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Simulation Method for Shear Fracture Propagation in Natural Gas Transmission Pipelines

Hiroyuki Makino
Corporate Research & Development Laboratories, Sumitomo Metal Industries Limited,
Amagasaki-city, Hyogo, Japan

Takehiro Inoue
Steel Research Laboratories, Nippon Steel Corporation, Futtsu, Chiba, Japan

Shigeru Endo
Steel Research Laboratories, JFE Steel Corporation, Fukuyama, Hiroshima, Japan

Takahiro Kubo
Steel Research Laboratories, JFE Steel Corporation, Chiba, Japan

Takeshi Matsumoto
Iron & Steel Sector, Kobe Steel Ltd., Tokyo, Japan

ABSTRACT

The High Strength Line Pipe Committee (HLP Committee) organized by the Iron and Steel Institute of Japan has carried out a series of 7 full-scale burst tests using X70 pipes. A simulation model for the propagating shear fracture in pipelines was developed from theoretical investigations of the test results. This paper gives a summary of all the full-scale burst test results, an outline of the HLP Committee's simulation model, the verification of its accuracy, investigation of the effects of several factors on crack propagation and calculated arrest energy requirements for varied pipeline conditions.

INTRODUCTION

The propagating shear fracture has been a serious theme for the fracture control of natural gas transmission pipelines since Eiber's report (1969). It is the interactive phenomenon between gas decompression and crack propagation. Once the crack starts, the inner gas flows out from the pipeline's ruptured portion, and the decompression wave proceeds in the pipeline. The crack follows the decompression wave, so that a fast crack produces high pressure and a slow crack produces low pressure at the crack front. The interaction determines the extent or the distance of the propagating shear fracture.

The High Strength Line Pipe Committee (HLP Committee) was organized by the Iron and Steel Institute of Japan (ISIJ) in 1978 to investigate the propagating shear fracture in natural gas transmission pipelines. The HLP Committee carried out a series of 7 full-scale burst tests (Sugie et al., 1982, 1984, 1987a∼c) in 1978-83 on X70 linepipes in API grade, with a 48-in outer diameter and an 18.3-mm wall thickness. Five full-scale burst tests were carried out with air as the pressurizing gas in Kamaishi, Japan, and 2 full-scale burst tests with rich natural gas at the British Gas Corporation (BGC) test site. From theoretical investigations of the test results, a simulation model for the propagating shear fracture in pipelines was developed (Sugie et al., 1987c; Makino et al., 2001a, b, 2002) which is able to calculate instantaneous fracture velocity and propagation distance.

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KEY WORDS: Pipeline, linepipe, propagating shear fracture, full-scale burst test, simulation, DWTT test, Charpy energy.

FULL-SCALE BURST TEST RESULTS

Table 1 shows the test conditions of the full-scale burst tests. In Kamaishi, A and B series tests were carried out with air. In the A series tests, the pipes were arranged so that the notch ductility (C_v) of the pipe increased as the crack propagated into the subsequent pipe. In the B series tests, the notch ductilities of some neighboring pipes were intended to give nearly uniform values in order to achieve long crack propagation and arrest within 2 pipe lengths. At the BGC test site, C series tests were carried out with rich natural gas. The gas compositions were designed so as to

Test site	Kamaishi, Japan		BGC, UK	
Series	A	B	C	
Number of tests	3	2	2	
Test pipes	API X70, 48 in OD × 18.3 mm WT			
Pressurizing gas	Air		Rich natural gas	
Pressure	11.6 MPa		11.6 MPa	10.4 MPa
Hoop stress	0.80SMYS		0.80SMYS	0.72SMYS
Test temp.	+3 to +12°C		−5°C	

Table 1 Test condition of full-scale burst tests