REVIEW

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"

Author: Assoc. Prof. Tzanka Dimitrova Dikova, PhD
Theme: „Properties of additively manufactured dental materials"

Reviewer: Professor Jordan Maximov, DSc

1. Actuality of the dissertation work

One of the fastest developing fields in the engineering science is the synthesis and study of the mechanics of new materials. The numerous specialized scientific journals for material sciences, the policy of managing these journals by their editors, and of course the content and quality of published articles are proof of this. The layered manufactured dental materials, subject to this dissertation, are in the category of these new materials. In the aspect of the above, I believe that the actuality of the dissertation thesis is beyond doubt.

2. An overview of the cited literature

The list of used literature contains 359 titles, 47 of which are e-mail addresses. The remaining 312 references are distributed as follows: 1) in Bulgaria – 4 reports in proceedings of conferences, 2 PhD dissertations, 6 textbooks, 2 teaching aids, 7 books, 2 articles; 2) abroad – 6 dissertations (5 PhD and 1 MSc), 2 patents (1 USA and 1 PCT patent application), 14 reports in proceedings of conferences, 29 books and monographs and 238 articles in journals of too broad a spectrum – from "unknown" university journals to authoritative journals of ELSEVIER (such as Wear, Journal of Materials Processing Technology, International Journal of Machine Tools and Manufacture, Surface and Coatings Technology, Materials Science and Engineering) and of SPRINGER (as, for instance, International Journal of Advanced Manufacturing Technology). In other words, the achievements of the whole scientific community on the problem are known to the author of the dissertation thesis. On this basis, the author defines the main purpose and tasks of achieving the goal, thus expanding what has been achieved so far.

3. Method of study

Considering the scale and complexity of the problem being addressed, the author has correctly selected a combination of experiments and numerical simulations.

4. A brief description of the material on which the contributions are formulated

Chapter 1 is dedicated to a review of layered manufacturing technologies, their application in dentistry, as well as to dental materials and constructions obtained by layered manufacturing technologies. The relevant conclusions have been made and on this basis the aim of the dissertation has been defined and the tasks to achieve the goal.

Chapter 2 presents study methods and detailed algorithms for implementing these methods. As I noted above, it is about: 1) natural experiments - geometry and micro-geometry of objects (accuracy and roughness); density study, microstructure and chemical composition; mechanical properties and mechanical characteristics (tensile and bending strength); adhesion and tribological properties; 2) numerical simulations by means of finite element method (MKE) – stress analysis using CAE part of Solid Works CAD system.

Third, fourth and fifth chapters contain the relevant experimental results and KE analysis outcomes.

Chapter 6 is devoted to the application of the layered manufacturing technologies in the dental medicine – manufacturing temporary constructions and non-removable dentures.

5. Contributions of the dissertation work

Regardless of the author's view, I have summarized and classified the contributions to the dissertation as follows:

A. Scientific contributions

A1. Formulating a New Theory

● The importance of the optical properties of dental plastics for creation of structures with high accuracy as well as the importance of the increased roughness of the dental alloys for the adhesion strength of non-replaceable metal ceramic prostheses are justified.

A.2. Demonstration with new means of significant new aspects of already existing scientific areas, problems, theories, hypotheses and other

● No contributions in this category

B. Scientific-applied contributions

B.1. Creating new classifications, methods, constructions, technologies, etc.

♦ Method and apparatus for testing the bending of dental alloys.

♦ Non-destructive in-vitro method for assessing the accuracy of fitting dental structures.

♦ Criterion for assessing the nature of the destruction of porcelain coating on dental alloys.

♦ Technologies for production of temporary and permanent prosthetic structures have been created.
♦ Method for testing the adhesion strength of ceramic and composite coatings has been created.
B.2. Receiving and proving new facts
♦ The optical properties of the monomers used influence the roughness of the dental plastic as well as the formation of the surfaces at the beginning or the end of the process.
♦ Young's modules of porcelain and composite have been found.
♦ The mechanism of disruption of porcelain and composite coatings on Co-Cr dental alloys has been established.
♦ The mechanism of destruction of Co-Cr dental alloys produced by casting and by selective laser melting has been established.
♦ It has been established that the bending force causing macro-crack of Co-Cr dental bridges, obtained by conventional or layered manufacturing tecnologies, is close to the bending causing destruction of laser manufactured dental bridges made of Co212-f alloy.
♦ It has been established that the laser-made alloy exhibits greater corrosion resistance and wear resistance in comparison with Biosil-F alloy obtained by casting.
♦ It has been established that the hardness of laser-made Co212-f alloy and Biosil-F alloy, obtained by casting, is changed differently after baking a two-sided porcelain coating on them.
♦ It has been proved that stereolithography and multi-sided printing provide a higher quality dental plastic compared to the material layering process
♦ It has been proved that the roughness of layered manufactured materials, obtained by means of 3D print or selective laser melting, is two to four times higher than that of conventionally produced materials.
B.3. Receiving confirmation facts
♦ Here I include contributions with numbers 2.11, 2.13, 2.14, 2.15 as they are formulated by the author

C. Applied contributions
■ Modes for 3D printing of foundry models.
■ Correction coefficients and algorithms for designing virtual models guaranteeing high accuracy of denture constructions, obtained through layered manufacturing.

6. Publications and citations of these publications
The quality of the published research results in the form of scientific articles is generally in direct correlation with the place and the form of publication. The publications in international scientific journals with a high impact factor issued by, for example, Elsevier, Springer, ASME, Wiley, SAGE have a high quality and significance certificate due to the guaranteed high level of the review process by two, three, four, and

sometimes more scientists from around the world, recognized in their field. That is why I have paid more attention to this section of the review for two reasons: 1) maximum objective assessment (as far as possible by the subject) of the form and location of published dissertation results; 2) help the author to really appreciate his current position.
The author has published a total of 24 scientific papers on the dissertation, distributed as follows:
1). Scientific papers presented at scientific conferences in Bulgaria - 6 papers (all conferences are organized by Scientific and Technical Union in Mechanical Engineering);
2) Scientific articles in scientific journals issued in Bulgaria – 10 articles:

- Journal of IMAB (International Medical Association Bulgaria), Publisher Peychinski, Pleven, Bulgaria – 3 articles;
- Scripta Scientifica Medicinae Dentalis, issue of the Medical University of Varna – 3 articles;
- International Scientific Journal "Materials Science. Non-Equilibrium Phase Transformation", issue of Scientific and Technical Union in Mechanical Engineering, Sofia – 2 articles;
- International Journal „Machines, Technologies, Materials", issue of Scientific and Technical Union in Mechanical Engineering, Sofia – 2 articles.

3) Scientific papers in international scientific journals published abroad – 7 articles:

- Deformation and Destruction of Materials, Russian journal, published in russian – 1 article;
- Procedia Structural Integrity, issue of Elsevier (a journal that prints materials presented at scientific conferences; there is no information on the presence of an impact factor) – 1 article;
- Archives of Materials Science and Engineering, issue of Association for Computational Materials Science and Surface Engineering in collaboration with the Material Science Committee of the Polish Academy of Sciences, indexed by Scopus, RG Journal Impact = 0.48, there is no impact factor – 2 articles;
- Journal of Achievements in Mechanical and Materials Engineering, issue of Association for Computational Materials Science and Surface Engineering in collaboration with the Material Science Committee of the Polish Academy of Sciences, indexed by Scopus, RG Journal Impact = 0.48, there is no impact factor – 1 article;
- Engineering Fracture Mechanics, issue of Elsevier, IF=2.580 – the author has sent 1 article;
- Engineering Failure Analysis, issue of Elsevier, IF=2.157 – the author has sent 1 article.

4) Chapter from a book published abroad by InTech, which publication I appreciate very high.
Five of the 24 publications are self-contained. In the remaining 19, Assoc. Prof. Dikova is the first author in 12, the second author in 6, the sixth author in 1 publication. 17 of the 24 publications are in English.

The reference in the google scholar citation shows the presence of citations of dissertation publications. For example, the article under number 2.1 in the list of publications by Prof. Dikova (excluding the 14 self-citations) is quoted 7 times, as 5 of the citations being made by authors from abroad.
On the basis of the above data it can be concluded that the results of the dissertation of Assoc. Prof. Tsanka Dikova have gained a reputation abroad, which should be expected from a major (DSc) dissertation.

7. Authorship of the results obtained
Given the statistics made in Section 5 and my personal impressions by the author, I have no doubt that Associate Professor Dikova has a decisive role in the contributions to the dissertation work.

8. Abstract of the dissertation
The abstract reflects the essence of the dissertation and is done according to the requirements established over the years.

9. Remarks on the dissertation work
The dissertation is structured and written very well. I highly appreciate the micro- and meso-level studies: SEM analysis, fractography and others. I have no remarks of principle. Some smaller notes, related mainly to Mechanics of Deformable Solid, are listed below:
▪ Some concepts of Mechanics of Deformable Solid are incorrect. For example, the "bending" term, as a type of resistance, is defined for a beam element in whose cross-sections the internal forces are equivalent to a bending moment. In the dissertation, this term refers to a denture that is obviously not a beam. Also, the phrase "equivalent stress of bending" relative to the dental prosthesis which, given the above, is also not correct. The equivalent stress is introduced at complex stressed state, while in pure bending the stressed state (with the exception of the points from the zero line) is one-dimensional
▪ The equivalent stresses are calculated according to von Mises for porcelain (porcelain coating). It is speaking of the equivalent stress according to the energetic (fourth) theory of strength. As it is well know, this theory of strength shows good results for tough-plastic materials (for instance steels), but it is not applicable to materials with fragile behavior. Whether the porcelain has a tough-plastic behavior under the specific application? Obviously not.
▪ The coatings in the FE model of Fig. 2.11b are represented by one row of tetrahedral FEs. If these elements are 4-node, the deformation matrix is numeric, i.e. the deformations and stresses are one and the same in the entire volume of the finite element (the presence of a stress gradient is a consequence of the average results in the integration points of the contacting elements in a given node). Therefore, the results obtained in the coatings are unrepresentative.

▪ Page 66: s The expression (formulation) "linear static analysis with linear isotropic hardening" is meaningless unless the stress-strain curve is bi-linear. The latter, however, contradicts the experimental curve in Fig. 2.12.
▪ Page 67: Concerning the formulation "non-linear elastic behavior of dental alloys". This means that in the FE study a constitutive model of hypelastic material has been used. In fact, $\sigma - \varepsilon$ data from Fig. 2.12 are used. If the expression is correct, it means that the loading and unloading curves (in Fig. 2.12 only the load curves are shown) coincide, that is, deformations are reversible. But in the Table 2-6 for these materials, respective yield limits are given, that is, there are irreversible deformations. Therefore, the above formulation is wrong.
▪ I think the software used (CAE part from Solid Works) is not at the level of the research problem. For instance, CAE system ABAQUS would give much more opportunities, for example in the material constitutive models used.
▪ Contributions should be refined and summarized - not quantity, but quality is relevant in this case. For instance (see contribution 2.5), the use of methodology alone can not be a contribution. Contribution is the creation of the methodology and, eventually, the result of its use.
▪ I recommend Assoc. Dikova to publish in the future the results of her research in prestigious journals with impact factor in Materials Science, published by Elsevier and Springer.

10. Personal impressions

I think that Assoc. Prof. Tsanka Dikova is a scientist with established positions in the international scientific circles of Materials Science. She has visited many research centers and has established relevant personal contacts. The reference in google scholar citation shows that it has h-index = 6 and a total of 128 quotes.

11. 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. The results obtained give me the reason to propose to the academic jury the scientific degree "Doctor of Science" to be given to Assoc. Prof. Tsanka Dimitrova Dikova, PhD in the 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

03.06.2019 Reviewer /signature/

Gabrovo Professor Jordan Maximov, DSc