Eddy current distribution inside a thin aluminium layer.

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TetraPak develops, manufactures and markets systems for processing, packaging and distribution of liquid food, and in particular packaging materials, filling machines and full packaging lines equipments.
Studio di Ingegneria is an Italian partner of Cedrat company.
The studies here presented have been developed in the frame of a collaboration between University of Padova, Electroheat laboratory, TetraPak and Studio di Ingegneria.

The sealing of the packages can be mainly performed by four technologies: induction heating, hot air, hot tools and ultrasounds. Induction heating is the most important one when the packaging material utilised is a multilayer composed by paperboard, polyethylene and aluminium. The aluminium foil, 6-9 microns thick, is both the physical support for induced currents and the barrier to protect the packed food from light and oxygen.

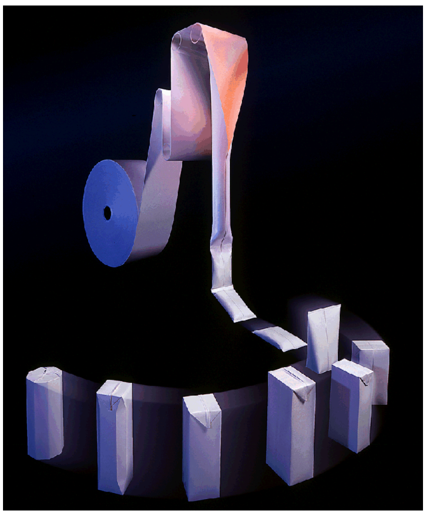


Figure 1: The Tetra Brik filling concept.

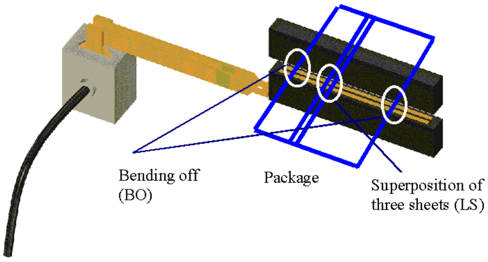


Figure 2: Schematic of the system and position of the zones LS crossing and BO.

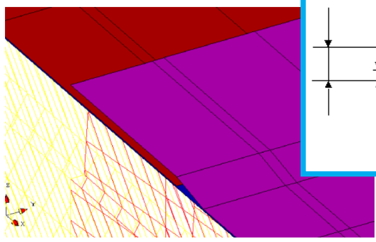


Figure 3: Inductor and magnetic yoke geometry.

The sealing process is shown in figure 1. In Tetra Brik Aseptic machines, a long strip of packaging material is longitudinally rolled up to form a tube, sealed along the overlap and then filled with the product. The final pack is obtained by pressing, sealing and cutting the tube along its transversal direction. The sealing is achieved by melting and pressing the two opposite polyethylene layers, heated up to melting point. Induction Heating technique is applied to heat the aluminium foil, and consequently the polyethylene layer, in a really short time.
Border effects of the eddy currents into the aluminium foil can be seen on the edge of the transverse heating pattern and in proximity of the longitudinal overlap as a reduction of the heat pattern width. Our aim is the reduction of the border effects to assure a uniform sealed region.
FLUX3D Magneto-Dynamic module has been applied to describe border effects in two different regions called 'BO' [Bending Off] and 'LS' [overlapping of three sheets], shown in figure 2.
In the bending off zone (BO) the 3D configuration of power density distribution is due to the discontinuity of the aluminium sheet over the inductor, while in the LS crossing zone two effects are combined: the discontinuity of the aluminium sheets and the superposition of three layers of material that creates different current density patterns.

FLUX3D can describe thin layer region, like the aluminium foil, by means of a bi-dimensional region, inside a three dimensional model. In this 2D shell region we can impose an electrical conductivity and compute eddy current patterns. The use of the shell region is allowed when the skin depth of the electro-magnetic fields is much higher then the depth of the region. A 3D model of the aluminium foil requires a very large number of elements in the mesh because, if you want to avoid bad shaped elements, you must set an element dimension value close to the depth of the sheet. The use of a REGion SURface in air allowed us to build a mesh scheme with a quite low number of elements.

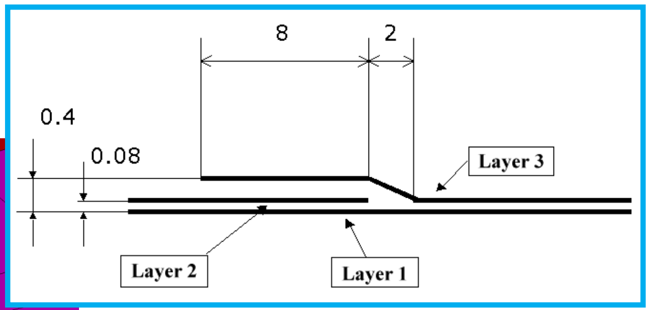
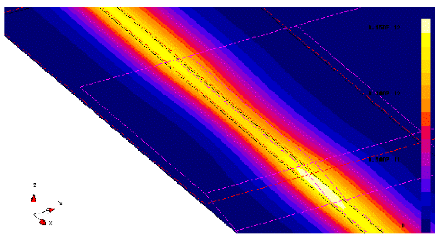


Figure 4: Layers set-up in the LS zone.

Model

The model used to describe the LS region is shown in figure 3. In this model, we can modify the material properties of each volumetric region describing the magnetic core.



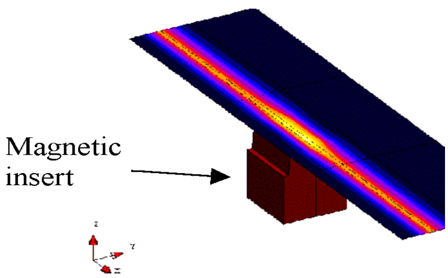


Figure 5 & 6: Plot of power density distribution in the layer 1 f=500 kHz.

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Eddy current distribution inside a thin aluminium layer. (continue)

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In this way we can take into account the effects of a magnetic insert like magneto-dielectric material.
The overlapping layer region has been described as in figure 4.

Power density distribution on the first layer, the layer closer to the inductor, is presented in figure 5 and figure 6. In first case, the magnetic core is entirely made of a compound characterised by a low relative permeability, in the second case we considered a magnetic insert. Figures show clearly the importance of a magnetic concentrator to increase the width of the heating pattern.

Bending-off

In figure 8 some results are presented. The analysis has been performed at different frequencies considering the presence of a magnetic insert. It can be noted that the effect of increasing frequency is visible in the path of eddy current density. In fact at lower frequency the path is larger in transversal direction (y axis) in the "regular zone" (the zone far from the edge of the sheet) and the spot in the edge region is wider. It can be said that at higher frequencies the current density patterns are more similar to the pattern of the inductor current and that the edge spot shape follows almost at 90 degrees the profile of the sheet. The shielding effect of the first layer on the second one increases as the frequency increases. Also in this case the effect of the insertion of magnetic materials has been taken into consideration.

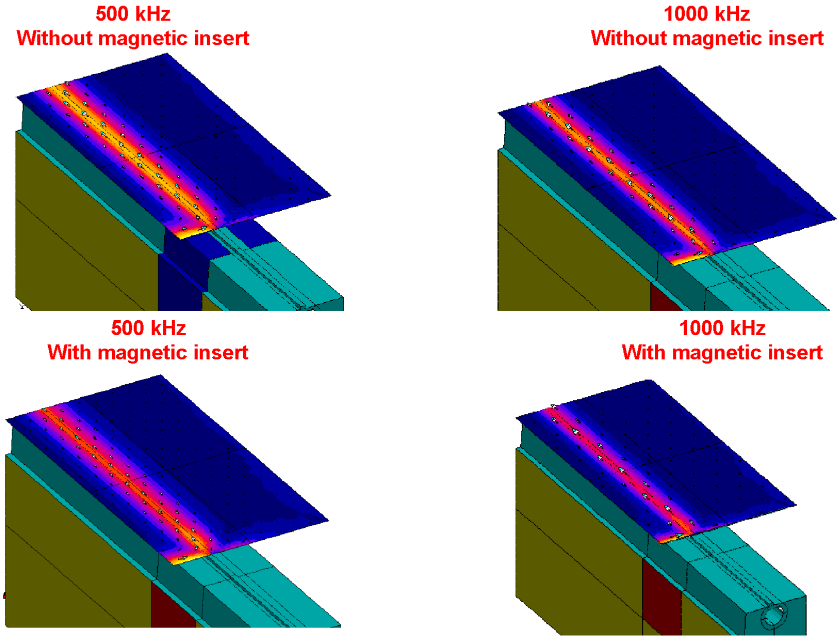

Figure 6: Current densities distribution (color shade and region vector plot).

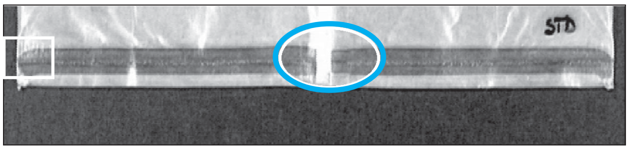

Figure 7: A standard Transversal Sealing view of the dissolved paperboard with BO and LS zone highlightened.

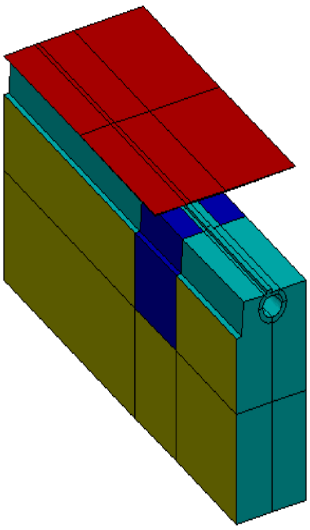

Figure 7: Geometry for the bending off region.

Comparison with experimental results

A particular technique for sealing evaluation consists of dissolving the paperboard of the package in a solution of NaOH. After the treatment, only the internal polyethylene bag remains and the heat pattern (i.e. the sealing) can be clearly spotted and evaluated.

In figure 9 the sealing of a standard TS inductor is shown, and the oval puts in evidence the reduction of the heat pattern width in the LS crossing zone. The effect of a magnetic insert is shown in figures 10-11 for the BO zone.

Conclusion

The comparison between numerical and experimental results shows a good agreement: FLUX3D has been a powerful tool to predict the effect of frequency variations and different material properties.

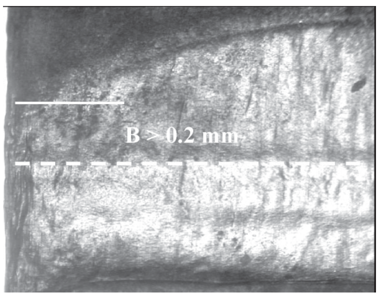

Figure 8: Bending off zone with a bad B value parameter (without magnetic insert).

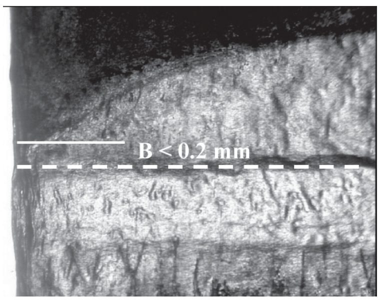

Figure 9: Bending off zone with a good B value parameter (with magnetic insert)