INSTITUTE OF MACHINE AND INDUSTRIAL DESIGN

FME

Faculty of Mechanical Engineering
Brno University of Technology

Review of Doctoral Thesis

1. PhD candidate
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2. Name of PhD programme
Design and Process Engineering
3. Title of PhD thesis
Study of Energy Absorption in Micro-Strut Lattice Structure Produced by Selective Laser Melting

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7. Overview of the scope of PhD thesis[1]
Very good
The thesis aims at developing a numerical model of the deformation behaviour of SLM-produced lattice structures out of AlSi10Mg. The main steps taken are: 1) process development (laser power, scan speed and scan strategy) for optimized density and surface roughness. 2) Design and qualification of a drop weight impact testbed for the referencing/validation of the numerical model. 3) Development and validation of numerical model including porosity, surface roughness and strut shape deviations. This is an appropriate and good approach. The analyzation of the influence of SLM process parameters on the formation of internal material defects and surface roughness during the SLM production of the lattice structure represents the largest part of the thesis. The hypothesis is that these defects degrade mechanical properties of the structure and their removal will improve the mechanical properties. (Yet, this is a bit inaccurate. We know from literature that even porosity of some percent have only little influence on static performance of bulk parts. On the other hand side the hypothesis is absolutely true for the dynamic performance). Based on the process optimization the deformation behaviour of the manufactured lattice structures is analysed on the developed drop weight impact device. The deformation behaviour is evaluated using the image analysis of a high-speed camera and a force record from a strain gauge. The results of the mechanical testing is then finally used for the validation of the developed numerical model. In that model the real shape of the produced lattice structure was implemented in the form of an elliptical

[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.

geometry along with the information on the real mechanical properties in the form of the developed material model. The resulting comparison of the experimental results and the numerical model prediction show a good match at the maximum load (deviation of approx. 5 %).

8. Significance of the topic and clarity of problem statement

Very good

The topic is absolutely relevant for various fields of application, such as aerospace, lightweight design in general of shock absorbing structures. The problem of porosity and especially surface roughness is well addressed. For complex lattice structures, post treatment (i.e. to reduce surface roughness) is difficult to achieve. Hence the deterministic description of those quality factors and finally the evaluation of the outcome - tensile strength, fatigue strength, etc. – are crucial for the use of such lattices in industry. The idea of a simulation driven design will help future designers to incorporate lattices into their thinking and design approaches. Besides this, the procedure can be driven further for the evaluation of thin structures (e.g. in topology optimization) in general.

9. Knowledge of existing literature

Good

Main literature sources are cited. Yet, 65 sources could be improved. Some mistakes are made throughout the theses. For example, AlSi10Mg was used in Laser Powder Bed Fusion (or SLM, as it is called here) for more than 10 years now. In the thesis it is stated, that this material is in use for not more than 3 years. On the other hand side the extend of chapter two and three (State of the art) make up to approx. 35% of the whole thesis which seems to be a bit exaggerated.

10. Choice of methods and technical soundness

Good

The choice of methods is appropriate. Especially the design and qualification of a drop weight impact testbed for the evaluation of the SLM-produced lattice structures is innovative and new. The exploitation of uCT method for the volumetric evaluation of porosity (backed by the metallographic analyzation) and the surface roughness is well chosen. The determination of the strut shape and the consequent adaption of the numerical model (ellipse instead of circular shape) by means of optical measurement methods is appropriate, too. In the field of SLM process development three main parameters are optimized (laser power, scan speed, scan strategy). Especially the "contour only" strategy is well chosen for the build up of struts. Besides this, there are many other parameters that influence porosity and surface roughness. One of the most decisive ones is the specimen position on the build plate (due to inhomogeneous atmosphere and flow conditions in the build chamber). This is not taken into consideration at all and marks a major mistake in this work.

11. Quality, originality and significance of the results

Good

Overall, the results of the thesis are good. The method is appropriate and the developed test procedures are innovative. The quality of the SLM process development is very good, the combination of an adapted scan strategy for struts with the evaluation of appropriate Line Energy is promising. Yet, this is foiled by the missing evaluation of other very important influencing factors, like positioning on the build platform. The evaluation of the energy absorption of the optimised lattice structures is innovative, this is a very good

approach. This is also the case for the newly developed material model and the adaption of strut surface and porosity equivalent. In sum, the results are very good and promising. Yet, the missing puzzle pieces (choice of influencing parameters on porosity and surface roughness, categorization / classification of defects and their impact, poor explanation of strut size choice, ..) and the blotted presentation of pictures (fuzzy, missing legends, scales, etc.) and diagrams (in some cases not readable at all) preclude a better evaluation.

12. Quality of attached papers

Very good

The papers attached to the thesis are well written and show the importance and significance of this work. Yet, there are only two papers available, this could be improved. This impression is underlined by missing information and interpretations, e.g. the development of gas pores in downskin areas. What is the condition of the powder in terms of humidity? Was there a drying process performed before the actual AM process? The grain size distribution seems to be coarse compared to "standard" 10-45 um. Why was the coarser fraction chosen? Why is the strut diameter chosen to be 0.8mm? More background information and cause-effect descriptions could be given.

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

Good

The thesis is well structured with a clear objective stated in the very beginning. The work is innovative and relevant. The development of the numerical model and the underlying process development is well presented. Yet, some crucial facts are missing, e.g.: 1) It is known that the position of specimen on the substrate play major role in the formation of defects, this is not touched at all in the thesis. 2) The explanation why BCC unit cells are used and the reason for the choice of the strut diameter are in need for improvement 3) The difference between thicker and thinner struts in terms of susceptibility for pores, defects compared to the absolute thickness is not sufficiently categorized 4) The indication of the influence of the degree of porosity (here to be found between approx. 0.1% ...3%) is not presented. Besides this, the quality of the pictures is in approx. 50% of all cases insufficient. Either diagrams or legends are hardly readable or legends and scales are missing completely. Some abbreviations are introduced within the text, some have to be taken from the annex, this makes the thesis hard to read at some points. Overall, there are many small mistakes throughout the text which in the end sum up and leave the impression of blotted paper work. In sum, the very good idea and work carried out in this thesis is foiled by a lack of accuracy. The thesis is between good and very good.

14. Questions and comments

Rework pictures, many of them are fuzzy and barely readable. Add scales and legends to the pictures.

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	
14/03/2019	

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*