Pitting corrosion,
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SURFACE TREATMENT OF STAINLESS STEEL INTENDED FOR UROLOGICAL STENTS

Abstract: The work presents the influence of the surface treatment of Cr-Ni-Mo stainless steel, intended for implants applied in urogenital surgery, on their corrosion resistance. The tests were carried out in the simulated urine at the temperature 37±1°C and pH = 6÷6,4. In particular, the pitting corrosion resistance tests were carried out.

1. INTRODUCTION

Stents in urology are used either to eliminate narrowing of the urethra or ureter. Stent insertion to urethra, while urether was narrowed by the Bening Postatic Hyperpalsion (BPH), was described for the first time in 1980 by Fabian [3, 9]. The catheterization which is uncomfortable for patient is not necessary when we use stent. Nowadays endoscopic stent implantation method which is used to treat the BPH is also used to treat narrowing of bulbar urethra caused by instrumentation, trauma, inflammation or congenital problems [10]. Stents implantation is also recommended for narrowing or cancerous narrowing of ureter. It is especially useful for patients who are qualified to surgery but with some serious disabilities that make normal operation impossible [1, 10, 18].

Stainless steels are the most common metallic biomaterials used for stents. Almost 90% of these stents is made of steel [4÷6, 14, 15, 23÷26]. Since many years this group of biomaterials is in common use mainly as short term implants, for example in an orthopedic surgery, a dental surgery and thoracosurgery [7, 8, 12, 16, 17, 20, 21].

Very little is known about the corrosion resistance of metallic implants in a urine. This knowledge is a basic condition related with the usage of this kind of stents. It is known that the type of corrosion and its intensity depend on a chemical and phase composition of the biomaterial, stress and strain fields, geometrical features of implant and the operational technique.

The quality of the surface layer also plays important role. A qualitative and a quantitative description of corrosion processes in artificial urine will determine the efficiency and the clinical usefulness of implants and will impinge on postoperative complications. For this reasons a surface treatatment of the Cr-Ni-Mo alloy is presented in this work. The surface treatment is important because of corrosion resistance minimizing reactions and postoperative complications [2, 11].

2. MATERIAL AND METHODS

The corrosion resistance of Cr-Ni-Mo stainless steel intended for implants applied in the little invasive surgery of urogenital system was tested. The tests were carried out on samples in the form of a rod of diameter d = 5 mm and length equal to l = 15 mm. The tested material met implantation requirements concerning the chemical composition, the structure and mechanical properties.

The tests were carried out on samples of the following surfaces: grinded – average roughness R_a = 0,31 μm, electropolished – average roughness R_a = 0,10 μm and electropolished and chemically passivated in conditions worked by the authors – fig.1. In order to measure the roughness the Surtronic 3+ surface analyzer was applied.

The pitting corrosion tests were realized by recording of anodic polarization curves with the use of the potentiodynamic method. The VoltaLab® PGP 201 system for electrochemical tests was applied – fig. 2 [19]. The saturated calomel electrode (SCE) of KP-113 type was applied as the reference electrode. The tests were carried out in electrolyte simulating urine at the temperature of 37±1 °C and pH = 6÷6,4. The electrolyte consisted of two solutions A and B mixed together in the ratio of 1:1 – table 1.

Observations of samples surfaces were carried out both before and after the corrosion tests. The observations were realized with the use of the MST ZOOM stereoscopic microscope in the magnification range from 6 to 37.

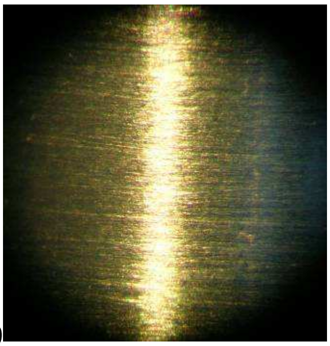
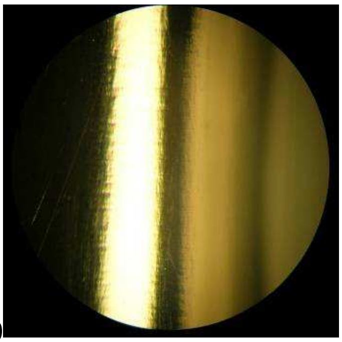
a)  b) 

Fig. 1 View of the samples surface: a) grinded R_a = 0,31 μm, b) electropolished R_a = 0,10 μm

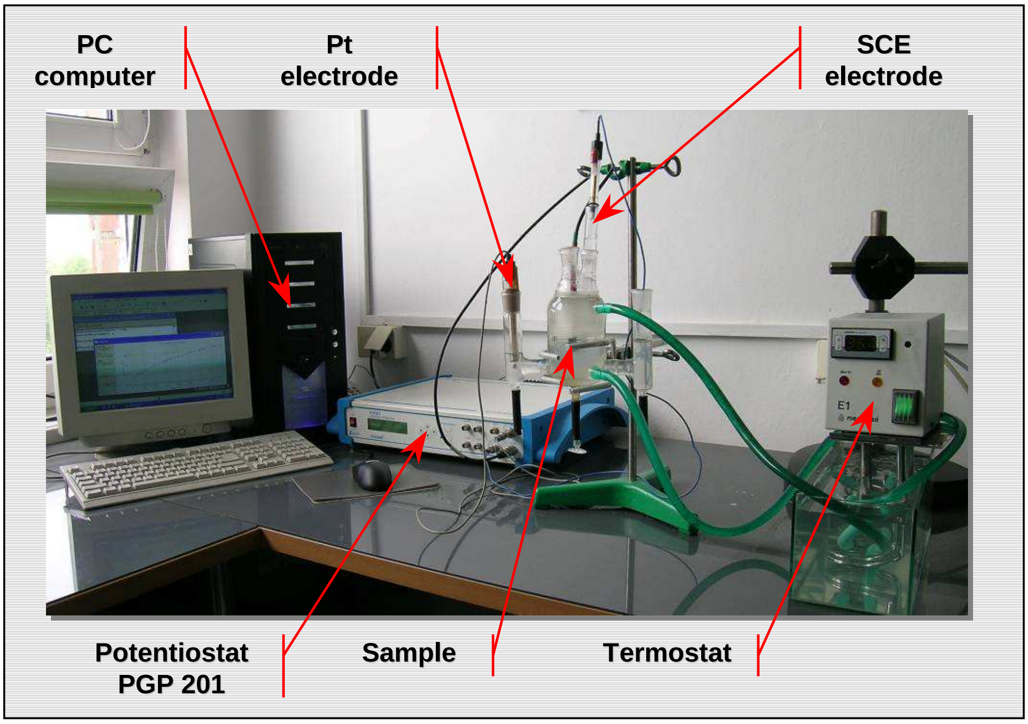


Fig. 2 Diagram of the corrosion resistance set

Table 1.
Artificial urine (A : B= 1:1) [13, 22]

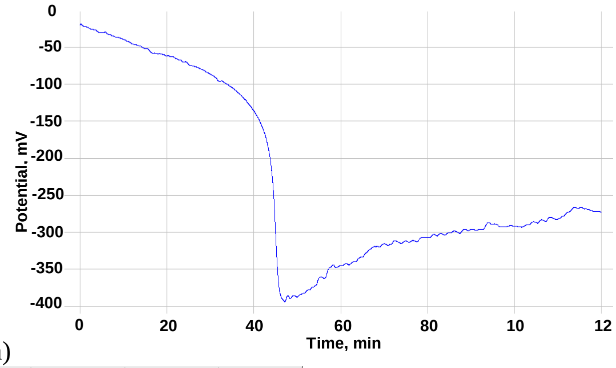
Ingredients A	g/l distiled water	Ingrediends B	g/l distiled water
$CaCl_2 2H_2O$	1.765	$NaH_2PO_4 2H_2O$	2.660
Na_2SO_4	4.862	Na_2HPO_4	0.869
$MgSO_4 7H_2O$	1.462	$Na_3Cit{\cdot}2H_2O$	1.168
NH_4Cl	4.643	NaCl	13.545
KCL	12.130		

3. RESULTS

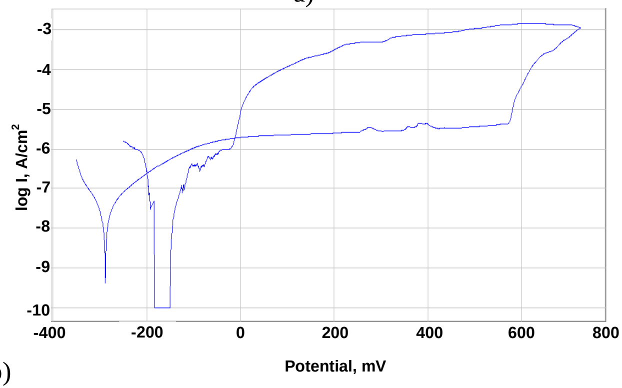
Results of electrochemical tests have revealed the influence of surface preparation of the Cr-Ni-Mo steel on the corrosion resistance – table 2. For the grinded samples, the corrosion potential was in the range E_{kor}=-250÷-134 mV - fig. 3a. Polarization of samples caused the increase of anodic current for potentials in the range E_B = +565÷+657 mV – fig. 3b. The repassivation potential was in the range E_{cp}=-22÷+272 mV. Polarization resistance of the samples was equal to R_p=536 kΩcm^2.

Table 2.
Pitting corrosion resistance of Cr-Ni-Mo alloy

Surface preparation method	Corrosion potential E_{kor}, mV	Breakdown potential E_B, mV	Repassivation potential E_{cp}, mV	Polarization resistance R_p, kΩcm^2
Grinded	-250 ÷ -134	+565 ÷ +657	-22 ÷ +272	536
Electropolished	-72 ÷ -38	+819 ÷ +942	0 ÷ +140	931
Electropolished and passivated	-61 ÷ -38	+1257 ÷ +1296	-48 ÷ +20	1940



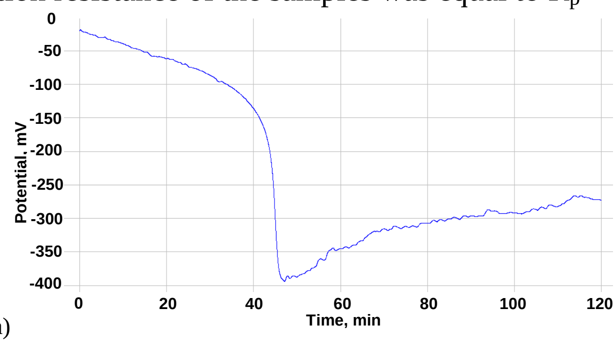
a)



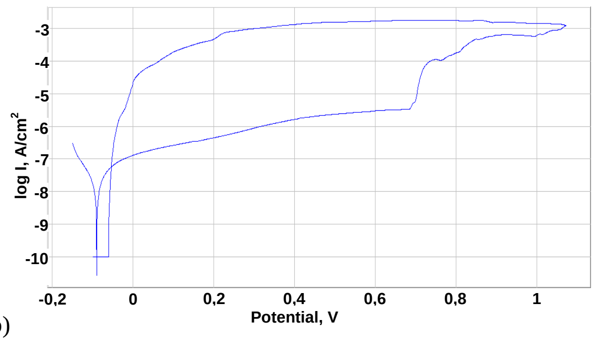
b)

Fig. 3 a) corrosion potential changes in time for grinded samples, time 120 min,
b) anodic polarization curve for grinded samples

For the electropolished samples, the corrosion potential was in the range E_{kor}=-72÷-38 mV – fig. 4a. Polarization of samples caused the increase of anodic current for potentials in the range E_B=+819÷+942 mV – fig. 4b, The repassivation potential was in the range E_{cp}=0÷+140 mV. Polarization resistance of the samples was equal to R_p = 931 kΩcm^2.



a)



b)

Fig. 4 a) corrosion potential changes in time for electropolished samples, time 90 min,
b) anodic polarization curve for electropolished samples

For the electropolished and passivated samples, the corrosion potential was in the range E_{kor}=-61÷-38 mV – fig. 5a. Polarization of samples caused the increase of anodic current for potentials in the range E_B=+1257÷+1296 mV – fig. 5b, The repassivation potential was in the range E_{cp}=-48÷+20 mV. Polarization resistance of the electropolished and passivated samples was equal to R_p=1940 kΩcm^2.

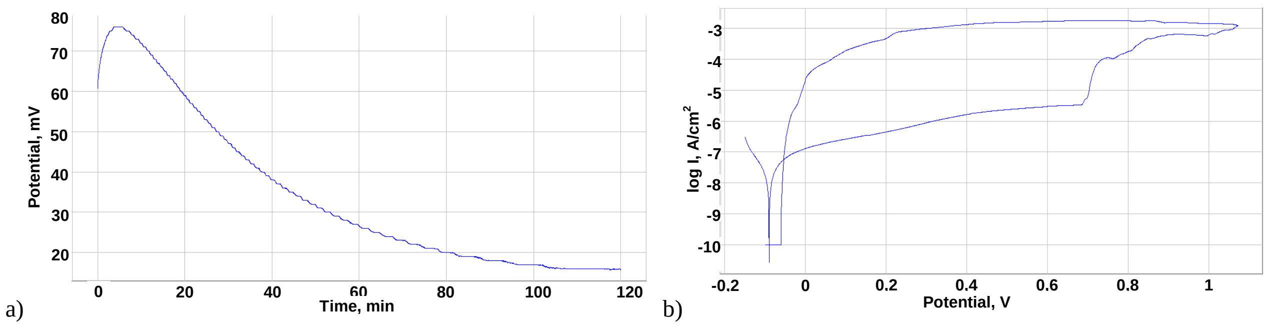


Fig. 5 a) corrosion potential changes in time for electropolished and chemically passivated samples, time 120 min, b) anodic polarization curve for electropolished and chemically passivated samples

The recorded curves of the anodic polarization were mainly characterized by the decrease of the anodic current density in the range of human body potentials ie. 0÷0,4 V The smallest density was observed for the electropolished and passivated samples – fig. 6.

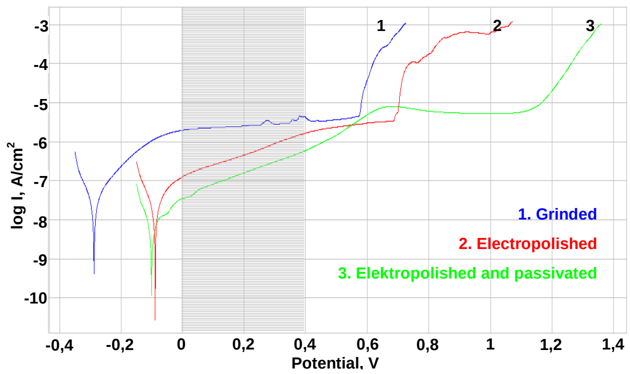


Fig. 6 Anodic polarization curves of Cr-Ni-Mo samples after diverse surface preparation

Observations of samples surfaces with the use of the stereoscopic microscope were carried out after the corrosion tests. Single pits were observed on every sample – fig. 7.

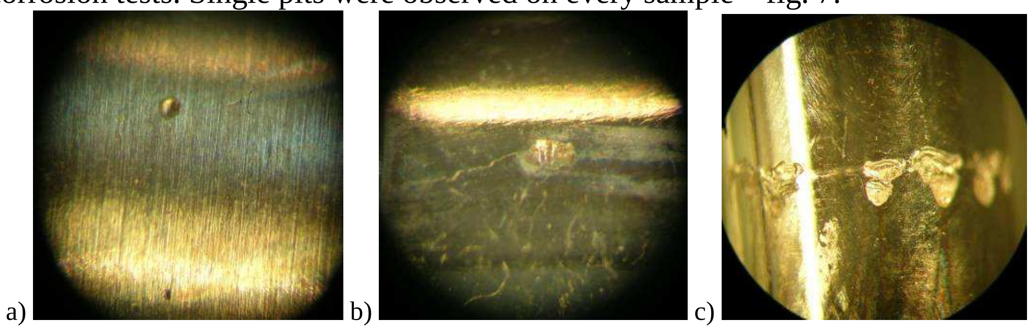


Fig. 7 Single pits on the samples surface: a) grinded specimens, b) electropolished specimens, c) electropolished and chemically passivated specimens

4. CONCLUSION

The aim of the research was the usefulness evaluation of the Cr-Ni-Mo stainless steel, commonly used for stents in operational cardiology, for application in urogenital system.

The obtained results have shown favorable influence of the applied surface treatment process on the corrosion resistance of samples made of the Cr-Ni-Mo stainless steel. The tests have revealed that the passive layer created in the electropolishing and the chemical passivation process improves the corrosion resistance of the investigated steel.

In spite of the clear influence of the surface condition on the corrosion resistance of the Cr-Ni-Mo stainless steel, further research on metallic biomaterial, appropriate for application in urogenital system, seems to be necessary.

To this end it seems to be necessary to carry out analogous corrosion resistance tests in simulated urine for other metallic biomaterials intended for stents. The tests should be completed with evaluation of susceptibility to incrustation. Ni-Ti alloys and Co-based alloys seem to be promising.

ACKNOWLEDGEMENTS

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