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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Stanislav Chernyshikhin

PhD Program: Mathematics and Mechanics

Title of Thesis: Tailoring the functional properties of NiTi shape memory alloy by high-resolution laser powder bed fusion

Supervisor: Associate Professor Igor Shishkovsky

Name of the Reviewer: Ivan Sergeichev

Associate Professor, director

Center for Materials Technologies

Skolkovo Institute of Science and Technology

I confirm the absence of any conflict of interest. **Ivan Sergeichev**	**Date: 18-09-2023**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

Review on the doctoral thesis by Stanislav Chernyshikhin entitled

"TAILORING THE FUNCTIONAL PROPERTIES OF NITI SHAPE MEMORY ALLOY BY HIGH-RESOLUTION LASER POWDER BED FUSION"

The work of candidate Chernyshikhin Stanislav is aimed at expanding knowledge about the functional properties of Nickel-Titanium alloy (NiTi) obtained by laser powder bed fusion (LPBF). The thesis is well-written and well-structured. Chapter 1 refers to introduction of the material, technology, and state of the art. Chapter 2 describes conducted experiments in detail. Chapter 3 contains valuable data required for the simulation of the melt pool during LPBF. In chapter 4 simulation of the evaporation was performed. As one of the main practical results it is necessary to note the adoption of LPBF technology to manufacturing of Self-Adjusting Files (Chapter 5). The principal aspects of the research are highlighted in detail and the conclusions well reflects the main results.

In the experimental part of the thesis, thin-walled samples were obtained from pre-alloyed NiTi powder by scanning the powder bed with a single laser passage per layer. The author investigated main factors influencing the process of melting, such as laser power and scanning speed. The resulting specimens were tested by a single cyclic loading to evaluate irreversible strains. The deformation processes on the surface of flat samples were studied using digital image correlation (DIC) system. DIC allowed accurate measurements of deformation and visualization of Lagrange displacement fields for superelastic flat samples. After uniaxial static tests of flat samples by tension to failure, fractograms with cup and cone morphology were received. Such mechanism refers to ductile fracture of the austenite NiTi phase and correspond to the known results of other authors. This indicates the validity of the methods used by the candidate and the reliability of the results obtained. The applied traditional and modern techniques made it possible to obtain a fairly complete picture of the relationship between mechanical properties and structural-phase state of the samples.

The author discovered a consistent effect of increasing laser energy density on the thickness of the formed wall and the magnitude of irreversible deformation after cyclic tensile loading. The discovered dependencies are significant for future studies of the micromechanics for thin-walled and volumetric cellular structures operating under alternating loads, such as endovascular stents, endodontic files, endoprostheses for bone and soft tissues. The results obtained in the work and the approaches developed are of great practical importance for the manufacturing by additive methods of such widely demanded products as endovascular superelastic stents in vascular surgery, endodontic files in dentistry and endoprostheses in reconstructive surgery.

The fluid dynamics in the melt pool were investigated using experimental data and a high-fidelity physical model, taking into account aspects such as the Marangoni effect, recoil pressure, two-component evaporation, powder deposition and energy absorption by laser beam tracing. The work of Stanislav Chernyshikhin is an important contribution to solving the problems of laser powder bed fusion technology utilization for NiTi alloy and its practical application in medicine.

The candidate published two papers in Materials journal that are referred to the contents of the thesis, additionally received a patent for invention, and one publication is currently under revision process. The publication list meets all requirements of PhD Program.

To improve the thesis, I would recommend adding an explanation of process parameters optimization for endodontic files in Chapter 5. It is obvious that this procedure was made on the basis of all previous chapters (2-4) devoted to experiments and calculations, but there is no generalization of this new knowledge. According to the results of mechanical tests, more significant stress/strain characteristics can be determined. In particular, the values of superelastic recovery strains and recovery ratios. This would deepen the analysis of mechanical behavior. Figure 41 depicts calculated temperature dependences of partial Gibbs free energy, activity coefficient, and activity for whole range of NiTi compositions. These diagrams can be presented as appendix as far as it is preliminary result before the actual calculation of evaporation dynamics.

Evaluating the work of Stanislav Chernyshikhin, I recommend the thesis for the formal thesis defense procedure.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*