Simulation of the Thermal Expansion of an Inductively Heated Gear Wheel for Shrink Fitting Purposes

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Abstract

In engineering it is a common practice to shrink a gear wheel on a shaft. Therefor an interference fit in the initial constellation is necessary, i. e. the inner diameter of the gear wheel is marginally smaller than the outer diameter of the shaft. Heating the gear wheel leads to a temporary expansion of it and this allows joining both parts. Hence, an interference fit assembly occurs during the cooling process of the gear wheel to ambient temperature. The interference of the compound prevents by friction, that both parts are loosened. Usually the heating in such shrink fitting processes is realized by placing the gear wheel in a conventional oven or a hot oil bath, which are energy demanding and time consuming [1, 2].

In this work, the heating process is realized by induction heating. The purpose of using this technique is to make the process more efficient, i. e. the reduction of heat losses and process time is aspired. Furthermore induction heating enables to concentrate the heat generation in the component to heat, whereas conventional heating systems are disadvantageously coupled with the heating of contacting fluids or surrounding materials. The magnetic field is generated by an induction coil (Figure 1-2). For the specific development of an appropriate geometry, the use of simulation software is beneficial, because some analytical methods give only estimations for the resulting physical quantities like the thermal expansion. The results given by the software allow the analysis of all relevant physical quantities in spatial format, so that the geometry can be improved iteratively and subsequent practical tests are reduced in extent.

In COMSOL Multiphysics® the simulation of this task was implemented by using the physical interfaces Magnetic Fields, Heat Transfer in Solids and Solid Mechanics. The coupling of the different interfaces was realized by taking the electromagnetic heat source formed by the interactions between the magnetic field and the gears material. The increase in temperature causes thermal expansion modeled in Solid Mechanics.

The magnetic flux distribution (Figure 3) of the geometrical design variant (Figure 1-2) illustrates the magnetic flux around the induction coil. This magnetic flux is concentrated to the desired direction of the gear wheel and in comparison to an induction coil without attached flux concentrator the simulation results showed the magnitude of the enhancement of the magnetic flux. Besides analyzing the magnetic flux distribution for designing an appropriate design of the induction coil, the displacement field is the most relevant physical quantity (Figure 4), especially concerning the process control. The necessary time for a certain required expansion can be evaluated. With the knowledge of the simulation results, there is a more accurate prediction of the necessary time for a certain required expansion in comparison to simplified analytical calculations possible.

Using simulations enables to develop a new induction heating system. Beside the simulation of thermal expansion of a gear wheel for shrink fitting purposes, the detachment of the composite between a gear wheel and a shaft is under investigations for a future model.

Reference

[1] S. Wang et al., Analysis on the Process of Induction Heating for Shrink-Fit Chuck, Advanced Materials Research, Vols. 383-390, pp. 2850-2855 (2012)
[2] P. Pedersen, On Shrink Fit Analysis and Design, Comput Mech, Vol. 37, pp. 121–130, (2006)

Figures used in the abstract

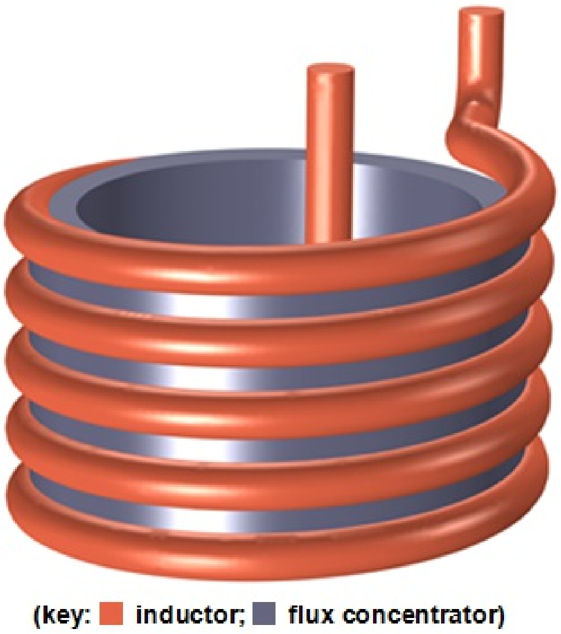

Figure 1: Induction coil with flux concentrator, which can be screwed on the induction coil.

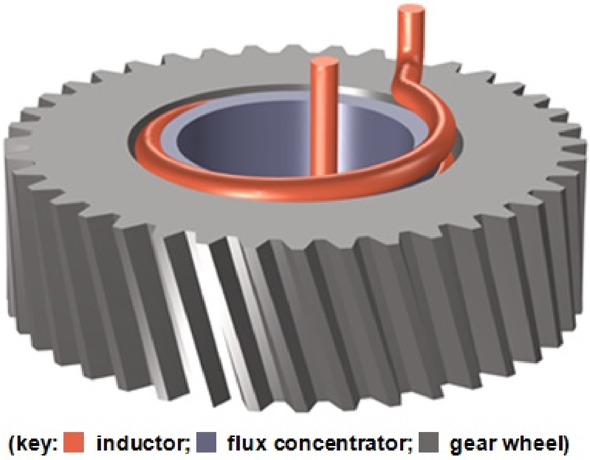

Figure 2: Complete geometry with gear wheel.

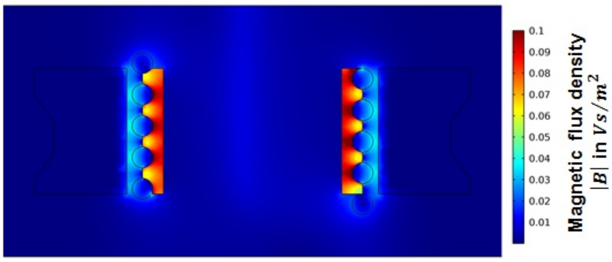

Figure 3: Magnetic flux (absolute value) in a vertical cross section through the system.

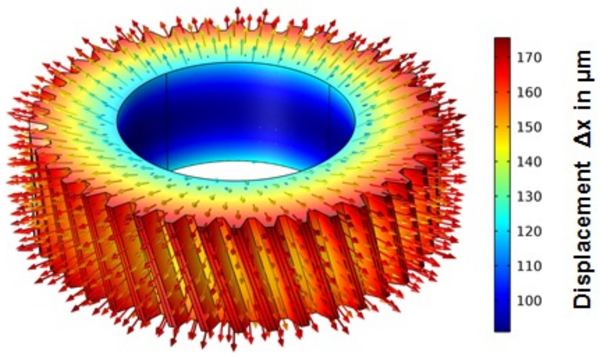

Figure 4: Thermal expansion of the gear wheel caused by increase in temperature with arrows to illustrate the direction of the expansion.