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INTEGRITY ASSESSMENT OF LINEPIPES FOR TRANSPORTING HIGH PRESSURE HYDROGEN BASED ON ASME B31.12

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ABSTRACT

Current hydrogen pipeline code ASME B31.12 requires that pipe materials shall be qualified for adequate resistance to fracture in hydrogen gas based on Article KD-10 of ASME BPVC, Sec. VIII, Division 3. In order to assess the integrity of a hypothetical hydrogen pipeline, fracture toughness and fatigue crack growth tests under gaseous hydrogen at up to 21MPa were first conducted using a recent Grade X65 linepipe with fine grained bainitic microstructure. Fatigue crack growth in the pressurized linepipe with semi-elliptical surface flaw was calculated by the procedures described in the Article KD-10 using the da/dN data obtained from the X65 linepipe and the fatigue crack growth equation specified in ASME B31.12. Pressure cycles were applied to the pipe with a surface flaw to investigate the effects of pressure range and design factor. The critical crack size was analyzed using the failure assessment diagram (FAD) concept which is also specified in Article KD-10. Significant fatigue crack growth was not observed under the lower design factor such as f_D=0.5 with small pressure range, while fatigue crack growth was drastically accelerated under the higher design factor and large pressure fluctuation. Integrity assessment by FAD analysis for longitudinal semi-elliptical crack and girth weld flaw clarified how the toughness value affects the critical condition.

Keywords: High pressure gaseous hydrogen; linepipe steel; fatigue crack growth; fracture toughness; FAD analysis

NOMENCLATURE

BM = base metal
CGHAZ = coarse grained heat-affected zone
CT = compact tension
FAD = fracture assessment diagram
FCGR = fatigue crack growth rate
f_D = design factor
F.L. = fusion line
HAZ = heat-affected zone
J_{IC} = plain strain elastic-plastic fracture toughness
J_Q = measured elastic-plastic fracture toughness
K, K_{max}, K_{min} = stress intensity factor; maximum, minimum
K_{IA} = applied stress intensity factor
K_{IH} = stress intensity factor in hydrogen
K_J = stress intensity factor determined from J
K_{JQ} = fracture toughness determined from J
K_r = ratio of stress intensity factor to fracture toughness
L_r = ratio of applied load to plastic collapse load
OD = outer diameter of pipe
R = stress ratio
TMCP = thermo-mechanical controlled processing
TS = tensile strength
WM = weld metal
WT = wall thickness of pipe
YS = yield stress
ΔK = stress intensity factor range
ΔP = pressure range

1. INTRODUCTION

1.1 Hydrogen Effect on Linepipe Steels

Hydrogen is one of the promising energy carriers for a carbon neutral society. Pipeline systems are necessary for transporting gaseous hydrogen. It is suggested that existing natural gas pipelines could be safely used with hydrogen blend