CORROSION RESISTANCE OF PLASTICALLY DEFORMED STEEL SAMPLES WITH Al-Si COATING

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Abstract

The aim of the study was to determine the corrosion resistance of the plastically deformed and heat treated aluminized steel samples. It was the non-standard study, but the most important conditions have been taken from the standards. Determined corrosion weight loss (K_m), and visually identified changes on the surface being tested in various stages of research, with particular emphasis on the size of the damage, the type and quantity of the products and the uniformity of corrosion. Results were determined according to standard.

Keywords: Al-Si coatings, corrosion resistance

1. INTRODUCTION

The cost of damage caused by corrosion in highly developed countries is approx. 4 % of GDP. About 20 % of this loss can be avoided by the use of knowledge about corrosion protection. In addition to the financial losses should be special attention given to safety and service life of the construction. Corrosion tests are the basis for the prevention of corrosion. They consist mostly on the samples subjecting of natural or artificial corrosive environment, interacting chemically, electrochemically or mechanically to the tested surface [1].

Among the many methods of protection metallic materials against corrosion very important is the role of protective coatings. The most common are zinc coatings and their variants, as well as aluminum and silumin coating. Aluminized steel sheets have features that combine the advantages of steel and aluminum. The modulus of elasticity of steel is three times higher compared to pure aluminum, and the coefficient of thermal expansion of steel is about half that of aluminum. Advantages of aluminum, which are transferred to the coating of steel is: corrosion resistance, oxidation resistance and thermal conductivity up to 90 %. Steel is coated with aluminum in a continuous process in the lines similar to those used in hot-dip galvanizing. Cold-rolled steel sheets are heated and immersed in liquid aluminum or aluminum alloy with 5-8 % silicon. Dip coating has many advantages such as good adhesion, the possibility of alloying the steel by diffusion, high density and smoothness of the coating, abrasion resistance, water resistance and the possibility of automating the production process. These advantages make dip coating method better than other methods of coating [2-7].

Among the many steel products used in construction and the automotive industry is a large group of steel strips produced as aluminized. Dip aluminizing process was developed after World War I. There are two types of aluminized strips. Strips covered with pure aluminum are referred to as Type 2 [8-9] is characterized by the presence of the diffusion layer of Al-Fe between the coating and the substrate having a thickness of approx. 60 % of the coating thickness [10-22]. Due to the great fragility of the Al-Fe layer, strips have a limited ductility. The addition of the silicon in about 8-11% affects the formation of a thin diffusion layer of Al-Fe-Si, which is about 10-20 % of the total coating thickness. At the same time fine-grained structure of eutectic and hypereutectic and lowering the temperature in the aluminizing process is obtained. Reducing the thickness of the diffusion layer improves the ability of the strip coated Al-Si for metal forming. Strips with Al-Si coating are referred to as Type 1 [23-24].

Steel strips coated Al-Si are used in household appliances and in automotive industry. Exhaust system components operate in a wide temperature range. The heat treatment in a varied range of exposure has the influence (air, vacuum and neutral gases) on changes in the coating and the thickness of the intermetallic layer, the geometrical structure of the coating surface, as well as time limitations on the materials exposed to the temperature without the risk of adverse changes occurring in the coating [25].

The study aimed to verify the corrosion resistance of the steel and to compare the effect of metal forming and the heat treatment in different temperature ranges.

2. METHODOLOGY

For research were prepared samples from the steel strip DX52D+AS120. For this purpose, from the steel strip coated with Al-Si were cut five rectangular samples with dimensions 20 x 40mm. In the next step 5 samples was heat treated in a laboratory chamber furnace according to the following temperature ranges and times:

1. T = 300 °C, t = 180 min.

2. T = 500 °C, t = 180 min.

3. T = 600 °C, t = 30 min.

4. T = 700 °C, t = 180 min.

5. T = 1000 °C, t = 15 min.

The sixth was a reference sample, has not been subjected heat treatment.

Next thermally treated samples were subjected to plastic deformation by stamping, according to the following process parameters:

- diameter of the disc D = 60 mm,
- filet radius of the die r_m = 5 rm,
- die diameter d_m = 35.5 mm,
- punch diameter d_s = 30 mm,
- filet radius stamp r_s = 4 rm.

After stamping, draw piece cut in half, and the edges secured with oil paint. The area on both sides of the half draw piece was s 28.26 cm^2. The samples were degreased in an ultrasonic bath and purified.

The samples were then subjected to the corrosion test. The study consisted cyclical immersing the samples in a solution of snow mud. Aggressive components of the snow mud were mainly salt, pollution from vehicle exhaust and sand. After removing samples from a corrosive environment they maintained at a wet state while allowing free air drying. The immersion times, removing and total duration of samples were subsequently 4 h, 20 h and 36 days. The study was divided into 3 twelve days stages, after which the inspection was performed, quantitative measurements and photographic documentation.

Method of evaluating the degree of corrosion was a comparison of samples weights before and after each stage of the corrosion test, measured on an analytical balance with an accuracy of 10^{-4} g. In addition, the average layer thickness before and after the test was identified.

The average change in coating thickness determined from the formula (1):

$$K_1' = \Delta l/2 \qquad (1)$$

where: $\Delta l = l_n - l_0$

l_1 - sample mass before the test [g]

I'_1 - weight of sample after the n-th stage and removal of the corrosion products [g]

Individual corrosion increase in weight (K_m), expressed in g/cm^2 was calculated using the formula (2):

$$K_m = \Delta m / A \quad (2)$$

where: $\Delta m = m_n - m_0$

m_0 - sample mass before the test [g]

m_n - weight of sample after the n-th stage and removal of the corrosion products [g]

A - area of the sample [cm^2]

3. RESULTS AND DISCUSSION

Pictures of the samples with and without heat-treated and stamping and after corrosion tests are shown in **Table 1.**

Table 1 Samples with and without heat-treated and stamping, and after corrosion tests

Heat treatment [°C / min]	Before corrosion test	I step of the corrosion test	II step of the corrosion test	III step of the corrosion test
-				
300 / 180				
500 / 180				
600 / 30				
700 / 180				
1000 / 15				

The first corrosion change appeared after the first phase. After removing the samples from the corrosive environment occurred sharp increase in the concentration of aggressive components of the solution. To 24 day of the test process occurred fastest, after which the corrosion products formed on the samples surface protective layer. The samples heat treated at 300 °C were not corroded due to the undamaged Al-Si layer.

Figure 1 shows points of measurement of the samples coating thickness subjected to the corrosion test.

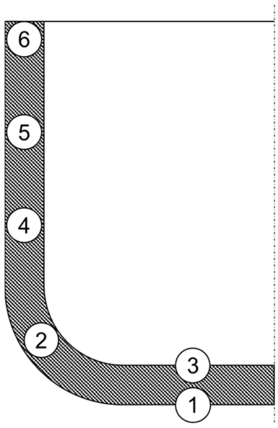

Figure 1 Points of measuring the coating thickness

Figure 2 shows a comparison of the average coating thickness after the corrosion tests measured at different points.

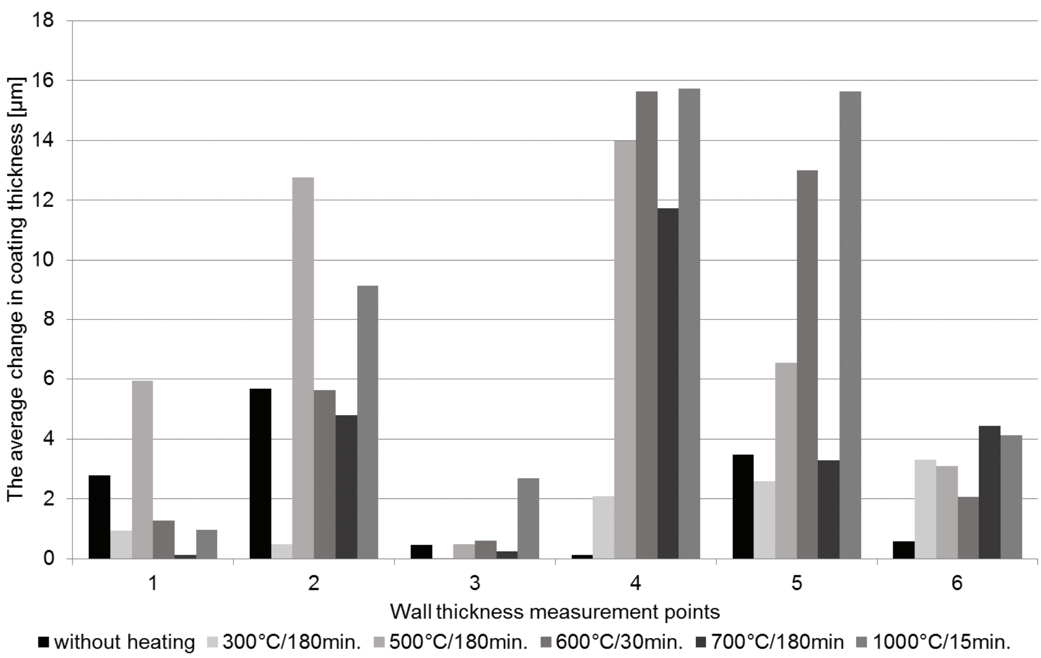

Figure 2 The average thickness of the coating after corrosion tests

The mass of the samples heat treated at 300 °C increased, but could contribute to this residue deposits from solutions. Unit corrosive increments increase for not heat treated and heat treated at 300 °C was respectively 0.00099 and 0.00161 g / cm^2. The sample heated at 500 °C had significantly damaged coating and corrosion products was spread from the exposed area and over time also overlap on the Al-Si coating.

Figure 3 shows a comparison of unit corrosive increments.

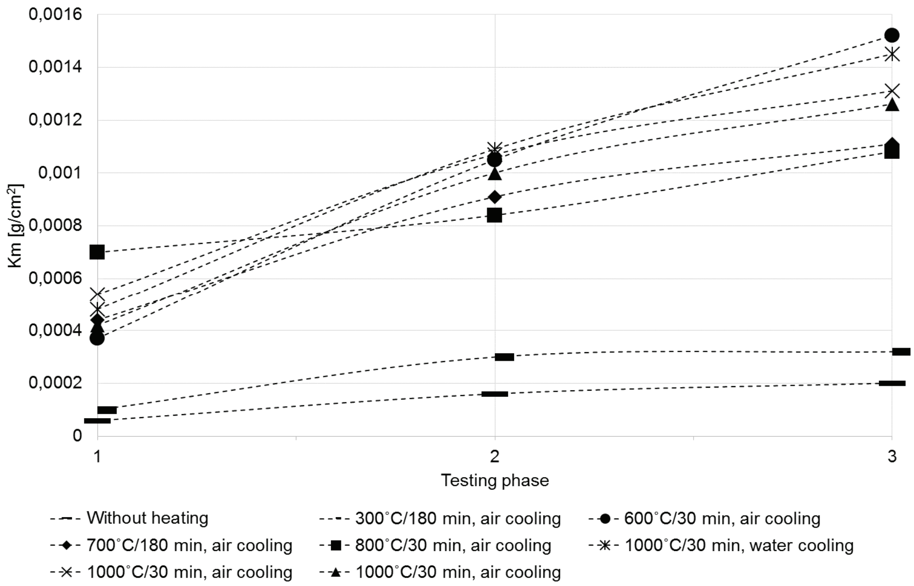

Figure 3 Unit corrosive increments after each of the stages of testing

In areas where the wall thickness was thinnest (thinner space by pressing), and the protective coating (Al-Si) was the thinnest corrosion followed quickly and most intensively.

4. CONCLUSION

Based on the corrosion study of the aluminized steel strips DX52D+AS120 and analyzing the results put forward the following conclusions:

1) Heat treatment parameters, e.g. time and temperature have a negative influence on the corrosion resistance in aggressive environments. Material subjected to heat treatment at very high temperature is not resistant to corrosion in the snow mud.
2) After heat treatment at temperatures of approx. 600 °C samples surface showed strong matting, darkening and cracks of the protective coating.
3) Stamping heat treated discs resulting in the destruction of the protective coat in the form of cracks; destruction intensified with increasing heat treatment temperature.
4) Discs stamping caused variations in coating thickness in the different zones of the samples, and consequently reduced the corrosion resistance in this areas.
5) Corrosion resistance of aluminized steel in the environment of snow mud decreased with increasing annealing temperature. The samples treated at very high temperatures quickly covered by intense corrosion products.

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