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A prediction methodology for the high cycle fatigue life of hydrogen-loaded structures

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For a practical high temperature application under hydrogen atmosphere, hydrogen diffuses into the structure during the hot run. As hydrogen diffusion rates are much smaller at ambient temperature, hydrogen is trapped inside the structure during the cold flow and the non-operating phases of the hydrogen-loaded structure. Therefore, steady state hydrogen concentrations can be assumed to be reached after a few hot run loading cycles. For simplification purposes of the work described in the proposed presentation/paper, this cyclic hydrogen charging of a real hot run structure was replaced by a single hydrogen pre charging of hourglass shaped HCF samples. Inconel X-750® was chosen as the test material, because it is one of the view materials for which hydrogen concentration determination parameters are published in open literature.

During the experimental part of the work, the effect of internal hydrogen on the high cycle fatigue (HCF) life duration of Inconel X-750® in the hydrogen concentration range between 5 and 39 wppm at ambient temperature was investigated using an ultrasonic HCF test bench. For an alternating stress equal to 0.6 times the yield stress of the hydrogen-free material, a drop of two orders of magnitude in the high-cycle fatigue durability of the material has been measured over the investigated hydrogen concentration range.

New numerical tools have been developed to predict with little effort the drop in life duration of metallic structures due to internal hydrogen embrittlement and the identification of the fracture position. A simple approach has been considered to rapidly get a first assessment of the HCF life duration of hydrogen-pre-charged structures based on steady state hydrogen concentration conditions. The core of this proposed Finite Element calculation-based method is the “double Wöhler curve”, i.e. a three-dimensional Wöhler curve with the hydrogen concentration as the third dimension. The process of charging the material with gaseous hydrogen at high temperatures that precede the HCF testing has been simulated and the predicted hydrogen distribution and concentration have been compared to measurements.