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Effect of Chemical Composition on J-R Fracture Resistances of Type 347 Weld for Surge Line Piping

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1. Introduction

The leak-before-break (LBB) design concept has been applied to high energy piping of Korean Standard Nuclear Power Plant to enhance safety and to reduce cost. For LBB analysis, it should be verified that the crack in structure would grow stably through the elastic plastic fracture mechanics. The J-R fracture resistance supply key parameters to LBB analysis [1]. The materials for primary piping have enough fracture properties for LBB analysis except the pressurizer surge line piping made of Type 347 austenitic stainless steel and their welds have the smallest safety margin due to metallurgical variations. It has been predicted that the variations of mechanical properties are mainly affected by the microstructural difference originated from the chemical variations of the weld materials, but little systematic researches were directed in this matter [2, 3].

The purpose of this study is to investigate the chemistry effects on the fracture resistance of Type 347 welds.

2. Experimental

2.1 Materials and specimens

Six heats of Type 347 welds which were deposited by each different welding rod were prepared. The carbon, nitrogen and niobium contents in welding rod were varied within AWS ER347 welding rod specification. The welds were produced by GTAW (gas tungsten arc welding) method to simulate field welding. The thickness of welded plates was 30 mm and groove angle was 30°.

The chemical analysis results for Type 347 welds used in this study are listed in Table 1.

Table 1. Chemical compositions of Type 347 welds.

Elem. / Mat.	C	Cr	Ni	Mo	Mn	N	Nb	Fe
SS347W-1	0.047	19.72	9.47	0.154	1.91	0.065	0.550	Bal.
SS347W-2	0.037	19.69	9.76	0.155	1.94	0.058	0.363	Bal.
SS347W-3	0.027	19.58	9.69	0.174	1.92	0.039	0.264	Bal.
SS347W-4	0.029	19.51	9.59	0.156	1.92	0.066	0.820	Bal.
SS347W-5	0.026	19.97	9.62	0.150	1.94	0.089	0.277	Bal.
SS347W-6	0.037	21.57	8.70	0.151	1.91	0.058	0.372	Bal.

The compact tension type of 1-inch-thick specimens with 20% side grooves were used for measuring J-R curves.

2.2 Experimental Procedures

The J-R curves were determined using the single specimen unloading compliance technique. The tests were conducted at 316°C (600°F) using a servo-hydraulic test machine in general accordance with the ASTM Standard E 1820-01 [3].

Scanning electron microscopy, SEM (JEOL JSM-6300, 20kV) was used in conjunction with an energy dispersive spectrometer (EDS) to allow the observation of the microstructures and the primary identification of the second phase particles. The electrolytic extractions of the precipitates were carried out for the quantitative analysis and identification of precipitates. The selected extractions were analyzed by X-ray diffraction to determine the structure of the precipitates.

3. Results and discussion

3.1 Microstructural Analysis

The cross sections of J-R tested specimens were examined to observe ductile fracture process 3-dimensionally. It was found that the 2nd phase particles in the welds acted as initiation sites of micro cracks. The 2nd phases in Type 347 welds were identified as Nb(C, N) through the SEM-EDS and X-ray diffraction analyses.

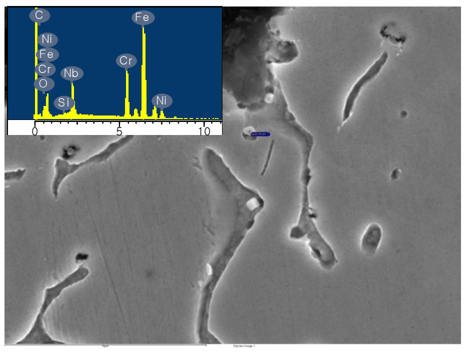

Fig. 1. SEM-EDS analysis for ppts providing void initiation sites.

The contents of Nb(C, N) precipitates in Type 347 welds were measured by using electrolytic extraction method. Fig. 2 shows the correlation between Nb(C, N) contents and contents of carbon, nitrogen and niobium

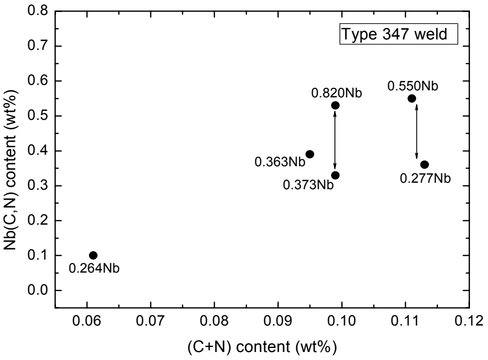

Fig. 2. Correlation between contents of Nb(C, N) contents and contents of carbon and nitrogen.

in welds. The contents of Nb(C, N) were in proportion to the sum of carbon and nitrogen contents generally, but the Nb(C, N) contents were also varied with niobium content as shown in Fig. 2.

3.2 J-R Fracture Resistance

The J-R curves measured for Type 347 welds with various compositions were shown in Fig. 3.

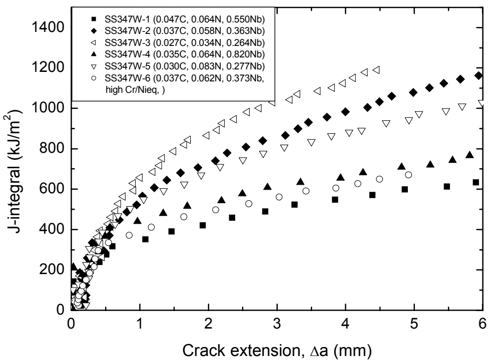

Fig. 3. J-R curves for Type 347 welds at 316°C.

Fig. 4 shows the effect of chemical composition on J-R fracture resistance more evidently. The dJ/da values measured from the J-R curves were in inverse proportion to the sum of carbon and nitrogen contents linearly when the niobium contents levels were close. The dJ/da values were dropped obviously in Type 347 welds having high niobium contents even though the sum of carbon and nitrogen contents levels are almost same.

Therefore it was induced that the J-R fracture resistance of Type 347 weld was affected by mixed effect of carbon, nitrogen and niobium contents i.e., the precipitates content level being determined by the combination of carbon, nitrogen and nitrogen contents affected the J-R fracture resistance of Type 347 welds dominantly.

The correlation between dJ/da values and Nb (C, N) contents shown in Fig. 4 supports this induction. In

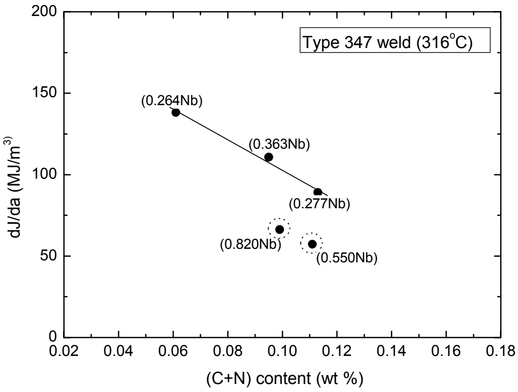

Fig. 4. Correlation between dJ/da and the sum of carbon and nitrogen contents in Type 347 welds.

conclusion, the J-R fracture resistance of Type 347 weld is in inverse proportion to Nb(C, N) content which is determined by the combination of carbon, nitrogen and niobium contents.

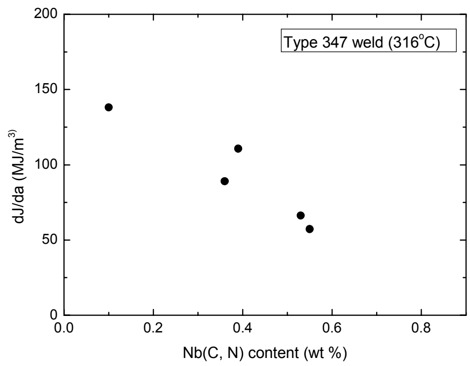

Fig. 5. Correlation between dJ/da and Nb(C, N) content in Type 347 weld.

4. Conclusions

1) The 2nd phase particles which had initiated micro cracks in Type 347 welds were identified as Nb(C, N) precipitates.

2) The Nb(C, N) contents in Type 347 welds were determined by combination of carbon, nitrogen and niobium.

3) The fracture resistances of Type 347 welds were reduced linearly as the Nb(C, N) contents are increased.

REFERENCES

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