ACOUSTIC EMISSION STUDIES ON ENVIRONMENTAL CRACKING IN BRASSES

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ABSTRACT

Acoustic emission signals during the cracking of alpha and alpha-beta brass cup specimens in mercurous nitrate solution, liquid mercury and ammoniacal solution have been recorded as root-mean-square, V_{RMS}, of the AE signals versus time plots. Both low and high level AE signals are detected during the initiation and propagation of cracks. In different environments the plots have displayed characteristic patterns. The observed difference in AE signals have been utilised to explain the difference in cracking mechanism of brass in these three media.

KEY WORDS

Acoustic emission ; stress corrosion cracking ; mercury cracking; brass.

INTRODUCTION

A material undergoing crack growth both generates and transmits a signal (acoustic emission) which can be detected by suitable instrumentation and whose source can be located by using seismic techniques. Kaiser (1953) reported first comprehensive investigation of acoustic emission (AE). In the sixties the use of acoustic emission as a non-destructive inspection technique developed in the United States for the inspection of welded structures.

The association of a brittle fracture step in the mechanism of stress corrosion cracking led some investigators (Van Rooyen, 1960; Pardue, Beck and Fontana, 1961) to detect any sound generated during cracking. Pardue, Beck and Fontana (1961) reported that acoustic emissions were produced only in the case of transgranular failure and not during an intergranular failure and emphasized on a difference in mechanism in these two types of failure. Hartbower and co-workers(1972) detected the crack initiation through acoustic emission studies in high strength steels and titanium. Okada, Yukawa and Tamma (1976) reported of a correlation of acoustic emission counts and fractographic detection of quasi-cleavage crack in high strength steels in boiling nitrate solutions. Pugh and co-workers(1975,1977) reported the evidence for the discontinuous nature of the growth of single cracks in Mg-Al and admiralty metal from acoustic emission studies. They found discrete acoustic emission signals and calculated the crack velocities from crack advance distance and average time interval between discrete emissions, which showed reasonable agreement with the values of crack velocities determined by direct experiment. Bentley(1976) reported on acoustic emission from stress corrosion cracking in 316 stainless steel.

De Michelis, Farina and Sala (1981) made use of the application of acoustic emission in the study of kinetics of fracture of brass in mercurous nitrate solution. They detected both low and high level AE signals during fracture nucleation and progress and some characteristic patterns of acoustic activity were recognised and correlated to specific stages of the fracture process.

The literature shows that, though limited in number, the application of acoustic emission technique has been made with diversified aims in the field of environmental cracking of metals. The work of De Michelis and colleagues (1981) is very significant in that it correlates the acoustic emission patterns to the cracking process. A material like brass is prone to various types of environmental cracking ; it shows stress corrosion cracking in ammoniacal environments and also shows stress cracking in both liquid mercury as well as in mercurous nitrate solution. In an earlier paper AE technique on cracking of brasses was employed (Agrawal, Chatterjee and Sircar, 1984). The present work is an attempt to make use of the acoustic emission patterns to identify the difference in the mechanism of the cracking processes in these three environments.

EXPERIMENTAL

Alpha brass and alpha-beta brass sheets having 36% Zn and 40% Zn respectively, have been used in the present study. These were annealed at 500 C for 2 hours. Round samples of 65 mm diameter were cut from these sheets. For studies in cold-worked condition the sheets were first cold-rolled to give the requisite reduction in thickness and then the samples were cut. All the samples were subjected to deep drawing, according to the Erichsen procedure (sphere diameter of 20 mm) upto 3/4 of the maximum sag at rupture.

The cup specimens were kept horizontally over four rubber prods fixed to a wooden board in order to minimise extraneous signals. The AE transducer was acoustically coupled to a plane corner of the specimen with a thin silicon grease layer, and fixed with adhesive tape. Acquisition of the AE data started immediately after the cavity had been filled with the test solution. The plots of the root mean square of the AE signa, V_{RMS}, as a

function of time were recorded on paper, the start and end of the activity were noted. All the plots were made at a total amplification of 148 dB.

The ammoniacal solution used was one of Mattsson type(Mattsson, 1961) containing 0.08 g.atom/l of copper and 3.2 g.mole/l of NH_4^+. The mercurous nitrate solution contained 2% $HgNO_3$ with 1% HNO_3 in one litre of water. Liquid mercury used was in 0.5% zinc amalgamated state.

RESULTS

Annealed samples of both alpha and alpha-beta brass did not crack in mercurous nitrate solution. The V_{RMS} vs. time plots (Fig.1) showed absence of any signal for the initial period. The low amplitude disconnected signals appeared afterwards and continued till the AE experiments were discontinued.

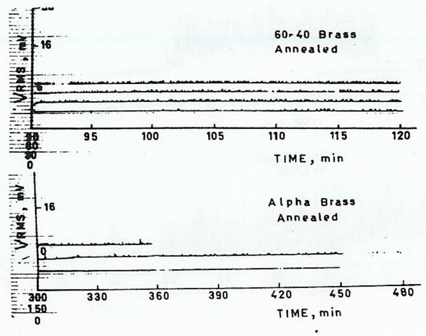

Fig.1: AE signals in $HgNO_3$ solution, for annealed brass.

In contrast to annealed samples, the cold worked samples gave cracking in $HgNO_3$ solution and the AE plots were distinctly different(Fig. 2 and Fig. 3). The onset of cracking was marked by a high amplitude peak, often accompanied by a visible crack in the sample. A number of such peaks were obtained in the plot during the course of experiment and the visible cracks, mostly radial, were also quite a few in number. In the case of alpha-beta brass (Fig. 3) these peaks occurred in close succession showing intensive AE activity in this case. The cracks were found to progress in steps during this high activity period and these were seen to be intergranular in both the cases, when viewed microscopically.

In liquid mercury, alpha brass showed no cracking either in annealed or in cold-worked condition. The alpha-beta brass also did not crack in annealed or in 15% cold-worked state, but cracking was encountered in samples cold worked above 20%. Large peaks were encountered in the V_{RMS} vs. time plots within a few

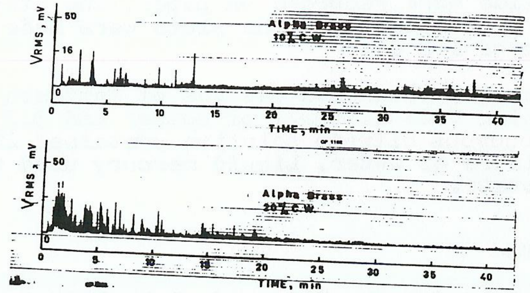

Fig. 2: AE signals for cracking of alpha brass in $HgNO_3$ soln.

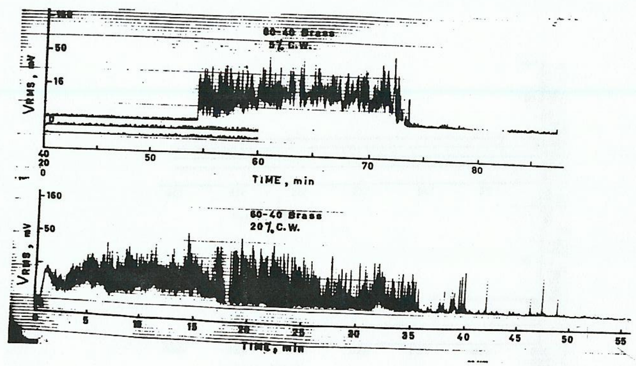

Fig. 3: AE signals for cracking of alpha-beta brass in $HgNO_3$ solution.

seconds to 5 minutes' exposure (Fig. 4). The cracks were immediately visible and their propagation was instantaneous. The peaks observed in these cases were much higher compared to those observed in $HgNO_3$ solution and their number was also less. The range of intense activity showing successive peaks were also absent in this medium. The cracking was intergranular in this case as well.

In Mattsson solution, annealed and 20% cold worked samples were used, which gave cracking in this medium, but acoustic signals were low as can be seen from Figs. 5 and 6. The cracks were observed with the onset of AE activity and the AE signals were maintained even after 10 hours with the simultaneous growth of visible cracks. Although the AE signals were similar in alpha and alpha-beta brasses, the cracking the former was intergranular and in the latter it was transgranular.

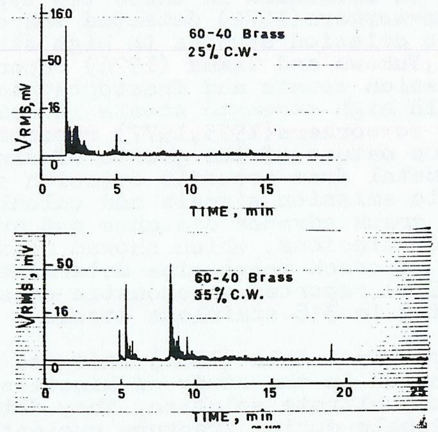

Fig. 4: AE signals for cracking of α-β brass in liquid mercury

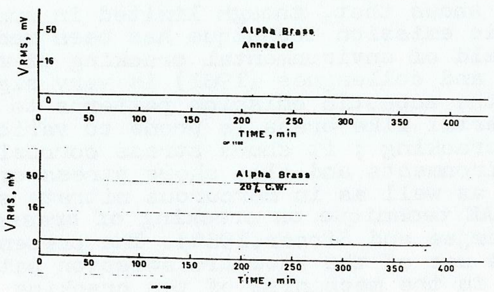

Fig. 5: AE signals for corrosion cracking of alpha brass in Mattsson soln.

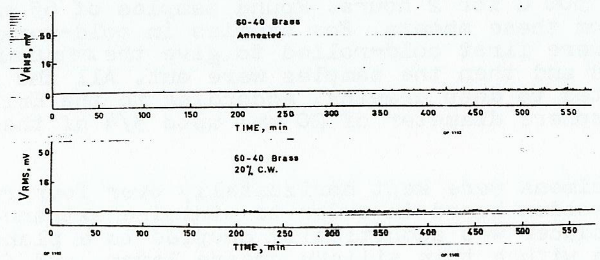

Fig. 6: AE signals for stress corrosion cracking of alpha-beta brass in Mattsson solution.

DISCUSSION

The results show that, in general, the onset of cracking can be identified with the appearance of a peak in the plot, which is an outcome of acoustic energy release during the cracking process. The process itself varies from system to system so that the height of the peaks and their subsequent occurrence in the plot have varied widely in the three systems studied.

The picture of the cracking process of brass in $HgNO_3$ solution, as has been derived from its response to external polarisation (Agrawal,1984), is one of electrochemically initiated cracks propagating through the penetration of cemented mercury whereas in liquid mercury the plastic deformation of metal has been visualised to facilitate mercury interaction at certain sites to initiate a crack, which propagates in a brittle manner as a result of mercury penetration. Both the initiation and propagation stages of stress corrosion cracking of alpha brass in ammoniacal solution, on the other hand, have been shown(Sircar,Chatterjee and Sherbini,1978) to be electrochemical in nature. These proposed models get support from the acoustic emission signals observed in the present study.

In $HgNO_3$ solution, the high amplitude peaks and their closed occurrence are indicative of crack formation at multiple sites of attack. The extension of each crack is limited by the relaxation of the local stress and a fresh crack starts thereafter.It is also probable that the sucking in of the solution, which is less viscous than the cemented mercury, inside the growing crack prevents the mercury to reach the crack tip and consequently the crack is halted. The complex stress in cup samples, however, provides numerous sites for a fresh crack to start and this process is repeated so long as the magnitude of stress is high enough to sustain a crack growth. As a result, multiple peaks in close association have been observed. However, the peak height in such case is much less than in liquid mercury because of release of much less acoustic energy.

In the case of cracking in liquid mercury, on the other hand, peaks of higher amplitudes have been encountered. They are,nevertheless, discrete and fewer compared to those in $HgNO_3$ solution. The visual observation on progress of crack correlates well with the signals encountered, which clearly indicates the fast progress of a brittle fracture due to decohesive action of mercury penetration without any slow electrochemical step.

In Mattsson solution, the peaks observed have been of much lower amplitude, but such peaks were quite large in number. This indicates electrochemical initiation at a large number of sites, similar to the situation as in $HgNO_3$ solution, but the propagation stage being electrochemical, large acoustic emission due to a brittle fracture is absent in this case. It has been claimed by some investigators(Van Rooyen, 1960 ; Pardue, Beck and Fontana,1961) that AE signals are obtained only in the case of transgranular SCC, which is thought to involve a mechanical fracture step, but in the present study almost similar results have been obtained with alpha and alpha-beta brass giving intergranular and transgranular cracking respectively.

The low amplitude acoustic signals obtained for annealed alpha and alpha-beta brass in $HgNO_3$ solution look similar to those obtained in Mattsson solution. In the former case cracking is, however, absent, and the results appear to be somewhat confusing. It is sometimes claimed(Gerberich and Hartbower,1967; Dunegan and co-workers,1968,1971) that AE studies could well be utilised for predicting the possibility for the progress of an existing flaw as a crack and in such cases the AE signals can be registered much before the appearance of a visible crack. But in the present study, the cracks usually appeared simultaneously with the onset of AE signals. It is, however, possible that the low peaks encountered in the annealed materials in $HgNO_3$ solution are indicative of the possibility of fracture in these materials with longer exposures or at higher stresses.

CONCLUSIONS

The acoustic emission patterns encountered in the environmental cracking of brass in $HgNO_3$ solution, in liquid mercury and in ammoniacal solution are different in the three media. The observed patterns support the proposed model of mercurous nitrate cracking involving a slow electrochemical initiation step, that of stress corrosion cracking having both initiation and propagation stages as electrochemical and that of mercury cracking as a rapidly occurring brittle fracture process.

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