The Acoustic Emission Monitoring During the Bending Test of Q235 Steel Box Beam

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Abstract:

Acoustic emission characteristics of the Q235 steel box beam with external crack are monitored during the bending test. The AE parametric characteristics and location characteristics of the crack propagation in the test are discussed. The AE intensity and gross in the elastic deformation section are less than the section after yield deformation. The maximum amplitude is 64dB in elastic deformation section. The defect can hardly be located when the box beam is loaded less than the maximum load of it with external crack during the elastic deformation section. The results indicate that the linear location method can be used well for the AE sources location of box beam when the external crack was propagated during the three-point bending test.

Keywords: Q235 steel; external crack; acoustic emission; bending test

1. Instruction

In manufacturing process of modern industry, the cranes are the indispensable equipments and are used extensive in the work of hoisting, transport, loading an unloading, installation, the transfer of the people and so on. There are more than 556 thousands of cranes in China [1]. The crane metal structure support the whole self-weight and the outside load adding on the crane, form the working system and movement space to accomplish all of the functions of crane. So, the state of the crane metal structure affects the security and reliability of the whole machine directly. The cracks are one of the familiar faults in crane structures [2].

The nondestructive testing techniques [3] used in cranes ordinary are eyeballing, ultrasonic, stress testing, etc. But the faults are easy to be missing, and cost much in these ordinary methods. The acoustic emission (AE) is a supplemental technique for the testing. The activity defects can be found in the whole structures in once loading test, which cut the inspecting cycle and costs.

There are some experiments on the testing of crane girder using the AE technique by the scholars both in China and abroad [4, 5]. But AE characteristics of the Q235 steel box beam structures' used in the crane widely are rarely studied. For the purpose of application in the local, we should research and get the AE characteristics of the materials and structures firstly. Therefore, the specimen of Q235 steel box beam with prefabricated external crack was designed, and the AE technique was used to monitor the AE parameters and location characteristics of the crack propagation during the three-point bending testing.

2. Experimental

2.1 Dimension of the specimen

The box beam specimen was welded by four pieces of Q235 steel plate with thickness of 8mm. The external cracks, named as Defect 1 and Defect 2, were prefabricated on the bottom cover plate of the box beam, utilizing the brass wires and the FeS powder respectively. The shape and dimensions of the specimen are shown in Figure 1.

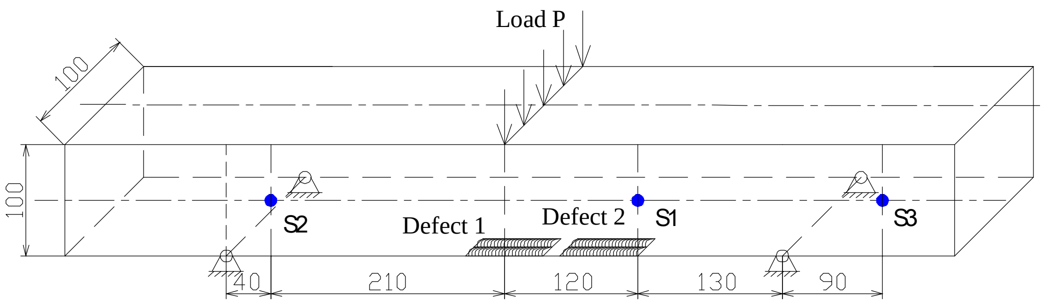


Figure 1 Dimension and sensors arrangement of the specimen (mm)

2.2 Chemical composition for Q235 steel

The Chemical composition and mechanical properties for Q235 steel are shown in Table 1.

Table 1 Chemical composition and mechanical properties for Q235 steel (%)

C	Si	Mn	P	S	σ_s (MPa)	σ_b (MPa)	δ_s (%)
0.16	0.19	0.54	0.021	0.030	335	475	34.0

2.3 Instruments

Servo hydraulic universal testing machine used in the bending test was SANS SHT4206 model. Its' capacity was 2000kN.

A fully digital multi-channel AE system series AMSY-5 were used, which were made from Vallen-Systeme GmbH, including sensors, preamplifiers, computer software, cables etc. In the test, the VS150-RIC and VS900-RIC model sensors, and the AEP4 preamplifiers were used to acquire the AE signals from the specimen. The gain of the preamplifier was 34dB.The sensors S1, S2 and S3 were arranged on the web plate and its model were VS900-RIC, VS150-RIC and VS150-RIC in turn, as shown in Figure 1. S2 and S3 were used for the linear location, and S1 used for guarding. The threshold was 40dB.

2.4 Loading procedures and noise-reduction

The dead load would be loaded on the specimen before the external cracks were prefabricated, with the purpose of removing the noise released by the residual stress. The maximum dead load was 306kN, and the specimen was still in elastic deformation section. To separate the noise from the AE signals in the test, the Polyvinylchloride (PVC) plastic plates were put in the interfaces of the specimen with the pivots and pressure head. Then the specimen was loaded three times, and the maximum load was less than 306kN each time. There were scarcely AE signals in the last two times, that indicated that the noise caused by the residual stress and the mechanism friction were reduced well.

Then, the specimen was loaded. The load procedures were: first time, loaded from 0 to 280kN, and then unloaded to 0; second time, the same as previous one; third time, from 0 to 378kN, and then unloaded to 0. In the third time, the load was held for a few minutes at the load 240kN and 280kN.

3. Results and Discussion

3.1 AE parameters

Cumulative AE counts with time in the whole load time are shown in Figure 2. The first loading time periods is 0~300s, the second is 2400~2800s and the third is 3300~4450s. The curve in the third time from 280kN to 378kN rises faster than it in the first time from 0 to 280kN. That is, as the load increased, the AE counts raise fast. It indicates that the velocity of the crack propagation intensifies with the load increasing.

Distributive AE amplitudes with time in the whole load time are shown in Figure 3. In the three loading periods from 0 to 280kN, there are AE signals most in the first loading period than the others, and the maximum amplitude is 64dB presented in the first time. That shows that, the open and close of the crack surface, under the load less than the maximum of the specimen with external crack, also bring some AE signals, but its amplitude and gross are smaller and less than the first time. Farther, the amplitude of the loading process from 280kN to 378kN is greater than the process from 0 to 280kN, and the gross are more. That is to say, the AE amplitude is strengthening as the load increasing.

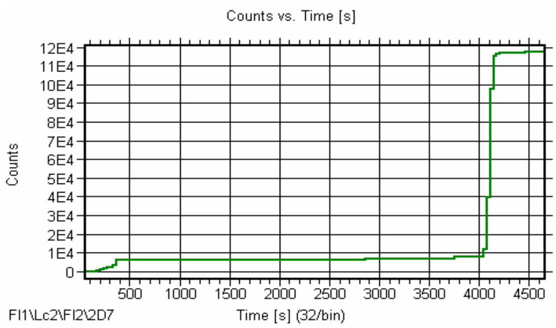


Figure 2 Cumulative AE counts vs. time

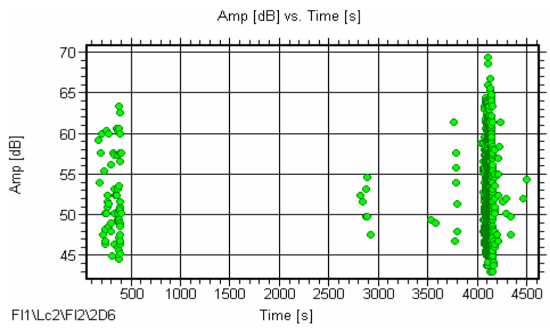
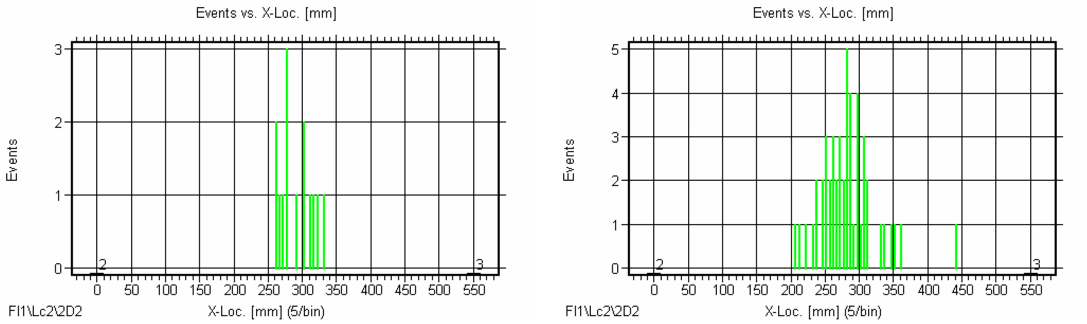


Figure 3 Distributive AE amplitudes vs. time

3.2 AE location characteristics

Distributive AE events with location of the Q235 steel box beam specimen under the load in the first time and third time are shown in Figure 4. In the test, the PVC plastic plates were broken off by the extrusion of the specimen with the pivots and pressure head. There are some AE events appearing in the pivots and pressure head. Using the filter of parameters, the sources in the pivots and pressure head are removed, and others are preserved. The Figure 4 shows that there are no AE location sources at the coordinates of the two pivots and pressure head.



(a) (b)

Figure 4 Distributive AE events vs. Location (a) 0~280kN (b) 0~378kN

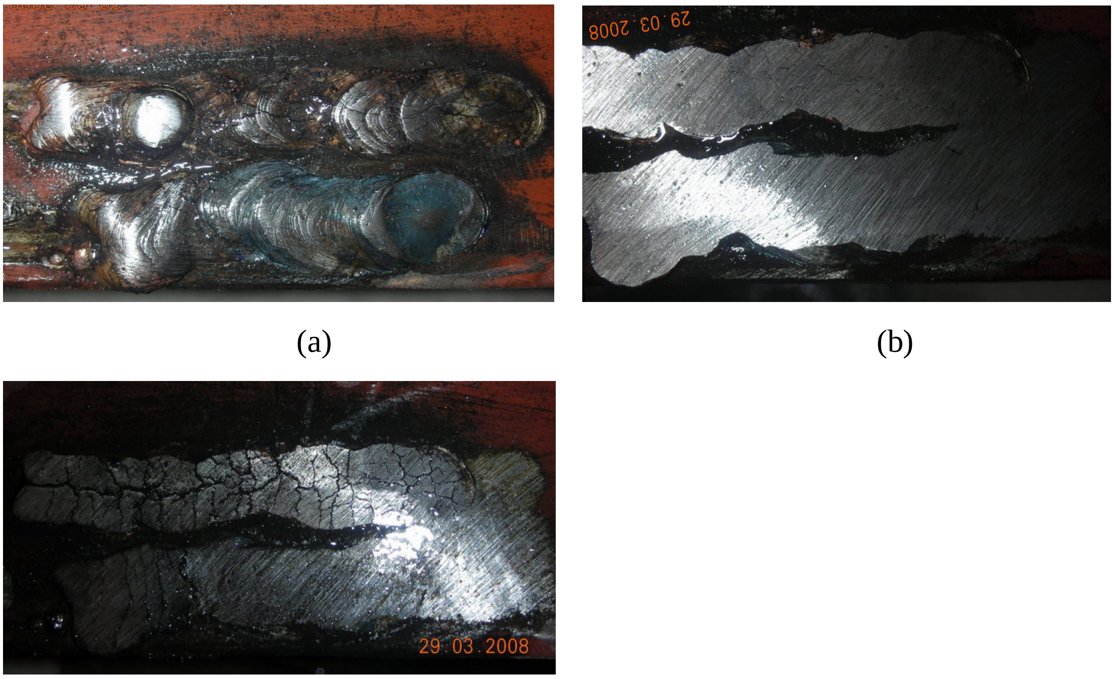
The Figure 4(a) shows that the coordinates of the AE location sources distribute in the range from 260mm to 330mm during the first loading process, and the largest number of the AE hits are 3 appearing at 278mm. From the Figure 4(b) we know that, the coordinates of the AE location sources distribute in the range from 210mm to 360mm during the third loading process, the AE location events which number are more than 2 distribute from 250mm to 310mm, and the maximum number of the events is 5 appearing at 282mm. The coordinates' ranges of the Defect 1 and Defect 2 at the two ends are [210,270] and [280,380]. The coordinates of the AE location sources measured in the test fall in the range of the prefabricated defect. The results show that, the defect can be located accurate using the linear location method in the box beam, while the crack is propagating. The parameters' ranges of the AE signals located are shown in table 2.

Table 2 AE parameters characteristics of the signals located

AE parameter	Range	Mainly range	AE parameter	Range	Mainly range
Amplitude(dB)	43~70	44~55	Duration(μs)	$1\sim6*10^3$	$500\sim3*10^3$
Energy	1~700	1~100	Rise time(μs)	1~1000	1~300
Counts	1~600	15~200			

3.3 Macroscopic features of the external cracks

The appearances of the external cracks on the Defect 1 are contrasted before and after the bending test, shown in Figure 5. The Defect 1 includes two welds with prefabricated external cracks, shown in figure 5(a). Using the magnetic particle testing, the external cracks can be observed. The external cracks on the above weld are clearer than another in the Defect 1. After the first loading process, the welds were polished and tested using magnetic particle to observe. Figure 5(b) shows the appearances of the external cracks at the load 280kN, in which the specimen is still in elastic deformation section. The macroscopic cracks are appearance and mainly distribute in longitudinal way. Figure 5(c) shows the appearances at the load 378kN, which is overcome the strength limit. On the weld, the numbers of the longitudinal crack increase and propagate in the length and deepness. Contrasting the cracks before and after the test, we know that, the cracks are growing incessant along with the load increasing. The cracks in elastic deformation section, its numbers are smaller, length is less and the deepness is shallower than the yield deformation.



(a) (b)

(c)

Figure 5 Appearances of the Defect 1 (a) before the test (b) 280kN (c) 378kN

4. Conclusions

Based on the AE monitoring during the bending test of the Q235 steel box beam, we can conclude that:

(1)The defect can be located accurate using the AE linear location method on the box beam while the crack is propagating. The noise can be excluded effectively by releasing the residual stress, separating the noise and setting the AE parameter filter.

(2)Along with the load increasing on the beam with prefabricated external cracks, the numbers, length and deepness of the macroscopic cracks are increasing. Its velocity of the cumulative AE counts rises fast, and the AE amplitude is strengthened.

(3)In the elastic deformation section, when the specimen with external cracks was loaded repetitious on the same load level, there are many AE signals and location sources in the first time, but less and lower amplitude AE signals appearing in the other times.

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