Hydrogen embrittlement susceptibility study of conventional and 3D printed (AM) austenitic and martensitic stainless steel

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The hydrogen economy represents a key component in a future climate-neutral society. The materials used in hydrogen production, storage and transport need to withstand high mechanical demands, moreover they need to be resistant to the degradation caused by interaction with hydrogen – hydrogen embrittlement (HE). This is mostly unknown when it comes to high-performance additive manufactured (AM) metal alloys, characterized by fine columnar grain microstructure, high dislocation density, micro-segregations, defects and anisotropy. The operational conditions in energy production as well as in other industries can lead to HE and cause sudden and unpredictable failure of structures.

In this study the initial results of the hydrogen embrittlement susceptibility of two types of stainless steels are presented. These include two common stainless steels used in facilities related to hydrogen economy: austenitic (AISI 304) and martensitic (AISI 420) stainless steel, each one produced conventionally and by AM (laser-powder-bed-fusion manufacturing). For determination of the hydrogen impact on mechanical properties, the slow strain rate tensile (SSRT) tests were used as a primary method, complemented with the impact toughness measurement. Cathodic pre-charging at several pre-selected current densities in NaOH solution was selected as the hydrogen charging method. The actual hydrogen concentration was determined by the fusion melt method and the hydrogen diffusion coefficient measured. The susceptibility of hydrogen embrittlement was also correlated to the micro-structure. For that purpose, a thorough microstructural analysis of all materials was made. Several different analytical methods, including EBSD, were applied for detailed post-exposure/post-fracture microstructural examination and characterization, to enable the clarification of the HE mechanisms and identification of differences between conventional and AM material.