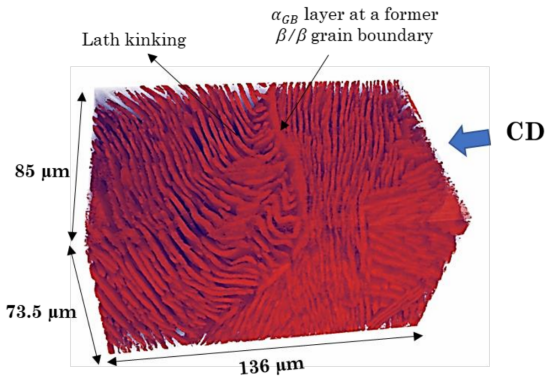
PhD Position: Bridging scales in Titanium alloys

The European Commission has established a target of reducing greenhouse gas (GHG) emissions of the European Union by over 80% by 2050, in comparison to 1990 levels. Additionally, the Commission aims to achieve carbon neutrality by that same year. In the aeronautics industry, one of the ways to achieve these objectives is to reduce the weight of structures, thereby reducing fuel consumption.

In this context and due to its lightweight, titanium alloys emerge as a material with a huge potential. Depending on its composition and manufacturing process, a rather wide range of mechanical properties can be obtained which means that Titanium alloys could potentially replace multiple steel components in quest of weight reduction.

As for all other materials, its properties are the consequence of its microstructure. However the biphasic (α/β) nature of the material and its phase fraction evolution at different temperatures makes it difficult to develop numerical models that could be used to predict both its microstructural evolution and associated mechanical properties. Furthermore, the microstructure of titanium alloys is complex and evolves over large span of length scales, starting from milimeter size β grains in the raw material, all the way to fine microstructures containing micrometric α grains and laths.

The aim of the project is to develop and explore different simulation techniques in order to describe the mechanical behavior of titanium alloys. Different approaches will be explored including self-consistent schemes FE and FFT based approaches. The complexity of the α/β titanium microstructures is shown in the Figure below



3D reconstruction of the Ti64 α phase after deformation at 950^0 C, 0.1 s^{-1} and 1.3 strain level [PhD M. Brozovic, 2022].

Numerical modeling

As a first step in order to simulate the microstructural evolutions taking place in hot forming Titanium alloys consists in developping an accurate model for the estimation of the energy distribution (plastic strain) between the α/β phases.

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The numerical tools available in the team are based on the use of the finite element method (FEM). When dealing with mechanical computations FEM might induce significant computational costs. For this reason a coupling between the existing FEM tools and a new FFT-based full-field model will be developed.
The use of FFT-based mesoscopic models allows to significantly reduce the computational time since these methods take advantage of the efficiency of the Fast-Fourier Transform. Another advantage of FFT-based methods is that, in contrast to finite elements, the condition number of the system is not degraded as the discretization size is reduced (mesh refinement).
The mechanical contrast induced by the bi-phase nature of titanium alloys makes it difficult to identify the material parameters that should be feed to the material constitutive laws of the α/β phases. For this reason a parameter identification approach will be proposed using inverse analysis approaches.
Finally using the proposed model and the identified parameters, the full-field approach will be used to predict the energy distribution in the α/β phases to be used as input for phase transformation simulations.

Candidate profile

The candidate must hold Master degree in computational mechanics, high performance computing, material science, or a closely related field. The candidate should demonstrate a strong interest in numerical modeling and programming within a high-performance modeling environment.

Partners

The project is being conducted as part of a academic/industrial collaborative work carried out within the *Continuum* consortium. The consortium is formed by Safran, Airbus, Aubert&Duval and Timet and three academic teams at Chimie ParisTech, Institute Pprime and CEMEF MINES Paris.