Ph. D. Proposal in Artificial Intelligence and Numerical Simulation for Energetic Transition

Digital Twin and Deep Learning on optimized and low CO_2 footprint design of industrial glass furnaces

The glass industry, at the heart of Europe's strategic materials sectors, is currently facing an unprecedented transformation. The need to drastically reduce its carbon footprint, combined with performance and quality requirements, is forcing a deep change in thermal processes. Among the most promising levers, electric furnace is emerging as an effective means of decarbonizing production, but it also entails major upheavals in thermal regimes and fluid dynamics, calling into question the very foundations of current furnace design: service life, glass quality, energy efficiency.

In this context, the Ph. D. thesis is part of the ambitious ANR "TwinHeat" industrial chair, which brings together five major partners: three glass producers (Saint-Gobain, Verallia and Pochet), a furnace designer, a software editor, and the Center of Material Forming (CEMEF) at Mines Paris PSL. The common objective is to design a new generation of digital twins, capable of faithfully reproducing the thermal and fluidic behavior of furnaces, while being controlled and optimized by advanced artificial intelligence techniques. This project is based on a novel coupling between high-fidelity numerical simulation tools (CFD, FEM, …) and Deep Learning algorithms, with the aim of reducing computational times, exploring the design space more widely, and satisfying growing industrial requirements.

The aim of the Ph. D. thesis will be to develop an intelligent numerical framework for designing, simulating, and optimizing glass furnace environments according to demanding requirements, including reducing the carbon footprint, improving energy performance, and maintaining product quality. The main challenge lies in the ability to integrate a deep learning agent at the heart of a complex physical simulation, while ensuring the robustness, training speed and genericity of the model. Where conventional approaches (such as adjoint methods) require costly adjustments for each situation, the use of Deep Learning (RL, GNN, …) will enable us to provide a global, adaptive solution that can be transposed to industrial scale.

The work will focus on several areas: the development of simulated learning environments coupled with physics, the implementation of intelligent agents (such as PPO, PBO or DDPG) capable of optimizing furnace architecture and regulation according to physical and energy metrics, and the integration of meta-learning methods to enable the transferability of solutions to other geometries or regimes. All of this will be assessed on concrete industrial use cases provided by the partners, including historical data, real operating constraints, and numerical test benches. The project is supported by High-Performance Computing (HPC) platforms, cutting-edge software tools and scientific supervision at the CEMEF UMR CNRS, Mines Paris PSL research center, based in Sophia-Antipolis, with immersion planned at various French industrial sites.

Contacts:
Franck Pigeonneau : franck.pigeonneau@minesparis.psl.eu
Elie Hachem : elie.hachem@minesparis.psl.eu

Partenaires :