ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

fakulta jaderná a fyzikálně inženýrská

Prof.Dr.Ing. Michal BENEŠ
katedra matematiky
fakulta jaderná a fyzikálně inženýrská
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE
Trojanova 13
120 00 PRAHA 2

Tel.: *(420-2)-2435 8540*
Fax: *(420-2)-2491 8643*
E-mail: *michal.benes@ fjfi.cvut.cz*

Scientific board
FJFI ČVUT Praha

Ref: Kol/18

Prague, June 18 2018

Supervisor's report

PhD student: Ing. Miroslav Kolář

Thesis: **"Motion of Curves with the Application to Dislocation Dynamics"**

The submitted thesis has been prepared within the framework of the research carried out in the Department of Mathematics, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, and given by the contacts to the University of California, Los Angeles. The author deals with the motion of curves in plane or on a surface with the application to the dislocation dynamics. The purpose of the thesis was to develop advanced parametric description of curves moving along given surfaces and apply such a knowledge in the specific situation of interaction of dislocation curves.

First part of the thesis explains how the topic of curve motion fits into the domain of free boundary problems. Here, particular cases of interface motion are summarized. This chapter results in determining the planar curve dynamics as well as the manifold curve dynamics.

Second part of the text focuses on summarizing the physics of dislocations as material defects and their importance for macroscopic material properties. Physical model of dislocation dynamics is given by the evolution law for the dislocation curve and mutual force interactions. The author underlines relationship between the force field profiles, friction and cross-slip criterion. The phenomena leading to topological changes and, in particular, to slip plane changes are described as well. Physical model of

dislocation motion is treated in the subsequent part where the motion of single and multiple interacting dislocations is described. Deterministic conditions for cross-slip are mentioned as well.

Next part of the thesis is devoted to the mathematical treatment of curvature driven flow. The author summarizes the suitable mathematical methods of level sets, phase field and parametric approach to this flow. The choice of the parametric method is commented more in detail including the tangential redistribution. The author provides information on fundamental mathematical properties of the curvature driven flow. This chapter introduces several emerging types of motion such as the area preserving motion and the geodesic curvature flow.

The numerical scheme for the solution of the degenerate parabolic equation for the curve dynamics is based on spatial discretization by flowing finite volumes. Temporal discretization leads to the semi-implicit scheme or to the higher-order scheme of Runge-Kutta type. The author dealt with the redistribution algorithms and introduced schemes for the planar curvature flow, area preserving planar flow and for the geodesic flow which has been used for modeling the double cross-slip of dislocations.

The final chapter presents computational results obtained for the mentioned types of curve dynamics. They are collected to the parts presenting the quantitative computations related to the curvature flow, area preserving flow in plane or on a surface, to the interaction of dislocations with obstacles. The qualitative results show the ability of the developed algorithms to treat complex constrained curve flow as well as elementary dislocation motion, interaction with obstacles, multiple dislocation motion and double-cross-slip.

The submitted thesis summarizes the achievements of the author during his work on the topic, where the study of the area preserving geodesic flow and geodesic treatment of the double cross-slip are new. The author so far published 4 articles directly related to the topic in the impacted journals (1 more is accepted) and some parts of his work are still worth of publishing.

The PhD study of the candidate made part of the cooperation between the CTU in Prague and several institutions abroad. He visited the Japanese universities and the Comenius University in Bratislava. He

also participated in several international conferences, namely twice in the ENUMATH conferemce and in the prestigious Multiscale Material Modeling conference with talks in specialized minisymposia. His results were published in peer-reviewed journals and conference proceedings. He actively participated in the educational process in the Department of Mathematics, supervised students, has been guiding exercises in basic courses. He also several time held the English taught course in calculus and the course in variational methods for the Japanese exchange students.

During the work on the topic, the candidate proved very high ability to independently master and develop problems of interdisciplinary character. By his work, the topic of geodesic curve dynamics has become integral part of the research activities of the department. Respecting the above mentioned facts, I have all reasons to recommend the candidate to the committee for the defence of the degree Doctor of Philosophy.

prof.Dr.Ing. Michal Beneš

(supervisor)