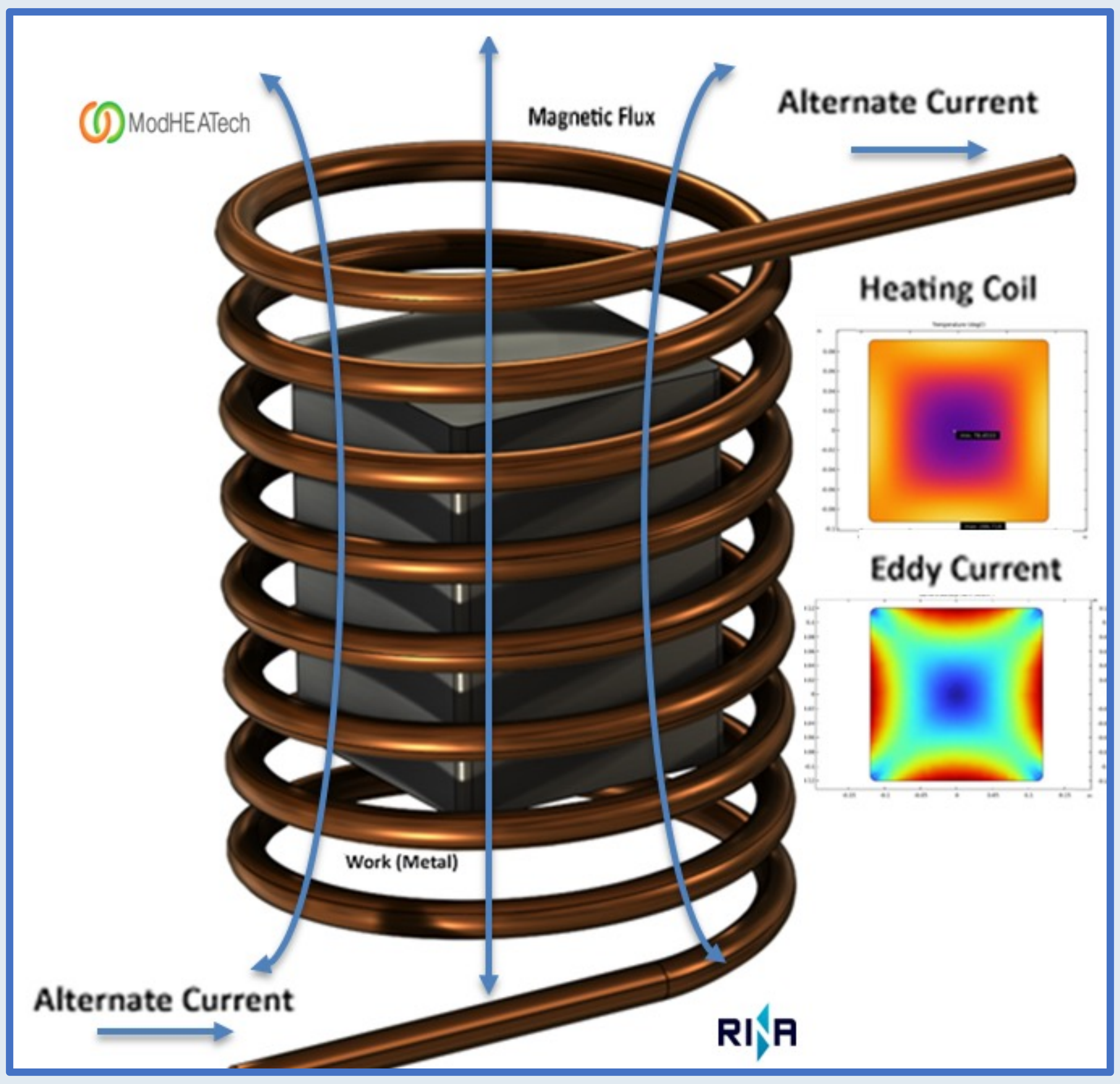

Induction Heating Optimizing for Steel Billets: Advanced Electromagnetic-Thermal Modeling Approach

The present work is aimed at simulating electromagnetic induction billet heating process by means of the development of a mathematical model and experimental investigation in the industrial field.

M. Freda[1], F. Macci[1], E. D'Amanzo[1], A. Colaneri[1], V. M. Santisteban[2]
1. RINA Consulting – CSM S.p.a., Rome, Italy.
2. SIDENOR, Basauri (Bizkaia), Spain.

Abstract

In the frame of the decarbonization of steel industry, with the aim of creating new technologies and applications, RINA-CSM developed for the EU project Horizon ModHEATech an electromagnetic-thermal model with COMSOL Multiphysics® in order to study the heating of a steel billet by induction, before rolling mills. The activity is related to the modeling of a multiphysics process controlled in power or voltage or current.
The model was used to determine the optimal process parameters in order to respect the production and quality requirements.

The thermal distribution and the current density distribution inside the billet has been studied on the basis of:

- Steel grades
- Applied supply power/current
- Frequency
- Initial/Final Temperature of the billet
- Productivity

The study has been focused on the Reheating Furnace of SIDENOR plant, as use case; based on the simulations results, different scenario has been compared to find the best layout configuration for introduction of induction heating in the industrial site.

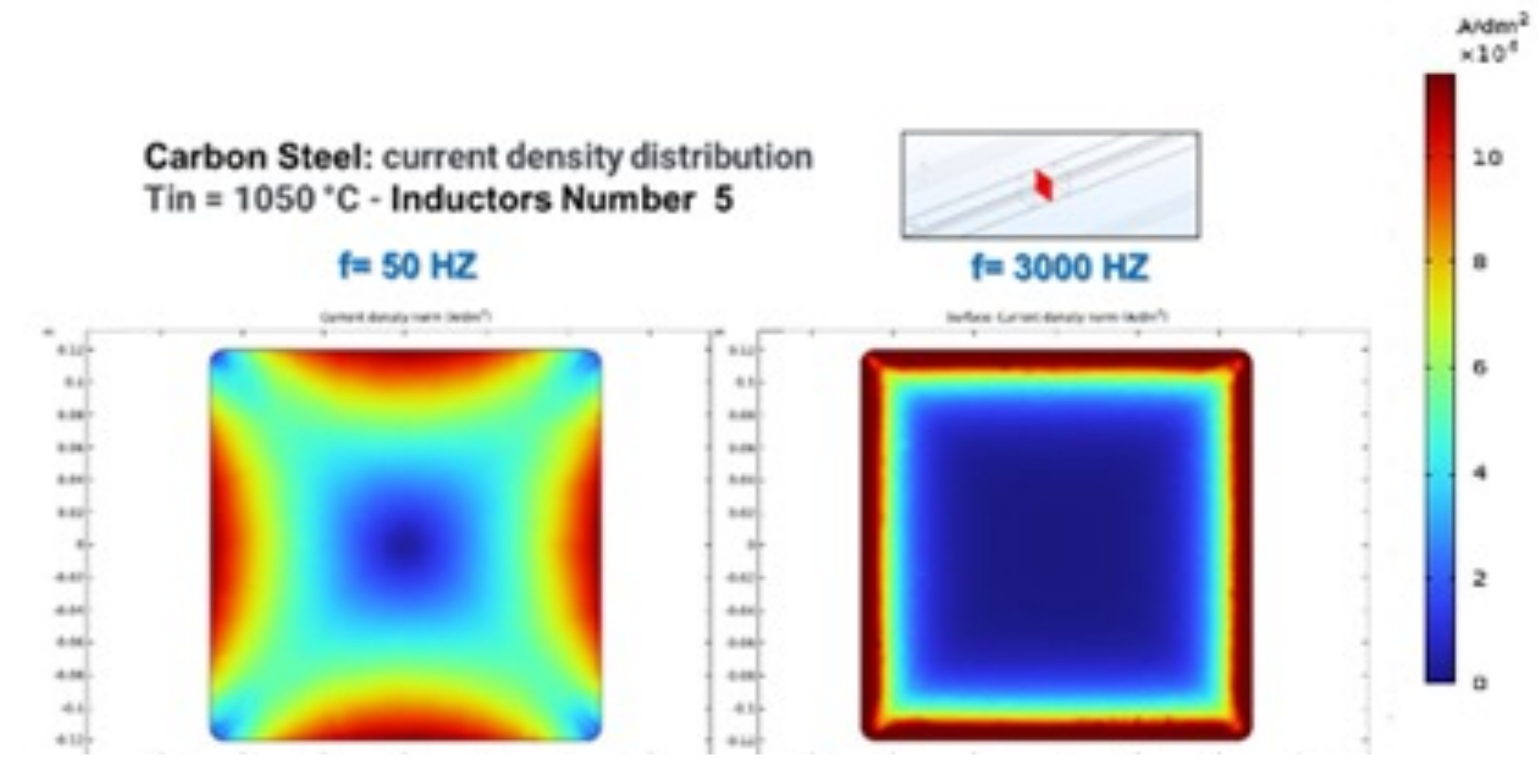

FIGURE 1. The billet 2D-profiles current density distribution as a function of the frequency (Skin Effect): cut plane yz.

Methodology

An induction furnace is made from a number of spaced inductors and the billet to be heated. The billet passes through an inductor with a certain speed, determined by the productivity. The inductor is powered with the alternating. The alternating current of the inductor generates an electromagnetic field in the surrounding domain and this electromagnetic field generates induced currents on the surface of the billet. The induced eddy currents generate an increase in the surface temperature of the billet in the area under the inductor. The temperature tends to homogenize towards the center of the billet due to conduction in the areas external to the inductors. A reliable, flexible and robust 3D model has been made for simulating the induction heating for steel billets in COMSOL Multiphysics® environment. The process is modelled as a multiphysics system where electromagnetism and heat transfer are solved simultaneously to generate magnetic fields and temperature distribution.
The model merges:

- the magnetic field generated by the coil that creates induced currents on the billet
- the heating by the joule effect generated by the currents induced on the surface of the billet.

Results

The model is a valuable tool for conducting feasibility study, analysis, design, testing, and maintenance of the electromagnetic induction heating plant. The model's results were validated by comparing them to real process data. It has been proven that in simulation, it is possible to keep the maximum temperature difference in line with the requirements for product quality. In the simulated cases, the impact of frequency was assessed. At low temperatures (below the Curie temperature), working at frequencies of the order of tens of Hz (for example, at 50 Hz) is the recommended method for the materials being studied; at high temperatures (above the Curie temperature), working at frequencies of the order of kHz (for example, at 3000 Hz) is the recommended method for the materials being studied (Figure 1). By simulating the SIDENOR plant cases, it was possible to understand the importance of the homogenization phase of the electromagnetic heating furnace configuration. To obtain permissible temperature gradients along the billet profile (Figure 2), the space between two inductors (homogenization zone) must be appropriately sized. This dimension is related to the type of material, the geometry of the billet, the speed of the billet, the initial temperature of the billet, the thermal power provided by the inductors in the heating zone, and the operating frequency.

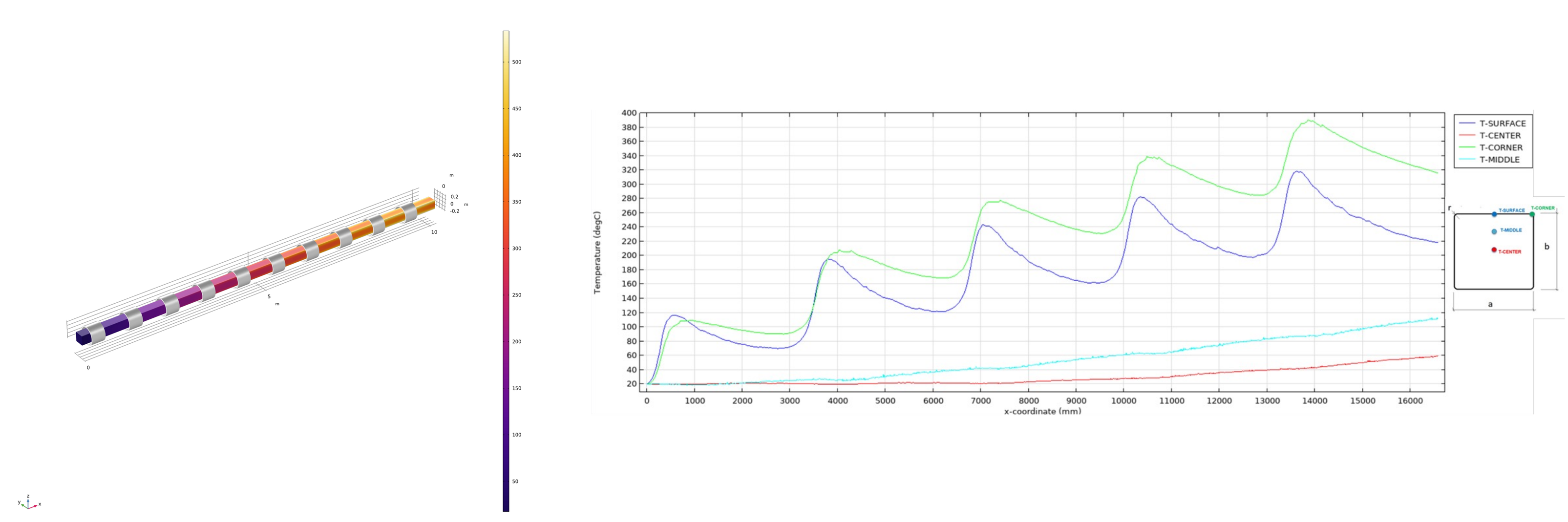

FIGURE 2. Carbon steel billet thermal profiles with Tin=20°C at f0=50 Hz and 10-inductors.

REFERENCES

1. Induction Heating | Heating | Hardening | Annealing | Brazing | Welding - Bernard Nacke, Egbert Baake (eds.) - 1st edition 2016.
RWE – Information Induktive Erwärmung.
2. A. A. Bhat, S. Agarwal, D. Sujish, B. Muralidharan, B. P. Reddy, G.Padmakumar and K. K. Rajan - Thermal Analysis of Induction Furnace - 2012 COMSOL Conference.
3. Gruppo AMBREL Precision Induction Heating - Le basi del riscaldamento a induzione - 2021: https://www.aminditalia.com/
COMSOL Multiphysics, User Manual and Model Library.