International Conference On Preconditioning Techniques For Scientific And Industrial Applications
Eindhoven University of Technology, Eindhoven, The Netherlands
17-19 June 2015

Block-preconditioning of finite-volume methods used in industrial CFD

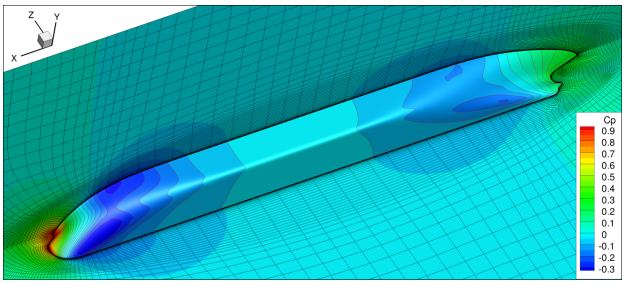
C.M. Klaij* and C. Vuik

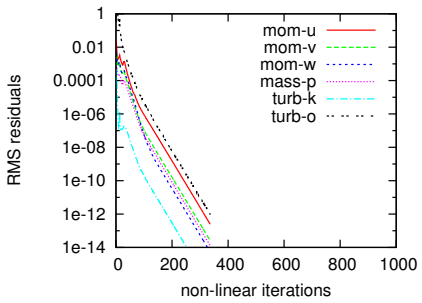
Maritime Research Institute Netherlands, P.O.Box 28, 6700AA Wageningen, The Netherlands
Delft University of Technology, Mekelweg 5, 2628CD Delft, The Netherlands

Abstract Finite-volume methods with cell-centered, co-located variables are de facto standard in both commercial and open-source CFD packages used by industry. Engineers appreciate their local conservation property and geometrical flexibility. Various iterative methods, notably segregated pressure-correction methods, are available to solve the discrete system of equations. However, iterative methods based on block preconditioners are missing. These type of methods are successful in the context of finite elements, at least for academic cases, and consist of a Krylov subspace method for the linearized system of momentum and mass equations and a preconditioner that exploits the system's block structure. The difficulty of this approach is to find a good approximation of the Schur complement. The SIMPLE method for example, originally a segregated solver, can be used as a block preconditioner:

$$\text{system:} \quad \begin{bmatrix} Q & G \\ D & C \end{bmatrix} \begin{bmatrix} u \\ p \end{bmatrix} = \begin{bmatrix} f \\ g \end{bmatrix} \qquad \text{precon:} \quad P^{-1}_{\text{SIMPLE}} = \begin{bmatrix} I & -\frac{1}{dQ}G \\ 0 & I \end{bmatrix} \begin{bmatrix} Q & 0 \\ D & R \end{bmatrix}^{-1}$$

with Q the advection-diffusion block, G the gradient, D the divergence, C the stabilization [1] and $R = C - D\frac{1}{dQ}G$ the Schur approximation. This block preconditioner was implemented in MARIN's CFD package ReFRESCO [3] and has been applied successfully to problems from maritime industry such as the flow around ship hulls [2]. The simulations routinely complement model testing by providing flow field details for diagnosing problems and improving designs. In this presentation, we will discuss block preconditioners for finite volume methods and show some applications from maritime industry.





References

[1] C.M. Klaij. On the stabilization of finite volume methods with co-located variables for incompressible flow. *Submitted to Journal of Computational Physics*, 2014.

[2] C.M. Klaij and C. Vuik. SIMPLE-type preconditioners for cell-centered, colocated finite volume discretization of incompressible Reynolds-averaged Navier-Stokes equations. *International Journal for Numerical Methods in Fluids*, 71(7):830–849, 2013.

[3] ReFRESCO webpage. `http://www.marin.nl/refresco`, 2015.

* *Email address:* `c.klaij@marin.nl`