Hydrogen Diffusion and Trapping Behavior of Linepipe Steel
Under Dead Weight Test Condition

1Gyu Tae Park, 2Hwan Gyo Jung, 2Seong Ung Koh and 1Kyoo Young Kim
1Graduate Institute of Ferrous Technology, Pohang University of Science and Technology
Nam-gu, Pohang, Republic of Korea
2Technical Research Center, POSCO
Nam-gu, Pohang, Republic of Korea

ABSTRACT

The aim of this research is to study the effect of constant elastic load on the hydrogen diffusion and trapping behavior of linepipe steel under NACE TM0177 A method. API X65 grade linepipe steel having high HIC resistance was used and a membrane type of sheet steel tensile specimen was designed. The electrochemical hydrogen permeation test was modified in reference to ISO17081 and combined with dead weight test. Results showed that clear hydrogen transient was obtained when the steel surface was carefully controlled even though no Pd was plated. Increase in the elastic load decreases the hydrogen permeability and it means that the steel under higher stress can contain more hydrogen. Loading followed by unloading method revealed that lattice expansion by elastic stress increases the solubility of hydrogen, while hydrogen diffusion becomes slow.

KEY WORDS: Linepipe steel; hydrogen; diffusion; trapping; permeation; dead weight test; diffusible hydrogen.

INTRODUCTION

When the high strength low alloy (HSLA) steel is exposed to corrosive aqueous environment containing H2S gas, it suffers cracking problems such as hydrogen induced cracking (HIC) or sulfide stress cracking (SSC). [NACE International, 2002] Although the relationship between hydrogen and HIC is well understood by lots of efforts, the effect of hydrogen on SSC failure is not clearly investigated because of limited analysis method. For clear understanding of sulfide stress cracking (SSC) phenomena of the linepipe steel, it is important to study the effect of strain on the hydrogen diffusion and trapping behavior of linepipe steel.

There are several experimental methods to study the hydrogen behavior in steels. Among them, the electrochemical hydrogen permeation test (HPT) method proposed by Devanathan and Starchurski is easy to perform in a laboratory, but it requires careful experimental exercise to obtain reliable and reproducible results. [ISO17081, 2004] It has been known that thin Pd or Ni coating on the steel surface at hydrogen detection side effectively increases the hydrogen oxidation current because the coating layer prevents the surface corrosion and the formation of oxide which acts as the barrier against hydrogen diffusion and the recombination reaction of diffused hydrogen atoms can be suppressed by this layer. [Manolatos, 1995] However, it is difficult to get consistently the uniform and thin Pd coating layer by electroplating. Non-uniform Pd coating layer induces the poor reproducibility of hydrogen oxidation current. [Casanova, 1996] Even soft Pd coating can be easily deformed when the steel sheet is strained and the internal change in the coating can affect the HPT results. In this research, the steel membrane without the Pd coating was used and the surface conditions of steel membrane were strictly controlled to minimize the barrier effect of oxide layer on the hydrogen diffusion.

By combining the slow strain rate test (SSRT) and HPT, trapping and transport of hydrogen by plastic deformation is well understood. Dislocations are usually considered as the major defects affecting the hydrogen trapping in the presence of plastic deformation. [Brass, 2006] However, the NACE TM0177 A method, constant load test (CLT) or dead weight test, evaluating the SSC resistance uses elastic straining to simulate the hoop stress condition of linepipe steel and therefore the study on the hydrogen transport and uptake of linepipe steel under constant elastic load is required to clearly understand the role of hydrogen on SSC. [TM0177, 2005]

In this research, modified HPT in reference to ISO17081 was combined with CLT and the steel specimen with no Pd coating was not utilized. To overcome the barrier effect of surface oxide, several conditions were carefully applied and by obtaining clear hydrogen transient curve, the effect of elastic load on the hydrogen diffusion and trapping behavior is discussed in terms of the internal changes in microstructure during elastic deformation and hydrogen permeation.

EXPERIMENTAL PROCEDURE

Specimens Preparation

In this research, HSLA steel plates equivalent to API X65 grade were used as specimen. Tested steel showed high HIC resistance because a strict steelmaking process was applied to control the inclusion level and proper microstructure was obtained by thermomechanically controlled process (TMCP). Results after NACE TM0264 showed no HIC crack occurred at all from all tested specimens.