Alloying Effect on Corrosion Property of High Mn Steel in Sour Environment

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ABSTRACT

The effect of Cr addition to high manganese (Mn) steel on its corrosion property is evaluated in sour environment. The stability of corrosion product scale is examined by SEM and EDS analysis. The beneficial effect of Cr addition to high Mn steel in sour environment is fully realized after 8 days immersion with formation of protective Cr-hydroxide. In the corrosion product scale, the inner layer is composed of Cr-hydroxide and MnCO₃, while the outer layer is composed of FeS and Cr-hydroxide. This dual layer is responsible for increase in the corrosion resistance of high Mn steel with Cr addition in sour environment.

KEY WORDS: High Mn steel; Cr addition; electrochemical polarization test; sour environment; Cr-hydroxide.

INTRODUCTION

The working condition in oil and gas field has become severe because of depletion of high-quality oil and gas resources, so that steels with high strength and high toughness are required in the future oil and gas field. The high manganese (Mn) steel having full austenitic structure has very attractive mechanical property for future application. It has excellent combination of high strength in the giga pascal range and high ductility over 65% elongation [Kwon, 2011] [Chin, 2011] [Park, 2012]. The high Mn steel also has a good wear property. However, for feasible utilization in oil and gas industry, the corrosion property of high Mn steel is a key property to be confirmed.

Although the high Mn steel has excellent mechanical property, its corrosion property in aqueous environment is very poor because of high Mn content. Only a few study has been done for corrosion of high Mn carbon steel in limited number of aqueous environments such as 0.1M H₂SO₄, 0.1M NaOH and 3.5% NaCl solution [Zhang, 1999] [Kannan, 2008]. In general, comparing to interstitial free (IF) steel, high Mn steel shows the corrosion resistance significantly lower in H₂SO₄ solution, relatively lower in NaCl solution, but no significant difference in NaOH solution. The effect of alloying element on the corrosion property of high Mn steel has been studied with addition of Cr and Al. No particular beneficial effect of Al is observed.

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 [Nesic, 2007] [Zhang, 2012]. At temperatures higher than 70°C, the scale in the form of FeCO₃ becomes protective and has good adhesion at CO₂ pressure greater than 10 bar. Addition of 3-5 wt.% Cr to carbon steel improves significantly the CO₂ corrosion resistance.

Recently, we have studied corrosion property of high Mn steel in sweet environment [Seo, ISOPE 2015]. The high Mn steel with 18 wt.% Mn dissolves in sweet environment and no protective scale is formed. However, addition of 3 wt.% Cr is very effective to improve its corrosion resistance. 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.

Since the beneficial effect of Cr addition to high Mn steel is observed in sweet environment, in this study, the corrosion property of 3 different steels is evaluated in a sour environment with respect to Mn content and Cr addition. The corrosion property is evaluated by the electrochemical polarization tests and scale analysis. The morphology and stability of surface scale are examined by SEM and EDS analysis.

EXPERIMENTAL

Table 1 lists the chemical composition of the specimens used in this study. The high Mn steel A and Cr-added high Mn steel B were solution treated at 1150 °C for 2 hr, hot rolled at 850 °C, and quenched with water. The commercial carbon steel C, equivalent to X65 linepipe steel, was used for comparison. Specimens were manufactured as cylindrical shape (Ø 9.50 mm x 12.80 mm L) for working electrode of electrochemical tests and hanging coupons (Ø 9.50 mm x 2 mm t with Ø 3 mm hole) for long term immersion test. The hanging coupons were manufactured with a hole to be tied up with non-conducting polymer wire and immersed into test solution without electrochemical interruption. Specimens were subsequently ground with P1200 grit sand paper and rinsed with distilled water.