CHARLES UNIVERSITY
Faculty of Mathematics and Physics
Department of Numerical Mathematics
Sokolovská 83, 186 75 Prague, Czech Republic
Tel.: (+420)221 913 364, e-mail: knm@karlin.mff.cuni.cz

doc. Ing. Libor Šnobl, Ph.D.
proděkan
Faculty of Nuclear Science and Physical Engineering
Czech Technical University in Prague

July 22, 2021

Review of the habilitation thesis of Pavel Váchal

The habilitation thesis deals with the development of Lagrangian and namely the ALE (Arbitrary Lagrangian–Euler) methods for the numerical solution of various physical problems. This topic is currently very popular and challenging due to its applicability in a wide range of practical problems. The thesis summarizes several contributions of Dr. Váchal to this research areas achieved in cooperation with several collaborators during last 10 years. Particularly, the thesis is the compilation of 10 articles published in international journals accompanied by an introduction, specification of several topic of interest and detailed comments to each article. Thesis also contains description of current research of the author and future prospects.

ALE method exhibits a very promising approach for modelling a complex time-dependent problems in complicated geometries, e.g., fluid-structure interaction where the computational domain is changes in time due to various force interactions. However, in order to obtain physically relevant numerical approximations, several important aspects have to be take into account, e.g., conservation of physical quantities (geometric conservation of laws), capturing of discontinuities and steep gradients (show waves), enforcing the second thermodynamical law, etc.

The area of research of ALE methods is rather wide so Dr. Váchal focus on several interesting aspects. Namely, the artificial viscosity techniques (ensuring the physically acceptable numerical solutions), the preserving of symmetry (guaranteeing the physical symmetry of numerical solutions, if any), the proper choice of equation of states for hydrodynamic simulations and the rezoning/remapping techniques which exhibit the fundamental part of ALE computations. The developed methods are applied for mostly for the simulations of the laser-target interactions and transport hydrodynamics for laser plasma modelling.

The thesis contains several interesting and original techniques applicable in numerical simulation of physical systems. There is only very few theoretical results of numerical analysis but the proposed methods are always carefully investigated and tested by the sets of numerical experiments. I appreciate that not only simple academic examples are treated but also some challenging test cases are taken into account.

As mentioned above, the main core of the thesis consists of 10 papers published in recognized scientific journals. However, none of the belongs to the top decile, may be with one exception. Eight papers were written with co-authors from abroad, some of them belong surely among the top class of researchers. The papers selected for the thesis have altogether almost 150 citations which clearly demonstrate the impact of the results on the community.

The thesis is well arranged and well balanced, it contains enough of information in a con-

densed way which shows the expertise and range of knowledge of Dr. Váchal. The numerical examples presented in the thesis were achieved by the in-house codes developed at the Faculty of Nuclear Science and Physical Engineering, Dr. Váchal is one of the developer and his role in the presented papers is fundamental. Therefore, I strongly *recommend* to award him the title *docent*.

I have the following topics for the possible discussion.

1. The time discretizations are carried out by predictor–corrector method. Is it possible to solve the resulting ODEs fully implicitly? Which possible obstacles can we expect?

2. The used methods have first or second order of accuracy. Are there techniques using higher order methods, e.g., discontinuous Galerkin method?

3. The reliability of the developed methods is demonstated mostly by comparison with reference results. However, the problem of aposteriori error analysis is untouched. Are there any approaches dealing with this subject?

4. Currently, very popular and demanding are high-performance computing (HPC). Are the any plans to use the developed methods in HPC? Which aspects do seem to be most critical?

Prof. RNDr. Vít Dolejší, Ph.D., DSc.
Charles University
Faculty of Mathematics and Physics
Sokolovská 83, 186 75 Prague 8, Czech Republic
tel.: (+420) 221 913 373
e-mail: dolejsi@karlin.mff.cuni.cz