Electrochemical Corrosion Property of High Mn Steel in Sweet Environment

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ABSTRACT

The high manganese steel can be applied for the structural material used in the oil and gas industry since it has very high mechanical strength and good ductility. For proper utilization in oil and gas industry, however, its corrosion property should be understood clearly in the oil field environment. The corrosion property of 3 different steels is evaluated in a sweet environment with respect to Mn content and Cr addition. The corrosion behavior is evaluated by the electrochemical polarization tests and electrochemical impedance spectroscopy. The stability of surface scale is examined by SEM and EDS analysis.

The result shows that addition of 3 wt.% Cr improves the stability of the corrosion product formed on high Mn steel. A small amount of Cr hydroxide present in a mixture of Mn-Fe carbonate matrix suppresses the porosity of Mn-rich surface scale. The barrier effect of scale formed on high Mn steel containing 3 wt.% Cr becomes better as the immersion time is increased.

KEY WORDS: High Mn steel, Cr, long-duration test, EIS

INTRODUCTION

The high manganese (Mn) steel containing 15-30 wt.% Mn has fully austenitic phase at room temperature and excellent combination of high strength and high ductility. For commercial applications, the high Mn steel has been studied to meet the various manufacturing and service requirements. For automotive application, the high Mn twinning-induced plasticity (TWIP) steel has been successfully developed for commercialization even though applied to limited services. [Kwon, 2011] [Chin, 2011] [Park, 2012]. TWIP steel has high strength in the giga pascal range with up to 65% elongation. However, a further study is required to solve the problems involving welding and hydrogen delayed fracture [Chun, 2012] [Koyama, 2012].

The high Mn steels have excellent mechanical property, however, they have poor corrosion property because of high Mn content. The effect of Mn on the corrosion property of steel has been conducted mainly for the stainless steel to replace Ni with Mn. Only a few study has been done for corrosion of high Mn carbon steel in limited number of environments [Zhang, 1999] [Kannan, 2008]. Kannan et al. [Kannan, 2008] have compared the corrosion property of Fe-29.5 wt.% Mn-3.1 wt.% Al-1.4 wt.% Si (Fe-Mn-Al-Si) steel with that of interstitial free (IF) steel in the aqueous solution of 0.1M H\textsubscript{2}SO\textsubscript{4}, 0.1M NaOH and 3.5% NaCl. Comparing to IF steel, the Fe-Mn-Al-Si steel shows the corrosion resistance significantly lower in H\textsubscript{2}SO\textsubscript{4} solution, relatively lower in NaCl solution, no significant difference in NaOH solution. Addition of 25 wt.% Mn to mild steel is very detrimental to the corrosion resistance in aqueous solutions [Zhang, 1999]. Addition of aluminum (Al) to Fe-25Mn steel increases the corrosion resistance in 1M Na\textsubscript{2}SO\textsubscript{4} solution, 50% HNO\textsubscript{3} and 10-50% NaOH solution. In 10% HCl and 3.5% NaCl solution, the Fe-25Mn-Al steel shows no passivation.

With depletion of high quality oil and gas, the working condition in the oil and gas field becomes severe, so that high strength and high toughness steel such as high Mn steel will be required in the near future. Then, the corrosion property of high Mn steel becomes one of the key properties to determine its applicability. The corrosion property of carbon steel used in oil and gas field depends on various process and material parameters including chemical composition of environment (sweet or sour), pH, temperature, gas pressure, water/oil ratio, flow rate, corrosion inhibitor, steel composition and characteristics of surface scales. In sweet environment, the low carbon steel has been used successfully in the limited working conditions because the surface scale formed on the steel effectively prevents its corrosion [Nestic, 2007] [Zhang, 2012]. At temperatures higher than 70°C, the scale in the form of FeCO\textsubscript{3} becomes protective and has good adhesion at CO\textsubscript{2} pressure greater than 10 bar. Addition of 3-5 wt.% Cr to carbon steel improves significantly the CO\textsubscript{2} corrosion resistance.

In this study, the corrosion property of 3 different steels is evaluated in a sweet environment with respect to Mn content and Cr addition. The corrosion behavior is evaluated by the electrochemical polarization tests and electrochemical impedance spectroscopy. The stability of surface scale is examined by SEM and EDS analysis.

EXPERIMENTAL

The experimental high Mn steel A and B were solution treated at 1150 °C for 2 hr, hot rolled at 850 °C, and quenched with water. The commercial carbon steel C was used for comparison. Table 1 lists the chemical composition of specimens. Specimens were manufactured as