OPINION

on dissertation work
for the acquisition of educational and scientific degree "doctor" in

Field of higher education - 5. Technical sciences
Professional direction - 5.6 Materials and Materials Science
Doctoral program „Materials Science and Technology of Mechanical Engineering Materials"

Author: MSc Eng. Simeon Tsankov Tsenkulovski
Topic: "Peculiarities of laser marking of layer-reinforced composites on a polymer basis"
Member of the scientific jury: Prof. Galya Velikova Duncheva, DSc, PhD

1. Topic and relevance of the dissertation

The development of technological lasers in recent decades based on continuous or pulsed radiation with a duration of milliseconds to several femtoseconds in a wide range of powers determines the great potential of laser techniques as effective thermal processes used for various industrial applications. The possibility of precisely localized heating of a wide range of industrial materials (metals, polymers, ceramics, composites, textiles) in air (or other gas or liquid medium) in a very short time, without the need for a cooling medium and other consumables, favors the development of laser marking as a cost-effective process with an ecological impact on the environment.
The dissertation is based on a conceptual model for the development of a laser marking system for layer-reinforced polymer-based composite materials, which eliminates the shortcomings of existing systems. The above proves the relevance and practical usefulness of the topic of the dissertation.

2. Research methodology

The dissertation uses a theoretical-analytical approach to assess the structural, physical and chemical effects of the interaction of laser radiation with polymer layered composites and the stages of the laser marking process. The main conclusions are made on the basis of the assumption of equivalence of the radiation power density with a uniform distribution and a Gaussian distribution. Given the specificity of the problem under study, the experimental research approach has no alternative. Experimental studies include pre-

planning and planning of the experiment, analysis of variance (ANOVA), regression analysis and multi-objective optimization based on the search for a Pareto front. To find the latter, a non-dominant sorting genetic algorithm II (NSGA II) was used. For statistical processing of the results, the specialized software QStatlab was used.

3. Contributions of the dissertation work

3.1. Scientific and applied contributions

The scientific and applied contributions of the dissertation work are in the following categories:

Creation of new classifications, methods, constructions, models, methodologies, algorithms:

● *Conceptual model for the development of a laser installation for marking layer-reinforced polymer-based composites;*

● *Mathematical models of the influence of laser beam power and marking velocity on the penetration depth and stroke width in laser marking of glass textolite and textolite;*

Obtaining and proving new facts:

● *The geometric parameters of the marking (depth, stroke width and cross-sectional profile) for two materials (glass textolite and textolite) have been established depending on the technological parameters of the laser marking process.*

3.2. Applied contributions

● *A functional laser installation for marking layer-reinforced polymer-based composites.*

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4. Publications and citations of publications on the dissertation work

A total of 10 scientific works have been published on the dissertation, distributed according to the place of publication, as follows:

- 4 reports at scientific conferences in Bulgaria;
- 1 report at a scientific conference abroad (Rēzekne, Latvia);
- 3 articles in Bulgarian journals;
- 2 utility models.

MSc. Eng. Simeon Tsenkulovski is the first author in five scientific works (three reports and two articles), and the second author in the remaining articles and reports. The information on the utility models on the dissertation is incomplete, since the authors are not indicated.

5. Authorship of the results obtained

Based on the statistics of authorship of the publications on the dissertation,

it can be concluded that the doctoral student has a leading role in conducting the research. The inventive activity of the doctoral student is remarkable. I believe that MSc. Eng. Tsimeon Tsenkulovski has significantly improved his qualifications in the field of the research problem.

6. Remarks and recommendations

I have the following remarks regarding the dissertation, which are primarily aimed at refining the scientific information:

1). In Fig. 1.2 the abbreviation "OKG" is used, which is not included in the list of abbreviations used;

2). Fig. 1.3 is a scanned image from the respective cited source and contains text in English. Regardless of the leading role of the English language in scientific literature, the dissertation presents scientific content in Bulgarian;

3). Page 27: In the context of heat transfer in the treated area, three physical characteristics are introduced: thermal conductivity coefficient k; specific heat capacity c and thermal conductivity coefficient *a*. Temperature is a quantitative characteristic of heat in an elementary volume in solids and fluids. Obviously, the concept of "thermal conductivity coefficient a" is incorrect. In this case, it is a linear thermal expansion coefficient;

4). Page 27 and page 69: "k" is used to denote two different quantities: the coefficient of conductive thermal conductivity (page 27) and the flux concentration coefficient characterizing the shape of the normal distribution curve (page 69, formula (3.1));

5). Analyzing the specifics of the interaction of laser radiation with opaque non-metallic materials, it is claimed that "the absorbed energy is almost instantly converted into thermal energy and creates a secondary (local) heat source on the surface". On the other hand, it is claimed that "high heating rates are realized – up to 10^{10} K/s, and cooling – up to 10^{8} K/s, respectively there is a naked temperature gradient". The latter effects are characteristic of the response of metals and alloys to the impact of a concentrated energy flow, in which conduction has a dominant role in heat transfer. As a result, a self-cooling effect (mass cooling) occurs. The resulting very high cooling rates provide a technological advantage for unconventional processes such as electron beam or laser hardening of steels compared to conventional ones. In the context of the latter, a publication is cited relating to laser marking of metals and alloys (source [33]). Obviously, the phenomena described above have a different physical basis and manifest themselves to different degrees when treating metallic and non-metallic materials with concentrated energy flows.

7. Conclusion

I believe that the presented dissertation meets the requirements of the Act on the Development of the Academic Staff in the Republic of Bulgaria. The achieved results give me grounds to **propose** that the educational and scientific degree "Doctor" be acquired

by MSc Eng. Simeon Tsankov Tsenkulovski in the
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6.08.2025 **Member of the scientific jury** **/п/**

/Prof. Galya V. Duncheva, DSc, PhD/