

R E E N C I O N

by Assoc. Prof. Dr. Eng. Nikolay Todorov Dolchinkov, Department of "Protection in
Emergency Situations" of the National Military University "Vasil Levski" in Veliko
Tarnovo

of the dissertation work
of M.Eng. Petar Stoyanov Tsvyatkov

on the topic: "OPTIMIZATION OF THE LASER COLOR MARKING PROCESS OF
CARBON STEEL PRODUCTS"

for awarding the educational and scientific degree "doctor"
in the field of higher education: 5. "Technical Sciences",
professional field: 5.1. "Mechanical Engineering" and
Doctoral program "Precision Instrumentation"

The basis for this review is Orders No. 3-01-339/03.07.2026 and No. 3-01-
344/09.07.2026 of the Rector of the Technical University of Gabrovo

1. General description of the dissertation and the materials attached to it

The dissertation work proposed for review is 164 pages long and 20 pages of appendices, structured in an introduction, 5 separate chapters, conclusion, contributions, used literature sources and appendices to the dissertation work. The developed scientific work is of sufficient volume and is structured according to the requirements of the current regulatory framework in Bulgaria and at the Technical University of Gabrovo for the formation of a dissertation work. To illustrate the conducted research, 20 tables and 108 figures were used – 88 in the main part and 20 in the appendices, which fully sufficiently present the work of the doctoral student. The figures used are photographs of studied samples, graphs of the dependencies obtained in the research, views of the literature used, diagrams of the equipment used and the conduct of the experiments, and others, which show the broad nature of the research and good knowledge of the subject. 150 literary sources in Bulgarian, English and Internet resources were used, which indicates that the author is well acquainted with the subject of laser marking. The sources are from authors from many countries - Bulgaria, Latvia, Czech Republic, China, Germany and others, which confirms the in-depth knowledge of the subject and the use of the best achievements in the world. The literary sources in almost their entirety are from the last decade, which confirms the study and application of the latest and best results achieved in the field of laser marking.

2. Relevance of the problem

Since the 1960s, the development of laser technologies has begun. Over the past 65 years since the discovery of the laser, it has found increasing application in modern science, technology, medicine, special production, and others. In recent years, there has been a growing interest in the application of laser technologies for marking corrosion-resistant steels, due to the high precision and adaptability of the method. This prompted doctoral student Petar Tsvyatkov to choose the topic of his

dissertation. The relevance of the experiments conducted by the doctoral student is supported both by the results achieved and by modern scientific publications on the topic by authors from all over the world. Also attached are results of corrosion tests of laser-marked surfaces with Test Protocol No. 420/24.01.2024 conducted in the Laboratory for Analysis and Testing of Materials and Calibration of Measuring Instruments (LIMK) at the Institute of Metallurgy, Facilities and Technologies with the Center for Hydro- and Aerodynamics "Acad. A. Balevski" - BAS. The study of the process of laser color marking on carbon steel contributes to expanding the practical application of the technology in the industrial sector, the advertising sphere and scientific research activities, which is also confirmed by the proposed dissertation.

3. Knowing the state of the problem

Petar Tsvyatkov is well acquainted with the issues of laser marking on various materials. The issues are well presented in the introduction and chapter one of the dissertation; he is also well acquainted with the practical work on marking surfaces. He studied at the Technical University of Gabrovo in the doctoral program "Precision Instrumentation" and successfully completed his training. Under the Erasmus+ program, he visited a laser center in TAP Rezekne, Latvia, where he conducted part of his research in modern conditions. The doctoral student combined the practical application of laser marking from the study with conducting experiments and based on "Technoles" OOD Gabrovo and "Diomex" OOD Gabrovo with conducting experiments with samples from real production provided by them. He also conducted relevant research and analysis of the quality of laser marking in comparison with other marking methods. This element of his dissertation emphasizes his broad knowledge in the field of marking on various surfaces of carbon steel types. In chapter two, he examined in detail the factors that influence the quality of laser marking. He presented in detail the factors related to the laser source, those related to the technological process and those that are complex in nature and are fundamental to the process. The factors related to the properties of the marked material were also examined. Based on the analysis of the factors that influence the laser marking process, the corresponding 8 conclusions were made, which systematize and summarize the work done by the doctoral student in this area.

4. Approach and solution to the problem

The doctoral student is well acquainted with theoretical and practical laser marking in its various forms and principles of operation and has partially presented in the second chapter the main components for conducting high-quality laser marking and the method for optimal selection of the parameters of the laser installation for each specific experiment. The factors that influence high-quality laser marking and the physical processes occurring in different types of lasers and, accordingly, the marking that they perform are also presented. In the third chapter, the approach to solving the set goal of the dissertation work is presented in a concise and understandable form for the readers. The theoretical aspect of the conducted research is very well considered, and the description of the numerical methods and theoretical calculations used can be optimized. In a language understandable to the readers, the mathematical apparatus used is presented in a concise form, illustrated with specific optimal values for conducting the research in tabular form. Based on theoretical and experimental results, the choice of the parameters of the laser installation for conducting the marking is justified. The possible permissible errors in

marking are also described and considered in the presentation of the results. A corresponding analysis has also been made to minimize the errors that may be made when conducting the study. Accompanying studies have also been made on the quality of the resulting marking and its resistance to rusting, scratching and other external influences. As a result of the detailed analysis of the theoretical calculations and practical experiments, the choices of optimal values for conducting the final experiments have been justified and 7 conclusions and findings have been made in order to obtain very good results not only in the doctoral student's experiment, but also in future other studies.

5. Reliability of the results obtained

The doctoral student has developed a very good methodology for conducting the experimental part of his research, which is described in detail in chapter four. The equipment used to conduct the experiment and the chosen methodology of the experiments conducted are described in depth and professionally. The results obtained are presented and illustrated in chapter five to a sufficient extent and are reliable. All experiments were performed at least 2 times to obtain reliable and real results from the research. This is also confirmed by other similar studies with other laser devices and with other materials, which are part of the literary sources of the work. There are gaps in the formulation of the results obtained and the corresponding conclusions. They should be presented, systematized and be more specific. General formulations should be avoided in such works, they should be presented more precisely and specifically, which the doctoral student has corrected in the final version of the dissertation.

6. Abstract

The abstract is 32 pages long and meets the requirements for the formation of an abstract for a dissertation work of the national regulatory framework and the requirements of the Technical University of Gabrovo. It presents the essence of the dissertation work and the relevant main parts of the introduction, the 5 chapters, the conclusion, the conclusions and the contributions of the author. All the most important conclusions, contributions and results have found a place in the abstract. A translation has also been made into English, which will contribute to better visibility of the results of the research. The author's publications on the dissertation work are duplicated on p. 6 and p. 31, which could have been avoided. This does not reduce the quality of the research, but I find it a technical oversight.

7. Main Contributions

The author's contributions are applied in the dissertation work and the abstract and are formulated in 2 main directions - scientific-applied and applied. 4 contributions are indicated as scientific-applied, and 3 as applied. The contributions have been edited and optimized by the preliminary defense and thus they systematize the results obtained by the doctoral student and summarize the work on the entire dissertation. I accept the proposed contributions in the revised form, and I believe that in this form they emphasize the practical results obtained from the experimental part.

8. Personal contribution of the author

The set goal of the research has been successfully realized. The influence of the operating parameters and the characteristics of the beam on the obtained color marking of carbon steel has been studied. The research was carried out by the doctoral student under the guidance of his scientific supervisors, which confirms the capabilities of Petar Tsvyatkov and his knowledge in the field of laser marking. I am not aware of any research with this type of laser on this specific type of steel in this volume before those made by the doctoral student, which is a confirmation of his qualities and his personal contribution to the results obtained and their analysis. The obtained dependencies between various factors for conducting high-quality laser marking are the result of the doctoral student's in-depth work and with their help the optimal values of the laser installation for conducting laser marking on this specific type of carbon steel have been found.

9. Publications on the topic of the dissertation.

The 6 publications mentioned are in leading journals in Latvia, Bulgaria and other countries. Some of them are referenced in the Scopus database. The weakness of the doctoral student is that all publications are co-authored and there is only 1 independent publication. As a recommendation for his scientific activity in the future, I will also point out the need for independent publications. The publications mentioned are more than necessary for acquiring the ONS "doctor" and some of them may be left for future procedures of the doctoral student. From the results obtained from the research conducted, more publications can be made in reputable journals as a continuation of the in-depth work begun.

10. Using the results obtained in practice

Based on the results obtained and the author's contributions, it can be proposed to apply laser color marking of carbon steel in industrial enterprises in Bulgaria, Latvia and other countries that specialize in the production of products from this type of material. Experimental samples from "Technoles" Ltd. Gabrovo and "Diomeks" Ltd. Gabrovo were used and it is reasonable to implement these results in their production. Application can also be found in the specialized production of enterprises of the military-industrial complex.

11. Critical notes and recommendations on the dissertation

The dissertation meets the requirements of the regulatory framework of Bulgaria and the university, and I consider it to be a completed work. Technical shortcomings have been noted in the design of the dissertation, the formulation of the conclusions and contributions of the doctoral student, which are the result of the abundance of information and insufficient time for the technical design. As a recommendation to Petar Tsvyatkov, I can indicate that he continues his research in the field and publishes his dissertation as a book based on the defended dissertation and continue and deepen his experiments in the field of laser marking.

12. Critical notes and recommendations on the abstract

As a remark on the abstract, I only have one remark regarding the duplication of publications on the topic by the doctoral student, Mag. Petar Tsvyatkov. As a recommendation, he should distribute his abstract on scientometric sites to gain greater visibility for his research and consider publishing it with copyright.

13. Conclusion

I believe that the dissertation submitted for review meets the requirements of the RAS Act and I give it an overall positive assessment. The remarks made are aimed at improving the quality of the doctoral student Petar Tsvyatkov's dissertation, which will acquire an even better and higher-quality appearance and will prepare for the publication of a book based on the defended dissertation.

Doctor " be awarded to M.Eng. Petar Stoyanov Tsvyatkov in the field of higher education: 5. "Technical Sciences", professional field: 5.1. "Mechanical Engineering" and doctoral program "Precision Instrumentation".

08/26/2026

Reviewer:

/ Nikolay Dolchinkov/