

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Eldar Shakirov

PhD Program: Engineering Systems

Title of Thesis: Integrated analysis of engineering and manufacturing change management in the additive manufacturing context: a simulation-based modeling framework

Supervisor: Professor Igor Uzhinsky, Skoltech

Co-supervisors: Professor Clement Fortin, Skoltech; Professor A. John Hart, MIT

Name of the Reviewer: Prof. Dr.- Ing. M. Zäh

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	<p style="text-align: right;"><i>01.06.2021</i></p> <p>Date: DD-MM-YYYY</p>
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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

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Provisional Recommendation

<input checked="" type="checkbox"/> <i>I recommend that the candidate should defend the thesis by means of a formal thesis defense</i>
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<input type="checkbox"/> <i>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</i>

<input type="checkbox"/> <i>The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense</i>
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Technical University of Munich | Boltzmannstr. 15 | 85748 Garching
Institute for Machine Tools and Industrial Management (iwb)

Skolkovo Institute of Science and Technology
Professor Ighor Uzhinsky

Garching, June 1st, 2021

Review of the doctoral thesis of Eldar Shakirov with the title “Integrated analysis of engineering and manufacturing change management in the additive manufacturing context: a simulation-based modeling framework”

Dear jury members,

It is a pleasure for me to be part of the jury committee. Please find my assessment of the required criteria below.

Yours sincerely,



Michael Friedrich Zäh

1. Evaluation of the thesis quality and overall structure of the dissertation

Thesis quality

The dissertation is of high quality and deals with an important topic in the field of additive manufacturing (AM). For this purpose, a scientific and consistent approach was applied. The results were clearly elaborated and properly documented.

Structure

In the introduction, the main aspects of the research motivation are addressed in a condensed form and the global objective is derived. The approach to identifying research gaps with associated research objectives and research sub-questions is highly structured. At this point, a clearer separation of the fundamentals from the state of the art would further clarify the need for research. Based on the problem statement, the three main chapters follow, which represent the core of the dissertation. The state of the art on the chapter-specific topics is given, which should, however, have been moved to the beginning. The dissertation concludes with a discussion of the results obtained and a subsequent outlook that addresses new areas of research.

Conclusion: The structure of the dissertation is mostly clear and comprehensible, resulting in a logical chain of reasoning.

Further aspects

Figures and tables: Most figures and tables enhance understanding of the work and are appropriately integrated into the text flow. However, not all figures are of high quality. They display an inconsistent color scheme as well as variations in text size and font style.

Scientific language style: The scientific language style is at a high level throughout the document. However, long and convoluted sentences impede the reading flow at some points.

Citation: Citations are used correctly. However, linking multiple sources for one paragraph should be avoided because otherwise the assignability of the sources to the contents is not clear.

Terminology: Definitions and terms specific to the subject area are provided in footnotes or in the full text. However, additional information that goes beyond the core of the dissertation is also given in the footnotes.

Conclusion: The documentation of the dissertation shows minor weaknesses and potential for improvement.

2. Relevance of the topic of dissertation work to its actual content

The methodical approach pursued in the dissertation ensures that the core contents are sufficiently addressed.

Initially, a concept for integrated change management (ICM) in the AM context is proposed. Second, the impact of AM is consolidated using an interview-based case study. At this point, it should be noted that the study was conducted with only one manufacturer in the energy sector. It appears that the results have a limited generality and thus transferability to different industries. Third, a simulation-based analytical framework is elaborated capable of an integrated quantitative assessment of engineering and manufacturing planning decisions in the AM context. The results have been validated by conducting a case study in the aerospace industry.

Overall, it is unclear to what extent the results can be applied to other AM processes as new metal-based technologies gain importance.

Conclusion: The content of the dissertation work corresponds well to the intended topic, although few important issues are not addressed, such as the transferability to other AM processes and industries.

3. Relevance of the methods used in the dissertation

In Chapter 3 (Developing an understanding of integrated change management in the Additive Manufacturing context), an approach for AM-specific integrated change management is elaborated using various methods. In Chapter 4 (Model-based analytical framework: evaluating the cost and times of the integrated change management), various methods from product development (PD) are combined to set up a model-based analytical framework. For this purpose, the state of the art

regarding PD and more specific engineering change management (ECM) and manufacturing change management (MCM) was reviewed in detail. This ensures that the currently most suitable methods are used for the problem addressed.

Conclusion: The methods used in the dissertation are well selected with regard to the purpose and are based on an in-depth study of the current state of technology.

4. Scientific significance of the results obtained and their compliance with the international level and current state of the art

The selection of suitable methods was based on an in-depth analysis of the state of the art. Therefore, the results obtained show a high scientific significance and a scientific added value compared to the state of the art.

Conclusion: The dissertation addresses an important and so far little considered challenge in the context of AM, which is of great importance for the integration of AM processes in the production of series components.

5. Relevance of the obtained results to applications (if applicable)

The dissertation is expected to empower, in particular, the following:

- End users integrating additive manufacturing technologies, especially the L-PBF process, into existing production networks or production planning
- Practitioners dealing with management of changes

Conclusion: The dissertation represents a useful tool for estimating the cost-benefit ratio of introducing additive manufacturing processes. This is of high importance, since the application of these technologies is associated with costs and must show an economic advantage.

6. Quality of publications

The research results obtained were published in an internationally recognized journal and in conference proceedings. The author's publication list could, however, have been supplemented by a scientific paper in a journal with a higher impact factor.