17 May 2024

PhD contract offer

Segregations at grain boundaries and austenite grain growth: influence of residual elements from steel recycling

General information

Workplace: Institut Jean Lamour, Nancy, France
Type of contract: PhD contract with CNRS
Contract period: 36 months
Expected date of employment: October 2024
Remuneration: 2135 € / month (gross salary)
Desired level of education: Master's degree in material science, metallurgy

Context

The steel industry, which is one of the main contributors to CO_2 emissions, is aiming to reduce its emissions to almost 0% by 2050 (carbon neutrality). One of the main ways to achieve this goal will be to increase scraped-based steel production by electric arc furnaces. The development of steel recycling will increase the presence of residual elements (Mo, Cr, Ni, Cu, Sn, As, Sb among others) which cannot be eliminated by existing liquid metal refining technologies. These "tramp elements" have a noticeable impact on the development of microstructures throughout the process and, subsequently, on the ultimate properties of the steel [1]. Currently, knowledge is lacking to optimize the design, the processing and the properties of steel products in presence of residual elements [2].

The aim of OPTISCRAPS project (ANR – PEPR DIADEM www.pepr-diadem.fr), starting on 2024, is to fill this gap. The project will focus on the annealing (heating to austenitic domain followed by cooling) of cold-rolled steel sheets for manufacturing of high-strength steels. It will gather ArcelorMittal (Research Center at Maizières-Lès-Metz) and several laboratories: IJL (Nancy), SIMAP (Grenoble), GPM (Rouen), PIMM (Paris), UMET (Lille), LIST (Luxembourg). Three theses will be launched to study the effects of residual elements at different stages of the process:

- Segregation and austenite grain growth. This is the present offer, which is detailed below.
- Austenite decomposition on cooling.
- Microstructure-Property relationship.

The scientific strategy of OPTISCRAPS involves the following steps (Figure 1).

- Use high-throughput experimental methods to explore the numerous possible combinations of these residual elements, their respective effects and their interactions. This includes first the elaboration of steel samples with graded chemical composition of one or more elements (diffusion couple or additive manufacturing). Then, phase transformations kinetics will be tracked in situ by High-Energy XRD experiments at synchrotron beamlines.
- Carry out mechanical and chemical characterization of the different produced microstructures by coupling different cutting-edge techniques.
- Develop hybrid metallurgical metamodels that couple processes, microstructures, and properties. These models are based on physics but enhanced by automated learning methods that combine numerical and predictive performance.

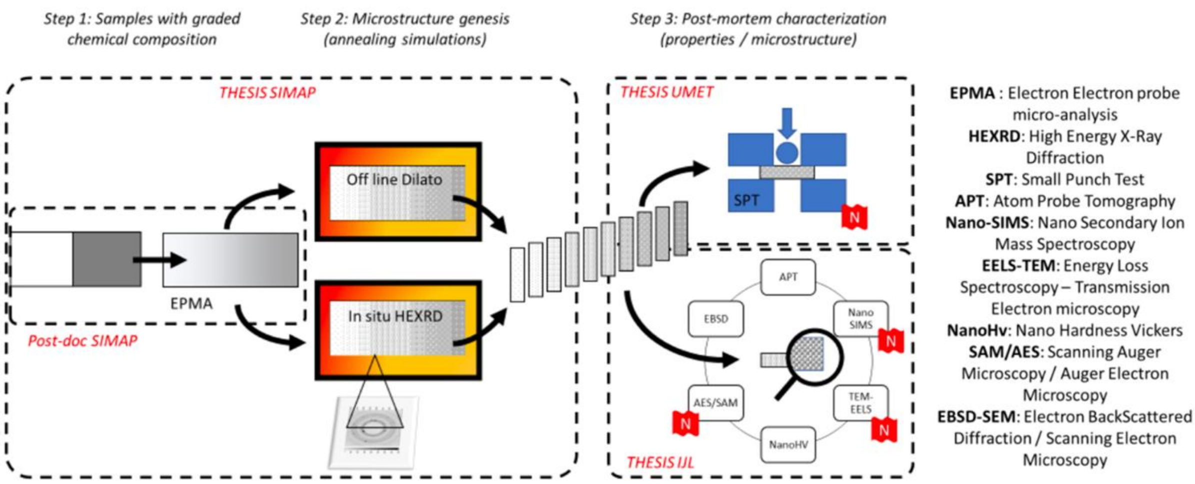

Figure 1. Schematic representation of the experimental strategy of OPTISCRAPS project. N flags highlight exploratory techniques needed to be developed and assessed during the project.

Missions / Activities

The hired PhD student will study the phenomena of residual elements segregation at austenite grain boundaries and their consequences on austenite grain growth.

The first objective will be methodological and will aim to benchmark the characterization techniques of equilibrium segregation at grain boundaries. This analytical approach is challenging due to the low concentration of residual elements and the scale of investigation. It requires the development of new methodologies based on complementary imaging techniques combining high sensitivity, high spatial resolution and statistical representativity. As it stands, the reference technique is atom probe tomography (APT) [3] but it suffers from statistical representativeness. It is for this reason that the potential of nano-SIMS [4], SAM/AES and TEM [5] will be compared to APT in this study. The scientific objective is to achieve a better knowledge of the segregation mechanisms at the austenitic grain boundaries of alloys (segregation energy) but also to identify possible competitions between the elements (including main alloying elements such as C, Mn or Cr). This knowledge on the segregation of residual elements will then serve as a basis to better understand their possible effects on grain boundary mobility (austenitic grain growth). In this context, EBSD and laser scanning confocal microscopy [6] will be key tools.

Second objective of the thesis will be to develop physically based models for the segregation of residual elements at austenite grain boundaries and for austenite grains growth [6,7]. These models will be coupled to other models addressing the decomposition of the austenite on cooling and the relationship final microstructure / properties. Final aim of OPTISCRAPS is to achieve seamless simulation of steel production downstream process with accounting of residual elements.

The thesis will be done in interaction with the other laboratories participating to OPTISCRAPS and more particularly with both other theses mentioned above. An important part of the study will be done at GPM (Rouen) to conduct and analyze APT experiments.

References

[1] Marique, C. Tramp elements and steel properties: a progress state of the European megaproject on scrap recycling. *Revue de Metallurgie* **97** (1997) 74-75.
[2] Raabe, D., Tasan, C. C., Olivetti, E. A. Strategies for improving the sustainability of structural metals. *Nature* **575(7781)** (2019) 64-74. https://doi.org/10.1038/s41586-019-1702-5
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[5] Ledieu, J., Feuerbacher, M., Thomas, C., de Weerd, M. C., Šturm, S., Podlogar, M., Ghanbaja J., Migot S., Sicot M, Fournée, V. The (110) and (320) surfaces of a Cantor alloy. *Acta Materialia* **209** (2021) 116790. https://doi.org/10.1016/j.actamat.2021.116790
[6] Kern M., Bernhard M., Bernhard C., Kang Y-B. Grain boundary mobility of γ-Fe in high-purity iron during isothermal annealing. *Scripta Materialia* **230** (2023) 115431. https://doi.org/10.1016/j.scriptamat.2023.115431
[7] Dépinoy, S., Marini, B., Toffolon-Masclet, C., Roch, F., & Gourgues-Lorenzon, A. F. Austenite Grain Growth in a 2.25Cr-1Mo Vanadium-Free Steel Accounting for Zener Pinning and Solute Drag: Experimental Study and Modeling. *Metallurgical and Materials Transactions A* **48** (2017) 2289-2300. https://doi.org/10.1007/s11661-017-4002-4

Work context

Main localization will be at IJL (Nancy) and the research team “Microstructures and Stresses”, which is specialized on phase transformations in solid state in metallic alloys. Regular stays of several months are planned at GPM (Rouen).
The thesis will be directed at IJL by Dr Julien Teixeira and supervised by Dr Julian Ledieu. It will be supervised at GPM by Dr Frédéric Danoix.
Travels and scientific exchanges with other partners are planned in frame of OPTISCRAPS project.
The PhD student will have access to all the experimental resources of IJL (including Auger microscopy, TEM, laser scanning confocal microscopy, EBSD) and GPM (Atom Probe Tomography). He/She will also participate to nanoSIMS experiments at LIST.

Skills

Holder of an engineering degree or a Master's 2 in materials engineering/metallurgy.
Good knowledge of solid-state phase transformations in metal alloys.
Experience in materials characterization would be appreciated.
Proficiency in English, writing and oral communication.

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.

About Institut Jean Lamour

The Institute Jean Lamour (IJL, https://ijl.univ-lorraine.fr/) 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.
It gathers 183 researchers/lecturers, 91 engineers/technicians/administrative staff, 150 doctoral students and 25 post-doctoral fellows. Partnerships exist with 150 companies and our research groups collaborate with more than 30 countries throughout the world.
Its exceptional instrumental platforms are spread over 4 sites; the main one is located on Artem campus in Nancy.

Application

Applicants are invited to send CV, cover letter, names of references and M1/M2 marks together to:

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