Call for PhD applications in computational solid mechanics

Subject: Development of advanced numerical methods in contact mechanics for aerospace applications
Scientific advisers: Vladislav Yastrebov, Georges Cailletaud, Frédéric Feyel
Period: 36 months (CIFRE)
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Keywords: computational contact mechanics, high performance computing, friction, augmented Lagrangian method, surface-to-surface, mortar method

Context

Recent developments [1, 2] in the finite element software Z-set [3, 4] allows to solve efficiently most problems involving friction and contact. However, the implemented methods make use of specific contact discretizations that lack of accuracy in load transfer between contacting surfaces. In consequence (i) the contact patch test [5] for non-conforming meshes cannot be passed, (ii) locally the contact pressures experience spurious oscillations, and (iii) elements with higher order interpolations require specific treatment. These problems are associated with under-interpolation of contact forces and non-satisfaction of LBB[1] condition. To overcome these difficulties a new class of "surface-to-surface" contact discretizations will be implemented. Because of the weak fulfillment of contact constraints, this class of methods allows to avoid the aforementioned drawbacks and to treat contact problems with higher accuracy and improved robustness.
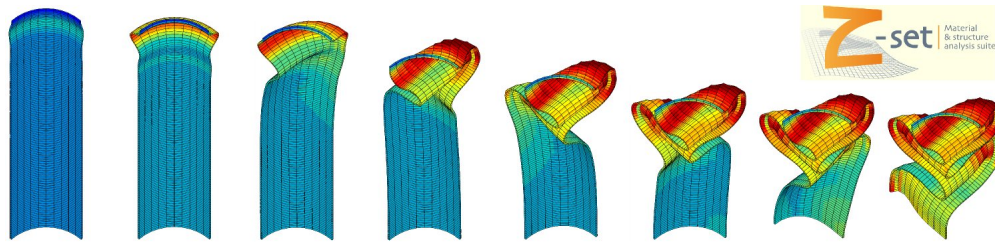

Fig. Example of finite element analysis of a post-buckling folding of a thin walled structure
Finite strain formalism + plasticity + contact

Objectives, challenges and milestones

The objective of this project is to improve numerical algorithms and resolution techniques to treat frictional contact problems in the framework of (1) parallel computing, (2) large deformation/large sliding friction contact and (3) highly non-linear materials. All developments will be carried out in the finite element software Z-set and employed to solve problems from aeronautic industry including millions degrees of freedom. The ultimate aim is to deliver a robust, multipurpose and accurate contact algorithm capable to treat efficiently contact problems.

The candidate will carry out a cutting edge research in the field of the optimization theory and its application to contact problems. He or she will be in charge for an intensive *code development* (C++) and *finite element simulation* of contact problems within the parallel environment.

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[1]Ladyženskaja-Babuška-Brezzi condition

First, the candidate will become familiar with the finite element software both as user and developer, by **(1)** implementing specific techniques allowing to alterate on-flight the contact parameters necessary to improve the convergence of existing contact/friction algorithms (penalty method, augmented Lagrangian method). The unguided iterative convergence procedure frequently fails as some contact elements may infinitely switch between stick, slip and non-contact states. For the moment, an efficient and mathematically motivated smart adaptation procedure for penalty/augmentation parameter has not yet been proposed. Next **(2)** the candidate will study recent numerical methods which employ the "surface-to-surface" contact discretization: mortar [6, 7], dual mortar [8, 9], Nitsche [10]. These methods, however, lack maturity and have not yet been extensively tested by the engineering community, see e.g. recent improvements of the dual mortar method [9], where the author reveal some drawbacks of the original formulation. Many improvements have to be done in terms of robustness and accuracy through an extensive testing, existing and emerging ideas, such as shadow projection, penalty regularization, topological and historical state preservation [2]. On the other hand, all the aforementioned methods were tested mostly on elastic material models. When the contact, friction, geometrical and material nonlinearities are all present in the model some techniques fail to work or demonstrate severe deterioration in convergece rate. However, the efficient treatment of all these nonlinearities is crucial for the purpose studies including complex material models (crystal plasticity, generalized visco-elasto-plasticity) under coupled thermo-mechanical loading cycles. A novelty of this study would be suggesting new resolution strategies preserving the highest convergence rates under coupled or uncoupled resolution of all nonlinearities. **(3)** The implementation of the retained strategy will be carried out in the parallel computing environment with a strong support of the team of code developers. **(4)** The following work on the increasing of robustness and accuracy is presumed through intensive testing and validation procedures on industrial problems. This work will require from the candidate an in-depth understanding of nonlinear finite elements and outstanding creativity.

Milestones of the thesis:

Task	Period (months)	Passed time (months)
Bibliography review	3	3
Z-set code study, case studies	4	7
Draft code	12	19
Case studies, code improvements	6	25
Relevant applications, article	4	29
PhD thesis writing	6	35

Reports are planed after 12 and 24 months, the final PhD thesis is expected in 36 months.

Contributions

This thesis has an ambition to make a step forward in efficiency and robustness of numerical methods for contact treatment with arbitrary material models within the implicit finite element method on parallel computer architectures. At the same time the thesis will contribute to advancement of the finite element software Z-set and, hopefully, to the resolution of several important contact/friction/fretting problems encountered in aeronautical industry.

Requirements

The candidate should have a strong background in applied mathematics, solid mechanics and numerical modeling. Knowledge of the finite element analysis and adequate programming skills are mandatory: programming experience in C++ is a must, knowledge of MPI and OpenMP is a plus.

Contacts

Please submit your candidature (CV + motivation letter) to people listed below:

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