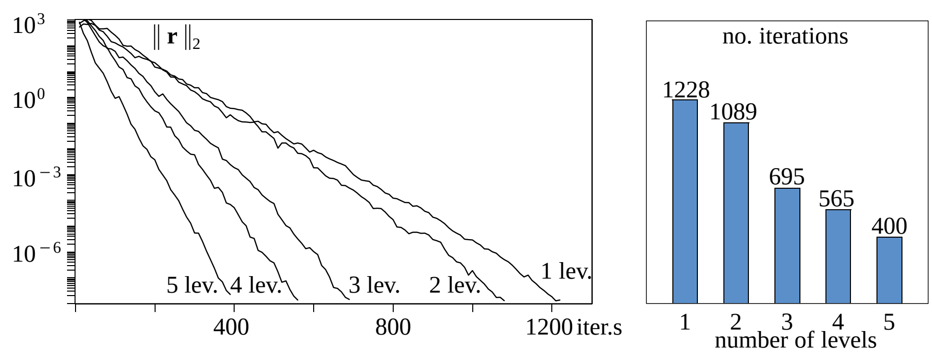
A MULTILEVEL APPROACH TO THE PARALLEL SOLUTION OF LARGE–SCALE NONLINEAR SHELL PROBLEMS

M. Gee, W.A. Wall and **E. Ramm**

Institute of Structural Mechanics, University of Stuttgart
Pfaffenwaldring 7, D–70550 Stuttgart, Germany
{ gee | wall | eramm }@statik.uni–stuttgart.de
http://www.uni–stuttgart.de/ibs/

The analysis of large–scale nonlinear shell problems asks for parallel simulation approaches. One crucial part of efficient and well scalable parallel FE–simulations is the solver for the system of equations. Due to the inherent suitability for parallelization one is very much directed towards preconditioned iterative solvers. However thin walled structures discretized by finite elements lead to ill–conditioned system matrices and therefore performance of iterative solvers is generally poor. This situation further deteriorates when the thickness change of the shell is taken into account. A preconditioner for this challenging class of problems is presented combining two approaches in a parallel framework.
The first is a parallel multilevel approach. A hierarchy of coarse grids is generated in a semi–algebraic sense using an aggregation concept [2],[3]. On each grid level mutually disconnected patches (aggregates) are constructed from the system of equations and from some geometric information taken from the next finer grid. No coarse grid triangulations have to be supplied. The intergrid transfer operators $\mathbf{P}^{(j+1)}_{(j)}$ (j = 1 to n–1 levels) are build such, that the rigid body modes of each patch are represented exactly. Except for the coarsest level, each level supplies smoothers based on an overlapping domain decomposition with inexact solves on subdomains. On the coarsest grid, the correction is obtained via a direct exact solve.



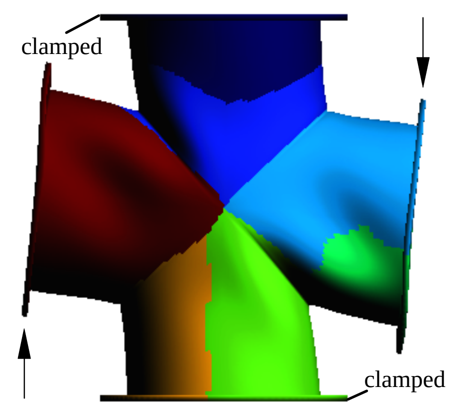


Fig. 1: steel tube intersection, 131.388 dofs , AMG–preconditioned CG, (exact solve on coarsest grid only with 5–level preconditioner)

The second approach is a mechanically motivated improvement called Scaled Director Conditioning (SDC) [4] and is able to remove the extra – ill conditioning that appears with three dimensional shell formulations [1], compared to formulations that neglect thickness change of the shell. It is introduced at the element level and harmonizes well with the multilevel algorithm. The formulation of this combined preconditioning approach is given and the effects on the performance of iterative solvers is demonstrated via some numerical examples. Implementation issues concerning performance and parallelity of the algorithms for distributed memory machines will be discussed.

References

[1] N. Büchter and E. Ramm, ”3d–Extension of Nonlinear Shell Equations Based on the Enhanced Assumed Strain Concept”, *Computational Mechanics in Applied Sciences*, Elsevier, C. Hirsch (ed.), pp. 55–62, 1992.

[2] R.S. Tuminaro and C. Tong, ”Parallel Smoothed Aggregation Multigrid: Aggregation Strategies on Massively Parallel Machines”, *Proceedings of SuperComputing 2000*, J. Donnelley (ed.), 2000.

[3] P. Vanek, J. Mandel and M. Brezina, ”Algebraic Mulitgrid Based on Smoothed Aggregation for Second and Fourth Order Elliptic Problems”, *Computing*, v. 56, pp. 179–196, 1996.

[4] W.A. Wall, M. Gee and E. Ramm, ”The Challenge of a Three–Dimensional Shell Formulation – The Conditioning Problem –”, *Proceedings of IASS–IACM 2000, Crete, Greece*, 2000.