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Predict automotive electric rotor coil multiphysics’ impregnation

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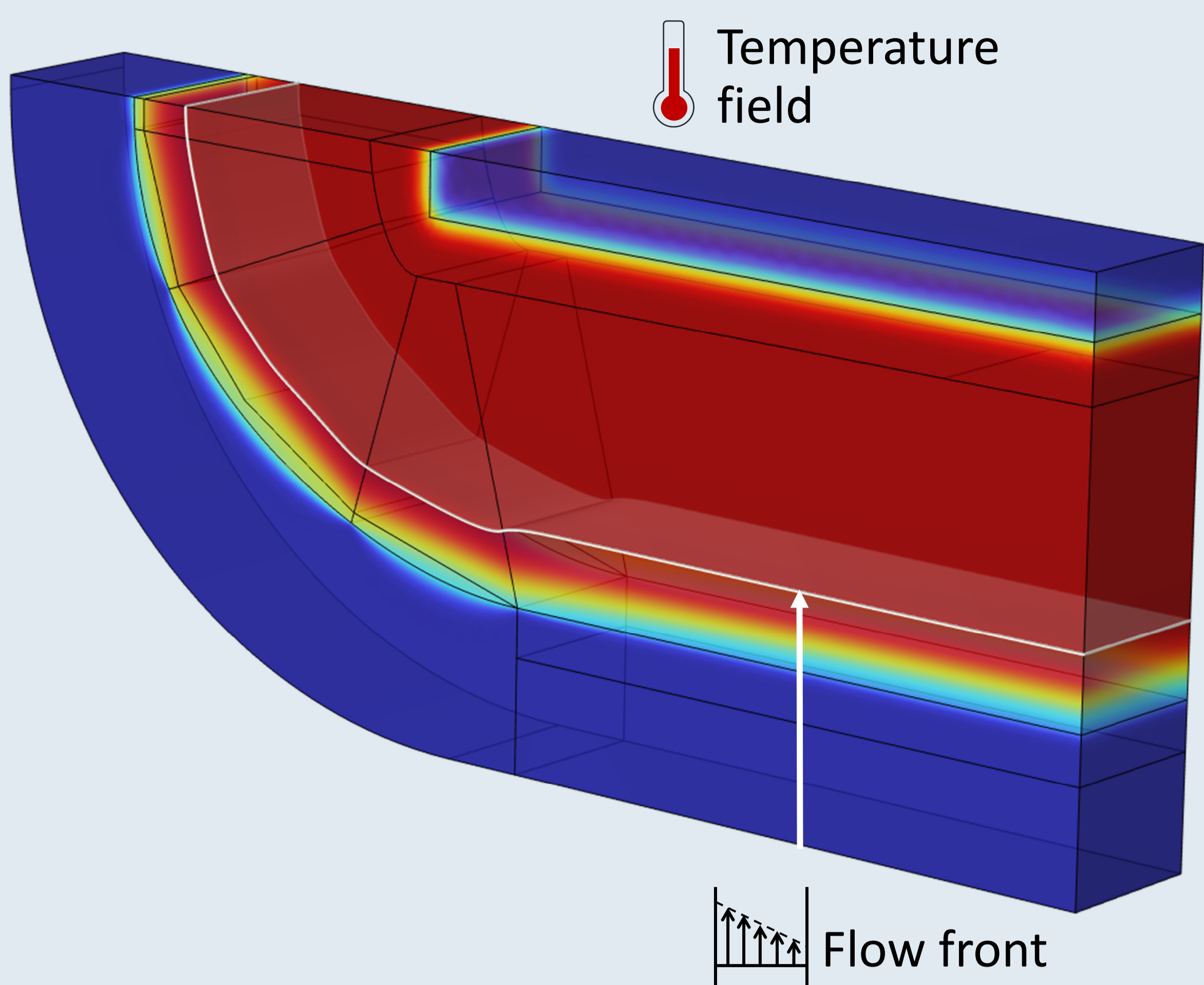
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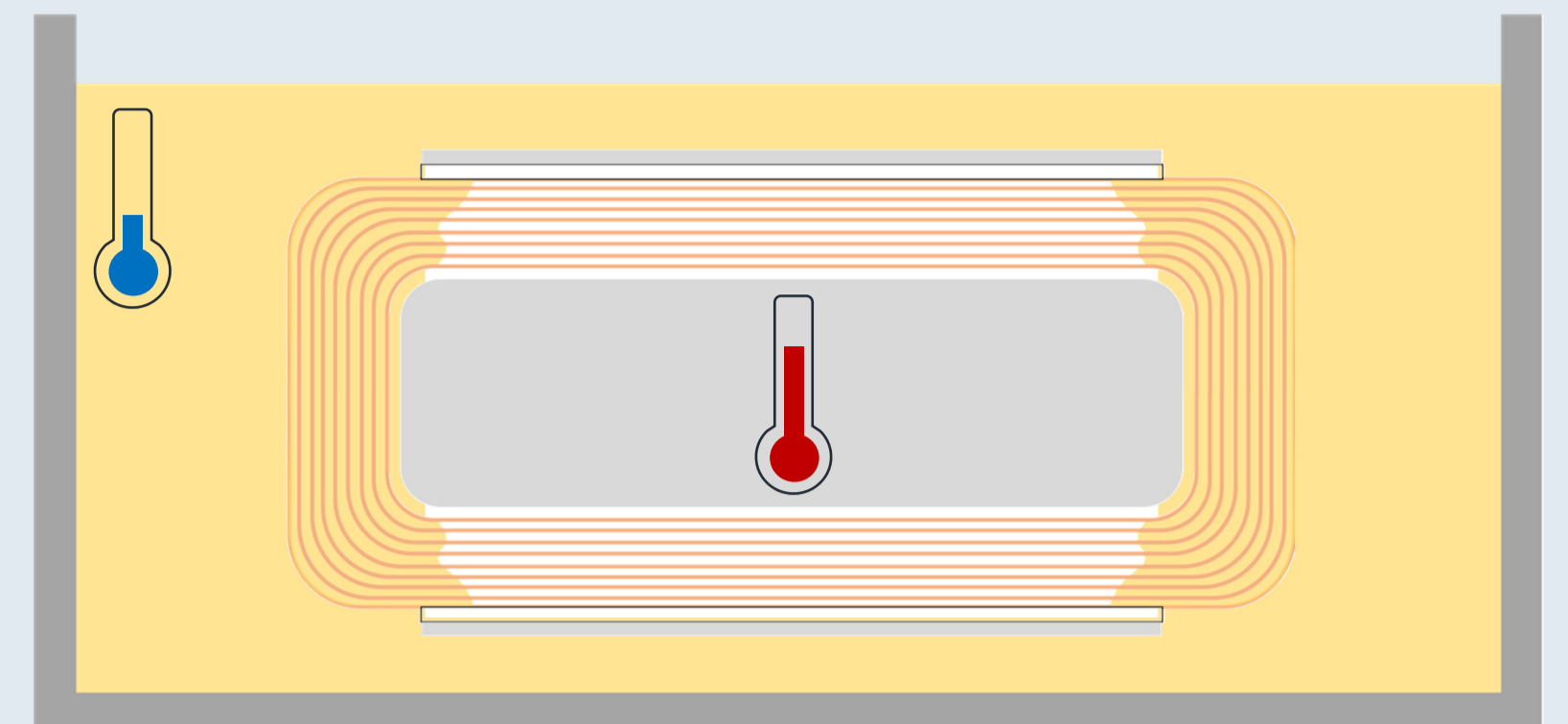
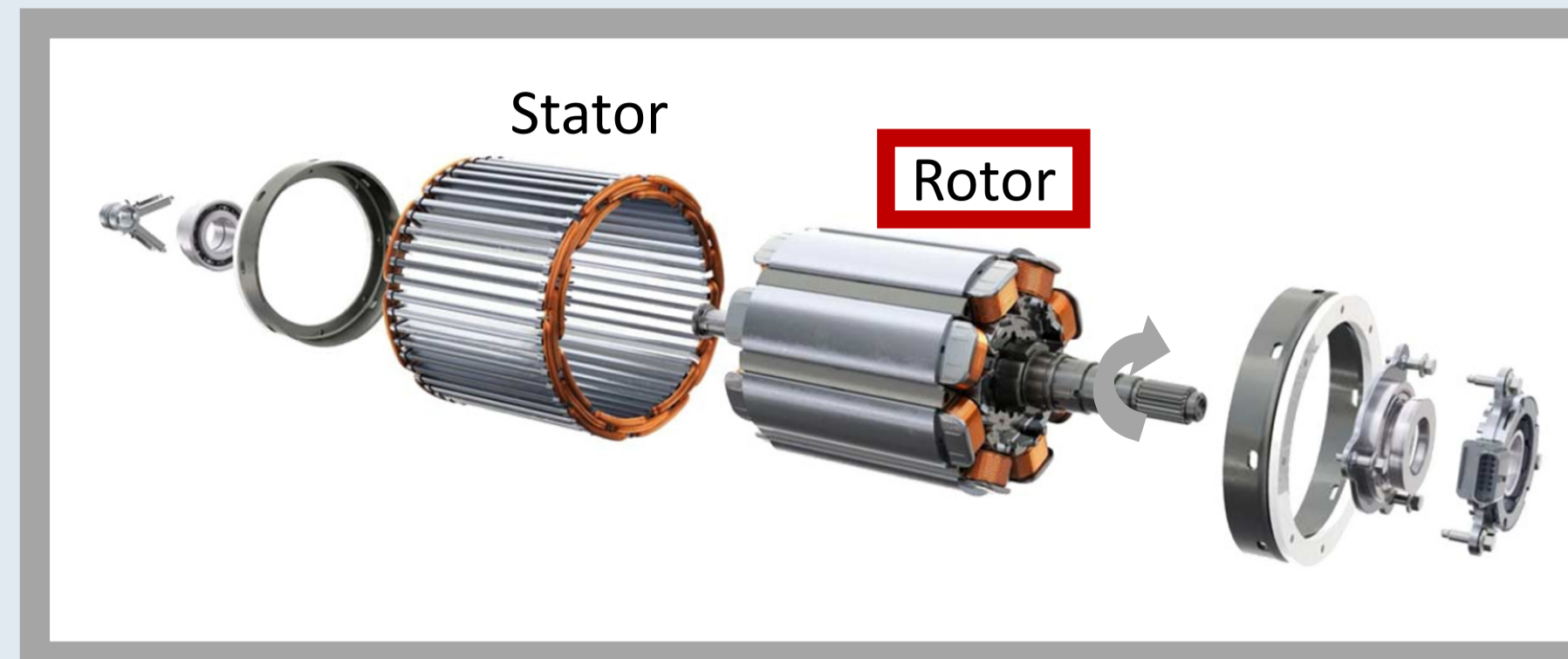
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Predict automotive electric rotor coil multiphysics' impregnation



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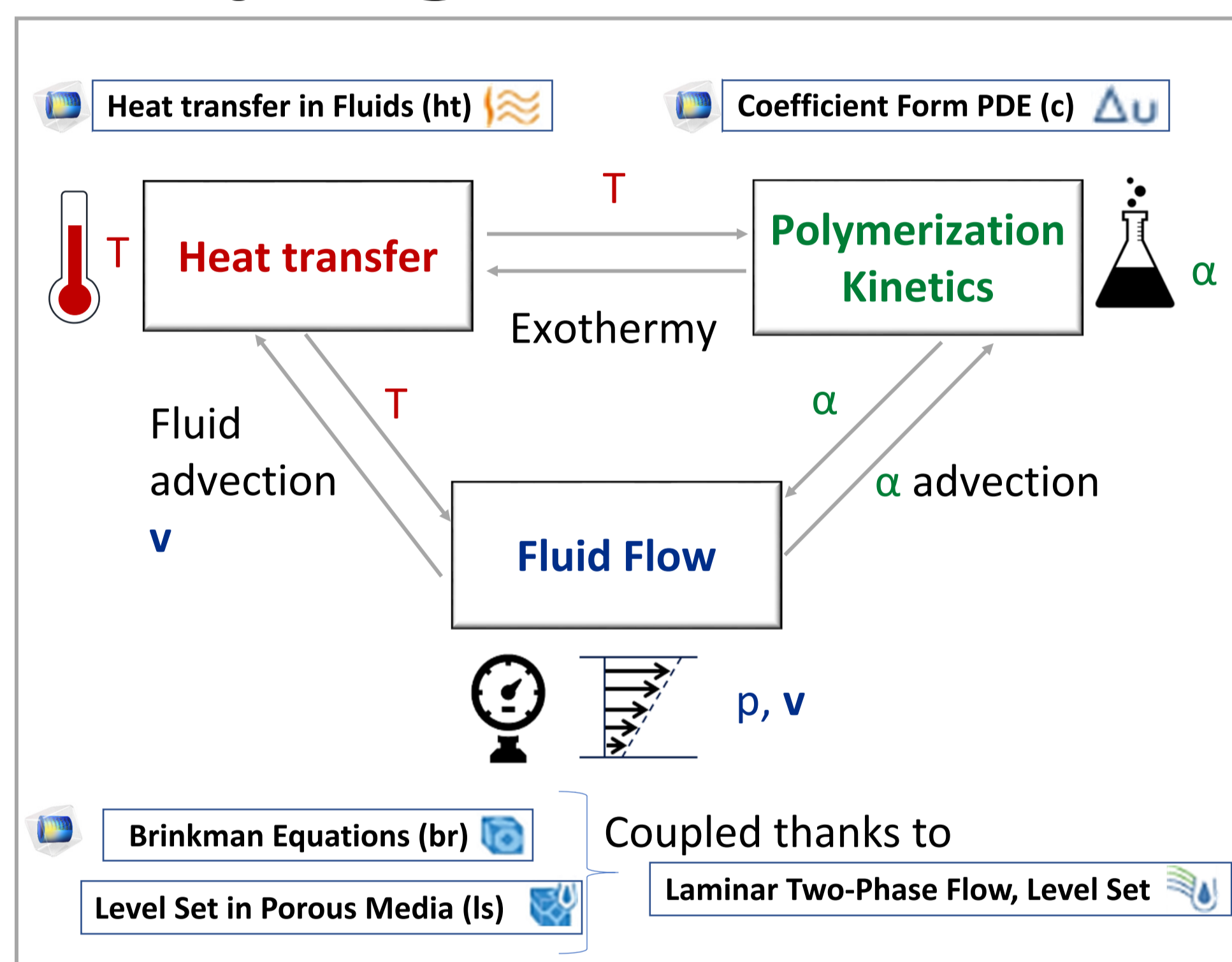
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Abstract

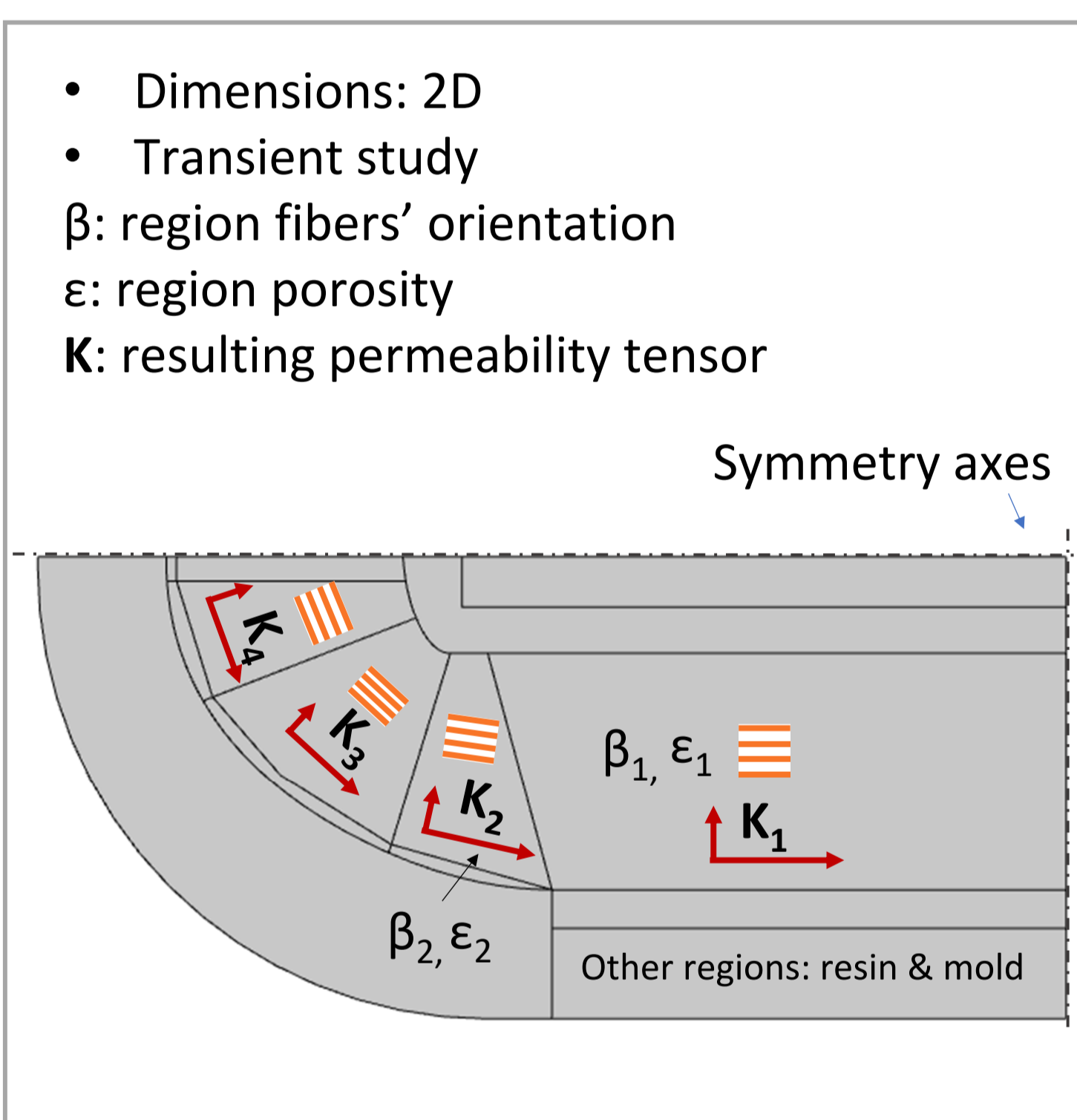
In the context of electric engines, insulated copper wires coils are immersed into a thermosetting resin bath, ensuring the durability of the motor. The impregnation occurs under controlled temperature to facilitate the flow and the polymerization. This process does not involve any pressurization. This suggests that capillary and gravity forces play a significant role. The global objective is to evaluate the impregnation quality. It requires characterizing, modeling and

simulating a multi-materials and multi-physics process in which heat transfer, polymerization kinetics and capillary-driven resin flow are strongly coupled. The COMSOL Multiphysics® software is used to perform a 2D coupled anisothermal simulation on a homogenized domain, providing the polymerization and thermal gradients and their impact on fluid dynamics.

Coupling



Domain



Physics

$$\rho c \frac{\partial T}{\partial t} + \rho c \mathbf{v} \cdot \nabla T = -\nabla \cdot \mathbf{q} - \epsilon \rho \Delta H_r \frac{d\alpha}{dT}$$

Heat

$$\nabla \cdot \mathbf{v} = 0$$

$$\mathbf{v} = \frac{1}{\eta(T, \alpha)} \mathbf{K} (-\nabla p + \rho \mathbf{g})$$

Flow in porous medium

Conduction Source term: exothermy + kinetics equation

Viscosity

- Level-set method enables to use a fixed mesh. Initial conditions & method parameters must be chosen to ensure convergence.
- The preset COMSOL coupling improves the convergence compared to manual coupling.
- More detailed info. on modeling choices available in [1] (α , η , \mathbf{K} , initial & boundary conditions).

FIGURE 1. Coupling of the physics and COMSOL interfaces used FIGURE 2. Homogenized coil modeling

Results

- Results fields are post treated to be compared to experimental results. The coil saturation is extracted using Domain Probe tool:

$$S = \frac{\text{Impregnated coil surface}}{\text{Total coil surface}} = \frac{\int^{\text{coil}} \Phi}{\int^{\text{coil}} 1}$$

& local temperature evolutions are extracted with the Cut Point 2D tool.

- Comparison with experimental data validates the predictivity of the process thanks to simulation.

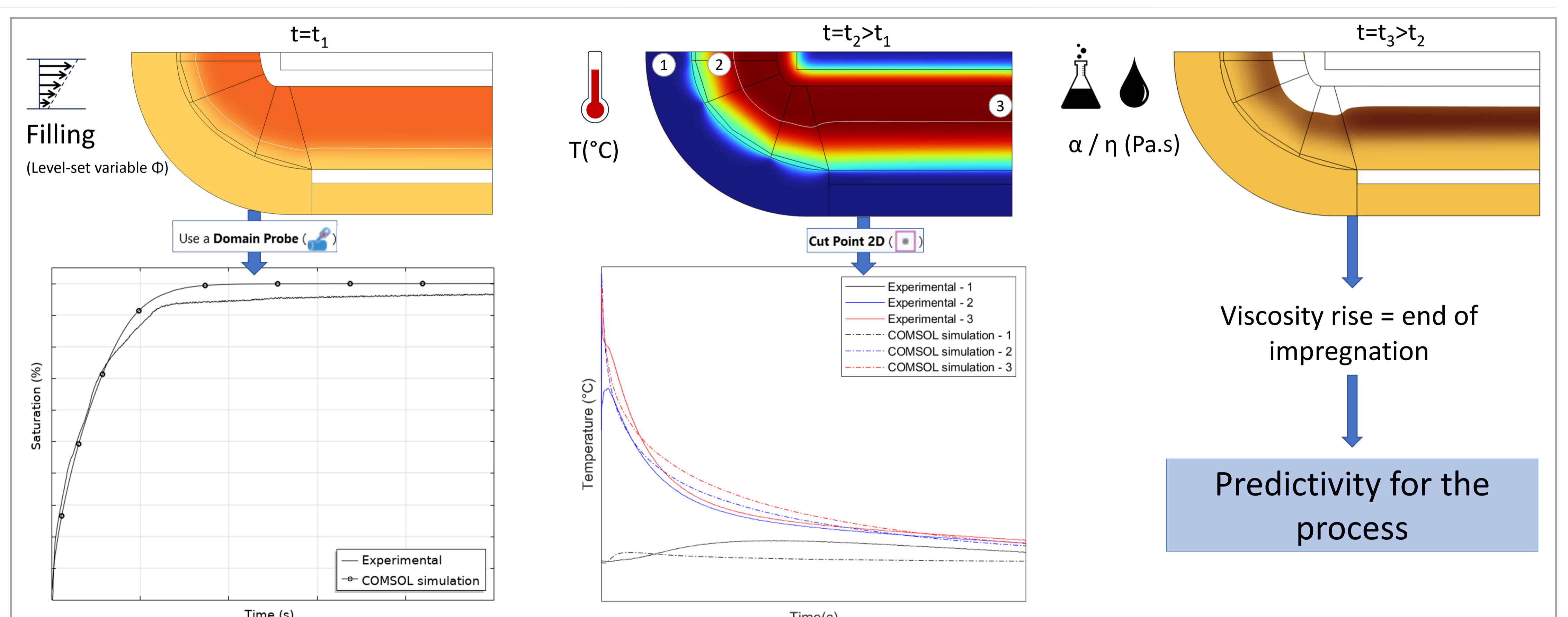


FIGURE 3. Result fields and post treatment for experimental data comparison & simulation validation

REFERENCES

1. Moisy, A., Comas-Cardona, S., Désilles, N., Genevée, P., & Kolehmainen, J. (2023). " Multiphysics simulation of an anisothermal reactive spontaneous capillary rise between electric rotor wires". *Frontiers in Materials*, (vol. 10), p. 1124176, 2023.

