

가

Fracture Mechanics Analysis of CANDU Feeder Pipe Integrity

103-16

1996 12 8 Point Lepreau Channel S-08
 가 가 1998 8
 “ 1
 ”
 ,
 . ASME Sec. XI
 가 NRC
 IP2ELBOW
 (J value)
 (crack initiation)
 가
 ,
 ,
 ASME Sec. II

Abstract

Heavy water coolant leakage from first elbow part of channel S-08 feeder pipe occurred at Point Lepreau CANDU plant in 1996 due to through-wall crack. On request of regulatory body KEPRI and Wolsong nuclear power generation department made "Wolsong Unit 1 feeder pipe wall thinning status report" in 1998 summer according to ASME Sec XI procedure. However, this procedure is about straight pipe fracture

mechanics analysis. In this paper, elbow fracture mechanics analysis have been made by using NRC Code IP2ELBOW. With this program material and applied fracture toughness value at crack initiation and propagation were calculated in order to investigate fracture mode of feeder pipe when the maximum allowable wall thinning amount was assumed to be the crack depth. Fracture mode appeared to be limit load fracture in the case of feeder pipe. With comparison of operational load and crack initiation load, we can confirm that unstable fracture does not occur in the operational load condition.

1.

Point Lepreau 1996 12 8 , 1 kg 가
^[1] , Channel S-08 가
 35mm) , 63mm (Grayloc 98mm
 , 1995
 S-08 (positioning assembly) 가
 , S-08 S-09 (spacer)
 (cantilevers beam hanger)
 10 ° 가 ^[1]
 AECL Chalk River (CRL)
 , , , x
 (fatigue- striation) (scallop)가 . AECL
 가
 (FAC, flow accelerated corrosion)
 가
 , 0.1mm/year
 (hoop stress) 350 MPa,
 520MPa . 15%
 300MPa . 79%
 가 (applied stress intensity factor)가
 (critical stress intensity factor)
^[2]
 1997 AECL 1
 82 . 1998 3 가
 “Feeder ” 1998 12
 4 가 가
^[3]
 1998 8 “ 1
 ”

[4]

가

NRC

(elbow)

IP2ELBOW^[5]
(J value)

2.

CODE

1



1

1 Canada AECL TS-XX-33029-1&2
 ASME SA 106 Grade B(0.01 0.03wt% Cr)¹⁶¹
 (extrados) 가 (intrados) 가
 1.5 3.5 (3.8 8.9cm)
 가 4%, 539 K,
 11.31MPa
 CANDU 1.5 , 2 , 2.5 , 3 , 3.5
 가 가
 1 , 380 2 60
 2.5
 (diffuser) 2.0 2.5 3.0
 3.5
 8 20m 가 (Grayloc
 fitting) 가 가 (extrados) ,
 가
 90 ° , 30 73 °
 1.5 가 10
 28kg/sec , 8 18 m/sec
 0 4%
 ASME Sec. III ASME Sec. II NB-3641.1

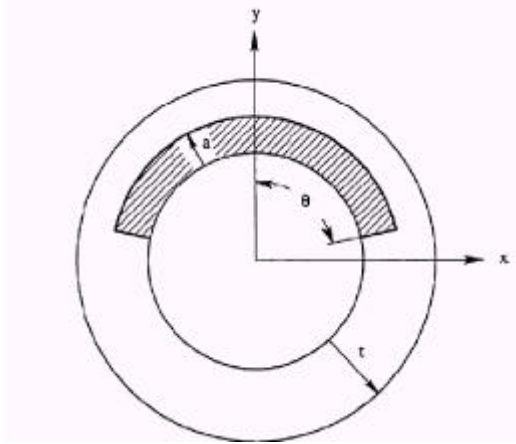
$$t_m = \frac{pD_o}{2(S_m + y \times p)} + m$$

, p = ,
 D_o = ,
 S_m = ,
 y = ,
 m =

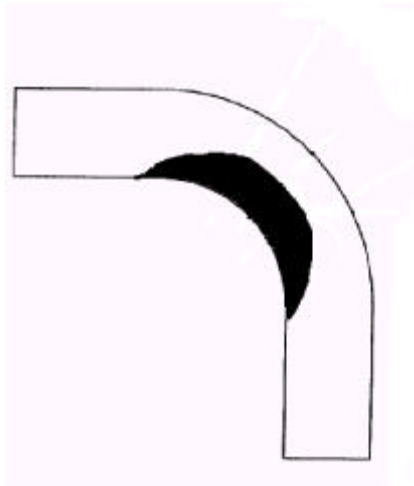
2.5 0.154 (3.16mm)¹⁸¹ 2 0.133 (2.61mm),

3.

1 NRC Pipe Elbow Code(IP2ELBOW)



. 2



. 3

	2.5	2.0
Diameter(m)	0.073	0.060
Wall Thickness(m)	0.00619	0.00492
Pipe Pressure(MPa)	10	
Depth of Flaw(m)	3.03	2.31
Total Length of Flaw(m)	104.9	86.5
Yield Stress(MPa)	342	
Ultimate Stress(MPa)	647	
Flow Stress(MPa)	494.5	
Ramberg-Osgood Parameters (Figure)	(MPa) σ_o	342
	ϵ_o	0.002
	α	1.436
	n	4.88
Material J- R Data File	Figure	

2,3

NRC CODE

1

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, ASME Sec.

III App. G

6

50%

. SA 106B

, flow stress, J-R

Data

NRC

"Pipe Fracture Encyclopedia"

Ramberg-Osgood Parameter

(σ_o)

(ϵ_o) 0.2%

(α) 가

(n) Microsoft Origin

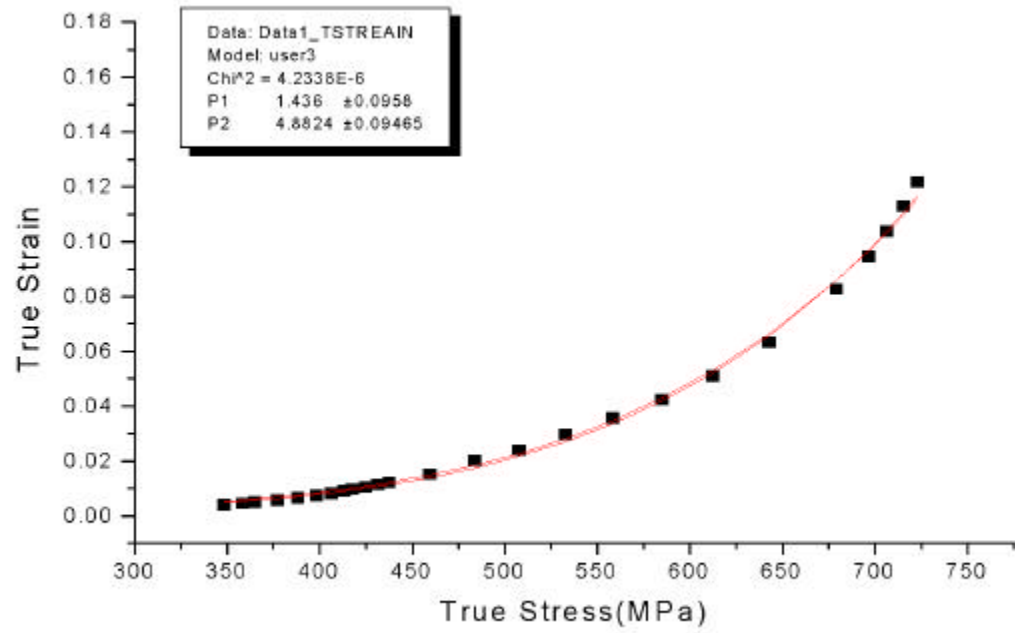
Curve Fitting

4

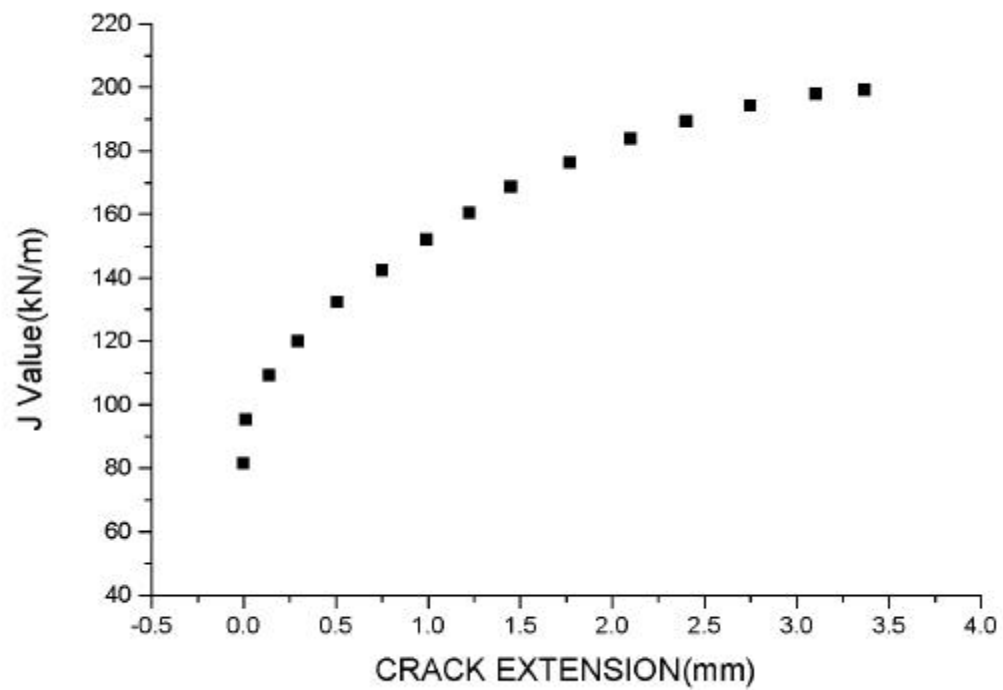
. CODE

JR Data

5



4. Curve Fitting for finding SA 106 B Ramberg-Osgood Parameters



5. SA 106 B J- R Curve

4.

$\frac{2}{2}$, $\frac{2}{2}$,
 ,
 (J=81.4MN/m) (67777MN/m²)가
 (1056MN/m²)

, ASME

Sec. II

2.

(,)	2.5	2.0	2.5	2.0
= (mm)	3.03	2.31	3.03	2.31
(mm)	104.9	86.5	18.18	13.86
Calculated initiation moment(m- MN)	0.0323	0.0181	0.0191	0.0104
Calculated maximum moment(m- MN)	0.0323	0.0181	0.0191	0.0104
Applied J value(MN/m)	81.4	81.4	81.4	81.4
Material J value(MN/m)	81.4	81.4	81.4	81.4
dJ/da (Applied)(MN/m ²)	67777	82180	18176	28796
dJ/da (Material)(MN/m ²)	1056	1108	1056	1108
Nominal Remote Stress(Initiation, MPa)	1477	1538	875	888
Nominal Remote Stress(Maximum, MPa)	1477	1538	875	888
(MPa)	70	65	116	130
(MPa)	230	180	231	260
()				

5.

NRC IP2ELBOW
(J value) (crack
initiation) 가

, ASME Sec. II

- (1) AECL, Point Lepreau Feeder Leak, 1998
- (2) Michael G Hare, PHTS Feeders Inspection and Maintenance Plan, COG/IAEA 5th Technical Committee Meeting Operating Safety Experience of PHWR, Mangalia, Rumania, 1998.
- (3) 4 가 , 1998 12
- (4) 1 , “ ”, 1998. 8
- (5) NUREG/CR-6445, Development of a J-estimation scheme for internal circumferential and axial surface cracks in Elbows, 1997
- (6) 1 FSAR
- (7) ASME, Nuclear Power Plant components division subsection NB, ASME Boiler and Pressure Vessel Code, 1986
- (8) G Hare, PHTS Feeders Inspection and Maintenance Plan, Point Lepreau Generating Station, COG/IAEA 5th Technical Committee Meeting Operating Safety Experience of PHWR's, 1998

