# FINE INSIGHT ON HIGH TEMPERATURE HYDROGEN ATTACK INITIATION AND MORPHOLOGY ON CASE STUDIES

Camille Flament, Univ. Grenoble Alpes, CEA, LITEN, 38000 Grenoble, France
camille.flament@cea.fr
Nicolas Chevreux, Univ. Grenoble Alpes, CEA, LITEN, 38000 Grenoble, France
Thomas David, Univ. Grenoble Alpes, CEA, LITEN, 38000 Grenoble, France
Olivier Gillia, Univ. Grenoble Alpes, CEA, LITEN, 38000 Grenoble, France
Laure Guetaz, Univ. Grenoble Alpes, CEA, LITEN, 38000 Grenoble, France
Romain Soulas, Univ. Grenoble Alpes, CEA, LITEN, 38000 Grenoble, France
Charles Le Névé, TotalEnergies, Total Research and Technology Gonfreville, 76700 Harfleur, France
Raphael Goti, TotalEnergies, Total Research and Technology Gonfreville, 76700 Harfleur, France
Eric Andrieu, CIRIMAT-ENSIACET, 31030 Toulouse, France

Introducing hydrogen in refinery processes, and biomass retreatment is far from its end. For this purpose, vessel materials have to face the High Temperature Hydrogen Attack (HTHA), which is still difficult to predict. Two questions arise; the first one is about the location and the trigger of the initiation of the attack. Answering this question is useful to help tailoring more resistant carbon steel grades. The second question is about the kinetics and the evolution of the attack morphology (voids, cracks). Answering this question will as well help in tailoring better steel grades, but is also useful in the frame of a Fitness For Service (FFS) approach during the lifetime of the pressure vessels. In this work, a careful attention has been paid to the location of initiation and the morphology evolution on a post analysis of damaged vessels at different degrees. On a much-attacked C-steel vessel, observations at micronic scale by scanning electron microscopy revealed a particular attack profile. This profile is globally decreasing from the inner surface submitted to the hydrogen atmosphere, with some peculiar variations, as well as some particular orientation of the cracks. Cracks are orthoradial near the inner surface and radial near the outer surface. On a much less attacked vessel, advanced characterization technics as high resolution FIB+SEM (Slice&View) technic have permitted to visualize in 3D the link between hydrogen attack in form of small voids, carbon phases and inclusions (figure 1). Coupled with TEM observations, it has shown that small inclusions are mainly nanometric AlN precipitates. When they are close to carbon phases, they seem to promote void nucleation, which has never been highlighted at this fine scale so far to our knowledge, showing that the advanced characterization technics used here are very useful for understanding the early hydrogen attack stage.

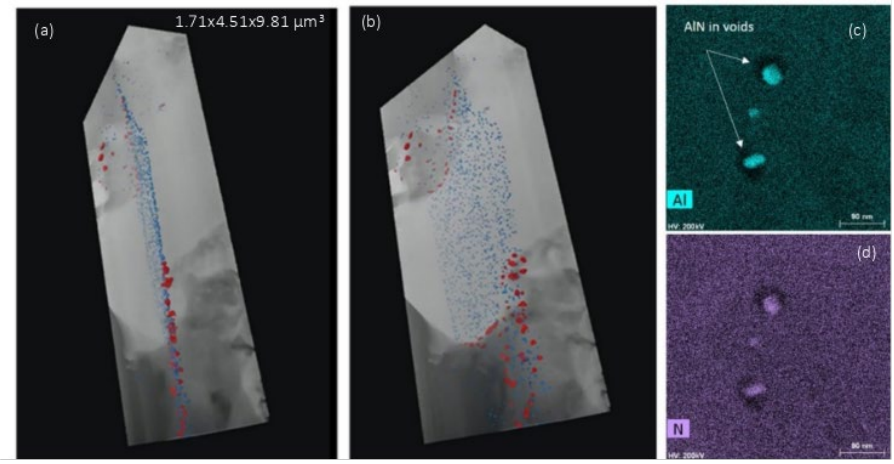


*Figure 1: (a,b) 3D view of an alignment of small inclusions (blue objects) in ferrite (light grey) linked to cavity nucleation (red objects) when the inclusion plane interfere with the carbon phase - cementite (dark grey). (c,d) A STEM-EDX study shows that these inclusions can be AlN precipitates.*