

Physics-based block preconditioning for mixed dimensional beam/solid coupling

Max Firmbach¹ Alexander Popp² Matthias Mayr³

Multigrid methods are known to be highly efficient and scalable preconditioners, not only for single-field problems but also for mortar methods ranging from contact mechanics to meshty-ing problems. An interesting application in this field is the mixed-dimensional coupling of slender beam structures embedded into three-dimensional solid bodies. Such beam/solid interactions can be found in several engineering scenarios (e.g. fiber-reinforced composite materials or reinforced concrete). Imposing the coupling constraints via a penalty method as proposed in leads to an ill-conditioned and highly non-diagonal dominant matrix. Solving such problems in an efficient and scalable manner with iterative solvers is difficult and makes an appropriate preconditioning essential. Using algebraic multigrid methods (AMG) in this context is yet again challenging as there are several open questions regarding AMG for beams and the coarsening of the mixed-dimensional coupling terms.

This talk will discuss a physics-based block preconditioning approach based on AMG. The outer block iteration is taken care of with an inexact LU-decomposition. A crucial part of the calculation is the approximation of the inverse appearing in the Schur complement. Using a sparse approximate inverse approach based on an appropriate sparsity pattern helps to retain a low iteration number and parallel scalability. Multilevel ideas will be used to approximate the block inverses appearing in the system. We will assess the performance and the weak scalability of the proposed block preconditioner using examples of the interaction of solids with torsion-free Kirchhoff-Love and Simo-Reissner beam finite elements.

References:

- [1] <https://onlinelibrary.wiley.com/doi/10.1002/nme.6680?af=R>
- [2] <https://link.springer.com/article/10.1007/s00466-020-01907-0>
- [3] <https://epubs.siam.org/doi/abs/10.1137/S1064827594276552?journalCode=sjoc3>

¹University of the Bundeswehr, Civil Engineering and Environmental Sciences
max.firmbach@unibw.de

²University of the Bundeswehr, Civil Engineering and Environmental Sciences
alexander.popp@unibw.de

³University of the Bundeswehr, Civil Engineering and Environmental Sciences
matthias.mayr@unibw.de