Research Paper Computer Science

The Use of Applied Mechanics in The Diagnosis of the State Of Degradation

Mariusz Zoltowski	UTP University of Science and Technology in Bydgoszcz, Poland
Bogdan Zoltowski	UTP University of Science and Technology in Bydgoszcz, Poland
Jozef Melcer	University of Zilina in Zilina, Slovakia

ABSTRACT

In the Mechanical Engineering growing technical diagnosis which is based primarily on the use of information about the changing state machine is able to oversee the security threat and the progressive destruction of the machine throughout its lifecycle. Changes in - mapped methods of technical diagnostics - to prevent the causes and effects of the damage.

KEYWORDS security, diagnostics, status, operation, defect, failure.

INTRODUCTION

The processes of destruction of technical systems affecting the safety necessitate changes need to supervise their technical condition [1,2,3,4,10,12]. Methods and means of modern technical diagnostics are a tool for diagnosing the state of technical systems, which is the basis for operational decisions [1, 4,6,7,8,15].

Confrontation changed requirements and new opportunities generated new classe research problems, intensified others, while many directions of research has become irrelevant without the possibility of application, by:

- access to advanced technologies worldwide;
- the possibility of purchasing the latest generation of test equipment;
- of the latest applications in the field of hardware and software;
- access to databases, the capital market and wide possibilities of cooperative relations.

It's all a radically different views and achievements in the area of detection and surveillance of changes in methods of technical diagnostics facilities, especially in the area of safety task of shaping technical objects. This gives the opportunity to supervise the status changes, fault location and minimize the effects of damage and security risks [16,17].

CHANGES MACHINES

Damage is one of the most important events occurring in the use of machinery, determining the reliability of the machines, the efficiency of their use, a process supported technical and technical diagnostics range of needs.

Generally, the term damage to the machine can be defined as an event in which the transition of the machine (team member) with an airworthy condition to a state of unfitness. By the airworthiness status it is understood as a state of the machine, where it meets designated functionality and maintains the parameters set out in the technical documentation. By contrast, the state of unfitness meant a state of the machine, where it does not meet even one of the requirements set out in the technical documentation.

As a result of the impact of the environment and the implementation by the property his initial task of object properties may change, which reflects a change in the baseline characteristics and possibly measurable change in immeasurable qualities. Damage to equipment in operation may occur as follows:

- as a result of slow, irreversible aging processes and of wear occurring in the machine;
- due to the appearance of reversible different waveform caused by a temporary excess max value of one or more factors forcing;
- in jumps, manifested by a discontinuous transition of one or more features beyond the limits adopted as acceptable for the machine.

Taking into account the previous considerations can indicate the main causes of damage which are classified as follows:

a) construction - damage caused by errors and construct an object, usually by not taking into account extreme loads, ie. the values that significantly exceed the nominal force, leading directly to the damage;
b) production (technological) - damage caused by errors and inaccuracies technological processes (lack of dimensional tolerances, surface finish, thermal treatment, etc.) or defects in materials object elements;
c) operational - damage resulting from non-compliance with the applicable operating rules or due to external factors unforeseen effects for conditions of use of the object, which leads to weakness and premature wear and achievements of the state border;
d) aging and Consumables - always associated with operation of facilities and the resulting irreversible, leading to deterioration of strength and interoperability of the individual elements.

Damage or destruction of a technical object takes the influence transferred its energy. Depending on the type of energy that dominates in the circumstances, causes damage to the components can be divided into the following groups:

a) mechanical - static stress, creep, fatigue, pitting, frictional wear;
b) chemical - corrosion of metals, aging rubber, paint, insulation, rotting wood;
c) electric - electro-corrosion;
d) heat - fusion bond, intensification course of phenomena.

CLASSIFICATION OF DAMAGE

For a correct characterization of changes of ownership and phenomena cause them occurring in the machines during their operation, and especially the events leading to the formation of cracks need reliable data about the functions of individual teams and working conditions of their work, which involves the need for classification of devices.

For technical equipment can be distinguished:
* active elements that are directly involved in the conversion of energy, power transmission, processing kinds of movements working on other types, load bearing, etc.;

* base elements which determine the correct placement of active and supporting elements, for example. Bodies, guides, frames;

* support elements that protect the device from overload or exceeding of the limit.

Clarification of utility functions and carry out the classification of the characteristics (properties) of the object is possible methods of technical diagnostics. The most widely used is the following division features:

* critical parameters that determine the degree of threat to human life or health, environmental threat, the threat of cooperating systems and the total loss of the use value of the object (product) to be monitored;

* traits important having importance for the assessment of (life) of the object, defining threat to the structure, changing reversibly during the operation;

* features not important causing of negligible and reversible reduction in the efficiency of the facility.

The characteristics due to the method of evaluation can be divided into:
* qualities measurable and define their nominal value and limit;
* immeasurable qualities that assessment shall be made only organoleptically.

Traveller critical features is carried out usually in the form of monitoring, for each of them separately, and give rise to the shutdown facility of use, and does not meet the requirements of any feature. The nominal values and limits for these characteristics are determined by the relevant standards, or are determined by the user.

Features are important basis for assessing the current state of the object and delimit the scope and need for maintenance and repair.

Damage depending on the nature of the appearance can be divided into [28]:
1) primary (independent), that is, the occurrence of which was not caused by another damage;
2) whot by AD (subsidiaries), if the damage was caused by one device damage to another device;
3) lock the manual, or damage to the separate elements of the same unit occurring at the same time,
4) p oh s errors in june when they appear separately;
5) gradually which is generated as a result of changes in time of the parameters that determine when the occurrence of damage due to the impact of various physical, chemical, etc.

From the viewpoint of the causes of damage can be divided into:
1) accidental with constant risk of exploitation in the process; damages such are subject to elements whose condition does not depend on the time of operation,
2) due to faulty manufacture and service of the fading risk of occurrence in the operation;
3) due process of wear and aging elements, the growing risk of occurrence in the operation;
4) caused by non-established operating conditions, such as overloading of a different nature; distribution of damage during is generally unknown; it shall be the most constant risk of their occurrence in the operation.

PREVENTING DAMAGE

Reducing the destructive impact of an aging physical and use of mechanical objects is necessary in all phases of the existence of the facilities. Measurable results for reducing the number of failures of technical objects can shape:

* in the field of construction - by the proper selection of materials and shapes to load shaping unit pressure, choice of materials and materials for friction pairs, eliminating dry friction, wide use of appropriate seals, ensuring proper temperature;
* technology - the selection of the optimal type of machining, forming an optimal surface layer, choosing the right heat and thermo-chemical, properly assembled and regulations;
* in the field of operation - by observing the frequency and scope of operations (lubrication, adjustments, corrosion protection), avoiding overloads and abrupt changes in speed, status monitoring.

In general, so methods to counteract damage to the machine can be divided into two groups Practices:
- exploatations methods used in the development phase (evaluation), construction and machinery manufacturing, with a clear indication that they are the most efficient in economic terms;

- methods of operation used during the operation, even if these measures are not envisaged in the development process.

At the design stage are determined characteristics of machines to determine their shapes and dimensions of the materials of which are made, tolerance, surface finish and accuracy of the method for their mutual connection. The design documentation also durability of the material, the type of geometric surface structure, and sometimes a method of processing element.

When designing machine remember to reduce the danger of provoking damage minimum by the service. Simplifying, typing and standardization of components and mechanical systems lead not only to obtain good reliability, but also reduces costs and simplifies design.

For operational methods to prevent damage include:
- rational exploitation of machines in given conditions and specific purpose;
- examination of and monitoring of lesions developing diagnostic methods;
- compliance with the requirements specified in the technical documentation - movement in the frequency and scope of activities supported technical;
- statistical surveys damage in operation for modernization (redesign) machines, rationalization of spare parts, etc.

Improper operation causes intense impact wear processes, leading to premature failure and security risks.

CONSEQUENCES FOR DAMAGE - DAMAGE STATISTICS

During operation, variable ambient conditions and loads, frequent start and work in a wide range of speeds and loads accelerate consumption and pollutant formation leading to damage. For example, the ADAC [8.10] reports that 25.7% of damage is attributable to damage to engine components (the rest falls on engine systems, such as fuel system, injection, cooling). Damage engine components are distributed as follows:

pistons and connecting rods - 24.1%
crankshafts - 18.5%
cylinder liners - 16.1%
Bearing - 14.9%
the housing (body) - 9.6%

the cylinder head - 7.6%
the timing elements - 5.8%
other - 5.4%.

Damage to vehicle technical largely efect the safety of the driver, as well as create a danger to other road users. It was found that the technical damage on vehicles is about 2% of all cases of which damage:

brake - 25%
tires - 20%
lights - 14%
steering and suspension - 7.5%.

It is estimated an increase of 7% of the number of car accidents caused by technical defects. This is due to the lack of concern about the condition of the vehicle (the cause of approximately 25% technical damage).

The frequent occurrence of damage is manifested by reduced quality of vehicle services. This affects significantly the duration of the order and comfort of the vehicle. Long repair and short periods between repairs make the vehicle more time in repairs than doing the job, for which it is intended.

Deterioration in the quality of our services caused damage of vehicles it is also significant effects of an economic nature. Too many times the execution angry of comfort and a small indicator of technical readiness that cause loss of customer and thus lowering the profits from their activities. Many companies providing services vehicles in recent years, it took the issue of the intensity of damage to the vehicle a little closer, seeing here the cause of low competitiveness. These companies have invested in the acquisition of high-quality fleet, experienced drivers entrusted to him, and servicing carried out at authorized service stations. This resulted in the emergence of highly competitive, supported by high quality services and thereby improving the finances of these companies.

DIAGNOSTICS IN THE EVALUATION OF DAMAGE DEVELOPMENT

Technical diagnostics includes the following forms of action:

1. assessment of the state,
2. forecasting the state,
3. state genesis - the least recognized.

These forms of activity are realized by intelligent diagnostic systems (mobile software and hardware with a noose self-learning and risk assessment).

In clinical condition of the objects we use the models: physical or symbolic, that are presenting physical or mental examined the original.

Modelling for diagnosis includes physical modelling, mathematical and energetycze, which gives the basics: the diagnosis of symptoms, holistic and energy.

Problems major diagnostics of machines include:

- acquisition and processing of diagnostic data;
- build models and diagnostic relations;
- inference diagnostic and limits;
- classification of the states of the machine;
- anticipate another time of diagnosis;
- imaging information decision-making.

These thematic groups are an area of interest in methods and methodologies shaping and sustaining quality of the machinery, which is conditioned by the dynamic development of the following issues:

- modelling of objects
- methods of diagnosis, forecasting
- diagnostic susceptibility (friendly methods and objects).
- a cost-effective and accurate means of research,
- the possibility of experiments in subsequent phases of the existence of the machine,
- methods for evaluating the effectiveness of application of research methods,
- design methodology and implementation of measurement systems,
- methods of artificial intelligence research.

Diagnostic signals

Physics phenomena of the work each machine based on the model of signal generation is the basis of good diagnostics and based on the knowledge describe the dynamics of the machine, which facilitates a smooth transition to the area of diagnostics (MEB, MES, MSES, AM).

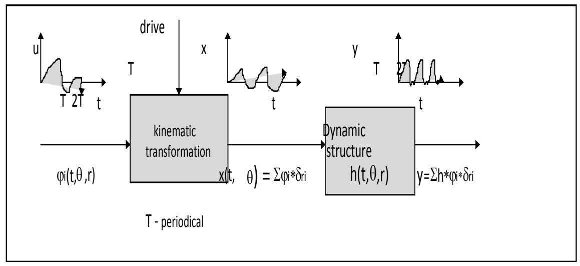

Figure 1. Diagnostic model of signal generation machine

Selection of diagnostic parameters

A set of diagnostic parameters signal stands out from the set of output parameters associated with operation of the machine. Determination set of sensitive diagnostic parameters should include:

- mapping capability status changes during operation,
- amount of information about the technical condition transmission,
- sensitivity parameter values during operation.

Methods for determining diagnostic symptoms are as follows:

- Method of maximum sensitivity parameter to change the condition.
- Method of maximum relative change in the diagnostic parameter.
- Method maximum capacity of diagnostic parameter information.
- Method of maximum variability of the diagnostic parameter.

The advantage of these methods is that they allow you to choose from a set of output parameters one-piece and multi-element sets of diagnostic parameters.

Optimization criteria set of diagnostic parameters:

1. Diagnostic parameters should characterize the process of destruction of the object and be closely associated with him.
2. Diagnostic parameters should be sensitive to changes in the ongoing process of deterioration suitability of the object.
3. The number of diagnostic parameters cannot be too large, because a significant number makes it difficult, and sometimes impossible to know the process of deterioration of the object.
4. Diagnostic parameters should be measurable nature.
5. There must be reliable statistical and analytical award-parameters (BEDIND, SVD, PCA).

The problems of technical diagnostics

Technical diagnostics - is developing in two directions:

- Developing methods for testing the condition of the object (structure, functioning, physical and chemical processes, models of signal generation);
- Diagnostic process planning (generalization of the formalization: description, diagnostic activities, methods of optimization - models diagnostic, diagnostic programs, stock checks).

This will give you an answer - how best to explore business?
Optimization problems diagnostic system (strength and means to perform the testing process) are analyzed much less. These

include: the organization structure of the control and measurement, fixed and variable programs diagnosis, selection of methods and measuring devices to determine the relationship end, manner of presentation, etc.

The diagnostic system becomes a subject of separate considerations and diagnostic properties of these systems need to be developed and described (with mathematical formalization).

Recent topics diagnostics dynamically developed are:
1. modern methods of signal processing;
2. multidimensional diagnostics of machines;
3. numerical analysis and synchronous methods;
4. energy diagnostics;
5. diagnosis by identification;
6. diagnostics according to the model;
7. elements of artificial intelligence in the diagnosis;
8. modern information technologies in the diagnostics;
9. designing computer diagnostic systems;
10. intelligent diagnostic agent.

The problems of technical diagnostics:
1. time constitution of a diagnostic symptom;
2. change the value of a symptom - preventive action;
3. comprehensive assessment of the state: measurement, a reference to the limit, forecasting the state, causes changes in the value of the measured symptom, set a date for another diagnosis;
4. surveillance developing damage (fault tolerance, STOP - for critical damage by Sgr);

THE DIAGNOSTIC SYSTEM
The diagnostic system is a set of components and relationships that are needed in order to diagnose. Because this process consists of a series of actions in which information about the properties of the object is converted into information about his condition, therefore, a diagnostic system depends on the type of object and diagnostic activities needed to develop diagnoses.

Detailed definition diagnostic system exists in the form of:
"The diagnostic system is a team of diagnosticians, collection methods and means of obtaining, processing, presentation, and collecting information and a collection of objects, their models and algorithms for diagnosis, prognosis and genezowania states, as well as the relationship between these elements, designed to make reliable decisions about the affiliation of the object to a certain class of conditions. "

The structure of the diagnostic system proposed in Figure 2 shows the basic relationship between the object of study, his model of diagnosis and system diagnosis of the condition and decision.

Organizing structure of the system is expressed by a set of relationships and on selected properties of its components, with the result that stands out various structures, such .: organizational structure, economic, technological, etc.. The diagnostic systems belong to the class of information systems, and distinguished by the fact that:

* Aim of these groups is to identify the status of other objects (or systems), substantially without influencing the change of the condition,

* Purpose of this is to develop diagnosis, realizable by processing information about object properties for information about his condition.

For these reasons, the main attention should be given diagnostic information system structure and design it, optimize and evaluate due to the circulation of information.

Different form the various constituent elements and their use in the system creates the possibility of diagnostic systems with different structures and varying degrees of automation.

A non-automated diagnostic system includes a human (or team of people); which performs all operations using measuring instruments, instructions on methods of collecting and processing information about the examined object and generates a diagnosis, which if necessary registers (eg. in the protocol). This system comprises a measuring instrument, diagnostician and user data. With these diagnostic systems meet still relatively common in industrial practice.

B. The automated diagnostic system uses an arrangement of technical devices that perform the diagnostic process in accordance with a predetermined program. Human intervention is minimal, usually comes down to turn on the system. Automatic diagnostic systems are usually subject to self-control, and the existence of damage is signalled. They can then be incorporated elements of reserves or controlled object is turned off from traffic. The individual results of the inspection or only results that go beyond the preset boundaries are recorded automatically.

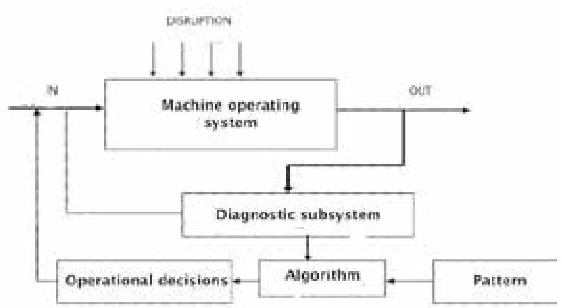

Figure 2. Diagnostic system controls the operation of machinery

ASSESSMENT OF MECHATRONIC SYSTEM
Mechatronic system is a modern machine composed of parts of mechanical, electronic and electrical, integrated modern information technologies in the area of artifacts and associated processes. Systems for monitoring the status of such systems is an essential piece of equipment that protects against the onset of damage or failure. Algorithmic solutions organize these systems acquisition process, filing and processing of measured data according to established rules, assisting states classification or diagnostic decision support.

Hardware solutions define multichannel measurement systems cooperating with any sensors, control systems own measuring circuits, links integrate with a variety of transducers or regulatory systems, identifying situations, alarm or exclusionary.

Mechatronic systems and their development, as the next stage in the development of quality machine construction, are closely associated with the development of cybernetics and general systems theory and information theory and management. They perform these systems from the complexity of relationships, networks and feedbacks within the system, mechanisms of stability, dynamism, self-regulation, the collection and processing of information.

Mechatronics is becoming a frontline development of bionics, which examines the principles of construction and operation of biological systems in order to be able to construct mechanisms, machines and technical equipment, whose characteristics are similar to characteristics of living systems. Next to mechatronics, biomechanics, bioenergetics, allowing to predict the formation of a mixed technical systems consisting of mechanical parts, electronic and living organism.

This should meet the challenges of the future technical diagnostics, for which provision should be made now new challenges. The current state of development of technical diagnostics of mechatronic systems is just the beginning of many new,

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not always yet fully known substantive and methodological challenges.

Monitoring systems of these systems are based on sensing changes in the sources of partial intelligent sensors (sensors), systems of information gathering and the operator station. The main elements of such systems are smart transmitters which include block acquisitions, and block communication with the environment. Their advantages compared to previous generation devices are as follows:

- the ability to develop measurement procedures in digital form;
- the ability to implement algorithms for processing without changing the structure of the instrument;
- communication capabilities involving the use of specialized measuring interfaces to generate information and controlling decisions.

It all makes intelligent transducers have adaptive characteristics, enabling based on measurement conditions, object properties, requirements and restrictions, choice of measurement algorithm according to a given problem. In the transmitter memory is a set of software algorithms and software of their choice. The choice is conditioned in accordance with the implemented features, accumulated knowledge and information on the measurement conditions.

The most generally understood diagnosis of such systems within its scope covers all activities related to:
• observation of diagnostic facilities
• the processing of data collected in the Diagnostic Observation in order to get input into the process of diagnostic,
• carrying out various numerical experiments support the inference diagnostic
• diagnostic prevention, the results may be plans for appropriate action to restore the full usefulness diagnosed objects and other activities of a reorganization and correction (eg. Plans for staff training - modernization of machinery and technology in use, etc.)
• sharing the results of diagnostic tests appropriate group of recipients, in particular those governing the operation of the group of technical measures.
The factor that brings all these steps into one modern technologies. Such systems (SCADA) system may consist of several levels:
• Level sensors

They process a variety of process variables (temperature, voltage, current, power, pressure, vibration, etc.) Into an electrical signal.

• Level PLC

PLCs can create a master-slave structure, in which one of them can manage the work of others. This allows you to create complex structures, measurement and control.

• The level of connection PLC computer systems

PLCs can be connected to computer systems via industrial networks or local area networks.

• Level data station

The station data - collects data from sensors attached to the SCADA drivers.

• Level of local networks

It allows you to connect client stations with the station data, allowing for access to process data from workstations located in different places of the organization.

• The level of client stations presenting the measurement values in the form of synoptic image.

Diagnostic systems have the ability to retrieve information from the test object. They also have processing capacity as a received information until a diagnosis of the state of the object included. From an information point of view of each element of the system thus it has two inputs and one output.

TECHNICAL DIAGNOSTICS IN PRACTICAL APPLICATIONS
Monitoring the status of machines, in terms of functional reliability (treated as a machine's ability to complete the task) as well as in terms of physical diagnosis (identifying the causes of the damage) occurs at the level of maintenance machinery. In the process of operation, assisted diagnostic methods, taking into account the nature of the changes extortion (load) acting on the object stands out:

- Accidental damage (sudden) that arise as a result of stimuli causing jumping above the established values of the parameters proper operation; sudden damage cannot be predicted on the basis of the results performed supported, including the diagnosis;

- Damage and wear (natural), as a result of changes in the properties initial object occurring during due to aging and wear; Consumables damages arise from stimuli that accumulate during its use, and you can anticipate having the results of diagnostic measurements.

The practice of diagnostic applications include many important areas, such as [7]:
1. organization diagnostic system (Dsem).
2. management and Quality Systems (TQM, TPM).
3. modern information technology (ISZOT).
4. modelling operating systems with diagnosis and risk assessment.

In practice, the functioning of enterprises operating problems and diagnostics are integrated into specialized information systems functioning [7.12].

Features of the operation subsystem can be defined as tasks:
- leads the classification and records of all fixed assets
- propose technical and economic indicators of the economy fixed assets,
- supervise the use of fixed assets,
- analyses data from monitoring and making decisions
- requested the liquidation of fixed assets,
- plans, oversees and implements all types of inspection, maintenance and repairs.

The very functioning diagnostic system, from the methodology used technical diagnostics tools for ongoing assessment and forecasting of machine condition requires knowledge [7.12]:

- symptoms of the state machine: $s_1, s_2, \ldots, s_m$;

- the limit values symptoms: $S_g = \bar{s} + \sigma\sqrt{\frac{P_g}{2A}}$;

- periodicity of diagnostic tests: $T_b = \frac{(1-P_g)(S_g - S_u)}{S_u}\theta_u$

Knowledge of the technical state of the so-functioning diagnostic operating system (DSEM) is the basis for making operating decisions: to continue to use, refer to the technical operated or liquidation.

REQUESTS
Shaping and quality assessment methods of technical diagnostics of machines is closely connected with the need to maintain an appropriate level of functional characteristics under certain conditions. These features, complies with the safety and representative of the condition of the vehicle (team member) should be determined at the time of constructing and verified during manufacturing and operation.

For the awards, evaluation and maintenance of traits used:

- The possibility of technical diagnostics, including construction diagnostic assessment of the quality creations, operational diagnostics, methods and means of technical diagnostics, power diagnostic tests computer technology;
- Reliability tests in phases: pre-production, production and post-production with the use of bench studies, modeling deterministic and stochastic factors forcing, computer-aided reliability tests;
- The methodology to shape the "quality" over "quality control system company" with regard to the quality standards EN series 29 000;
- Research manufacturability maintenance and repair of vehicles, forming the intensity of aging and wear of the elements, shaping vulnerability and to evaluate the effectiveness of vehicle operation.

These thematic groups are an area of interest a wide range of operational community, contributing to the development of methods and methodologies shaping and sustaining the suitability of vehicles.

Technical diagnostics, next to tribology, reliability, bezpieczeń¬stwa theory and the theory of operation is one of the fundamental teachings of rational eksplo¬atacji objects. Understanding the physical phenomena occurring during operation of the machine allows you to specify the qualitative relationships between the destructive processes taking place and the state machine.

REFERENCES

1. Cempel C., Natke H.G.: An introduction to the holistic dynamics of operating systems. Progress Report No.2, CRI - B - 2/92, 1996.
2. Ďurica P., Juráš P., Gaspierik V., Rybarik J.: Long-term monitoring of thermo-technical properties of lightweight construction of external walls being exposed to the real conditions. In Procedia Engineering,111 (2015) pp.176-182.
3. Eykhoff P.: Identyfikacja w układach dynamicznych. BNInż., Warszawa 1980.
4. Findeisen W. ii: Analiza systemowa - podstawy i metodologia. PWN, Warszawa 1985.
5. Hadzima B., Vičan J.ii: Influence of tempering on the deformation level of the multi-layer hard faced samples. In Procedia Engineering,111 (2015) pp. 49-56.
6. Niziński S., Michalski R.: Diagnostyka obiektów technicznych. ITE, Radom 2002.
7. Uhl T., Giergiel J.: Identyfikacja układów mechanicznych. PWN, Warszawa 1990.
8. Vičan J., Jošt J., Gocál J.: Analysis of the stringer-to-cross-beam revited joints behaviour, In: Civil and environmental engineering, ISSN 1336-5835, vol. 10, no. 1 (2014), s. 50-60.
9. Zeigler B.: Teoria modelowania i symulacji. PWN, Warszawa 1984.
10. Żółtowski B.: Podstawy diagnostyki maszyn. ATR, Bydgoszcz 1996.
11. Żółtowski M.: Analiza modalna w badaniu materiałów budowlanych. ITE - PIB, Radom 2011s.167.
12. Żółtowski M.: Informatyczne systemy zarządzania w inżynierii produkcji. ITE - PIB, Radom 2011.
13. Żółtowski M.: Investigations of harbour brick structures by using operational modal analysis. Polish Maritime Research, No. 1/(81), vol.21, ISSN 1233-2585, 2014, pp. 42-54.
14. Żółtowski M.: Assessment State of Masonry Components Degradation. Applied Mechanics and Materials Vol. 617(2014), Trans Tech Publications, Switzerland 2014, SSN 1662-7482. pp. 142-147.
15. Żółtowski B., Żółtowski M.: Vibrations in the Assessment of Construction State. Applied Mechanics and Materials Vol. 617(2014), Trans Tech Publications, Switzerland 2014,. ISSN 1662-7482. pp. 136-141.
16. Żółtowski M.: Badanie niezawodności elementów infrastruktury murowej z użyciem operacyjnej analizy modalnej. Materiały Niezawodności, Szczyrk 2013, pp.127-129.
17. Żółtowski M. ii.: Study of the state Francis Turbine. Polish Maritime Research, No.2/ (78), vol.20, ISSN 1233-2585, 2013, pp. 41-48.