OPINION

by Prof. Nikolay Lichkov Georgiev, D.Sc.
regarding a dissertation work for awarding the educational and scientific degree "DOCTOR" at the Institute of Robotics of the Bulgarian Academy of Sciences.

Dissertation topic: Emission and sensor registration of microparticles in inhomogeneous structures under uniaxial deformations

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Field of higher education: "Technical sciences", Professional direction: 5.2 Electrical engineering, electronics and automation (Elements and devices of automation and computing technology),

Basis for drawing up the opinion: Decision of the Scientific Council of IR-BAS reflected in Protocol No. 4/08.05.2024 (item 2.), Order for the appointment of a Scientific Jury of the Director of the Institute of Robotics No. 32/15.05.2024 and minutes of the first meeting of the Scientific Jury from 17.05.2024.

Data on the PhD candidate.

The doctoral student, M.Sc. Eng. Martin Lachezarov Ralchev graduated from the Technical University - Sofia in 2020 with the qualification "Electrical Engineer", after which he was enrolled in a part-time doctoral program in the "SITRM" section at the IR-BAS. The dissertation research was carried out in fulfillment of the Scientific Plan of the doctoral student and the Scientific Program of Project BG05M2OP001-1.002-0006 for the establishment of the Center for "Quantum Communication, Intelligent Security Systems and Risk Management QUASAR", financed by the European Fund for regional development through the Operational Program "Science and Education for Smart Growth".

General characteristics of the presented materials

The applicant has submitted the documents required according to the regulatory framework, checked by the relevant administrative authorities.

The dissertation is 114 pages long and contains an Introduction, Five Chapters, Scientific and Applied Contributions, References, 68 Figures and 3 Tables.

The relevance of the dissertation work lies in the need to find new phenomena and methods for establishing the deformation status and revealing the mechanisms for the occurrence of the pre-critical states preceding the destruction

of various infrastructural mechanical objects - industrial and other buildings, road facilities, bridges and tunnels, rocks education etc.

The aim of the dissertation work is to study the established effect of emission occurrence in pre-critical states of particles from the surface of inhomogeneous rock systems from the territory of the country.

The main tasks that the doctoral student has set himself to solve are:

1. To analyze the rock samples under uniaxial deformation and the associated formation of finely dispersed mineral particles in the nano- and micro-sized range, clarifying the change in their intensity depending on the load value.
2. To determine the influence of the type of rocks from different regions of Bulgaria on the intensity and composition of the formed micro- and nanoparticles.
3. To establish the functional relationship and dependencies between the emissions of particles, the level of deformation of the rock structures, the area of the samples, etc.
4. To design, implement and research innovative engineering solutions for obtaining integral information about the state of rock systems.

In the First chapter, State of the problem, the doctoral student presents the origin and the main methods for the diagnosis of rock massifs, which since ancient times has been connected with the development of construction, earth sciences and specialized equipment construction.

In the Second chapter, Formation of microparticles under loading of rock structures, the classification of rock types in geology and the structural inhomogeneities of thiopian rock masses are discussed. Using the finite element method, using the computer program ANSYS MAXWELL in IR, the doctoral student modeled the deformation and destructive processes in cylindrical cavities during uniaxial compression of different types of rocks and investigated the formation of particles from their surface. Based on the finite element method and the Ansys Maxwell program, an innovative model of the deformation and destructive processes in rock cylindrical cavities under uniaxial loading has been developed. On this basis, two sources for the generation of microparticles in the cylindrical cavities are identified: one is the region of maximum compressive strains and the other is the region of maximum tensile stresses.

In Chapter Three, Experimental set-up for the study of dynamic processes in inhomogeneous structures, the doctoral student proposes specific experimental methods, sensor devices and equipment for obtaining reliable information about the processes in rock structures under uniaxial loading. According to the methodology, three configurations of experimental setups were tested to measure the generated microparticles. They are mainly determined by the geometric shape of the test bodies. The dissertation presents the experimental set-up and the equipment used, the methodology for conducting the tests and analyzing the

results.

In the Fourth chapter, Experimental results, the regularities of the effect of the emission of micro- and nanoparticles in inhomogeneous structures under uniaxial deformations, defined by the doctoral student, are established. Research has been conducted and data on the number of particles emitted from the surface of the cylindrical cavity under applied load to samples of granite, marble, rhyolite and limestone have been analyzed, with the load having a relative value of 0.8 of Max. Also presented are background particle concentration data under laboratory conditions under which the study was conducted over a 60-second period, providing a comparative or benchmark basis for emission analysis. Based on the research, the regularities in the behavior of the materials (limestone) under the influence of compression were revealed. The study illustrates in detail that as the compressive stress approaches 4.0 megapascals (MPa), a significant increase in particle emissions is observed in all size ranges. This phenomenon is interpreted by the PhD student as an indicator of the beginning of structural changes in the material, which lead to a higher degree of fragmentation and, accordingly, to an increase in the number of particles.

In Chapter Five, On the origin of the emission effect and prospects for its upgrade, the doctoral student presents his physicochemical interpretation of the origin of the effect and prospects for its upgrade, especially for the purposes of seismicity and infrastructure prevention. The applicability of the obtained results is based on the clear and categorical reproducibility of the new regularity in the same rock structures obtained from different areas of the country. A first attempt is made to explain the generation of particles in inhomogeneous solid structures under uniaxial impact. The results of the research are aimed at establishing a sensor method used as an integral indicator for measuring the emission characteristics determining the pre-destructive and catastrophic processes in the rock massifs.

The following scientifically applied contributions were obtained in the dissertation work:

1. A previously unknown regularity was experimentally found in solid inhomogeneous systems - rocks and concretes, consisting in the generation of particles under the influence of high uniaxial deformations. It has been proven that the amounts of emitted mineral microfractions in the range 0.3 μm – 5.0 μm are reproducible for a specific type of rock in the various mountain massifs of regions in Bulgaria.
2. Based on an original methodology, an experimental set-up was designed, constructed, implemented and tested in four variants depending on the geometric shape of the rock samples to study the emission of fine mineral fractions under uniaxial pressure. It is equipped with modern sensor devices, measuring with high accuracy and sensitivity the characteristics

of the released microparticles.

3. The functional dependence of the generation of particles on external factors has been determined, as in the case of deformation, their intensity and size depend on the type of rocks delivered from different regions of the country. A phenomenological and physicochemical interpretation of the new regularity is proposed.
4. At levels of deformation pressure of rock structures up to the limit of their disintegration, there is a sharp, in first approximation, exponential growth of particles in all their size ranges. Their amount is directly proportional to the generating surface of the samples, and the intensity of the emission process is justified to serve as an indicator for predicting their destruction.
5. An integral method and system for dynamic determination of the stress-strain state of rock massifs has been proposed and developed. The continuous monitoring of microparticles serves for early disclosure of pre-emergency and emergency situations in critical infrastructure with applicability in: seismically active areas for detecting the folding of tectonic plates; mining industry; the construction of tall buildings and their pre-destructive conditions; landslide prevention; controlling the state of dam walls, bridges, viaducts, etc.

The abstract has a total of 35 pages, reflects the main part of the dissertation and meets the regulatory requirements.

Personal impressions

I have known Eng. Martin Lachezarov Ralchev since 2020, when our joint work on the QUAZAR project began. My impression of him is very good, as an intelligent and well-prepared young specialist, having the capacity for in-depth scientific research using a variety of scientific methods and tools. He works actively to realize his developments, including through their implementation in national and international projects, demonstrating extremely rich and successful administrative and organizational experience.

I have no scientific research or publications in common with Eng. Ralchev.

RECOMMENDATIONS

In my opinion, some weaknesses have been admitted in the dissertation work, the most important of which are:

- The formatting of the names of some of the sections is not exactly in accordance with what is specified in the Regulations for the implementation of the Law on the Development of the Academic Staff in the Republic of Bulgaria;
- I do not consider it expedient to summarize its content and contributions in the introduction of the dissertation;
- Although it is logical, it is necessary to justify in more detail the choice of

rock formations as the only object for the study of inhomogeneous structures.

The indicated weaknesses do not significantly affect the quality of the dissertation work, but should be avoided in the future scientific activity of the author.

CONCLUSION:

In the dissertation, an innovative integral method for assessing the stress state of the investigated non-uniform structures is proposed. In the study, a successful interpretation was made to clarify the root causes and mechanisms that lead to the generation of fractions during deformations. The hypothesis was confirmed that the amount and characteristics of the microfractions released during uniaxial deformation can serve as an indicator of the internal stresses, the accumulated potential energy and the structural integrity of the rock massifs. Through the emission of these micro- and nano-sized particles, the possibility of early warning and prevention of impending destruction in critical infrastructure is revealed.

Main achievements and results of the dissertation have been popularized in 3 scientific publications from national and international conferences and in 3 inventions, with the new regularity included in the BAS Report for 2022. This, together with the exams passed and the courses held, fully satisfies the requirements of normative documents for awarding the educational and scientific degree "DOCTOR".

MSc. Eng. Martin Lachezarov Ralchev has presented the necessary materials, which in their totality exceed the minimum national requirements according to the Law on the Development of the Academic Staff in the Republic of Bulgaria and the Regulations for its implementation. The quality of the submitted materials and the applicant's overall research and development activity give me reason to conclude that he meets the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria. Therefore, **I give a positive assessment of his dissertation**, and I suggest that the Scientific Jury award the M.Sc. Eng. Martin Lachezarov Ralchev, the educational and scientific degree "DOCTOR" in professional direction: "Technical Sciences", Professional direction: 5.2 Electrical engineering, electronics and automation (Elements and devices of automation and computing technology).

Sofia

07.06.2024 г.

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