

PhD contract offer

Modeling of physical and chemical evolutions of non-metallic inclusions in liquid steel reactors

General information

Workplace: Institut Jean Lamour (Nancy, France), OPTA Affival (France), Cinvestav (Saltillo, Mexico)

Type of contract: CIFRE

Contract period: 36 months

Expected date of employment: 2026

Proportion of work: Full time

Remuneration: around 2300 € / month (minimum)

Desired level of education: M.Sc. in Process Engineering or Metallurgy

Experience required: -

Missions / Activities

Mechanical performances of metallic alloys, and specifically steels, are strongly impacted by the presence of non-metallic inclusions (NMI) in the metallic matrix. Inclusion populations within the metal alloys are conditioned during the very early stages of the metallurgical process, before solidification. Controlling the mechanical performances thus requires controlling the inclusion populations, which in turn requires a deep knowledge of the inclusion transport, interactions and evolution through physical and chemical transformations in metallurgical reactors.

The behavior of inclusions in metallurgical processes has already been studied with a good level of details by people involved in this project, essentially via numerical simulations at the process scale where computational fluid dynamics (CFD) were coupled with population balances [1, 2] and thermodynamic models [3]. Inclusion transport, aggregation and reaction phenomena govern the evolution of inclusion populations and process-scale simulations must rely on accurate models for them to properly capture the physics at play in a metallurgical reactor. This study aims at providing models for inclusion evolution in the presence of several chemical additives in the liquid metal to characterize how they can help control inclusion cleanliness. The work will combine numerical simulations at the scale of individual inclusions and lab reactors with experiments to determine models for the chemical and physical evolution of inclusions reacting within liquid metal as well as for their transport and interaction (aggregation) in agitated reactors.

CFD simulations will be performed using a pre-existing model [3] of a metallurgical reactor previously developed by the partners of this project in a former collaboration. In this project, this model will be extended and coupled with a population balance model (PBM) [2] to resolve the transient evolution of inclusion populations. The PBM will need to be fed with chemical reaction kinetics and equilibria, that will be determined based on experiments in the two collaborating labs (Institut Jean Lamour in France and Cinvestav in Mexico) and simulations using thermodynamic databases.

References

- [1] **J.-S. Kroll-Rabotin**, M. Gisselbrecht, B. Ott, R. May, J. Fröhlich & J.-P. Bellot. Multiscale Simulation of Non-Metallic Inclusion Aggregation in a Fully Resolved Bubble Swarm in Liquid Steel. *Metals*, 10(4), 2020.
- [2] A. Das, **J.-S. Kroll-Rabotin**, T. Quatravaux, & J.-P. Bellot. Investigating Chemical Heterogeneity in Inclusion Populations : A Multivariate Population Balance Model Study in Gas-Stirred Ladles. *Industrial & Engineering Chemistry Research*, 62(48), 2023.
- [3] **E. Castro-Cedeño**, A. Jardy, B. Boissiere, J. Lehmann, P. Gardin, **A. Carré**, S. Gerardin & J.-P. Bellot. Numerical simulation of modification of non-metallic inclusions by calcium treatment in the argon-stirred ladle. *Metallurgical Research & Technology*, 116(515), 2019.

Work context

Research work will be conducted as a collaborative project between the company Opta Affival, and two labs, Institut Jean Lamour and Cinvestav. Work time will thus be spent in all three sites. PhD applicants will be hired by Opta Affival hosted for their research in the labs, spending roughly a third of their time in Mexico at Cinvestav, and the rest in France, mainly at Institut Jean Lamour with regular stays at Opta Affival.

The PhD student will be enrolled in the doctoral school Chemistry-Mechanics-Materials-Physics (C2MP) at Université de Lorraine under the direction of J.-S. Kroll-Rabotin (Institut Jean Lamour) and will be co-supervised by E. Castro-Cedeño (Cinvestav) and A. Carré (Opta Affival).

About the hosting institutions

• Opta Group, Affival

Affival is part of Opta group and specialized in cored wire injection for liquid metals. The leading supplier of performance materials and specialty chemical solutions Opta Group (Opta), manufactures a diverse product portfolio designed to meet the specialized needs of the metallurgical, construction and specialty chemical end-markets. Opta group has a global industrial footprint in 4 continents, 11 countries and 35 locations and employs more than 900 people worldwide.

• Institut Jean Lamour, Université de Lorraine

The Institute Jean Lamour (IJL) is a joint research unit of CNRS and Université de Lorraine. Focused on materials and processes science and engineering, it covers: materials, metallurgy, plasmas, surfaces, nanomaterials and electronics.

By 2026, IJL has 258 permanent staff (33 researchers, 133 teacher-researchers, 92 IT-BIATSS) and 389 non-permanent staff (146 doctoral students, 43 post-doctoral students / contractual researchers and more than 200 trainees), from some seventy different nationalities.

Partnerships exist with 150 companies and our research groups collaborate with more than thirties countries throughout the world. Its exceptional instrumental platforms are spread over 4 sites; the main one is located on Artem campus in Nancy.

• Cinvestav

The Center for Research and Advanced Studies (Cinvestav) is a decentralized body of the Mexican Ministry of Public Education. Cinvestav has presence in 10 Mexican states, offering 66 graduate programs distributed across 34 departments and four disciplinary areas: Biological and Health Sciences, Social Sciences and Humanities, Engineering and Technology Sciences, and Exact and Natural Sciences. From its inception until 2024, it awarded 15,527 graduate degrees: 10,537 master's degrees and 4,990 doctoral degrees. Its academic staff comprises 583 researchers. The academic productivity is high, with 1828 publications in 2024 and 286 projects in progress, 44 of them with international resources. The Cinvestav Saltillo research unit is focused on metallurgy, ceramics, energy/sustainability and robotics/advanced manufacturing.

Skills and requirements

Applicants must hold Master's degree and have validated courses in Process Engineering, in Metallurgy, in Fluid Mechanics or in Numerical Modelling and Simulation. They must have a taste for simulations and Computational Fluid Dynamics, but not necessarily a full experience in these domains. They must also be able to write scientific documents in English. Good technical writing and speaking are required in English. Knowing a little French and/or Spanish will help during the stays in France and Mexico but is not required for day-to-day work.

Constraints and risks

The position you are applying for is located in a sector relating to the protection of scientific and technical potential. It therefore requires, in accordance with the regulations, that your arrival be authorized by the competent authority of the Ministry of Higher Education, Research and Innovation.

Application

- Alexandre Carré <alexandre.carre@affival.com>
- Edgar Castro-Cedeño <edgar.castro@cinvestav.mx>
- Jean-Sébastien Kroll-Rabotin <jean-sebastien.kroll-rabotin@univ-lorraine.fr>

Please apply by e-mail. Send your application in a single e-mail to all contact addresses. Describe your motivation for this offer in the content of your e-mail and attach a resume, preferably in PDF.