

# Proceedings AES-ATEMA'2015 International Conference Series

OTTAWA'2015 AES-ATEMA 26<sup>th</sup> International Conference  
(Ottawa, CANADA: October 12 – 16, 2015).

Advances and Trends in  
Engineering Materials and their Applications

Edited by

**Y. M. Haddad**

University of Ottawa, Ottawa, CANADA.

**ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (BOOK)**

**Advanced Engineering Solutions [AES.COM]**

**Ottawa, Canada.**



Proceedings of OTTAWA'2015 AES-ATEMA 26<sup>th</sup> International Conference on  
Advances and Trends in Engineering Materials and their Applications  
(Ottawa, CANADA: October 12 - 16, 2015)

Conference chair & host:  
Professor Dr. Y. M. Haddad, P. Eng.  
Chair: AES-ATEMA International Conference Series

A record of this book is available at Library and Archives Canada  
ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (BOOK)

**Published by Advanced Engineering Solutions [AES.COM] - Ottawa, Canada.**

**Sold and distributed by Advanced Engineering Solutions [AES.COM] - Ottawa,  
Canada.**

For all information pertinent to this publication, please contact the editor:

***Prof. Dr. Y. M. Haddad, P. Eng.***

Chair & Host: AES-ATEMA International Conference Series

Tel. +1 (613) 830 22 42

Email: yhaddad@uottawa.ca; aesatema@gmail.com

All rights are reserved.

© 2015, Advanced Engineering Solutions [AES.COM] - Ottawa, Canada.

No part of the material published herein may be reproduced or utilized in any form or by  
any means without written permission of the Publisher.

Printed in Canada.

**OTTAWA'2015 AES-ATEMA 26<sup>th</sup> International Conference**  
**“Advances and Trends in Engineering Materials and their**  
**Applications” (Ottawa, CANADA: October 12 - 16, 2015)**  
**ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (BOOK)**

## **Preface**

I wish to express my sincere gratitude to all delegates of the OTTAWA'2015 AES-ATEMA 22nd International Conference for their valuable contributions which made this Conference outstandingly successful. I trust that all delegates have had a unique experience by participating in this Conference, both scientifically and culturally.

The AES-ATEMA Conference Series is sponsored and administered by Advanced Engineering Solutions [AES. COM], in cooperation with “Advanced Engineering Solutions International”, within the mission of “AES Technical Reviews International Journal Series - ISSN 1915-5409. In this regard, I wish to express my full indebtedness to Advanced Engineering Solutions International and also to the members of the International Editorial Board of “AES Technical Reviews International Journal Series”.

I hope that the valuable scientific and engineering contributions presented on / in this CD-ROM / book proceedings will provide guidance to Science and Engineering students, educators and researchers who are working in the pertinent fields. I hope also that these proceedings will be of significant value to scientists and engineers who are involved in the production, processing of engineering materials and the study of their properties, in addition to all other pertinent fields.

***Prof. Dr. Yehia Haddad, P. Eng.***

Chair & Host: AES-ATEMA International Conference Series

Tel. +1(613)830 22 42

Email: *yhaddad@uottawa.ca; aesatema@gmail.com*

**AES Technical Reviews International Journal (Series)\*  
ISSN 1915-5409**

“*AES Technical Reviews*” is an international refereed journal series dedicated to advances in engineering and interdisciplinary research. It is principally sponsored by “Advanced Engineering Solutions [AES.COM]” in cooperation with “Advanced Engineering Solutions International” with headquarters in Ottawa, Canada. AES Technical Reviews International Journal Series is currently inviting articles for publication in the following journals:

**Part A: International Journal of Nano and Advanced Engineering Materials (IJNAEM) – ISSN 1916-5358**

**Part B: International Journal of Advances in Mechanics and Applications of Industrial Materials (IJAMAIM) – ISSN 1718-5505**

**Part C: International Journal of Advances and Trends in Engineering Materials and their Applications (IJATEMA) – ISSN 1916-5366**

**Part D: International Journal of Reliability and Safety of Engineering Systems and Structures (IJRSESS) – ISSN 1916-5374**

Copies of published AES Technical Reviews International Journal Series issues are available at the *Library and Archives Canada (Bibliothèque et Archives Canada)*.

**Authors are invited to submit their work to:**

**Professor Dr. Y. M. Haddad, P. Eng.**

**Series Editor**

**Chair: AES-ATEMA International Conference Series**

**yhaddad@uottawa.ca; aesatema@gmail.com**

# AES Technical Reviews International Journal (ISSN 1915-5409)

## INTERNATIONAL EDITORIAL BOARD

Professor Nabil Bassim  
University of Manitoba, Canada

Professor Wilfried Becker  
Technical University of Darmstadt, Germany

Dr. Christos Chamis  
NASA Glenn Research Center, USA

Professor Fu-Kuo Chang  
Stanford University, USA

Professor Roberto Contro  
Technical University of Milan, Italy

Professor Yehia M. Haddad  
University of Ottawa, Canada

Professor David Hui  
University of New Orleans, USA

Professor Adrian Leijten  
Eindhoven University of Technology, The Netherlands

Professor Fujiu Ke  
BeiHang University, PR China

Professor Akhtar Khan  
UMBC – University of Maryland, USA

Professor Michal Kotoul  
Brno University of Technology,  
Czech Republic

Professor Gerard Maugin  
Université Pierre et Marie Curie, France

Professor Sergei Mileiko Solid State  
Physics Institute, Russia

Professor José Moya  
Instituto de Ciencia de Materiales de Madrid,  
Spain

Professor Alfonso Nappi  
Università degli Studi di Trieste, Italy

Professor Lucio Nobile  
University of Bologna, Italy

Professor George Papanicolaou  
University of Patras, Greece

Professor Valdim Potapov  
Moscow State University of Communications  
Means, Russia

Professor Olli Saarela  
HUT – Technical University of Helsinki,  
Finland

Professor Shinsuke Sakai  
University of Tokyo, Japan

Professor Yasuhide Shindo  
Tohoku University, Japan

Professor George Sih  
Lehigh University, USA  
East China University of Science and  
Technology, PR China

Dr. Rer. Nat. Ewa Soppa  
Materialprüfungsanstalt (MPA) -  
Universität Stuttgart, Germany

Professor Costas Spyropoulos  
National Technical University of  
Athens, Greece

Professor João Tavares  
University of Porto, Portugal

Professor David Thambiratnam  
Queensland University of Technology,  
Australia

Professor Yoshihiro Tomita  
Kobe University, Japan

Professor Yue-Sheng Wang  
Beijing Jiaotong University, PR China

Professor Andrew Wilczynski  
Warsaw University of Technology, Poland

Professor Anastasius Youtsos  
Democritus University, Greece

Professor Liangchi Zhang  
The University of New South Wales, Australia



**PROCEEDINGS**  
**OTTAWA'2015 AES-ATEMA 26<sup>th</sup> International Conference**  
**(Ottawa, CANADA: October 12 - 16, 2015)**  
**“Advances and Trends in Engineering Materials and their Applications”**  
**ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (BOOK)**

**CONTENTS**

Preface

**5**

AES Technical Reviews International Journal Series

**6**

International Editorial Board

**7**

Opening Welcome

**9**

Conference Main Topics

**11 - 13**

Conference Program at a Glance

**15 - 20**

Contents

**21 – 22**

**Conference Presentations**

The Development of Thermal Conductivity and Wear Properties of HVOF Thermal-Sprayed SiC-Added Cr<sub>3</sub>C<sub>2</sub>-NiCr Coatings.

**Wei Tien Hsiao\* and Wu Han Liu**

Industrial Technology Research Institute, Chutung 310, and National Chung Hsin University, Taichung 402, **TAIWAN**.

**25 - 30**

Effects of Moisture on Preventing of Soot Generation and Controlling of Carbon Potential in Direct Carburizing

**M. Okumiya\*, J. H. Kong, Y. Tsunekawa, S. Simizu and S. Miura**

Materials Processing Lab. Toyota Technological Institute, Nagoya, 468-8511, and TOHO GAS CO., LTD., Tokai, 476-8501, **JAPAN**.

**31 - 36**

Corrosion and Wear Resistant Nanostructured Metal Coatings Characteristics, Analysis.

**A. Urbahs\*, G. Rijkuris and K. Savkovs**

Institute of Aeronautics, Riga Technical University, Riga, **LATVIA**.

**37- 41**

Factorial Study of Process Parameters on the Orientation State of Injected Bamboo Fibre/ Polypropylene Composite Parts.

**Jorge I. Fajardo\*, Jonnathan D. Santos, Luis Garzón and Luis J. Cruz**

Dept. of Mechanical Engineering, Universidad Politécnica Salesiana, Cuenca, **ECUADOR**.

**42 - 50**

**PROCEEDINGS**  
**OTTAWA'2015 AES-ATEMA 26<sup>th</sup> International Conference**  
**(Ottawa, CANADA: October 12 - 16, 2015)**  
**“Advances and Trends in Engineering Materials and their Applications”**  
**ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (HARD COPY)**

On the Simulation of the Random Microstructure of a Fibrous Network with Elastic Bonds.

**E. Jacquelin and Y. M. Haddad**

Université Claude Bernard Lyon I, **FRANCE**, and University of Ottawa, **CANADA**.

**51 - 70**

On the Optimization of a Class of Short Fibre Composites: A Trade-off between Damping and Stiffness.

**J. Feng and Y. M. Haddad**

University of Ottawa, Ottawa, **CANADA**.

**71 - 90**

**Author's index** **91**

**\***  
**indicates "Correspnding author"**



**PROCEEDINGS**  
**OTTAWA'2014 AES-ATEMA 26<sup>th</sup> International Conference**  
**(Ottawa, CANADA: October 12 - 16, 2015)**  
**“Advances and Trends in Engineering Materials and their Applications”**  
**ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (BOOK)**

**Conference Presentations**



ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (BOOK)

# AES ATEMA'2015 Ottawa, CANADA

OTTAWA'2015 AES-ATEMA 26th International Conference  
“Advances and Trends in Engineering Materials and their Applications”  
(Ottawa, CANADA: October 12 – 16, 2015)

---

## Corrosion and Wear Resistant Nanostructured Metal Coatings

### Characteristics Analysis

A. Urbahs<sup>1\*</sup>, G. Rijkuris<sup>2</sup>, K. Savkovs<sup>3</sup>

<sup>1</sup> Professor, Institute of Aeronautics, Riga Technical University, Riga, Latvia  
(Email: aerti@rtu.lv)

<sup>2</sup> Research assistant, Institute of Aeronautics, Riga Technical University, Riga, Latvia  
(Email: gints\_rijkuris@inbox.lv)

<sup>3</sup> Senior researcher, Institute of Aeronautics, Riga Technical University, Riga, Latvia  
(Email: aerti@rtu.lv)

\*Corresponding Author

#### **Abstract**

*One of the most efficient technologies for improving durability of a product is applying different coatings on the effective area. Due to their flexibility ion-plasma methods of applying corrosion and wear resistant coatings are becoming more widely used in modern industry. Methods differ with high controllability of the process; capability of getting chemical compounds and alloys of given composition including films with better adhesion to the surface, etc.*

#### **Keywords**

Corrosion, wear resistance, coatings.

#### **1 Introduction**

The analysis of the losses that are caused due to corrosion is an important input in the economy of Latvia and the European Union. The

corrosion of the metal and equipment accounts for a considerable proportion of the total corrosion losses, thus it is the impetus for further investigation and developments for protection from corrosion, providing the transport systems and industry with corrosion preventive materials and tools. Protection of metals from corrosion is a particularly topical issue, which affects all areas of the global economy. The growing world economic growth leads to increase the number of transport vehicles and hence different systems and mechanisms unit increases that are subject to aggressive environmental influences and the various processes that cause metal corrosion.

Damage caused by corrosion could be prevented by reducing either by choosing the appropriate metal at a fixed location, either by using metal coating. The topic deals with corrosion processes occurring under certain

operating conditions. The analysis of operating characteristics of the research object and the parameters associated with the surface layer characteristics is carried out.

During the experiment there has been developed corrosion-resistant coating theoretical model. As a result of experiment there has been obtained versatile multi-layer corrosion resistant and abrasion resistant coating for carbon steel products.

## 2 Thermodynamics of corrosion process

Corrosion is one of the most common naturally occurring processes that have been studied by thermodynamics – including oxidation process, metal disruption, and its chemical and electrochemical effects under environment influence.

Corrosion mechanism is the basic set of processes, which are determined by the reaction of metals with the environment. It determines the stages of the process and corrosion processes, distinguishes elementary processes, thus enabling to look for ways to control this process. There are 2 types of mechanisms – chemical and electrochemical corrosion. [1, 2, 5]

*Chemical corrosion* is an arbitrary process of metal exposure to corrosive environment, when metal oxidation and environmental oxidation components regeneration take place simultaneously. It occurs in dry gasses, liquid electrolytes and non-electrolytes. Chemical corrosion mechanism in electrolytes is not discussed in this paper, because electrolytes, in which corrosion mechanism is observed, are not used in ship building, operation and maintenance. On seagoing vessels, various elements of power plants, fuel combustion

products discharged into the system, oil tanks, fuel tanks and other structures are subject to chemical corrosion. In shipbuilding and ships repairing the metal constructions which are processed in high temperatures (e.g., welding, cutting) is the subject of corrosion [3, 5].

*Electrochemical corrosion* is an arbitrary process of metal exposure to corrosive environment (electrolyte), when metal oxidation and environmental oxidation component regeneration do not take place simultaneously – their regeneration speed depends on electrolyte potential.

## 3 Kinematics of corrosion process

The kinematics of corrosion process significantly changes the external (composition, temperature, pressure, physical state environmental) and internal (chemical and phase composition, structure, physical and mechanical metal chemical) properties. Corrosion rate [4] – quantity of metal that is ionized in time unit dependable from area unit and is characterized by

$$K = \frac{W_0 - W_1}{S\tau}, \quad (1)$$

K – corrosion rate,  $g/(mm^2h)$ ;

$W_0$  – sample weight before corrosion process started, g;

$W_1$  – sample weight after corrosion removed, g;

S – corroded area,  $mm^2$ ;

$\tau$  – duration, h.

#### 4 Research object and test procedure

One of the most important characteristics of coatings for any purpose is adhesion. Ion-plasma coating were produced by the upgraded vacuum unit NNV-6, 6-I1 [4]. For the experimental research two sources of metallic plasma were used – the electric arc vaporizer and magnetron. During sputtering with the electric arc vaporizer electromagnetic movement stabilization, focus of the cathode spot on the face of the evaporated cathode and separation of the flow of the sputtered material from the droplet phase were provided.

The argon pressure in the chamber was  $0,133...0,399 \cdot 10^{-3}$  MPa the nitrogen pressure -  $0,026...0,266 \cdot 10^{-3}$  MPa. The microhardness of the coatings was measured by nanoindentation by means of the micro-durometer PMT-3M. Hitachi S-3000N scanning electron microscope was used for analysis of chemical composition of the obtained compound [7]. Research was made around two protective coatings on the basis of (TiAl)N and Ti-Al-N conglomerate coatings.

#### 5 Potential determination

Prior to initiating any measures against corrosion metal potential is determined in order to choose the appropriate metallic coating. In order to determine the potential platinum electrode should be used which is immersed in sulphuric acid electrolyte (Figure 1).

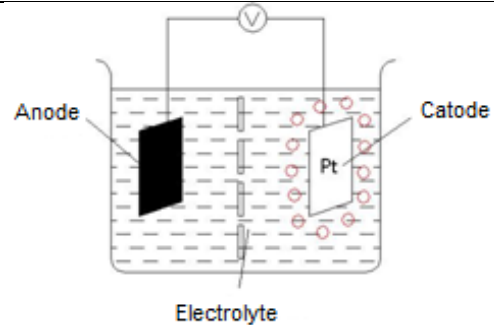


Figure 1. Potential electrode determination scheme with standard hydrogen electrode.

V – Potentiometer [6].

Platinum electrode, the hydrogen ions, is a benchmark for determining the potential, but during the experiments authors use a simpler option for determining the potential. Authors use self made potential measuring device. Basic electrode (copper) in the potential detection device is constant so all measurements should be done against the copper [6]. Potential Measurement for (TiAl)N coatings is done with self-made copper electrode potential measuring device. Potential values are relative to the Cu electrode. (Figure 2).

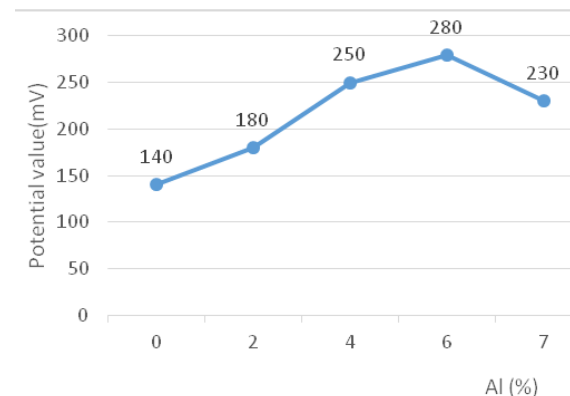


Figure 2. Electrode potential depending on the Al quantum in (TiAl)N coating.

It can be concluded that most potential value for (TiAl)N coating is when Al composition is relatively 6%, when the magnetron current is 6A, (it depends on the Al coating composition). The smallest metal potential value is when Al composition in coating is least, respectively, when a current is 0A. When Al composition increases from 0 to 6, potential of coating is growing reaching its maximum value, then decreasing.

## 6 Corrosion rate experimental detection using gravimetric method

The method includes detection of the mass change of the sample. Two couples of samples are taken - one of the sample is raw (ST-3), the other is from the first experimental group - titanium aluminum nitride (TiAl)N.

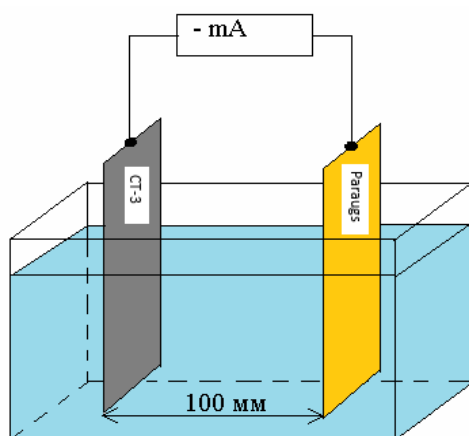


Figure 3. Primary cells corrosion current detection circuit (left) and samples before the experiment.

Both samples are placed in a 10% NaCl electrolyte solution see (Fig.3) and submerged at a depth equal to the uniform contact area electrolyte. For electrochemical reaction they are connected with copper wire. The distance between the two samples is 100 mm. Samples

are kept in the NaCl solution for 72 hours. Every 24 hours samples are removed from the solution, washed in running water and drained (see Fig. 4). After sample weight is determined using analytical scales RADWAG AS 160 / X with an accuracy of 0,00001g.

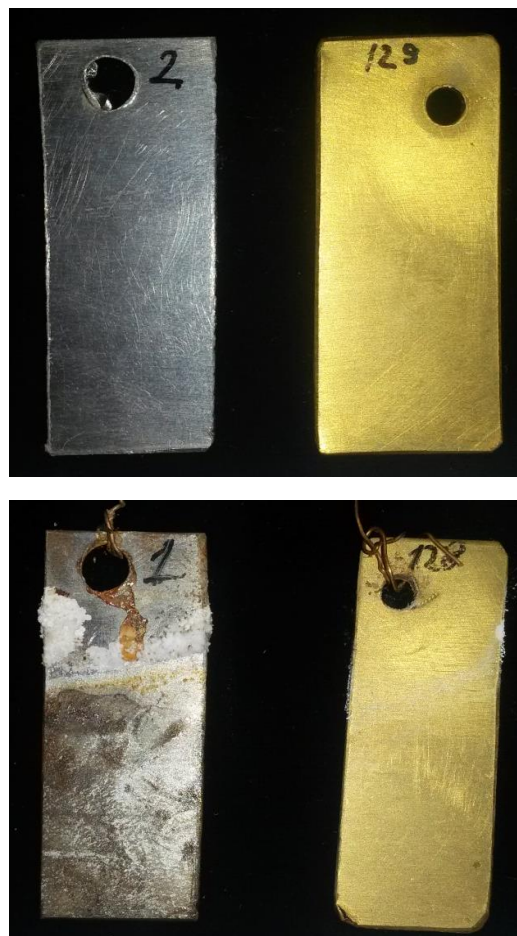


Figure 4. Samples (with and without coating) before the experiment (left) and after 72 h of an experiment.

It is registered that coated samples after 72 hours have not corroded (Fig.4). Also it proved that chosen chemical composition of Al for the samples shown is optimal.

Sample weight taken after each 24 h is summarized in comparative graph of sample

pairs ST-3 uncoated sample and the sample with (TiAl) N coating (Fig.5).

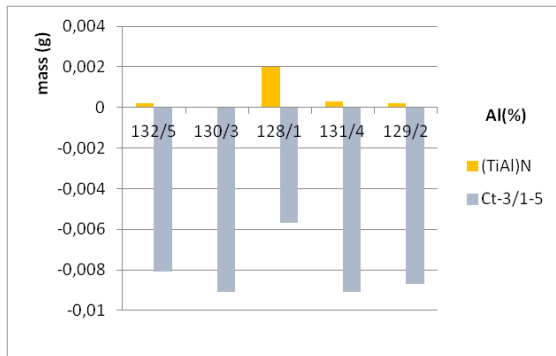


Figure 5. Change of mass in 72h time period.

After 72 h it is registered that samples made

Table 1. The change of mass during the experiment (in 10% NaCl electrolyte).

Sample Nr.	Duration, h				$\Delta m(g)$	$\Delta m(g/cm^2)$	Comments
	0	24	48	72			
1	9,4197g	9,4172g	9,4150g	9,4140g	-0,0057	-0,0015	ST-3 without coating
2	9,4268g	9,4247g	9,4223g	9,4181g	-0,0087	-0,0027	
3	8,6295g	8,6274g	8,6254g	8,6204g	-0,0091	-0,0025	
4	9,8295g	9,8273g	9,8249g	9,8204g	-0,0091	-0,0024	
5	8,7573g	8,7556g	8,7531g	8,7492g	-0,0081	-0,0024	
128	8,0722g	8,0732g	8,0731g	8,0742g	0,0020		(TiAl)N I=4A
129	9,4256g	9,4254g	9,4254g	9,4258g	0,0002		(TiAl)N I=7A
130	8,3937g	8,3938g	8,3938g	8,3937g	0		(TiAl)N I=2A
131	8,1366g	8,1362g	8,1363g	8,1369g	0,0003		(TiAl)N I=6A
132	7,7086g	7,7089g	7,7087g	7,7088g	0,0002		(TiAl)N I=0A

As per graph (Fig.6.) it is shown that only ST3 steel uncoated sample have lost weight, but the rest of the samples mass loss values are positive, that means that weight is gained.

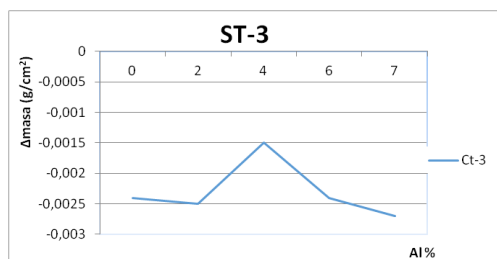


Figure 6. ST-3 samples without coating change of

from ST-3 have lost weight. In Fig.5 it is shown that mass losses for every sample pair differ. It proves that mass losses depend on Al chemical composition in the coating, also different corrosion speed is registered for samples.

Calculating corrosion rate after weight loss for raw ST3 sample with corrosion area of 368 mm<sup>2</sup> is  $K = 103,3 \text{ mg/(mm}^2\text{per year)}$ . Results for all samples are shown in table 1.

mass, g/cm<sup>2</sup>.

This kind of mass gains could be explained by imperfect sample cleaning from corrosion products, but it would be correct if steel ST3 mass increased, but it did not happen. So it is assumed that the protective coatings were sub coated by oxide film (passivation film) which increased mass of the sample.

## 7 Conclusions

Damage caused by corrosion could be prevented by reducing either by choosing the appropriate metal at a fixed location, either by

using metal coating. Research was made around two protective coatings on the basis of (TiAl)N and Ti-Al-N conglomerate coatings.

Experiments were conducted placing samples in a 10% NaCl electrolyte solution. Samples were kept in the NaCl solution for 72 hours. Every 24 hours samples are removed from the solution, washed in running water and drained. Experiment proved that developed (TiAl)N coating with an optimal Al composition relatively 6% protects sample for at least 72 hours in comparison with uncoated sample. In 72 hours coated sample have no corrosion products on its surface.

### Acknowledgments

This work has been supported by the European Social Fund within the project “Development of multifunctional nanocoatings for aviation and space techniques constructive parts protection:  
No.2013/0013/1DP/1.1.1.2.0/13/APIA/VIAA/0

27

### References

- [1] Gardiner C. P., R. E. Melchers, *Corrosion analysis of bulk carriers, Part I: operational parameters influencing corrosion rates* [revised 05.09.2011.]. [www.elsevier.com/locate/marstruc]
- [2] Gudze M. T., R. E. Melchers, *Operational based corrosion analysis in naval ships*: [www.elsevier.com/locate/corsci] [revised 09.09.2011.], p. 3296- 3303
- [3] Lublinsky E. Ya., Pirogov V. D. and others, *Corrosion and protection on ships*. (in Russian)., S. Petersburg «Shipbuilding» 1987, p.6-41
- [4] Urbahs, A., Bogdanova, S., Urbahs, M., Savkovs, K., Rijkuris, G. Investigation of the Heat Resistance of Protective Decorative Ion-Plasma Coatings. *Journal of Engineering and Technology*, 2013, No.1, pp.267-270. ISSN 1338-2330.





## PROCEEDINGS

OTTAWA'2014 AES-ATEMA 26th International Conference (Ottawa, CANADA: October 12 - 16, 2015)

"Advances and Trends in Engineering Materials and their Applications"

ISBN 978-1-927838-21-1 (CD-ROM) & 978-1-927838-20-4 (BOOK)

## AUTHOR'S INDEX

### C

Cruz, L. J. 42

### F

Fajardo, J. I. 42

Feng, J. 71

### G

Garzón, L. 42

### H

Haddad, Y. M. 51, 71

Hsiao, W. T. 25

### J

Jacquelin, E. 51

### K

Kong, J. H. 31

### L

Liu, W. H. 25

### M

Miura, S. 31

### O

Okumiya, M. 31

### R

Rijkuris, G. 37

### S

Santos, J. D. 42

Savkovs, K. 37

Simizu, S. 31

### T

Tsunekawa, Y. 31

### U

Urbahs, A. 37