Microstructure evolution during Hot Form Quench of 2XXX series aluminum alloys for aeronautic applications

General context

In the context of necessary carbon emissions reduction, development of new alloys and processes for materials forming in the aeronautic industry are prolific research topics. Hot Form Quench (HFQ) is a disruptive forming technology which enables to obtain complex shapes of the parts with high geometrical and aerodynamic performance tolerance using thin wall Ultra High Strength aluminum (2xxx, 6xxx, 7xxx series) alloys. HFQ is an alternative to conventional deep drawing process combined with heat treatments which allows simplified complex manufacturing routes, hence highly reducing carbon emissions of the process.

Figure 1. HFQ represents an efficient alternative process for different parts of planes' structure

Airbus is a strong advocate of innovative technologies to reduce Buy-to-Fly ratio, to improve integration & cost saving. HFQ is considered to be an important technology pathway to achieve this ambition. However, because of its novelty, the understanding of the mechanical and metallurgical aspects of the HFQ process needs to be developed.

As a first step in a global collaboration strategy between CEMEF (Mines Paris) and Airbus, two PhD positions are proposed. The first one, already started since January 2024, focuses on the finite element simulation of the HFQ process in addition to the development of an experimental lab scale bench capable of reproducing the industrial thermo-mechanical conditions.

The research topic of the second PhD, with the participation of Institut Jean Lamour in Nancy, is briefly described since only few informations on the HFQ process and Airbus parts of interest can be presented for confidential reasons. The originality and success of the overall project relies on the complementarity between the two PhD projects. **The candidate will have the opportunity to develop advanced skills mainly in aluminum metallurgy, but also in thermomechanical design of laboratory experiments applied to the development of new parts for current and future Airbus aircrafts.**

Global objectives:

This PhD aims at investigating microstructural evolution during HFQ. Samples obtained from the first PhD using lab scale tests with well-controlled thermo-mechanical conditions will be analyzed with quantitative microstructural investigation applying different complementary techniques (hardness measurements, EBSD, TEM, DSC, electric resistivity and XRD[1]). Therefore, the effect of HFQ processing conditions on further microstructure evolution will be established for an 2XXX alloy and can be presented as processing-like map.

The activated physical mechanism and their interactions will be accessed through the analysis of microstructure evolution during the HFQ process with several microstructural quantities (grains size and orientation spread, dislocation density and sub-structures, second phase particle size distribution and volume fraction, crystallographic texture…). Those mechanisms will then be modeled for microstructural predictions and coupling with mechanical behavior.

The main challenges rely on the analysis of interactions between precipitation of hardening phases and plasticity which may involve a number of phenomena: heterogeneous nucleation, faster growth and coarsening of precipitates, recovery and dynamic recrystallisation. The experimental plan was carefully established to get insight into mechanisms which control microstructure evolution of 2XXX series aluminum alloys during HFQ.

- **Keywords:** thermomechanical processing, plasticity, hardening precipitation, recrystallisation and recovery, microstructure characterization
- **Candidate profile:** Master or engineering degree in materials science with good knowledge of phase transformations and plasticity mechanisms in metallic alloys. Motivation for experimental work.
- **Localization:** This PhD will take place in CEMEF in Sophia Antipolis (18 months) and Institut Jean Lamour in Nancy (12 months) and the last 6 months at Airbus Nantes
- **Salary**: 2700 €/month (gross salary)
- **Contacts:** charbel.moussa@minesparis.psl.eu and vladimir.esin@univ-lorraine.fr

[1] Electron BackScatter Diffraction, Transmission Electron Microscopy, Differential Scanning Calorimetry and X-ray Diffraction respectivelly)