Acoustic Emission Analysis for the Evaluation of the SCC Process of Brass

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ABSTRACT

This paper presents results of a systematic work about the stress corrosion cracking (SCC) behaviour of the brass CuZn37 in sodium nitrite solutions of different concentrations using acoustic emission analysis.
As a basis for the investigation of the process of the crack initiation, the multiplication and the propagation up to the fracture a constant load test with an electronic regulating unit and the in-situ analysis of the characteristic parameters of the acoustic emission was used.
The work has shown that the lifetime to fracture of the brass has a minimum at a concentration between 0.2 to 0.4 mol/l $NaNO_2$. At a concentration of 2 mol/l $NaNO_2$ a protective layer was formed and the lifetime increased. The cracking kinetics in both concentration fields is different. Furthermore it was shown that an addition of a benzotriazole (BTA)-based inhibitor to a 0.25 mol/l $NaNO_2$ solution influenced the cracking kinetics importantly.
The results show the possibility to investigate the SCC susceptibility of the brass CuZn37 using acoustic emission analysis.

Keywords: stress corrosion cracking, brass, constant load test, sodium nitrite, inhibitors, acoustic emission analysis

INTRODUCTION

The influence of sodium nitrite on SCC of brass was studied over the last years by our own systematic research using the possibility of acoustic emission analysis [1-3]. Worldwide several models for the SCC mechanism of brass in sodium nitrite were suggested. Some authors have investigated the physical and electrochemical mechanism of brass, the dezincification, the oxide transport properties forming a film mainly composed of CuO_2, the electrochemical conditions over a wide range of electrolyte concentrations or the NO gas development in $NaNO_2$ solutions [4-12].
Also some authors have studied the influence of 1,2,3-BTA-inhibitors and special blends on the SCC-process of brass in sodium nitrite [13-15].
This paper describes own results of the electronic regulated constant load tests for the brass CuZn37 in various concentrations of sodium nitrite solutions with an in-situ analysis of acoustic emissions. The work shall connect to the electrochemical level of knowledge with new insights from the crack-induced acoustic emission.

EXPERIMENTAL DETAILS

The CuZn37-specimens were cut from commercial rolled plates with a thickness of 1mm. The dimension of the tensile specimen was 250 x 30 mm. The wide of the sample which is exposed in the sodium nitrite solution, was reduced to 12 mm.
The electronic regulated constant load test was adjusted to a constant stress of $R = 223\ N/mm^2$, just below the yield strength.
The range of the concentration of the $NaNO_2$ solution reached from pure aqua dest to 2 mol/l $NaNO_2$ with a pH value from 7.0 to 9.0.

The AE signals are preamplified (40dB, 100-1200 kHz) and processed using PAC's PCI-DISP4-AE-system with a resonant piezoelectric sensor (PAC R80, resonant frequency 200 kHz). The change of the AE (ring down) counts, hits, peak amplitude, energy, duration, risetime, frequency and other waveform parameters were evaluated.
Figure 1 shows the set up and the experimental process.

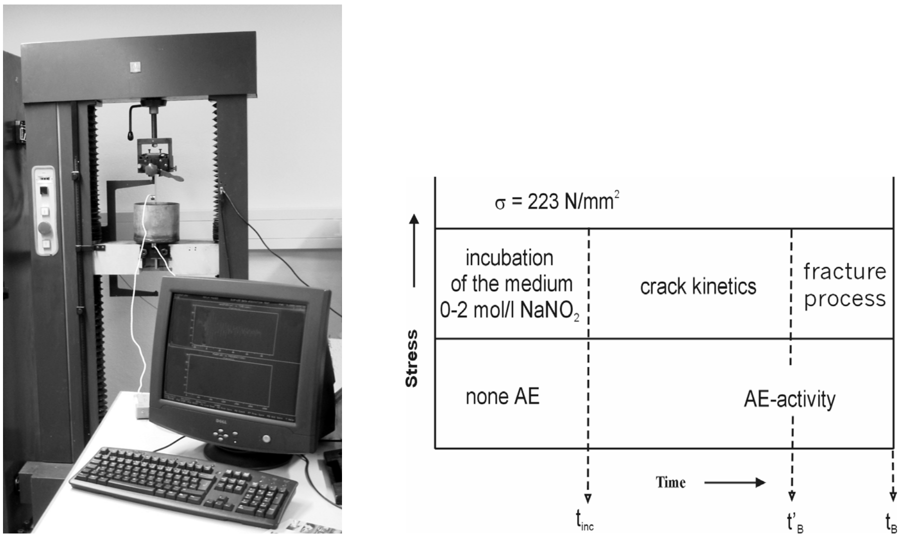


Fig. 1 Set up and experimental process

RESULTS AND DISCUSSION

The figure 2 illustrates the influence of the sodium nitrite's concentration to the time of fracture t_B and also to the incubation time corresponding to the start of the AE activity. In case of the distilled water it was observed that an incubation time of 430 hours was not enough to activate damage and to detect an acoustic emission.

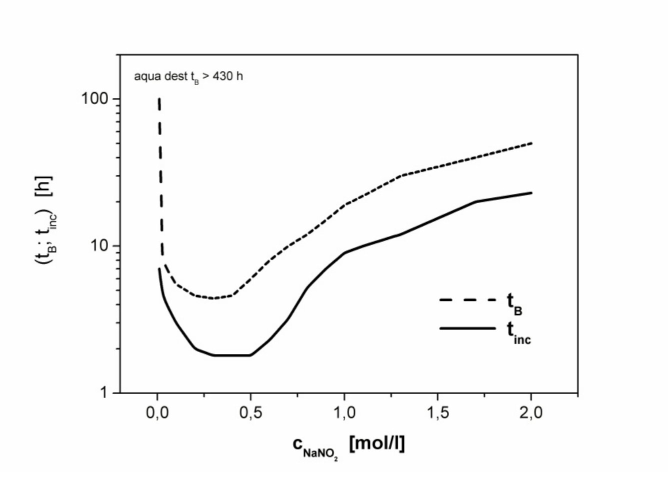


Fig. 2 Dependence of the time of fracture and the time of AE activity on the concentration of $NaNO_2$ during a CLT of CuZn37

However a concentration of 0.2-0.4 mol/l $NaNO_2$ solution reduced the lifetime to 4 – 5 hours. The AE activity started between 1.6 to 2 hours. After an increasing of the $NaNO_2$ concentration the lifetime again rose and reached a value of 50 hours at 2 mol/l $NaNO_2$. An enhanced AE activity was detected after 23 hours.
The figure 3 and 4 illustrate the absolute continuous increasing of time of enhanced AE activity with the increasing of the $NaNO_2$ concentration, but in relation to the lifetime time of the AE activity reached a constant level at 60%.

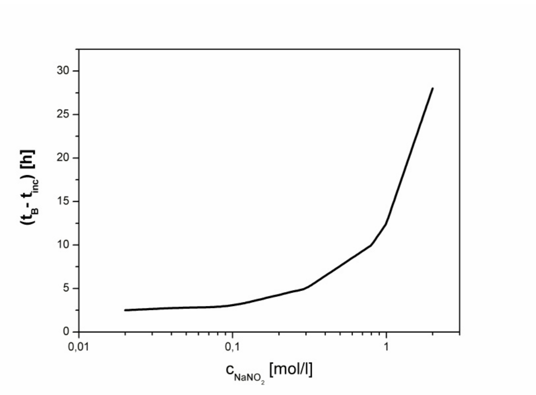


Fig. 3 Time of enhanced AE activity in correspondence of the concentration of $NaNO_2$ during a CLT of CuZn37

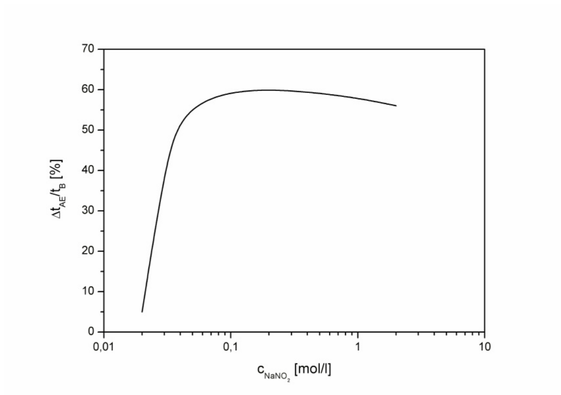


Fig. 4 Relation between the time of AE activity and the fracture time over the concentration of $NaNO_2$

The time dependence of the acoustic emission represented by the cumulative counts and hits during the CLT under different concentrations of $NaNO_2$ is given in figure 5 and 6.

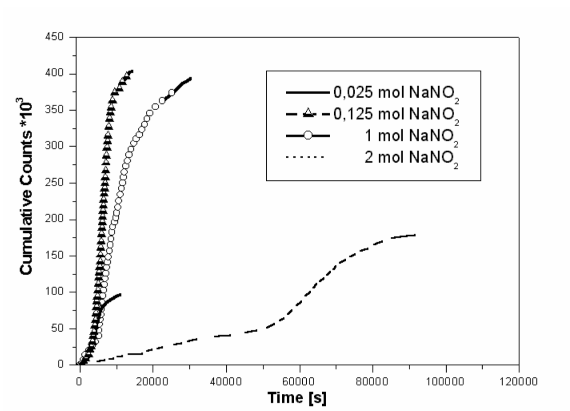


Fig. 5 Cumulative counts of AE signals during a CLT for CuZn37 in different concentrations of $NaNO_2$

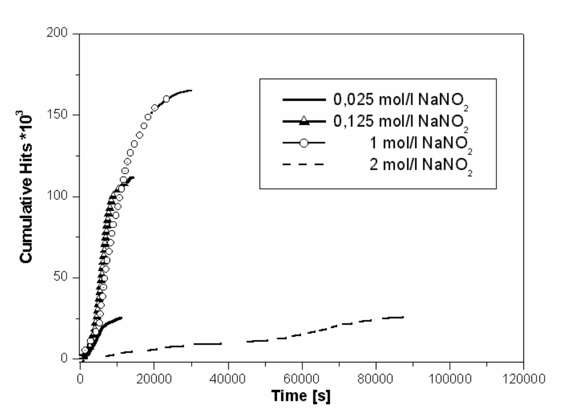
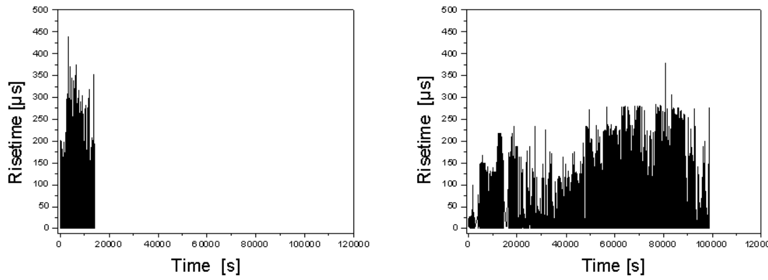
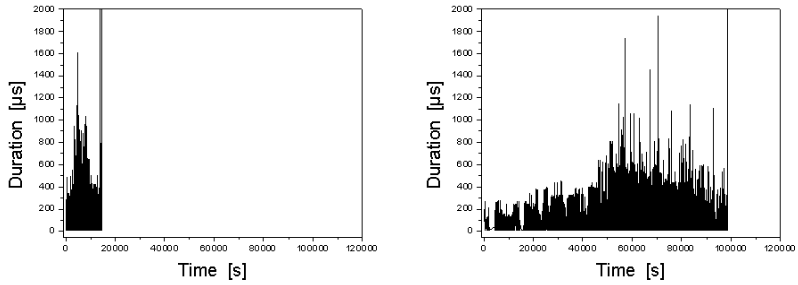


Fig. 6 Cumulative hits of AE signals during a CLT for CuZn37 in different concentrations of $NaNO_2$

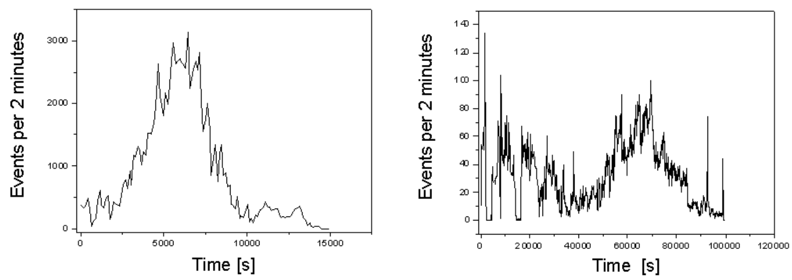
Two different crack kinetics could be observed. In the range of a concentration of 2 mol/l $NaNO_2$ a protective layer was created. The figure 7 presents an analysis of AE parameters of CLT in a solution of 0.125 mol/l $NaNO_2$ and 2 mol/l. The rise time and the duration of the acoustic signal show depending on the concentration a different time characteristic. Also, the absolute energy, the frequency and the hits per 2 minutes describe a characteristical acoustic emission signature function and in principle the initiation and propagation of the stress corrosion cracks up to the fracture. Thus the process can be better understood and a study of the dissolution of the protective layer created at a concentration around 2 mol/l $NaNO_2$ is possible.



a)



b)



c)

Fig. 7 Comparison of the AE parameters risetime (a), duration (b) and the distribution of the AE events (c) of a CLT between 0.125 mol/l $NaNO_2$ (left) and 2 mol/l $NaNO_2$ (right) starting after the incubation time

The influence of the blends of 1,2,3-BTA-inhibitor (type Cobratec 939) was very interesting. A minimal addition of 0.001 % Cobratec 939 in 0.25 mol/l $NaNO_2$ solution was extended the lifetime by a factor of 4.5. The incubation time was increased by eight times. It is caused by the creation of an organic film. The figures 8 and 9 present two examples for the change of the crack kinetics due to the inhibitor.

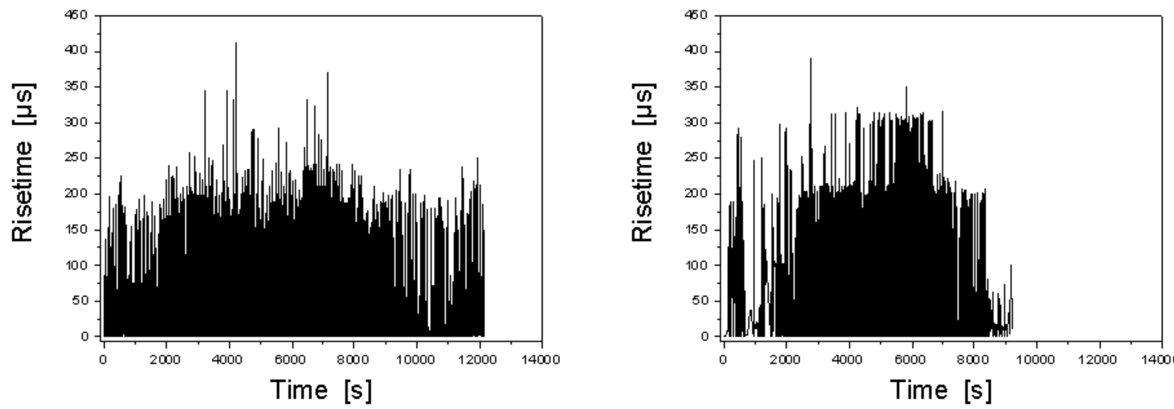


Fig. 8 Comparison of the risetime during a CLT in 0.25 mol/l $NaNO_2$ without (left) and with (right) an addition of 0.001 % BTA – blend starting after the incubation time

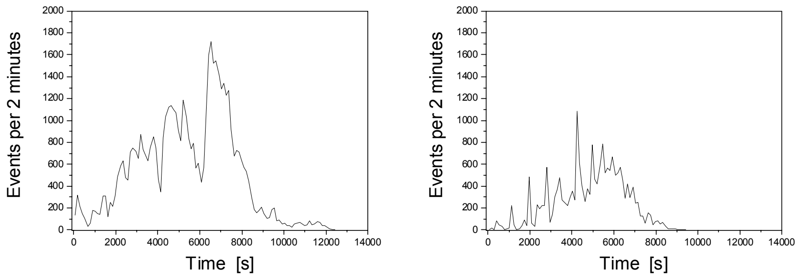


Fig. 9 Comparison of the distribution of the AE events during a CLT in 0.25 mol/l $NaNO_2$ without (left) and with (right) an addition of 0.001 % BTA – blend starting after the incubation time

The time from the crack initiation up to the fracture was reduced. The value of the rise time near the fracture was decreased, too. Also the AE activity represented by the distribution of the hit was less. The acoustic emission characteristic was changed completely by the inhibitor. In relation to the layer caused by the higher concentrated $NaNO_2$ solution the protective process of the created organic film is apparently different.

CONCLUSION

The presented results show the possibility of the acoustic emission analysis to characterize the SCC process of the brass CuZn37 in a sodium nitrite solution under electronic regulated constant load conditions. Two different mechanisms of crack kinetics depending on the concentration of $NaNO_2$ and a completely changed mechanism under the influence of the BTA inhibitor could be found.

REFERENCES

[1] U.-D. Hünicke, M. Schulz, R. Budzier, J. Eberlein, J. Acoustic Emission **20,** pp. 172-178 (2002)
[2] U.-D. Hünicke, M. Schulz, R. Budzier, Proc. DGZfP-Conf. 2002, 06.-08.05. 2002, Weimar (G)
[3] U.-D. Hünicke, M. Schulz, Proc. DGZfP-Conf. 2003, 26.-28.05. 2003, Mainz (G)
[4] B. Malki, A. Legris and D. Gorse, Corrosion Sci. **41**, pp. 1031-1035 (1999)
[5] B. Malki, A. Legris, J.-L. Pastrol, G. Lorang and D. Gorse, J. of the Electrochemical Soc. Vol. **148** No. 9, pp. B357-B367 (2001)
[6] J. Yu, R.N. Parkins, Corrosion Sci. Vol. **27**, No. 2, pp. 159-182 (1987)
[7] J. Yu, R.N. Parkins, Y. Xu, G.Thomson and G.C. Wood, Corrosion Sci. Vol. **27**, No. 2, pp. 141-157 (1987)
[8] J. Morales, P. Esarza, G.T. Fernandez, S. Gonzalez, J.E. Garcia, J. Ceaceras, R.C. Salvarezza and A.J. Arvia, Corrosion Sci. Vol. **37**, No. 2, pp. 211-229 (1995)
[9] R.N. Parkins, N.J.H. Holroyd, Corrosion Vol. **38**, No.5, pp. 145-255 (1982)
[10] G. T. Burstein, G, Gao, J. Electrochem. Soc. Vol. **141**, No. 4, pp.912-921 (1994)
[11] R.B. Rebak, R.M. Carranza and J.R. Galvele, Corrosion Sci. Vol. **28**, No 11, pp. 1089-1106 (1988)
[12] R.M. Carranza and J.R. Galvele, Corrosion Sci. Vol. **28**, No3, pp. 233-249 (1988)
[13] S.M. Sayed, E.A. Ashour and B. G. Ateya, Corrosion Sci. Vol. **36**, No.2, pp. 221-230 (1994)
[14] E.A. Ashour and B.G. Ateya, Corrosion Sci. Vol. **37**, No. 3, pp. 371-380 (1995)
[15] L. Tommesani, E. Brunoro, A. Frignani, C. Monticelli, M. Dal Colle, Corrosion Sci. Vol. **39,** No. 7, pp. 1221-1238 (1997).