INSTITUTE OF MACHINE AND INDUSTRIAL DESIGN

FME

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

1. PhD candidate
Ing. Ondřej Vaverka/ Ondrej.Vaverka@vut.cz
2. Name of PhD programme
Design and Process Engineering
3. Title of PhD thesis
Additive manufacturing of topologically optimised parts

4. Principal supervisor
doc. Ing. Daniel Koutný, Ph.D./ Daniel.Koutny@vut.cz
5. Co-supervisor

6. Reviewer
Dr.-Ing. Dirk Herzog / dirk.herzog@tuhh.de
Hamburg University of Technology

7. Overview of the scope of PhD thesis[1]
Very good
The scope of the thesis comprises the design and manufacture of topologically optimized (TO) parts from hardenable Aluminium-Silicon alloys (AlSi10Mg, AlSi7Mg0.6), using PBF-LB/M. It comprises enhancements to the TO, the manufacture including heat-treatment and the determination of the properties of lattices manufactured from the Al-Si material. The candidate focuses his work on the TO with respect to the TO process/procedure, and finds that a 3-step TO-process and a reversal of loads and constraints improves the material distribution. The design restrictions stemming from the PBF-LB/M process to minimize support structures should be considered last. The work on the heat treatment is focused to find the best compromise between strength and ductility, which is found for the T6 treatment. As for the properties, lattices are found to be influenced by varying cross-sections of the struts and anisotropy between xy and z direction. The candidate has described the scope within his thesis (mainly in chapter 4 – 'Aim of the thesis') in a clear, precise and thus very good manner. The title of the thesis however is much broader and could be better aligned with the scope.

8. Significance of the topic and clarity of problem statement
Very good

[1] Overview of the scope of PhD thesis is a short description of objectives of PhD thesis's research and summary of main findings and scientific achievements.

The topic itself is significant for the scientific community as well as for industry. The selected alloys are among the most often used materials in PBF-LB/M technology. Despite these are already investigated by numerous research groups and a high number of publications, there are still relevant research questions as the interplay between design, production and properties is complex. The thesis delivers new insights here, which – to the best of my knowledge – have not been available before. The main problem statement, namely that especially for structured materials (lattices, strut-based cellular geometries) a lack of knowledge on the static properties depending on initial design, processing and heat treatment for the given alloys is present, is stated by the candidate in the motivation chapter of the thesis in a sound manner. For each of the three areas – Topology Optimisation, Heat Treatment and Properties – clear scientific questions and hypothesis are developed by the candidate, which help structure the thesis.

9. Knowledge of existing literature

Good

The candidate cites a total of 186 sources. Given the interdisciplinarity of the topic, the amount of sources is absolutely adequate. The literature that is cited is in general very suitable, and of no doubt the candidate has performed a thorough literature study. The literature is also up to date including work form the last few years. The conclusions that the candidate derives from the state of the art are comprehensible. Two areas where the state of the art could have included additional work (and insights from it) are the heat treatment of the AlSi alloys from PBF-LB/M, and the interplay between process parameters / processing strategies and lattice / strut manufacturing. For the first topic, the observed ductility after T6 treatment appears to be lower than what is reported in some literature work (e.g. in EOS AlSi10Mg parameter sheet, 11% elongation should remain after T6 treatment). For the latter topic, I miss more information on parameter selection for the PBF-LB/M of lattices and struts. In that area, I think the candidate could also have profited from the work of Alexander Großmann et al. (https://doi.org/10.1016/j.matdes.2019.108054) which gives additional insights on melt-pool dimension and its use for producing lattices / struts of a defined diameter.

10. Choice of methods and technical soundness

Very good

The candidate's choice of methods is suitable in order to answer the research questions. The Topology Optimization (TO) follows common practice using a well-established Software package (Inspire, Co. Altair) with some modification in its usage to determine ideal procedure. The stepwise approach that was chosen and the combination with the reversal of loads rendered the best results, and the TO result was cross-checked with a FEM. Overall, the TO procedure appears to be sound and leads to credible results. The experimental approach for the heat treatment itself is based on typical, proven procedures and thus comparable to literature results. The different heat treatment conditions that have been investigated are limited, but considering the effort needed per trial, this is understandable. However, as the resulting ductility is rather low, I am missing a critical discussion in the thesis against (industrial) references and literature, and potential causes for deviations. For the measurement of residual stresses, the cantilever beam method is used which is also a common practice among researchers in Additive Manufacturing. The mechanical testing was performed to ISO 6892-1 standard using specimens as per DIN 50125, which is good scientific practice. Dimensional analysis of the lattices uses state of the art equipment.

11. Quality, originality and significance of the results

Very good

The thesis produces new results in all of the three above-mentioned areas. As for the Topology Optimization, the candidate followed common practice in high quality, with the originality stemming from modifying the use of the software. Using a multi-step approach in combination with load reversal is a clever idea and interestingly yielded very good results. The approach was proven on a case study, which clarifies its significance for applications in e.g. automotive (sports) vehicles. Regarding the heat treatment, the result mainly confirms what is expected from literature and showing that T6 treatment gives more or less optimal balance between strength and ductility. The determination of the effect of the different heat treatments on the residual stresses is however considered a new and original result, same as that the quenching leads to new stresses. Both of this information may be used to improve the process (regarding design and orientation of part, which can lead to more precise manufacturing. Also, its specific effect on the structured material is shown, which can lead to a new research field (i.e. optimized heat treatments for lattices / thin structures). As for the structured material, the thesis also shows some very interesting results, e.g. the effect of heat dissipation close to the build platform, as well as the anisotropy between z-direction and xy-direction. When this is implemented into clever part design, significant further weight saving may be achieved.

12. Quality of attached papers

Excellent

The papers, especially the journal papers, are of very high quality. The papers are written in a very concise and clear manner, making it easy to follow the motivation, the procedures and the final results. The artwork is also clear with 'to the point' descriptions. There is no doubt that all the information is provided to verify the paper's results through own experiments by the reader. The paper 'Numerical and Experimental Evaluation of Structured Material for Use in Multiscale Topology Optimization' published in Advanced Engineering Materials (well-known journal, Impact factor 3.4) stands out from the other, also very good publications, as it covers the topic in a quite exhaustive, complete manner. The numerical studies presented appear very sound and the experimental evaluation is also of highest quality. The paper could become one of the 'standard' references for the emerging field of topology optimization using multiple lattice structures under different orientations respecting manufacturing constraints from PBF-LB/M technology.

13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)

Very good

The Thesis 'Additive manufacturing of topologically optimised parts' by Ondřej Vaverka is a clearly written, well structured work dealing with the design, manufacture and heat treatment of Al-Si alloys specifically with respect to structured materials, i.e. lattices and strut-based structures. Despite the diverse available literature, which is presented by the candidate in a detailed way and mostly complete, the thesis focuses on specific open research questions. The candidate follows good scientific and engineering practices in line with today's state of the art. The methods used are described comprehensible. For each of the areas addressed, there are key innovations such as a modified Topology Optimization procedure or the introduced residual stresses during the T6 heat treatment, for example. It thus is a valuable contribution to the advancement of Additive Manufacturing. The results have been published in several high-quality papers, of which the one 'Numerical and Experimental Evaluation of Structured Material for Use in Multiscale Topology Optimization' published in Advanced Engineering Material stands out as an excellent contribution with the potential to become a 'standard' reference for the emerging field of topology optimization using multiple lattice structures. Only very minor weaknesses exist in terms of a more critical discussion of the obtained elongation values.

14. Questions and comments

15. Conclusion
PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.
YES

16. Date and signature	
Date: 25. August 2025	

Please note

A. *Evaluate categories 7 to 13 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent. The qualification of 'excellent' should only be given for a PhD Thesis in the top 3% of the research in your field of expertise.*
B. *E-mail the completed form to:* Klara.Javorcekova@vut.cz

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Review of Doctoral Thesis

1. PhD candidate
Ondřej Vaverka / Ondrej.Vaverka@vut.cz
2. Name of PhD programme
Name
3. Title of PhD thesis
ADDITIVE MANUFACTURING OF TOPOLOGICALLY OPTIMISED PARTS

4. Principal supervisor
Title and Daniel Koutný / E-mail
5. Co-supervisor
Title and name of co-supervisor / E-mail

6. Reviewer
Title and name of reviewer / **c.ayas@tudelft.nl**
Place of employment: Delft University of Technology

7. Overview of the scope of PhD thesis[1]
Very good
The dissertation investigates a very important topic: the manufacturability of topology optimized designs. Manufacturability is considered holistic, accounting for the prevention of support structures that are costly from a material and processing point of view, residual stresses, and mechanical properties of the additively manufactured metal parts. Furthermore, the last paper proposes a material interpolation scheme that can be easily incorporated into multi-scale TO and defines the suitability of different lattice cells for different loading directions.

8. Significance of the topic and clarity of problem statement
Good
The research questions are clearly stated and supported by the hypothesis to be tested. However, as stated in the literature review, the state-of-the-art DfAM typically evolved into incorporating manufacturing limitations into the design process itself. In contrast, a manual design alteration is performed in the first paper. The results obtained in the second and third papers are in accordance with the previous literature and are as expected. In the last paper, both the problem statement is strong and its resolution leads to multi-scale TO schemes.

[1] Overview of the scope of PhD thesis is a short description of objectives of PhD thesis's research and summary of main findings and scientific achievements.

9. Knowledge of existing literature
Very good
The literature review was thoroughly explained and organized, indicating that the candidate understands the existing literature well. Moreover, the recent developments in the literature were also incorporated into the discussion chapter.

10. Choice of methods and technical soundness
Good
The methods used during the production of samples and their mechanical characterization have been sound and performed competitively. Analysing the lattice dimensions with computer tomography and measuring the deformation of cantilever samples lays a firm basis for the results obtained. One minor issue is the reliance on commercial software for TO and FEA, where the processing of input to create output is not entirely transparent.

11. Quality, originality and significance of the results
Good
The dissertation investigates a broad range of topics from manufacturability issues in LPBF to material properties due to thermal evolution during printing and subsequent heat treatment. The originality of the results is demonstrated by contrasting with the state of the art in the literature. In terms of significance, the last paper stands out as its findings are the most consequential.

12. Quality of attached papers
Good
The state-of-the-art DfAM typically evolved into incorporating manufacturing limitations into the design process itself, while a manual design alteration is performed in the first paper. The results obtained in the second and third papers are in accordance with the previous literature and are unsurprising. The fourth paper explores the strut diameters during LPBF, a vital issue faced during the production of LPBF. The fifth paper is the most important and the strongest paper of the thesis, which explores multi-scale TO, which is also the most innovative part of the work.

13. Overall assessment, strengths and weaknesses (based upon the above evaluation categories 8–12)
Good
Overall, the research was performed with careful experiments supplemented with numerical modelling. The literature survey has been comprehensive. The problems formulated are very relevant and are intensively researched worldwide. The last two papers are the most impactful and innovative.

14. Questions and comments

. Some papers comprising the thesis are co-authored by people besides the candidate and the PhD supervisor. It would be important to state the candidate's contribution in the papers to assess the PhD thesis better.

15. Conclusion
PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.
YES

16. Date and signature	
27/08/2025	

Please note

A. *Evaluate categories 7 to 13 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent. The qualification of 'excellent' should only be given for a PhD Thesis in the top 3% of the research in your field of expertise.*
B. *E-mail the completed form to:* Klara.Javorcekova@vut.cz

Principal supervisor's final report on the PhD study

1. PhD candidate
Ondřej Vaverka / Ondrej.Vaverka@vut.cz
2. Name of PhD programme
Design and Process Engineering
3. Title of PhD thesis
Additive Manufacturing of Topologically Optimised Parts

4. Principal supervisor
Assoc. prof. Ing. Daniel Koutný, Ph.D. / Daniel.Koutny@vut.cz
5. Co-supervisor
Assoc. prof. Ing. David Paloušek, Ph.D. / palousek@fme.vutbr.cz

6. Stays at other institutions (min. 7 days)
Delft University of Technology/ Netherlands / 28/10/2024 / 28/11/2024 Delft University of Technology/ Netherlands / 02/03/2025 / 31/03/2025 Delft University of Technology/ Netherlands / 18/08/2025 / 28/08/2025

7. Teaching activities
Machine design fundamentals / 26 hrs Machine Design / 282 hrs CAD / 208 hrs Design and CAD / 52 hrs CAD Modeling / 33 hrs Team Project / 26 hrs 3D Digital Technology and CAD / 8 hrs Additive Technologies / 62 hrs

8. List of main publications

Papers published in journals with impact factor:

JAROŠ, J.; OŽVOLDÍK, D.; VAVERKA, O.; NOPOVÁ, K.; HURNÍK, J.; ZIKMUND, T.; KAISER, J.; KOUTNÝ, D. Influence of Laser Strategies on Performance of Lattice Structures from Magnesium Alloy WE43 Produced by Laser Beam Powder Bed Fusion. Advanced Engineering Materials, 2025, vol. 27, no. 7, ISSN: 1527-2648.
Journal impact factor = 3.3, Quartile Q2, Citations = 0

JAROŠ, J.; VAVERKA, O.; SENCK, S.; KOUTNÝ, D. Influence of Process Energy on the Formation of Imperfections in Body-Centered Cubic Cells with Struts in the Vertical Orientation Produced by Laser Powder Bed Fusion from the Magnesium Alloy WE43. Micromachines, 2024, vol. 15, no. 2, ISSN: 2072-666X.
Journal impact factor = 3.0, Quartile Q2, Citations = 1

VAVERKA, O.; ČERVINEK, O.; JAROŠ, J.; KOUTNÝ, D.; PANTĚLEJEV, L. Numerical and Experimental Evaluation of Structured Material for Use in Multi-scale Topology Optimization. Advanced Engineering Materials, 2024, vol. 26, no. 13, ISSN: 1527-2648.
Journal impact factor = 3.3, Quartile Q2, Citations = 1

ČERVINEK, O.; WERNER, B.; KOUTNÝ, D.; VAVERKA, O.; PANTĚLEJEV, L.; PALOUŠEK, D. Computational Approaches of Quasi-Static Compression Loading of SS316L Lattice Structures Made by Selective Laser Melting. Materials, 2021, vol. 14, no. 9, p. 1-24. ISSN: 1996-1944.
Journal impact factor = 3.748, Quartile Q2, Citations = 19

ČERVINEK, O.; PETTERMANN, H.; TODT, M.; KOUTNÝ, D.; VAVERKA, O. Nonlinear dynamic finite element analysis of micro-strut lattice structures made by laser powder bed fusion. Journal of Materials Research and Technology, 2022, vol. 18, no. 1-16, p. 3684-3699. ISSN: 2238-7854.
Journal impact factor = 6.267, Quartile Q1, Citations = 13

VRÁNA, R.; VAVERKA, O.; KOUTNÝ, D.; DOČEKALOVÁ, K.; PALOUŠEK, D. Shape and Dimensional Analysis of Lattice Structures Produced by Selective Laser Melting. MM Science Journal, 2020, vol. 2020, no. 2, pp. 3938-3942. ISSN: 1803-1269.
Journal impact factor = 0.1, Quartile Q4, Citations = 2

VAVERKA, O.; KOUTNÝ, D.; PALOUŠEK, D. Topologically optimized axle carrier for Formula Student produced by selective laser melting. RAPID PROTOTYPING JOURNAL, 2019, vol. 25, no. 9, pp. 1545-1551. ISSN: 1355-2546.
Journal impact factor = 3.099, Quartile Q1, Citations = 8

Papers in conference proceedings:

VÍTEK, P.; HURNÍK, J.; VAVERKA, O.; KOUTNÝ, D. Forging measurement using passive stereo vision. In Proc. SPIE 12618, *Optical Measurement Systems for Industrial Inspection XIII*. SPIE, 2023. ISBN: 9781510664456.

VAVERKA, O.; ZABLOUDIL, J.; KOUTNÝ, D.; PANTĚLEJEV, L.; PALOUŠEK, D.; DOČEKALOVÁ, K. Effect Of Heat Treatment On Mechanical Properties Of AlSi7Mg0,6 Aluminium Alloy Processed By SLM. In: *European Powder Metallurgy Congress and Exhibition, Euro PM 2019*. EPMA, 2019. ISBN: 978-1-899072-51-4.

VRÁNA, R, O VAVERKA, O ČERVINEK, L PANTĚLEJEV, J HURNÍK, D KOUTNÝ and D PALOUŠEK. Heat treatment of the SLM processed lattice structure made of AlSi10Mg and its effect on the impact energy absorption. In: *European Powder Metallurgy Congress and Exhibition, Euro PM 2019*. EPMA, 2019. ISBN: 978-1-899072-51-4.

VAVERKA, O.; KOUTNÝ, D.; VRÁNA, R.; PANTĚLEJEV, L.; PALOUŠEK, D. Effect of heat treatment on mechanical properties and residual stresses in additively manufactured parts. In *ENGINEERING MECHANICS 2018*. Engineering Mechanics 2018. Praha: Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences, 2018. pp. 897-900. ISBN: 978-80-86246-88-8. ISSN: 1805-8256.
WOS Citations = 5

9. Assessment of the supervision process
Very good
Justification for evaluation: The main communication with the doctoral student regarding the topic of his thesis was carried out in the form of regular meetings on weekly bases. More detailed discussions of the topic of the dissertation, including planned experiments, partial results and proposals for further steps, then took place approximately every four to six months. The student also actively discussed specific topics of prepared studies with supervisor specialists and other experts in the field. Throughout the course of the study, communication went smoothly, and certain disruptions and slowdowns in activities only occurred during the COVID-19 pandemic. The extension of the study beyond the standard time was also due to the effort to publish the results in first-quartile journals, which involved a demanding and lengthy review process in several journals.

10. Assessment of the candidate's ability to work independently
Very good
Justification for evaluation: The doctoral student proved his ability to work independently. From the beginning of the studies, he participated in many research projects and contracts with industrial partners. The tasks he received were done on time and in a good quality. He became one of the most experienced and reliable team members. He proved to be capable to guide student projects, bachelor and diploma thesis. His students passed very well. The student also demonstrated the ability to formulate hypotheses on his own research and test them with experiments he designed. During his studies, he actively supported formula student team and initiated cooperation with other institutes at the faculty. Based on the achieved results, he initiated international cooperation with prof. Langelaar at TU Delft, where he later took internship and developed further cooperation.

11. Assessment of the contribution that the research makes to knowledge in the field
Very good
The thesis provides significant advances in integrating topology optimisation with additive manufacturing by systematically addressing manufacturability, material behaviour, and structural performance. The research demonstrates that applying DfAM rules after mono-scale optimisation leads to stiffer components while reducing reliance on complex support structures. A major contribution is the detailed evaluation of heat treatments for Al-Si alloys produced by LPBF, which revealed the trade-offs between strength, ductility, and residual stress, and identified the T6 regime as the most effective compromise, though with important implications for deformation control. Equally impactful are the studies on lattice-structured materials, where the work confirmed that proper topology selection can yield mass reductions exceeding 35% while preserving stiffness—results that significantly extend beyond prior state-of-the-art limited to low-density structures. Moreover, the discovery of anisotropic mechanical behaviour in heat-treated AlSi10Mg lattices, not previously described in the literature, adds a novel dimension to the understanding of material performance. By bridging theoretical optimisation with experimental validation, the thesis offers practical guidelines for designing lightweight, reliable, and manufacturable parts, advancing both academic knowledge and industrial readiness in additive manufacturing.

12. Other comments

Project on which student participated or led during his PhD studies: 2025 – 2026, TAČR Increasing the energy self-sufficiency of small sources through residual heat conversion, team member 2021 – 2024, TAČR FW03010160 – TREND, Surface treatment of very thin structures realized by 3D metal additive manufacturing, team member 2020-2022, ATCZ229, Research of magnesium alloys for additive manufacturing of structural and biomedical parts, team member 2017-2020, ESA Contract no. 4000123317/18/NL/GLC/hh, Additive Design for Aerospace Applications Capabilities (ADAAC), team member 2019 – 2022, TAČR TN01000071, National Competence Centre of Mechatronics and Smart Technologies for Mechanical Engineering, team member 2019 – 2020, TAČR TN01000029, National Competence Centre for Aeronautics and Space, team member of subproject: Design, optimization and evaluation of structural flight component made by additive manufacturing 2017 – 2019, TAČR TH02010514, Development of 3D printing for selected materials and topology optimization of components for aerospace industry, team member 2019, FV 19-19, Innovation of the subject Additive Technologies through the implementation of simulation tools, project leader

13. Conclusion
PhD thesis is an independent scientific work that presents a novel solution to a significant problem in the research area and demonstrates the candidate's ability to conduct independent research.
YES

14. Date and signature	
29/08/2025	

Please note

A. *Evaluate categories 9 to 11 using the following scale: unacceptable, acceptable, satisfactory, good, very good, excellent.*
B. *In each category 9 to 11 explain reasons for evaluation using between 100–200 words.*
C. *E-mail the completed form to:* Klara.Javorcekova@vut.cz