

CORROSION EFFECT OF 20 % NaCl SOLUTION ON BASIC CARBON STRUCTURAL S235JR STEEL

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Abstract. All structural steels offer economical properties of mean strength and low corrosion resistance. There are ferritic-perlitic steels and very often used as construction materials in industrial applications. The purpose of this article is to investigate corrosion resistance using weight loss and profile roughness parameters of typical structural steel in grade S235JR in 20 % NaCl solution in distilled water. Corrosion tests show that the tested steel in both corrosive environments is characterized through continuous corrosion. Roughness parameters for every of the research times determine the size of steel corrosion.

Keywords: steel, structural steel, carbon steel, corrosion, corrosion rate, profile roughness.

Introduction

Steel is the most popular constructional material. The mechanical, physical and chemical properties of low carbon steel are under the influence of different factors, including the chemical composition and manufacturing technology. The properties and practical applications of all constructional materials, including steel, are determined mostly by their microstructure. The structural low carbon steels have a ferritic-perlitic microstructure. The percentage of each microstructure phase shapes the properties of the steel. The microstructure depends on the manufacturing technology and heat treatments of steel. Corrosion resistance is an important factor of the quality and application of structural steels [1-12].

Low-carbon steel as a construction material is also very popular. Steels from this group have wide range of industrial applications, mainly as a welded material. The microstructure and properties of these steels are still tested to improve the quality. These steels are willingly used because they are cheap and well welded. Steel structures with low-carbon structural steel can be built by welding quickly at a low price, but still the main problem is their corrosion protection [13-16].

The influence of inner structural stresses caused by the corrosion notches as well as stresses resulting from production with stresses resulting from external load plays an important role in premature destruction of the construction by formation and development of initiation cracks and cracks. Structural stresses also depend on the percentage of each phase in the microstructure and their shape. Microstructure morphology is shaped in the process of manufacturing, heat treatment and welding processes. Corrosion processes are able to extract metal atoms from the metal lattice, which atoms during the process pass to corrosion products. Corrosion causing local diffusion of metal atoms is particularly dangerous [17-25]. The problem is huge because low-carbon structural steel is sensitive to corrosion. The corrosion rate first of all depends on different environment [2; 5; 13; 20].

One of the corrosive environmental factors are chlorides. They are mainly found on the coast as an aerosol of sea water, and in large quantities in large industrial areas. Because of this structural steel has been often tested with NaCl on corrosion resistance [14; 17; 18; 24]. Having regard to the importance of the problem, this study was carried out to investigate the corrosion resistance of low carbon structural steel in 20 % NaCl water at ambient temperature.

Materials and methods

The experiment was performed on low carbon S235JR (1.0038) steel designation according to the EN 10025-2:2004 [26], plate thickness $t = 5.00$ mm. The real chemical composition of the tested steel is presented in Table 1.

Average mechanical properties at ambient temperature are presented in Table 2. The properties are according to the standard EN 10025-2:2004 [26].

Before the performed experiments, the specimens after mechanically cut off with an area of 13 cm^2 ($40 \times 10 \times 5$ mm) were successively polished with water paper to $R_a = 0.32 \text{ }\mu\text{m}$, and next cleaned with 95 % alcohol.

Table 1

Chemical composition of S235JRsteel

C	Si	Mn	P	S	Cr	Cu	Ni	N
0.19	0.22	0.90	0.03	0.04	0.03	0.02	0.02	0.01

Table 2

Mechanical properties at ambient temperature of S235JRsteel

R_{eH}	R_m	A	HB
MPa	MPa	%	HB
247	386	27	145

The samples with ferritic-perlitic microstructure were tested in accordance with the standard dedicated for stainless steel PN EN ISO 3651-1 [27], corrosive media were represented by 20 % NaCl.

The corrosion rate of S235JR steel measured in mm per year was calculated with the use of the below formula (1), measured in $\text{g}\cdot\text{m}^{-2}$ was calculated with the use the below formula (2):

$$r_{\text{corr}} = \frac{8760 \cdot m}{S \cdot t \cdot \rho}, \quad (1)$$

$$r_{\text{corr}} = \frac{10000 \cdot m}{S \cdot t}, \quad (2)$$

where t – time of soaking in a corrosive solution of 20 % NaCl water solution, h,
 S – surface area of the sample (starting value was assumed), cm^2 ,
 m – average mass loss in solution (measured as difference of initial mass and mass after corrosion time), g,
 ρ – sample density, $\text{g}\cdot\text{cm}^{-3}$.

The corrosion resistance of S235JR steel in 20 % water solution NaCl was tested using weight loss. The mass of the samples were measured by Kern ALT 3104AM digital laboratory precision scales with accuracy of measurement 0.0001 g.

Profile roughness parameters were analyzed according to the PN-EN 10049:2014-03 standard (*Measurement of roughness average R_a and peak count RPC on metallic flat products*) by the Diavite DH5 profilometer.

Results and discussion

The microstructure of raw S235JR steel is presented in Fig. 1. The effect of hot rolling on the phase orientation presents the elongated ferrite phase (white area) at the background perlite (gray area). Next, the corrosion tests in 20 % NaCl water solution at ambient temperature for time 192 hours are presented in Fig. 2.

Profile roughness parameters of S235JR steel after the corrosion tests in 20 % NaCl are presented in Fig. 4 with: R_a – arithmetical mean roughness value (μm), R_p – maximum roughness depth (μm), R_q – mean peak width (μm), R_t – total height of the roughness profile (μm) for time range: 48, 96, 144, 192, 240, 288, 336, 384 and 432 hours of soaking are presented in Fig. 5. The regression equations and correlation coefficients r are presented in (3)-(6).

$$R_a = 10^{-5}t^2 + 0.01024964 \cdot t + 1.6738 \text{ and } r = 0.9970, \quad (3)$$

$$R_q = 0.0067 \cdot t + 2.9611 \text{ and } r = 0.9912, \quad (4)$$

$$R_t = 7 \cdot 10^{-5}t^2 + 0.0012 \cdot t + 17.905 \text{ and } r = 0.9889, \quad (5)$$

$$R_p = 0.0198 \cdot t + 16.636 \text{ and } r = 0.9810. \quad (6)$$

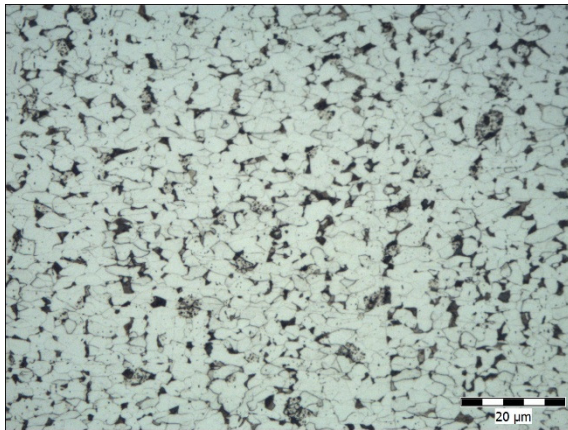


Fig. 1. Microstructure of S235JR: light etched ferrite and dark etched perlite

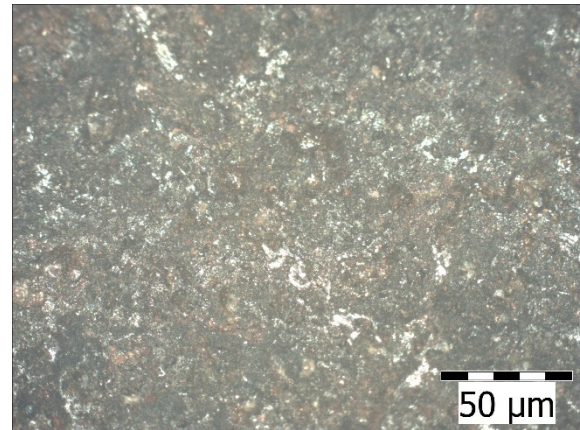


Fig. 2. Surface of S235JR after corrosion tests in 20 % NaCl water solution at ambient temperature for time 192 hours

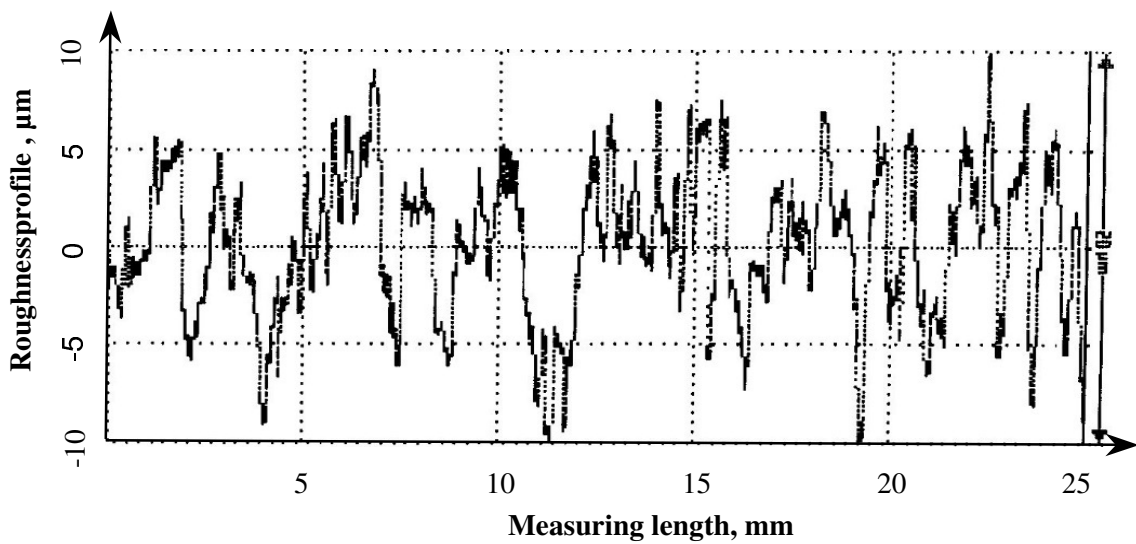


Fig. 3. Profile roughness of S235JR steel after corrosion tests in 20 % NaCl water solution at ambient temperature for time 192 hours

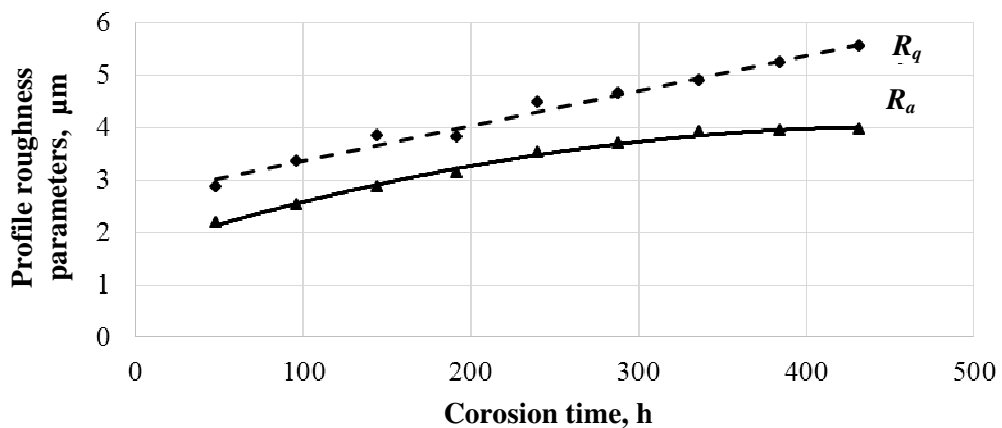


Fig. 4. Profile roughness of S235JR steel after corrosion tests in 20 % NaCl water solution at ambient temperature for different corrosion time: R_a – arithmetical mean roughness value (μm); R_q – mean peak width (μm)

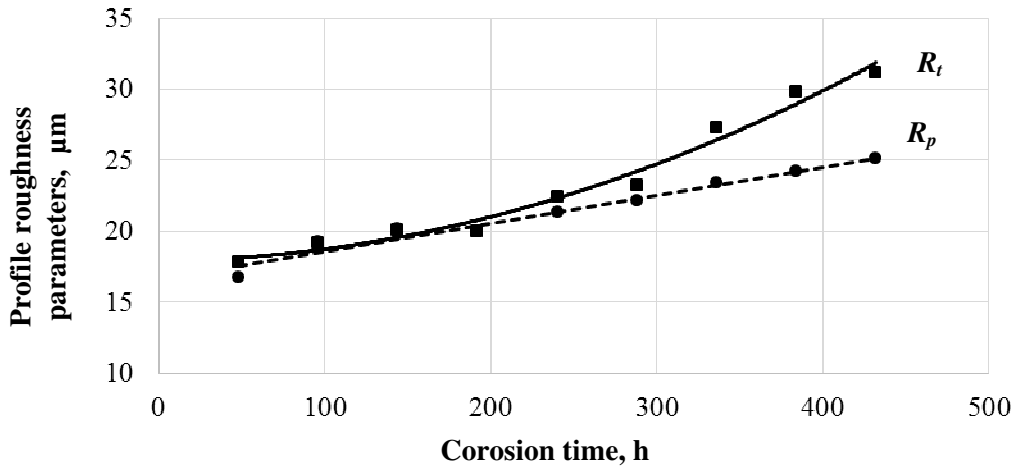


Fig. 5. Profile roughness of S235JR steel after corrosion tests in 20 % NaCl water solution at ambient temperature for different corrosion time: R_p – maximum roughness depth (μm); R_t – total height of the roughness profile (μm)

The influence of the time of soaking the S235JR structural steel in 20 % NaCl water solution at ambient temperature on the relative mass loss (RML) is presented in Fig. 6, regression equation and the correlation coefficient r in (7).

$$RML = 0.0013 \cdot t + 0.0492 \text{ and } r = 0.9995. \tag{7}$$

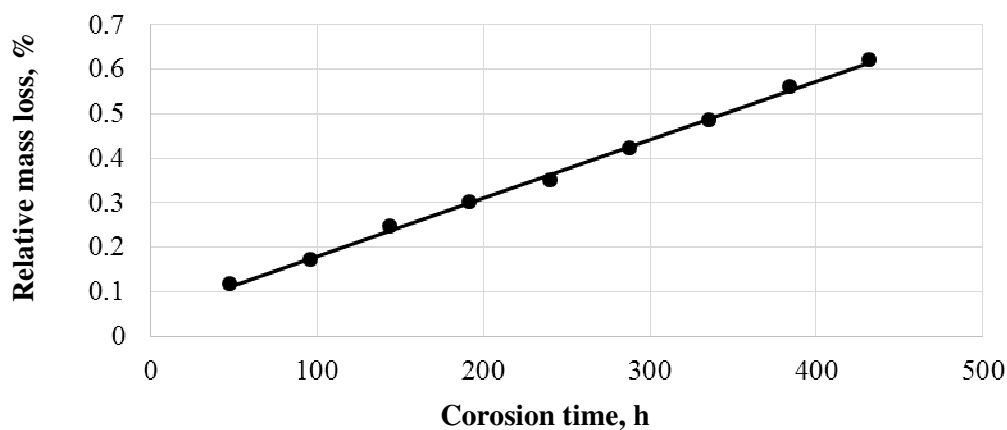


Fig. 6. Influence time on the relative mass loss (RML) at ambient temperature of S235JR structural steel of soaked in 20 % NaCl water solution

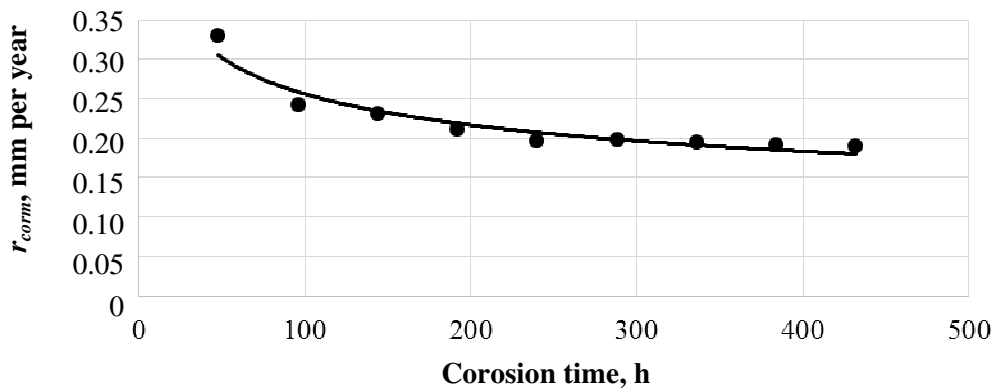


Fig. 7. Influence time of soaking S235JR structural steel in 20 % NaCl water solution at ambient temperature on the corrosion rate measured in mm per year

The influence of the time of soaking S235JR structural steel in 20 % NaCl water solution at ambient temperature on the corrosion rate measured in mm per year is presented in Fig. 7, regression equation and the correlation coefficient r in (8).

$$R_{corr} = 0.7730 \cdot t^{-0.24} \text{ and } r = 0.9624. \quad (8)$$

The influence of the time of soaking S235JR structural steel in 20 % NaCl water solution at ambient temperature on the corrosion rate measured in gram per m² is presented in Fig. 8, regression equation and the correlation coefficient r in (9).

$$R_{corr} = 0.6938 \cdot t^{-0.24} \text{ and } r = 0.9624. \quad (9)$$

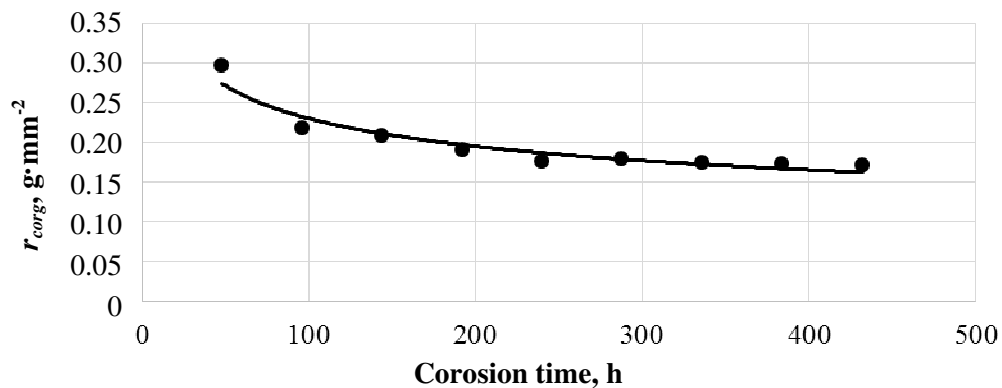


Fig. 8. Influence time of soaking S235JR structural steel in 20 % NaCl water solution at ambient temperature on the corrosion rate measured in gram per m²

Conclusions

1. The results of the research show that the weight loss of S235JR steel soaking in 20 % NaCl water solution at ambient temperature is proportional to the time of corrosion. The roughness of the sample increases, but the corrosion rate measured as a corrosion velocity decreases with time.
2. Profile roughness parameters such as R_q – mean peak width and R_p – maximum roughness depth increase linearly and with the increase of the time of the corrosion process. R_t – total height of the roughness profile increase grows in accordance with developments of the polynomial function second degree with increase of the time, while R_a parameters – arithmetical mean roughness value in the first stage of corrosion to about 350 hours intensively, but then its growth rate decreases.
3. Based on the course of the roughness profiles for each of the test times, it is possible to determine the velocity of corrosion of the test steel at any time.
4. The obtained corrosion velocity equations can be used to model the course of corrosion processes.

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