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Opponent's review of the Doctoral Thesis

Candidate   Ing. Marek Tyburec

Title of the doctoral thesis   Modular-topology optimization of structures and mechanisms

Study Programme Physical and Material Engineering

Tutor   Prof. Ing. Jan Zeman PhD

Opponent   Michal Kocvara

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Topicality of the doctoral thesis theme

Commentary: Topology optimization is a technique used in many branches of mechanical and civil engineering. Despite this, the commercially available tools have some severe limitations. Among those are (i) interpretation of the results, (ii) manufacturability of the optimal structures, (iii) application to structures such as beams and shells, (iv) rigorous introduction of important constraints, e.g., on stability of the optimal structure. The goal of this thesis is to address most of these issues by (a) introducing modularity of the structure in order to address point (ii) of its manufacturability, and (b) using modern methods of mathematical optimization, in particular convex conic optimization, in order to address points (i), (iii) and (iv).

As such, the topics of the thesis are very timely, in particular, in connection with additive manufacturing techniques that allow real-world interpretation of the results of topology optimization as never before.

$\boxtimes$ excellent	$\square$ above average	$\square$ average	$\square$ below average	$\square$ poor

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Fulfilment of the doctoral thesis objectives

Commentary: The three research goals raised in Section 1.1 of the thesis were fully reached.

$\boxtimes$ excellent	$\square$ above average	$\square$ average	$\square$ below average	$\square$ poor

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Research methods and procedures

Commentary: Apart from standard models of topology optimization, the thesis introduces new techniques, including

(i) Efficient use of conic optimization; the candidate formulates some difficult optimization problems as convex conic optimization ones and uses several advanced "tricks" to make the formulations efficient and solvable by available software even for rather large dimensions.

(ii) Use of recent techniques of polynomial optimization, in order to find global solutions of highly nonconvex topology optimization problems; this is, as far as I know, one of the first attempts to use global polynomiall optimization techniques (Lasserre hierarchies) in structural optimization.

(iii) Bilevel optimization combining techniques of standard topology optimization with generation of quasi-periodic structures using Wang tilings; this allows the author to interpret the very general results of, for instance, free material optimization by manufacturable structures that are significantly "better" (lighter/stiffer) than those produced by standard topology optimization techniques, such as SIMP.

| ☐ excellent | ☒ above average | ☐ average | ☐ below average | ☐ poor |

Results of the doctoral thesis – dissertant's concrete achievements

Commentary: The candidate demonstrated broad knowledge of topics from structural engineering, advanced techniques of modern mathematical optimization, to practical questions and requirements of additive manufacturing. The thesis concists of four chapters, all of them bringing new view and new, so far unpublished and not-considered techniques. While the first three Chapters (2,3,4) are co-authored, the candidate was a leading author in all of them; the last Chapter 5 is solely authored by the candidate.

| ☒ excellent | ☐ above average | ☐ average | ☐ below average | ☐ poor |

Importance for practice and for development within a branch of science

Commentary: The whole thesis is driven by the idea of practical utilization of topology optimization in mechanical and civil engineering. It brings topology optimization closer to practitioners. The novel techniques presented in the thesis are very important in the light of today's focus on energy savings and green technologies.

| ☐ excellent | ☒ above average | ☐ average | ☐ below average | ☐ poor |

Formal layout of the doctoral thesis and the level of language used

Commentary: The whole thesis is extremely well structured and presented.

| ☒ excellent | ☐ above average | ☐ average | ☐ below average | ☐ poor |

Remarks

None.

Final assessment of the doctoral thesis

This is an excellent thesis merging techniques of structural optimization, manufacturing, and modern mathematical programming.

Following a successful defence of the doctoral thesis I recommend the granting of the Ph.D. degree

yes ☒ *no* ☐

Date: 14th December 2021

Opponent's signature:..