Multiphysics modelling of Quasi Resonant Induction Cooktops

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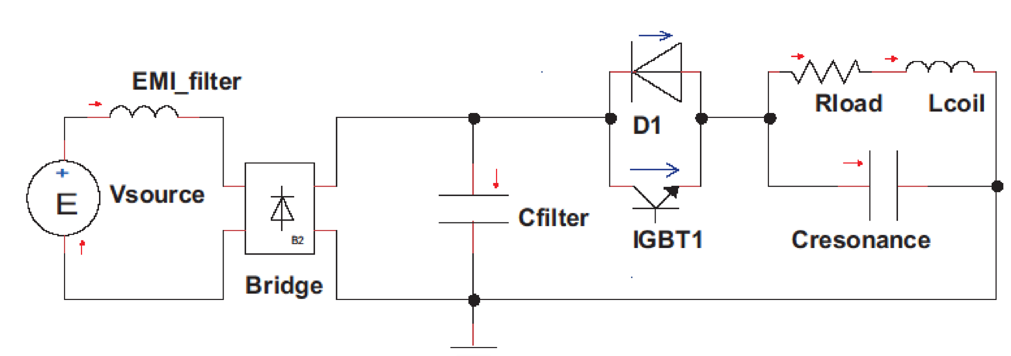
Introduction

Currently induction hobs are the most innovative and efficient among home cooking technologies.
Benefits of induction cookers include high efficiency, safety and quickness, if compared to traditional gas or electrical radiant hobs.
An induction hob is constituted by a ceramic glass with serigraphy, a set of three or four inductors for heating of the pot through induced eddy currents, an electronic board usually working in the frequency range of 20-100 kHz, a user interface with a proper software for the control of power levels and a mechanical structure.

A fully coupled model for the simulation of real working condition of Quasi-Resonant type induction hobs is presented. Specific experimental tests on prototypes validated the suitability of the procedure, giving errors in the range of 3 to 6% in all the important metrics both for the inductors and the QR converter components. This procedure has been used to design a mass production pancake coil for induction hobs.

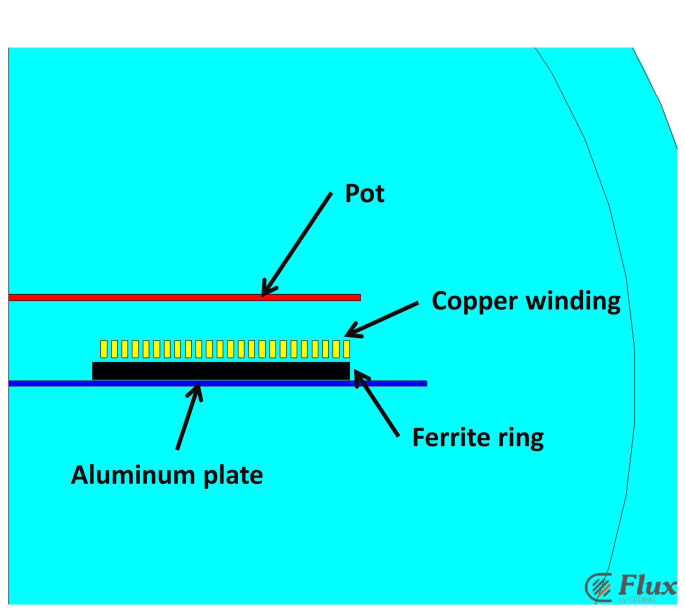
The model

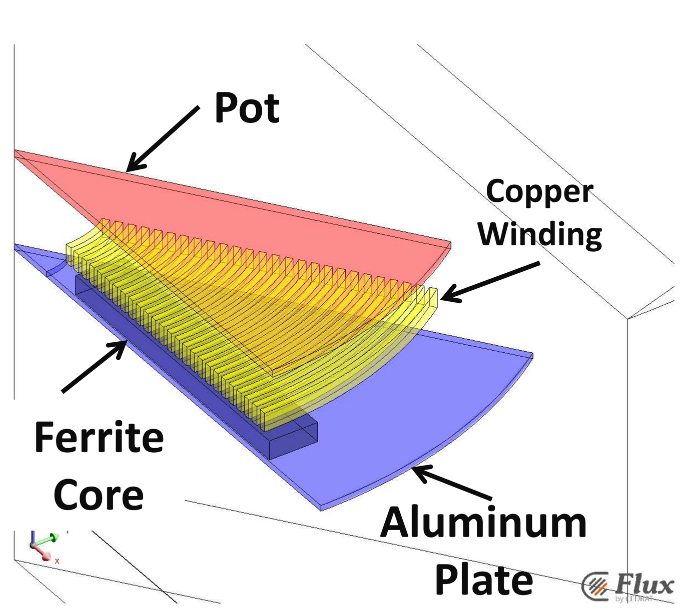
Quasi-Resonant converter



The **control variable is the T_{on}**, while the Period (T_{on}+T_{off}) depends of natural oscillation of RLC circuit. Moreover the coil current has not zero mean value.

The coil design is based on 2D or 3D FEM transient magnetic model coupled with circuit simulation at several frequencies and duty cycles.



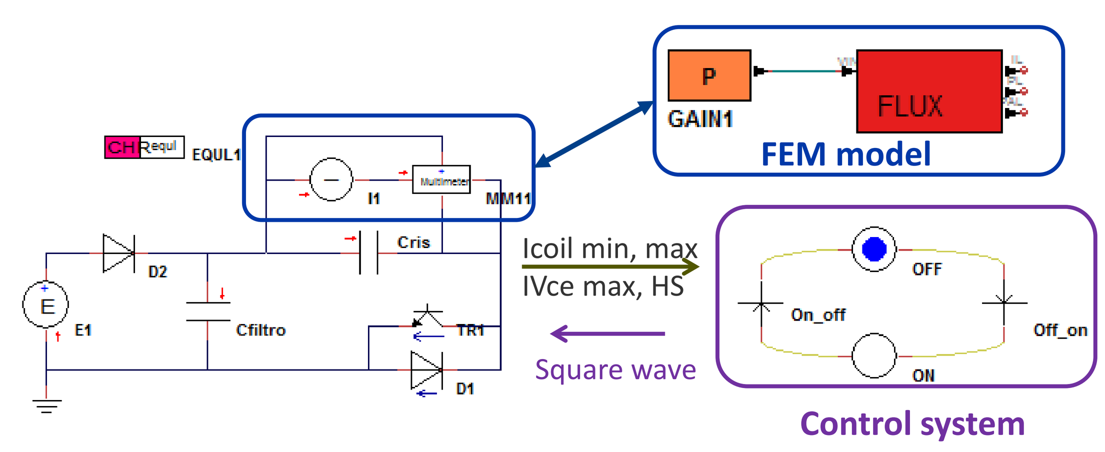


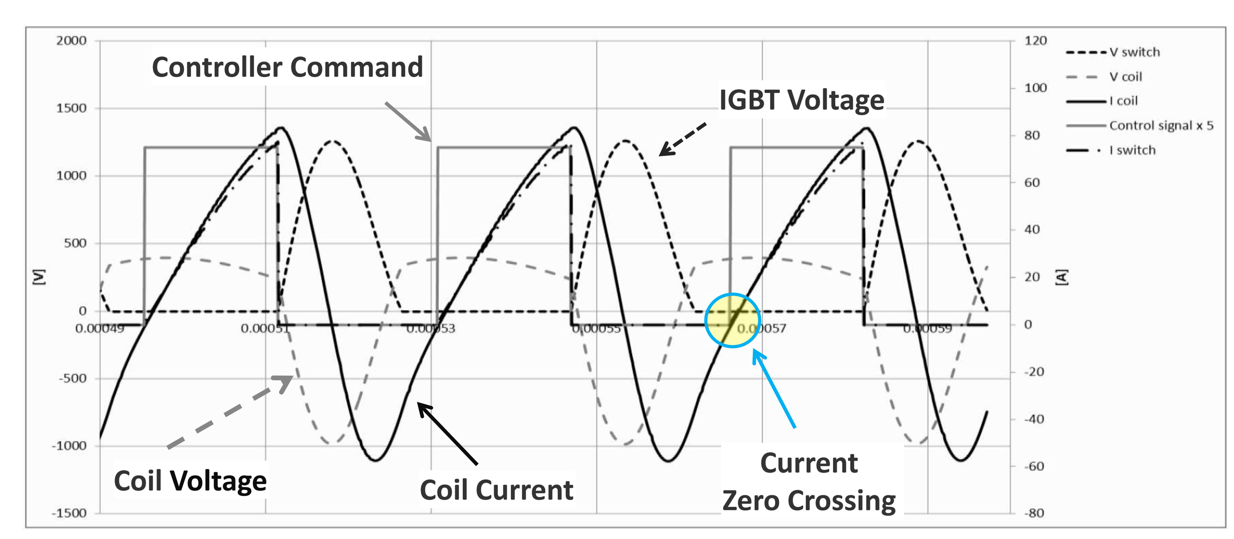
In 2D FEM, ferrite cores are replaced by a ferrite ring with an equivalent magnetic permeability. In 3D FEM, only a slice of the whole coil has been simulated. The simulations were performed with common pot materials like AISI409 and AISI430, nonlinear B(H) characteristic and resistivity about 0.6-0.7 [$\mu\Omega$ m].

Co-simulation results

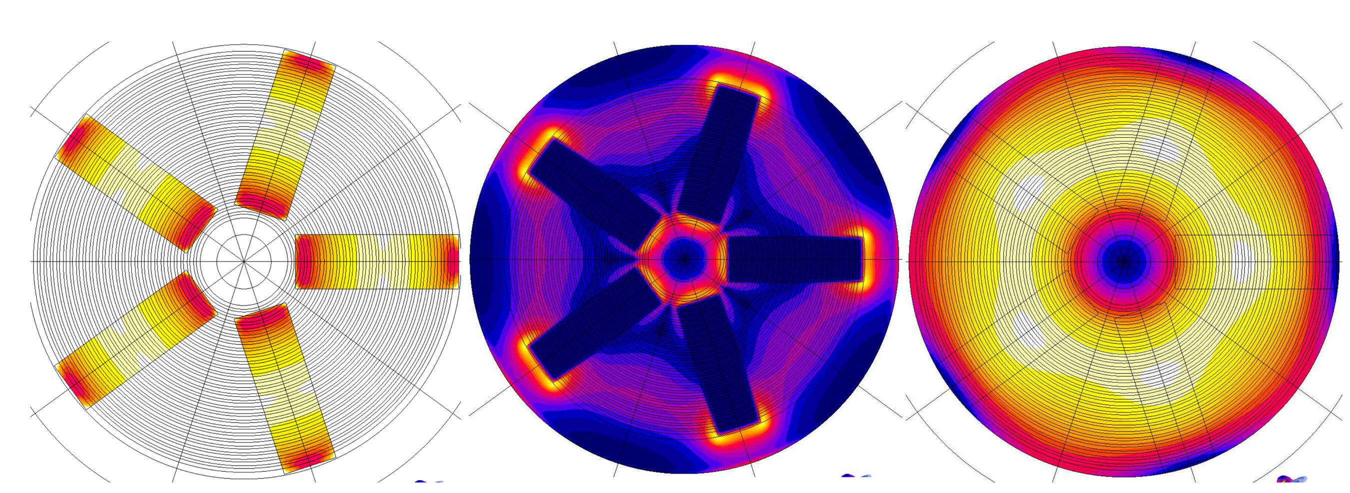
The simulation was performed with a multiphysics coupling between FEM and circuit model because:

- ✓ the coil works in transient magnetic condition (not zero mean current)
- ✓ the coil is driven with an nearly square wave voltage source
- ✓ T_{on} is the control variable, and period is defined by the coil current zero crossing, not detectable within FEM simulation.





The multi physics circuital model simulation provides the power delivered to the inductor, voltage and current stresses on components and the frequency of the controller command.



Ferrite cores Flux density *AluPlate Current density* *Pot Current Density*

Conclusions

A fully coupled model for the simulation of real working condition of QR induction hob has been presented. The experimental tests on a prototype series have demonstrated the suitability of the procedure giving errors in the range of 3-6 % in all the important metrics both for the inductors and the QR converter components. The drawback is the computation time, especially in coupled 3D FEM-circuit simulations.
This procedure was used to design a mass production pancake for induction hobs.