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INITIATION OF STRESS CORROSION CRACKING ON X-65 LINEPIPE STEELS IN NEAR-NEUTRAL pH ENVIRONMENT

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Initiation and early growth of stress-corrosion cracking (SCC) of X-65 linepipe steel in near-neutral pH environment were studied in NS-4 solution saturated with N_2/5%CO_2. The occurrence of SCC is discussed in terms of (1) generation of an environment that causes cracks to initiate; (2) initiation and early growth of cracks; and (3) effect of the mechanical loading spectrum. SEM observations of cracks at specimen surfaces showed that stress-corrosion cracks were initiated at bottoms of corrosion pits. Pits that lead to initiation of SCC can develop from surface discontinuities, which can be geometrical; for example, surface roughness, or metallurgical factors, such as inclusions and second phase particles, etc. The formation of large cracks resulting from coalescence of micro-cracks was also studied. The complexity of SCC is reflected in the complex changes in diverse parameters with time as well as in the experimental challenges in obtaining field-relevant, reproducible laboratory data [1-2]. Stress corrosion encompasses major effects from metallurgical, mechanical, and environmental parameters, all of which can be dominant under specific conditions [3]. In studying SCC initiation, it should be emphasized that the locations where cracks start are possibly related to metallurgical factors, such as nonmetallic inclusions, grain boundaries, specific phases, or other forms of surface discontinuities or surface defect.

This study focused on crack initiation, types of cracks, crack behavior, role of crack initiation sites, inclusions, factors governing crack growth, and the crack coalescence process in the context of low-pH SCC in X-60 linepipe steel. The function of applied mechanical loading conditions includes the effects of stress level (for static and cyclic loading), strain rate (for dynamic loading), stress ratio, R, and loading frequency, f. For the current research, the validation of the results under accelerated test conditions is based on the assumption that the micro-processes, microstructural features, and specific sites associated with initiation of cracks in laboratory tests are those associated with the initiation of SCC in operating pipelines.

Table 1. Chemical Composition (wt.%) of the TCPL X-65 Linepipe Steel

C	Si	Mn	Cu	Al	S	P
0.12	0.26	1.5	0.014	0.029	0.0046	0.017

Table 2. Composition of NS-4 Solution, Simulated Dilute Ground Water (mg/L)

KCl	$NaHCO_3$	$CaCl_2.2H_2O$	$MgSO_4.7H_2$
122	483	181	131

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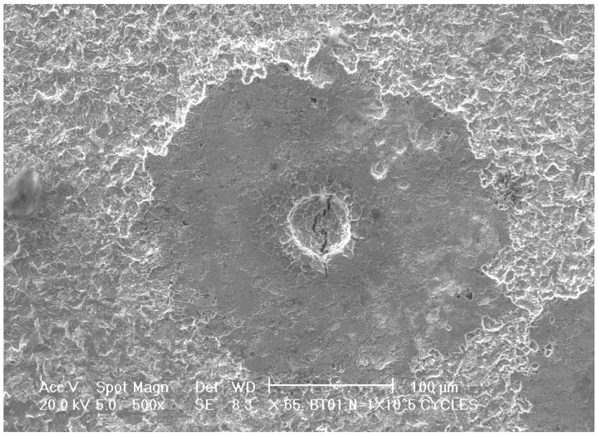
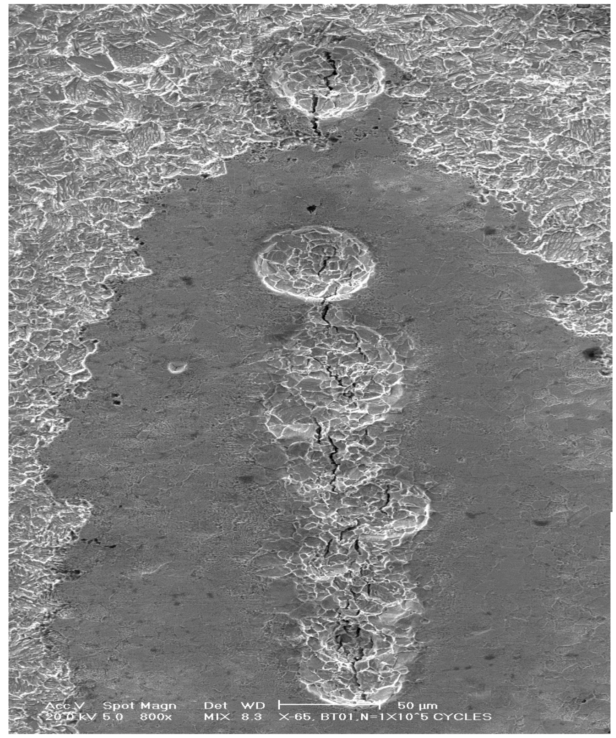


(a)



(b)

Figure 1. The morphology of cracks in specimen X-65, after cycling at smax = 90% YS, R =0.6 and F = 0.1 Hz in NS4 solution bubbled with 5% CO_2 balance N_2, showing the association of "shade" areas around pits. (a) A single pit and (b) a series of pits that linked and the shade area around them.

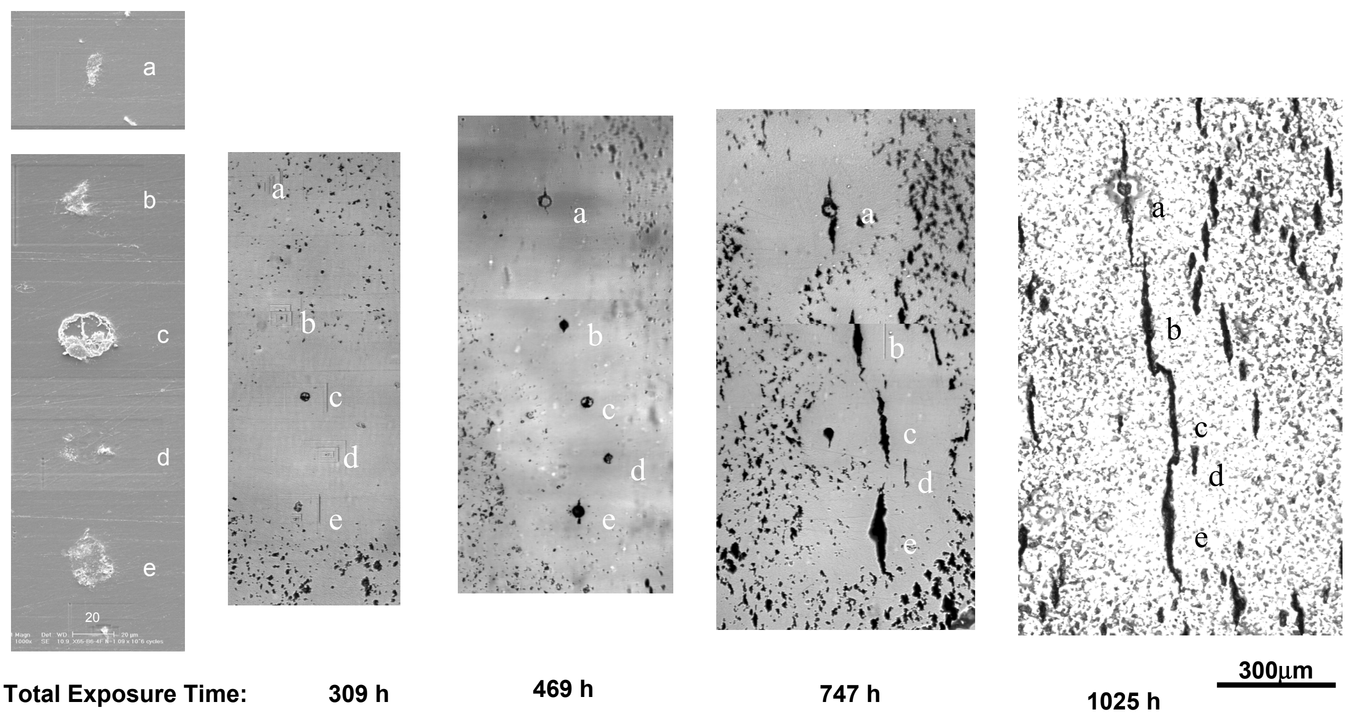


Fig. 2. Development of 5 cracks, a, b, c, d and e, after the total exposure time shown, in a X-65 specimen at σ_{max} = 70% YS, R = 0.4 and f = 1 Hz in NS_4 solution saturated with CO_2, showing the correlation of crack initiation, pits and non-metallic inclusions and the interaction and coalescence of cracks (observations were made on replicas).

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