

## Fatigue crack propagation under high pressure of gaseous hydrogen: experiments and modeling

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**Gilbert Hénaff** (Professor) e-mail: [gilbert.henaff@isae-ensma.fr](mailto:gilbert.henaff@isae-ensma.fr)

**Damien Halm** (Professor) e-mail: [damien.halm@ensma.fr](mailto:damien.halm@ensma.fr)

**Mandana Arzaghi** (Associate Professor) e-mail: [mandana.arzaghi@ensma.fr](mailto:mandana.arzaghi@ensma.fr)

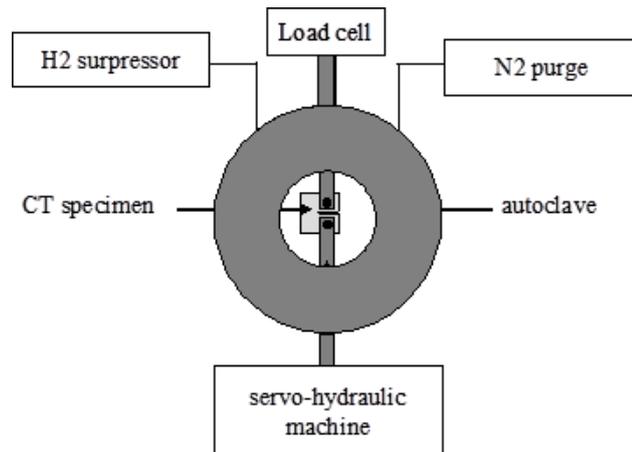
**Guillaume Benoit** (Engineer) e-mail: [guillaume.benoit@ensma.fr](mailto:guillaume.benoit@ensma.fr)

**Clara Moriconi** (PhD, 2009-2012)

**Giovambattista Bilotta** (PhD, 2012-2015)

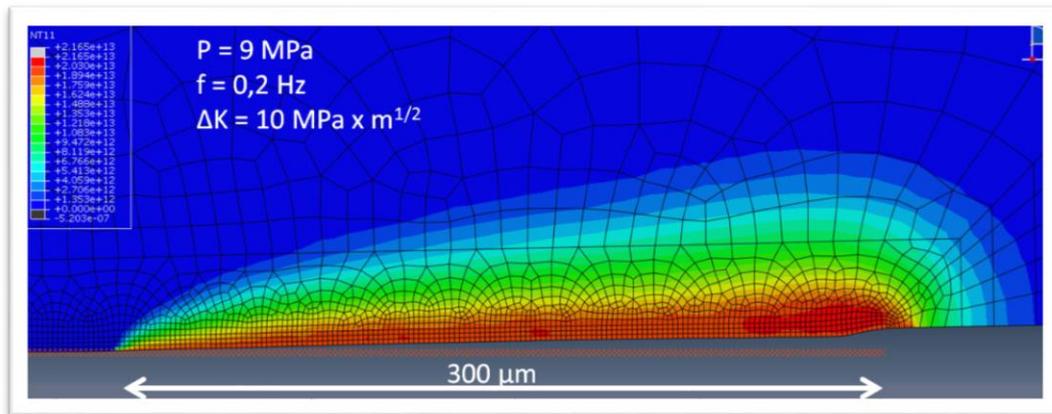
*Collaboration with LaSIE laboratory, University of La Rochelle (2013-2014)*

Previous studies carried out in our laboratory have widely documented the deleterious effect of hydrogen resulting from the decomposition of adsorbed species at the crack tip on the fatigue crack growth resistance of metals. A renewed interest in the role of hydrogen on fatigue crack propagation has more recently raised from issues about hydrogen compatibility of structural materials in view of the development of a so-called “hydrogen economy”. In this framework, a special test rig has been designed in order to investigate the effect of high pressure of gaseous hydrogen on crack propagation (please see: <http://www.sandia.gov/matlsTechRef/advmat.html>).



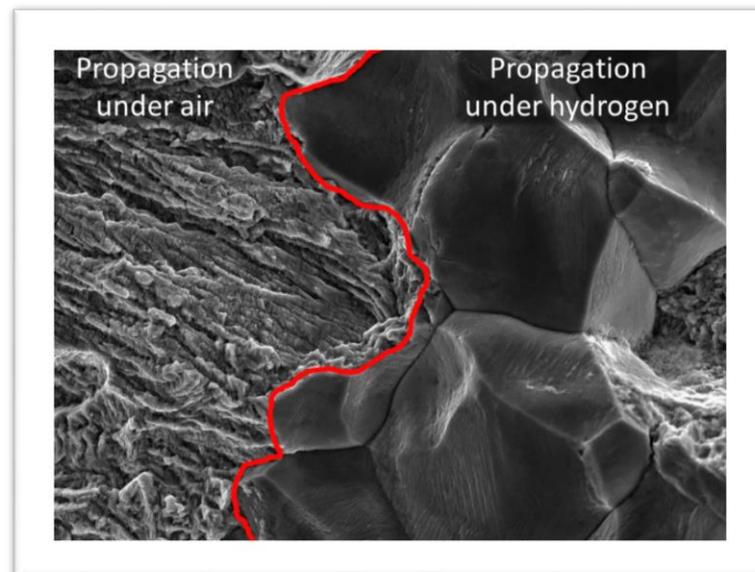
*HYCOMAT Test Rig*

The results obtained on a martensitic stainless steel indicate that the fatigue crack growth enhancement can be tremendous, depending on pressure and loading frequency [1, 2]. In order to simulate the crack growth rate enhancement, it was decided to develop a simulation tool based a Cohesive Zone Model (CZM) dedicated to cracking under cyclic as well as monotonic loadings. Meanwhile, the model should provide insights into the various physical processes governing damage at the crack tip in relation with loading and exposure conditions. The proposed model [3, 4] has been implemented in the ABAQUS finite element code. Particularly, a specific traction-separation law, adapted to account for the gradual degradation of the cohesive stresses under cyclic loading and sensitive to the presence of hydrogen at the interface is formulated. The coupling between mechanical behaviour and diffusion of hydrogen is furthermore modelled using a coupled temperature - displacement calculation available in ABAQUS.



*Numerical simulation of hydrogen diffusion in the crack tip stress field*

Current work aims in getting deeper insight into the different steps involved in the degradation mechanisms at the crack tip which influence crack growth kinetics. With this respect, the interactions between cyclic deformation substructures and the hydrogen diffusion and trapping in ARMCO iron are examined. The objective is to enrich the model with physical parameters enabling a quantitative evaluation of these interactions.



*Influence of gaseous hydrogen on fracture made in ARMCO iron*

#### References:

- [1] Z. Sun, G. Benoit, C. Moriconi, F. Hamon, D. Halm, F. Hamon, G. Hénauff, Fatigue crack propagation under gaseous hydrogen in a precipitation-hardened martensitic stainless steel, *International Journal of Hydrogen Energy*, 4th Asian Bio-Hydrogen Symposium, 36 (2011) 8641-8644.
- [2] Z. Sun, C. Moriconi, G. Benoit, D. Halm, G. Henaff, Fatigue Crack Growth under High Pressure of Gaseous Hydrogen in a 15-5PH Martensitic Stainless Steel: Influence of Pressure and Loading Frequency, in: *Metallurgical and Materials Transactions A*, Springer Boston, 2012, pp. 1-11.
- [3] C. Moriconi, G. Henaff, D. Halm, Cohesive zone modeling of fatigue crack propagation assisted by gaseous hydrogen in metals, *International Journal of Fatigue*, 68 (2014) 56-66.
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