

The Effect of Metallurgical Factors on SOHIC in HIC Free Linepipe Steels

¹Wan Keun Kim, ²Hwan Gyo Jung, ²Seong Ung Koh and ¹Kyoo Young Kim

¹Graduate Institute of Ferrous Technology, Pohang University of Science and Technology
Pohang, Korea

²Technical Research Center, POSCO
Pohang, Korea

ABSTRACT

The purpose of this study is to evaluate the effect of metallurgical factors on SOHIC of two HIC free linepipe steels in a sour environment. HIC, SSC and SOHIC tests of two steels were performed in reference to NACE TM0284, 0177 and 0103 standard test methods, respectively. Results showed that ferrite-acicular ferrite microstructure is more resistant to SSC and SOHIC than ferrite-pearlite. Inclusions in two steels acted as crack nucleation sites. In the point of view of crack propagation, SOHIC characteristics of two steels were consistent with SSC test results.

KEY WORDS: Linepipe steel; HIC; SSC; SOHIC; microstructure; inclusion; diffusible hydrogen.

INTRODUCTION

Cracking of linepipe steels in the environments containing hydrogen sulfide gas (H₂S) is generally categorized into two types; hydrogen induced cracking (HIC) and sulfide stress cracking (SSC). Both HIC and SSC belong to hydrogen embrittlement phenomena. Hydrogen atoms generated by a sulfide corrosion process are adsorbed on the steel surface and diffuse into the steel. In the steels, hydrogen diffuses to the regions with a high triaxial tensile-stressed condition, or various defects such as inclusions, precipitations or dislocations that act as hydrogen trapping sites and causes embrittlement of steel. [Kimura, M., 1989]

Unlike HIC which develops at conditions without applied stress, SSC occurs under externally or internally stressed or strained conditions and propagates perpendicularly to the tensile stress direction. SSC of linepipe steels exposed to sour environment under external stress is classified into type I and type II. Type I SSC can be understood in two stages. The first stage is the formation of hydrogen induced internal blister cracks parallel to applied stress. In the second stage, the blister cracks link together perpendicularly to applied stress. Generally, type I SSC is referred to as stress-oriented hydrogen induced cracking (SOHIC) because of formation of the blister cracks parallel to the applied stress. On the other hand, type II SSC is recognized to be the

cracking which results from the typical hydrogen embrittlement. [A. Takahashi, 1996] The final failure occurs in the direction perpendicular to applied stress in the manner of quasi-cleavage. Specifying the maximum hardness of 248 in Vickers hardness has been required to prevent type II SSC. [NACE committee, 2003]

This study focuses on type I SSC. Type II SSC was excluded from the present study because hardness of the tested steels is less than 248 in Vickers hardness. It has been reported that the prevention of HIC under an absence of external applied stress is effective for the prevention of SOHIC. [NACE committee, 2003] However, more recently, work funded by the Materials Properties Council in USA, has indicated that HIC resistant steel may indeed be more susceptible to SOHIC than conventional steels. Thus, the relationship between HIC and SOHIC is uncertain even recently. [Pargeter, R., 2007] This study investigates the effect of metallurgical factors on SOHIC of two HIC free linepipe steels. The results are discussed in terms of microstructure, inclusion and hard 2nd phase. The relationship between HIC and SOHIC is also discussed in the point of view of the crack nucleation.

EXPERIMENTAL PROCEDURE

Specimens, Microstructure and Mechanical Properties

Two commercial high strength low alloyed (HSLA) steel plates were used as specimens. The two steel plates have the thickness of 22mm satisfying API X65 grade. Hereafter, the two steels will be identified as steel A, steel B. The nominal compositions of steel A and steel B are 0.045C-0.1Cr and 0.045C-0.2Cr, respectively. Specimens of two steels were obtained at t/4 and t/2 positions (t: thickness).

For microstructure observation, the specimens were degreased with acetone and etched with a nital solution (a mixture of 5% nitric acid and ethanol). The microstructure was examined with optical microscope (OM) and scanning electron microscope (SEM). The yield strengths (YS) and ultimate tensile strengths (UTS) of two steels were determined by using a tensile testing machine. The hardness values were measured by a micro Vickers hardness tester.

HIC, SSC and SOHIC Tests

HIC tests were performed by using NACE TM0284 standard method