OPINION

on a dissertation work
for acquiring the scientific degree "Doctor of Science" in

Area of Higher Education – 5. Technical Sciences
Professional Field – 5.6. Materials and Material Science
Scientific specialty – „Material Science and Technology of Machine Building Materials"

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Theme: „Properties of additively manufactured dental materials"
Member of the Scientific Jury: Professor Galya Velikova Duncheva, DSc

1. Theme and actuality of the dissertation work

Nowadays, the investigations related to the new materials synthesis evolve in parallel with the technologies for their production. In this direction, the additive technologies for production in which the objects are obtained by adding of material sequentially layer by layer (layered manufacturing) are developed especially intensively. The basis of these technologies is the idea of reproducing a virtual 3D model by photopolymerizing, melting or sintering the source material. Therefore, the complex of properties of the finished object (mechanical, physical and geometric) depends on the source material and the specific technological process. The objective of this dissertation thesis is the properties of a wide range of dental materials (plastics, photopolymers, ceramics, composites, Co-Cr alloys, etc.), casting models and dental structures obtained by different layered manufacturing technologies at room temperature and high local temperature - stereolithography (laser or digital light projection), fused deposition modeling and selective laser melting. The ability to control and management the properties of personalized parts as a part of CAD-CAM systems in the conditions of waste-free production and the manual operations elimination prove the actuality of the research problem.

2. Methodology of research

The basis of the research problem is the relation "application of the studied materials and structures - necessary properties - technological process". From this point of view, the use of native experiments is no alternative. To systematization and generalization the experimental results, regression analysis and two-objective optimization were used. For evaluation the tensile strength and bending of various dental materials and structures, and the adhesion strength of porcelain and composite coatings, a combined approach is used. It is based on natural experiments, numerical simulations in SOLIDWORKS Simulation, microstructural analysis and fractographic analysis.

3. Contributions of the dissertation work

I classify the contributions to the dissertation as follows:

3.1. Scientific contributions

♦ ***Formulating a New Theory***

● *It is justified the decisive importance of the optical properties of dental plastics for the production of high precision structures obtained by stereolithography;*

♦ ***Demonstration with new means of significant new aspects of already existing scientific areas, problems, theories, hypotheses and other***

No contributions in this category

3.2. Scientific-applied contributions

♦ ***Creating new classifications, methods, constructions, technologies, etc.***

● *Method and apparatus for bending study of a four-member bridge dental structure;*
● *Non-destructive in-vitro method for assessing the fitting accuracy of dental structures;*
● *Modified criterion for assessing the destruction nature of a porcelain coating on dental alloys;*
● *Modified technologies for layered manufactiring of temporary and irremovable dental structures;*

♦ **Receiving and proving new facts**

● *It has been established that the increased roughness of dental alloys made by layered manufactiring technologies provides higher adhesion strength of porcelain coatings;*
● *It has been established that the roughness of dental plastics made by stereolithography depends on the formation of the surfaces at the beginning and the end of the process and the optical properties of the monomers used;*
● *The modules of elasticity of porcelain and composite have been obtained experimentally;*
● *The destruction mechanism of porcelain and composite coatings to Co-Cr dental alloys, obtained by casting with layered manufacturing models and selective laser melting, has been established and proven;*
● *The destruction mechanisms of dental bridge structures produced by casting and selective laser melting have been justified and proven;*
● *It has been established that bending loads causing the macro-crack formation in a Co-Cr dental bridge structures, cast by conventional technology or layered manufacturing models, are close to the load of destruction of laser-produced bridge structures made of C212-f alloy;*
● *It has been proven that a C212-f alloy produced by selective laser melting has greater corrosion resistance and wear resistance than a Biosil-F alloy made by casting;*

♦ **Receiving confirmation facts**

● *It has been proven that processes stereolithography and multi-jet modeling provide higher accuracy and lower roughness compared to the fused deposition modeling process;*
● *It has been experimentally confirmed that the fitting accuracy of irremovable dental structures made of dental plastics and alloys obtained by layered manufacturing technologies is higher than that obtained by conventional technology;*
● *It has been experimentally proven that the roughness of layered manufactured dental plastics and dental alloys, molded with 3D printed models or made by selective laser melting, is 2-4 times higher than that of conventionally made materials;*
● *It has been confirmed that the microstructure of Co-Cr bridge structures cast with layered manufactured models is inhomogeneous with dendritic morphology, including γ-phase in dendrites, small amounts of ε-phase and microevhetics in the interdental spaces;*

● *It has been confirmed that a C0212-f alloy produced by selective laser melting is characterized by clear boundaries between the layers, and the microstructure is fine and homogeneous with dendritic structure, including γ-phase in dendrites, increased amount of ε-phase and mixed type carbites* $M_{23}C_6$*;*

● *It has been confirmed that the laser-produced alloy C212-f has a higher hardness and yield strength than a cast alloy;*

3.3. Applied contributions

● *Modes for 3D casting models printing providing greater adhesion strength of porcelain coating to cast alloy;*

● *Algorithms and correction coefficients for designing virtual models guaranteeing high precision of temporary and permanent prosthesis constructions obtained by layered manufacturing technologies.*

4. Publications and citations of dissertation publications

The author has published a total of 24 scientific papers on the dissertation, as follows: 1 chapter from a book published abroad; 17 scientific articles in Bulgaria and abroad; 6 scientific papers presented at conferences in Bulgaria. A total of 7 scientific articles have been published abroad. Of the articles published in Bulgaria, 6 scientific papers have been published in the Journal of International Medical Association Bulgaria and Scripta Scientifica Medicinae Dentalis), and the other 4 - in scientific journals published by the International Scientific Journal "Materials Science". Non-Equilibrium Phase Transformation" and International Journal "Machines, Technologies, Materials". Scientific papers published abroad are: 2 articles were submitted to Impact Factor magazines, respectively Engineering Fracture Mechanics (IF = 2.580) and Engineering Failure Analysis (IF = 2.157); 2 in Archives of Materials Science and Engineering, indexed by Scopus (RG Journal Impact = 0.48); 1 article in the Journal of Achievements in Mechanical and Materials Engineering, indexed by Scopus; 1 article in Deformation and Destruction Material (in Russian); 1 article in Processia Structural Integrity (Elsevier Edition). These data prove that the academic works of Assoc. Prof. Tsanka Dikova have gained popularity abroad.

The list of citations includes 22 citations, 12 of which are in scientific journals, referenced and indexed in world-wide databases.

5. Authorship of the results obtained

Assoc. Prof. Tsanka Dikova is a self-contained author of 5 scientific papers, one of which is a chapter of a book published abroad. She is the first author in 12 publications from the other 19 publications. Based on these data and my personal impressions, I believe that Assoc. Prof. Tzanka Dikova has a main contribution to the dissertation work.

6. Remarks on the dissertation work

The dissertation work contains an impressive amount of scientific research which are clearly presented and structured very well. I especially appreciate the microstructural and fractographic analysis to clarify the experimental results obtained for the behaviour of the dental materials and structures studied. Some of my remarks and recommendations are related to certain inaccuracies and strategies used in the FE models developing:

1). Some expressions and concepts related to the solid state mechanics are written incorrectly and unclearly. The sentence "In most cases, the stress limit is yield stress of the

material" (p. 182) is incorrect, as this assumption refers to materials with tough-plastic, not with brittle behaviour;

2). Taking into account the brittle behaviour of the porcelain, the use of von Mises' equivalent stresses as a criterion of strength is inappropriate;

3). p. 66 - The expressions "linear static analysis" and "linear isotropic hardening" in one sentence are incompatible. The accepted material model is based on the $\sigma - \varepsilon$ curves (Fig. 2-12) and the yield stress (Table 2-6) obtained from one-dimensional tensile tests. Consequently, the expression "linear static analysis" is meaningless;

4). p. 67 - In the simulations related with the adhesion strength study of a porcelain coating on dental alloys, a material model of non-linear elastic behaviour of dental alloys was adopted. This model of the material, in itself, excludes the yield stress from a Table 2-6;

5). Taking into account the symmetry of the experimental specimens (with and without coatings) in the simulations concerning tensile strength and adhesion strength, it is advisable to model half the length and simulate the load by kinematic action. This will exclude the singular points in the FE model (following the Saint-Venant principle) and the computation time will be reduced.

7. Conclusion

I think that the presented DSc dissertation corresponds to the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria. Achieved results give me the reason **to propose** to the Scientific Jury the scientific degree "Doctor of Science" to be given to **Assoc. Prof. Tsanka Dimitrova Dikova** in:

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06.06.2019 Prof. DSc Galya V. Duncheva