The Study on the Fracture Characteristic for the Nuclear Structural Material using Acoustic Emission

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1. Introduction

In order to evaluate the nuclear structural integrity, non-destructive test methods were used such as radiographic test, ultrasonic test and eddy current are generally used in the industrial field. However, these methods have restrictions that defect detection is possible after the crack growth. For this reason, Acoustic Emission Testing (AET) could be one of powerful inspection methods to verify the structural integrity of pressure vessels, high temperature reactors and pipes, and a number of other equipment. AET has an advantage that it is able to monitor the structure continuously.[1]

AE sensor used to detect sound wave that occurs between 20kHz to 20MHz. and Sound wave result may vary depending on sensor's sensitivity.

In this study, AE signal was collected from stainless steel 304 specimens using two sensors by tension test. AE fracture signal was founded by tension test result. And AE fracture signal was divided to 4 groups by cluster analysis. It was demonstrated that crack signal of two sensor is not different by statistical analysis of null hypotheses. Based on the results, waveform of this tension test is crack signal.

2. Methods and Results

2.1 Tension test

The material and dimensions of the specimens are stainless steel 304 with 180 mm in length, 20 mm in width and 3 mm in thickness. And the acoustic sensors were attached as shown in Fig. 1 in order to collect proper fracture acoustic emission signal using 2-channels.

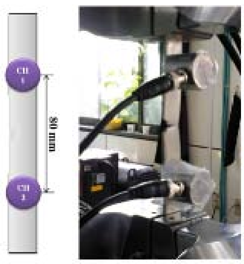


Fig. 1. Sensors fitting condition for the experiment

The applied load was 5 mm/min and machine is MTS system. The tests were continued until the specimens failed ultimately due to the crack growth or fracture. Acoustic emissions from all test specimens were monitored and recorded by an advanced DiSP-4 system and two sensors, with 150 kHz resonant frequency. Table 1 was shown to Spec. of two sensors.

Table. 1. Spec. of Sensor

	Sensor A	Sensor B
Case material	STS 304	STS 304
Face material	Ceramic	Ceramic
Connector	BNC	BND
Seal type	Epoxy	Epoxy
Operating Freq.	150-800kHz	200-900kHz
Resonant Freq.	125kHz	1030KHz
Preamp Gain	40dB	40dB(9-30V)

Material and outside condition of sensors are all same. But Operation Frq. And Resonant are very different. Using this difference, determined the impact of sensitivity of sensor.

Tension test was performed 8 times. Depending on the material and the sensor, tension test was performed over four times, 1st tension test condition is sensor A, 4times. 2nd tension test is sensor B, 4times. Sensor bottom location is using R15 of PAC, reference sensor as fig. 1.

Fig. 2 is shown result of tension test. This graph is Stress-time graph. Using this graph, we were determined fracture time and AE fracture signal.

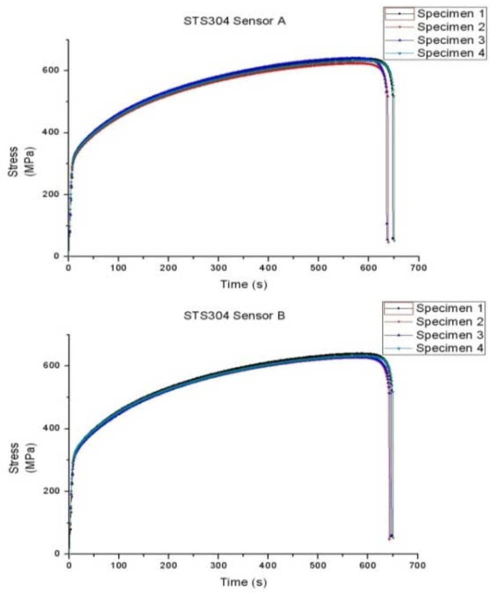


Fig. 2. Stress-Time graph depending on the sensor

2.2 Acoustic Emission test

Fracture time of Stress-time graph apply to AE signal. And AE fracture data could be obtained various AE date depending on time. Table. 3 shown AE fracture signal data.

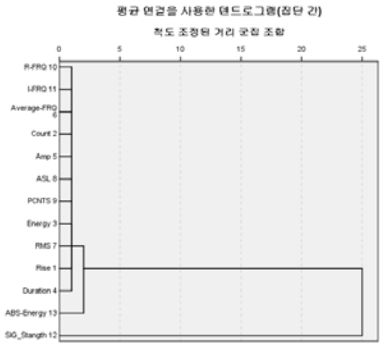
Table. 3 AE fracture signal parameter

Sensor A	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Rise	3656	4136	1733	886
Count	1805	2088	1164	1712
Energy	36663	32375	37057	31940
Duration	20683	31679	21122	17136
Amp	99	99	99	99
Average-FRQ	87	66	55	100
RMS	0.4952	0.4504	0.5142	0.4812
ASL	76	76	77	76
PCNTS	430	620	189	200
R-FRQ	80	53	50	93
I-FRQ	117	149	109	225
SIG_Stangth	229012000	202231000	231473000	199516000
ABS-Energy	1227000000	1058000000	1322000000	1157000000
Sensor B	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Rise	668	230	2900	2241
Count	2471	2182	1661	1480
Energy	6933	4326	4073	3471
Duration	27682	20970	15520	13731
Amp	85	85	85	85
Average-FRQ	89	104	107	108
RMS	0.0866	0.0684	0.0678	0.0694
ASL	61	59	59	59
PCNTS	65	20	309	338
R-FRQ	89	104	107	99
I-FRQ	97	86	106	150
SIG_Stangth	43308000	27024000	25443000	21685000
ABS-Energy	38873000	23507000	23158000	18772000

2.2 Analysis of AE signal

AE fracture signal parameters are Rise, Count, Energy, Duration, Amp, Average-Frq, RMS, ASL, PCNTS, R-Frq, I-Frq, Sig_Strangth, ABS-Energy as table. 3. Cluster analysis is applied to these signal parameter. In this study, single linkage method of hierarchical cluster analysis was used. Fig. 3 shown result of cluster analysis.

Fig. 2. Stress-Time graph depending on the sensor



Cluster analysis group is classified as 4 groups. 4 groups were Duration, SIG_Strangth, ABS-Energy and others as table. 4. Using these parameter group, result value of two sensors were assumed to subgroup. And we proved that fracture signal values of two sensors do not differ by null hypothesis.

2.3 Statistical Analysis

Null hypotheses are as follows when do not known average and variance of the population:

$$H_0 : \sigma_1^2 = \sigma_2^2$$

$$H_1 : \sigma_1^2 \neq \sigma_2^2$$

Criteria for rejection

$$F_0 > F_{\alpha/2,n_1-1,n_2-1} \ or \ F_0 < F_{1-\alpha/2,n_1-1,n_2-1}$$

Result of Average-Frq applied null hypotheses is 0.250. $F_{1-\alpha/2,n_1-1,n_2-1}$ is 15.4392. $F_{\alpha/2,n_1-1,n_2-2}$ is 0.0648. Therefore null hypotheses is agreed, not differ between sensor A and sensor B.

2.4 AE Waveform

According to section 3, AE fracture waveform is not different. Because of AE fracture parameters are based on waveform which is defined individually. Fig. 3 shown AE fracture waveform for sensor B.

Fig. 3. AE fracture waveform for STS304

3. Conclusions

The fracture characteristic of signal during tensile test in the stainless steel was examined by monitoring the acoustic emission testing. This result of null hypotheses is considered by means of the unique fracture signal.

4. Acknowledgment

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