Modeling of Induction Heating of Steel Billets for Control Design Purposes

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Abstract

This paper deals with numerical modeling of modular industrial induction heating of steel billets for hot forming applications using the COMSOL Multiphysics. A mathematical model based on Finite Element Method is presented. Design of induction heaters is constantly evolving and improving in terms of electrical and thermal efficiency. In recent years there is a trend of modular designed induction heating systems with separated power supply which replaces conventional one coil-one power supply heaters. The primary goal of computer modeling was to investigate the steady-state thermal dynamics generated by four-module heater. Obtained results and generated step responses of each module were loaded into Matlab DPS Blockset for purpose of design the progressive control circuit based on distributed parameter systems (DPS). The 3D model of 3 meters long inductor was provided by Czech company Roboterm (Figure 1). There was used induction heating multiphysics module including the translational motion and radiation heat transfer. Model geometry was transformed into 2D axisymmetric space dimension. Non-linear temperature dependency of electrical and thermal material properties of 16MnCrS5 steel and four coil groups with different current load were taken into account. Custom combination of distributed, mapped and free quadratic mesh was applied to achieve good accuracy-to-computing time ratio (Figure 2). Example of obtained thermal profile and temperature-time graph of heated billets is shown on Figure 3. The expected forming temperature between 1400-1450K was achieved during time of approximately 400s with billet velocity of 1cm/s which meets the requirements of industrial hot forging production. The desired temperature distribution gives a fairly accurate view on induced heat to the surface of billet and to the core as well. Generated time-spatial temperature profile of four-module inductor was successfully used to achieve the step responses from each module what is essential for identificational analysis of process for distributed parameter system control design purposes. Figure 4 shows a simple DPS Blockset circuit schematic of temperature control for four-module induction heater.

Reference

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Figures used in the abstract

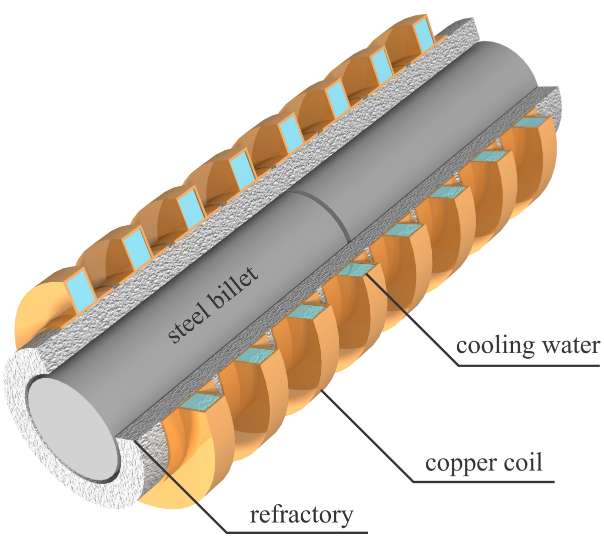

Figure 1: Small part of rendered 3D inductor model.

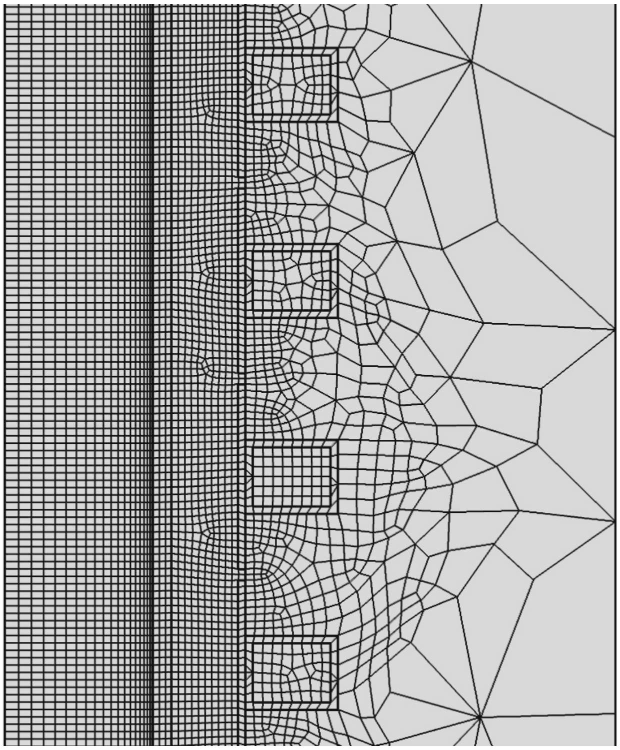

Figure 2: Detail of applied mesh in axisymmetry.

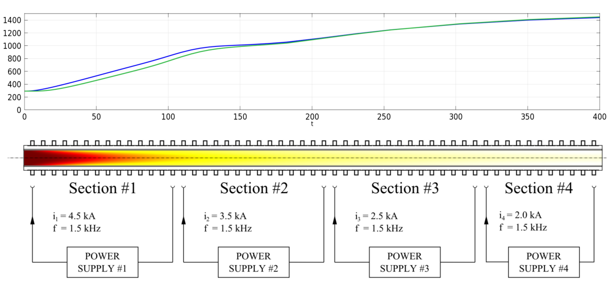

Figure 3: Thermal profile and temperature-time dependance of heated billet.

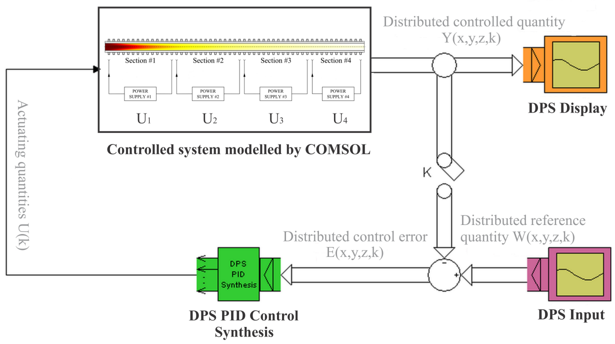

Figure 4: Simple schematic of DPS control circuit suited for modular induction heater.