Modélisation et Simulation Multi Echelle MSME UMR 8208

Intern position: Process Modeling and Techno-Economic Analysis of Biomass Pyrolysis Systems.
Location: Laboratoire MSME, 77420, Champs-sur-Marne (https://msme.univ-gustave-eiffel.fr).
Duration: 4-6 months.
Supervisors: Amine Chadil (MSME), Jamal Chaouki (Polytechnique Montreal) and Souad Abderafi (Ecole Mohammadia d'Ingénieurs, Maroc).
Key words: Biomass pyrolysis, thermochemical conversion, bioenergy, process modeling, Aspen plus, Techno-economic analysis.

Biomass pyrolysis is a thermochemical process that converts organic feedstocks into three main product streams: a solid carbon-rich biochar, a liquid bio-oil, and a mixture of combustible gases often called syngas. This process has gained attention as a pathway for decarbonization because it can simultaneously produce renewable fuels and sequester carbon. In particular, the solid biochar can lock away biogenic carbon (acting as a negative emission when stored or used in soils), while the bio-oil and syngas can be used as renewable energy carriers (e.g. for heat, power, or biofuel production). Pyrolysis thus plays a dual role in emerging energy strategies: it provides dispatchable renewable energy and yields carbon sequestration via biochar, making it highly relevant for climate-neutral energy system integration. Moreover, in the context of biorefinery design, pyrolysis allows biomass to be fractionated into multiple valuable products, which can be upgraded into fuels, chemicals, or materials, enhancing the sustainability and economic viability of bio-based industries.

Despite its promise, there are ongoing challenges in scaling up pyrolysis technology from the laboratory to commercial plants. Pyrolysis reactors exhibit complex heat and mass transfer behavior, and scaling is not a linear process. Indeed, as reactors become larger, issues such as uneven temperature distribution, heat transfer limitations, and feedstock flow dynamics can lead to performance deviations. For example, certain reactor designs (e.g. auger or fixed-bed pyrolyzers) may face inefficient heat transfer or mixing at industrial scale, causing inconsistent product yields and quality. Tar formation and other operational issues also tend to exacerbate with scale if not properly managed. As a result, experimental results from lab-scale pyrolysis often do not directly extrapolate to industrial conditions, and overcoming these scale-up hurdles requires careful engineering. Modeling and simulation have become essential to address this gap: by using tools like computational and process simulators, engineers can analyze reactor behavior, optimize designs, and bridge the gap between laboratory findings and industrial-scale applications. In addition, system-scale simulations support broader techno-economic analysis (TEA) and life cycle assessment (LCA) of pyrolysis processes. Traditional lab experiments reveal fundamental kinetics and yields, but they provide limited insight into the economic feasibility and environmental impacts of a full-scale pyrolysis plant. By building a comprehensive process model, one can estimate capital and operating costs, energy efficiency, and greenhouse gas emissions for the entire system. This approach enables informed assessments of whether a proposed pyrolysis-based solution will be cost-effective and sustainable in practice, guiding decisions in decarbonization strategies and biorefinery deployments.

In this internship, the selected student will contribute to a research project focused on system-scale modeling of a biomass pyrolysis process, using state-of-the-art simulation and analysis tools. The intern will develop a detailed process model (for example, using Aspen Plus or a similar process simulator) to represent a biomass pyrolysis reactor and its associated subsystems (feed preparation, the reactor unit, product separation, and heat integration). The model will be used to perform parametric simulations, varying conditions such as reactor temperature, feedstock type/moisture, and residence time, to examine their impact on product yields, energy efficiency, and char quality. The simulation will be tightly integrated with a techno-economic analysis, meaning the mass and energy balance results will feed into cost estimation models to evaluate the process's economic viability (e.g. calculating product cost per unit, energy return, etc.). The intern could also incorporate an environmental assessment component by coupling the process data with an LCA framework to quantify metrics like net greenhouse gas emissions, carbon footprint (including biochar carbon sequestration credits), and other environmental impacts. Through these integrated studies, the project aims to identify optimal operating conditions and design parameters for scaling up the pyrolysis system, and to assess how such a system could be integrated into larger energy or biorefinery networks for decarbonization and energy system integration. By the end of the project, the intern will have helped produce a validated simulation model and a set of scenarios/analyses that inform both the technical design and the techno-economic/environmental feasibility of biomass pyrolysis at scale.

We invite individuals who are rigorous, motivated, creative, and hard-working to join us in this exciting opportunity to develop their research abilities within a top-level research environment equipped with advanced laboratory infrastructure.

The applicant must be a MSc or 5th year Engineering School student in Chemical Engineering, Mechanical Engineering, Energy Systems Engineering, or a closely related field. A strong academic foundation in thermodynamics, heat and mass transfer, and reaction engineering is required.

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