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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: Associate Professor Alex A. Volinsky, Ph.D.

Associate Professor

Department of Mechanical Engineering

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I confirm the absence of any conflict of interest. Alex Volinsky	**Date: 19-09-2023**

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

Over the past decade, additive manufacturing (AM) came out on top when selecting a manufacturing technique capable of producing metallic parts with complex geometry. Thanks to its versatility and high precision, laser powder bed fusion (LPBF) is one of the most promising AM technologies and can be used to process not only conventional but also functional materials, such as shape memory alloys (SMA). Combining the AM and SMA potentials allows 3D printing to be transformed into its more advanced option, namely 4D printing. Therefore, the Doctoral Thesis of Stanislav Chernyshikhin "Tailoring the functional properties of NiTi shape memory alloy by high-resolution laser powder bed fusion" is undoubtedly relevant.

The dissertation follows a traditional structure, text of the thesis is written logically and is coherent. The first chapter consists of a literature review, where previous work related to the research topic is discussed. This chapter provides the necessary background information and sets the context for the subsequent chapters, while also formulating the purpose and objectives of the study. The second chapter includes the experimental part of the study, where the researcher describes the research methodology, samples' manufacturing, mechanical tests, differential scanning calorimetry, and X-ray diffraction used in the study. This chapter outlines the results obtained by these techniques. The third chapter is dedicated to experimental measurements of the thermophysical properties of NiTi required for fluid dynamics simulation. The author provided experimental data on the surface tension of NiTi melt and the temperature dependence of thermal diffusivity for solid NiTi. In the fourth chapter simulation of the melt pool during laser melting is presented. The novelty of the numerical study lies in the utilization of the bicomponent evaporation model for NiTi alloy to evaluate the final chemical composition after laser processing. The fifth chapter refers to the feasibility of manufacturing endodontic Self-Adjusted Files from NiTi SMA via high-resolution LPBF technology. The final part of the thesis is the conclusion chapter, where the main findings and conclusions of the study are summarized based on the research objectives. This chapter also discusses the significance of the findings in the broader context and provides recommendations for further research.

The work is devoted to the development of high-resolution laser powder bed fusion of NiTi SMA for high-precision manufacturing of parts with thin structural elements (walls/struts). It compares favorably with a comprehensive approach to the study, including the experimental study of single track-based manufacturing via LPBF; study of NiTi thermophysical properties; simulation of the NiTi melt pool during LPBF; the particular application of the technology for manufacturing of endodontic files. The results of the studies of the first three sections certainly have a scientific novelty. The final part of the work emphasizes its practical significance. This approach, as well as the established relationships of the influence of LPBF regimes on the geometry and functional properties, are the main advantages of this work. However, there are a few improvements that can be made in the work that are listed below.

1) The change in the critical temperatures of the martensitic transformation should be illustrated as a function of the linear energy density.
2) The assessment of the change in the amount of B19' martensite from the integral intensity of the X-ray lines should be carried out together with the assessment of the change in B2 austenite.
3) Section 2.8 is dedicated to the demonstration of the high-resolution LPBF 4D printing concept. A sample was printed with various transformation temperatures which was proved experimentally. However, Figures 28-29 can be corrected to better depict the correlation of each part of the sample with its regime.

4) Is it possible to carry out the mesoscale simulation discussed in Chapter 4 to achieve the geometry of Self-Adjusting Files that are referred to in Chapter 5? Results can have practical applications as far as it was shown that files have requirements of geometry and mechanical properties. Such an approach also may have additional outcomes from the simulation of the melt pool during LPBF.

The list of publications consists of 3 research articles and a patent. The first publication includes a single-track analysis with the simulation of the melt pool and the second is dedicated to the resolution study of the laser powder bed fusion. It should be noted that both publications already received citations from the scientific community (17 and 6 citations, respectively) which indicates the high quality of the published research. The third manuscript is currently under review. Stanislav participated in 7 international conferences with oral reports of his own results. The number of publications and conferences satisfies all Ph.D. requirements.

To conclude, given the significance of the thesis topic, the amount of experimental and numerical data provided by the author, and the potential utilization of the knowledge in real manufacturing methods, it is recommended to consider the research presented in the thesis for the formal thesis defense.

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*