REVIEW

of the master's degree graduate qualification work on "Thermo-mechanical model to study microstructure during additive manufacturing" by student, Nikhil Mohanan, group: 3640103/80201

<u>Paragraph 1</u>: Please reveal the main significance of the topic studied in the graduation work: relevance (for whom, why), character (applied, theoretical, etc.). In specific, what is the relevance of the topic at the present time, and with what is it connected with?

The work of Nikhil Mohanan concerns the extension of thermomechanical modeling, including the introduction of such model in finite elements codes, to crystal thermo-elasto-plasticity in order to be able to model the effects of the thermomechanical cycles on the material during additive manufacturing. This topic is of higher interest towards the modeling of solid-solid phase transformations at the crystal scales, which is one of the biggest challenges in additive manufacturing.

More practically, this is a very detailed theoretical and numerical work, which can be easily applied to more complex problems in additive manufacturing process modeling.

<u>Paragraph 2</u>: Please tell us the degree to which the objectives of the work are justified and the extent to which the work is methodically justified, along with the level of scientific and their practical implementation, and the rationality of the applied solution methods.

Please tell us of the general conclusions on the work as a whole, emphasizing on:

- a. compliance of conclusions and recommendations with the content of the graduate qualification work and the validity of the achievement goals and objectives;
- b. the importance of practical results or theoretical research for further research and educational process.

The introduction of the work is very clear and based on a large number of consistent bibliographic references. It is shown that, even if works already exist in thermomechanics, the extension of this framework for strong thermomechanical couplings in crystal plasticity still has to be done. The work ok Nikhil Mohanan is a systematic step-by-step work in this direction. As the objective is to introduce such thermomechanical models in finite elements framework, the FenicS project has been chosen. Then, a precise, methodic approach has been developed, coming from strong formulations to weak ones and finally to a variational one. The time discretization problem is also discussed. The work comes through elasticity, thermoelasticity, dynamics from homogeneous to heterogeneous problems. When possible, results are compared to analytical or numerical ones.

The presentation of the results is based on nice pictures and graphs. The discussion of the results is clearly done with precise conclusions. We can mainly underline that the implementation proposed in each case, gradually step by step more complicated, allows to recover analytical solutions or solutions coming from other validated numerical methods.

The work goes until the heterogeneous thermo-elasto-dynamics case, which already consists in a very nice and interesting step for this master's degree graduation.

I personally appreciate the form given to the report: systematic presentation of the method, clear notations, practical toolboxes, etc

This work could be very interesting in educational process as it gives precise guidelines for every people who would like to begin finite element simulations with FenicS in thermomechanics. The extension to crystal

plasticity is under progress which shows that the present work opens new ways to further research in crystal based thermomechanics.

Paragraph 3: Please tell us of the shortcomings of the final qualification work which you have noted.

Honestly, I didn't see shortcomings in this very nice work, nor in the form, nor in the contents.

Conclusively, I believe that N. Mohanan's graduate qualification work on "Thermo-mechanical model to study microstructure during additive manufacturing" meets the necessary requirements for the university graduate qualification work in the direction of 01.04.03 "Mechanics and mathematical modeling" and is recommended for the defense.

I assess the work of N. Mohanan as excellent. In case of successful defense of the graduate qualification work, he can be awarded the master's degree.

Directeur de Recherche au CNRS, LMS, Ecole Polytechnique, PhD. 11.06.2020

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