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A Study of Corrosion Behavior of Austenitic AISI 304L and 316Ti Stainless Steels in the Animal Slurry

Krzysztof Rokosz[a], Tadeusz Hryniewicz[b], Michał Uran[c]

Division of Surface Electrochemistry and Engineering, Koszalin University of Technology, Racławicka 15-17, 75-622 Koszalin, Poland

[a-c]E-mail addresses: rokosz@tu.koszalin.pl , Tadeusz.Hryniewicz@tu.koszalin.pl , uranmichal@gmail.com

ABSTRACT

The aim of this study was to compare the pitting corrosion resistance of two austenitic stainless steels, AISI 304L and AISI 316Ti, which are often used for agricultural machinery building. For the corrosion experiments, animal slurry from a pig farm was used. The results obtained from electrochemical corrosion experiments were proceeded by significance tests in Statistica software. The average value of the pitting corrosion potential of AISI 304L stainless steel in the animal slurry is equal 1044.3±146.6 mV_{SCE} whereas the average potential for AISI 316Ti SS equals 1058.4 ±28.3m mV_{SCE}. Corrosion potential of AISI 304L SS is equal −549±80.5 mV_{SCE}, while for AISI 316Ti SS it equals −425.9±80.5 mV_{SCE}. The range of pitting corrosion potentials of AISI 304L SS (364 mV_{SCE}) was over four times higher than that for AISI 316Ti SS (84 mV_{SCE}); the minimum values of pitting corrosion potential for AISI 304L SS (779 mV_{SCE}) was lower than that obtained for AISI 316Ti SS (1012 mV_{SCE}). On the basis of the results it may be concluded that AISI 304L stainless steel is less resistant in case of pitting corrosion resistance than AISI 316Ti SS. For this reason, austenitic AISI 316Ti stainless steel should be used for the transportation or storage of animal slurry.

***Keywords*:** Animal slurry; AISI 304L and 316Ti SS; Pitting corrosion; Comparison

1. INTRODUCTION

The corrosion stability of design material in a natural environment is an important feature when analyzing its behavior as a construction for machinery and equipment used in farming [1-6]. Manufacturers of agriculture equipment, instruments, tools and machinery, construction equipment, livestock buildings, edifices and facility, take into consideration possible risk of corrosion occurrence during maintenance and operation [3-10]. The highest threat of corrosion of steel appears in case of contact with chemical fertilizers, organic fertilizers, livestock manure and animal slurry. This was the main reason the alloy steels were used to operate with these means. Therefore the alloy steels may be used both for higher temperatures as well as aggressive environments.

Animal slurry is a by-product arising from breeding of livestock, here swine. It is a liquid mixture of feces/excrement, urine and water. This animal slurry is used as an organic manure thanks to the content of good assimilation of alimentary/nourishment components.

Dependent on the content of dry mass, the animal slurry may be characterized as thick, containing over 8% of dry mass, or diluted slurry of its content below 8%. The content of the components depends on the way of breeding, sort of livestock and feeding/nourishment: the average content of nitrogen equals 0.2-0.35%, potassium 0.2-0.3%, and phosphorus 0.05-0.1%. As an organic manure, it provides macro- and microelements to the soil thus resulting in changes of its physicochemical and physical properties [10-12].

The animal slurry which is to be used as the organic manure should be supplied to the soil by means of special hoses drugged after barrel or applied subsurface. Moreover it should be used in the periods regulated by a proper law [13].

The basic aim of the study was to determine the corrosion behavior of two austenitic stainless steels, AISI 304L and AISI 316Ti, after cold rolling (AR), in the aqueous solution of animal slurry [14-21]. This natural manure/slurry is used in agriculture to enrich the soil in elements and compounds of potassium and phosphorus. Knowledge on the corrosion action/behavior of steel containers/tanks and hoses is of great importance during their use and the slurry storage.

2. METHOD

2. 1. Set up and samples

Potentiodynamic studies of corrosion resistance have been carried out at the Surface Electrochemistry Division, Koszalin University of Technology, on the set-up using ATLAS 98 EII with IMP98 software, the same as described recently in [WSN]. A calomel electrode (Eurosensor EK-101 No. 184) was applied for the reference, with platinum used as a current electrode. The studied samples, made of austenitic steel, were used as working electrodes. The electrochemical cell, with all electrodes used, was presented in [18]. Rectangular samples cut off of 2 mm thick sheet of austenitic cold-rolled AISI 304L and AISI 316Ti stainless steels [19-24] of dimensions 40 × 30 mm were used for the studies. The experiment was repeated seven times for each of the samples used.

2. 2. Solution used for corrosion resistance studies

The animal slurry was used as the solution for the studies, with composition presented in **Table 1**. For each experiment, the electrochemical cell was filled in with 20 ml of the fresh solution.

Table 1. Composition of the animal slurry used for experiments [10].

pH	Dry mass, wt %	Contents of elements and compounds, wt %, in the fresh mass of solution				
		N	P_2O_5	K_2O	Mg	Ca
8.01	0.35	0.011	0.025	0.096	0.008	0.007

3. RESULTS

3. 1. Corrosion study results for AISI 304L SS in the slurry

The main corrosion study results of AISI 304L SS, with 7 repetitions, are given in Figures 1, 2, 3 and in Table 2. Corrosion potentials, measured against a calomel electrode, were in the range from –601 mV to 1143 mV. It results from the studies that the average value of the pitting corrosion potential equals 1044.3±146.6 mV_{SCE}, at the range and median equaling 364 mV_{SCE} and 1119 mV_{SCE}, respectively. Corrosion potential of the linear Tafel region for this steel equals –549±80.5 mV_{SCE}, with the median of –550 mV_{SCE}.

Table 2. Potentiodynamic corrosion study results of AISI 304L SS in the animal slurry [10].

Sample No.	AISI 304L SS	
	E_{pit}, mV_{SCE}	E_{corr}, mV_{SCE}
1	1119	–554
2	1143	–550
3	1107	–560
4	1143	–521
5	893	–534
6	779	–601
7	1126	–523
Average	**1044.3**	**–549**
Sta. deviation	**146.6**	**27.5**
Median	**1119**	**–550**
Maximum	**1143**	**–521**
Minimum	**779**	**–601**
Range	**364**	**80**

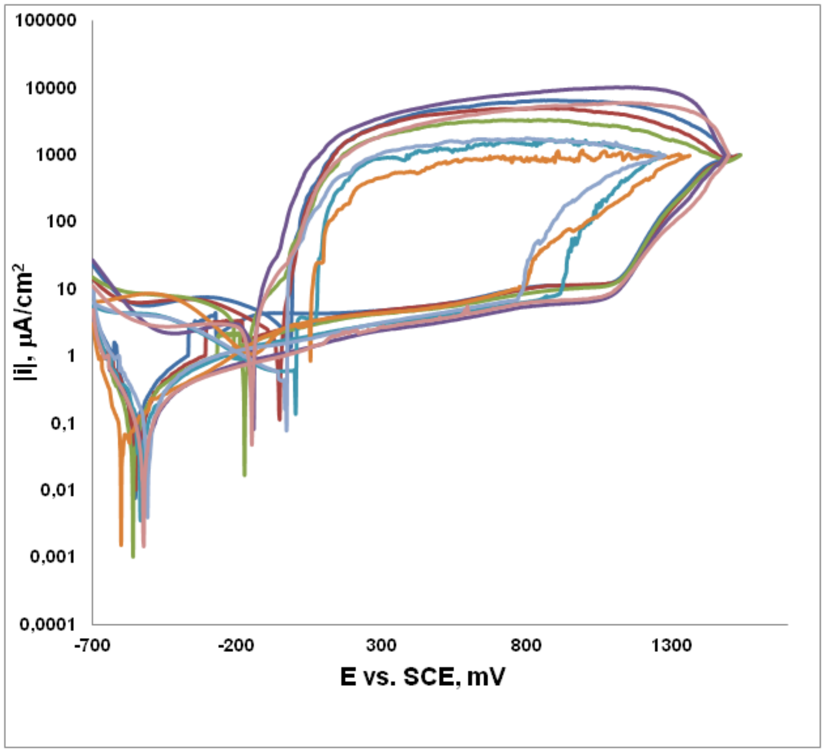

Fig. 1. Potentiodynamic polarization studies of AISI 304L SS in the animal slurry: logarithmic vertical scale [10].

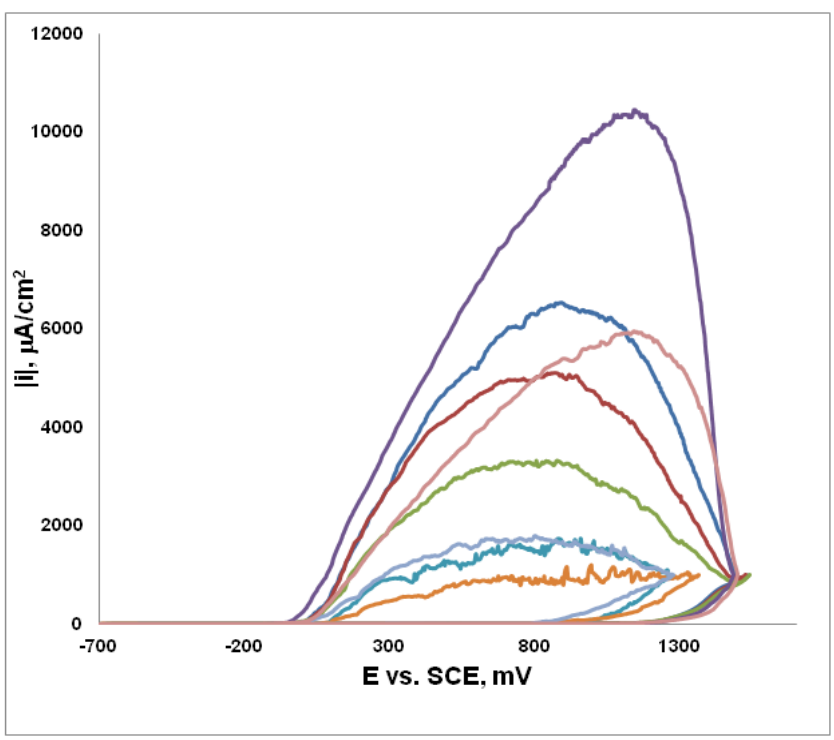

Fig. 2. Potentiodynamic polarization studies of AISI 304L SS in the animal slurry: linear vertical scale [10]

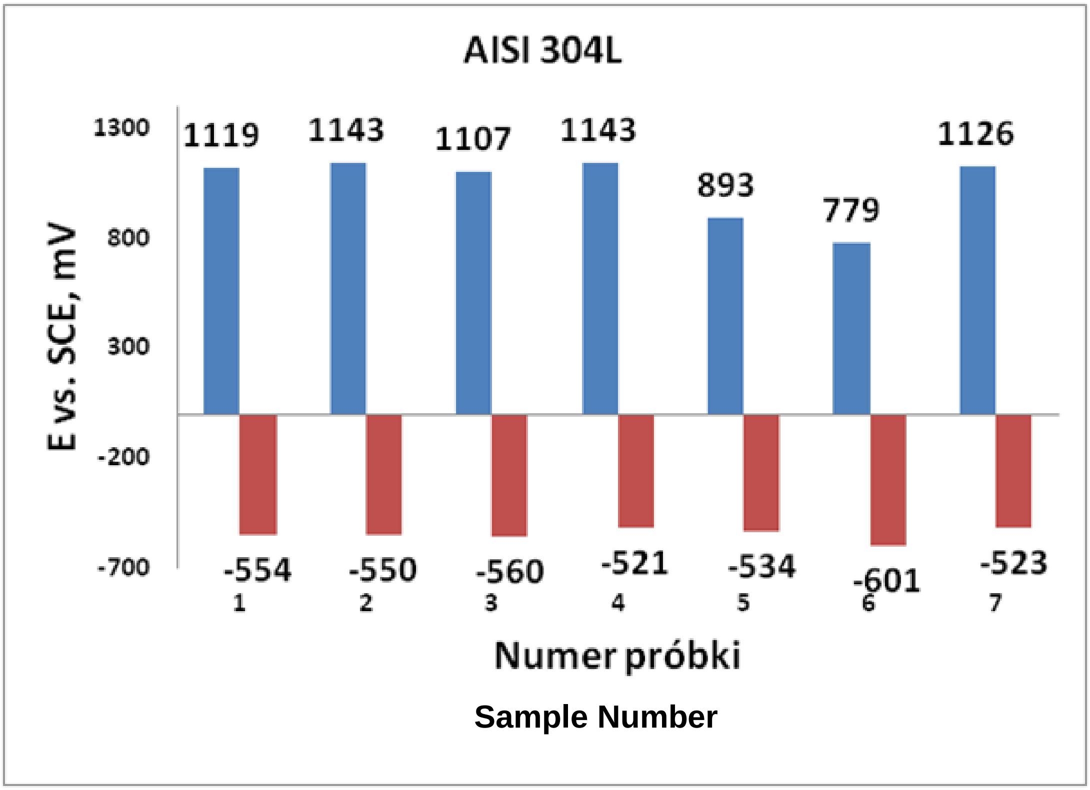

Fig. 3. Values of E_{pit} and E_{corr} of AISI 304L SS in the animal slurry [10]

3. 2. Corrosion study results for AISI 3316Ti SS in the slurry

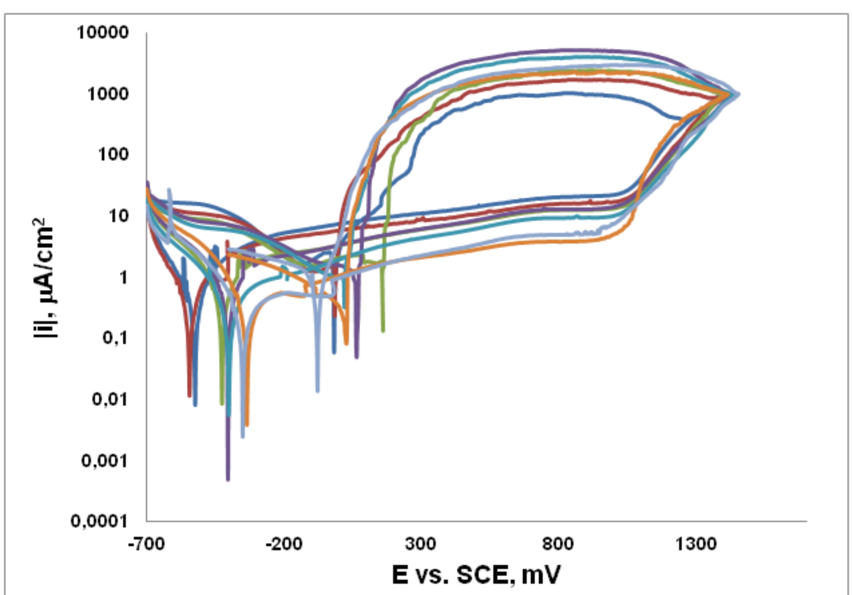

Fig. 4. Potentiodynamic polarization studies of AISI 316Ti SS in the animal slurry: logarithmic vertical scale [10]

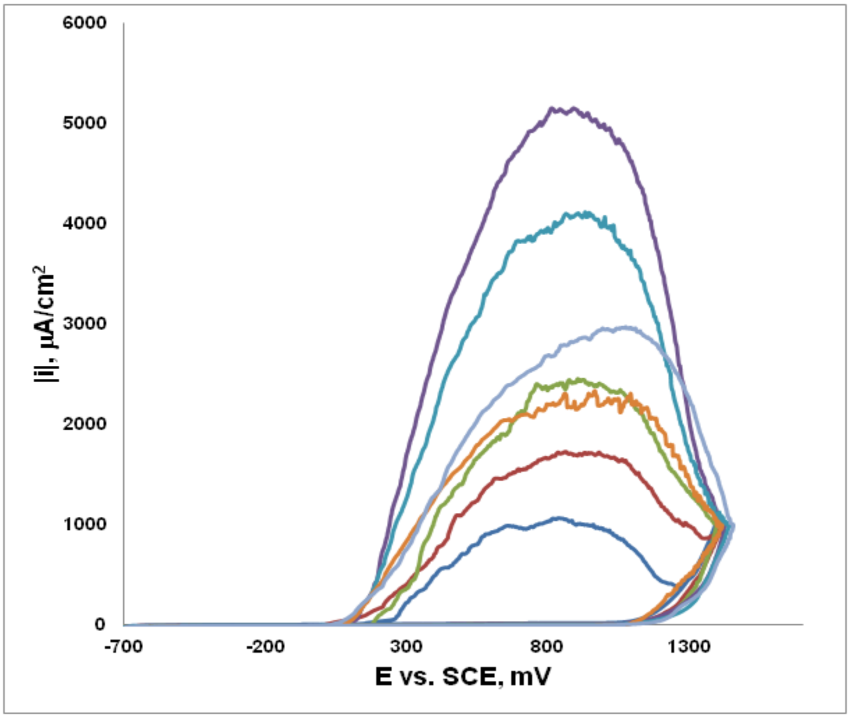

Fig. 5. Potentiodynamic polarization studies of AISI 316Ti SS in the animal slurry: linear vertical scale [10].

The corrosion study results of AISI 316Ti SS, with 7 repetitions, are given in Figures 4, 5, 6 and in Table 3. Corrosion potentials, measured against a calomel electrode, were in the range from –544 mV_{SCE} to 1079 mV_{SCE}. In the studies, the average value of the pitting corrosion potential for this steel in the animal slurry was 1058.4±28.3 mV_{SCE} at the range and median equaling 84 mV_{SCE} and 1059 mV_{SCE}, respectively. Corrosion potential of the linear Tafel region was –425.9±80,5 mV_{SCE}, at the median of –404 mV_{SCE}.

Table 3. Potentiodynamic corrosion study results of AISI 316Ti SS in the animal slurry [10].

Sample No.	AISI 316Ti SS	
	E_{pit}, mV_{SCE}	E_{corr}, mV_{SCE}
1	1012	–523
2	1041	–544
3	1079	–426
4	1077	–404
5	1059	–401
6	1045	–334

7	1096	–349
Average	**1058.4**	**–425.9**
Sta. deviation	**28.3**	**80.5**
Median	**1059**	**–404**
Maximum	**1096**	**–334**
Minimum	**1012**	**–544**
Range	**84**	**210**

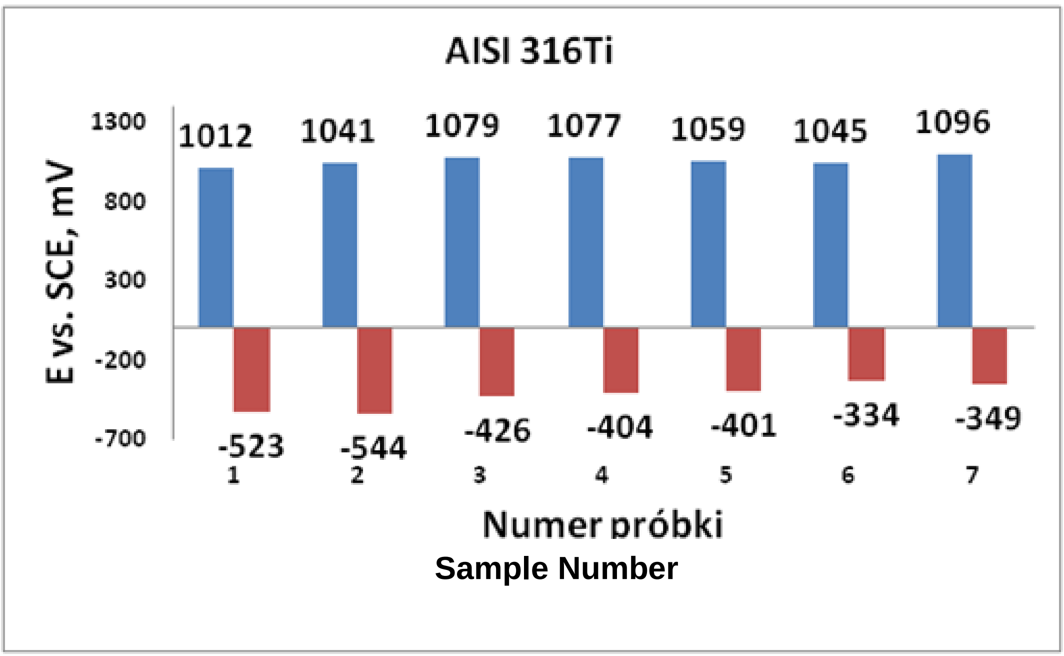

Fig. 6. Values of E_{pit} and E_{corr} of AISI 316Ti SS in the animal slurry [**10**]

3. 3. Statistic analysis of the corrosion study results

To compare the corrosion study results obtained on AISI 304L and AISI 316Ti stainless steels in the animal slurry, the Statistica software, presented in the consecutive Figures 7 through 10, were used. The obtained results indicate that there are no essential differences in average pitting corrosion potentials between the two tested steels, AISI 304L and AISI 316Ti, in the animal slurry. However, considerable differences were noted for the average potentials of general corrosion of the two studied steels, AISI 304L and AISI 316Ti [10]. In addition, it must be pointed out that in case of pitting corrosion potential the average is not so important as a minimal value, because it determines the initiation of pitting corrosion.

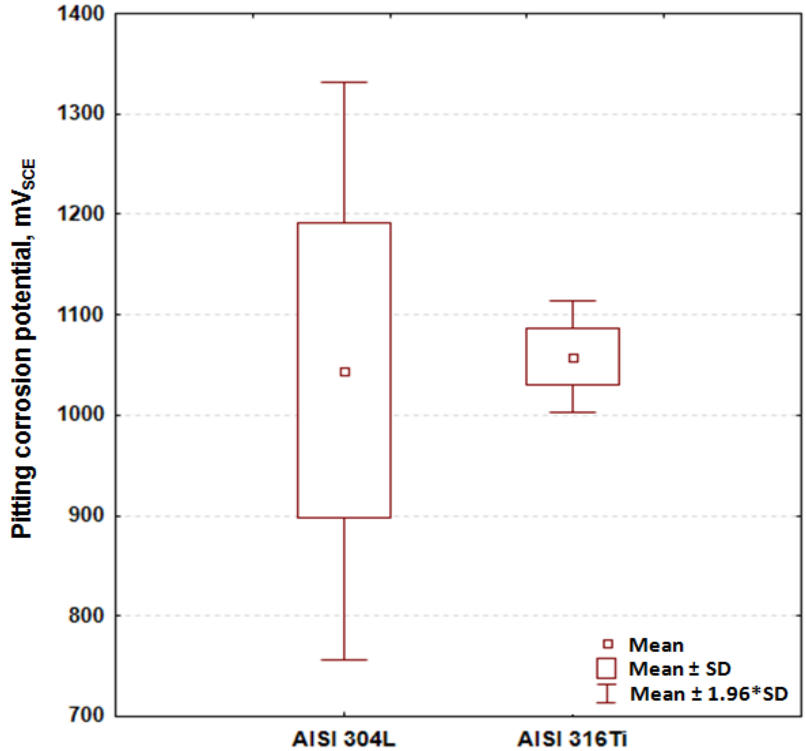

Fig. 7. Comparison of mean values of E_{pit} and E_{corr} regarding standard deviation of AISI 304L and 316Ti SS samples in the animal slurry [**10**]

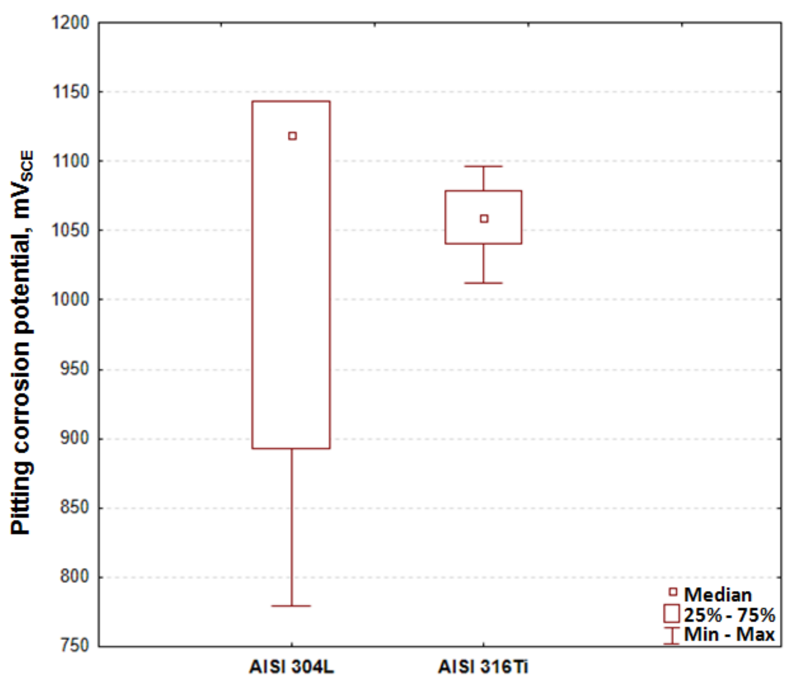

Fig. 8. Comparison of median values of E_{pit} regarding range of AISI 304L and 316Ti SS samples in the animal slurry [10].

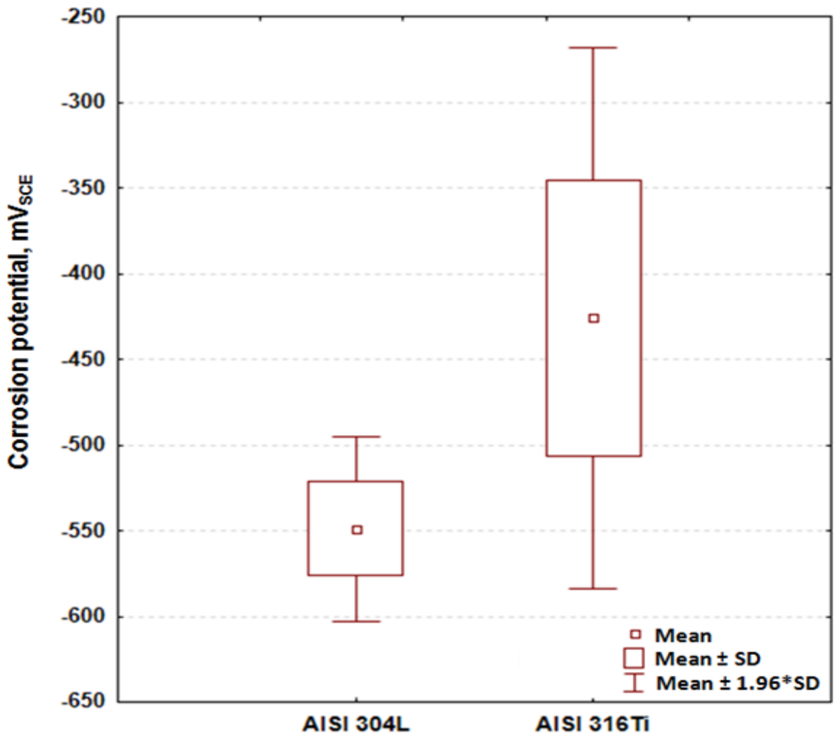

Fig. 9. Comparison of mean values of E_{corr} regarding standard deviation of AISI 304L and 316Ti SS samples (linear Tafel range) [10].

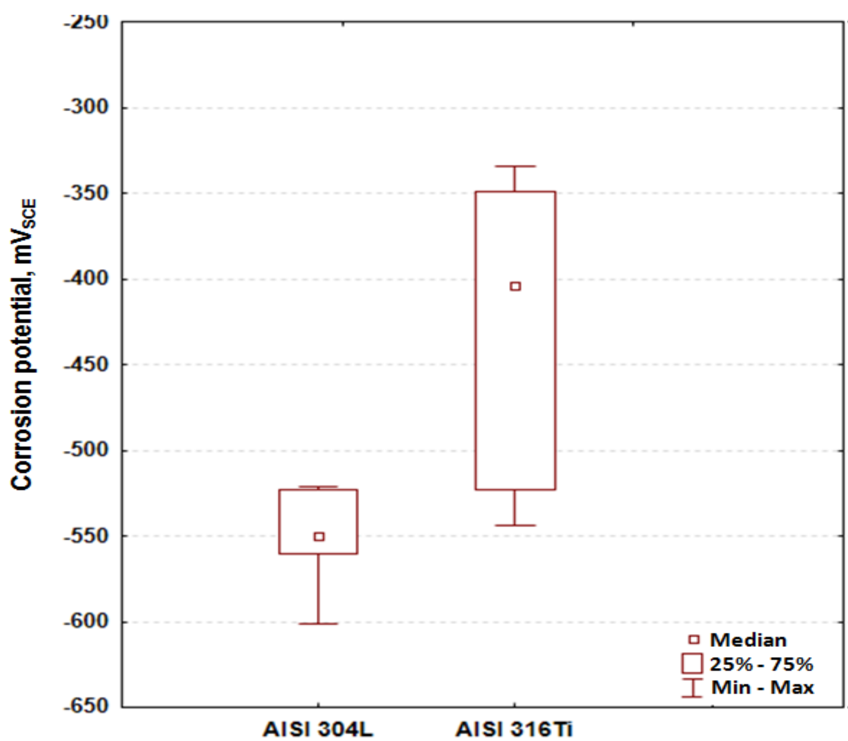

Fig. 10. Comparison of median values of E_{corr} regarding range of AISI 304L and 316Ti SS samples (linear Tafel range) [10].

4. DISCUSSION

This work was to present the effect of the animal slurry on the pitting corrosion of two austenitic stainless steels, AISI 304L and AISI 316Ti, used to manufacture working elements of machines for agriculture, such as septic tankers/haulers. Seven repetitions, under the same external conditions, concerning temperature and the slurry composition, were performed in the experimental studies. Results of the studies reveal that there is no crucial difference in the resistance to pitting corrosion in the animal slurry of both AISI 304L and AISI 316Ti SS. It concerns both the average value of pitting corrosion potential, and linear Tafel range. However, a big range of results in case of the pitting corrosion of AISI 304L (364 mV_{SCE}) in relation to that of AISI 316Ti SS (84 mV_{SCE}) shows the first one is less predictable in corrosion behavior. Moreover, when analyzing the minimum value of the pitting corrosion potential which decides of the initiation of pitting occurrence, it equals 779 mV_{SCE} for AISI 304L and 1012 mV_{SCE} for AISI 316Ti SS. It was proved that the steel with the addition of molybdenum and titanium reveals a better corrosion resistance. The use of a less costly steel, AISI 304L, with the difference between minimum pitting corrosion potential of the two stainless steels equaling 233 mV_{SCE}, may result in a risk of occurrence of pitting. This indication should be taken into account when building the tankers to carry and/or containers to maintain/store the animal slurry.

5. CONCLUSIONS

Based on the results obtained and the statistical analysis carried out, the following conclusions may be formulated:

(1) The average value of pitting corrosion potential of AISI 304L SS in the environment of animal slurry equals 1044.3±146.6 mV_{SCE} (median: 1119 mV_{SCE}), whereas that of AISI 316Ti SS is 1058.4±28.3 mV_{SCE} (median: 1059 mV_{SCE}).

(2) No essential difference exists in pitting corrosion resistance in animal slurry between austenitic AISI 304L and 316Ti SS.

(3) Corrosion potential of linear Tafel range of AISI 304L SS equals –549±80.5 mV_{SCE} (median: –550 mV_{SCE}), whereas that of AISI 316Ti is –425.9±80.5 mV_{SCE} (median: –404 mV_{SCE}); here also no essential difference in the corrosion potential of Tafel range appears.

(4) Range of results of pitting corrosion values of AISI 304L (364 mV_{SCE}) is over four times higher than that of AISI 316Ti (84 mV_{SCE}); here also the minimum value of pitting corrosion potential of AISI 304L (779 mV_{SCE}) is lower than that of AISI 316Ti (1012 mV_{SCE}).

(5) The austenitic stainless steel 304L is less predictable, concerning pitting corrosion occurrence, than that containing Mo and Ti, AISI 316Ti SS, with better pitting corrosion resistance.

(6) Both steels, AISI 304L and 316Ti, may be used to construct cisterns and applicators for the animal slurry, with less risk expected in case of using the second one.

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