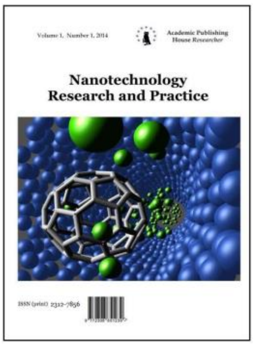

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Improving Nano-Hardness of Stainless Steel Cr18Ni10Ti Through Electrochemical Machining

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Abstract

One of the major mechanical and physical parameters for surface quality is hardness. In this paper was studied the electrochemical machining (ECM) to improve the surface micro-hardness and nano-hardness of stainless steel samples. The materials studied are used as samples of stainless steel Cr18Ni10Ti after electrochemical machining under different current density in a water solution of NaCl with various concentrations. The results showed that with increasing the current density from 0 to 28.3 A/cm^2 the surface micro-hardness and nano-hardness of samples after the ECM increases and maximum value was 5.06 GPa.

Keywords: electrochemical machining (ECM), Cr18Ni10Ti, surface, micro-hardness, nano-hardness.

Introduction

Electrochemical machining (ECM) is a complex of processes, which give by anodic dissolution, create shapes for workpiece [1]. ECM removes from surface layer of workpiece that turned defective as a result of other treatment. ECM do not shaping defective [2]. ECM creates better surfaces roughness, and clean surfaces, etc [3].

The increasing of micro-hardness of stainless steel has been described in [4], using electrical discharge machining. Plasma nitriding at 400 °C and 570 °C for samples from AISI316 stainless steel was studied over a range of processing conditions, the results showed that corrosion resistance and micro-hardness of surface layer increased [5]. The samples from AISI 304L austenitic stainless steel have been plasma nitrided at temperatures ranging from 400 to 600 °C, the results showed that corrosion resistance increased and the maximum Knoop hardness after plasma nitriding is about 1400 HK 0.01 [6]. In paper [7] plasma nitriding at 420 °C, 460 °C or 500 °C for 20 h for AISI 410 martensitic stainless steel was studied, the results showed that this procedure not only improved the surface hardness but also improved the corrosion resistance of the AISI 410 steel. In paper [8] laser bending of stainless steel AISI 304 sheet was researched, and micro-hardness of the bend zone increased 2 times. In paper [9] was researched surface mechanical attrition treatment to improve mechanical properties of AISI 316L stainless steel.

The surface layer nano-crystallization of samples from 304 stainless steel was produced using a sandblasting and annealing process, the results showed that this procedure not only improved the surface mechanical properties and also improved corrosion resistance [10]. In paper [11] electrochemical micro-machining or micro-ECM was studied, a review is presented on research, development and industrial practice, micro-ECM has high precision machining operations (±1–50 µm). In paper [12] the electrochemical machining (ECM) characteristics of titanium aluminide are examined, surface hardness of the ECM TiAl decreased by 46% with respect to conventionally machined surfaces. The pulse ECM by bipolar current was studied, this procedure is creating special physical-and-chemical properties of surface, reducing micro-roughness on the machined surface and increasing machining precision of the machined surface [13]. Process, which integrates the merits of electrochemical smoothing (ECS) and roller burnishing (RB) for minimizing the roundness error and increasing surface micro-hardness of cylindrical parts, is proposed [14], surface micro-hardness considerably increases about 31.5% and roundness 2.32 µm. Micro-pins of tungsten carbide alloy created by ECM using a neutral electrolyte, $NaNO_3$ water solution with different machining conditions, results is micro-pin with the diameter about 20 µm, the length about 2 mm [15]. A tungsten micro-rod with a high aspect ratio fabricated by electrochemical micro-machining, result is straight rod in diameter of 2 µm with an aspect ratio of 120 from a tungsten rod with a diameter of 200 µm using a tool electrode with an end diameter of 50 µm under two-stage procedure [16]. The micro-hardness values of Cr18Ni10Ti steel before treatment were 250 MPa, and after the electrochemical treatment on interelectrode gaps midget (0.2 mm) in the electrolyte with 5% $NaNO_3$ – 260 MPa, after treatment in the electrolyte of 5% NaCl – 200 MPa [17]. In paper [18] was investigated the nano-hardness tungsten surface after ECM, which achieves maximum nano-hardness values 28.5 GPa, the sample after cutting abrasive wheel.

Analysis of other scientists study data showed that the macro, micro and nanoscopic parameters surface hardness materials after the ECM are strongly associated with processing parameters such as current density, pulse duration, electrolyte concentration, and others.

From these analyses, the study of the potential to increase surface nano-hardness after the ECM is the purpose of the research.

Material and Methods

In this article the surface micro-hardness and nano-hardness of samples from Cr18Ni10Ti stainless steel after ECM was studied, which was performed at a current density of 0 to 30 A/cm^2 in a water solution 5; 10 and 15% NaCl [3]. A study was conducted using an electrochemical cell, which was manufactured in the work [19].

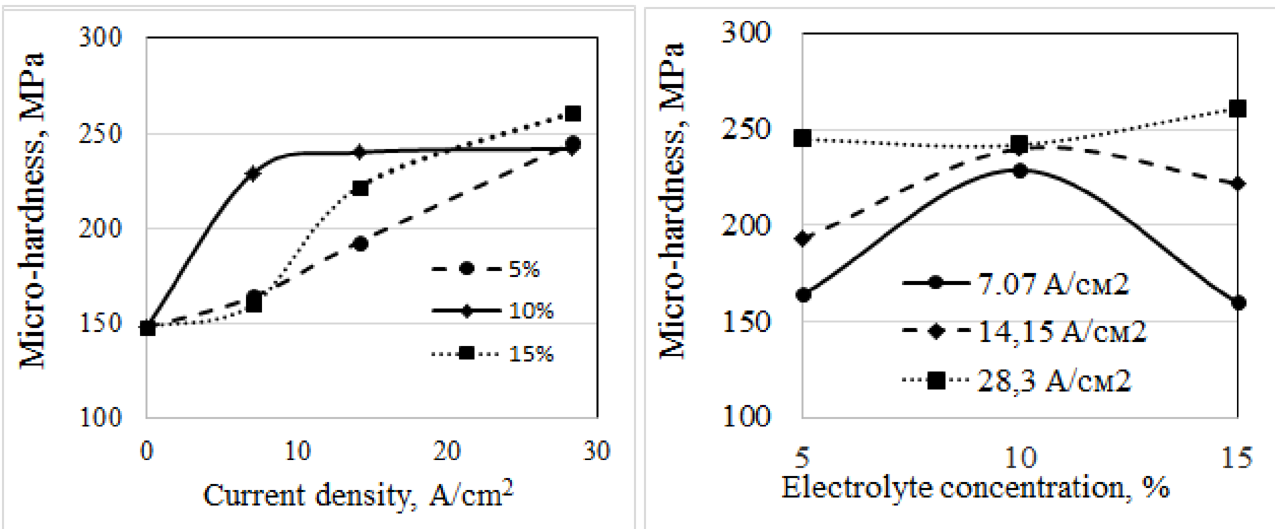
The study of micro- and nano-hardness of the surface of the material was carried out on samples previously studied by optical microscopy. The surface micro-hardness of samples was measured according to GOST 9450–76 [20] on the micro durometer instrument PMT–3 (GEO-NDT Ltd., Russia) [21]. Material surface nano-hardness of samples was measured with a scanning probe microscope (Microtestmachines Co.) [22] and a scanning nano-hardness testers "NanoScan" (Federal State Budgetary Institution “Technological Institute for Superhard and Novel Carbon Materials”, Russia), which operates in contact mode, with a maximum scan field 3/3/1 µm and resolution 3/3/1 A0.

Results and Discussion

Figure 1 shows images on the surfaces of the steel Cr18Ni10Ti samples after the ECM under different conditions: in aqueous solution 5-; 10-; 15% NaCl and different current densities in the range of up to 28 A/cm^2.

Fig. 1. Surfaces images of stainless steel sample Cr18Ni10Ti after the ECM

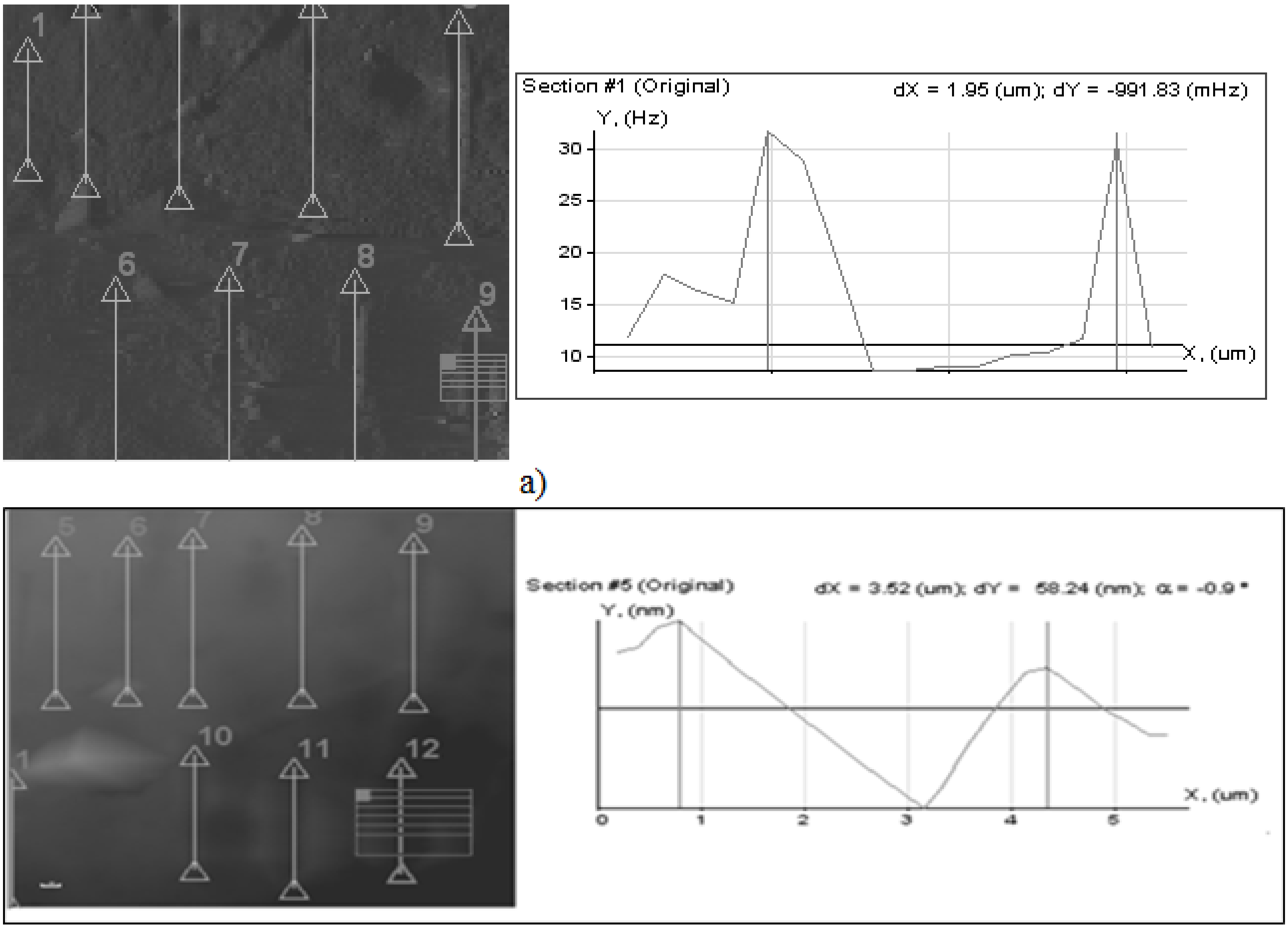
As a result, we obtained the surface micro-hardness of samples, and its dependence on current density and the electrolyte concentration, which are presented in figure 2.



a) b)

Fig. 2. Micro-hardness surface Cr18Ni10Ti after ECM:
a) – for different values of the electrolyte concentration; b) – for different values of current density

Thus, micro-hardness of the details after ECM is increased with increasing current density. At a current density 28.3 A/cm² in water solution of 15% NaCl micro-hardness of the surface of stainless steel details Cr18Ni10Ti reached 261 Mpa, increased 1.8 times. Micro-hardness in water solution of 10% NaCl is slightly dependent on the current density.



a)

b)

Fig. 3. Surfaces with drawing of scratches and section profilograms of surfaces of details from stainless steel Cr18Ni10Ti after ECM in water solution of 5% (a) and 15% (b) NaCl and at a current density of 28.3 A/cm²

Figure 3 shows SPM-images of stainless steel Cr18Ni10Ti surface with drawing of scratches and section profilograms with a load of 20.000 µN. The increase current density and electrolyte concentration leads to an improvement of stainless steel sample surface and hence scratching process occurred easily. Data are obtained from the analysis of images obtained by the depth of scratches nano-hardness value.

Figure 4 shows surface nano-hardness of stainless steel Cr18Ni10Ti after ECM depending on the current density and the electrolyte concentration.

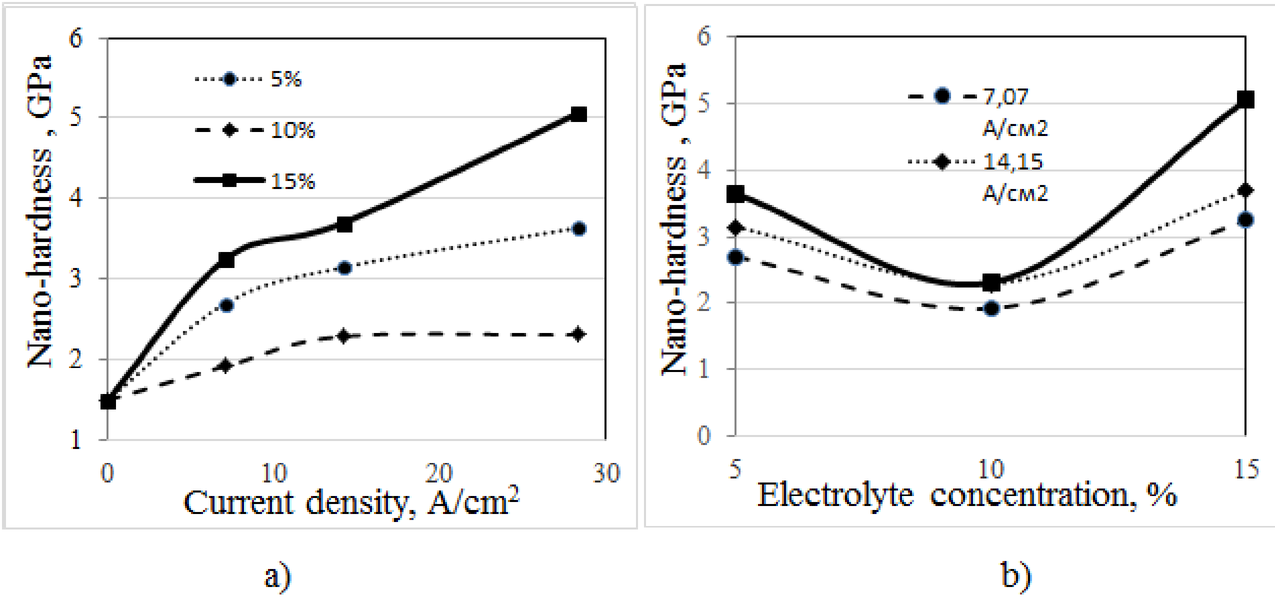


Fig. 4. Nano-hardness surface Cr18Ni10Ti after ECM:
a) – for different values of the electrolyte concentration; b) – for different values of current density

It is seen that with increasing the current density increases the surface nano-hardness of stainless steel in independence with the electrolyte concentration. Surface nano-hardness of stainless steel Cr18Ni10Ti after ECM is directly proportional to the current density, and therefore unity is depending on surface micro-hardness and nano-hardness after ECM on the current density. The maximum value of surface nano-hardness of stainless steel Cr18Ni10Ti at a current density 28.3 A/cm² in water solution of 15% NaCl, reached 5.06 GPa, i.e. increased 5 times. And when current density is fixed, the surface nano-hardness increases with increasing NaCl concentration from 10 to 15%.

Conclusion

The article studied the surface micro-hardness and nano-hardness of samples from stainless steel Cr18Ni10Ti by ECM. With increasing current density from 0 to 28.3 A/cm² the surface micro-hardness and nano-hardness of samples after ECM increases. In this research the maximum value of nano-hardness was 5.06 GPa. And thus, the ECM can improve surface micro-hardness and nano-hardness of samples made from stainless steel Cr18Ni10Ti.

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Повышение нанотвердости поверхности нержавеющей стали Х18Н10Т путем электрохимической обработки

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Аннотация. Одним из основных механико-физических параметров качества поверхности является твердость. В этой статье исследовалась электрохимическая обработка (ЭХО) для повышения микротвердости и нано-твердости поверхности образцов из нержавеющей стали. В качестве исследованных материалов использованы образцы из нержавеющей стали Х18Н10Т после электрохимической обработки при различной плотности тока в водном растворе NaCl с различными концентрациями. Результаты показали, что при увеличении плотности тока в диапазоне от 0 до 28.3 А/см^2 поверхности микро-твердость и нано-твердость образцов после того, как ECM увеличивается, и максимальное значение было 5.06 ГПа.

Ключевые слова: электрохимическая обработка (ЭХО), Х18Н10Т, поверхность, микро-твердость, нано-твердость.