Multiphysical Simulation of an Induction Sealing Process for Cups with Laminated Aluminum Foil

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Abstract

The filling process of thermoformed cups with food like yogurt is followed by placing a laminated aluminum foil for hermetic sealing on top of the cup. By today's standards the sealing of the thermoformed aluminum foil with the cup is primarily realized by contact heat with a hot stamp. However this method has tremendous disadvantages. The hot stamp may locally cause a detachment of the color coating of the foil. Furthermore, the process is inefficient due to considerable heat losses to the ambience.

In this work an alternative sealing method based on induction heating to attain a more efficient and more precise process is realized. The induction coil can be cooled by water to avoid a hot sealing tool. Furthermore the electromagnetic induction is contactless besides the necessity of pressing the encapsulated induction coil on the cup to reach enough strength of the sealing weld. The motivation to use COMSOL Multiphysics® for simulating the induction sealing process was to verify the feasibility of substituting the common process and to identify effects like probably occurring boundary effects, which are quantitatively not to anticipate without the simulation of the induction sealing process and to derive optimization potentials.

In COMSOL Multiphysics® a model was established by using the physical interfaces 'Magnetic Fields' and 'Heat Transfer in Solids'. An induction coil shaped like the annular region to be heated up was modeled using the subinterface 'Multi-Turn Coil'. The induction coil was covered by a magnetic flux concentrator to realize a more efficient process. The melting of the cups' polymeric material was taken into account using the subinterface 'Heat Transfer with Phase Change' considering the temperature range and the latent heat of melting of the polymer. The coupling between the magnetic field and the heat transfer was realized by applying the thin aluminum foil as boundary heat source with the surface electromagnetic heating as input. The static electromagnetic study and the time dependent thermal study were separated in two sequential studies avoiding a frequency-transient study to reduce the demand of internal memory (RAM) to about 40 GB. A multigrid solver was used to reduce the computation time.

The simulation results underlined the feasibility of applying induction heating. The reduction of the necessary heat-up time comparing utilizing a coil with and without a flux concentrator was quantified. Furthermore, boundary effects caused by the special shape of the aluminum foil in the present non-2D-axisymmetric geometrical constellation were identified and improved geometrical designs especially concerning the flux concentrator

could be derived. Statements concerning the feasibility and potentials of design improvements were possible without the necessity of performing cost-intensive practical tests, which nevertheless would have to be conducted before implementation in industrial test surroundings for validation reasons.

Figures used in the abstract

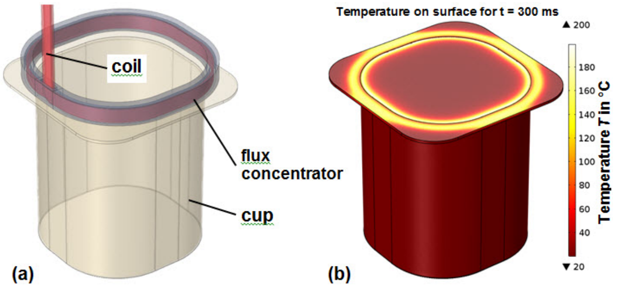

Figure 1: (a) 3D model of the investigated induction heating system (b) Temperature field of the cups' annular region to be heated.