Performance of AM Stainless Steels in Hydrogen Rich Environments

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Properties of common metals are detrimentally affected by exposure to hydrogen, which may lead to hydrogen embrittlement (HE). Deterioration depends on the specific environment, mechanical loading and internal stresses, but mainly on the type of material and its microstructure. Microstructure of metals deviate significantly when using different processing routes. The characteristics of laser-based additive manufacturing (AM) processes are high temperature gradients, residual stresses, anisotropy and complex microstructures with high dislocation density. These specifics can have critical impact on susceptibility to HE.

In terms of reducing pollution related to energy production, AM provides light-weight high-strength design with reduced energy needs, while green hydrogen represents viable alternative to fossil fuels. However, the main challenge in combining these two technologies is susceptibility of AM materials used in production, storage, transport and use of hydrogen to HE.

The main aim of our research was to investigate differences in properties of conventionally and AM produced stainless steels and how they are affected by exposure to hydrogen. Investigation was focused on two types of stainless steel, martensitic AISI 420 and austenitic AISI 304. AM was performed by AconityMIDI machine using LPBF process and powders of 50 µm. Conventionally and AM produced steels were subjected to electro-chemical charging in 0.1 M NaOH for 48 h at 65°C and 20 mA/cm2. Performance was evaluated in terms of Slow Strain Rate testing, toughness, tensile strength, as well as fatigue and wear resistance. Results indicate that in general AM materials show higher strength and wear resistance but reduced toughness. Both materials show drop in performance when exposed to hydrogen, however reduction in properties depends on type of microstructure and production route. For AISI 304, AM material shows reduced HE susceptibility as compared to conventional one, while for AM420 few fold increases and critical drop in properties was observed.