MECHANICALLY ASSISTED DEZINCIFICATION AND STRESS CORROSION CRACKING OF 60/40 BRASS

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Dezincification studies and slow strain rate tensile testing of annealed and cold rolled 60/40 brass were carried out in 10 N NH_4 OH. Applied elastic stresses increase dezincification from the brass, and pre-exposure to elastic stresses causes greater susceptibility to stress corrosion cracking. Plastic deformation by cold rolling increases the corrosion of the brass at low percentage reductions but the effect is reversed at higher reductions. A similar trend was found in the loss in ductility of the brass during slow strain rate tensile testing. Fracture occurs by a predominantly ductile mode. The present results suggest a major role for dezincification in the stress corrosion cracking of brasses.

Commercial brasses are susceptible to dezincification and stress corrosion cracking phenomena. There is much renewed interest <1,2> in the dezincification phenomenon because of its possible role in stress corrosion cracking of brasses. Many theories have been proposed to explain the stress corrosion cracking behaviour of brasses <3>. In tarnishing ammoniacal solutions, SCC of brasses may be accounted for by the film rupture theory which is based on the balance between the rates of anodic dissolution of the crack tip area and repassivation. The strong dependence of SCC susceptibility of α-brasses on their zinc contact in such solutions <4> is thought to be due to the influence of zinc on the repassivation kinetics of the alloy <3>. No data on this influence is available, but it has been suggested <5,6,7> that the slower repassivation kinetics observed on stress corrosion crack surface may be due to dezincification at the crack tip. Large amounts of zinc have been detected <6,8> in the tarnish film which again points to a significant role of zinc in the repassivation kinetics.

In non-tarnishing environments, SCC of brasses is thought to be due to some embrittlement <3>. The normally ductile matrix is embrittled either due to adsorption of some specific species like copper ammonium complex or hydrogen, or due to the dezincification. Forty <9> suggested that dezincification might produce a brittle zone at the crack tip which facilitates the observed discontinuous brittle fracture. The tendency of 70/30 brass to undergo SCC in concentrated ammonium hydroxide has been attributed <10> to dezincification at the base of cracks and the subsequent weakening of the matrix. A dezincification factor of 4 has been evaluated within the stress corrosion crack <10>. The great susceptibility of brasses for SC in ammonia has been attributed <11> to the ability of ammonia to form a soluble zinc species which facilitates selective removal of zinc. Crack velocity measurements<12,13> showed that SCC in α-brass occurs by preferential anodic dissolution of Zn-rich regions near the crack tip. Several recent publications suggest strain induced <1> or mechanically assisted <14> dezincification.

All these findings indicate a prominent role for dezincification in SCC of brasses. As the crack tip region in a stress corroding specimen is under severe stress concentrations and, probably, also plastic deformation, the effect of elastic stresses and plastic deformation on dezincification is of much interest. Recent work <15> on commercial and ($\alpha + \beta$) brasses in 10 N NH_4OH has shown that applied elastic stress accelerates dezincification. The effect of plastic deformation by cold rolling was much less significant, and was of a retarding nature <16>.

This paper gives correlations between stress corrosion cracking and mechanically assisted dezincification in a commercial 60/40 brass.

EXPERIMENTAL

Materials

Commercial grade 60/40 brass containing 61.10% Cu and 38.86% Zn was used for present study. The as received brass in the form of 1.6 mm thick sheet was stress-relief annealed for 1 hour at 500°C and air cooled. Few strips were then cold rolled to different degrees of reduction in thickness. All tests were conducted in 10 N NH_4 OH solution prepared from pure grade ammonia and distilled water.

Dezincification

Strips 15.5 cm long 1.3 cm wide were dead loaded in a tensometer and exposed to the ammonia solution. Periodically one mL. aliquots of the solution were taken out for chemical analysis. To evaluate dezincification from cold rolled specimens, 2 cm x 2 cm strips were completely immersed in ammonia and solution analysis carried out periodically. Copper and zinc contents of the ammonia solutions taken out were determined using an atomic absorption spectrometer. A dezincification factor was then calculated using the formula

$$\text{Dezincification factor } Z = \frac{(Zn/Cu)\ \text{Ammonia}}{(Zn/Cu)\ \text{Bulk alloy}}$$

Stress Corrosion Cracking

Stress corrosion cracking was studied by means of slow strain rate tensile tests and scanning electron fractography. Unnotched tensile specimens of guage section 2 cm x 0.5 cm were in-situ exposed to 10 N NH_4OH during tensile tests which were done at a strain rate of $1 \times 10^{-5}\ S^{-1}$ In a series of tests, the specimens were loaded to different elastic stress levels, exposed for two hours and then loaded to fracture. In another series, cold rolled specimens were exposed at zero stress for 2 hours and tested. The susceptibility to stress corrosion cracking was determined on the basis of the percentage losses in yield strength, U.T.S. and % elongation. These losses were calculated as follows:

$$\%\ \text{Loss in property} = \frac{(\text{Property})_{air} - (\text{Property})_{exp.\ condition}}{(\text{Property})_{air}}$$

Fracture surface were examined using a scanning electron microscope.

RESULTS AND DISCUSSION

Deszincification

Figure 1 shows the variation in the dezincification factor of annealed 60/40

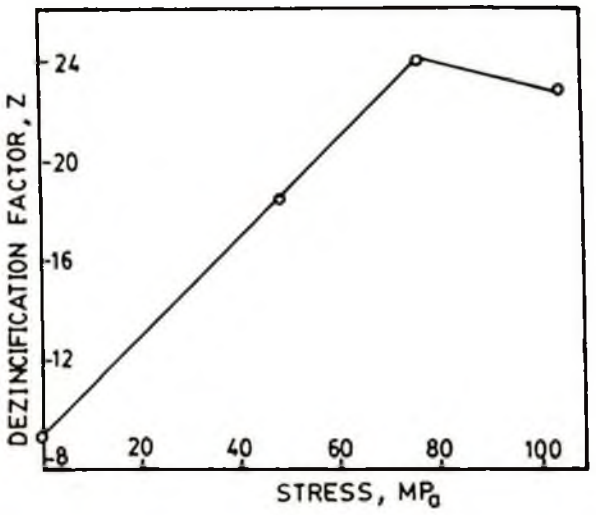


Fig. 1 Effect of applied elastic stresses on the dezincification factor.

brass as a function of applied elastic stresses. A threefold increase in Z occurs at applied stress levels below 100 MPa which is much below the 0.2% offset yield strength (152 MPa) for this material. The decrease is Z observed above 75 MPa may be due to the onset of irreversible deformation and disloaction motion which may be possible even below the yield stress <17>.

During stress corrosion cracking, stress concentrations approaching the yield stress are built up in regions well ahead of the propagating crack tip. Rresults shown in Fig.1, as well as similar results obtained for other α and $\alpha + \beta$ brasses <15> suggest that accelerated dezincification of the crack tip could occur due to this stress concentration alone. This would lead to an easier crack propagation and reduced strength and ductility for the material.

Figure 2 gives the effect of cold rolling on the dezincification factor of the brass. In contrast to the effect of elastic stresses, platic deformation by cold rolling is seen to produce a graual decrease

in the dezincification factor. Since Z is calculated on the basis of the Zn and Cu

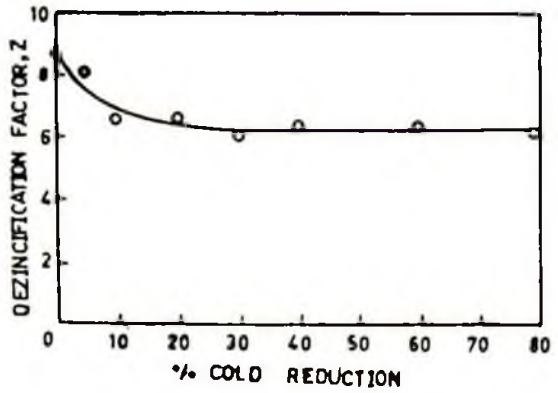


Fig. 2 Effect of percentage reduction in thickness by cold rolling on the dezincification factor.

dissolved from the brass, it is worthwhile to examine these dissolution rates as a function of cold work.

Table 1 indicates the results of atomic absorption analysis. From Table 1 it is seen that both Zn and Cu losses from the brass increase upto 20 to 30% cold reduction. The increase in Cu dissolution rate

TABLE 1

DISSOLUTION OF Zn AND Cu FROM 60/40 BRASS
10 N NH_4 OH, 2 hr. EXPOSURE

% Cold reduction	Zn loss (mg/cm^2)	Cu loss (mg/cm^2)	Dezincification factor, Z
0 (Annealed)	0.214	0.036	8.76
5	0.213	0.040	8.08
10	0.224	0.051	6.62
20	0.241	0.055	6.58
30	0.232	0.057	6.05
40	0.216	0.052	6.28
60	0.101	0.023	6.49
79	0.079	0.019	6.22

is more than the corresponding increase in Zn dissolution and this causes the small decrease in the dezincification factor. Beyond 30% cold reduction, dissolution rates of both element decreases proportionately, so that the dezincification factor remains nearly constant, upto 79% cold reduction.

The present observation of a diminished dezincification factor with increasing plastic deformation is contrary to the general observation of a strain enhanced dealloying <1> and general corrosion <18>. However, as shown by Pickering <19> and others <1,18> only dynamic straining is effective in inducing de-alloying or enhancing corrosion rate. In this case moving dislocations may transport zinc atoms along with them to the surface, and emerging slip steps on the metal surface expose fresh material to the corrodent. Cold work or static plastic deformation used in the present study, on the other hand, may lead to minor enhancement of diffusion of atoms via dislocations, at low levels of deformations, as seen in Table 1. At higher deformations, the dense dislocation tangles formed in the alloy may trap the zinc atoms rather than enhance its diffusion. Also crystalographic texture developed at large deformations may lead to a retardation. Much slower corrosion rates in cold rolled 60/40 brass in concentrated ammonia have been reported <20> which agree with the lowered Cu and Zn losses found at higher deformations in Table 1.

Stress Corrosion Cracking

In order to see whether dezinncification results given above have any bearing on the stress corrosion behaviour of the alloy, two series of tests were carried out. In the first set, tensile speciemens were loaded to various elastic stress levels, allowed to dezincify for 2 hours and then slow strain rate tested to fracture. In the other set, tensile specimens prepared from cold rolled material (along the rolling direction) were exposed to the ammonia solution at zero stress for 2 hrs and then loaded to failure. Figures 3 and 4 give the results obtained from these series of tests. Losses in yield strength, U.T.S. and % elogation at fracture are taken as indices of stress corrosion cracking susceptibility. Fig. 3 shows that pre-exposure at elastic stress levels increase the SCC susceptibility of the brass. Losses in yield strength, tensile strength and ductility all increase with applied stress levels. Fig.4 for the cold rolled materials also show large losses in tensile ductility which is maximum for 30% reduced materials. While tensile strength remains essentially unaltered, yield strength is reduced in highly cold worked materials.

Fracture surface of the tensile tested

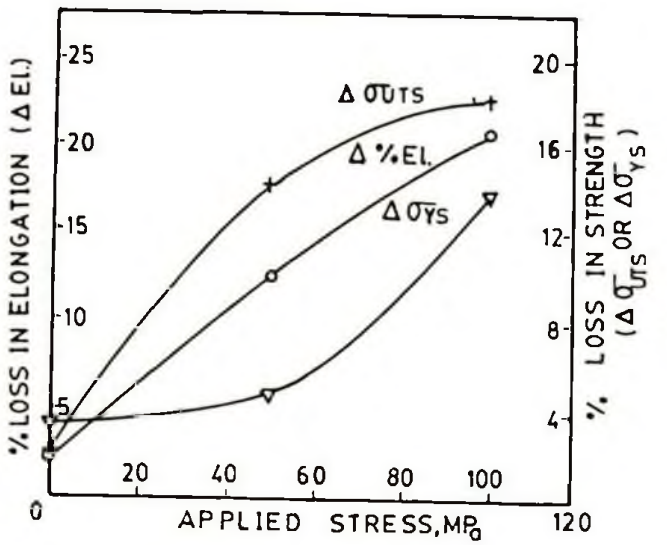


Fig.3 Effect of applied plastic stresses on the stress corrosion cracking susceptibility on the basis of % loss in tensile properties.

specimens were examined in a scanning electron microscope. The fracture mode in

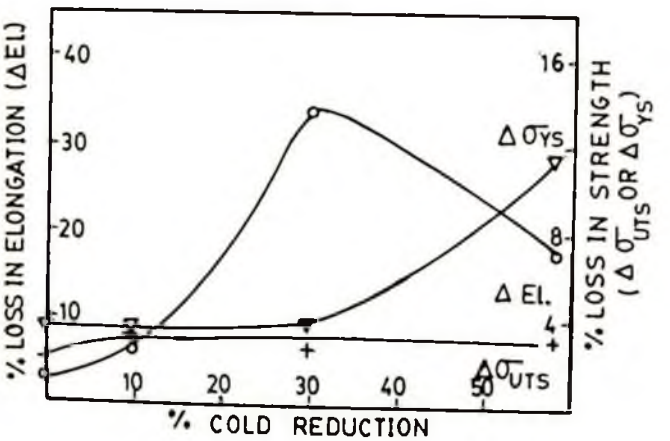


Fig. 4 Effect of plastic deformation by clod rolling on the stress corrosion susceptibility.

all cases was ductile with variation in dimple shape and size with test conditions. Large proportion of flat surfaces were seen in prestressed and cold rolled specimens.

CONCLUSIONS

From the present study the following conclusions may be drawn:

(1) Applied elastic stresses cause significant increases in the dezincification factor of 60/40 brass in 10N NH_4 OH. Along with the previous observation<15> of such effects in other α and $\alpha+\beta$ brasses, this effect suggest an accelerated dezincification ahead of a stress corrosion crack. The stress corrosion cracking tests of this study show greater susceptibility in specimens pre-exposed at elastic stress levels and support a dezincification mechanism for stress corrosion cracking.

(2) Plastic deformation by cold rolling lead, to a small decrease in the preferential dissolution of zinc at low percentage reductions, and a retardation in the general corrosion of the alloy at higher deformations. Effect of cold reduction on stress corrosion susceptibility is maximum at intermediate deformation levels and its relation with dezincification is not very clear.

(3) Slow strain rate tensile testing produces a microvoid coalescence fracture mode under all conditions. No cleavage or intergranular fractures were observed. Changes in dimple morphology results from the SCC conditions.

ACKNOWLEDGEMENTS

The authors express their thanks to Messers S.N. Lal, M. Lal, R.D. Sharma and Miss Pushpa Gupta for assistance during this work. They are grateful to the Head, Department of Metallurgical Engineering, Banaras Hindu University, for provision of facilities. This work was partially supported by CSIR under their grant-in-aid scheme 10(97)/83-EMR II.

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