S T A T E M E N T

by Assoc. Prof. Georgi Georgiev Komitov, PhD

on the dissertation thesis of Eng. Petar Stoyanov Tsvyatkov

entitled:

“Optimization of the Process of Laser Color Marking of Carbon Steel Products”

for the award of the educational and scientific degree “Doctor” (PhD)

in professional field 5.1 “Mechanical Engineering”

Scientific specialty “Precision Engineering”

1. General description of the dissertation and the submitted materials

The dissertation submitted to me consists of 184 pages, structured into five chapters, conclusions, scientific contributions, and a reference list. The list of cited literature includes a total of 150 titles. Attached to the dissertation are an abstract (extended summary) of 32 pages and 6 scientific publications.

The layout and presentation of the dissertation and the abstract comply fully with the requirements of the Development of Academic Staff in the Republic of Bulgaria Act (DASRBA), the Regulations for its implementation, and the Regulations for Academic Staff Development of the Technical University of Gabrovo.

2. Relevance of the problem

In modern mechanical engineering and tool manufacturing, there is an increasing demand for fast, precise, durable, and indelible identification of finished products. Traditional methods (inkjet/thermal transfer printing, chemical and electrochemical etching, thermal oxidation) are characterized by a number of drawbacks—use of toxic/aggressive chemicals, generation of hazardous waste, low resolution, slow throughput, and insufficient resistance of the marking under extreme operating conditions.

The transition toward environmentally friendly (“green”) and energy-efficient technologies is a modern industrial standard. Laser color marking (via controlled laser oxidation) is a fully non-contact, eco-friendly, and high-speed method that requires no consumables or chemicals, while enabling full automation and seamless integration into the Industry 4.0 framework.

While scientific literature is extensively focused on laser color marking of titanium and stainless steels, carbon steels remain significantly under-researched. There is a lack of systematized data, theoretical-mathematical models, and optimized technological regimes for obtaining stable, high-contrast, and reproducible colors on this class of materials.

The problem is directly linked to the practical needs of industrial enterprises in the region and country manufacturing cutting tools from C75 carbon steel. The development of quantitative relationships between laser parameters (power, scanning speed, pulse repetition frequency, line

spacing/hatch pitch, focal position) and functional performance metrics of the marking (contrast, surface roughness, microhardness, color difference ΔE, wear resistance, and corrosion resistance) addresses a direct manufacturing challenge.

The topic of the dissertation is highly relevant as it resolves a specific technological problem in mechanical engineering—replacing traditional chemical and polluting marking methods with an eco-friendly, non-contact, and high-speed laser technology. The research delivers clear scientific-applied value by optimizing laser parameters to achieve high reproducibility, contrast, corrosion resistance, and wear resistance of the marking.

3. Degree of knowledge of the state of the problem

The thorough analysis of the literature sources demonstrates that Eng. Petar Tsvyatkov possesses deep knowledge of the state of the problem in the field of laser color marking. The literature review shows that he is excellently acquainted with the theoretical foundations of the process, systematizing the primary color formation mechanisms (formation of thin oxide films and surface microstructuring).

The research gap in global literature has been correctly identified—while studies on titanium alloys and stainless steels are widely represented, research on laser marking of carbon steels (and specifically C75 steel) is scarce and unsystematized. The author skillfully highlights the drawbacks of conventional methods (chemical etching, inkjet printing) and properly argues the necessity of establishing precise technological windows (power, speed, frequency, line spacing, focus) to reproduce colors with high corrosion and wear resistance. The extensive scientific literature used is cited correctly and serves as a solid foundation for formulating the aim and tasks of the dissertation.

4. Approach and solution to the problem

The PhD student has adopted a methodologically sound and well-structured experimental-analytical approach to achieve the set goal. The research methodology combines theoretical modeling with a wide range of modern experimental studies on C75 carbon steel specimens.

To systematize the process, the candidate utilizes full factorial experiments and mathematical-statistical models to identify the influence and interactions among main laser parameters (laser power, scanning speed, pulse repetition frequency, hatch spacing, and focal offset). The solution to the problem is realized through the construction of technological matrices for controlled generation of a broad color spectrum. The properties of the resulting markings are thoroughly analyzed using advanced methods for color difference determination (ΔE according to CIELAB), spectrophotometry, surface roughness measurement, microhardness testing, as well as specialized tests for wear and corrosion resistance. The selected set of methods ensures high reliability of the obtained results and practical applicability of the developed regimes in actual industrial production.

5. Reliability of the obtained results

The reliability of the scientific and scientific-applied results in the dissertation is fully guaranteed and beyond doubt. It is based on a precisely planned experimental methodology involving the use of modern, calibrated equipment, standard testing procedures, and correct application of mathematical-statistical analyses. The main conclusions are drawn from a sufficient volume of experimental data and validated against objective quantitative criteria—spectrophotometric measurements in the CIELAB color space, profilometric roughness tests, standard microhardness testing, and wear and corrosion resistance assays. The high level of credibility is further confirmed by the fact that the main research findings have been presented and critically discussed at scientific conferences and published in peer-reviewed specialized journals.

All these results give me full confidence to accept that the findings of the dissertation thesis by Eng. Petar Tsvyatkov are authentic and reliable.

6. Abstract (Extended Summary)

The abstract consists of 32 pages, reflecting the main results of the research work. It includes a general overview and characterization of the dissertation thesis, outlining the aim and tasks, conducted investigations, scientific novelty, practical applicability, approbation of results, publications, and overall structure. The abstract contains summary sections of all five chapters, overall conclusions, contributions, list of publications, and an abstract in English. The chapter numbering and mathematical formulas correspond to those in the dissertation, whereas figure and table numbers differ.

The abstract represents a complete document that fully satisfies all formal and quality criteria.

7. Main contributions

I accept the contributions presented in the abstract. They represent original achievements of the author and the research team he collaborated with. They pertain to obtaining new scientific knowledge, enriching existing research, and demonstrating the practical applicability of the results obtained, which I assess as highly relevant and significant.

8. Personal contribution of the author

The personal contribution of Eng. Petar Tsvyatkov to the dissertation thesis is distinct and indisputable. The PhD candidate personally planned, organized, and conducted the complete volume of experimental and analytical research. The mathematical-statistical models and technological matrices defining optimal laser marking regimes on C75 steel are his own work. The author independently processed, interpreted, and systematized data obtained from physical-mechanical and corrosion testing. The formulated scientific-applied and practical contributions, as well as the publications derived from them, are a direct result of the candidate's diligent individual work and creative research approach.

9. Publications on the dissertation topic

Six scientific publications reflecting the main results of the thesis have been presented. All publications are in English, with one being single-authored. The remaining papers are co-authored, demonstrating the candidate's capability for effective teamwork.

This gives me full justification to accept that the candidate's participation in the co-authored papers is equal to that of the other members of the author team.

10. Practical application of the results

The results achieved in the dissertation possess clear and immediate practical applicability in manufacturing industries. The developed technological matrices and compiled graphical processing databases allow for rapid selection of optimal laser parameters (power, speed, frequency, hatch pitch, focus) to achieve desired color outcomes on C75 carbon steel components.

The results can be directly implemented in mechanical engineering companies producing cutting tools, circular saw blades, band saw blades, and structural parts, effectively replacing hazardous and non-durable conventional methods with an eco-friendly, high-speed, and fully automated technology. The optimized regimes guarantee high color reproducibility, contrast, corrosion resistance, and retention of operational performance, aligning with digital transformation goals under Industry 4.0.

11. Critical remarks and recommendations regarding the dissertation

I have no fundamental critical remarks regarding the essence of the presented dissertation that would diminish the value of the obtained results and formulated contributions. Nevertheless, to enhance the author's future research activities, the following two recommendations are offered:

- The study focuses primarily on C75 steel. For practical benefits in future research, the proposed methodology could be tested and validated on other widely used carbon and alloyed tool steel grades.
- The corrosion and wear resistance testing provides an excellent initial assessment; however, tracking oxide layer degradation during long-term operation under real production conditions (e.g., intensive friction and elevated working temperatures) would yield valuable supplementary insights for industry.

These recommendations do not reduce the high scientific and practical value of the completed research.

12. Critical remarks and recommendations regarding the abstract

The presented abstract complies fully with the requirements of the Development of Academic Staff in the Republic of Bulgaria Act (DASRBA) and its Implementing Regulations. It objectively, concisely, and accurately reflects the structure, content, methodology, and main

scientific and practical contributions of the dissertation. I have no critical remarks or objections regarding the abstract.

13. Conclusion

Taking into account the quality and comprehensiveness of the submitted materials, which constitute a complete and integrated scientific research study, and considering the relevance, significance, and demonstrated contributions of the work, I consider that the dissertation thesis submitted to me meets all requirements of the Development of Academic Staff in the Republic of Bulgaria Act (DASRBA), and I give it an overall positive evaluation.

I recommend that the doctoral candidate Eng. Petar Stoyanov Tsvyatkov be awarded the educational and scientific degree “Doctor” (PhD) in the scientific specialty “Precision Engineering”, professional field 5.1 “Mechanical Engineering”.

August 20, 2026

Statement prepared by:
/Assoc. Prof. G. Komitov, PhD/