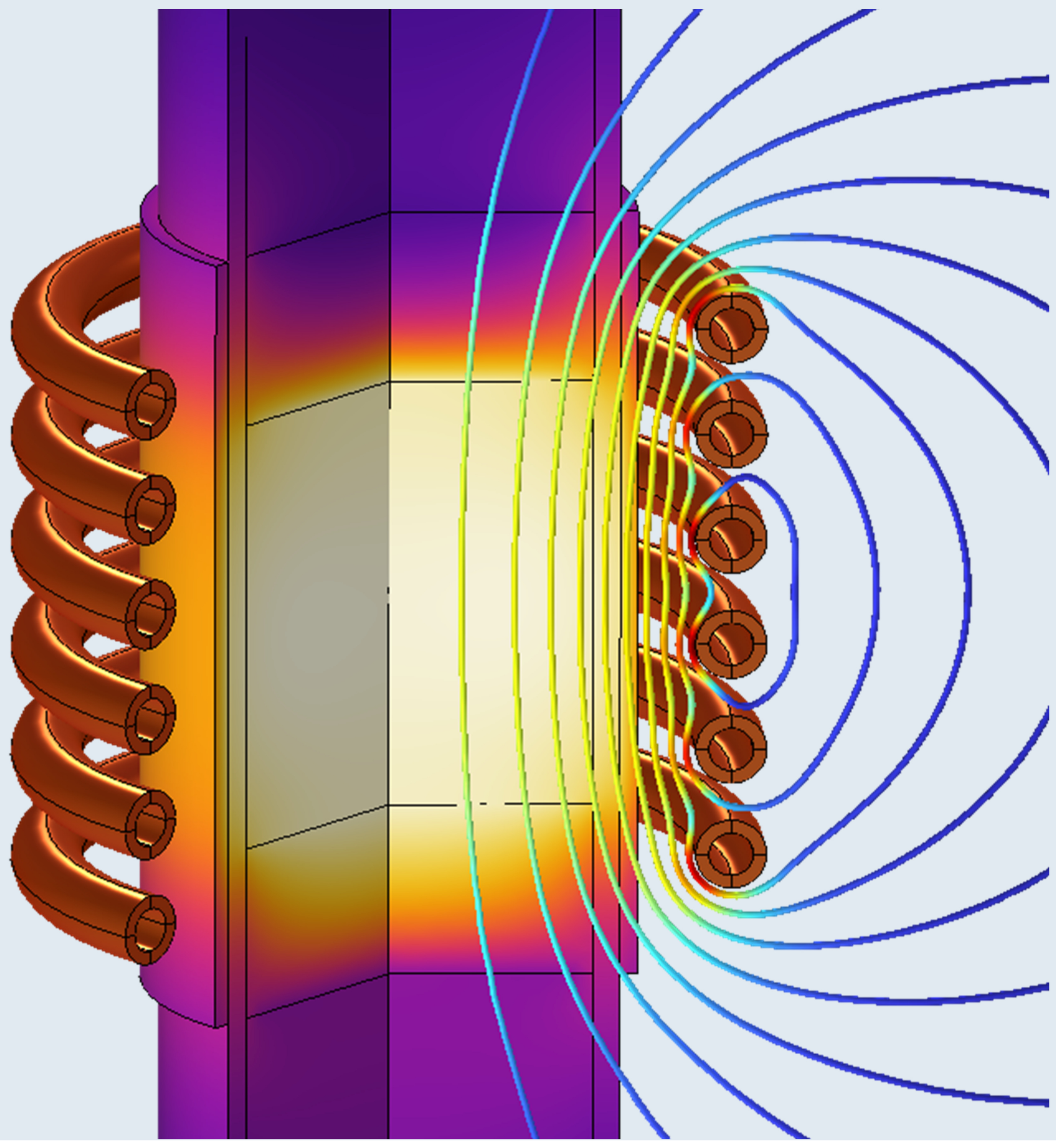

Gas Treatment by Induction Heating : Process Evaluation via Homogenized Modeling Approach

Induction heating (IH) is an electrically driven process use for decarbonization of the industry to replace gas burner and avoid CO_2 emission [Ref.1]. A challenge is to apply these technology for electrification of chemical processes with safer, cleaner, more reproductible and simplified reactor advantages.

M. Dumont[1], A. Essyed[2], X.H. Pham[2], L. Truong-Phuoc[2], J.-M. Nhut,[2] C. Pham-Huu[2]

1. EMDPI, Jam Consulting, Grenoble, France
2. ICPEES, UMR 7515 CNRS-University of Strasbourg, Strasbourg, France

Introduction

IH is a promising route for chemical synthesis, catalytic reactions [Ref.2,3,4],... Heat is generated directly into the reactor at the surface in contact with the gas flux passing through a specific electrically conductive substrate. Chemical reactions can be enhanced by selecting an active material. IH allows energy saving, process intensification and production costs reduction [Ref.2].

Modelling description with simplified homogenized and stepwise approach give tools for better understandings of such IH processes. One key parameter to estimate first is the induction efficiency: ratio of Joule power transferred to the material to the total delivered electrical power. In a second step, the global efficiency is obtained : ratio of power needed by the reaction versus total power spent.

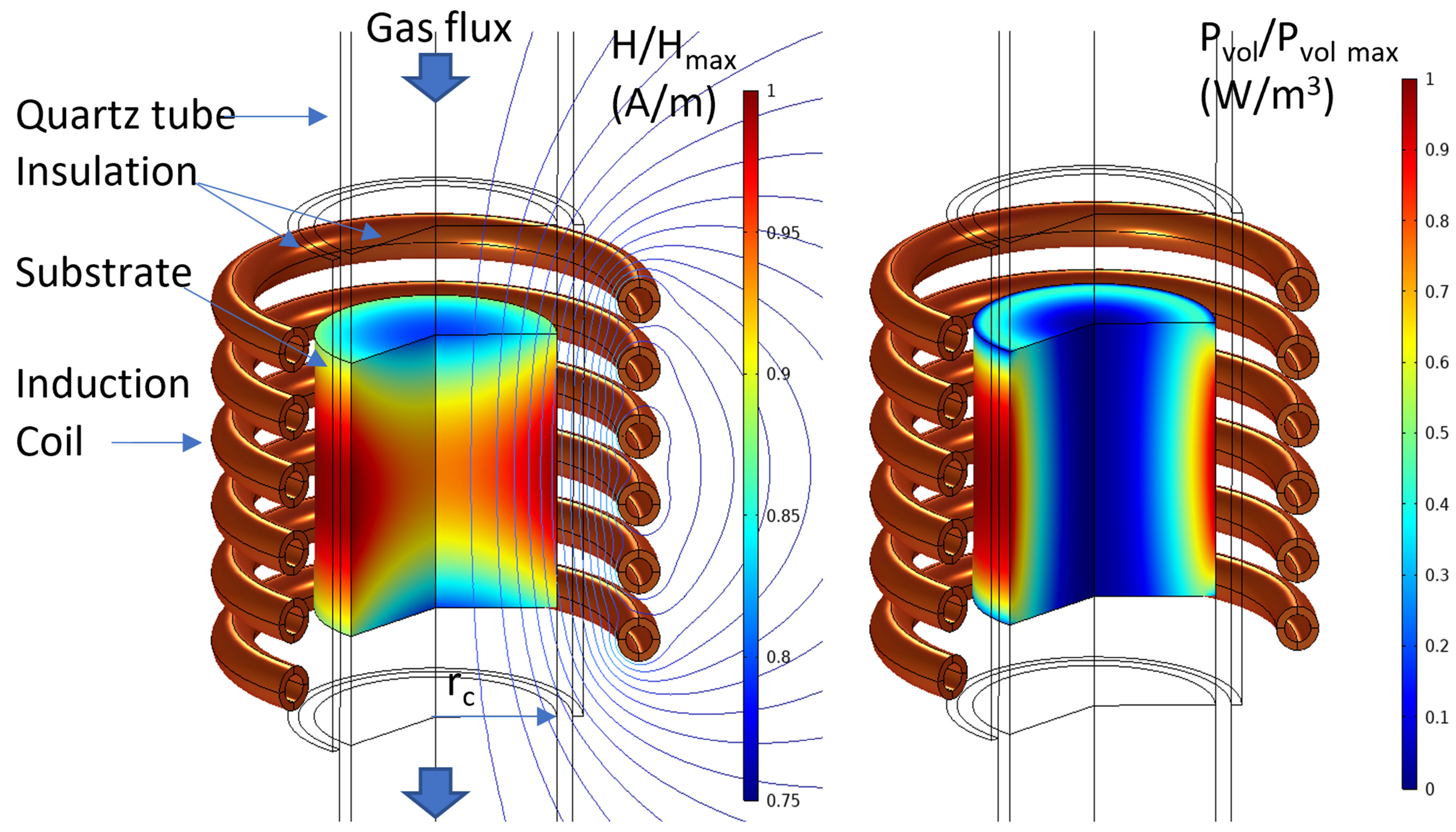

FIGURE 1. Normalized magnetic field and power density distribution in heated substrate at final stage.

Electromagnetic Description

The Magnetic Fields interface (AC/DC Module) and a frequency domain formulation is implemented to estimate the power density distribution in the substrate with a simplified homogenized modelling approach (Fig. 1) : a dense material is considered with an effective electrical conductivity (σ_{eff}). A parametric study is realized to estimate the induction efficiency as a function of σ_{eff} or a normalized ratio r_c/δ (substrate's radius versus electromagnetic skin depth). Such curve gives guidelines for process optimization to obtain a maximum induction heating efficiency (> 90%) through a fine tuning of process parameters. The electrical conductivity σ_{eff} is estimated by using correlation between modelling results and experimental process data.

Heating Description

A coupling with heat transfer is realized by considering radiative losses at the external surfaces and heat convection term due to the gas flux. A Porous Medium node is used to describe the substrate (with effective thermal conductivity) and the gas flux defined by a constant velocity depending on inlet gas properties and substrate macroporosity. Another heat source terms is added for taking into account endothermic reaction. Specific curves are implemented to simulate temperature dependence of physical parameters and power needed for the chemical reaction. The coil current is tuned to maintain the final desired temperature. The impact of gas inlet flow rate (up to 5 times) is also studied for productivity optimization (Fig. 2). Too large flowrate modify temperature profile with a shift at the output and reduce the residence time for the reaction.

These approach was fruitful for process enhancement and give tools to predefine a design at industrial scale with promising energetic efficiency.

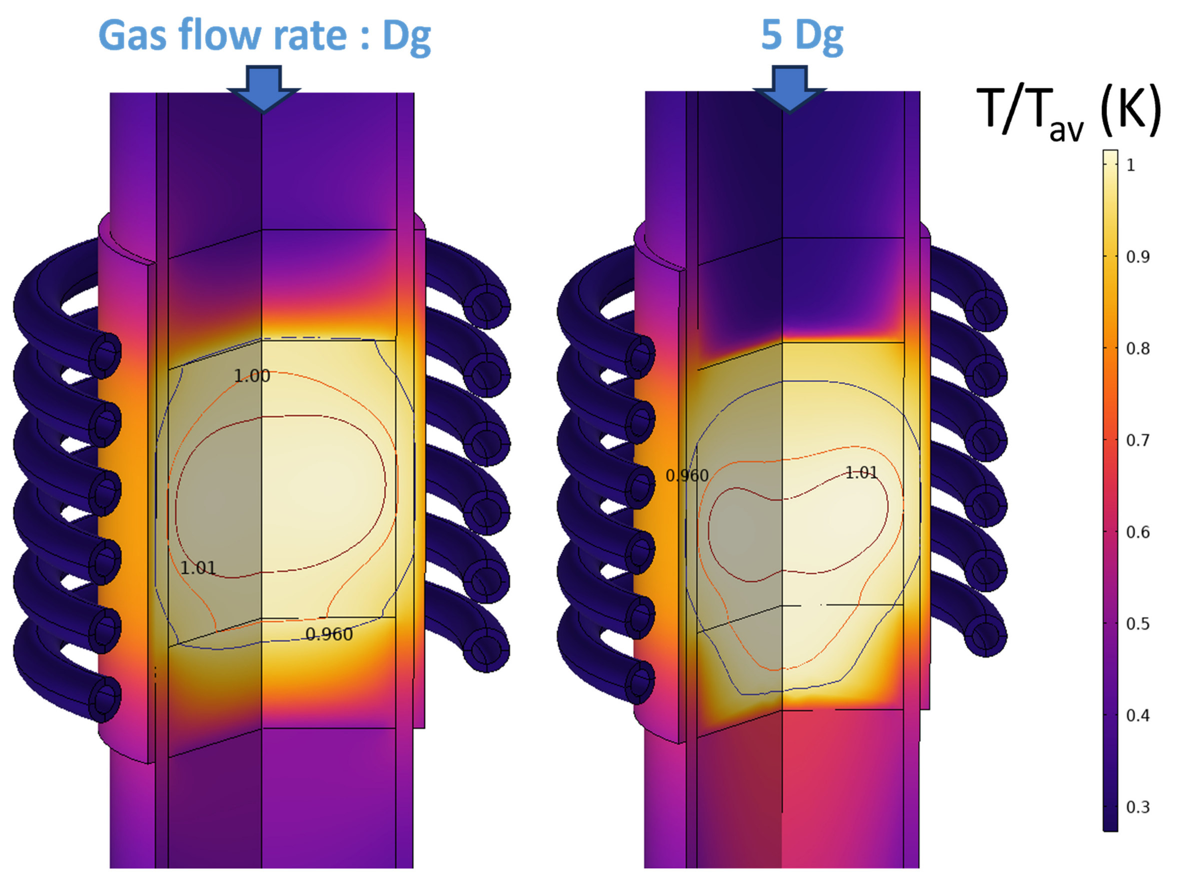

FIGURE 2. Normalized temperature distribution in the reactor at the final stationary state - Effect of gas flowrate.

REFERENCES

[1]. M. Dumont and al, "Electromagnetic processing - from AC to DC Field - A way for process improvement and innovation", in *EPM Conference*, Cannes, France, 2015.
[2]. W. Wang and al, "Induction Heating: An Enabling Technology for the Heat Management in Catalytic Processes", *ACS Catal.* 9, 7921-7935, 2019.
[3]. A. Ambrossetti, "A perspective on power-to-heat in catalytic processes for decarbonization", *Chemical Eng. And Processing Journal*, 182, 101987, 2022.
[4]. C. Kuhwald and al, "Inductive heating and flow chemistry-a perfect synergy of emerging enabling technologies", J. Org. Chem. 18, 688–706, 2022.

eMDpi induction expertise

www.emdpisolutions.com

ICPEES Institut de Chimie et Procédés pour l'Énergie, l'Environnement et la Santé

Excerpt from the Proceedings of the COMSOL Conference 2023 Munich