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POST-DOCTORATE PROPOSAL

Title : Micromechanical modeling of fatigue life reduction in titanium alloys exposed to high temperature oxidizing conditions.

Reference : **PDOC-DMAS-2024 -01**
(to be recalled in all correspondence)

Start of contract: 01/03/2024	**Application deadline:** 20/02/2024

Duration: 18 months - Net yearly salary: about 25 k€ (medical insurance included)

Keywords

Titanium alloys, Oxygen embrittlement, Micromechanical Modeling, Fatigue, Crystal Plasticity

Profile and skills required

PhD in mechanics or material mechanics. Experience with metallic materials and numerical modeling.

Presentation of the post-doctoral project, context and objective

Aerospace components, especially engine parts, subjected to oxidizing environments and high temperatures, currently use nickel or cobalt alloys, which have excellent high-temperature properties but also a high density. The replacement of these materials with titanium alloys, half as dense, is a promising avenue for balancing weight reduction, thermomechanical performance, and durability for these parts. However, the mechanical properties and environmental resistance of current titanium alloys limit their use in aviation to temperatures of around 600 °C. Indeed, oxygen ingress significantly alters their mechanical properties, leading to a considerable reduction in fatigue life. Hence, developing numerical strategies to simulate the interactions between oxidation and fatigue life is essential to support the design of new titanium alloys for high-temperature applications. In this context, one the major scientific challenges lies in the understanding and accurate modeling of the oxygen-plasticity interactions at the scale of the microstructure, that is required to simulation of their influence on fatigue crack nucleation.

The PHYDOM research convention, funded by the DGAC, and conducted at ONERA, aims at tackling this challenge, in order to produce a multiscale and multiphysics simulation framework to predict the fatigue life of titanium alloys exposed to high-temperatures. The project focus on the study of the quasi-α alloy Ti6242S, at a reference state and after a high-temperature oxidizing treatment. It involves a detailed experimental characterization of the material in those two conditions, relying on microstructural imaging (SEM, EBSD,TEM), oxygen concentration measurements (WDS, nano-indentation), mechanical characterization testing (monotonic, cyclic, fatigue), and micromechanical testing (in-situ SEM tension tests). The mechanical tests are conducted at room temperature and high temperature. On the other hand, a micromechanical simulation framework of the material has been developed, relying on crystal plasticity and a FFT-based[1] solver. It allows to run large-scale cyclic simulations on synthetic representative microstructure, or directly using microstructure imaging as input.

The proposed post-doc position will be devoted to bridging the gap between this experimental and modeling work, to reach two main objectives. The first is the proposition and identification of the Ti6242s crystal plasticity model, across the two temperatures of interest and the range of measured oxygen concentrations. For that purpose, an innovative strategy must be designed and implemented to identify the model using the rich multimodal experimental data generated by the project's experimental activities. This first stage of the postdoctoral work has two crucial outcomes. First, ensure that the model can predict both the macroscopic behavior and microstructural scale mechanical heterogeneities observed in those different conditions. And second, accurately capture the dependence of the mechanical behavior to the oxygen

[1] The AMITEX_FFTP solver, developed by CEA (https://amitexfftp.github.io/AMITEX/index.html#)

concentration in the material. For this second objective, the post-doc could recommend and (depending on his/her skills) carry out additional micromechanical tests on the oxidized material.

The second objective is fatigue crack nucleation modeling, with the ambition to predict both the fatigue lifetime and the crack nucleation location in the microstructure, observed in the reference and oxidized material, at the two temperatures of interest. This second part of the work will first involve the proposition of a modeling strategy, grounded on the experimental observation of cracking mechanisms and a literature review of fatigue crack modeling at the microstructural scale. Then, the proposed fatigue life model will be identified through comparison between micromechanical simulations and the fatigue experiments conducted in the project.

The post-doctoral fellow will work in close collaboration with a PhD student and two ONERA researchers. In addition, she/he will benefit from scientific exchanges within the project PHYDOM, which involve industrials and academics, and extend to the study of the oxidation and oxygen diffusion in titanium alloys. Finally, this project will provide the postdoctoral fellow with a strong background in crystal plasticity, micromechanical modeling with FFT-based solvers, and in the mechanics and fatigue of titanium alloys.

External collaborations

Possible collaborations with LaSIE (Université de La Rochelle), CIRIMAT (Université de Toulouse III), and with SAFRAN, AIRBUS, TIMET

Host laboratory at ONERA

Department : Département Matériaux et Structures

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