Chapter 15
Non-intrusive Coupling: An Attempt to Merge Industrial and Research Software Capabilities

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I have had the great pleasure to cooperate for several years now closely with Peter Wriggers who has been several times invited in LMT-Cachan. I have always been impressed by the profound understanding and practical knowledge of Peter regarding computational and material mechanics. I know that Peter has a deep concern regarding the application of fundamental researches which is the motivation of this paper. We hope to connect it more closely in the future to the seminal work of Peter, especially regarding contact and multiscale stochastic modeling of heterogeneous materials and damage. The recently accepted International Research Training Group Virtual Material and Structures and their Validation is therefore an exceptional possibility for us to continue and reinforce a close relationship with Peter, a great scientist and a great friend (O. Allix).

Abstract. In computational mechanics, it is often difficult to test research innovations on industrial problems because of software limitations: many of the commercial finite element packages commonly used in the industry lack flexibility and openness, whereas in-house research developments are usually very specific and may lack features required for “real-life” industrial simulations. Non-intrusive coupling is a tentative answer to this problem. It consists in introducing local enhancements and refinements into an existing industrial problem through a separate nonlinear local model that comes with its own solver; the two models are coupled by the means of an iterative exchange algorithm inspired from domain decomposition methods and multiphysics solution techniques, using both models and solvers without any modification. So far, the method has been implemented around the finite element package Abaqus and has been used to introduce local plasticity and geometric details into a linear elastic global problem. While current developments include the simulation of localized damage in slender composite structures, we think that the method could be adapted to a wide class of problems including hybrid experimental-simulation approaches.

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1 Introduction

In the last decade, many innovative modelling or solution techniques have been introduced in the field of computational mechanics. These techniques, such as enriched finite elements or multiscale models, enable performing complex simulations that are out of reach of conventional finite element analysis (FEA) tools, in terms of computational or human costs. However, although these techniques have proved their performance by extensive testing on academic applications, they are scarcely applied on actual industrial problems because they cannot be conveniently implemented into commercial FEA software packages, which are the basis of most industrial computational environments.

Non-intrusive coupling is a tentative answer to these limitations. It takes advantage of the fact that, in many industrial simulations, sources of difficulties (which are usually nonlinear phenomena, sometimes occurring at fine scales) are localized in small regions, and that the innovative techniques mentioned above were specifically designed to overcome such difficulties efficiently. Thus, the essential idea of non-intrusive coupling is to enhance an existing industrial simulation, that involves a complex model data set and a commercial FEA solver, by the means of a separate local model that is analyzed with its own dedicated solver. This way, the local model may contain innovative features that cannot be implemented conveniently into the commercial solver. The term “non-intrusive” means that in the process, neither the models nor the solvers need to be modified; they are used as “black boxes”, and a script is used to run the analyses and exchange displacements and forces between them.

Of course, this non-intrusive framework also has a significant drawback: one has to do with the limitations of the commercial FEA solver that is used. This can impact performance, particularly when using software that are not optimized for implicit solver coupling schemes. However, we believe that this possibly non-optimal performance is a fair price to pay for the convenience of such a black-box tool; in addition, depending on the solver, several adjustments can be performed to reduce computational costs dramatically. At the moment, the computational efficiency of such a non-intrusive strategy is still an open question. What is certain is that this framework provides a way of performing enriched simulations for which no “monolithic” software is available at the present time.

The rest of this chapter is organized as follows. Sect. reviews the essential ideas of non-intrusive coupling and the different ways it can be made more efficient. Sect. presents an application of this strategy to localized plasticity and first results on damage problems.

2 The General Principles of Non-intrusive Coupling

The proposed analysis strategy starts from an existing “industrial” model, analyzed using commercial FEA software; its behaviour is supposed to be completely linear