Evaluation of Material Properties in the TP347 Stainless Steel Pipe Bends Manufactured by Induction Bending

Mi Yeon Lee [a], Jin Weon Kim [a*], Tae Soon Kim [b]
[a] *Dep. of Nuclear Engineering, Chosun Univ., Gwangju, Rep. of Korea, KS008*
[b] *Center for Research Institute, KHNP, Daejeon, Rep. of Korea, KS015*
**Corresponding author : jwkim@chosun.ac.kr*

1. Introduction

The use of pipe bends fabricated by induction bending gradually increases in non-safety class nuclear piping systems as well as in piping systems of fossil power plants, because of several advantages such as eliminating welds between elbow and pipes, improving flexiblility of pipe routing, and less costs. Recently, it is attempted to use the pipe bends for safety class piping systems of nuclear power plants (NPPs). However, induction bending could locally change microstructure of pipe material induced by local heating and rapid cooling [1]. Thus, the material properties of the pipe bend would be different from those of straight pipe and show spatial variation within pipe bend. Therefore, it is necessary to investigate the material properties of pipe bend fabricated by induction bending. The investigation is more important for piping systems applying leak-before-break (LBB) concept because the lower bound material properties should be used for LBB evaluation [2]. In this study, tensile and J-R fracture toughness tests are carried out to investigate the local material properties of SA312 TP347 stainless steel pipe bend manufactured by induction bending. Also, microstructures and fracture surface were examined at different locations in the pipe bend.

2. Experiment procedure

SA312 TP347 stainless steel pipe bend fabricated by induction bending is used for the experiment. The pipe bend is 12inch, Sch.160, and the bend radius (R_b) is three times the outer diameter of pipe (D_o). The original straight pipe was solution-annealed at 1,060°C for 10min. and water quenched. The chemical composition of SA312 TP347 stainless steel pipe is listed in Table 1.

Round bar specimens with 6mm in diameter and 32mm in uniform length were used for tensile test. 1T-CT specimens with 50.8mm in width and 25.4mm in thickness were used for J-R fracture toughness tests. The specimens were machined from the various locations in the pipe bend, including intrados, extrados, and crown regions of bend, start and end of bend, and straight pipe. Fig.1 shows locations of specimens in the pipe bend. Tensile tests and fracture toughness tests are performed in accordance with the respective ASTM E8 [3] and ASTM E1820-09 [4]. In the J-R test, the crack extension length was determined by normalization method provided by ASTM E1820-09 [4]. Both tests were conducted at both ambient temperature and operating temperature of piping system (316°C).

Table 1 Chemical composition of SA312 TP347

C	Mn	Si	P	S	Cr
0.025	1.68	0.4	0.014	0.0001	17.25
Ni	Nb	Ta	N	Co	-
10.23	0.278	0.005	0.013	0.025	-

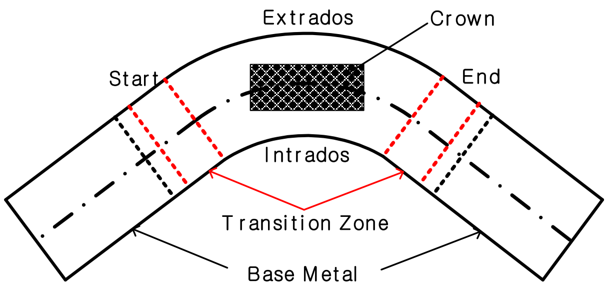


Fig. 1 Locations of specimens used for the experiment in SA312 TP347 pipe bend

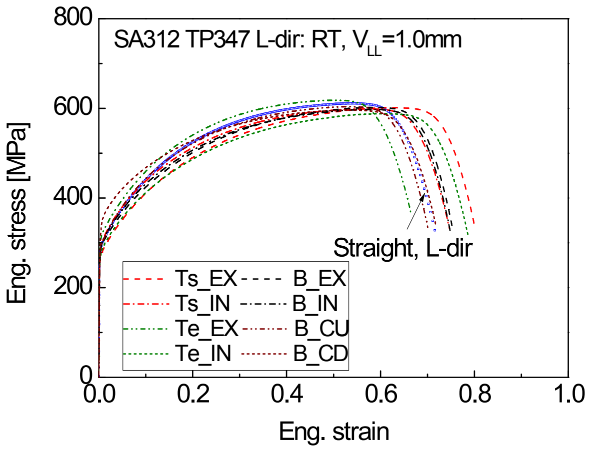
3. Results and Discussion

Fig. 2 shows the engineering stress-strain curves tested from the different locations in the SA312 TP347 pipe bend. The pipe bend region showed lower strength and higher ductility compared to original straight pipe at ambient temperature, but the pipe bend region showed higher strength and ductility than original straight pipe at operating temperature. More specifically, the change in the tensile properties by induction bending was insignificant at ambient temperature. The change in the yield and tensile strengths was less than ±10% and ±5%, respectively. At 316°C, also, the tensile strength of pipe bend was almost the same as that of original straight pipe, and its variation within pipe bend was insignificant. But, the yield strength at center of pipe bend was higher than that of straight pipe. The elongations of pipe bend were equal to or higher than those of straight pipe. At transition region, the elongations were higher about 10-20% than those of straight pipe.

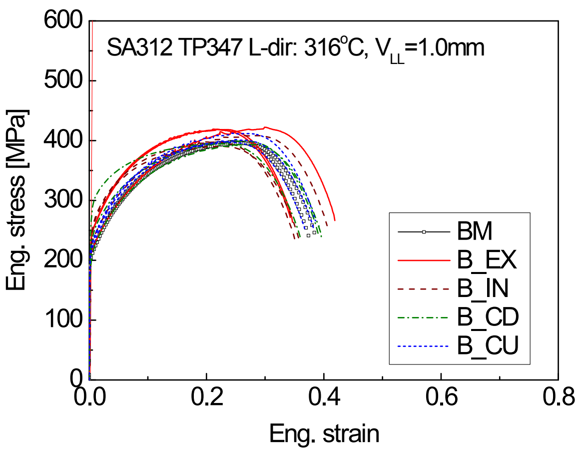
Fig. 3 shows J-R curves tested from the various locations of pipe bend including original straight pipe. Regardless of test temperatures, the J-R curves of pipe bend were always lower than those of original straight pipe. Within pipe bend, extrados of the center region showed a lowest J-R curve. However, the difference of J-R curves with locations in pipe bend was insignificant, except for the extrados region showed the lowest J-R curve.

4. Conclusions

This study carried out tensile and fracture toughness tests to investigate the local material properties of SA312 TP347 stainless steel pipe bend fabricated by high-frequency induction bending. From the results, the change in the material properties by induction bending was investigated by comparing the properties of pipe bend with those of straight pipe. Also, the spatial variations of the properties were observed.

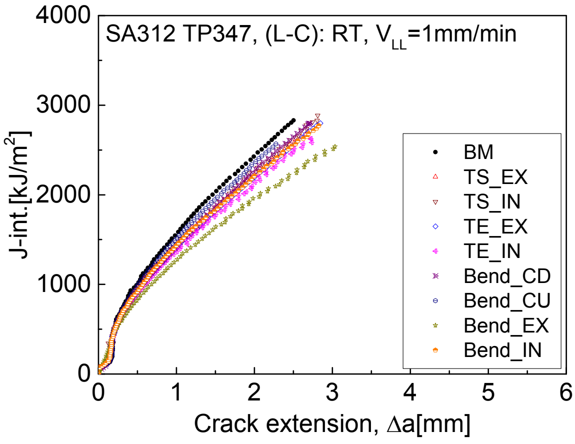


(a) RT

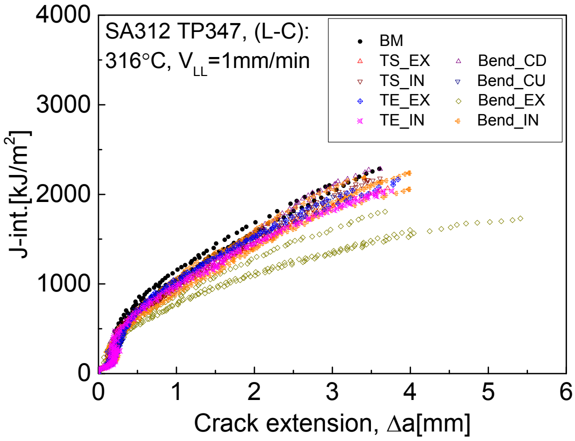


(b) 316°C

Fig. 2 Engineering stress-strain curves of SA312 TP347 pipe bend manufactured by high-frequency induction bending



(a) RT



(b) 316°C

Fig. 3 J-R curves of SA312 TP347 pipe bend in different locations

REFERENCES

[1] Hyun-Woo Lee, Jun-Ho Bae, Moon-Saeng Kim and Chul Kim, A. Optimum Design of Pipe Bending Based on High-frequency Induction Heating Using Dynamic Reverse Moment, Int. J. Prec. Eng. & Manuf., Vol. 12, No. 6, pp. 1051-1058, 2011.
[2] USNRC, Evaluation of Potential for Pipe Breaks, NUREG-1061, Vol. 3, 1984.
[3] ASTM, Standard Test Methods for Tension Testing of Metallic Materials, ASTM E8/E8M-09
[4] ASTM, Standard Test Method for Measurement of Fracture Toughness, ASTM E1820-09