

Prof. Dr. Alessandro Parente
SPP 2419 HyCAM Mercator Fellow
Université Libre de Bruxelles (ULB)
Brussels, Belgium



Invited Talk Abstract

Digital twins and agentic AI for on-demand combustion design and operation

ML-enhanced models are becoming increasingly pervasive in the combustion community to address our outstanding challenges in understanding, simulating, and controlling practical combustion systems. In particular, simulation-based digital twins are emerging, leveraging reduced-order models and sparse measurements to provide operational tools for design, optimisation and control. New developments in the area have extended previously developed approaches for stationary combustion systems to transient forecasting, providing a basis for monitoring, predicting, and controlling the response to changing operating conditions. Nevertheless, most existing approaches have been demonstrated in offline settings, with online demonstrations being sparse and not yet mature. A key question is therefore how to connect these individual capabilities and embed them in operational workflows that are useful for combustion systems newly designed or retrofitted to operate with new fuels such as hydrogen and ammonia, which push the boundaries of combustion science and technology due to their new and distinctive combustion signatures.

In this presentation, I will first review existing approaches to constructing digital twins, focusing on approaches based on the evolution of latent spaces, updated with a few experimental measurements. I will then discuss the perspective of agentic AI as a framework for coordinating and deploying them in online operations to support design and decision-making. Finally, I will outline the opportunities for collaboration during my three-year Mercator fellowship within HyCAM. The priority should be placed on connecting teams working on experiments, high-fidelity simulations and additive manufacturing. In particular, an area worth investigating is how an agentic AI framework could be used to design and tailor the injection and combustion chambers to enhance or moderate thermodiffusive effects, thereby controlling burning intensity and heat-release distribution.