MICROWAVE HEATING OF A COMPOSITE PART

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INDUSTRIAL AND SCIENTIFIC CONTEXT

This work is done in the framework of a H2020 European project called SIMUTOOL. The main concept of SIMUTOOL is the full modeling and simulation of the MW heating process using a combination of established modeling software packages (for the physicochemical phenomena) and CAD/CAE software packages which take into account the MW oven, novel tool, interactions of microwaves with all the materials inside the oven, modeling of the feedback loop control, and optimisation of the process.

The final aim is to offer a toolset providing a comprehensive insight into the physical and chemical phenomena that occur during the process.

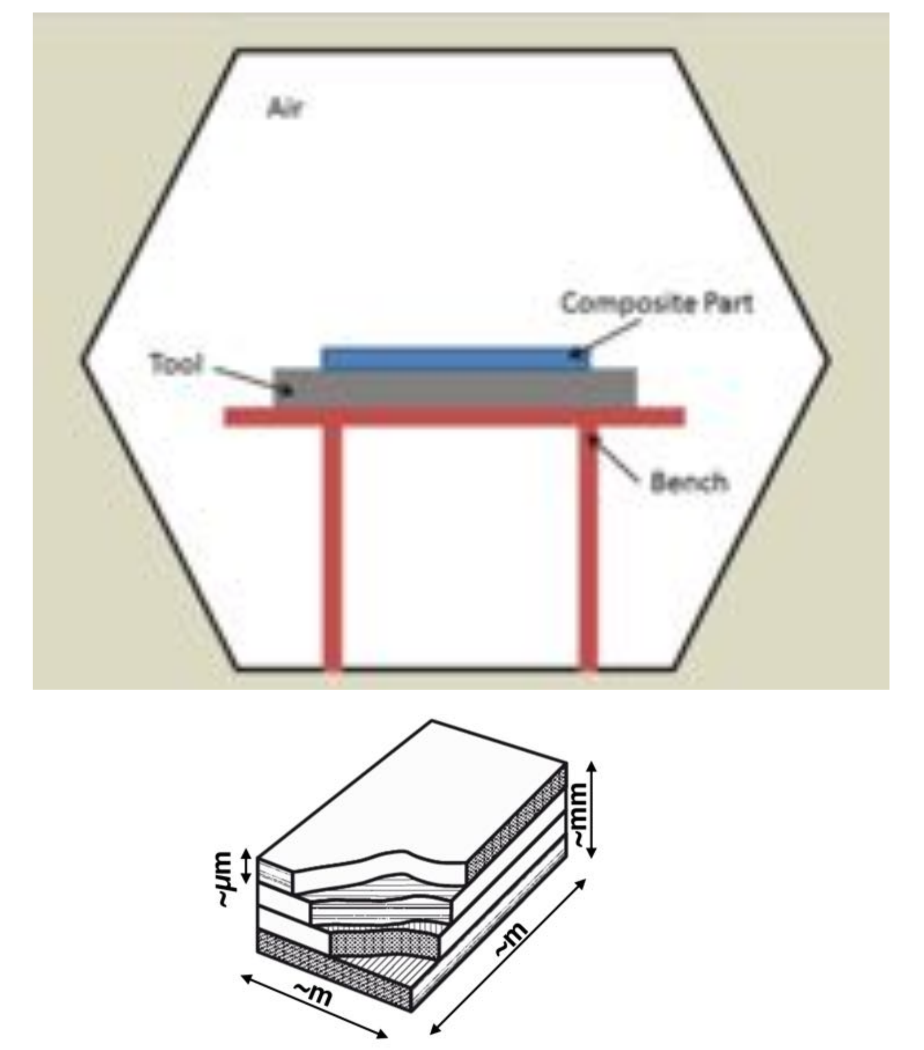
Objectives

- Build a process simulator for the interaction of the tool and composite material (TP matrix, carbon fibers) with MW field (coupled electromagnetic / heat transfer modeling) - at micro and meso scales.
- Understand the process control loop in the MW oven (temperature controlled through MW power input).
- Production of composite parts using 30% less energy compared to conventional processes

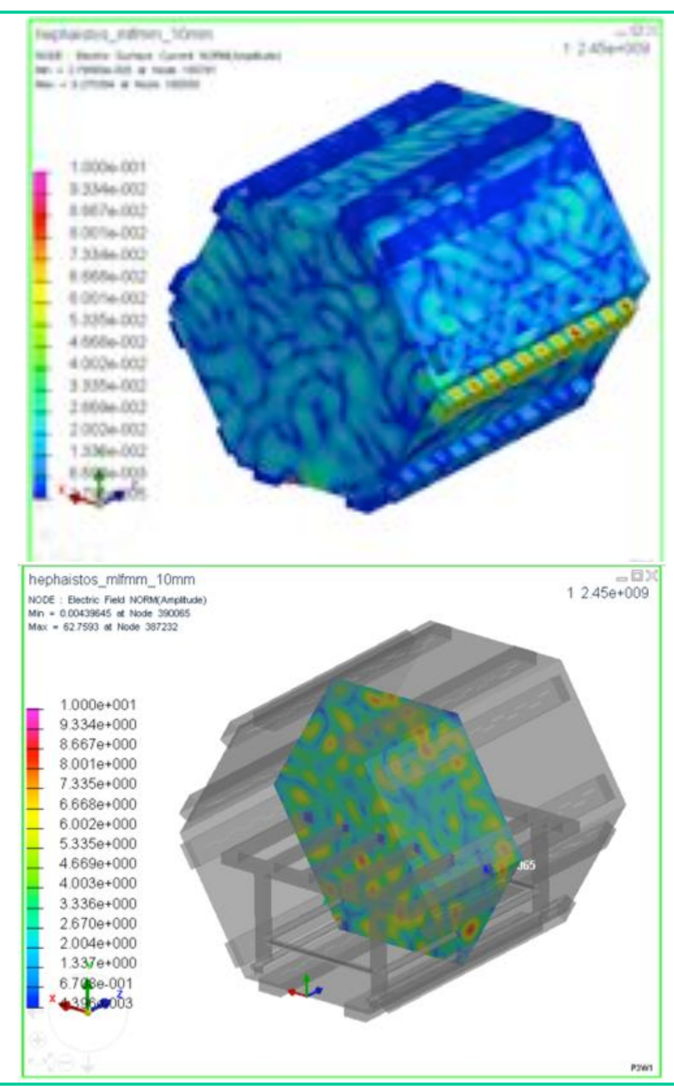
International Position

- The targeted modeling and simulation toolset of the MW heating process does not exist today.
- It will enable industries to take full advantage of the MW heating process.

METHOD : APPROACH, TOOLS, DEVELOPMENT



Schematic representation of the process



Simulation of the EM field in the cavity

$$\nabla^2 \mathbf{E} = \gamma^2 \mathbf{E}$$

$$\gamma^2 = i\omega\mu(\sigma + i\omega\varepsilon)$$

μ, σ, ϵ respectively the permeability, conductivity and permittivity of the considered material

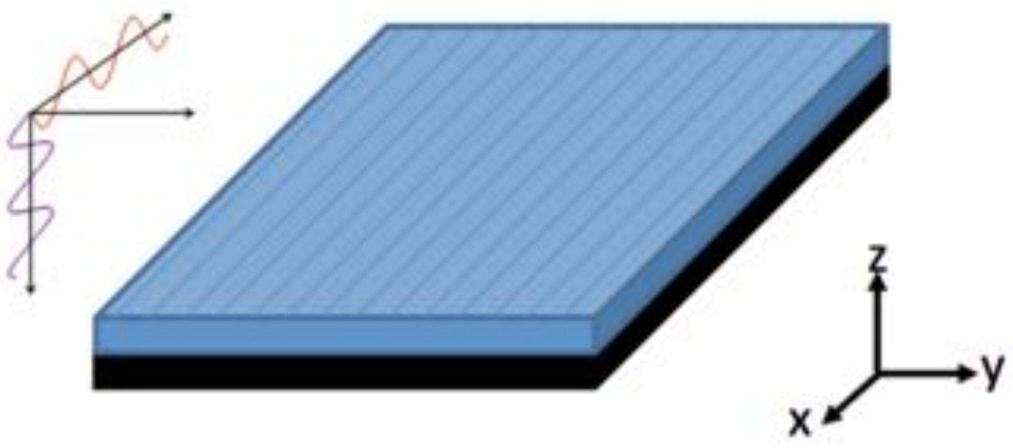
Wave Propagation of an harmonic electric field in the composite domain.

$$\mathbf{E}(x,y,z) \approx \sum_{i=1}^{N} \mathbf{X}_i(x,y) \circ \mathbf{Z}_i(z)$$

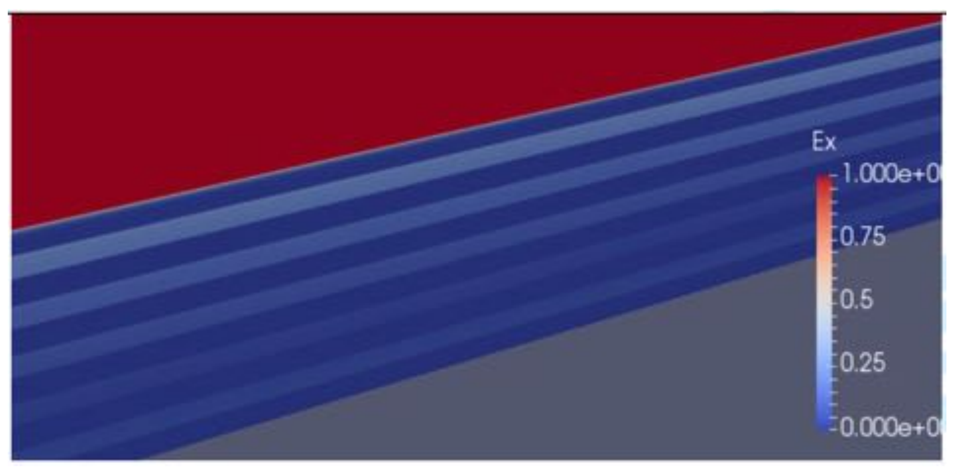
In-plane-out-of-plane separated representation of electric field within the Proper Generalized Decomposition framework [1].

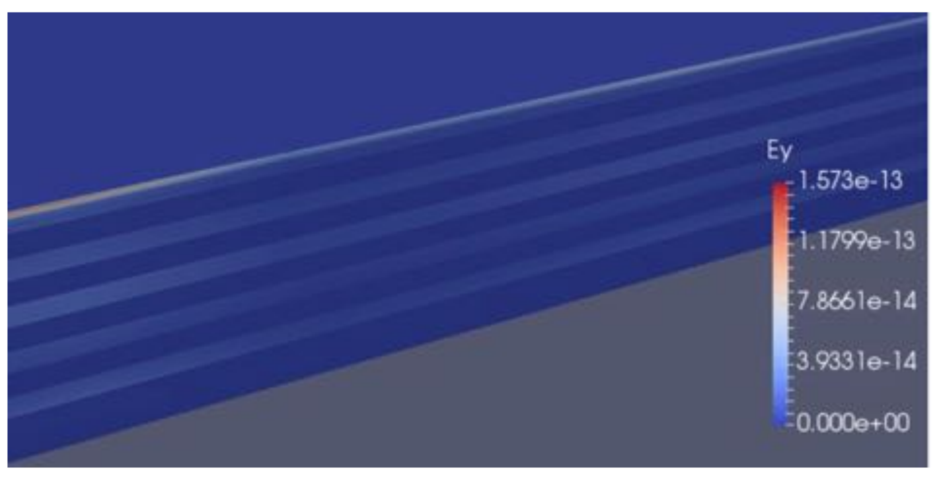
Resolution of the Maxwell Equations in the composite part

RESULTS :



- 10-plies laminate considered $[0,90]_5$ put on a conductor plate.
- each ply is 1mm thick and discretized in 10 elements
- orthotrope material behavior (UD carbon fibers plies)
- domain dimension : 1mx1mx11mm (100x100x111 nodes)
- Wave propagation in the thickness direction





The figures above depicts the Ex (left) and Ey (right) components of the Electric field. As expected the fiber orientation has an impact on the wave transmission. This will have repercussion on the thermal field evolution in the laminate.

DISCUSSION and CONCLUSION

The main challenge concerns the high-resolution description of the EM and thermal fields in a composite laminate involving plies whose characteristic in-plane dimension is order of magnitude higher than the one related to the thickness (typical aspect ratio are of 10^4).

The use of in-plane-out-of-plane separated representations within the Proper Generalized Decomposition –PGD- framework, allows calculating a very fine 3D solutions while keeping the computational complexity characteristic of 2D solutions (the ones involved in the calculations of function depending on the in-plane coordinates (x,y)).

Further developments are addressed about the homogenization of electromagnetic properties of composites materials and the coupling between the simulation of the EM field in the cavity and the one of the composite domain.

PARTNERS

TWI, LOIRETECH, ECN, ESI, ETS, AIRBUS Group, FAURECIA, UBA

REFERENCES

[1] F. Chinesta, R. Keunings, A. Leygue. Proper Generalized Decomposition for Advanced Numerical Simulations. A primer. Springerbriefs, Springer, 2014.