Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 5 (10): 1718-1721, 2005
ISSN 1812-5654

Effect of Cathodically Hydrogen Charged on Impact Loading Behavior of Tin Brass Heat Exchanger

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Abstract: It was observed that no change in fracture mode from microvoid coalescence with hydrogen charging in tin brass tested in impact loading. However, the fracture surface of the hydrogen charged tin brass showed fine and shallow dimples, whereas further charging led to the formation of large flat facets. Moreover, the Charpy V-notch impact energy absorbed by the material is reduced by hydrogen charging.

Key words: Tin brass heat exchanger, cathodic hydrogen charging, impact loading

INTRODUCTION

Recently, there has been significant work going well beyond the traditional attention to behavior of tensile specimens and establishing the fundamental fracture phenomena in notched and pre-cracked specimens, as has been reviewed[1,2]. The same broadening of interest has also been evident with regard to hydrogen phenomena in ductile fracture, with, for example, renewed attention to hydrogen effects at notches[3]. Hirth *et al.*[4,5] performed three-point bending tests on U-notched bend bars and observed that the strain for void initiation was reduced in the precharged specimens and that notch curvature had no effect on the critical strain for crack initiation. They concluded from these results that the main effect of hydrogen was a near-surface effect and that hydrogen promoted plastic instability along characteristic slip traces, thereby enhancing incompatibility stresses and, in turn, enhancing void initiation and growth. In addition, recent tests[6], including round tension tests, plane strain tests and three-point bending tests, have shown that depending on the supply of hydrogen to the critical region and the plastic strain state, hydrogen promotes plastic instability, as manifested in the early formation of shear bands.

The goal of this study was to clarify the effect of cathodic hydrogen charging on the ductile behaviour of tin brass using Charpy notched three-point bend specimens.

MATERIALS AND METHODS

Impact experiments were conducted on specimens cut from tin brass blank with dimensions of 55×10×10 mm. The specimens were then machined to the standard Charpy three-point bend specimen dimensions of a 45 deg. notch, 2 mm deep with 0.25 mm root radius as shown in Fig. 1. The axis of the notch was perpendicular to the original plate surface, while the specimen axis was perpendicular to the transverse. After machining the specimens were annealed to relieve residual stresses.

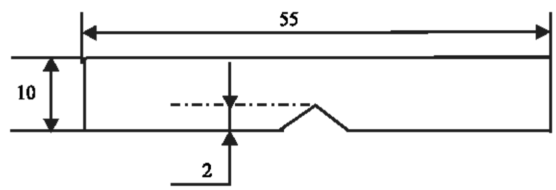

Fig. 1: Configuration of specimen used for impact load testing (dimensions in mm)

The specimens were cathodically hydrogen charged at 10 mA cm^{-2} for different times. After hydrogen charging, the specimens were tested in the Charpy three-point bend machine. The equipment had facilities for calculating the energy absorbed from the striker by the specimen. Testing was conducted at room temperature. Figure 1 shows the general arrangement for the fracture of the three-point bend experiments. Fractographic observations of specimens were made to determine the effect of cathodic charging on the fracture process. All fractographs were taken from areas near the notch. Charpy V-notch impact energy.

RESULTS AND DISCUSSION

A comparison of uncharged specimens with hydrogen charged specimens shows that cathodic hydrogen charging causes a decrease in the Charpy V-notch impact energy absorbed (Table 1), it was

Table 1: Charpy V-notch impact energies absorbed by tin brass uncharged and hydrogen charged specimens

Charging time (h)	Charpy energy (Joule)
0	22
12	20
24	19
48	17
72	16

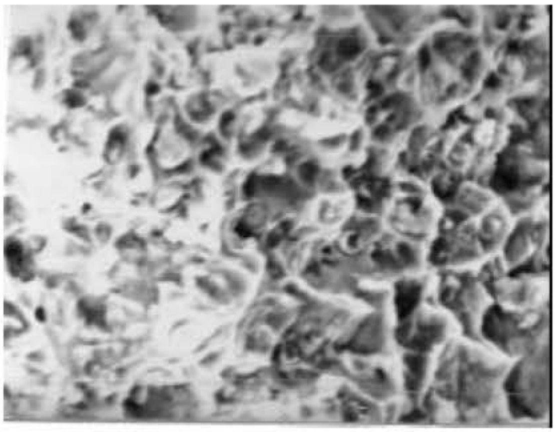

Fig. 2: Fracture surface of an uncharged tin brass specimen tested in impact loading

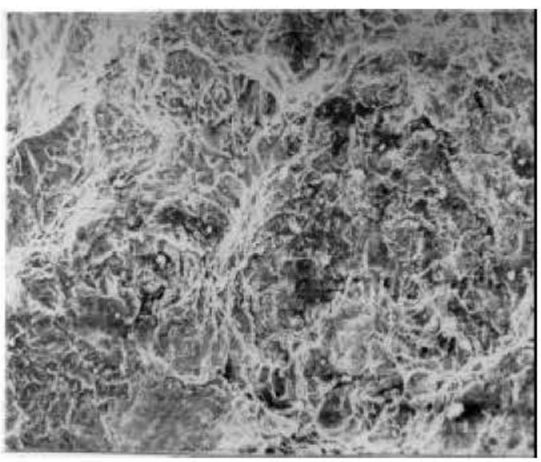

Fig. 3: Fracture surface of specimen cathodically hydrogen charged for 12 h then tested in impact loading

observed that cathodic charging of tin brass for longer times led to a more decrease in the Charpy V-notch impact energy absorbed.

Fractographic examination was conducted using SEM to determine hydrogen effects on fracture mode. The uncharged and hydrogen charged specimens fractured by impact loading showed complete ductile fracture modes. The fracture surfaces of both uncharged and charged composed of dimples resulting from a large amount of

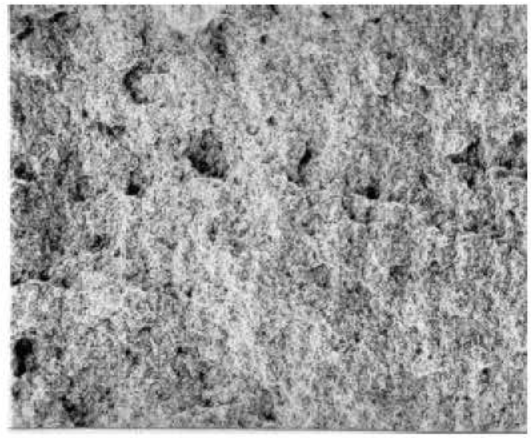

Fig. 4: Fracture surface of specimen cathodically hydrogen charged for 24 h then tested in impact loading

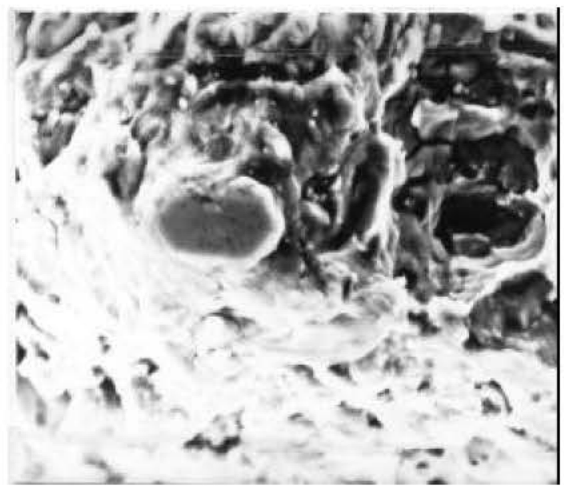

Fig. 5: Fracture surface of specimen cathodically hydrogen charged for 48 h then tested in impact loading

plastic deformation. The fractographs (Fig. 2 and 3) show a dimpled surface typical of microvoid coalescence. However, in hydrogen-charged specimens for 12 h, the dimples were smaller and shallower than in the uncharged specimens.

The fracture surface of the specimen charged for 24 h (Fig. 4) shows finer and more shallow dimples than those on the specimen charged for 12 h. It is believed that cathodic hydrogen charging for longer time provides a higher hydrogen fugacity than those for short-time charging. The fractograph of surface of a hydrogen-charged specimen for 24 h shows how the fracture surface begins to show planes of very fine dimples (Fig 4)

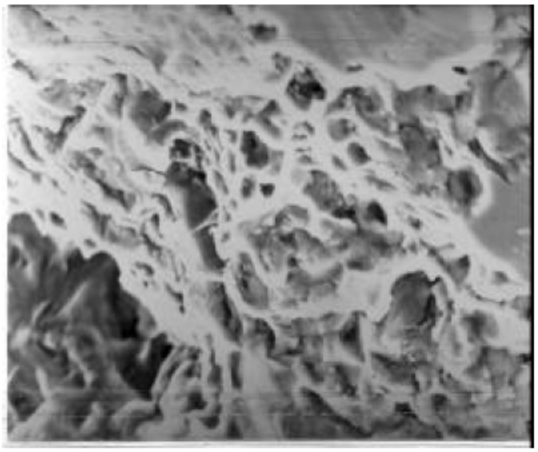

Fig. 6: Fracture surface of tin brass specimen cathodically hydrogen charged for 72 h then tested in impact loading

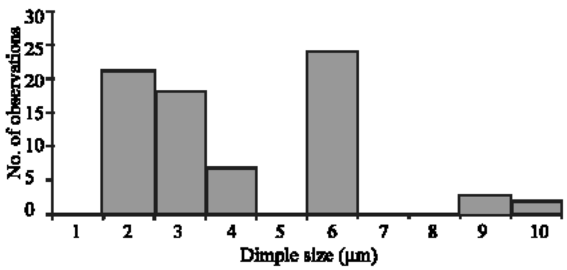

Fig. 7: Histogram of dimple sizes of uncharged tin brass specimen tested in impact loading

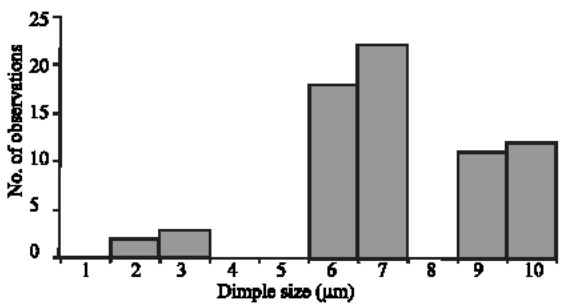

Fig. 8: Histogram of dimple sizes of tin brass specimen cathodically hydrogen charged for 12 h then tested in impact loading

suspected to have formed at grain boundaries. The fracture surface of the specimen charged for 48 h show large flat facets (Fig. 5) and the dimples had degenerated to relatively small. The flat facets are seen to be roughened by slip steps. Furthermore, the fracture surface of the specimen charged for 72 h show mixed mode of failure-intergranular and transgranular (Fig. 6).

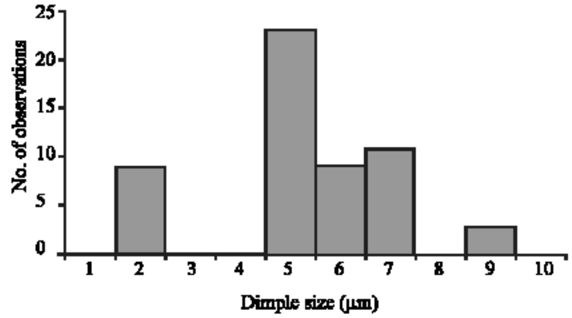

Fig. 9: Histogram of dimple sizes of tin brass specimen cathodically hydrogen charged for 24 h then tested in impact loading

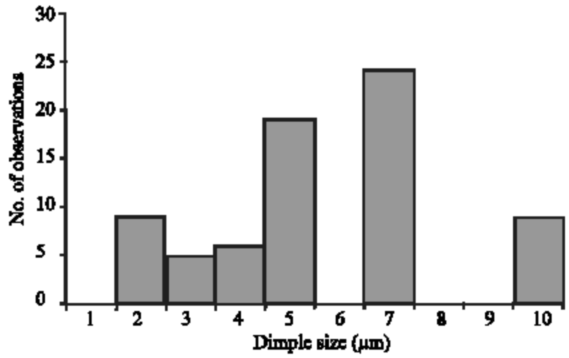

Fig. 10: Histogram of dimple sizes of tin brass specimen cathodically hydrogen charged for 48 h then tested in impact loading

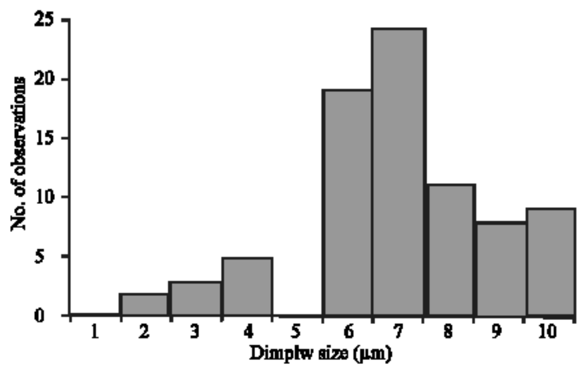

Fig. 11: Histogram of dimple sizes of tin brass specimen cathodically hydrogen charged for 72 h then tested in impact loading

The difference in dimple size between uncharged and hydrogen charged specimens was quantified by measuring 50 randomly dimples on fixed area on the surface of each specimen. Histogramm of fixed area dimple diameter of the uncharged tin brass specimen is shown in

Fig. 7. Figure 8-11 show histograms of the specimens charged for 12, 24, 48 and 72 h, respectively. It is clearly seen from the results that cathodic hydrogen charging causes a decrease the dimple size of tin brass.

CONCLUSIONS

Cathodic hydrogen charging decreased slightly the Charpy energy absorbed by tin brass specimens. The fracture surfaces of both uncharged and hydrogen charged tin brass specimens consisted of dimpled surface typical of microvoid coalescence. However, in hydrogen-charged specimens, the dimples were smaller and shallower than in the uncharged specimens.

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