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CORROSION EFFECT OF ANIMAL SLURRY ON LOW CARBON S235JR STEEL AT 333 K

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Low-carbon steels are often used for materials in the construction of machines and equipment for agricultural. One of the most important factors constructional material is corrosion resistance, first of all in demanding animal environment. Equipment with low carbon steel can be easy join by quickly welding at a low construction price, but one with the serious problem in aggressive environment is their corrosion resistance.

A few corrosion processes in crevices and awkward corners can be avoided at the design stage (low roughness parameters, round-section and other). But still the construction material is 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.

The main aim of this research is to investigate corrosion resistance in different time (48, 96, 144, 192, 240, 288, 336 hours). For this used weight loss of test samples and its profile roughness. The research was conducted on low carbon steel in grade S235JR in natural animal slurry at 333 K.

Corrosion tests confirmed that the research this steel in animal slurry as corrosive environments is characterized through proportionate to time corrosion process whose measure may be surface roughness. In industrial practice roughness parameters for all the research times can be used for determine the stage and size of steel corrosion.

Keywords: Animal slurry, carbon steel, corrosion, corrosion rate, roughness

INTRODUCTION

Carbon steel is one of the most popular materials in the construction of machines and equipment for agricultural because is cheaper then more resistance but expensive stainless steel (Dudek et al., 2014; Lipiński, 2016b; Sha and Yang, 2016). The S235JR low carbon steel is commonly used for agricultural industry. The properties constructional steel are determined mostly by their microstructure and production technology (Lipinski and Wach 2015, Nová and Machuta 2016; Szabracki and Lipiński, 2013; Ulewicz, 2003; Włodarczyk et al., 2011). Apart of this negative corrosion effect have mostly other metals inclusions which are dependent on their shape, numbers, size and distribution (Szabracki and Lipiński, 2014). 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 (Duryahina etal., 2007; Luu et al., 2011; Mahdi et al., 2014; De Belie et al., 2000; Pitrmuc et al., 2016). Usually corrosion of carbon steel was identified during the maintenance process. Unfortunately, corrosive processes of carbon steel can cause different forms of corrosion. Many research are conducted to evaluate the performance of carbon and stainless steel microstructures under a variety of corrosive conditions (Kusmic and Van Than, 2017; Lipiński, 2015, 2016b; Pilch et al., 2017; Scendo et al., 2013; Selejdak et al., 2014; Szabracki and Lipiński, 2014).

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, NOx and SOy, HzS and other. Penetration corrosion processes of low carbon steel with animal products are very aggressive (Aguirre and Walczak, 1017; Song and Du, 2017; Tang et al., 2008, Yang and Cheng, 2011; Zatkalíková et al., 2016). 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 (Naz et al., 2017; Uhlig and Revie, 1985; Yang and Cheng, 2012; Yu et al., 2013).

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

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resistance of low carbon structural steel in animal slurry. For intensification the corrosion process the samples was tested at temperature 333 K.

MATERIALS AND METHODS

The research was performed on low carbon commercial S235JR (1.0038) steel plate *t* = 5.00 mm thickness with chemical composition according to the EN 10025-2:2004 (EN 2004). The chemical composition of the tested steel is presented in Table 1 (Lipiński 2017a, 2017b).

Table 1. Real chemical composition of the commercial S235JR steel

Mean chemical compositions [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

Average mechanical properties of the S235JR steel at ambient temperature according to the standard EN 10025-2:2004 are presented in Table 2.

The specimens from plate t = 5.00 mm thickness was cut mechanically samples to size 40 x 10 mm (area of 13 cm2). Next the samples were polished with water paper successively to R_a = 0.32 μm, and cleaned by 95 % C_2H_5OH.

The samples prepared by sanding and degreasing with ferritic-perlitic microstructure were tested on the basis of corrosion guidelines for stainless steel accordance with the standard EN ISO 3651-1:2002 (EN 2002). 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 as a corrosive media were represented in Table 3 and its parameters in Table 4. The corrosion resistance steel was tested by measurement of loss in mass (Huey test).

Table 3. Mean chemical compositions animal slurry

Chemical composition of 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

Table 4. Parameters of animal slurry

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 Kjeldohl nitrogen

The corrosion rate samples performed from plate of S235JR steel was calculated in mm per year accordance to formula (1) and calculated in grams per square meter accordance to 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 soaking in a corrosive solution of animal slurry on temperature 33 K [hours],
S - contact surface of the sample with corrosive solution of the sample [cm^2],
m – average mass loss after the test in animal slurry [g],
ρ - tabular density of the sample [g/cm^3].

The corrosion rate in animal slurry the S235JR carbon steel was investigated using weight loss after the test in animal slurry. The mass of samples for every testing time were measured by Kern ALT 3104AM laboratory precision balance. The accuracy of measurement was 0.0001 g. The time range of research was: 48, 96, 144, 192, 240, 288, 336, 384 and 432 hours.

Surface roughness measurement were analyzed according to the EN 10049:2013 standard by the Diavite DH5 profilometer.

RESULTS AND DISCUSSION

The microstructure the S235JR steel before the corrosion process is presented at Fig. 1 - clearly visible the effect of manufacturing process this steel on the miceostructure as an elongated white ferrite phase and the dark perlite phase. Surface the test samples after corrosion tests in animal slurry at 333 K temperature for time 240 hours is presented at Fig. 2.

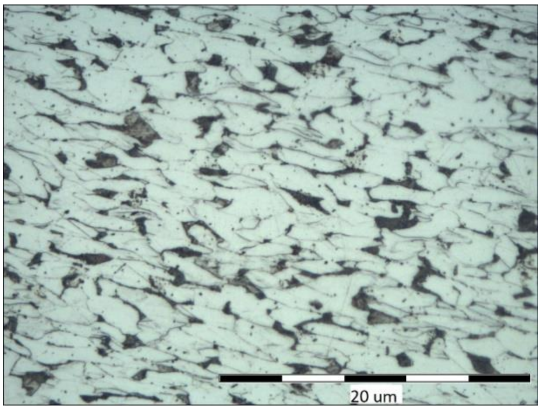

Figure 1. Microstructure of S235JR steel before corrosion testing: light ferrite and dark perlite

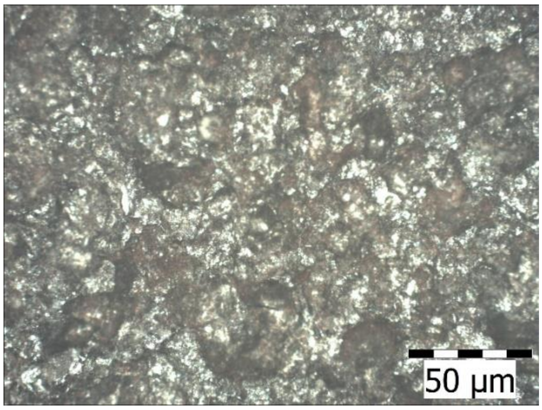

Figure 2. Surface of S235JR steel after corrosion tests in animal slurry at 333 K temperature for time 240 hours

Profile roughness parameters of S235JR steel after corrosion tests in animal slurry at temperature 333 K for 96 hours is presented in Fig. 3, for 240 hours in Fig. 4 and for 432 hours in Fig. 5. The roughness profile of S235JR steel with: R_a – arithmetical mean roughness value [µm], R_p – maximum roughness depth [µm], R_q - mean peak width [µm], R_t – total hight of the roughness profile [µm] for different corrosion time is presented in Fig. 6 for R_a and R_q and in Fig. 7 for R_t and R_p. Regression equation of the roughness and r as its correlation coefficient is presented in (3) – (6), where t-parameter is time in hours.

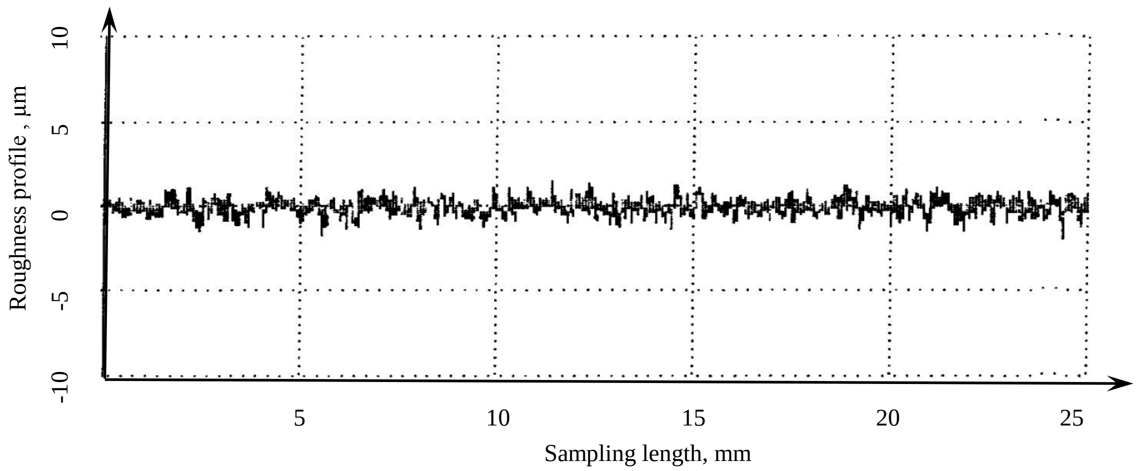

Figure 3. The roughness profile of S235JR steel after 96 hours corrosion tests in animal slurry at temperature 333 K

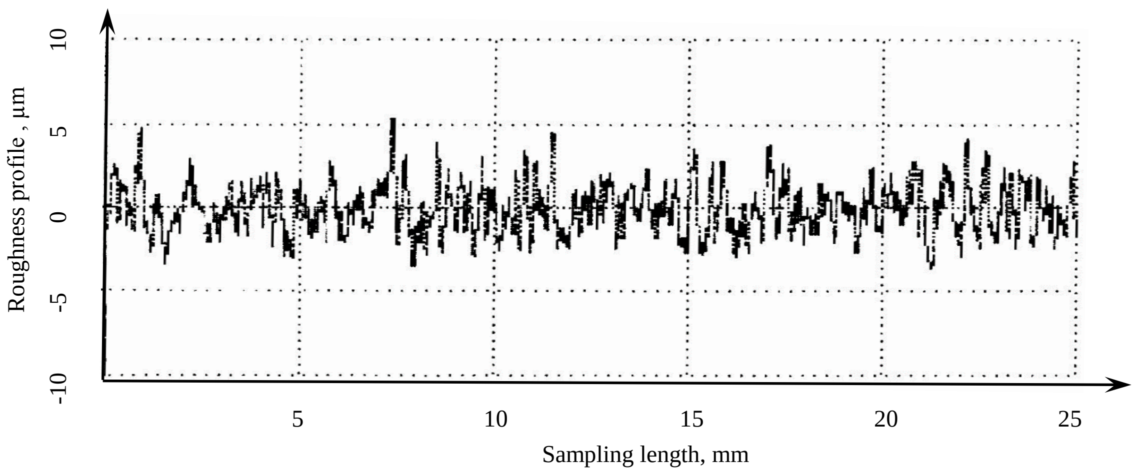

Figure 4. The roughness profile of S235JR low carbon steel after 240 hours corrosion tests in animal slurry at temperature 333 K

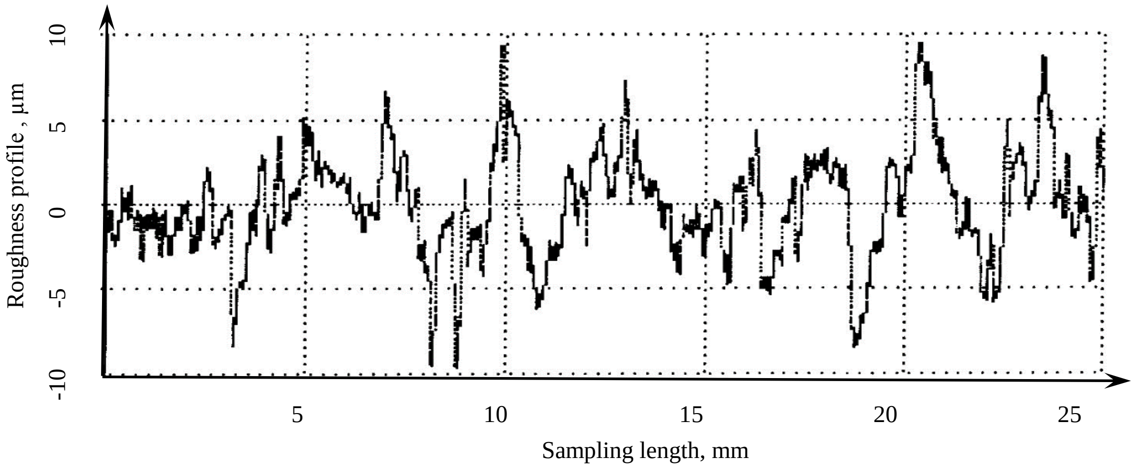

Figure 5. The roughness profile of S235JR low carbon steel after 432 hours corrosion tests in animal slurry at temperature 333 K

$$R_a = 5 \cdot 10^{-6} t^2 + 0.0034 \cdot t + 0.0188 \text{ and r = 0.9984} \quad (3)$$

$$R_q = 9 \cdot 10^{-6} t^2 + 0.0035 \cdot t + 0.0321 \text{ and r = 0.995} \quad (4)$$

$$R_t = 4 \cdot 10^{-5} \cdot t^2 + 0.0256 \cdot t + 0.0321 \text{ and r = 0.995} \quad (5)$$

$$R_p = 6 \cdot 10^{-5} \cdot t^2 + 0.0145 \cdot t + 1.45 \text{ and r = 0.9966} \quad (6)$$

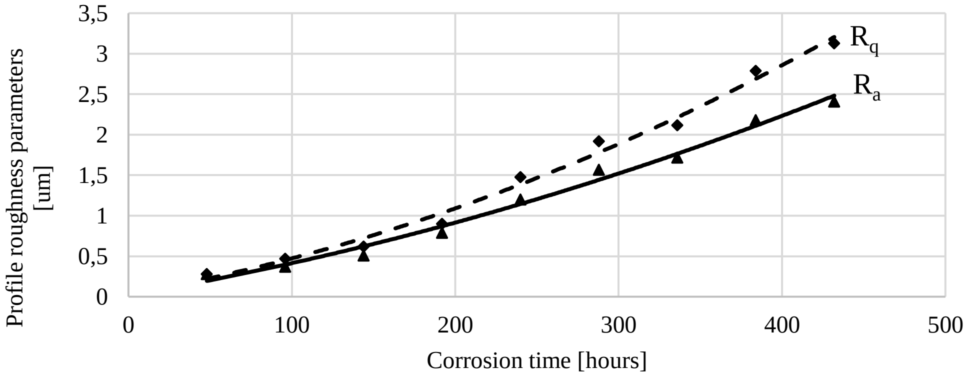

Figure 6. Roughness of S235JR low carbon steel after different time corrosion tests in animal slurry at temperature 333 K: *Ra* – arithmetical mean roughness value (µm); *Rq* – mean peak width (µm)

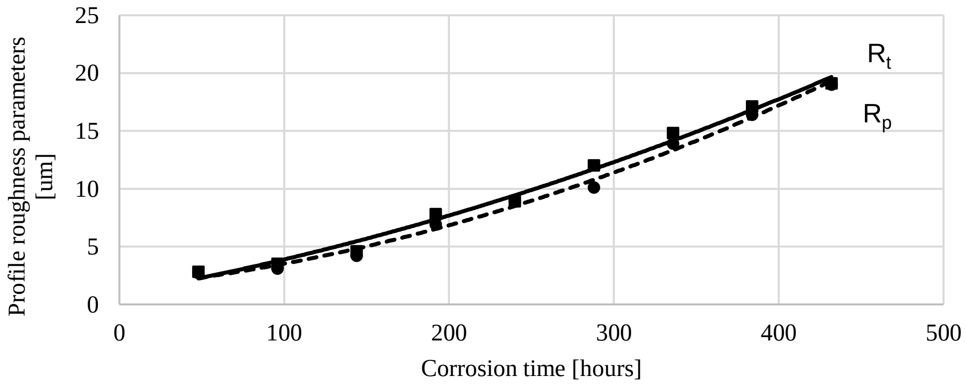

Figure 7. Roughness of S235JR steel after different time corrosion tests in animal slurry at temperature 333 K: *Rp* – maximum roughness depth (µm); *Rt* – total height of the roughness profile (µm)

The influence of the testing time the S235JR low carbon steel in animal slurry at temperature 333 K on the relative mass loss (RML) is presented in Fig. 8. The regression equation and r as its correlation coefficient is presented at (7).

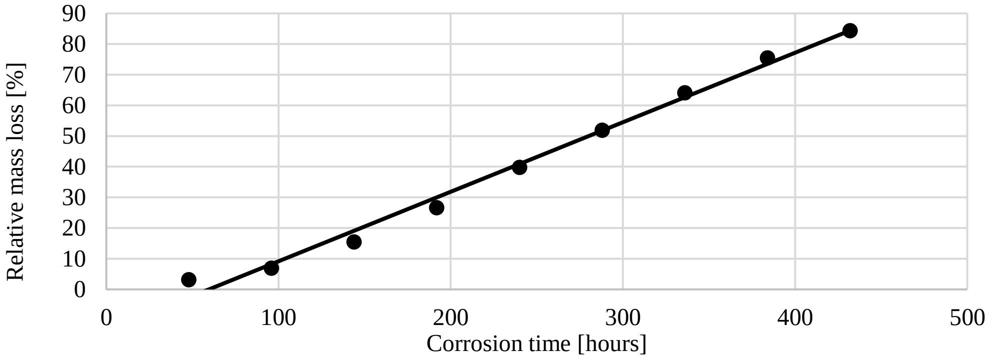

Figure 8. Relative mass loss (RML) the S235JR low carbon steel as a function corrosion time in animal slurry at temperature 333 K

$$RML = 0.2267 \cdot t + 13.506 \text{ and r=0.9953} \quad (7)$$

The corrosion rate S235JR low carbon steel calculated in mm per year after corrosion tests in animal slurry at temperature 333 K is presented in Fig. 9. The regression equation of corrosion rate rcorm and r as its correlation coefficient is presented at (8).

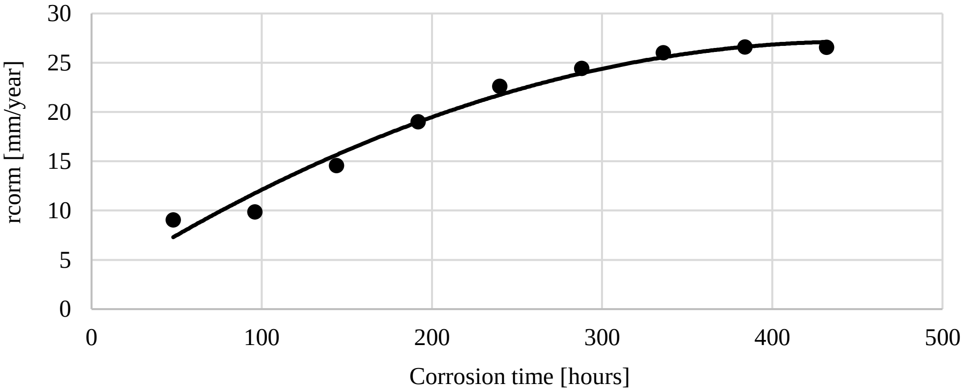

Figure 9. Corrosion rate measured in mm per year of S235JR steel after corrosion tests in different time with animal slurry at temperature 333 K

$$r_{corm} = -0.0001 \cdot t^2 + 0.1107 \cdot t + 2.2683 \text{ and r=0.9884} \quad (8)$$

The corrosion rate S235JR low carbon steel calculated in g per square meter after corrosion tests in animal slurry at temperature 333 K is presented in Fig. 10. The regression equation of corrosion rate rcorg and r as its correlation coefficient is presented at (9).

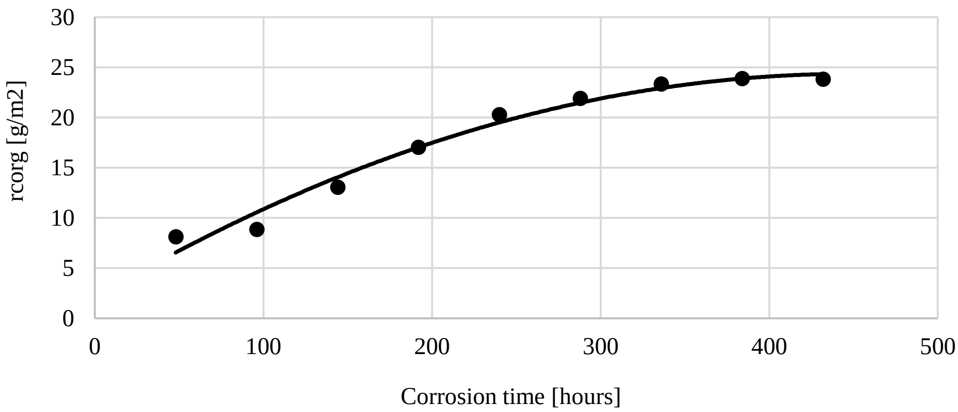

Figure 10. Corrosion rate measured in mm per square meter of S235JR steel after corrosion tests in different time with animal slurry at temperature 333 K

$$r_{corg} = 0.6938 \cdot t^{-0.24} \text{ and r=0.9624} \quad (9)$$

The microstructure of steel are with the corrosion time.

The surface of the S235JR carbon steel increases its cropacity along with the prolongation of the animal slurry as a corrosive medium's exposure time. The steel microstructure after 336 hours of soaking in animal slurry at temperature 333 K is shown in Fig. 11.

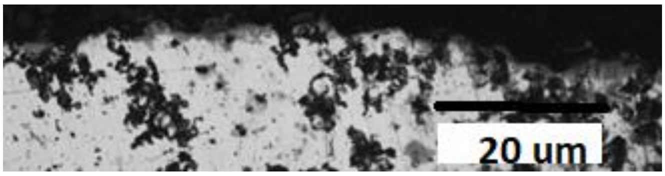

Figure 11. The microstructure of S235JR steel after corrosion tests with animal slurry at temperature 333 K

CONCLUSIONS

- The animal slurry is one of the most aggressive corrosion factors in agricultural industry. To establish the properties of S235JR steel degradation in animal slurry environments tested at 333 K is determining the change in the roughness parameters and corrosion resistance. Of course the high temperature was use to increase corrosion rate.
- Corrosion tests in animal slurry at temperature 333 K is sensible to the time of corrosion process.
- Good regression coefficients were obtained for the linear regression equation considered for all the tested parameters.
- The mass loss is good indicator corrosion process. By using equations describing material roughness or corrosion rate, it is possible to determine conditions for simply control of the condition of an agricultural object.

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