Computational Analysis for Induction Heating of Moving Wire

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Abstract

Induction heating has become increasingly used in the last years in various industrial manufacturing processes. It can be used at low frequencies (~50 Hz) for initial preheating before deformation, at higher frequencies (~ 4KHz -10 KHz) for processes involving metallurgical heat treatment. The main advantage includes; fastest heating rate, great precision in heating localization, instantaneous start/ stop and its good reproducibility. The basic induction setup for our tunnel furnace used, consist of two coils with 54 numbers of turns each (Figure 2), for preheating and constant heating purpose, and strand wire as a continuous metal work piece. The work piece is the secondary while the surrounding copper coils are the primary, linked or coupled with air, therefore forming an air core transformer.

The coils are supplied with alternating current with frequency range from 4KHz - 5KHz, therefore a rapid oscillating magnetic field induces and hence, eddy currents are induced over the periphery, based on the concept of skin effect, of the strand wire an account of the Joule effect.

Please refer to the setup illustrated in Figure 1.

The need arises to study the surface temperature variation along the length of the wire moving at constant line speed, within the residence time of the load (wire), and the significance of skin effect and its dependence on the frequency and power supplied. COMSOL Multiphysics® AC/DC module is used to study the skin effect with 3D model as shown in Figure 1, and with the help of Coil Group Domain; 2D axisymmetric model of the complete furnace is solved to study the surface temperature variation along the length (Figure 2)

Based on the expertise, developed in COMSOL Multiphysics®, we have obtained some of the promising results, however this is the initial step and we have to go further for more detailed explanation. Skin effect phenomena, in 3D modeling is best explained when we opted to go with the boundary layer meshing as shown in Figure 3 where the result obtained with the normal tetrahedral meshing was not helpful.

Owing to the memory constraint, we decided to model the complete furnace with 2D axis symmetric modeling technique and assumed the helical strand wire as cylindrical one with the

same power consumption per unit volume. So we studied the variation of the surface temperature along the length of the wire (Figure 4). This has helped us to study the effect of change in cross section of the coil over the induced surface current and the respective temperature variation, and eddy current variable across each section of the coils.

With these models, we now have the understanding of the induction heating phenomena and the basic physics involved in this. Since this is the initial step and we are moving to further fine tune the model as per our requirement and therefore, will further study the impact of operation parameter such as frequency, Voltage etc. across the coils and the variation of line speed, over the thermal profile and ultimately the changes in mechanical properties of the wire.

Figures used in the abstract

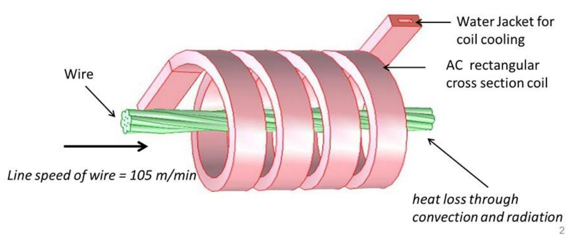

Figure 1: 3D model: Induction heating of strand wire

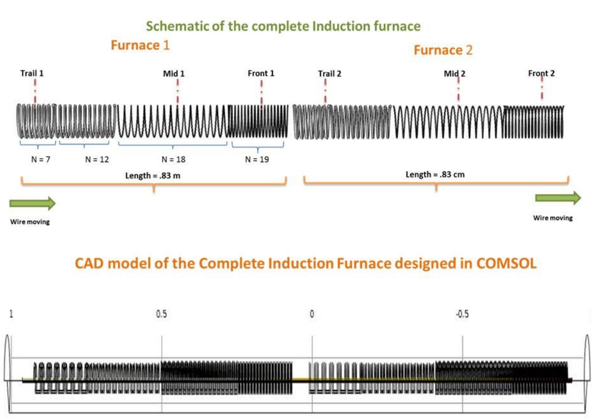

Figure 2: 2D model : Detail of the furnace (the modelled furnace is rorate to crete a 3D onject)

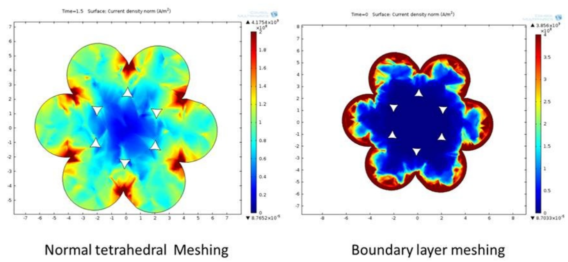

Figure 3: Induced current profile over the peripherry

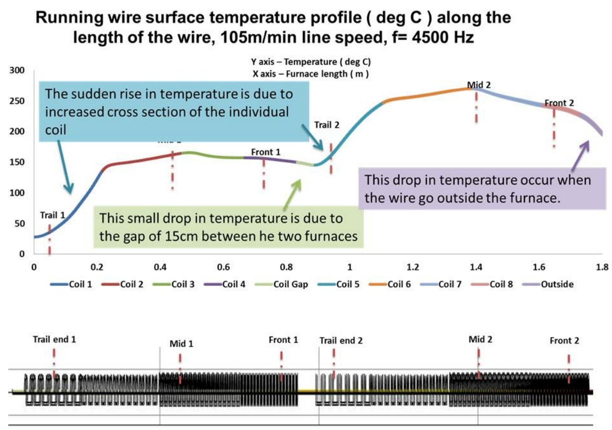

Figure 4: Temperatire profile along the length of the furnace