MITIGATION OF HYDROGEN EMB RITTLEMENT BY CARBON MONOXIDE IMPURITY IN GASEOUS H_2

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Hydrogen uptake in material is the first and essential process that can lead to hydrogen embrittlement (HE). In the case of HE in hydrogen gas (H_2), dissociation of hydrogen molecule into hydrogen atoms is requisite for the hydrogen uptake. An iron (Fe) surface created by crack propagation has a catalytic function that assists the dissociation of hydrogen molecule. When H_2 contains specific gas impurities that have stronger affinity to an Fe surface, the gas impurities preferentially adsorb onto the Fe surface, which results in deactivation of the catalytic function of the Fe surface. As a consequence, hydrogen uptake is suppressed, leading to mitigation of HE.
In this study, carbon monoxide (CO) was mixed into H_2 as an impurity, and its mitigation effect on HE was investigated by fracture toughness and fatigue crack propagation tests in association with the effect of loading rate and frequency, respectively. The material used was ASTM A333 grade 6 pipe steel.
The addition of CO to H_2 mitigated HE in both fracture toughness and fatigue crack growth tests; the mitigation effect of CO was lessened with a decrease in the loading rate or frequency in both tests. Since reduced loading rate or frequency contrarily results in an increase in the mitigation of HE in the case of an oxygen (O_2) impurity, these results indicate that CO has a different mitigation mechanism from O_2. From density function theory simulations of CO and O_2 approaching to an Fe surface, CO coverage is limited at 75% of the Fe surface, whereas O_2 achieves 100% coverage. Therefore, CO can reduce hydrogen uptake, although it cannot achieve complete prevention of hydrogen uptake. Thus, it is proposed that the reduced loading rate or frequency provided enough time to enhanced hydrogen uptake in the steel resulting in the decreased mitigation of HE in the case of the CO impurity.