Coupled Numerical Multiphysics Simulation Methods in Induction Surface Hardening

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ABSTRACT

Numerical simulation is a valuable tool to help investigate complex multiphysics problems of engineering and science. This also applies to inductive surface hardening with its coupled electromagnetic and temperature fields as well as the micro structure changes of the hardened material. In this field, numerical simulation is a well-established approach for effective process design. This is particularly true since an analytical approach usually fails because of the complexity of the problems. Also, experiments oftentimes are not leading to a solution in an acceptable period of time because of the big number of process parameters. Furthermore, numerical simulation can help to investigate effects that could not have been observed otherwise. An example is the Joule heat distribution within a heated work piece during inductive heating. However, the fields of application as well as the methods of numerical simulation have to keep pace with technological progress. Two examples of new applications and methods for numerical simulation in induction hardening are presented in this paper: A complex 3D model of a large bearing and a new approach for inverse process design.

In the first part of this paper, an application-oriented strategy to numerically model and investigate scan hardening processes for large bearings is introduced. It will be shown how the 3D model can be applied to different hardening setups by a user without deeper knowledge of the numerical software. The advantages of using the model for the development of complex inductor geometries compared to an experiment based approach will be pointed out. The model calculates the temperature profile within a work piece, which is shown exemplarily for an inner ring of a main bearing used in wind power systems.

In the second part of the paper, a new numerical model for calculating martensite microstructure in induction surface hardening processes is introduced. It takes into account the heating as well as the quenching process and uses the temperature history of a work piece to calculate martensite formation. The calculation is based on an empirical equation found by Koistinen and Marburger. A comparison between the heat distribution within a work piece at the end of the heating process and the distribution of martensite after quenching is performed for different process parameters. Thus, it is determined, in which case the temperature distribution is sufficient to predict the hardened layer and in which case the microstructure has to be calculated to receive accurate results. The model is verified by comparing simulation results with different experiments.