Induction heat treatment of large rolls with two independent power sources

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Abstract—**The two-inductor heat treatment system for rolls of rolling mills is highly flexible and can improve the quality of heat treatment while solving energy-efficiency and productivity problems. A digital model of induction heat treatment of rolls with the computation of electromagnetic, temperature and stress fields is developed taking into account the characteristics of power supplies and control systems for heat treatment modes. Particular attention is paid to the reliability of frequency converters in the presence of magnetic coupling between inductors. Recommendations on frequency selection and inverter settings are given. A universal method of digital design and control of thermal conditions in induction heat treatment systems is considered.**

Keywords— Coupled Electromagnetic and Temperature Fields, Electromagnetic processing of metals, Induction heating, Multiphysics Problems, two-inductor heat treatment system, frequency converters

I. Introduction

In the metallurgical industry the induction heating devices have a power level up to several hundreds of kilowatts or megawatts. The frequency range of used power sources is from tens of Hz to MHz.

Thermal processing of pipes and rolls is an important stage in manufacturing of high quality steel products like lengthy pipes and rolls with big diameters for rolling mills. Solidification and annealing are main types of heat treatment of pipes and rolls. Modern heat treatment requires strict implementation of temperature evaluation during heating, controlled cooling and, probably, repeated heating.

The developed numerical models of technological thermal processing include two-dimensional modeling of electromagnetic and thermal fields in the system. Thermal tension during processes of heating and cooling the pipes and rolls is simulated. These information is essential for defining the structure, hardness, size of a grain and other characteristics of the pipes' and rolls' metal.

The developed two-dimensional model was extremely effective not only for the induction heat treatment systems design of pipes and rolls, but also for a digital control of these complexes. However, it is necessary to use the temperature feedback under the presence of perturbations. The original way of controlling the temperature at the heater' exit is proposed by the control of the temperature at the special point in the "active zone".

The use of modular structure of induction heaters has a significant advantages in induction heating technology, since it allows optimizing the operation modes of equipment in relation to: energy consumption; scale formation; ability to maintain a constant exit temperature.

The advanced digital control allows to effectively process the possible disturbances, such as: changes of speed, diameter and initial temperature of the workpiece, and, therefore, to minimize the amount of defects during heating.

II. PROBLEM

Figure 1 shows the temperature distribution along the roll during quenching in 2 different modes. Each mode should provide the exit temperature of 1000 °C after the second inductor on the surface [1]. Two modes of hardening of the roll are presented in fig.1. 1 (indicated by 1) – is the hardening mode of the rolling mill's roll from two power supplies (each power source operates on its inductance coil) power of the first is 570 kW, power of the second power source is 200 kW. The operating frequency of both power supplies is 100Hz [2]. Tempering mode 2 (indicated by 2) – is the hardening mode from one power source, inductor connected in series, power 820 kW, frequency 65 Hz. The inductive speed in each case is 0.1 cm/s. 3 shows temperature at a depth of 100 mm for two quenching modes.

Inductors must be placed in a short distance from each other to ensure the required temperature distribution. In the 2 mode, the surface temperature has a strong unevenness. Just a small area reaches the required temperature, which requires a decrease in the speed of the inductor to maintain the necessary time for the recrystallization of the metal. Extension of the holding time can lead to overheating of the local zones of the part.

The mode 2 is much more complex, and the derived surface has a much lower quality, in comparison with the mode 1.

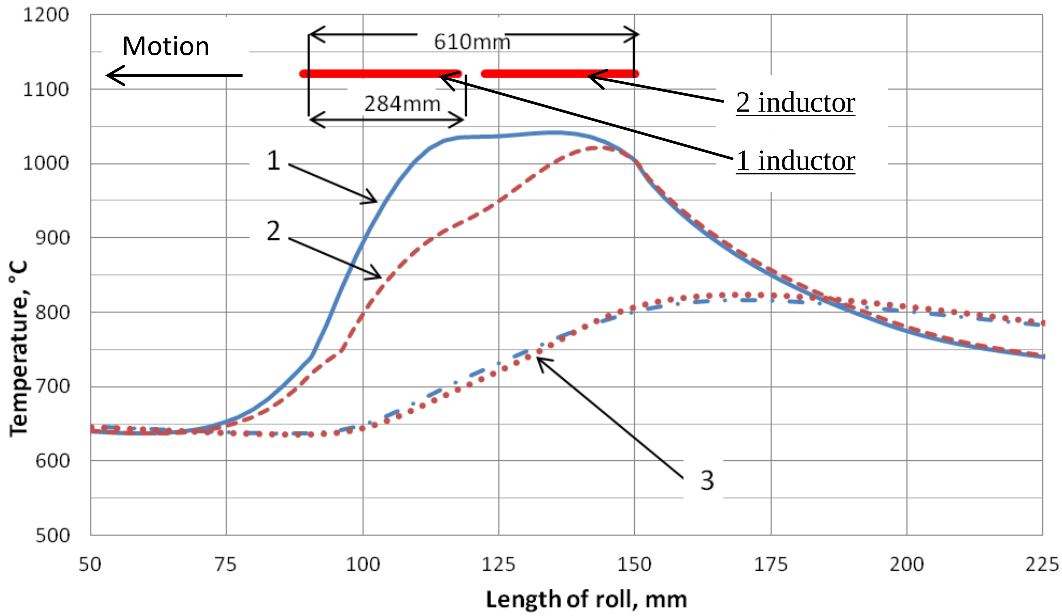

Figure 1. Hardening of the rolling mill roll

The 1 mode allows to achieve uniformity of the temperature almost under the entire surface of the 2nd inductor, avoiding the appearance of local maxima of the temperature distribution.

Thus, the use of the mode 2 allows obtaining a surface with improved characteristics, reducing the probability of defects, while increasing the productivity, in comparison with the mode 1.

Since the inductor is located at close range, there is instability in the operation of power sources due to the presence of magnetic coupling between the inductors.

Fig. 2 shows the hodograph of the induced reaction on the adjacent contour in conventional units of frequency, where f1, f2 are the resonant frequencies of the magnetically coupled circuits, the frequency f1 is the resonant frequency of the load circuit, and f2 is the magnetically coupled circuit.

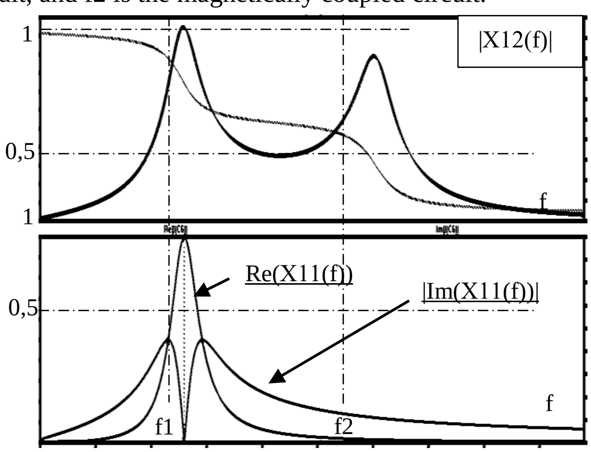

Figure 2. Dependence of the modulus of the induced reaction on the frequency and the dependence of the active and reactive components of the frequency

It can be seen that X12(f) has two local maximas: at the resonance frequency of the intrinsic circuit and at a frequency close to the resonance frequency of the neighboring contour. Also there are the modules of the imaginary and real parts of the response of the loading circuit in the graph. Thus, it can be seen that with a deviation from the frequency of the resonance, the amplitude of the induced interference sharply decreases, and the active component of the reaction also decreases, but the reactive component increases (within certain limits).

From the foregoing, we can determine the conclusion that the constructed model allows you to accurately determine the area of stable operation of inductors and power supplies for hardening rolls of rolling mills

CONCLUSIONS

New technologies for induction heat treatment of large diameter rolls of rolling mills with a barrel diameter of up to 65” are developed. It was found that the digital model of the induction system must necessarily include the calculation of electromagnetic and thermal fields, the calculation of stress and strain fields, as well as the calculation of power source parameters. This digital model can be used to create an intelligent control system for the installation of induction heat treatment of large-sized rolls of rolling mills.

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