# Implementation of specific surface condition to describe induction heating of multi-layered materials


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**INTRODUCTION:** For packaging and electronics applications, induction heating is used for sealing multi-layered materials constituted by a stack of polymer layers with thin metallic inserts acting as heating source. It is classically realized with pin-shaped inductors to generate mainly a transverse magnetic field at a frequency range around 300-500MHz.

A specific description is developed and implemented in Comsol in order to describe the stack only by one surface condition to overcome meshing difficulties due to dimensions ratio between thickness and length of the sheets.

**COMPUTATIONAL METHODS**:

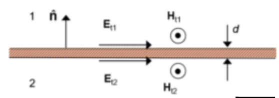
❑ **EM modelling :** AC/DC –Frequency domain- Vector Potential A

To reduce computing time and mesh complexity v*olume are replaced by surface description* – **Fig. 1:**

- ***Copper Coil :*** *single surface description* – Current Input : $I_{coil}$=100A
- ***Config 1: Transition Boundary Condition (TBC)*** for thin conductive layer (e ≤δ )-**Fig.1** :

$$Js_1 = n\times H_{t1} = (Z_S E_{t1} - Z_T E_{t2})/(Z_S^2 - Z_T^2)$$

$$Js_2 = -n\times H_{t2} = (Z_S E_{t2} - Z_T E_{t1})/(Z_S^2 - Z_T^2)$$




$$Z_T = \frac{-j.Z_C}{\sin(kd)} \quad Z_S = \frac{-j.Z_C}{\tan(kd)} \quad Z_C = \frac{\omega\mu}{k} \sim \frac{(1+j)}{\sigma\delta},\ k=\omega\sqrt{\mu(\varepsilon+\sigma/j\omega)} \quad j^2=-1,\ \delta=\sqrt{\frac{2}{\mu\sigma\omega}}$$

- ***Config 2 : 'Double' TBC for the whole stack*** *( Cu A + isolating layers + Cu B)- specific surface condition by extrapolation of TBC to multilayered materials -* ***Fig.1/2*** *:*

- Polymer isolating layer approximate by an inductance $Z_P$ ($e_P$<< λ)
- Same weak expressions than TBC on up and down surface for surface current : $Js_{1A}$ and $Js_{2B}$
- Expressions are added to evaluate $E_{t2A}$ by fixing the relation : $Js_{2A}$ +$Js_{1B}$ =0 and making a link with $E_{t1B}$

❑ **Heat transfer modelling** *: Time dependent*

*- Layered material interface and Heat transfer in shells with heat source in conductive layers from previous EM modelling in frequency domain*

**RESULTS :**

❑ **Analytical approach - Fig.2 :** An equivalent circuit is defined to describe the stack by a single surface ('double TBC') and to link up and down transverse component of the electric and magnetic field. A comparative 2D model is set up to validate this description.

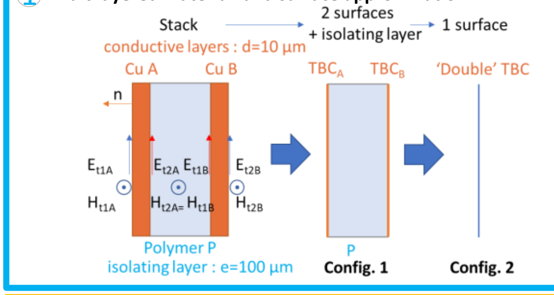
❑ **3D model - Fig.3/4 :** extrapolation to more realistic case with transverse magnetic field with a comparison between config 1 and 2.

- *Magnetic field (Fig 3a) , total induced current distribution in each sheet (Fig 3b) are similar between config.1 and 2 : difference <1,5% with more discrepancies near sheet's edges along x axis (~10%).*
- *Power injected in Copper A is 13% lower than Copper B (near the coil)*
- *Heating is localized in front of the coil with overheating near the edge along x axis due to the closure of the induced current*

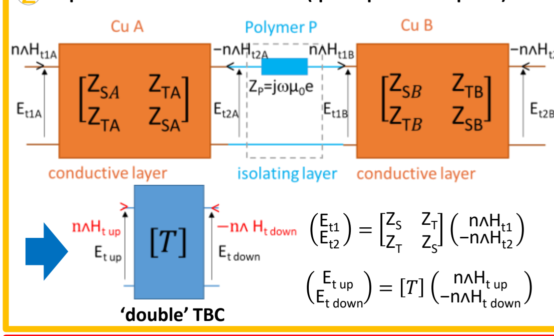
**CONCLUSIONS**: An efficient modelling of high frequency induction heating of multilayered materials was achieved with the implementation of a specific surface condition. A parametric study (frequency, layers thickness,..) can be realized to precise the robustness of such description. An extension to more complex geometry (several stacks, overlap,…) is also needed for description of industrial cases.

**FIGURES :**

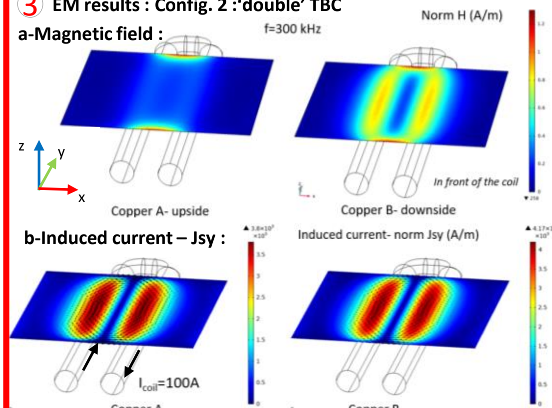
1 **Multilayered material and surface approximation :**



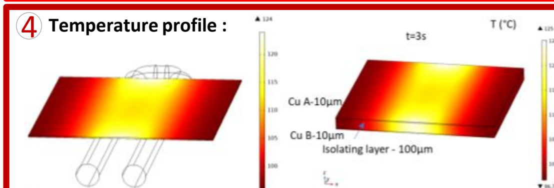

2 **Equivalent Circuit of the stack (quadripôle description) :**




3 **EM results : Config. 2 :'double' TBC**




4 **Temperature profile :**




**Config. 1**-TBC A/B+ isolating layer **Config. 2 :'double' TBC**

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