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PROPOSITION DE SUJET DE THESE

Intitulé : Mitigation of hydrogen embrittlement of the Inconel 718 produced by additive manufacturing using shot peening

Référence : **MAS-DMAS-2025-08**
(à rappeler dans toute correspondance)

Début de la thèse : septembre-décembre 2025	**Date limite de candidature : fin 2025**

Mots clés : additive manufacturing , Inconel 718, hydrogen transport, shot peening, mitigation, fatigue

Profil et compétences recherchées
Continuum mechanics, mechanical testing, hydrogen-material interactions, fatigue

Présentation du projet doctoral, contexte et objectif

Hydrogen has been experimentally observed to alter the mechanical properties of metals and earlier failures when compared to hydrogen free environment. The term hydrogen embrittlement (HE) comes from the widely accepted view that hydrogen exposure causes the metal fracture surface to change from a ductile to a brittle appearance. It usually describes the decrease in fracture properties of metals resulting from the interplay of the material's microstructure, mechanical loading, and the hydrogen environment, which can originate from internal sources (forming processes) or external sources (gas or liquid contact). Recently, research on HE of additive manufacturing (AM) material has significantly increased since the resulting microstructure has no equivalent in conventional metals, which therefore may modify the underlying HE mechanisms. AM is a process in which parts are created by adding materials layer by layer. One key benefit of AM lies in its ability to fabricate intricate structures that would otherwise be unfeasible using conventional manufacturing techniques. For instance, the development of new generations of reusable rocket engines as well as decarbonizing power systems produced by additive manufacturing is under active investigations.

Shot peening is a surface treatment that can significantly increase the fatigue life of ductile metals. In fact, shot peening introduces beneficial (biaxial) compressive residual stress and cold hardening, but it also detrimentally increases surface roughness for conventional metals. However, in as-built AM metal parts that contain undesirable high surface roughness, shot peening reduces the surface roughness, leading to a beneficial effect on fatigue life compared to machined parts [1]. Remarkably, shot peening has been shown to mitigate and even eliminate HE of steel and aluminium alloys tested under monotonic loading [2,3]. In the project herein, we propose to study the effect of shot peening on HE under cyclic loading by examining the interplay between the beneficial compressive stresses in the near-surface regions and the increase of plastic deformation, which in turn increase the H-trapping sites by the dislocations. **To what extent shot peening can decrease HE and increase fatigue life is a question this thesis aims to address.** To align with the mentioned industrial application this project centers on the HE of the nickel-iron-based superalloy Inconel 718 (IN718) produced using the laser powder bed fusion (LPBF) AM method.

This thesis is conducted in partnership with École Polytechnique Montréal. As a result, the candidate will divide their time between Montréal and ONERA Châtillon, starting in Montréal.

[1] C. Bianchetti, M.G. Tsoutsouva, L. Toualbi, P. Kanouté, Surface treatment impact on fatigue life at 550 °C of the as-built Inconel 718 manufactured by laser-powder bed fusion, Mater.

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[2] Y. Wang, H. Xie, Z. Zhou, X. Li, W. Wu, J. Gong, Effect of shot peening coverage on hydrogen embrittlement of a ferrite-pearlite steel, Int. J. Hydrogen Energy. 45 (2020) 7169–7184. https://doi.org/10.1016/j.ijhydene.2020.01.021.
[3] M. Safyari, M. Moshtaghi, Role of Ultrasonic Shot Peening in Environmental Hydrogen Embrittlement Behavior of 7075-T6 Alloy, Hydrogen. 2 (2021) 377–385. https://doi.org/10.3390/hydrogen2030020.

Collaborations envisagées : Myriam Brochu (Polytechnique Montréal), Aurélien Vattré, Vincent Bonnand

Laboratoire d'accueil à l'ONERA
Département : Matériaux et Structures
Lieu (centre ONERA) : Châtillon
Contact : Charles Bianchetti/Vincent Bonnand/Aurélien Vattré
Tél. : 0146734664 Email : charles.bianchetti@onera.fr / vincent.bonnand@onera.fr / aurelien.vattre@onera.fr

Directeur de thèse
Nom : Myriam Brochu / Aurélien Vattré
Laboratoire : Polytechnique Montréal / ONERA
Tél. : (514) 340 4711 – poste 4614
Email : myriam.brochu@polymtl.ca

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