EFFECT OF ANIMAL SLURRY ON CARBON STRUCTURAL S235JR STEEL AT 318 K

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Abstract

Carbon steels as a construction materials are still very popular, but exposed to corrosion. Low-carbon steel is often used as a construction material for agricultural equipment. Corrosion is a result of the chemical and electrochemical environment influence on the material. In alloys and metals changes occur as a result of interaction with the surrounding environment. One of the most important factors constructional material is corrosion resistance, first of all in demanding animal environment. Slurry is a mixture of animals dung and urine. The aggressive corrosive constituents in slurry are urea, uric acid, naturally excreted chloride and as well as ammonia or ammonium salts. In practice roughness parameters for every of the research times can be used for determine the size of steel corrosion. Equipment with carbon steel can be easy built by welding quickly at a low price, but biggest problem in aggressive environment is their corrosion protection. The purpose of this article is to investigate corrosion resistance in different time (48, 96, 144, 192, 240, 288, 336, 384 hours) using weight loss and profile roughness parameters of structural steel in grade S235JR in natural animal slurry at 318 K. Corrosion tests show that the tested steel in animal slurry as a corrosive environments is characterized through continuous corrosion process whose measure may be surface roughness.

Keywords: Steel, carbon steel, corrosion, corrosion rate, animal slurry

1.   INTRODUCTION

Carbon steel is a popular material in the construction of machines and equipment for agricultural because is cheaper than more resistance but expensive stainless steel. The properties of low carbon steel are influence of different factors, including chemical composition, manufacturing technology, working conditions and other. The properties steel, are determined mostly by its microstructure. The structural low carbon steels have a ferritic-perlitic microstructure. The percentage of each microstructure phase shapes the properties of the steel. The main factor of properties with is microstructure depends on the manufacturing technology and heat treatments of steel. Corrosion resistance is one with more an important factor of the quality and application of structural steels. The S235JR low carb on steel is commonly used for agricultural industry. Apart of this negative corrosion effect have mostly other metals inclusions which are dependent on their shape, numbers, size and distribution. Corrosion processes are able to extract metal atoms from the metal lattice, which atoms during the process pass to corrosion products. Particularly dangerous is the corrosion causing local diffusion of metal atoms. The problem is huge because each with low-carbon structural steel is sensitive on corrosion. The corrosion rate first of all is depends of different environment.

The accumulation of chemical elements with animal slurry near steel is the primary cause of corrosion. The results of corrosion of low carbon steel in machines and equipment for agriculture are geometry change can cause construction cracking, building up and increments of corrosion products what can caused to withstand load effects of constructions materials [1-3]. Usually corrosion of carbon steel was identified during the maintenance process. Unfortunately, corrosive processes of carbon steel can cause different forms of corrosion. Many researches are conducted to evaluate the performance of carbon and stainless steel

microstructures under a variety of corrosive conditions [4]. The wide variety of agricultural employed makes difficult to define where corrosion can be a little or most damaging. Corrosion in agricultural industry is also influenced by animal slurry and its products that have passed into the atmosphere such as chlorides vapors, NO_x (NO_2, NO_3), SO_y (SO_2, SO_4), and H_2S where S is the acid residue (H_2S, H_2SO_3) and other. The H_2S is the most corrosive agent that dissolves in moisture films where it undergoes oxidation by aerobic bacteria to very agresive sulphuric acid H_2SO_4. Penetration corrosion processes of low carbon steel with animal products are very aggressive [5-7]. Slurry is a mixture of dung and urine, and farmyard manure and etc. The corrosive constituents in slurry are firs of all: ammonia and its salts, urea, uric acid, naturally excreted chloride. Consequence influence corrosion processes during the maintenance low carbon steel with animal slurry atmosphere can be atmosphere corrosion effect, too. The animal slurry is important corrosive environmental factors in agricultural industry. Having regard to the importance of the corrosion resistance for exploitation, this research was carried out to determination the corrosion resistance of low carbon structural steel in animal slurry. For intensification the corrosion process the samples was tested at temperature 318 K [8-9].

The obtained results may be interested for steel producers [10-12], biotechnology industry utilizing apparatus also working in aggressive environments [13-15] and for waste utilization branch [16,17]. The rate of destruction may be also of interest to data analysts i.a. in image analysis [18-20], temperature field modeling [21], statistical design of similar experiments [22], especially when associated with non-parametric uncertainty estimation [23-25]. Last but not least, it should be also taken into consideration in management systems [26-27].

2.   MATERIALS AND METHODS

The research was performed on low carbon S235JR (1.0038) steel plate t = 5.00 mm thickness with chemical composition according to the EN 10025-2:2004 Hot rolled products of structural steels. The real chemical composition of the tested steel is presented in **Table 1**.

Table 1 Real mean chemical composition of the S235JR steel [wt. %]

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

The specimens from plate t = 5.00 mm thickness was cut mechanically samples to size 40 x 10 mm (area of about 13 cm^2). Next the samples were polished with water paper successively to Ra = 0.32 µm, and cleaned by 95 % C_2H_5OH. The samples despite the ferritic-perlitic microstructure were tested in accordance with the standard dedicated for stainless steel ISO 3651-1:1998 Determination of resistance to intergranular corrosion of stainless steels. The application of the criteria provided for stainless steel was intended to enable comparative assessment of the corrosion resistance of carbon steel and stainless steel in the future. Animal slurry mean chemical compositions and parameters as a corrosive media is presented in **Table 2** [29]. The corrosion resistance steel was tested by measurement of loss in mass (Huey test).

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

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

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

where:

　　　t – time of treatment in a corrosive solution of boiling nitric acid [hours],

　　　S – surface area of the sample [cm^2],

m – average mass loss in boiling solution [g],

ρ – sample density [g/cm^3].

Table 2 Mean chemical compositions and parameters animal slurry

P	K	Mg	Ca	Na	Cu	Zn	NO$_3$
(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
175	158	6.4	39.2	102	0.08	0.41	35
PH		EC		BOD		COD	TKN
		(mS/cm^2)		(mg/L)		(mg/L)	(g/L)
6.7		5.86		2350		2980	1.82

EC – electric conductivity, BOD Biochemical oxygen demand, COD – chemical oxygen demand, TKN – Total kjeldahl nitrogen

The influence of animal slurry on the S235JR carbon 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. The time range of research was: 48, 96, 144, 192, 240, 288, 336, 384 and 432 hours with accuracy of measurement 2 minutes.

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

3. RESULTS AND DISCUSSION

The result of time influence the soaking the S235JR carbon structural steel in animal slurry at temperature 318 K on the relative mass loss (RML) with determination coefficient is presented in **Figure 1**. The course of relative mass loss is well expressed in the exponential curve. With increasing soaking time, a progressive increase in the corrosive wear of steel was noted. This can be explained by systematic development of the surface of the tested steel. Thus, the impact of animal slurry with similar intensity on a larger surface causes an increase in the weight loss of steel. These assumptions confirm the results test the roughness parameters of S235JR steel for different corrosion time with determination coefficient is presented in (**Figure 2**) for Ra and Rq and in (**Figure 3**) for Rt and Rp.

$y = 0,0002x^2 + 0,111x - 5,3398$
$R^2 = 0,9922$
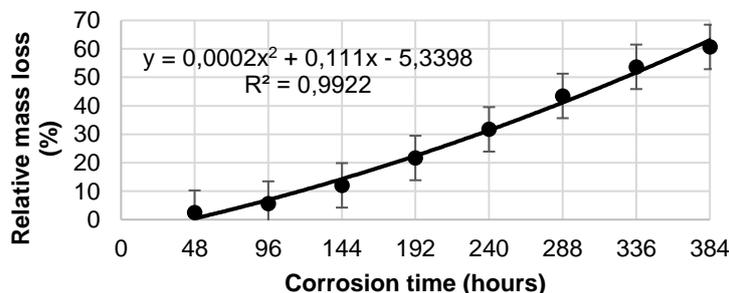
Figure 1 Percentage effects of corrosion time on the relative mass loss (RML) of S235JR carbon steel after corrosion tests in animal slurry at temperature 318 K

The effect of corrosion time on the corrosion rate measured in mm per year of S235JR steel after corrosion tests in animal slurry at temperature 318 K with determination coefficient is presented in (**Figure 4**). The effect of corrosion time on the corrosion rate measured in gram per m^2 of S235JR steel after corrosiontests in animal slurry at temperature 303 K with determination coefficient is presented in (**Figure 5**).

Analyzing the corrosion rate determined both in mm per year (**Figure 4**) as well as gram per m^2 (**Figure 5**), similar as in paper [28,29], different angles of the curve were observed. It was depended on the time of steel soaking in animal slurry at temperature 318 K.
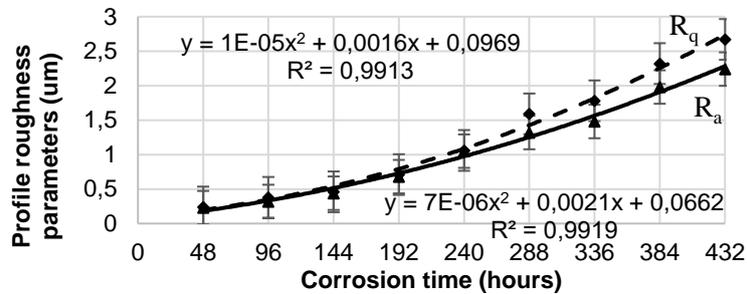
Figure 2 Profile roughness of S235JR carbon steel after corrosion tests in animal slurry at temperature 318 K for different corrosion time: Ra – arithmetical mean roughness value (μm); Rq – mean peak width (μm)
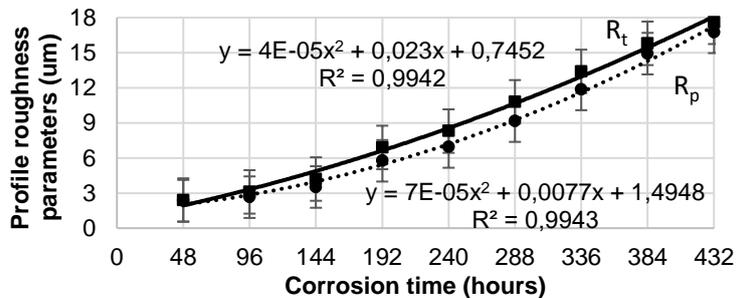
Figure 3 Profile roughness of S235JR carbon steel after corrosion tests in animal slurry at temperature 318 K for different corrosion time: Rp – maximum roughness depth (μm); Rt – total height of the roughness profile (μm)
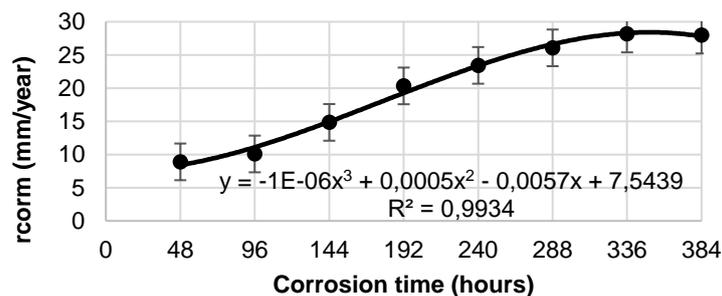
Figure 4 The effect of corrosion time on the corrosion rate measured in mm per year of S235JR carbon steel after corrosion tests in animal slurry at temperature 318 K

A slight increase in corrosion rate was observed during the first 96 hours. After extending the time, the corossion rate increased intensively. After soaking more than 240 hours in an aggressive environment, the corrosion rate began to slow down. This nature of changes can be explained by the slow formation of steel surface development in the first period of tested S235JR carbon steel. Then the rapid development of corrosion was caused by the rapid progressive increase of the contact surface of the aggressive environment with steel in the second period. In the third soaking period of steel tested , the corrosion rate stabilizes (**Figures 4 and 5**), but the mass loss continues to increase exponentially (**Figure 1**).
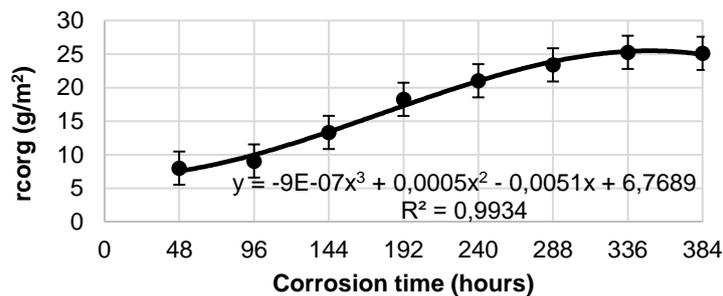
Figure 5 The effect of corrosion time on the corrosion rate measured in gram per m^2 of S235JR carbon steel after corrosion tests in animal slurry at temperature 318 K

4. CONCLUSION

In the study of the steel corrosion process, for a better presentation of its course one should present both the result of time the soaking the S235JR carbon structural steel in animal slurry on the relative mass loss as well as corrosion rate.

Corrosion rate equations, despite their inclusion in the standard for stainless steel, give good sense also for carbon steel. To better present the course of corrosion over time, the percentage corrosion loss and corrosion rate should be given simultaneously. The animal slurry environment is very aggressive and acid-proof steel should be used for equipment working in contact with it.

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