THE INFLUENCE OF PLASTIC DEFORMATION TO CORROSION OF PACKAGING SHEETS

Ing. Janka Majerníková, PhD.
prof. Ing. Emil Spišák, CSc.
Technická univerzita v Košiciach
Strojnička fakulta
Katedra technológií a materiálov
Mášiarska 74, 040 01 Košice
e-mail: jana.majernikova@tuke.sk
e-mail: emil.spisak@tuke.sk

Abstract

The tinplate has several important advantages, such as drawability, high soldering ability and corrosion resistance. Plastic and strength quality is higher because recrystallization annealing is included in the sheet production process. Some products may be either continuously annealed (CA) or batch annealed (BA). In the contribution we deal with the relation between the magnitude of plastic deformation and its influence on corrosion resistance of tinplates.

Key words: corrosion, packaging sheets, plastic deformation

INTRODUCTION

The thin steel sheets coated with tin constantly represent one of the predominant materials for packaging production. In spite of great widening of packaging made of plastics and combined materials, the packaging from steel tin sheets are characterized with own specific properties such as toughness of packaging, long lifetime and that’s why they are in terms of long-term storage of foodstuffs still unreplaceable. Within last twenty years their production went through considerable changes. In purpose to save the material the thickness of tinplates decreases, vice versa their plastic and strength properties have improved. These properties are improved because of changes in the steel production, where these sheets are produced, but also because of changes in actual production of these sheets (continual steels casting, continual annealing, batch annealing, double reduction).

Considerable changes in the production of these sheets have been caused also by the fact that tin is currently a deficit metal in the world market. Its supplies are limited, the price increases and that’s why during its production it lead to decrease of tin coating weight to tenth of weight on m2 – to present: 1 – 2 g/m2.

In present packaging industry packaging are made from steel sheets predominantly as two-piece. Most of these sheets are treated to the required shape by drawing. That puts further requests on the material in terms of plasticity. Long-term problem is the examination of plastic properties of packaging sheets by suitable tests. Nowadays we mostly use uniaxial tensile test for examination of these properties, which according to our long-term results and skills does not give a “real view” about plastic properties of packaging sheet. This test is very sensitive mainly to thin packaging sheets in the way of making samples, its roughness and accuracy. That’s why during the uniaxial tensile test of thin packaging sheets it often leads to localization of deformation already at the beginning of plastic deformation and in many cases it leads to damage of sample sooner than a whole measured part of sample is deformed. The loss of stability of plastic deformation during uniaxial tensile test is long-term problem of packaging sheets. Its causes are still not expressly established. This loss of plastic deformation stability – localization of plastic deformation to small capacity, leads into a significant reduction of thickness of protective tin layer and also into an increase of its porosity.

Therefore the protective properties of tin coating in place of plastic deformation localization expressly decrease. In the contribution we deal with the relation between the magnitude of plastic deformation and its influence on corrosion resistance of tinplates.

EXPERIMENTAL MATERIAL AND METHODS

For experiments there have been used two types of thin steel tinplates, which have been produced by different annealing process (continual annealing and batch annealing) - TH 435 CA, thickness 0.24 mm and TS 550 BA, thickness 0.16 mm.

Mechanical properties of tested tinplates have been established by uniaxial and hydraulic bulge test and they are shown in Tab. 1.

Fig. 1 shows the graphic relation between the stress and strain at hydraulic bulge test of tested material and sample after hydraulic bulge test. From the figure it is obvious that despite the material on the yield strength does not show the Luders’ deformation on the sample, after the hydraulic bulge test there are clearly noticeable slip bands and also the localization of plastic deformation.
Tab. 1 Mechanical properties of tested materials

<table>
<thead>
<tr>
<th>Tested material</th>
<th>Uniaxial tensile test</th>
<th>Hydraulic bulge test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R_e$ [MPa]</td>
<td>$R_m$ [MPa]</td>
</tr>
<tr>
<td>TH 435CA (0°)</td>
<td>472</td>
<td>451</td>
</tr>
<tr>
<td>TH 435CA (90°)</td>
<td>457</td>
<td>452</td>
</tr>
<tr>
<td>TS 550BA (0°)</td>
<td>529</td>
<td>538</td>
</tr>
<tr>
<td>TS 550BA (90°)</td>
<td>527</td>
<td>535</td>
</tr>
</tbody>
</table>

Fig. 1 The relation between the stress and strain of material TH 435 CA (left) and sample after hydraulic bulge test with slip bands (right)

RESULTS AND DISCUSSION

Samples after hydraulic bulge test have been exposed to corrosion environment influence in corrosion chamber with salt fog at the temperature 20°C. The time in corrosion environment represented the average period of three years in the real conditions and after by different plastic deformation (3%, 5%, 6% and 10%).

In Fig. 2 there are shown samples of corrosion tests. From figures it is evident that the largest impacted places are those where the localization of plastic deformation took place. Corrosive invasion after 10% of deformation is noticeable in the place of slip bands.

Fig. 2 Sheet TH 435CA after 5% (left) a 10% (right) deformation

For that reason we now deal more closely with the case of origin of the plastic deformation localization. According to the literature [1-3] these deformations can be divided into micro-, meso- and macrolevel. From the experiments we can say that the localization starts at micro level in the areas of material where the defects occur as inclusions of various kind. In this area it firstly arises to the slips in the surrounding grains by influence of tensile stress activity. If the number of impurities in certain area is bigger, it considerably decreases the cross-section of experimental sample, which transfers force, by which the tensile stress increases in certain area, which causes localization of plastic deformation in certain area. In some cases in these areas it leads to failure of experimental sample without any other plastic deformation of experimental sample (Fig. 3).

Fig. 3 Detail of plastic non-deformed parts of sample after uniaxial tensile test

In different cases the hardening in areas of local plastic deformation is such that sample starts to deform in other area and this process can repeat, which is caused by the origin of slip bands on the surface of experimental samples.

This reaction of tinplate during plastic deformation has a very negative impact on the production of metal packaging, on their subsequent...
long-term use and eventually on their lifetime. In such areas it often leads to increase of porosity of protective tin and varnish layer after drawing. If these areas are exposed to corrosive environment of filling which is in the packaging, for the longer period of time, they cause corrosion of these packaging [4].

In the Fig. 4, 5 and 6 we can see the examples of failure of meat packaging after long-term storage. In the Fig. 4 we can see a perpendicular cut that gives a view of place of corrosion failure of packaging exactly in the place of localization of deformation. In the Fig. 5 there is a view of the surface of tin sheet near the corrosion failure of the packaging. From the figures it is obvious that corrosion occurred in the place of localization of plastic deformation. In the Fig. 6 we can see that there is a corrosion failure of packaging in the place of the largest plastic deformation. These packaging has not been failure yet. But it is only a matter of time.
CONCLUSION

In the paper there have been investigated causes of plastic deformation localization of tinplates quality of TH 435 CA and TS 550 BA, continual and batch annealed, during uniaxial tensile test and hydraulic bulge stress. According to results of these tests we can say that the uniaxial tensile test is significantly more sensitive to inner defects of material, but mostly to accuracy and quality of surface of made experimental samples.

According to the metallographic analysis in the areas of failure there have been found out that the localization of plastic deformation occurs in the areas where inclusions in material do occur. This localization subsequently causes considerable decrease of protective properties of tin layer, by increasing its porosity in area of local plastic deformations. Just in these areas the corrosion of packaging made from thin steel sheets begins. To prevent corrosion is therefore possible by producing tinplates from high-purity steel which will be able to plastically deform in whole volume without formation of local plastic deformations at the beginning of the plastic deformation.

The second way of increasing of corrosive resistance of packaging made of tinplates showing localization of plastic deformation is the application of protective coatings after drawing out the cans, lids or twist caps.

References


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