THE INFLUENCE OF RESIDUAL STRESS ON THE CORROSION RESISTANCE OF H68A BRASS TUBES IN SEA WATER [1]

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ABSTRRACT

This paper reveals the morphological characteristics of the cracks formed in H68A brass tubes fully immersed in seawater, and studies the depth profiles of the residual stress of the tubes. The great residual stress in the wall results in stress-corrosion cracking, and the unique morphology of the cracks is due to the uneven distribution of residual stress through the depth of the tube.

Key words: Residual stress Corrosion resistance H68A bruss tube Seawater

1 INTRODUCTION

H68A brass tubes are widely used in many industries for their high tensile strength and low work hardening ratio. H68A tubes are thought to have applications in fresh water[1]. Immersed in natural sea water for 4 years, the parallel samples of tubes displayed considerable differences in the degree of corrosion. Most of them corroded seriously, and a number of cracks appeared on the surface, while some of them only corroded slightly. The results suggest that the residual stress of a tube plays an important role in the corrosion process. The drawing, heat-treating and straightening operations determine the level of manufacturer induced stress in the tubes. By varying the drawing, heat-treating and straightening operation, it is possible to produce tubes with either very low residual stress or yield strength level residual stress. The pattern of stress through-the-wall is also affected[2]. This paper reveals the morphological characteristics of the cracks formed in H68A tubes fully immersed in seawater. The process of formation and development of the cracks are further discussed by studying the residual stress along the depth profiles of the tubes.

1 EXPERIMENTAL MATERIALS AND METHODS

The chemical composition of H68A tubes is shown in Table 1. The tubes were provided in a half-hardened state.

Table 1 Chemical composition of H68A tubes

Cu	Zn	Fe	Pb	P
68.53%	Rem	<0.01%	0.006%	0.01%

The tubes(dia. 25) were cut into sections 35 mm in length, and then the samples with the maximum and the minimum residual stress were selected out by measuring the macro-residual stress in the sections. The samples with the maximum and the minimum residual stress are respectively № 1 and № 2.

The residual stress of H68A tubes was measured by a combination of X-ray diffraction -

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and corrosion-stripping. The X-ray diffraction method measured the change in the gap between special plane in the grain, that is, macro-residual stress was measured based on the movement of the diffraction line. In order to obtain the depth profile of the residual stress, we used the corrosion method to strip the layers one by one because X-ray diffraction can only measure the residual stress on the surface. The samples were put into a mixed acid solution after the inner walls were coated with resistant substances, so that the outer surface layers were removed one by one. The additional stress accounted for corrosion-stripping can be counted by elastic theory[3]. The residual stress was measured on a Strain Flex MSF-2M (Japan).

The specimens were from the sections, where cracks appeared on the H68A tubes immersed in the natural sea water.

3 EXPERIMENTAL RESULTS

There were a number of cracks on the outer surface of the H68A tubes which corroded seriously after immersion in seawater. Most of the cracks developed along the axial direction and some did along the circumferences, which indicates that there was large residual stress along the axes and circumferences of the tubes.

A crack in the cross transverse section of a H68A tubes immersed in seawater for 4 years is shown in Fig. 1. Except for the front of the crack being sharp, the crack was relatively wide, and becomes wider closer to the opening. Red corrosion products piled up in some parts of the crack. The front of the crack was further observed in Fig. 2. The front of the crack could be divided into three parts:

(1) A sharp part, in which no corrosion products existed;

(2) A dull part, filled with red corrosion products;

(3) A part between sharpness and dullness, which could be divided into sharp and dull portions.

Fig. 1 Micrograph of cracking of H68A tube immersed in seawater for 4 years

Fig. 2 Micrograph of cracking of H68A tube immersed in seawater for 4 years

Depth profiles of residual stress are shown in Fig. 3 and 4. The axial stress of the sample №. 1 was as high as −230 MPa on the surface, −140 MPa at a point 155 μm from the surface. There was a great change in the compressive state from the surface to a depth of 1/3 the wall thickness. The hoop stress displayed the same trend in the change of stress as the axial stress.

The axial and hoop stresses of sample №. 2 were obviously smaller than those of sample №. 1, and the degrees of change of these stresses were also smaller. Except that the axial stress on the surface was −230 MPa, both the axial and hoop stress were between ± 40 MPa and steady through the wall.

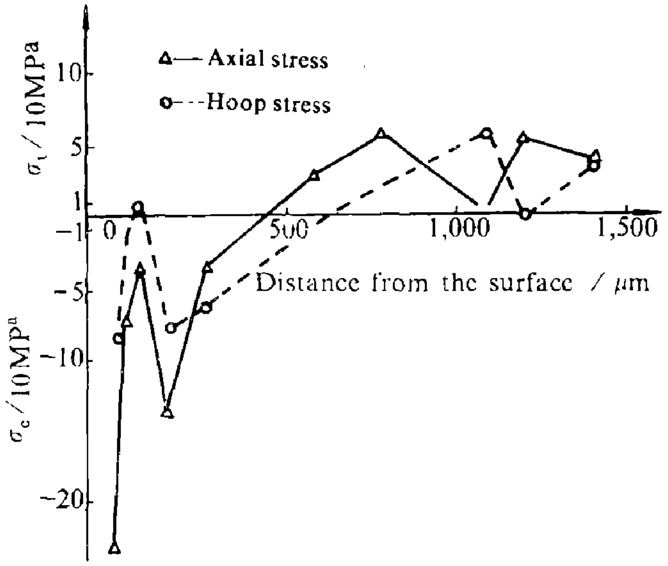

Fig. 3 Depth profiles of the residual stress of sample №. 1

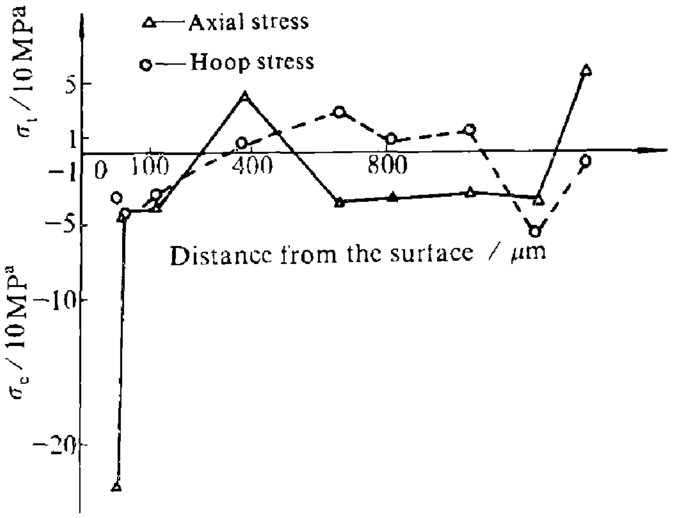

Fig. 4 Depth profiles of the residual stress of sample №. 2

In all, the two H68A tubes had very differ- ent residual stress states. For the sample №. 1, both the axial and hoop residual stresses were great in amount and in the degree of change, furthermore present in the compressive state in the outer of the wall and in the tensile state in the inner of the degree of change, and they were relatively steady through the wall of the tube. These results indicate the processing of the tubes was not strictly controlled.

4 DISCUSSION

It is important whether the H68A tubes can form a steady cuprous oxide film with exposure to seawater[1]. The residual stress could accelerate the corrosion process, influencing the formation and propagation of cracks.

The corrosion of H68A tubes with large residual stress in seawater is a kind of dissolution of metals under the stress. That is mechanical-chemical corrosion. The cracking of the surface of a tube immersed in seawater is certainly related to the large compressive residual stress in the surface layer.

Compressive stress had been generally believed not to cause stress corrosion. However, a number of studies[3] have shown that the standard electrode potential decreases with the increase of tensile or compressive residual stress, and the degree of the decrease is only related to the amount of stress. Therefore both tensile and compressive stress can cause the electrochemistry of a metal surface to be uneven, resulting in local corrosion. The uneven electrochemistry is not enough to cause stress-corrosion cracking. The cracking occurs when some combination of the unevenness in the electrochemistry and the unevenness in the distribution of residual stress appears. Once the residual stress reaches a value which can make the metal between tunnels (corrosion pitting developing deep) fracture, the crack forms. Therefore compressive residual stress can also produce corrosion cracking. The H68A tubes suffering serious corrosion in seawater had similar or greater residual stress than sample №. 1, on which a number of cracks appeared.

The unique morphology of the cracks of H68A tubes that corroded seriously in seawater is caused by the uneven distribution of residual stress. After the formation of the crack, residual stress has the same effect on the propagation of the crack as load stress. Mechanical-chemical activity is minimal where the residual stress equals zero, but with the increase of residual stress, the mechanical-chemical activity becomes greater.

Because the change in the residual stress of H68A tubes(corroded seriously in seawater) was great across the depth profile, the cracks of the tubes propagated in the following ways.

(1) In a region of large residual stress, the fracture of metals between tunnels was liable to happen due to the great mechanical-chemical activity, so that cracks went through the region quickly producing a sharp morphology;

(2) In a region of small residual stress, since the mechanical-chemical activity was low, cracks propagated slowly by crevice corrosion. In addition, dissolved copper ions obtained electrons for reduction due to the low concentrations of oxygen and hydrogen ions in the cracks. This led to the deposition of red corrosion products. Therefore the cracks developed a dull morphology;

(3) In the regions where the residual stress changed at great speed, cracks arose with both sharp and dull morphologies;

The part near the top of the crack was protected by the anodic current of the top, but the protective effect decreased as the distance from the top of the crack increased. Therefore the region near the top of crack retained its original corrosion morphology while the open part of the crack, as an anode, became wide by dissolution. This is the reason for the unique morphology of H68A tubes which corroded seriously in seawater.

H68A tubes experiencing slight corrosion in seawater had residual stress similar to sample №. 2. It is necessary to mention that annealed H68A planes immersed in seawater for 4 years had a low corrosion rate $10\mu m/y$ and the maximum depth of local corrosion was less than 0.35 mm, which shows that the H68A alloy has good corrosion resistance in quiet seawater.

5 CONCLUSION

(1) Sample №. 1 had large residual stress and great change in the residual stress through the wall of tube, while the residual stress of sample №. 2 is small and remainss steady through the wall;

(2) The great residual stress in the depth profile of the wall results in stress-corrosion cracking of H68A brass tubes;

(3) The unique morphology of cracks in H68A tubes results from the uneven distribution of residual stress in the depth profile. The cracks are sharp in region of large residual stress. In contrast, the morphology of the cracks in regions of small residual stress is dull.

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