CORROSION OF S235JR STEEL IN NACl ENVIRONMENT AT 3 °C

LIPIŃSKI Tomasz

1University of Warmia and Mazury in Olsztyn, The Faculty of Technical Sciences, Olsztyn, Poland, EU
tomaszlipski.tl@gmail.com

Abstract

Steel S235JR is one of the most popular structural material using on welding constructions. The microstructure of this steel consists of two phases: ferrite and perlite. This is the reason for this steel's low resistance to a number of aggressive environments. Despite this weakness, this steel is widely used in industry. The reason for its popularity is relatively low price and ease of joining in the process of manufacturing welded constructions. S235JR steel is often used in construction works in the NaCl environment. The corrosive processes occurring in the sodium chloride environment depend on the concentration and the state of the environment. A lot of papers showing corrosion processes in this environment use NaCl as an aerosol. Industry also needs information on the corrosion resistance of this steel in aqueous solution of NaCl. The experiment was performed with low carbon S235JR (1.0038) steel designation according to EN 10025-2:2004, plate - thickness t = 5 mm. Steel was held in aqueous solution for 432 hours testing its wear every 48 hours. Corrosion tests show that tested steel in both corrosive environments are characterized through a continue corrosion. Roughness parameters for every one of research times are determined and the level of steel corrosion. Loss of weight during the steel retention process in NaCl was determined in g / m² and mm / year. The dependence of corrosion time on steel surface quality was determined.

Keywords: Steel, structural steel, corrosion, corrosion rate, roughness

1. INTRODUCTION

Low-carbon structural steels very often are uses for construction elements. For good weldability they have low contents of carbon and alloying elements. Such chemical composition provides them with a ferritic-pearlitic microstructure. Thus, in practice, the microstructure of these steels, apart from the impurities, is composed of two phases: ferrite and secondary cementite. The presence of these phases side by side causes lowering of corrosion resistance of this steel group [1-6]. The main problem with the use of these steels is their tendency to corrode. This disadvantage greatly limits their application. Corrosion not only lowers the aesthetics of the structure but also reduces its strength, which over time leads to the need for accelerated material wear [7-12].

A typical representative of this group is S235JR steel. This steel is uses inter alia for construction elements, bridges, tanks, pressure pipes, grids, reinforcing bars for concrete. Since the range of these steel applications is very wide, their working conditions are also different. One of the corrosive agents in which S235JR steels work is the aqueous NaCl solution. Variable factors of corrosion process may be: the type of solution, its concentration, electrochemical parameters, operating temperature [3, 12].

The literature gives a lot of information about corrosion steels in air with 3 % NaCl [13-16], but very little information on the corrosion structural steels in NaCl solution in water. Because of this, it was decided to conduct tests on this process. The aim of the research was to present the corrosion resistance of S235JR steel in 5, 15 and 20% aqueous NaCl solution at 3 °C.

2. MATERIALS AND METHODS

The experiment was performed with low carbon S235JR (1.0038) steel designation according to EN 10025-2:2004 [17], plate - thickness t = 5.0 mm. The microstructure of S235JR steel is composed with two phases:
the elongated ferrite phase at the background the perlite. The chemical composition of the steel is presented in Table 1.

**Table 1** Chemical composition of the S235JR steel

<table>
<thead>
<tr>
<th>Mean chemical compositions [wt. %]</th>
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<tr>
<td>C</td>
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<tr>
<td>0.19</td>
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Real mechanical properties at ambient temperature of the S355JR steel, according to EN 10025-2:2004 is presented in Table 2.

**Table 2** Mechanical properties at ambient temperature of the S235JR steel

<table>
<thead>
<tr>
<th>Mechanical properties</th>
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<tbody>
<tr>
<td>$R_{\text{eh}}$</td>
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<tr>
<td>MPa</td>
</tr>
<tr>
<td>247</td>
</tr>
</tbody>
</table>

Before experiments, the test of pieces with an area of 13 cm$^2$ (40 x 10 x 5 mm) were successively polished with emery paper to about $R_a = 0.6$ µm, next cleaned with 95 % alcohol.

The samples with ferritic-perlitic microstructure were tested according to standard dedicated for stainless steel PN EN ISO 3651-1 [10, 18-20]. Corrosion test in 5, 15 and 20 % NaCl water solution medium was tested by measurement of loss in mass (Huey test).

The corrosion rate of the S235JR steel measured in mm/year was calculated with the formula (1), but measured in g/m$^2$ were calculated with the below formula (2):

$$r_{\text{corr}} = \frac{87600 \cdot m}{S \cdot t \cdot p}$$  \hspace{1cm} (1)

$$r_{\text{cor}} = \frac{1000 \cdot m}{S \cdot t}$$  \hspace{1cm} (2)

where:

- $t$ - time of corrosion test (for each sample counted from zero) [hours],
- $S$ - surface area of the sample [cm$^2$],
- $m$ - average mass loss in corrosion process [g],
- $p$ - sample density [g / cm$^3$].

The influence of NaCl on the S355JR steel corrosion resistance was investigated using weight loss. The mass of samples were measured by Kern ALT 3104AM general laboratory precision balance with accuracy of measurement 0.0001 g. Every with measurements was repeated five times.

Profile roughness parameters were analysed according to the PN-EN 10049:2014-03 standard (Measurement of roughness average $R_a$ and peak count $R_{\text{pc}}$ on metallic flat products) by the Diavite DH5 profilometer.

3. RESULTS AND DISCUSSIONS

Exemplary profile roughness of S235JR steel is presented in Figure 1.

Arithmetical mean roughness ($R_a$) value of S235JR steel in 5, 15 and 20 % NaCl at temperature of 3 °C between 48 to 432 hours with determination of coefficient $R^2$ is presented in Figure 2.
Profile roughness of S235JR steel after corrosion tests in 20 % NaCl and time 432 hours

Figure 1

Arithmetical mean roughness ($R_a$) value of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C

Mean peak width ($R_q$) value of S235JR steel in 5, 15 and 20 % NaCl at temperature of 3 °C from 48 to 432 hours with determination of coefficient $R^2$ is presented in Figure 3.

Figure 2

Maximum peak height ($R_p$) value of S235JR steel in 5, 15 and 20 % NaCl at temperature of 3 °C from 48 to 432 hours with determination of coefficient $R^2$ is presented in Figure 4.

Figure 3

Total height of the roughness profile ($R_t$) value of S235JR steel in 5, 15 and 20 % NaCl at temperature of 3 °C from 48 to 432 hours with determination of coefficient $R^2$ is presented in Figure 5.
Figure 4 Maximum peak height ($R_p$) value of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C

Figure 5 Total height of the roughness profile ($R_t$) value of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C

Effects of corrosion time on the relative mass loss (RML) of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C from 48 to 432 hours with determination of coefficient $R^2$ is presented in Figure 6. Relative mass loss is the quotient of mass loss and initial mass expressed as a percentage.

Figure 6 Effects of corrosion time on the relative mass loss (RML) of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C

Effects of corrosion time on the corrosion rate measured in mm per year of S355JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C from 48 to 432 hours with determination of coefficient $R^2$ is presented in Figure 7.
Figure 7 Effects of corrosion time on the corrosion rate of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C

Effects of corrosion time on the corrosion rate measured in gram per m² of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C from 48 to 432 hours with determination of coefficient R² is presented in Figure 8.

Figure 8 Effects of corrosion time on the corrosion rate of S235JR steel after corrosion tests in 5, 15 and 20 % NaCl at temperature of 3 °C

4. CONCLUSION

- The results of the tests indicate that the loss of weight of S235JR steel at tested temperature are depends of time of corrosion and on temperature of environment. Its indicator is relative mass loss.
- Analyzing the course of changes in roughness, it was found that its description of the function of the first degree is statistically adequate and has a high degree of fit (R²>0.95).
- The obtained roughness curves in the first corrosion period are proportional. In the second period of corrosion, there was more and more roughness in each subsequent unit of time. For this reason, the description of the curves of the roughness as a function of the second degree is more accurate.
- Equations describing the corrosion functions expressed in mm/year and g / m² are similar. Differences depend only on their position relative to the corrosion rate expressed in different units. Therefore, choosing one of these functions for the same corrosion conditions is optional (free).
- Counted (for each sample) from zero time of corrosion test showed a reduction in corrosion rate. In this way based on the graph or equation it is possible to estimate total corrosion rate at any time, counted from the beginning of the corrosion measurement.
- By using equations describing material roughness or corrosion rate, it is possible to determine conditions for automatic control of the condition of an object.
REFERENCES


