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- Theoretical and Methodological Foundations of Scientific Research
- Interdisciplinary Research Methodology
- Methodological Aspects of Innovative Technologies
- Empirical Methods in Scientific Research
- Ethical and Legal Aspects of Scientific Research

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CONTENTS

R. Titorenko, V. Tychkov, R. Trembovetska, V. Halchenko

QUALITY CONTROL SYSTEM FOR ANTICORROSIVE COATINGS OF STEEL PRODUCTS **5**

O. Zrazhevskyi

MITIGATING EXPLOITATION OF SOFTWARE VULNERABILITIES IN PROGRAMMING LANGUAGE INTERPRETERS **7**

A. Yaroslavskyi

APPLICATION AND MATHEMATICAL MODELING OF PIEZOCERAMIC ELEMENTS FOR INDUSTRY **10**

O. Yalynskyi

MODERNIZATION OF THE ENERGY SYSTEM OF UKRAINE **16**

R. Lutsenko

INTELLIGENT DATA ANALYSIS SYSTEMS FOR RESEARCH IN BEHAVIORAL ECONOMICS OF VIRTUAL ASSETS **19**

O. Protsenko

METHODOLOGY FOR ENSURING CYBER RESILIENCE IN THE CLOUD ENVIRONMENT AT THE ENTERPRISE **22**

V. Shymko, V. Dudka, A. Toptun

ANALYSIS OF THE EFFECT OF AIR POLLUTION ON THE CONDITION OF HUMAN HAIR BY SCANNING PROBE MICROSCOPY **25**

O. Filimonova, S. Filimonov

MUSCLE FOR A FLYING MINIROBOT **28**

O. Myhal

IMPROVING THE ENERGY EFFICIENCY OF THE SUPPLY SYSTEM OF COMPRESSED AIR **31**

Y. Korolkov

REACTIVE POWER COMPENSATION FOR RESIDENTIAL CONSUMERS **35**

B. Yakovlev

LEVERAGING ZABBIX FOR CYBERSECURITY **37**

V. Samsonenko, V. Palahin, O. Palahina

INTEGRATION OF COMPUTER VISION INTO ROBOTIC TECHNICAL SYSTEMS USING THE YOLO PLATFORM **40**

A. Grushnitskyi, V. Palahin

DEVELOPMENT OF AN END-TO-END ENCRYPTED MESSAGING CHATBOT **43**

B. Bielkov, V. Palahin, O. Palahina

DEVELOPMENT OF AN ANTI-SPOOFING METHOD FOR IMAGES IN BIOMETRIC SECURITY SYSTEMS USING ML **46**

D. Hrebeniuk

UTILIZING RUBY FOR MACHINE LEARNING WORKFLOWS **48**

R. Ptashkin **51**

FORENSIC EXAMINATION OF OBFUSCATED CODE

V. Simonov

METHODOLOGY FOR INFORMATION LEAK RESEARCH **54**

V. Chornodobravska

PSYCHOLOGICAL MANIPULATIONS IN CYBERSPACE: MECHANISMS OF SOCIAL ENGINEERING IMPACT ON POTENTIAL VICTIMS **56**

C. Bazilo, M. Bondarenko, L. Usyk, E. Faure

ULTRASONIC TECHNOLOGY FOR PRODUCING FUNCTIONAL BEVERAGES TO REHABILITE AND PREVENT POST-TRAUMATIC STRESS DISORDERS **59**

O. Shymko, V. Tuz

IMPROVING THE CONTROL SYSTEM OF AN UNMANNED VEHICLE **61**

V. Tupota, I. Zhaivoronok, M. Bondarenko

SYSTEM FOR DETERMINING THE MECHANICAL STRENGTH OF SAFETY GLASS **63**

V. Kodola, S. Saienko, M. Bondarenko

ANALYSIS AND MODELING OF HEAT TRANSFER PROCESSES DURING NANOMETRIC MEASUREMENTS **65**

A. Bobrov, V. Andreiko, M. Bondarenko

MULTIFUNCTIONAL LASER CORRECTION COMPLEX FOR OPTICAL SYSTEMS **67**

N. Bondarenko

DATA ANALYSIS IMPACT ON SCIENTIFIC RESEARCH **69**

O. Berezhnyi, V. Tuz, R. Trembovetska

DEVELOPMENT AND RESEARCH OF AN AUTOMATED SYSTEM FOR PREVENTING CRITICAL SHOCK AND WAVE LOADS **71**

V. Syvachenko, V. Tuz

CONTROL SYSTEM FOR A BIOREACTOR **73**

D. Holoborodko, S. Filimonov

DEVELOPMENT OF RADIO-CONTROLLED PIEZOELECTRIC ROBOT **75**

O. Stankevych, V. Tuz.

AUTOMATION CONTROL OF COUNTRY HOUSE BY VOICE AI ASSISTANT **77**

I. Chornovil, V. Tuz, R. Trembovetska

DEVELOPMENT AND RESEARCH OF AN AUTOMATIC REAGENT DOSING SYSTEM **80**

A. Sotnyk, V. Tuz

MODELING OF HIGH-PERFORMANCE SONAR FOR THREE-DIMENSIONAL MAPPING OF THE RESERVOIR BOTTOM **82**

V. Starikov, V. Tuz, V. Tychkov

IMPROVEMENT OF THE WIND TURBINE CONTROL SYSTEM **84**

S. Matviienko, V. Tuz

DEVELOPMENT AND RESEARCH OF A CONTROL SYSTEM FOR A ROD SUBMERSIBLE PUMP **86**

V. Bondar
THE MAIN TYPES OF MODELS IN MACHINE LEARNING **88**

I. Zdoryk, V. Tuz, R. Trembovetska
IMPROVEMENT OF THE CHARGING SYSTEM OF A LITHIUM-ION BATTERY **91**

V. Kulba, V. Tuz, V. Tychkov
CONTROL SYSTEM FOR URBAN TRAFFIC LIGHT NETWORK **93**

A. Romanov
ARTIFICIAL INTELLIGENCE APPLICATIONS IN THE ENERGY SECTOR FOR IMPROVING POWER SYSTEM MANAGEMENT **95**

O. Brunov
TECHNOLOGIES OF SUPERCONDUCTIVITY AND THEIR POTENTIAL IMPACT ON THE FUTURE OF ELECTRICAL ENGINEERING **97**

A. Toptun
ANALYSIS OF MATERIALS FOR THE PRODUCTION OF WIND TURBINE BLADES **99**

M. Manko, V. Tuz
ANALYSIS OF TYPES AND METHODS FOR GENERATING QUANTUM SECRET KEYS **101**

D. Polukhin
ANALYSIS OF AUTOMATION OF TECHNOLOGICAL PROCESSES BY ROBOTIC MANIPULATORS **103**

O. Snisarenko, V. Tuz
IMPROVEMENT OF AN AUTOMATED QUALITY CONTROL SYSTEM FOR OPTICAL PARTS **105**

B. Savosta, V. Tuz, V. Halchenko
MODELING AND DEVELOPMENT OF A SYSTEM FOR NON-CONTACT MEASUREMENT OF MECHANICAL CHARACTERISTICS OF THE ELECTRIC DRIVE **108**

D. Dvoriatkin, V. Tuz
IMPROVEMENT OF THE THERMAL REGIME CONTROL SYSTEM IN INDUSTRIAL PREMISES **111**

D. Moiseiev, V. Tuz, V. Halchenko
DEVELOPMENT AND RESEARCH OF A SYSTEM FOR CONTROLLING THE CONCENTRATION OF EXPLOSIVE DUST AND GAS COMPONENT OF THE ATMOSPHERE **114**

N. Bugaichuk, V. Tuz, O. Kamsha, R. Trembovetska
DEVELOPMENT AND RESEARCH OF A MICROPROCESSOR CONTROL SYSTEM FOR AN ELECTRICAL MEASURING ROBOT **117**

I. Tsarenko, S. Filimonov
IMPROVEMENT OF THE AUTOMATING SYSTEM OF THE THERMAL ENERGY PRODUCTION FACILITY **120**

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DEVELOPMENT AND RESEARCH OF AN AUTOMATED SYSTEM FOR PREVENTING CRITICAL SHOCK AND WAVE LOADS

Abstract. *This paper presents the development and research of an automated system designed to prevent critical impact-wave loads in coastal zones. The system aims to improve the safety and durability of coastal structures by providing real-time monitoring and prediction of wave forces. The study includes the design of a piezoelectric sensor system, numerical simulations of wave transformation, and experimental validation of the system in a laboratory basin. The results demonstrate the system's effectiveness in detecting and responding to critical wave impacts.*

Key words*: impact-wave loads, automated system, piezoelectric sensors, coastal protection, wave monitoring.*

Introduction. Coastal regions often face the destructive forces of waves, particularly during storms, which can cause significant damage to structures such as breakwaters, piers, and coastal buildings. The timely detection and prediction of critical wave loads are essential for reducing risks and preventing structural failures. This work focuses on the development of an automated system for monitoring and preventing critical wave impacts by using real-time data from sensors and predictive algorithms.

The developed system uses piezoelectric sensors to measure wave impact forces and mathematical models to predict potential wave transformations. This allows for timely warnings and automated responses to protect coastal structures.

The main objective of this study is to develop and test an automated system for preventing critical wave impacts on coastal structures. The specific goals are:

1. To develop a system that monitors wave impact loads in real time.
2. To design piezoelectric sensors for high-precision measurement of impact-wave forces.
3. To validate the system through laboratory experiments and numerical simulations.

Methods and Materials. The system architecture includes piezoelectric sensors placed on coastal structures to measure wave impact loads. These sensors are connected to a central processing unit that analyzes the data and predicts when critical wave loads may occur. The system can automatically trigger alerts or initiate protective measures, such as closing flood barriers or reinforcing vulnerable areas.

Wave impact loads are measured using piezoelectric sensors that convert mechanical stress into electrical signals. These sensors are sensitive to changes in pressure and are capable of capturing the dynamic loads generated by breaking waves. The sensors are calibrated to ensure accurate measurements over a range of force levels.

The transformation of waves as they approach shallow water is modeled using nonlinear shallow water wave equations. The simulation software, developed in MATLAB, predicts wave behavior based on initial conditions such as wave height, period, and seabed profile. These predictions are compared with real-time sensor data to improve the accuracy of the automated warning system.

The piezoelectric sensors were calibrated using known forces, and their response was recorded for various wave impacts. As shown in Fig. 1, the sensors exhibited a linear response to wave forces, confirming their ability to measure high-impact loads with precision.

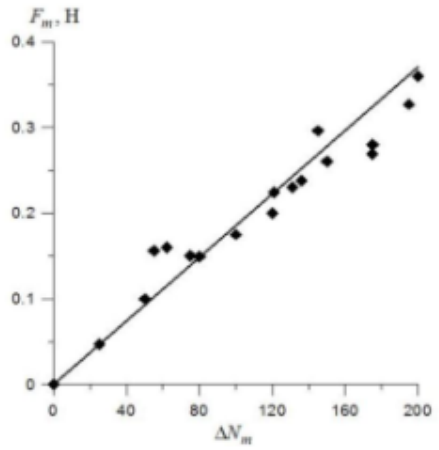

Fig. 1 Calibration characteristic of a piezoelectric pressure sensor

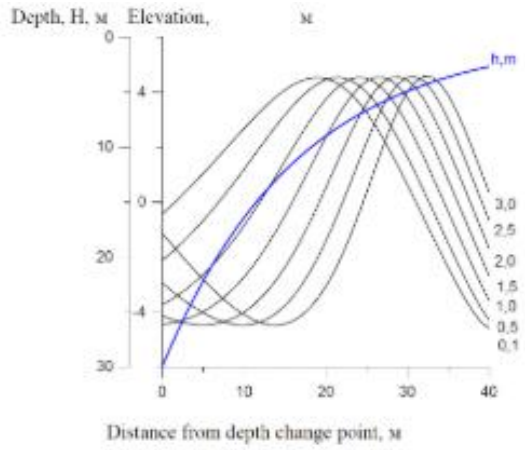

Fig. 2 Transformation of the wave profile in the zone of decreasing depth for time 0.1…3 s

In the experiments, the maximum recorded impact force reached 15 kPa during a storm simulation. This critical load was detected by the system, which successfully triggered an automated warning.

The MATLAB simulations closely matched the experimental results, particularly in predicting wave height and the timing of wave breaking. The model accurately forecasted critical wave loads, as demonstrated in Fig. 2, which compares simulated and experimental wave height data over time.

The system's ability to predict when waves would break and generate high-impact forces proved essential for preventing damage to coastal structures.

Conclusions. The developed automated system for preventing critical impact-wave loads offers a significant advancement in coastal protection. By combining real-time sensor data with predictive modeling, the system provides timely warnings and potential automatic responses to mitigate the effects of destructive waves. The system's accuracy was validated through experiments, confirming its potential for application in coastal engineering.

This technology has practical applications in improving the safety and durability of coastal structures, reducing the risk of failure during storm events.

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