Induction surface hardening

Kelvin Effect, Mean Curvatures and Load Impedance in Surface Induction Hardening: An Analytical Approach including Magnetic Losses

Abstract– Kelvin effect(Skin effect) is used in surface hardening produced by induction heating of gears, cam forms, camshafts and other work pieces of fairly complex geometries. The induction heating equipment for surface hardening of metals and alloys using LF (medium frequencies in the jargon of induction heating) is composed by a coil or coil assembly and a power semiconductor driving system up to 50 kHz. The load seen by the driving system is equivalent to a transformer.
The primary corresponds to the excitation coil or coil assembly, and the work piece corresponds to a short-circuited secondary. In these and others technical applications of Kelvin effect it is often necessary to be able to relate local skin depths with local curvatures of the surface of electrically conductive bodies. It was proposed recently a closed form analytical formula that relates the local skin depth with the local mean curvature and the well known skin depth for a flat conductive but non ferromagnetic body. The purpose of this paper is threefold. First, improve and give a critical discussion of the derivation of the aforementioned analytical formula. Second, generalize it to bodies with magnetic hysteresis losses. Third, apply the above mentioned generalized formula to describe the electrical load seen by the driving system in the conditions used for surface hardening.
The formulae given here could be applied to asses some characteristics of the load that may be of interest in the choice or design of the driving system, including the planning of digital simulations using complex computer codes. Index Terms–Induction heating, Load impedance modeling, Skin effect, Mean curvature, Hysteresis losses.

surface hardening

I_1

i_2

Work piece

I_1

I_1

Coil copper tubes