Effect of Fracture Toughness on Failure Assessment Diagram Approach to Stainless Steel Pipe containing circumferential Through-wall Crack under Combined Tension and Bending Loading

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1. Abstract

In this study, to predict the maximum supporting load of SA312 TP316 stainless pipe containing circumferential through-wall crack under combined tension and bending loading, Failure Assessment Diagram (FAD) approach in R6 procedure was conducted. Fracture toughness in FAD assessment was of J-R curves which were obtained from C(T) tests of various sizes and temperature conditions. The effect of J-R curve on FAD assessment was analyzed.

2. Pipe assessment using FAD

2.1 Pipe and Crack geometry

Outer diameter of the pipe for FAD is 114.3mm and thickness is 13.49mm. Circumferentially through-wall crack of θ/π=1/3 was considered. The cracked pipe is shown in Fig.1. The maximum load of the pipe under combined tension and bending loading was measured. Pipe tests were conducted at operating temperature (OT, 316°C) and at room temperature (RT). Two specimens were considered at OT and one specimen at RT.

2.2 FAD assessment

Fracture mechanics analysis of circumferential through-wall cracked pipe was conducted in R6 procedure. Failure Assessment Line (FAL) was drawn by option 2 expression in R6. Limit load, stress intensity factor and K_{mat} are needed to draw Failure Assessment Point and Tearing locus. Limit load and stress intensity factor were taken from the expressions in R6 and K_{mat} was calculated from J-R curves, which were obtained from C(T) tests of 2 different sizes and temperature conditions. Two different C(T) specimen are 1T standard C(T) and 2T standard C(T) of reduced thickness to 25.4mm (2T-25.4). 20% side-groove of thickness was machined to each specimen. The temperature conditions of C(T) tests were RT and OT. An example of FAD assessment for pipe is shown in Fig.2.

To remove blunting, J-R data from C(T) tests were fitted to expression in Eq. (1) by ASTM method. J_{IC} values were calculated at the intersection point between 0.2 mm offset of construction line and fitted J-R curve. Parameters of J-R curves in such conditions are tabulated in Table 1.

$$J=C_1 (\Delta a+ C_3)^{C_2} \tag{1}$$

The ratio of the maximum loads from the pipe tests and from FAD are tabulated in Table 2. As shown in the table, predicted values from 2T-25.4 are lower than those from 1T. Because, as crack grows 1T J-R curve becomes larger than 2T-25.4 J-R curve by the effect of C_1 and C_2 although J_{IC} of 2T-25.4 C(T) J-R curve is larger than that of 1T.

3. Conclusions

In this study, the maximum loads which pipe could carry under tension and bending loading were calculated by FAD assessment and the values were compared to the maximum loads of pipe tests. FAD assessment was conducted in R6 procedure and J-R curves used in FAD were obtained from C(T) tests of various size and temperature conditions. At each condition, the maximum load calculated by 2T-25.4 J-R curve is conservative than the maximum load by 1T J-R curve.

4. Figures, and tables

Table 1 J-R curve fitting parameters

		C_1	C_2	C_3	J_{IC}
OT	1T	840.7	430.9	0.2789	0.8980
	2T-25.4	1017	942.4	0.6040	0.3508
RT	1T	1170	788.9	0.3649	0.6923
	2T-25.4	1296	1197	0.5460	0.3218

Table 2 Comparison of maximum load from pipe test and from FAD assessment

SA312 TP316			2T-25.4	1T
Pre./Exp.	OT	#1	0.823	1.06
		#2	0.786	1.01
	RT	#1	0.792	0.890

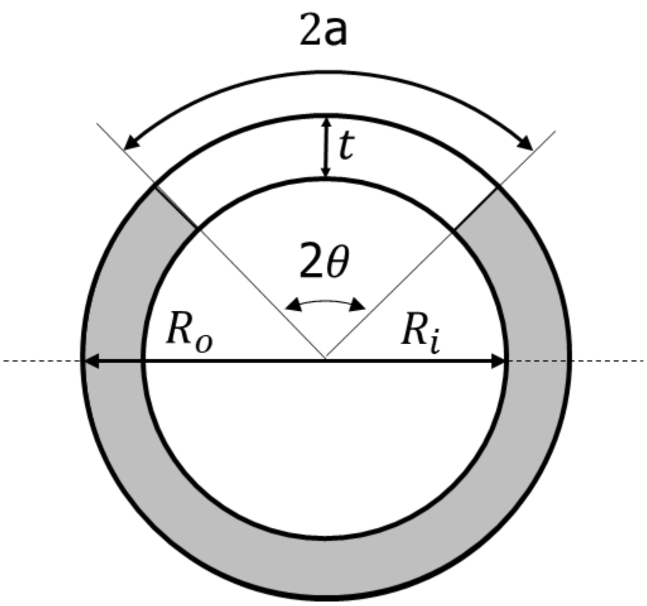

Fig.1 Schematic of Circumferentially Cracked Pipe cross-section

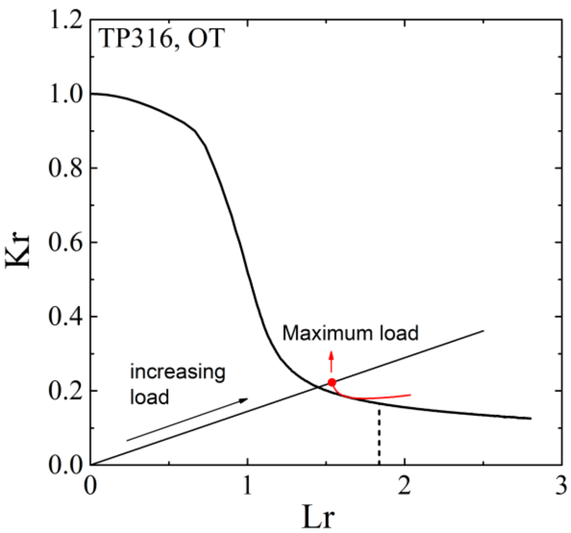

Fig.2 Example of FAD assessment

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References

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