<table>
<thead>
<tr>
<th>Title</th>
<th>Linear Source Location of Acoustic Emission from Weld Cold Crack in Steel : Application of Acoustic Emission Technique for Weld Cracking (I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Matsuda, Fukuhisa; Nakagawa, Hiroji; Morimoto, Yoshinori</td>
</tr>
<tr>
<td>Citation</td>
<td>Transactions of JWRI. 7(1) P.87-P.92</td>
</tr>
<tr>
<td>Issue Date</td>
<td>1978-06</td>
</tr>
<tr>
<td>Text Version</td>
<td>publisher</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/11094/5640">http://hdl.handle.net/11094/5640</a></td>
</tr>
<tr>
<td>DOI</td>
<td></td>
</tr>
<tr>
<td>rights</td>
<td>本文データはCiNiiから複製したものである</td>
</tr>
</tbody>
</table>

Osaka University Knowledge Archive : OUKA

http://ir.library.osaka-u.ac.jp/dspace/

Osaka University
Linear Source Location of Acoustic Emission from Weld Cold Crack in Steel†

— Application of Acoustic Emission Technique for Weld Cracking (I) —

Fukuhisa MATSUDA*, Hiroji NAKAGAWA** and Yoshinori MORIMOTO***

Abstract

Accuracy of linear source location of acoustic emission (AE) from weld cold crack of high strength steel is investigated. TGRC test is used which is conceived by the authors to induce the cold crack at an optional position. Specimens of 350 and 2000mm in length are used and two transducers are placed at intervals of 300mm and 1900mm. Main conclusions obtained are as follows: (1) AE source locations are scattered within the crack location ± about 10% in the expression of a relative location which is defined to be 0% at one of two transducers and 100% at the other. (2) Arithmetical mean of AE source location well agrees with the crack location within ±5% of an error at the largest. The standard deviations are about 5%. (3) There is little difference in the accuracy of AE source location between short and long specimens.

1. Introduction

Acoustic emission (AE) is a phenomenon that stress wave is emitted in material during plastic deformation, metallurgical transformation, crack initiation and propagation etc. Thus AE monitoring, on the one hand, has become a new technique for materials study, and on the other hand, has become a useful nondestructive tool for detection of crack growth in structure during and after fabrication.

In welding field, hot cracks and cold cracks are very troublesome problems for the fabricator, and the practical use of AE monitoring has been desired as a nondestructive technique of real-time. Therefore various attempts to apply the AE monitoring to various welding processes have been reported13-14 and the usefulness has been gradually recognized. However, there are many indistinct problems as regards the accuracy, reproducibility, quantitative analyses, treatment of noise, limits of application and so on.

While, weld cold cracks in steels have become more and more serious problems together with developments of high strength steels. However, it is said that AE from the cold cracks can be easily detected13 without noises from slag, since they are hydrogen-induced delayed cracks occurring mainly after welding and high amplitude AE signals are given off during the crack growth15 16 . Therefore a detailed investigation on source location of AE from the cold crack and estimation of the crack size etc. by the AE monitoring has been intended by the authors.

This first report discusses an accuracy of the AE source location for weld cold crack in steel.

2. Experimental Procedures

2.1 Weld Cracking Test

A weldable heat-treated high strength steel HT60 whose ultimate strength was 60 kg/mm² class was used for TGRC test, which was conceived and named by the authors to investigate the accuracy of AE source location for weld cold crack. The name of TGRC test is an abbreviation of Transversely Gapped Restraint Crack test, and the specimen configuration is shown in Fig. 1. The principle of the TGRC test is as follows: A transverse gap of about 1 mm width is prepared by machining, and a bead-on-plate welding is carried out across the gap. Then, a transverse crack is induced in the weld metal at the gap due to contraction strain

† Received on March 31, 1978
* Professor
** Research Instructor
*** Graduate Student, Osaka Univ.

87
after the welding. Since the crack location can be optionally selected by varying the gap position, the TGRC test is suitable to investigate the accuracy of AE source location for the weld cold crack by using two AE transducers placed near the both ends of the specimen.

Two types of specimen, which were 350 and 2000 mm in length, were used to observe effect of distance between the AE transducers on the accuracy of AE source location. The distances between the transducers were 300 and 1900 mm, respectively. Then, the gap position, which is expressed as L in Fig. 1, was selected to 60, 105, 150, 195 or 240 mm in the short specimen, and 190, 570, 950, 1330 or 1710 mm in the long specimen. Expressing them by a relative location which is defined to be 0% at the left transducer and 100% at the right one in Fig. 1, they corresponded to 20, 35, 50, 65 and 80% in the short specimen, and 10, 30, 50, 70 and 90% in the long specimen. The bead-on-plate welding was carried out with TIG-arc process to remove any noise from slag. Any filler metal was not used and a mixing gas of argon and 1% hydrogen in the total amount of 20 l/min was supplied as the shielding gas to cause a hydrogen-induced cold crack. The welding conditions were 150 mm/min of welding speed, 20V of arc voltage, 300A of welding current and about 100 mm of weld length.

2.2. Acoustic Emission Technique

2.2.1 Acoustic Emission Monitoring System

AE monitoring system used is Dunegan/Endevco 3000 series which has dual channels and thus has a capability of linear source location. The block diagram is shown in Fig. 2. The transducers are differential type Dunegan/Endevco Model D9201, which has flat frequency response and has sensitivity of $-84 \text{dB}$ referred to $1 \text{V/μbar}$. The diameter of the transducer is 25.4 mm. Preamplifiers provide a fixed gain of 40dB and contain exchangeable filters. In this report 100 to 350 kHz bandpass filters were used. The filtered signals are further amplified by main amplifiers in a dual signal conditioner whose gain is variable in 1 dB increments from 0 to 60 dB. The amplified signals over a 1 volt fixed threshold are converted to digital pulses by the signal conditioner and are counted by a dual counter.

The digital pulses are fed to a Model 920 distribution analyzer to determine the AE events and to locate the AE source. There are several methods to determine AE events dependent on AE apparatus, which are related to the accuracy of AE source location in a case of frequent burst of AE. The method in the distribution analyzer is illustrated in Fig. 3, where outputs of the signal conditioner and the event determiner are shown in relation to time. An output of the event
The TGRC test was carried out after the above preparation had finished. The AE monitoring was started from about 30 sec after the welding. AE waves were observed at need by a Tektronix 7633 memoryscope.

3. Experimental Results

General appearance of weld metal near the gap in the TGRC test specimen is shown in Photo. 1. A slightly curved transverse crack was formed in the weld metal at the gap. None of the crack was observed in other parts.

An example of changes in AE total count and AE total event vs. time is shown in Fig. 4, which reveals intermittent occurrence of AE peculiar to hydrogen-induced delayed crack. The AE wave was typical burst-type as seen in Photo. 2. The AE wave seems to have a sharp rising and a smooth attenuation, but has
not necessarily the sharp rising in a high magnified time scale. The example is shown in Photo. 3. This phenomenon appeared to be generally remarkable when the distance between the crack and the AE transducer was long, and thus must have been one of the causes of scattering of AE source location as mentioned later. By the way, it is seen in Photo. 3 that the frequency of AE near the rising part is about 200 kHz.

Figures 5 (a) and (b) show examples of spatial distributions of AE events by AE source location in the case where the relative crack location is 80% in the short specimen and where that is 90% in the long specimen, in which the AE source location is carried out for four specimens of the same condition respectively. AE events in 0% or 100% of relative location are due to AE signals which crossed over the threshold level in only one of the dual channels. Therefore the ringdown counts of these events are very small. Other AE events are scattered within 80% ± about 10% in (a) and 90% ± about 10% in (b), that is within the relative crack location ± about 10%.

All results of AE source locations for various crack locations are summarized in Fig. 6, in which AE events of four specimens of the same condition are
Source Location of AE from Weld Cold Crack in Steel

(a) specimen of 350mm in length

Fig. 6 Summary of AE source locations in various crack locations in TGRC test

(b) specimen of 2000mm in length

totalized. Figure 6 (a) shows the results in the short specimen and Fig. 6 (b) does those in the long specimen. It is observed that the scattering of AE events are similar to those in Fig. 5, independent of the crack location.

Figure 7 shows a relation between the crack location and the arithmetical mean of AE source location in Fig. 6, and further shows the mean location ± the standard deviation by I-shaped mark. The mean AE source location well agrees with every crack location within ± 5% of a relative error at the largest. The standard deviations are about 5%. Moreover there is little difference in the accuracy of AE source location between the short and long specimens, though the accuracy of the long specimen seems to be slightly better. Essentially the diameter of the transducer makes the accuracy inferior in the short specimen. On the other hand, wave dispersion and slow rising of AE wave make the accuracy inferior in the long specimen. Perhaps a compensation of these effects brought about the similar accuracies. Besides, a tendency is observed that the mean AE source locations for 10 and 20% of the crack locations are estimated slightly larger and that the mean AE source locations for 80 and 90% of the crack locations are estimated slightly smaller. This tendency is considered to have resulted from a factor that the error of AE source location due to the error in selecting the acoustic velocity generally becomes larger as the crack is located near one of the AE transducers.

For reference, results of AE source locations for a simulated AE source are shown in Fig. 8, where there is little scattering and thus not mean values but data themselves are plotted. Comparing Figs. 7 and 8, there is little difference in accuracy between the mean values in Fig. 7 and the data themselves in Fig. 8. The reasons for the scattering of AE source location for the weld crack may be related to (a) the shape of AE wave of the crack, (b) the distribution of AE amplitude vs. the threshold level, (c) the frequency of occurrence of AE events of the crack, (d) the change in the acoustic velocity due to the cracked temperature, and so on.

Above mentioned results in Figs. 5, 6 and 7 were obtained from the specimens in which the cold crack
was formed with preheating of 100°C. Photograph 4 shows the artificially fractured surface containing the crack which were colored black by an oxidation in an elevated temperature. The crack is observed at the lower part of the weld metal and the area is about 8 mm in width and about 1.5 mm in height. The spatial distribution of the AE events is shown in Fig. 9. It is observed that AE source location is satisfactorily possible in the same accuracy as in Fig. 6.

4. Conclusions

Accuracy of AE linear source location for weld cold crack of high strength steel was investigated. Main conclusions obtained are as follows:

(1) AE source locations are scattered within the crack location ± about 10% in the expression of a relative location which is defined to be 0% at one of two transducers and 100% at the other.

(2) Arithmetical mean of AE source location well agrees with the crack location within ±5% of an error at the largest. The standard deviations are about 5%.

(3) There is little difference in the accuracy of AE source location between short and long specimens used.

(4) AE source location could be applied for a small crack, the area of which was about 8 x 1.5 mm at the lower part of the weld metal.

Acknowledgement

The authors would like to thank Katayama Iron Works Co. for the offering of the materials and Mr. N. Kano, formerly student of Osaka Institute of Technology, for his cooperation in this investigation.

References