Effect of ammonia contained in hydrogen gas on hydrogen embrittlement of a low-alloy steel

Ryosuke Komoda

Department of Mechanical Engineering, Fukuoka University
International Institute for Carbon Neutral Energy Research, Kyushu University

Hydrogen embrittlement (HE) of steels, which is material strength degradation due to presence of hydrogen, needs hydrogen dissolution process including dissociation of hydrogen molecule into hydrogen atoms on the Fe surface. Hydrogen dissociation requires catalytic action of Fe surface. When hydrogen gas contains gas impurities that deactivate the catalytic action of Fe surface, such as O_2 and carbon monoxide (CO), hydrogen uptake is suppressed. As a result, HE is mitigated.

Ammonia (NH_3) is of interest as a hydrogen storage and transport medium because it can be liquefied under mild conditions at higher volumetric hydrogen density than liquid hydrogen. The objective of this study is to characterize the effect of NH_3 contained in H_2 gas on HE. To fulfill it, fracture toughness tests were carried out in H_2, N_2, H_2 + 1,000 vppm NH_3, and N_2 + 1,000 vppm NH_3. The gas pressure was 0.1 MPa and the temperature was kept at 20 ℃. The crosshead speed, V, was 2.0×10^{-3} and 2.0×10^{-5} mm/s. The material was JIS SCM440 low-alloy steel, which shows significant HE in H_2 gas.

When 1,000 vppm NH_3 was added to H_2 gas, the HE was almost recovered at $V = 2.0 \times 10^{-3}$ mm/s. However, the NH_3 mitigation effect significantly decreased with the decrease in the loading rate to $V = 2.0 \times 10^{-5}$ mm/s. HE was also occurred in the N_2 + 1,000 vppm NH_3 at $V = 2.0 \times 10^{-5}$ mm/s even though this environment initially did not contained hydrogen. This is due to hydrogen created by decomposition of NH_3 on the Fe surface. It was found that NH_3 has both mitigation and induction effect on HE, and the degree of the HE was governed by the competition between the two effects.