Full Ring Sulfide Stress Cracking Evaluation of X65 UOE Sour Linepipe Steels

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ABSTRACT

Application of sour linepipes has been expanded toward severe sour environment regions. Therefore, precise and strict material design should be needed in the production of Grade X65 UOE sour linepipe steels for preventing sulfide stress cracking (SSC). In four point bend (4PB) SSC tests, SSC occurred when the inner surface hardness exceeds the limit depending on hydrogen sulfide (H2S) partial pressure. Surface hardness of pipe increased with increasing the volume fraction of lath bainite (LB) microstructure. In the case of 1 bar or higher H2S partial pressure condition, the surface hardness limit was approximately 250 HV0.1kgf at 0.25mm from pipe inner surface. In this study, full ring SSC tests were conducted under the H2S partial pressure up to 16bar in order to clarify the hardness limit of SSC appearance using Grade X65 pipes. Then, SSC behaviors in 4PB SSC tests and in full ring SSC tests were compared. As a result, higher surface hardness pipe samples tended to be more susceptible to cracking and showed larger SSC crack depth in 1bar and 16bar H2S pressure condition. On the other hand, lower surface hardness pipe samples showed no SSC in 1bar and 16bar H2S pressure condition. This surface hardness limit around 250 HV0.1 in full ring SSC tests gave good agreement with that of 4PB SSC tests.

KEY WORDS: linepipe; sour gas; sulfide stress cracking; Thermo-mechanical controlled processing; Bainite; hardness; full ring SSC test.

INTRODUCTION

Application of sour linepipes has been expanded toward severe sour environment regions including higher H2S partial pressure conditions over 1bar. In 2013, actual sour gas pipeline failure occurred due to SSC under higher H2S partial pressure condition over 1bar (Newbury et al., 2018). One of the possible root cause of SSC was assumed by formation of hard spots in the steel. Fairchild et al investigated and summarized the three hard zone formation mechanisms including carbon contamination, dual phase microstructure and heat transfer variation in a recent paper (Fairchild et al., 2019; Newbury et al., 2019).

Precise and strict material design should be needed in a production of Grade X65 UOE sour linepipe steels for preventing SSC. In designing sour gas linepipe, hardness limitation are often required on material to avoid SSC as specified in NACE MR0175 standard which recommends a maximum hardness of 22HRC or approximately 250HV in carbon and low alloy steels (Omar, et al., 1981). Effect of hardness on SSC behavior has been investigated so far mainly in oil country tubular goods (OCTG) which is quenched and tempered and has relatively higher strength, or welds in which local hardness likely to be increased (Omar, et al., 1981; Pargeter, R. J, 2000). The effect of surface hardness on SSC behavior in sour gas linepipe has drawn much attention recently, because of its characteristic hardness distribution along plate thickness, though strength grade is lower than OCTG products. Steel plates for linepipes for sour service are produced by Thermo-Mechanical Controlled Processing (TMCP) to ensure fine bainitic microstructure, resulting in excellent HIC resistance and toughness. To minimize risk of SSC, deliberate cooling process design to suppress excessive surface hardness and to ensure homogeneous hardness distribution over whole plate is required. By improving cooling homogeneity as well as cooling rate, wide variety of high performance plate and pipe products with stringent sour specification has been available (Endo, et al., 2015). Typical beneficial effect from recent advanced cooling device is homogeneous plate surface hardness by controlling the surface cooling rate (Shimamura, et al., 2015). Process window of optimum conditions for controlled rolling and accelerated cooling that balances higher strength, toughness and moderate surface hardness has been successfully expanded. In the previous paper, 4PB SSC tests revealed that SSC occurred when the inner surface hardness exceeds the limit depending on H2S partial pressure (Shimamura, et al., 2019). And surface hardness of pipe increased with increasing the volume fraction of lath bainite (LB) microstructure. In the case of 1 bar or higher H2S partial pressure condition, the surface hardness limit was approximately 250 HV0.1kgf at 0.25mm from pipe inner surface (Shimamura, et al., 2019). In this study, full ring SSC tests were conducted under the H2S partial pressure up to 16bar in order to clarify the hardness limit of SSC occurrence using Grade X65 pipes.