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Influence of 10% NaCl on Carbon Structural P235TR2 Steel at 25°C

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Abstract

Steels dedicated to work in a corrosive environment are corrosion-resistant steels. Nevertheless, unalloyed steels also work in corrosive environments. Low-carbon non-alloy steels are a popular construction material for pipelines. They owe their popularity to low costs and good susceptibility to welding. An example of the use of steel is pipelines for the transmission of various substances. These substances often contain sodium chlorides. Unalloyed steels are prone to surface corrosion. This type of corrosion does not pose a high risk of failure, is completely predictable and can be monitored very well by measuring the wall thickness of the pipeline with non-destructive methods. Pipelines can be placed in production halls. Unless the temperature of the flowing medium is increased (these steels are not usually used for work at reduced temperatures), their operating temperature is about 20-25oC. Taking the above into account, tests of the corrosion rate of the popular P235TR2 steel grade at 25oC were carried out. The corrosive environment was a 10% NaCl aqueous solution. Samples were taken from the tube and soaked in NaCl solution for up to 432 hours, with weight loss determined every 48 hours. It was found that P235TR2 steel has a satisfactory corrosion resistance to low concentrations of NaCl at 25oC. The nature of the corrosion process was classic and consisted of two typical stages. In the first, the steel showed high resistance to the applied corrosive environment, in the second, due to the progressive development of the surface, the corrosion rate increased at a higher rate.

Keywords: Steel; Carbon steel; Corrosion; Corrosion rate

Introduction

Steel pipelines are a type of technical construction with specific requirements. The outer walls of the pipes can easily be covered with low-cost layers and protective coatings. Their inner walls can be protected but taking into account the type and operating conditions of pipelines, such treatments are much more expensive. The medium flowing inside the pipelines can wipe the coating used to protect the walls. For this reason, constructors are more likely to use thicker walls than protective layers [1,2]. In unprotected pipelines, the factor acting on the outer walls, e.g., moist earth and the working medium (flowing medium) can create an electrochemical potential that favors electrochemical corrosion. Usually, however, measures are taken to prevent such interaction of the medium with the environment [3-8].

Pipelines work by transporting various types of media. They can be acidic, neutral or basic. Of course, the concentration of the corrosive agent in the pipeline, and therefore the aggressiveness of the environment, forces the use of a material resistant to it. A number of corrosive agents are known in industrial practice. They cause accelerated degradation of the construction material. The resistance of steel to corrosive agents depends on chemical composition of steel, its microstructure, surface quality, temperature and pressure of the corrosive medium, etc. [9-14]. Experimental data are necessary to determine the durability of a pipeline operating in specific conditions. It is difficult to extract this data from naturally operated pipelines. This would require a lot of time. Accelerated tests are used in practice. Aggressive environments with a higher degree of aggressiveness than those planned for use in reality are used in these tests. A number of research results on the corrosion of steel in various environments are known [15-21]. Based on these results, different types of corrosion were identified [22-24].

In practice, high-alloy steels, which are expensive and difficult to join, are not used for commonly used pipelines. For economic reasons, unalloyed steels are usually used. Pipelines are manufactured by welding pipe sections. The condition for good weldability of steel is low carbon content. For this reason, non-alloy steels with low carbon content are used for pipelines that do not operate in particularly aggressive environments and do not carry heavy loads. Steels from this group are a material used for many years, so they should be a well-known material. However, a dynamic development of technologies and manufacturing techniques is observed in the industry. The need to use increasing amounts of recycled materials can also be observed more and more often. The development of research techniques also enables more effective research. The available literature presents many results of research on the corrosion of low carbon steel [25-33]. The problem is the ability to compare research results with each other. Standards and guidelines used in the industry provide many ways to determine corrosion resistance. In this work, it was decided to carry out an analysis of the corrosion resistance of typical low-carbon steel used for the production of rounds in the P235TR2 steel grade at 25°C. It was decided that sodium chlorides would be the corrosion medium. These tests are a continuation of tests of this steel grade in the same corrosion medium, carried out at a temperature of 10°C [34].

Materials and Methods

The tests were carried out on P235TR2 grade steel produced in accordance with EN 10216-1 [35] with the actual chemical composition shown in Table 1.

Table 1: Chemical composition of the tested P235TR2 steel.

Chemical Elements in % by Mass								
C	Si	Mn	P	S	Cr	Mo	Ni	Cu
0.11	0.30	0.58	0.02	0.01	0.21	0.03	0.01	0.18

Test samples were taken from a seamless pipe with a diameter of 168.3mm and a wall thickness of 6.3mm. using the mechanical cutting method. After cutting out the samples with dimensions of 10 × 40mm, they were subjected to normalization annealing. The steel to be tested has a microstructure of ferrite and pearlite. In order to be able to compare it with steels dedicated to work in a corrosive environment, it was decided to carry out the analysis of the results by weight using the equations intended for determining the corrosion rate of corrosion-resistant steels (PN-EN ISO 3651-1:2004 [36]). Aggressive environment in the form of aqueous solutions of 10% NaCl was used. The tests were carried out in two repetitions. For each of them, 9 samples were used. Soaking times were used in multiples of 48 hours up to 432 hours. Mass losses of samples after cleaning were weighed with an accuracy of 0.0001g. Mass losses tested calculated with (1) and (2):

$$r_{corm} = \frac{8760 \cdot m}{S \cdot t \cdot \rho}, \qquad (1)$$

$$r_{corg} = \frac{10000 \cdot m}{S \cdot t}, \qquad (2)$$

where

t – time of treatment in a corrosive solution of 10% NaCl, hours

S – surface area of the sample, cm^2

m – average mass loss in boiling solution, g

ρ– sample density, g/cm^3.

Results and Discussion

The ferrite and pearlite microstructure P235TR2 steel after normalizing is shown in figure 1.

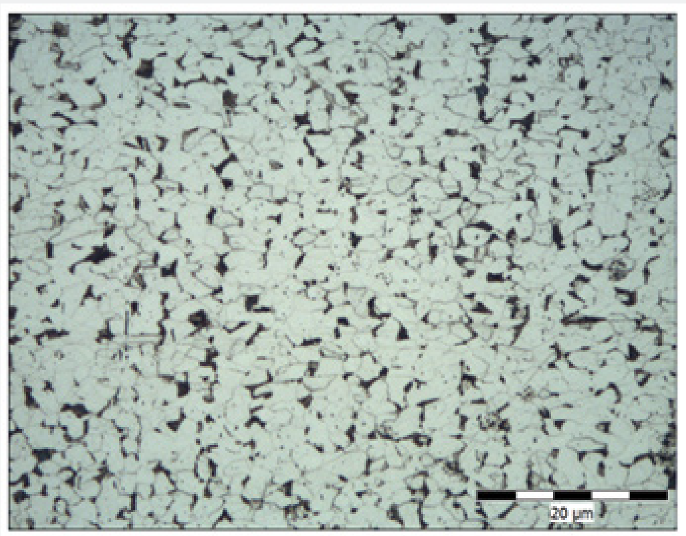

Figure 1: Microstructure P235TR2 steel after normalizing, etched by Nital.

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The equation showing the relative mass loss of the P235TR2 steel is presented in (3) with correlation coefficient 0.9963.

$$rml = 1.10^{-0.5} \cdot t^2 - 0.0007 \cdot t + 0.0801 \quad (3)$$

where: t - time, hours

Relative mass loss the P235TR2 steel after corrosion tests in 10% NaCl at 10°C is shown in figure 2.

The corrosion rate specified as mm per year in time is shown in figure 3.

Corrosion rate specified as mm per year the P235TR2 steel in time is presented in (4) with correlation coefficient 0.9874.

$$r_{corm} = 2 \cdot 10^{-0.6} \cdot t^2 + 6 \cdot 10^{-05} \cdot t + 0.1581 \quad (4)$$

where: t – time, hours

The corrosion rate specified as grams per m² is shown in figure 4.

Corrosion rate specified as gram per m² the P235TR2 steel in time is presented in (5) with correlation coefficient 0.9874.

$$r_{corm} = 2 \cdot 10^{-0.6} \cdot t^2 + 5 \cdot 10^{-0,5} \cdot t + 0.1418 \quad (5)$$

where: t – time, hours

The relative mass loss of samples soaked for up to 144 hours shows a directly proportional course of corrosion wear in relation to the soaking time (Figure 2). With the extension of the soaking time, an increase in the weight consumption of the samples is noticeable, which should be presented as a function of the second degree. Similar relationships were found for both specified corrosion rates of the samples (Figures 3 & 4). In both of these cases, a decrease in the corrosion rate was even noted in the range of 48-144 hours of soaking. This reduction is most likely due to imperfections in the weight loss measurement for the 144-hour soaking time. This may be due to the difficult cleaning of samples after soaking. These samples already had traces of surface corrosion, but they were too small to thoroughly remove the corrosion products without interfering with the steel surface. With such small weight loss, leaving even light oxides in the porosities of the samples could cause an error resulting in a decrease in the calculated corrosion rate. Increasing the soaking time causes a gradual increase in the corrosion rate beyond the proportional band. This increase can no longer be described by a linear function. It is a typical example of the second period of corrosion. To describe it, it is necessary to use the exponential function. The increase in speed can be explained by the deepening of corrosion pitting of the surface of the tested samples over time. These irregularities result in an increase in the contact surface of the corrosion medium with the surface of the sample, which results in a faster weight loss of the steel samples, and thus an increase in the corrosion rate. Noteworthy are the high correlation coefficients (above 0.9) which indicate a high stabilization of changes in the described process.

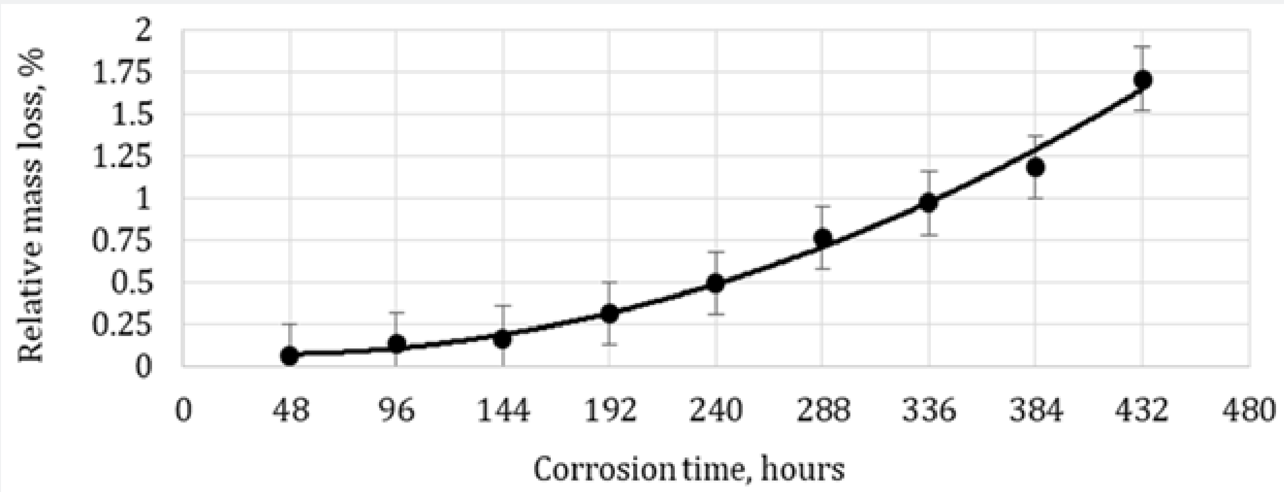

Figure 2: Relative mass loss the P235TR2 steel after corrosion tests in 10% NaCl at 10oC.

Comparing the results obtained in this experiment in the form of corrosion rate with the results presented for the same steel and in the same corrosive environment, but at a lower temperature of the corrosion medium (10°C) [34], it was found that in the first stage of soaking, i.e., until 144 hours, the change temperature of the reagent did not increase the corrosion rate. An increase

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in the corrosion rate for the soaking temperature of 25°C was noted only after the soaking time was longer than 144 hours, i.e., for the surface condition in which its development began. This observation leads to the conclusion that at the surface of steel with low roughness, the temperature of the NaCl aqueous solution is not of great importance until the time when the surface develops (corrosion pitting).

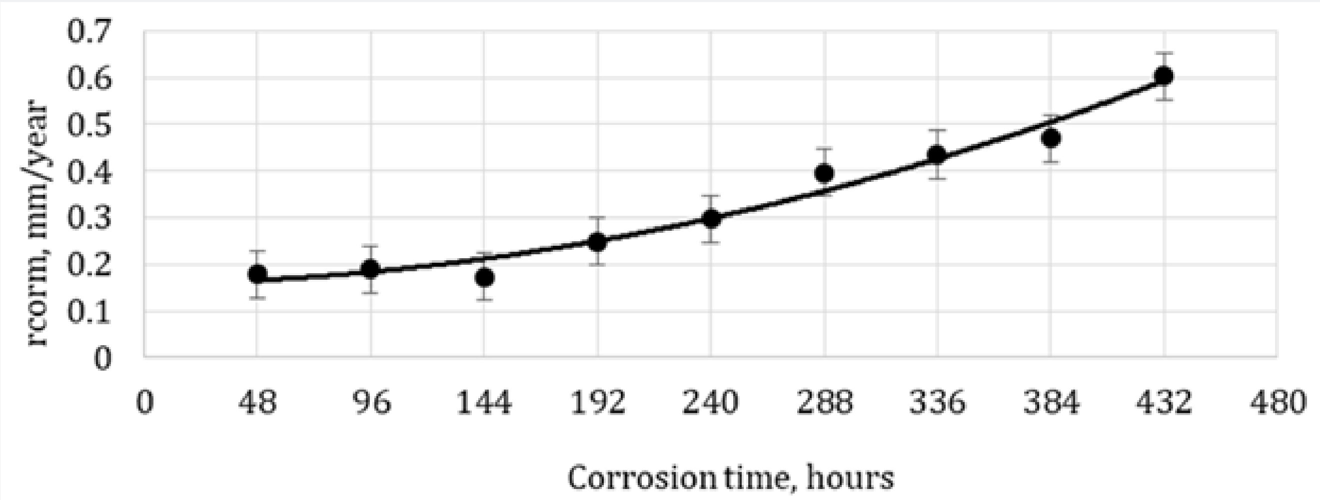

Figure 3: Corrosion rate specified as mm per year the P235TR2 steel after corrosion tests in 10% NaCl at 10oC.

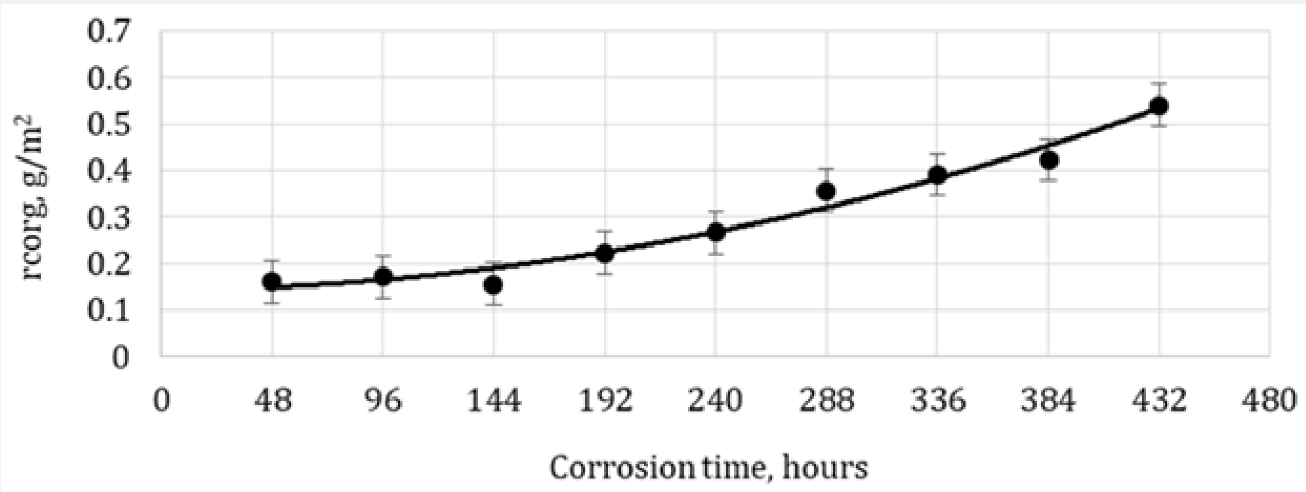

Figure 4: Corrosion rate measured in gram per m2 the P235TR2 steel after corrosion tests in 10% NaCl at 10oC.

Conclusion

Based on the presented test results, it was found that:

a) the tested steel in the first period of soaking has a low corrosion rate estimated at about 0.17 mm/year or 0.16 g/m^2.

b) in the second stage of corrosion, an increasing weight loss was observed with increasing soaking time in 10% NaCl.

comparing the steel tests carried out at 10°C and 25°C, the course of the corrosion rate in the first soaking period (up to 144 hours) was found to be without significant changes, while in the second period a higher corrosion rate was observed at a higher temperature of the corrosion medium.

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