Acoustic Emission Activity of the Structural Materials for Nuclear Power Plants

S. H. Lim, Y. S. Joo, H. S. Eom, J. H. Kim
Korea Atomic Energy Research Institute, P.O.Box 105, Yuseong, Daejeon, Korea, 305-353, ex-sahoe@kaeri.re.kr

1. Introduction

The acoustic emission (AE) method is to detect a transient elastic wave generated by a rapid stress relaxation due to a deformation and the fracture behavior of materials. The AE technique has become a mature nondestructive testing method with the demonstrated capabilities for characterizing a material's behavior and detecting the defects. AE has recently been successfully applied to the leak detection of the primary pressure boundary of nuclear power plants. Therefore the AE technology is expected to contribute to the assurance of nuclear safety as an on-line monitoring technique of the structural integrity of NSSS components and structures[1]. For the application of the structural integrity monitoring of pressure vessels and pipings, the AE signal from the growth of cracks and fractures should be characterized first of all[2, 3].

In this study the generation characteristics of the AE signal during the tensile test of SA508 and SS304 which compose the primary structures of nuclear power plants was evaluated.

2. Experiment

2.1 Tensile specimens

In order to establish the AE pattern of SA508 and SS304, a tensile test was performed. Tensile specimens whose dimension is 200mm in width, 30mm in height, 4mm in thickness and 40mm in gauge length were prepared from the plates of SS304 stainless steel and SA508 carbon steel. Also single notched specimens with an EDM notch of 3mm in length and 0.1mm in width were prepared. Same size and geometry in both kinds of materials were adopted in order to realize a free down from an influence due to size effects.

2.2 Acoustic Emission Measurement System

Tensile test was carried out in air at room temperature with an Instron 4505 tensile testing machine. The speed of the crosshead of the machine was set at 3mm/min. The Vallen AMSY-5 Unit with 4 channels, VS150-M sensor with a frequency range of 100-450kHz and an AEP4 preamplifier with a gain of 34dB were used to measure the AE. The measurement variables are hits, event counts, peak amplitude and rise time, i.e.

The block diagram for the AE measurement during the tensile test is shown in Figure 1.

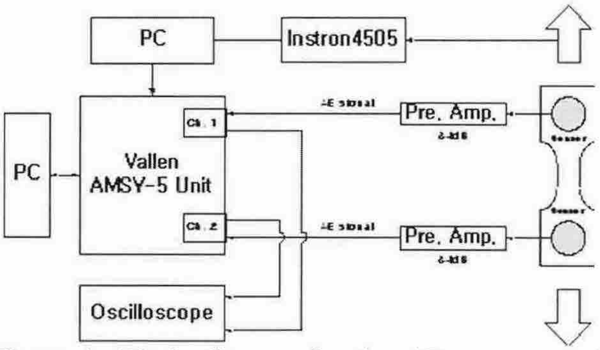


Figure 1. Block diagram for the AE measurement system.

3. Results and Interpretations

3.1 Tensile Test

The results of the tensile test are shown in Table 1. In the case of normal specimens, SA508 is larger than SS304 for the yield strength but smaller than it for the UTS. The case of the notched specimen is also similar to one of the normal specimens. As a result of the measurement of the maximum displacement, ductility of SS304 is higher than SA508.

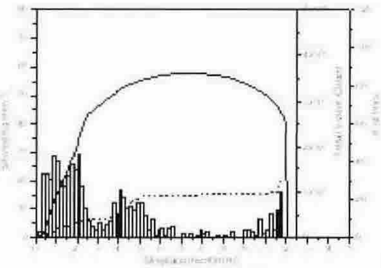
Macroscopic shapes of the fracture were different in both kinds of materials. The SS304 materials exhibited "double-cup faced" fracture patterns. On the other hand, SA508 materials showed a 45°-shear fracture. In the initiation of a crack growth, the surface displacement due to tensile force at the tip exhibited, respectively, symmetric in SS304 and asymmetric in SA508 with respect to the plane perpendicular to the direction of the tensile force.

Table 1. Result of the tensile test.

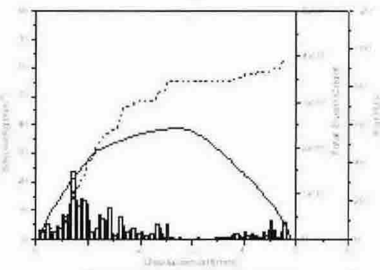
	SA508		SS304	
	normal	notched	normal	notched
Yield Strength [MPa]	433.8	289.1	393.4	258.2
UTS [MPa]	567.9	443.9	752.9	449.2
Max. displacement [mm]	6.85	2.60	27.52	6.63

3.2 Generation patterns of the Acoustic Emission Signal

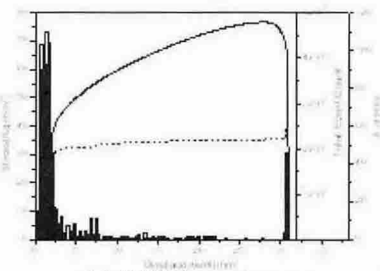
The Stress-displacement curve and AE activity of 4-types of specimens during the tensile test are shown in Figure 2. There are elastic-, plastic- and crack growing-regions in the stress-displacement curve.



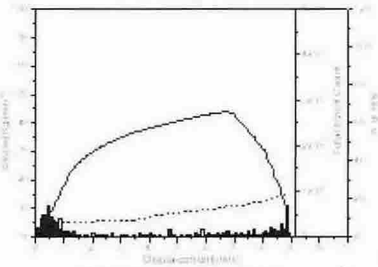
(a) SA508 specimen



(b) Notched SA508 specimen



(c) SS304 specimen



(d) Notched SS304 specimen

LEGEND
———— : Stress
- - - - - - - : Total event count
Bar graph : The number of hits

Figure 2. Stress and displacement curves and AE activity

In the case of the normal specimens, as shown in (a) and (c), the AE activity of the SA508 specimen is lower than the SS304 specimen in the elastic region and higher than it in the plastic region. On the other hand, for the SS304 specimen, the AE signals are seen distinctly in the elastic region and are decreased abruptly in the plastic region. In the event of the notched specimens, as shown in (b) and (d), predominant AE generations are observed in the elastic region for the SA508 specimen and in the crack growing region for the SS304 specimen, respectively. An anomalous lack of AE generation, in contrast with SS304 specimen, is observed during the crack growing region in the SA508 specimen.

4. Conclusion

In this paper, the characteristics of the AE signal generated on SA508 and SS304 steels which are structural materials of nuclear power plants were investigated during a tensile test. The fracture patterns of the SA508 and SS304 specimens are different, they are a 45°-shear fracture pattern and a double-cup faced pattern respectively. For the normal specimens, AE generations were observed in the elastic and plastic region for the SA508 specimen and in the elastic region for the SS304 specimen remarkably. For the notched specimens, AE generations were observed in the elastic region for the SA508 specimen and in the crack growing region for the SS304 specimen. The relationships between the AE characteristics and the fracture patterns suggest that, in SS304, the role of the stress induced martensitic transformation should be noted from the point of view of AE source as well as crack growth mechanism, while, in SA508, the nature of an anomalous lack of AE generation in the crack growing region should be understood on the basis of the material properties, for the purpose to contribute to the safety assurance of nuclear power plants by an AE technology application.

ACKNOWLEDGEMENT

This study was supported by the Korean Ministry of Science & Technology through its National Nuclear Technology Program.

REFERENCES

[1] Nondestructive Testing Handbook(2nd ed.), Vol. 5, Acoustic Emission Testing, American Society for Nondestructive Testing, 1987
[2] D. Parry, "Nondestructive Flaw Detection by Use of Acoustic Emission", IDO-17230, Phillips Petroleum Co., 1967.
[3] H.L. Dunegan, D.O. Harris and A.S. Tetelman, "Detection of Fatigue Crack Growth by Acoustic Emission Technique", Material Evaluation, Vol. 28, No. 1, pp.221-227, 1970.