Archives of Materials Science and Engineering

Volume 41
Issue 1
January 2010
Pages 21-27

International Scientific Journal
published monthly by the
World Academy of Materials
and Manufacturing Engineering

The analysis of the electrode potential shift in the examination of plastic-covered metal fatigue strength

K. Jamroziak*, W. Jargulinski
Tadeusz Kosciuszko Military Academy of Land Forces,
ul. Czajkowskiego 109, 51-150 Wrocław, Poland
* Corresponding author: E-mail address: krzysztof.jamroziak@interia.pl

Received 12.11.2009; published in revised form 01.01.2010

ABSTRACT

Purpose: A development of methodology of adhesive force measuring, and at the same time an estimation of its value change in the specifically designated group of materials that are used in technical objects' construction, requires defining the fatigue strength value changes. The one of the elements influencing adhesive force is electrode potential estimation in the relation to the function of adhesive force considering variable layers of the coatings.

Design/methodology/approach: This paper describes an issue of electrode potential shift influence on metals' fatigue strength. The issue was presented based on the literature and conducted tests.

Findings: The results of the examinations concern electrode potential shift influence on adhesion forces' increase in the materials covered with various coatings in relation to a defined coating thickness.

Research limitations/implications: After earlier made tests, when it was forecast that electrode potential influences an increase in fatigue strength. It was formulated for verification of the assumed hypothesis. The tests were conducted on samples of selected metals coated with various configurations of layers. The methodology was limited to the measurement of the research results with a single kind of demonstration (standard) electrode.

Practical implications: The results of the tests, in shape of charts representing the shift of electrode potential in relation to time, will allow the authors to resolve next research problem to describe a mechanism of hydrogen absorption by a metal base. This will allow to develop methodology of moist (damp) angle measure. The angle influences adhesion force that is responsible for an increase in fatigue strength.

Originality/value: The value of attained results will help to develop general assumptions for methodology of moist (damp) angle measure.

Keywords: Electrical properties; Fatigue strength; Adhesion; Electrode potential

Reference to this paper should be given in the following way:

K. Jamroziak, W. Jargulinski, The analysis of the electrode potential shift in the examination of plastic-covered metal fatigue strength, Archives of Materials Science and Engineering 41/1 (2010) 21-27.

PROPERTIES

1. Introduction

Recently, a tremendous development in material engineering has taken place. It is mainly connected to military technology. Particularly, it is true in relation to construction of mine and fragmentation projectiles protective vehicles. This kind of technical objects are under irregular stress. They are characterized by being in operation in constant or varying magnetic and electrical field. The materials of increased fatigue strength are used to construct such objects. The current requirements for used technology are a big challenge for the constructors (designers). Increased fatigue strength is required from a construction, which further results in its constant optimisation and search for new metals (metals and its alloys) and various ways to increase its fatigue strength, especially dynamically stressed. Apart from the known engineer's practical activity in this area, such as: thermo-chemical processing, surface cogging, covering metal surfaces with layers of various metals, there is also a method of covering metals with plastic coating. The conducted analysis of literature [1-10], and tests proved that plastic coats increase the fatigue strength regardless of a type of stress, metal (alloy) or material used for plastic coat.

Plastic coats covering metal samples that create Electric Double Layer (EDL), show a positive electrode potential shift. They are showing an increase in adhesion force to metal base, and an increase in fatigue strength. There is a common view that attraction of electric charges of opposing poles brings an additional strength to adhesive attraction caused by inter-particle forces [5]. Based on that view, this is the reason of increase in fatigue strength of plastic coated metals of various polarities EDL.

In this paper, the authors have focused on describing electrode potential shift mechanism in metals coated with selected plastics. It is a continuation of scientific description of electric double layer phenomenon influence on the increase of this adhesion force [11].

2. Problem formulation

The covering metals with plastic coatings, as mentioned in previous works [12-14], affects fatigue strength regardless of metal, plastic or stress. Many researchers [15-21] prove the increase in fatigue strength of plastic covered metals of different characteristics such as: construction, physical, chemical, electrical characteristics, and chemical composition.

The characteristic factor of these plastics is its construction – partly crystal with crystalloid factor α with value between 30% and 90%. Simultaneously, it is evident that they create EDL at the border with metal. The polarization of EDL varies and depends on a kind of the used plastic. The increase in fatigue strength does not depend on EDL polarization, but it is connected with the fact of its existence. In Fig. 1, a sample with EDL polarized negatively (Fe-PCW-Fe composition), and with EDL polarized positively (Fe-Epidiam 5-Fe composition) is presented.

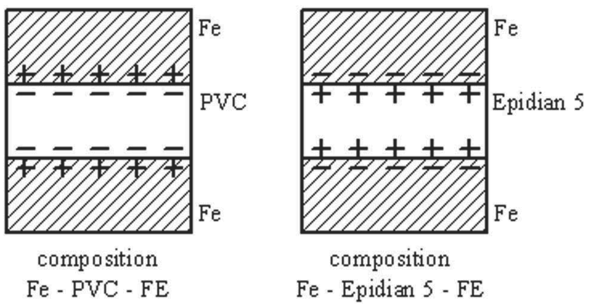

Fig. 1. Samples with EDL of negative (left) and positive polarization (right)

Until now, there has been no reference to the viewpoint claiming that adhesion-to-metal force does not influence changes of fatigue strength. Plastic coatings that cover metal samples indicate an electrode potential shift in the positive direction, and, at the same time, indicate an increase in adhesion-to-surface force and an increase in fatigue strength. The adhesive connections are created thanks to attraction forces between particles of adjoined parts (phases), which may have different origins, i.e. van der Vaals, dipole, ion, or metallic forces. The chemical connections may be created also in adhesive layer [5].

A part of adhesion force occurs because of the existence of EDL at the metal-plastic border. An attraction of surface charges of opposite poles brings additional factor into adhesion attraction caused by inter-element forces [5]. An indicator of adhesion is F_A force or work, and necessary for disengaging adjoining elements is calculated on a surface of contact unit [5].

3. Selected results of tests

3.1. Test object

The test objects were samples made of steel 45 and brass M63 based on technological drawing (Fig. 2). The samples were covered with plastic of various thickness (Fig. 3) of the following materials:

- Epoxide resin (Epidian 5),
- Paraffin,
- PVC type plastic.

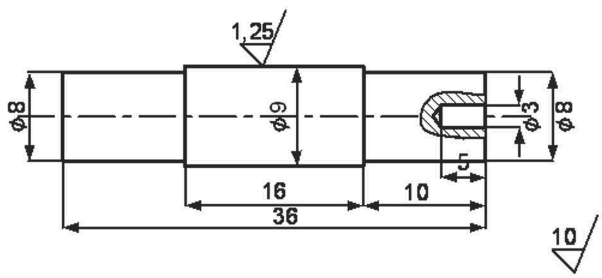

Fig. 2. Dimensions of sample for an electrode potential test

3.2. The tests and results

An electrode potential value has been registered for five hours, with use of the calomel electrode as a standard. The tests (Fig. 4) were conducted on non-coated metal samples (pure metals and alloys) and samples covered with various layers of various thickness.

Registered charts of electrode potential U in relation to time t are presented below (Figs. 5-11).

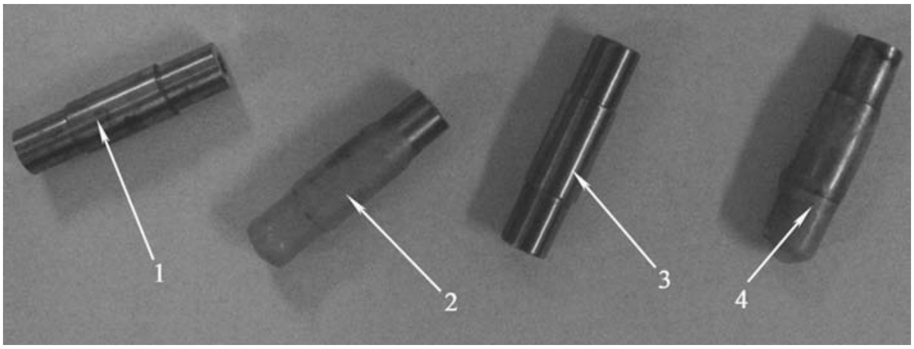

Fig. 3. Samples for tests: 1-brass M63, 2-brass M63 with coating, 3-steel 45, 4-steel 45 with coating

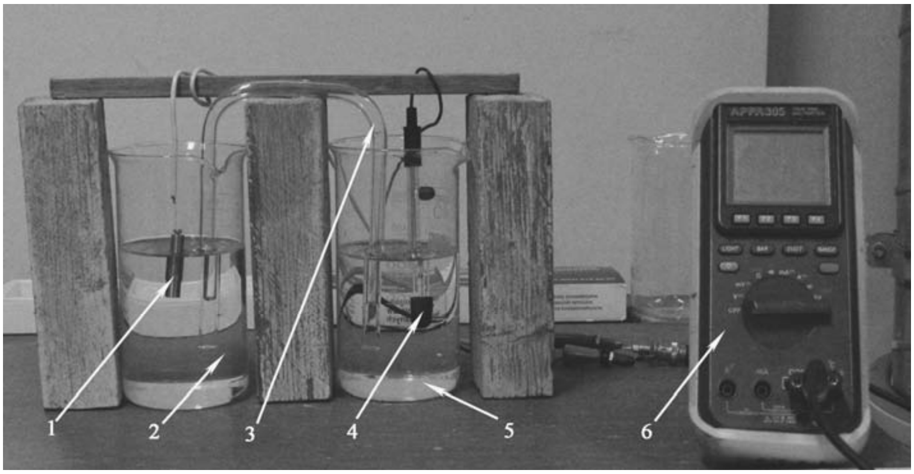

Fig. 4. View of research station: 1-Investigated sample, 2-electrolytic cell with 3% NaCl, 3-solution electrolytic bridge, 4-calomel electrode, 5-electrolytic cell with KCl saturated solution, 6-voltmeter

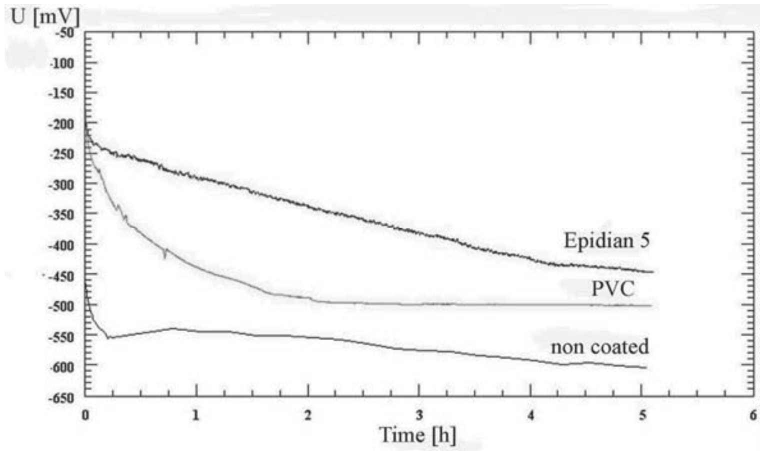

Fig. 5. Chart of measure of electrode potential of steel 45

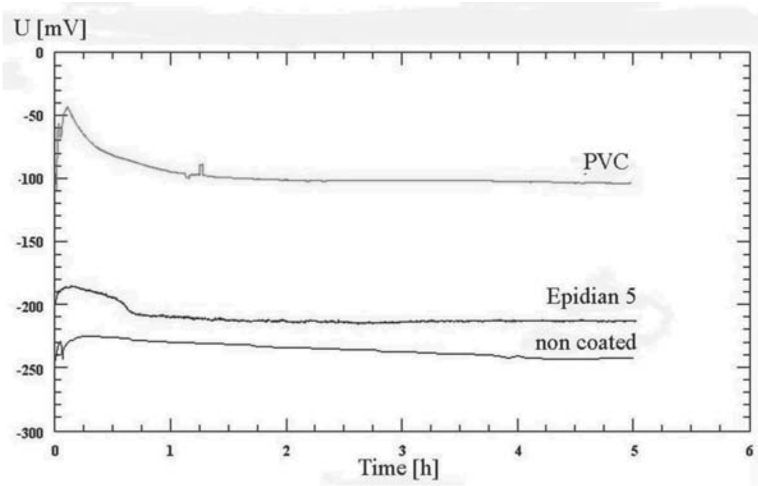

Fig. 6. Chart of measure of electrode potential of brass M63

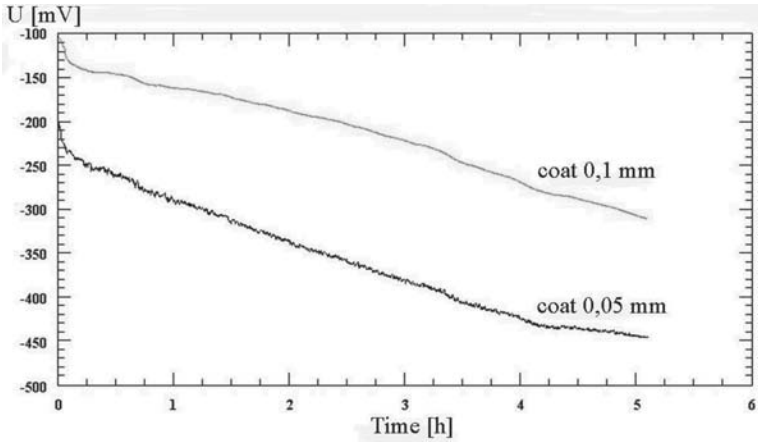

Fig. 7. Chart of measure of electrode potential of steel 45 covered with Epidian 5 with selected layer thickness

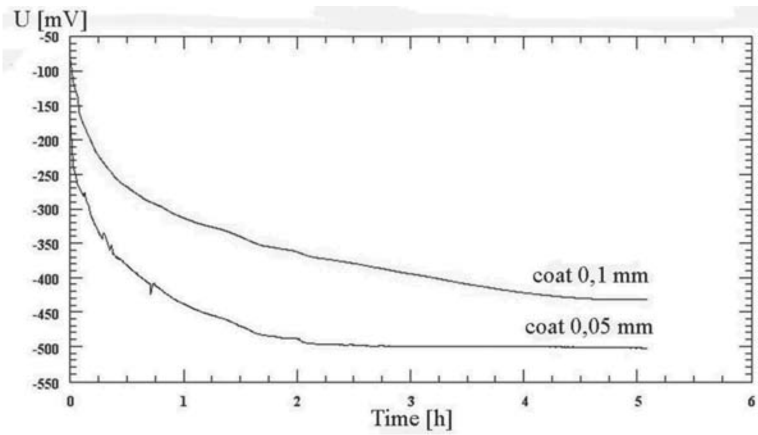

Fig. 8. Chart of measure of electrode potential of steel 45 covered with PVC with selected layer thickness

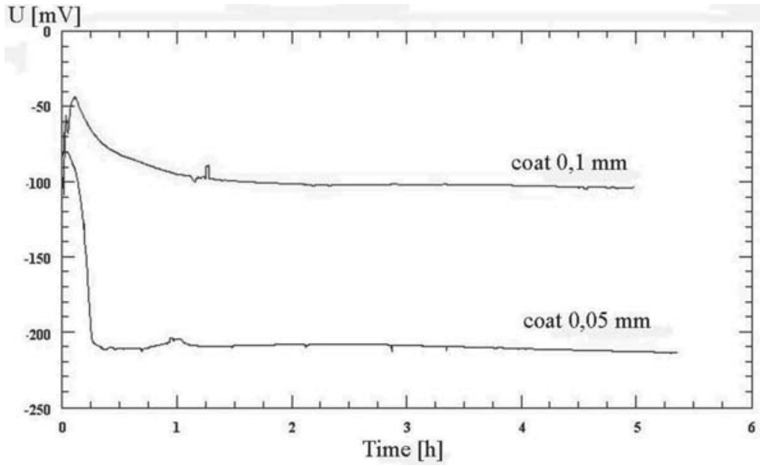

Fig. 9. Chart of measure of electrode potential of brass M63 covered with PVC with selected layer thickness

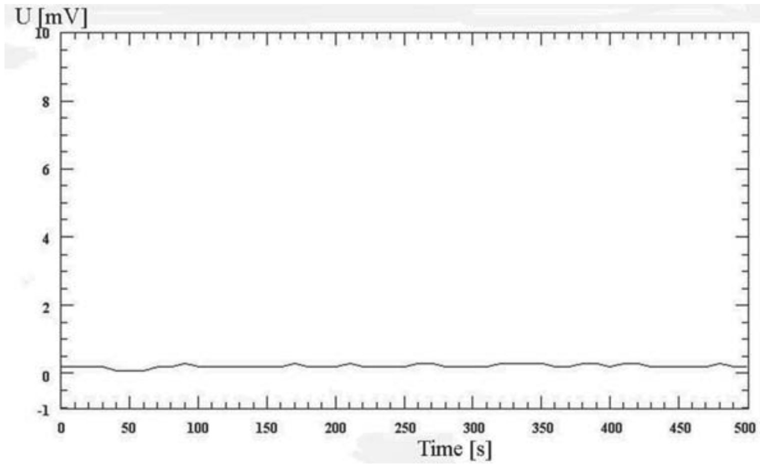

Fig. 10. Chart of measure of electrode potential of steel 45 covered with paraffin layer of 0.4 mm thickness

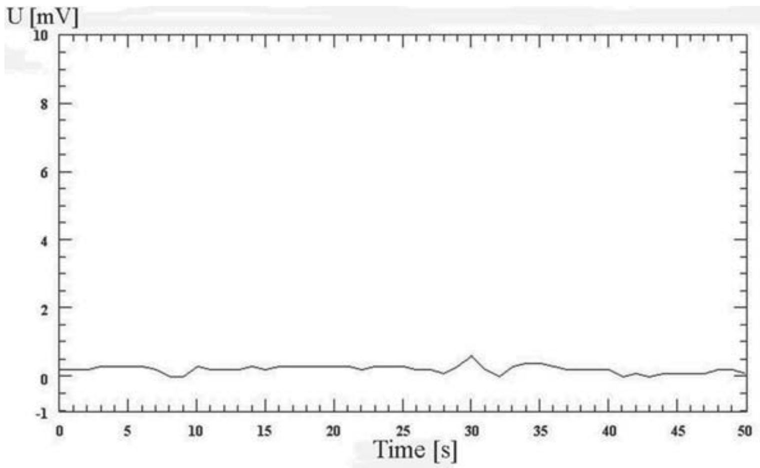

Fig. 11. Chart of electrode potential measure for brass M63 covered with paraffin layer 0.4 mm thick

The results of the tests for the electrode potential of metal samples covered with non-metallic coatings prove an existence of an electrode potential shift in the positive direction in comparison to non-coated metals. Selected coatings give various shift of the potential. The coatings have canals and blowholes, which are not so tight. During electrode potential measurement, the electrolyte ions are flowing through them. The smaller area of blowholes and canals, the harder flow of electrolyte ions, and stronger electrode potential shift in the positive direction, hence coating tighter.

Among all analyzed coatings, in laboratory conditions, only paraffin coating provided a complete tightness - an electrical current did not flow through a circuit (Figs. 10-11). It is important to mention that paraffin coatings are not used to increase fatigue strength. It was observed that the thicker coating (Figs. 7-9), the stronger electrode potential shift in the positive direction, because of the length of canals and blowholes that connect metal with electrolyte increases. Previous preliminary activities related to electrode potential researches conducted on steel samples were limited only to defining the direction of the shift of the potential. The results of conducted experiments unequivocally prove an influence of implemented coating, which is shown in Fig.5. Based on analysis (Fig. 6) it is evident that the kind of used coating does not limit its influence on this phenomenon. In this case, it can be observed that also the kind of covered material in some ways influences a shift of electrode potential.

The steel samples show, as presented on Figs. 5-6, two times smaller electrode potential shift in the positive direction. There is some deviation from the rule in case of PVC coating, which is three times smaller (thinner) for steel sample than for brass sample (coated with the same material). Another visible advantage of electrode potential shift is an influence of time on stabilization of electrode potential shift in the positive direction. Therefore, regardless of the kind of sample or thickness of plastic coating, the PVC coats shows much earlier (faster) stabilization, hence further measurements of potential do not indicate critical changes (Figs. 8-9). The measurement of electrode potential shift values of samples coated with Epidian 5 require more time to estimate them. Therefore, they are more time-consuming (Fig. 7). Additionally, as mentioned before, obtained results (potential values) are much worse (not precise). It could be assumed that adhesive forces are weaker (worse) in steel samples, than in brass samples, regardless of used kind of coating. However, this assumption requires further investigation and series of tests, where one of criteria should be the influence of sample surface and the coating technique.

4. Conclusions

Summarizing, it is necessary to stress that an electrode potential shift may be an indicator of usefulness of non-metal coating covering metal surface, because the connection was observed between the shift and an adhesion force of the layer to metal and fatigue strength. These are a far-reaching generalization, which requires a confirmation by thorough experimental research. At this stage, it is necessary to say that thicker coatings create stronger electrode potential shift in positive direction in contrast to thinner coatings.

Therefore, the following conclusions are formulated:

- Metals covered with plastic coatings cause an electrode potential shift in positive direction.
- The stronger electrode potential shift, the stronger adhesion force of coating to metal, and bigger fatigue strength of plastic coated metals.
- Spontaneously created a natural and irremovable EDL exists at the border of metal and plastic coating.
- An EDL increases adhesion force of coating to metal.
- An electrode potential shift depends on a thickness of non-metallic coating.
- An electrode potential shift may be a factor considered in choosing a material for coating of metal.

References

[1] V.M. Bogomolnyi, The dynamical theory of electrothermal degradation and NDT of defects in Metal-Dielectric-Metal (MDM) structures, Proceedings of the Conference Thermosense XXI, Orlando, 1999.

[2] H. Conrad, Study into the effects of electric fields and currents on the aging and quench hardening of steels, Final Report, North Carolina State University v. at Raleigh, Report No: ARD-26825.21-MS., January, 1993, 84.

[3] A. Gajewski, The process and electrostatic technology, PWN SA, Warsaw-Cracow, 2002 (in Polish).

[4] I. Gruin, Polymer materials, PWN, Warsaw, 2003 (in Polish).

[5] W. Przygocki, A. Włochowicz, The physic of polymers, PWN, Warsaw, 2001 (in Polish).

[6] L. Palaghian, S. Ciortan, V. Palade, M. Bucsa, The influence of magnetic field on the fatigue resistance in corrosive environment, Advances in Mechanical Behaviour, Plasticidy and Damage, Proceedings of Euromat 2000, Tours, 2000 1257-1262.

[7] M. Szata, Description of development of fatigue cracking in energetic approach, Monograph, University of Technology, Wroclaw, 2002 (in Polish).

[8] T. Winder, S. Hansen, U. Holzwarth, K. Maier, Sensitivity of positron annihilation to plastic deformation, Physical Review B-Condensed Master 57/9 (1998) 5126-5139.

[9] E. Leiva, W. Schmickler, New theories for the electric double layer at a metal/electrolyte solution interface, Proceedings of the Indian National Science Academy (Chemical Science) 97/3-4 (1986) 267-296.

[10] L. Ling, M. Qing-Han, Electrochemical properties of mesoporous carbon aerogel electrodes for electric double layer capacitors, Journal of Materials Science 40 (2005) 4105-4107.

[11] K. Jamroziak, W. Jargulinski, Electrical double layer and adhesive force in fatigue strength of metals coated with plastics, Archives of Materials Science and Engineering 36/2 (2009) 82-88.

[12] W. Jarguliński, The Electrostatic Field and Metals' Durability, Monograph, Tadeusz Kościuszko Military Academy of Land Forces, Wroclaw, 2006 (in Polish).

[13] K. Jamroziak, W. Jargulinski, Fatigue Life Forecasting of Modern Constructional Materials with The Use of Electric Double Layer, Proceedings of the 9th International

Conference, Computer Aided Engineering 2008, Opencast Mining, Issue 4-5, 2008, 148-151 (in Polish).

[14] K. Jamroziak, W. Jarguliński, J. Szelka, Electrical double layer and adhesive force in fatigue strength of metals coated with plastics, Journal of Achievements in Materials and Manufacturing Engineering 31/2 (2008) 678-682.

[15] J. Mikuła, L.A. Dobrzański, PVD and CVD coating systems on oxide tool ceramics, Journal of Achievements in Materials and Manufacturing Engineering 24/2 (2007) 75-78.

[16] E.P.M. Leiva, C. Vazquez, M.I. Rojas, M.M. Mariscal, Computer simulation of the effective double layer occurring on a catalyst surface under electro-chemical promotion conditions, Journal of Applied Electrochemistry 38 (2008) 1065-1073.

[17] L.A. Dobrzański, A. Grajcar W. Borek, Hot-working behaviour of high-manganese austenitic steels, Journal of Achievements in Materials and Manufacturing Engineering 31/1 (2008) 7-14.

[18] L.A. Dobrzański, R. Honysz, S.D. Fassois, On The Identification of Composite Beam Dynamics Based Upon Experimental Data, Journal of Achievements in Materials and Manufacturing Engineering 16 (2006) 114-123.

[19] B.T. Hughes, D.L. James, A. Ibraguimov, S. Liu, H. Temkin, One-dimensional axial simulation of electric double layer overlap effects in devices combining micro- and nanochannels, Microfluid Nanofluid 5/6 (2008) 761-774.

[20] K. Jamroziak, W. Jarguliński, Anti-hydrogen coats on metals, Journal of Science, Tadeusz Kościuszko Military Academy of Land Forces, Wroclaw, vol. 1, 2009, 96-106 (in Polish).

[21] R.R. Salem, Electrodynamics Applied To Electrode Potential and Electrochemical Kinetics. Protection of Metals and Physical Chemistry of Surfaces 45/1 (2009) 113-118.