FENFLOSS - a parallel implementation of the FEM in CFD-Engineering

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1 FENFLOSS - a parallel implementation of the FEM in CFD-Engineering

Simulation of flow phenomena in engineering applications gained more and more importance in the last two decades. The limiting factor in most cases was the available computing time and storage capacity. Nowadays, very complex flow problems can be simulated within acceptable time. However, the demand for more computing power still lasts, and simulation codes and algorithms have be adapted to the respective architectures.

The unsteady Reynolds averaged Navier Stokes solver FENFLOSS (**F**inite **E**lement based **N**umerical **FLO**w **S**imulation **S**ystem) is being developped at the University of Stuttgart, Institute of Fluid Mechanics and Hydraulic Machinery (IHS), since early 80s. Main applications are steady and unsteady turbulent flow problems of incompressible fluids in complex three dimensional geometries. To model the physical problem, a Q1P0 Petrov-Galerkin-formulation on hexahedral elements is applied. A Richardson-iteration folded by a time loop is used to solve the global non-linear problem. The linearised equations are solved by an iterative BICGStab-solver. In order to appropriately model turbulence, two-equation models or enhanced, adaptive turbulence models are available. Furthermore, a special formulation for rotating frames of reference is implemented.

Today, the typical problem size is about one to ten million or more grid points which means up to 60 million unknowns. Besides special matrix storage methods, this requires an appropriate size of available computing time and memory. In this case, the best way to reduce the absolute time to obtain a solution is parallel processing.

FENFLOSS uses a distributed memory (DMP) approach based on MPI. The domain decomposition technique is based on the METIS-library to guarantee good load balancing between the single processes. Communication is applied directly in the matrix-vector and scalar product of the solver. The main advantage of this approach, besides a very good speed-up ratio, is the independence of solution from the number of partitions. This allows the usage of massively parallel architectures such as PC-clusters.

In order to exploit the power of highly specialised vector computer architectures, such as the new NEC SX-8 installed at the HPC-Centre in Stuttgart, the code provides special storage schemes and loop orderings for vector processing. Though already vectorised, the solver of FENFLOSS is still further optimised and matrix reorderings yield another improvement in performance. Another way to use modern hybrid SMP-DMP architectures is the combination of shared memory parallisation (SMP) and DMP.

Performance measurements on the new SX-8 vector system for the diffent code optimi-

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sation steps will be discussed for a chosen example. Furthermore, the changes made in the code will be presented in detail and the issue of indirect addressing in vector computing will be addressed.

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