Effect of hydrogen induced by localized corrosion on mechanical behavior of new high strength steel for aeronautical application

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To meet the highest performance and reduce the emissions, new martensitic steels have been developed by aeronautics industry in the last decade. Thanks to a dedicated elaboration process and the controlled growth of fine precipitates during the aging treatment, this material exhibits high mechanical properties and guarantees the reliability of structures subjected to fatigue load for long service lifetimes. However, in case of protection defects, aeronautical structures can operate in corrosive environments likely to impact their performance. For structures submitted to fatigue stresses, this is generally attributed to existing synergistic mechanisms between electrochemical reactions, metallurgical state and accumulated load cycling. Indeed, localized anodic dissolution of metal surface can generate preferred initiation site for fatigue cracks initiation and can assist their propagation. Due to galvanic processes, hydrogen may also be produced by the cathodic reactions, may penetrate the material and have also a significant effect on its mechanical behavior. Considering the above, the comprehension of the electrochemical and mechanical interactions, taking place at different scales, constitutes a key point of the study of corrosion fatigue damage mechanisms.

This work focuses on the interaction of hydrogen induced by corrosion processes with the complex microstructure of a new high-strength steel, and its effect on the mechanical behavior. The steel studied is first characterized with a wide range of observations methods. A classic martensitic structure, made of lath of martensite organized in blocks and packets, is observed. The microstructure is containing nanometric intermetallic precipitates and carbides, and micrometric inclusions. Cathodic polarizations and thermo-desorption measurements in H2SO4 solution and NaCl solution have been performed and highlighted the significant quantity of hydrogen likely to penetrate into the material. Permeation tests and thermo-desorption analyses with specific heating rates have also been conducted to determine the energy of interactions between hydrogen and the different microstructure scales and defects. The mobility of hydrogen into the bulk material and the microstructural heterogeneities likely to reversibly or irreversibly trap it, could thus be studied. Then, the mechanical properties and the fatigue lifetime have been evaluated on the steel after electrochemical charging in hydrogen. The role of the different states of hydrogen and the microstructural heterogeneities (grain boundaries, precipitates, inclusions) on the hydrogen embrittlement mechanism is finally discussed.