The effect of deformation on stress corrosion of brass

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Abstract
Brass are some of the most common copper alloys, both due to its characteristics and utility technology. Corrosion fracture after stress corrosion are the most common form of destruction of brass. This is particularly dangerous because of the lack of early, visible signal of decohesion of the material. It is therefore important to know exactly this phenomenon to design and manufacture heavy loaded industrial constructions exposed to aggressive environments, as well as minimize the danger of destroying the structure. This paper presents the results of the influence of degree of plastic deformation on the stress corrosion of brass M63 grade. Material for the study were subjected to varying degrees of deformation. Research was conducted in the corrosive sea water environment. The tests were performed based on the method of BF, Brown beam test. Analyzing the results of stress corrosion tests it was found that the greater degree of deformation cause the greater resistance to stress corrosion fracture of this material. The paper also contains a characteristic scanning surfaces investigation of exemplary samples after stress corrosion tests.

Keywords: plastic, deformation, stress corrosion, brass, turning fatigue

1. Introduction
Destruction of brass due to corrosion are mainly the results of dezincification, pitting corrosion and stress corrosion. Fracture of brass depends on their chemical composition, and especially the content of zinc in chemical composition. Single-phase brass in contact with NH3 and under the influence of tensile stress with presence of oxygen or other depolarizators are cracking along the grain boundaries (intergranular corrosion). Intracrystalline cracking occurs when the alloy was subjected to cold treatment of significant plastic deformation.

Brass with a high content of zinc (45-50%) have microstructure β or β + γ and undergo stress corrosion cracking along the grain boundaries or through grains. This mechanism differs from observed in the α-brass (single phase) [1, 2].

Susceptibility of brass to stress corrosion can be reduced in whole or in part by the use of the following methods:
1. Stress relieving. In the case of brass containing approximately 30% of Zn applied in the annealing temperature of 300°C, which increases the resistance to fracture, without significant changes in physical properties
2. Avoid contact of alloy with NH3 and solutions containing NaCl and HCl.
3. Cathodes protection. In cathodes protection forced flow of current, or the cover of protector metal on the brass alloy (zinc example) are use.
4. The use of H2S as an inhibitor. The mechanism of protection may be (in this case) related to the response that is in the solution of free oxygen.
2. Purpose and Methodology of Research

The purpose of this study was to investigate the conduct of stress corrosion that occurs in single-phase brass M63 grade and to investigate the influence of the degree of plastic deformation on stress corrosion fracture.

After the designation of research material, it were made the test specimens and place them different degrees of deformation. This was followed by microscopic observations both before - and after etching, to identify the structure. The next step was the initiation of fatigue micro cracks at the notch of the samples for testing stress corrosion, and executing these tests in corrosive environment. The final stage of this study was to assess the progress of corrosion of each sample and analysis corrosion fracture.

3. Material for the Study and Measurement Technique

For the testing were chosen brass CuZn37 (M63 grade), which was delivered in the form of a flat bar. Table 1 shows its chemical composition.

Table 1. The chemical composition of CuZn37

<table>
<thead>
<tr>
<th>Element</th>
<th>Cu</th>
<th>Zn</th>
<th>Fe</th>
<th>Pb</th>
<th>Sn</th>
<th>Al</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents [%]</td>
<td>63</td>
<td>37</td>
<td>0,2</td>
<td>0,3</td>
<td>0,1</td>
<td>0,03</td>
<td>0,3</td>
</tr>
</tbody>
</table>

In Table 2 tensile properties of brass M63 after annealing are shown.

Table 2. Selected mechanical properties

<table>
<thead>
<tr>
<th>Rm [MPa]</th>
<th>Re [MPa]</th>
<th>HB</th>
<th>A [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>340</td>
<td>130</td>
<td>53</td>
<td>49</td>
</tr>
</tbody>
</table>

Then, after metallographic specimen microscopic observations were carried out in a position un etching, which showed occasional presence of nonmetallic inclusions. After etching tested brass specimens had a single phase solution structure. The next stage of the study was to give the material selected stages of deformation, which specification is given below:

Specimen 1 --------- the degree of deformation 5,32 %
Specimen 2 --------- as above 12,43 %
Specimen 3 --------- as above 19,96 %
Specimen 4 --------- as above 27,50 %

Samples for corrosion testing were prepared according to Standard Test for Stress Corrosion PN-EN 7539-6 [4]. They were beam samples and were used in constant load. The dimensions of the samples were 8 x 12 x 120 mm with notch at a depth of 3 mm and the angle of aperture 45°. For each sample, the fatigue micro-crack was introduced with a length of about 2 mm. It obtain recurrent fracture conditions for each sample. Stress corrosion tests were experiment with the method developed by BF Brown, [3]. It allows to create the right conditions for intensifying the corrosion by the action of stress concentrators, which were fatigue micro-cracks with a very small degree of rounding on the top. The studies are based on measuring the beam bend as a function of time until the break of the sample or the absence of crack increase. Samples were loaded only with the arm of the equipment (about 2,14 kg). The size of which determines the values of the applied load is 60% of R 02 of tested material. As a corrosion were used 5% NaCl solution, which is equivalent to sea water.

Figure 1 shows schematic diagram to stress corrosion test (BF Brown method).

4. Test results

Based on the results of research done graphs showing the change of position sensor (bend) in function of time for all samples (Fig.2).

The above diagram clearly shows a different character of fracture in following specimens. The sample with the lowest degree of deformation (5,32%) characterized by large faults in comparison to others. Fracture of the samples with 12,43 and 27,5% degree of deformation were almost identical and if not a fault in the sample 19.96%, all three samples were similar in nature of cracking. The comparative diagram – Fig.2 - also shows that when the degree of deformation is smaller it cause higher values of arm bend. There was no elastic range in all four specimens. In order to calculate the corrosion rate in individual samples were led regression lines on the diagram summary. Then set angles and calculated their tangency which are the value of corrosion rate. The diagram shown below in Figure 3.
Fig. 2 Comparative diagram showing the change of bend of samples for different degrees of deformation

Table 3 contains the values of the angles of slope of the regression line and the tangensy of inclination angle for individual samples.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>5.32%</th>
<th>12.43%</th>
<th>19.96%</th>
<th>27.50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle α</td>
<td>66°</td>
<td>38°</td>
<td>54°</td>
<td>39°</td>
</tr>
<tr>
<td>Tg α</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Fracture rate)</td>
<td>1.69</td>
<td>0.67</td>
<td>1.13</td>
<td>0.7</td>
</tr>
</tbody>
</table>

After calculating the rate of fracture, it was observed that the highest rate of fracture characterized specimen after lowest degree of deformation and it was over 2 times larger than the other. Figure 4 and 5 shows, for example, macro photography of surface samples after the fracture.

Fig. 4 Macro photography of the breakthrough - fracture of the sample with 12,43% degree of deformation

Fig. 5 Macro photography of breakthrough - fracture of sample with 19,96% degree of deformation

In order to determine the nature and type of cracking in the samples it was made microphotography using scanning electron microscopy. Some of them, for example, are shown in Fig. 6 – 8. 
5. Summary

After corrosion tests it was found that the greater degree of deformation cause the greater resistance on stress corrosion fracture of tested brass. In the initial stage of experiments (bend as a function of time), there was not observed elastic range - characteristic of stress corrosion - which is usually a straight line.

The most sharp character of the course of corrosion cracking was observed in samples with lowest deformation of 5.32%

Stress corrosion cracking of samples of the next higher levels of deformation as follows: 12.43%, 19.96%, 27.50% had similar course. The diagram show it as form of stable, monotonic increase in bend character of specimens.

SEM observations samples surfaces after stress corrosion cracking has indicated the existence of different fractures, the nature of which was dependent on the type of fracture. Ductile fracture was characteristic for a stable, slow increase of specimen fracture, without any sudden jumps. However, fracture, which was visible with a number of slip bands was characteristic for sharp up casts and it was present in samples with lowest degree deformation.

References


