EFFECT OF ANIMAL SLURRY ON CARBON STRUCTURAL S235JR STEEL AT 303 K

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Abstract. Construction materials arestill exposed to corrosion. Slurry is a mixture of dung and urine. The aggressive corrosive constituents in slurry are urea, uric acid, naturally excreted chloride and as well as ammonia or ammonium salts. Corrosion tests show that the tested steel in animal slurry as a corrosive environment is characterized through a continuous corrosion process, which measure may be surface roughness. In practice roughness parameters for every of the research times can be used to determine the size of steel corrosion. Low-carbon steel is often used as a construction material for agricultural equipment. One of the most important factors of constructional materials is corrosion resistance, first of all in demanding animal environment. Equipment with carbon steel can be easy built by welding quickly at a low price, but the bigest problem in aggressive environment is corrosion protection. The purpose of this article is to investigate corrosion resistance in different time (48, 96, 144, 192, 240, 288, 336 hours), using weight loss and profile roughness parameters of structural steel in grade S235JR in natural animal slurry at 303 K.

Keywords: animal slurry, carbon steel, corrosion, corrosion rate, roughness.

Introduction

Industry places high demands on construction materials. The reason for this is both the safety of persons and constructions. One with the main problem apart strength [1; 2] is corrosion resistance [3; 4]. This factor is the main in prevention rapid destruction of the material. They meet these requirements every one steels, not only stainless steels [5-8] but constructional carbon steels, too [9; 10].

High grade non-alloy structural S235JR steel described in EN 10025standard is a vital substance, which is consumed in construction industries. The S235JR low carbon steel is often used not only for industry, bat also in other areas of application, for example, agricultural industry. The main properties of constructional steel are determined mostly by the chemical composition, microstructure and production technology [11-16]. The more important is this that the negative corrosion effect is mostly important for the reason, for example, of other metal inclusions [17; 18], which are dependent on their shape, numbers, size and distribution determined properties of alloys, too [19; 20]. The accumulation of chemical elements with animal slurry near steel is the primary cause of corrosion in agricultural machinery and equipment [21; 22].

The results of corrosion of low carbon steel in machines and equipment for agriculture geometry change can cause construction cracking, building up and increments of corrosion products what can cause to withstand reduced load carrying capacity effects of constructions materials [23-25]. 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 [26-32].

The wide variety of agricultural equipment and different conditions, and their working environment makes it 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, NOx and SOy, HzS and others. Penetration corrosion processes of low carbon steel with animal products are very aggressive [4; 24; 31-33]. Slurry is a mixture of dung and urine, and farmyard manure etc. The corrosive constituents in slurry are first of all: ammonia and its salts, urea, uric acid, naturally excreted chloride. Consequence influence of corrosion processes, including carbon steel corrosion, causes removal of products during the maintenance [3; 25; 31; 34].

The animal slurry is an important corrosive environmental factor in agricultural industry. Having regard to the importance of the corrosion resistance for exploitation, this research was carried out to determine the corrosion resistance of S235JR low carbon structural steel in animal slurry. For intensification of the corrosion process the samples was tested at temperature 303 K.

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Materials and methods

The research was performed on a low carbon S235JR (1.0038) steel plate t = 5.00 mm thickness with the 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 [28; 29].

Table 1

Real mean chemical composition of the S235Jrsteel, 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 the plate of t = 5.00 mm thickness were cut mechanically in samples to the size 40 x 10 mm (area of 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 main chemical compositions and parameters as a corrosive media are presented in Table 2. The corrosion resistance steel was tested by measurement of loss in mass (Huey test).

Table 2

Mean chemical compositions and parameters animal slurry

P	K	Mg	Ca	Na	Cu	Zn	NO_3	PH	EC	BOD	COD	TKN
$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	-	$mS \cdot cm^{-2}$	$mg \cdot l^{-1}$	$mg \cdot l^{-1}$	$g \cdot l^{-1}$
175	158	6.4	39.2	102	0.08	0.41	35	6.7	5.86	2350	2980	1.82

Note: EC – electric conductivity, BOD biochemical oxygen demand, COD – chemical oxygen demand, TKN – total nitrogen

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

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

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

where t – time of treatment in a corrosive solution of boiling nitric acid, h;
S – surface area of the sample, cm^2;
m – average mass loss in boiling solution, g;
ρ – sample density, $g \cdot cm^{-3}$.

The influence of animal slurryon the S235JR carbonsteel corrosion resistance was investigated using the weight loss. The mass of samples was measured by a Kern ALT 3104AM general laboratory precision balance with accuracy of measurement 0.0001 g. The time range of the research was: 48, 96, 144, 192, 240, 288, 336, 384 and 432 hourswith 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.

Results and discussion

Profile roughness parameters of S235JR steel after corrosion tests in animal slurry at temperature 303 K for 240 hours are presented in Fig. 1 and for 432 hours in Fig. 2.

The distance between the individual peaks for both corrosion times (Figs. 1 and 2) is similar. The difference between the figures is visible in the size of the unevenness, which may indicate that the corrosion places were formed at the beginning of the process, and only its development was noted over time. Figs. 3 and 4 confirm this view.

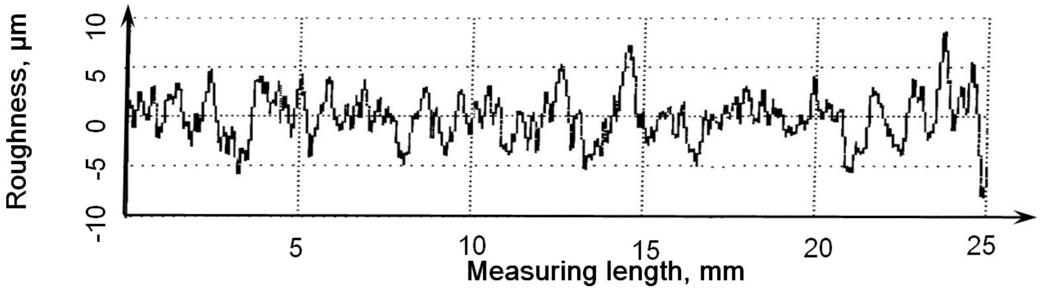

Fig. 1. **Profile roughness of S235JR steel after corrosion tests in animal slurryat temperature 303 K for time 240 hours**

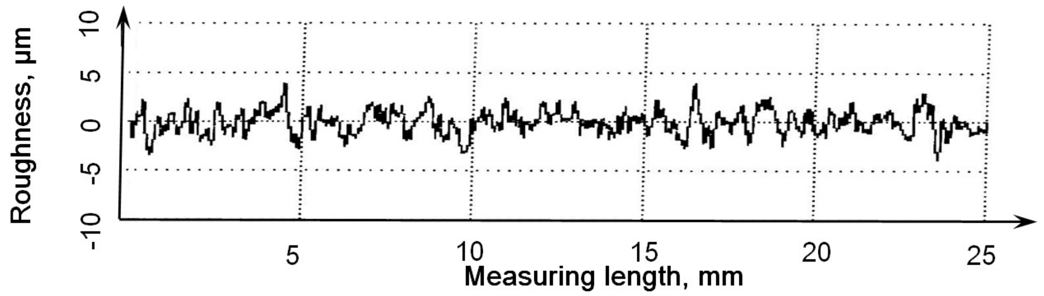

Fig. 2. **Profile roughness of S235JR steel after corrosion tests in animal slurryat temperature 303 K for time 432 hours**

Profile roughness parameters of S235JR steel for different corrosion time with the determination coefficient are presented in Fig. 3 for Ra and Rq and in Fig. 4 for Rt and Rp.

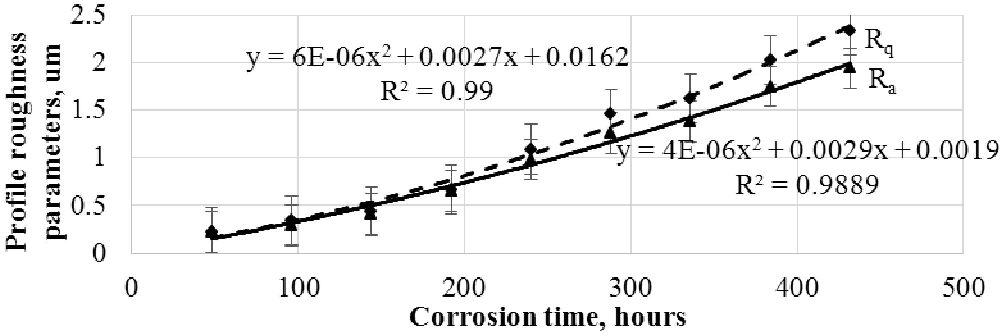

Fig. 3. **Profile roughness of S235JR steel after corrosion tests in animal slurry at temperature 303 K for different corrosion time**: *Ra* – arithmetical mean roughness value (µm); *Rq*– mean peak width (µm)

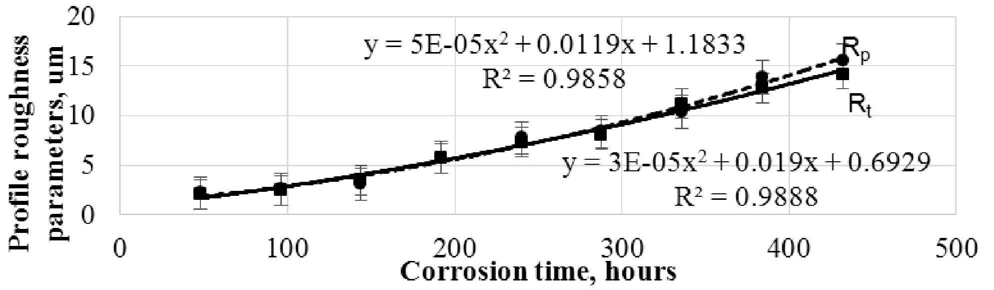

Fig. 4. **Profile roughness of S235JR steel after corrosion tests in animal slurry at temperature 303 K for different corrosion time**: *Rp*– maximum roughness depth (µm); *Rt*– total height of the roughness profile (µm)

The result of the time influence soaking the S235JR carbon structural steel in animal slurry at temperature 303 K on the relative mass loss (*RML*) with the determination coefficient is presented in Fig. 5.

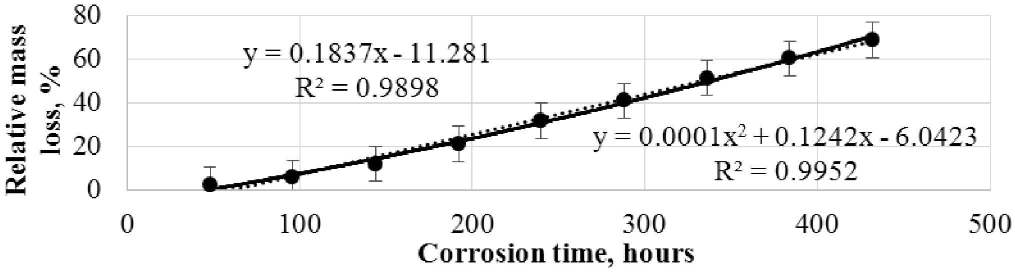

Fig. 5. **Percentage effects of corrosion time on the relative mass loss (RML) of S235JR carbon steel after corrosion tests in animal slurry at temperature 303 K**

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 303 K with the determination coefficient is presented in Fig. 6.

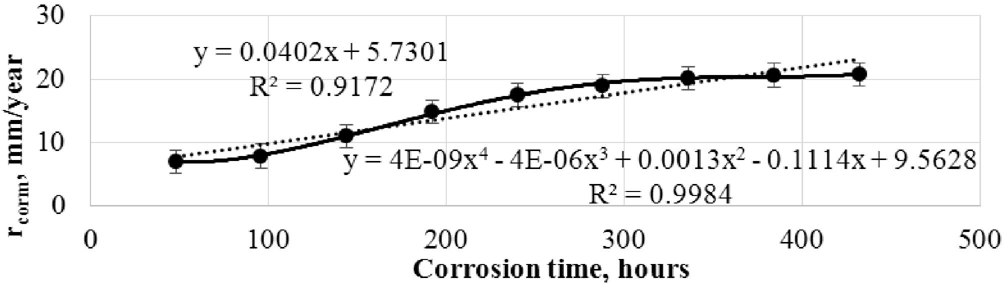

Fig. 6. **Effect of corrosion time on the corrosion rate measured in mm per year of S235JR steel after corrosion tests in animal slurry at temperature 303 K**

The effect of corrosion time on the corrosion rate measured in gram per m^2 of S235JR steel after corrosion tests in animal slurry at temperature 303 Kwith the determination coefficient is presented in Fig. 7.

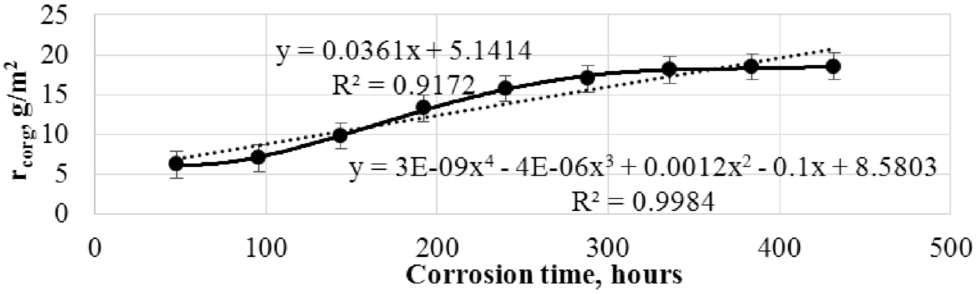

Fig. 7. **Effect of corrosion time on the corrosion rate measured in gram per m^2 of S235JR steel after corrosion tests in animal slurry at temperature 303 K**

Despite the proportional course of the relative mass loss curve (Fig. 5) over time, the corrosion rate (Fig. 6, Fig. 7) curve indicates three periods of corrosion. In the first period (up to approx. 140 hours), corrosion develops slowly. Then (up to 300 h) there was a dynamic increase in the corrosion rate. In the third period, the corrosion rate slowed down to a constant value. This seems to be natural. First, the aggressive medium must attack the steel surface in places with the least corrosion resistance, creating corrosive micro-pits, which growth speed increases rapidly in the second period of corrosion. In the third period, the corrosion rate remains constant, and its determinant is the corrosion resistance of grains and grain boundaries. Further investigation may involve advanced image analysis method [35-38].

Part of the relationship (Fig. 3-7) from the mathematical assessment point can be represented by linear functions. To emphasize the occurrence of several periods with different rates of change, it was decided to use the polynomial function. Polynomial functions allow to take into account the physical meaning of changes over time.

Conclusions

1. Based on the research and [39], it was found that animal slurry at temperature 303 K is an aggressive corrosive center for S235JR steel.
2. The corrosion rate and roughness of S235JR in animal slurry depends on time and can be present by linear and polynomial functions (taking into account corrosion periods).
3. The study results show three periods of corrosion development: the first slow, the second with a high corrosion rate and the third with a stable corrosion rate.

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