: The present investigation aims to present a mathematical model for the total heat loss of a thin ferromagnetic steel plate exposed to a linearly moving high-frequency induction heater, which is divided into two components: the losses due to eddy current and the hysteresis phenomenon. The outcome of this technical problem will enable us to guarantee the possibility of the efficient design and construction of electric devices with magnetic circuits characterized by reduced magnetic losses and may thereby help to reduce the need for costly experimentations. Furthermore, the educational benefits of adopting such a mathematical model are to enhance the knowledge of the thermal behavior of the ferromagnetic material in the time-varying electromagnetic field so produced. The distribution of eddy current and hysteresis losses across the rectangular plate is obtained in the context of Maxwell's equations and modified Ohm's law. Thereafter, treating the total heat loss (sum of eddy current loss and hysteresis loss) as the thermal loading of the plate material, the differential equations governing the temperature field, elastic field, and electromagnetic are solved using integral transform techniques. The results are displayed graphically to illustrate the influence of wave frequency, skin depth, electrical conductivity, magnetic permeability, hysteresis loss, and eddy current loss of steel plate on the various fields considered in the problem.

Key-words: Magneto-thermoelasticity, Maxwell's equations, Eddy current, Hysteresis loss, skin effect, finite Marchi-Fasulo transform