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DEVELOPMENT OF EVALUATION SYSTEMS OF METAL STRUCTURES OF CONSTRUCTION MACHINES BASED ON FUZZY MODELS

РОЗРОБКА СИСТЕМ ОЦІНКИ МЕТАЛЕВИХ КОНСТРУКЦІЙ БУДІВЕЛЬНИХ МАШИН НА ОСНОВІ НЕЧІТКИХ МОДЕЛЕЙ

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Анотація. Основною умовою забезпечення безаварійної роботи металевих будівельних конструкцій є загальна діагностика технічного стану, особливо наявних дефектів і пошкоджень. Застосування апарату теорії нечітких множин дозволяє здійснювати зв'язок впливу дефектів на несучу міцність елементів і конструкцій при поданні цих результатів у відносній (безрозмірній) формі з визначенням ступеня їх належності до проекту або нормативного значення.

Ключові слова: металева конструкція, дефект, теорія нечітких множин.

Abstract. The main condition for ensuring trouble-free operation of metal building structures is the general diagnosis of the technical condition, especially the existing defects and damage. Application of vehicle of theory of fuzzy sets allows to carry out the association of influence of defects on bearing strength of elements and constructions at presentation of these results in a relative (dimensionless) form with determination of degree of their belonging to the project or normative value.

Key words: metal construction, defect, fuzzy set theory.

Introduction.

In the process of model review determine the structural parameters of construction: actual sizes of elements, connections and weld-fabricated guy-sutures, mutual location of elements, their deviation from project position, concavity and curvatures of structural elements, presence of cracks, degree of corrosive wear of material of constructions, state of screw-bolt and riveting connections [1, 2].

At a general review the structural chart of elements, general of constructions, character of damages and zone, is specified with most of damages. Accordance of constructions is checked up, them separate elements and knots of project.

At an inspection, conforming to of materials of constructions the requirements of project documentation and operating normative documents is also checked up. For determination of the real properties of the applied materials experimentally investigate

physical and mechanical descriptions (durability of steel is on tension, clench, change, crumpling, shock viscosity).

Thus, basis for the estimation of the technical state are results of primary expert information (PEI) on quality of elements of construction, which is set as numerical values of actual sizes of geometrical parameters and calculation-mechanical descriptions of material [3, 4].

Presentation of the main material.

The defects educed in the process of inspection have a different degree of influence on bearing strength of structural elements. Thus, taking into account nonlinear dependence between the size of rejections and parameters of bearing strength, a necessity appears for their corresponding mathematical presentation.

On the basis of data of PEI and numerical and structural analysis of object the great number of parameters that determine in accordance with the requirements of the maximum states is formed, capacity of construction and building on the whole. In obedience to the standards of Ukraine, a qualificatory parameter is a physical parameter (index of quality), that characterizes the state of object, and achievement that some maximum value causes a refuse (out-of-limit state) [5].

For possibility of realization of mathematical operations from the association of results of their influence on bearing strength of elements of construction, they must be presented in a relative (dimensionless) form with determination of degree of their belonging to the project or (for calculation-mechanical properties of materials) normative value. This fact predetermines application of substantive provisions of theory of fuzzy sets, that allows in default retrieval of statistical data to estimate the degree of belonging of some qualificatory parameter him to the project (whether normative) value and to estimate the degree of influence of change of this parameter on quality of element.

Providing of long duration and reliable exploitation of building constructions of building due to timely prognostication and use of models and methods of the system of diagnostics of them the technical state is the theoretical, technical and economic issue of the day, that needs application of effective decisions on all stages of life cycle

of building and the “Normative documents are regulated by position on questions inspections, passport system, safe and reliable exploitation of productive building and building”.

The building constructions of building that are in exploitation as a rule, have different defects and damages that have exactly unclear description of degree of the influence on reduction of bearing possibility, predefined by absence of statistical selection. In addition, at an analysis subjective presentations of experts are used. Introduction of the corresponding mathematical estimations based on application of theory of fuzzy sets compensates the lack of objective information and promotes the level of authenticity of description of the system. Farther, laying out of unclear by the nature information on the determined amount of intervals on a segment $[0;1]$ considerably simplifies work of experts on attributing of level of damaged to one of such intervals instead of hard conclusion on a standard “capable” – “incompetent”.

Bearing possibility of elements of construction is determined by the certain great number of parameters (geometrical, stiff, durability, mechanical). Consider that all parameters that change the value under act of structural defects belong to the fuzzy set of variable quantities that are one common characteristic – description of bearing strength of structural element only.

Forming of function of qualificatory parameters requires corresponding mathematical presentation of expert information. Formalization of PEI consists in translation of research data in the corresponding dimensionless great number of degrees of belonging of actual values of parameters, which determine accordance of bearing strength of elements of construction to the project or normative value taken for unit.

During such translation in the qualificatory parameters (geometrical, hard, mechanical) of PEI must in the obligatory order pass procedure ranging in accordance with the degree of influence of the inspected parameters on bearing strength of elements of construction.

Parameters that determine bearing strength are casual sizes, conformities to law of changes of that are fully described by the differential function of normal distribution.

By researches from the theory of fuzzy sets set, that for the values of unclear functions that are near to some permanent parameter (for example, normative or project value), a function of belonging is near to the Gauss curve, that describes normal distribution of continuous casual size.

The measure of decline of bearing strength of structural element is a relative value of rejection of that or other qualificatory parameter from a project or normative value.

Then the analysis of structural risk for every element is taken to comparison of project, actual and maximum value of qualificatory parameters.

A construction or her elements become unapt for exploitation, when they pass through the maximum state is certain, id est, such state, outside that does not stick to even one of criteria that determine them bearing strength or fitness to exploitation.

At the estimation of the technical state of elements of building constructions certain difficulties are caused by the estimation of simultaneous influence of row of defects on the tensely-deformed state of constructions. Through the considerable variety of types of constructions, size and type of the added loading, location and type of defects there is not possibility to collect necessary statistical material for research of change of efforts in the elements of construction. Obviously, that additional loading in elements, which arise up as a result of accumulation of defects, it is impossible to take into account superpositions on principle.

At the same time, at the estimation of influence of present structural defects on the decline of bearing strength without a statistical selection from position of theory of fuzzy sets, task consists in determination belonging of parameters, that determine bearing strength of structural element, to such great number, where all totality of requirements and limitations is satisfied in accordance with project and normative documents.

Degree of belonging of qualificatory parameters of element of zero-defects, where all requirements of normative documents are satisfied, it is determined a great number by the operation of association of corresponding fuzzy sets that characterize the degree of belonging of every element (rule of rolling up).

The important method of estimation of reliability of on-the-road building

constructions indexes is research of process of accumulation of defects in constructions on all stages of life cycle with the use of statistical and diagnostic methods.

As statistical methods of study of process of accumulation of defects rational and effective is application of model of cumulative accumulation of damages and theory of fuzzy sets that allow in the generalized form to estimate influence of defects on behavior and reliability of on-the-road object indexes.

At application of cumulative model of accumulation of defects a process is examined on the basis of eventual stationary chain of Markov, at that the future value of process depends only on the known past value and does not depend on all previous values. The vehicle of conditional authenticity is thus used.

Conclusions.

Application of vehicle of theory of fuzzy sets allows to carry out the association of influence of defects on bearing strength of elements and constructions at presentation of these results in a relative (dimensionless) form with determination of degree of their belonging to the project or normative value. Thus a function of belonging can be an arbitrary function that at the same time allows uniting in itself influence on reliability of different types of defects indexes.

References:

1. Gorbatyuk Ie., Terentyev O., Mishchuk D., Bykov V. (2025). Integrated models of forecasting reliability of decision making of the system of diagnostics of the technical condition of buildings. *Girnychi, budivelni, dorozhni ta melioratyvni mashyny*, (105), 73–78. <https://doi.org/10.32347/gbdmm.2025.105.0501>.

2. Gorbatyuk Ie., Mishchuk D., Bulavka O., Komotska S. (2025). Estimation of simulation of high-speed pressure of blast wave of tower crane. *Girnychi, budivelni, dorozhni ta melioratyvni mashyny*, (105), 12–19. <https://doi.org/10.32347/gbdmm.2025.105.0201>.

3. Terentyev O. O., Tsiutsiura S. V., Gorbatyuk Iev. V. Software-technical complex of the implementation of the automatically-based system of diagnosis of construction condition of non constructions. “Science progress in European countries:

new concepts and modern solutions”: Papers of the 6th International Scientific Conference. April 19, 2019, Stuttgart, Germany. Published and printed in Germany by ORT Publishing (Germany) in association with the Center For Scientific Research “Solution” (Ukraine). P. 120-125.

4. Integrated models and methods of CAS of diagnostics of the technical state of constructions of building and building: textbook / O. O. Terentyev, I. V. Rusan, Ye. V. Horbatiuk, I. S. Ivakhnenko, O. V. Petrochenko, O. P. Kulikov. Kiev, 2019. 240.

5. Gorbatyuk I.V., Terentyev O.O. Methodology of estimation of imperfection of building constructions on basis of fuzzy sets. The 14th International youth conference “Perspectives of science and education” (January 17, 2020). SLOVO\WORD, New York, USA. 2020. 122-128.

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