Projects

HPC for Climate-friendly Power Generation

The joint research project CEC [1] funded by the Federal Ministry of Economics and Technology (BMWi) and the Siemens AG was launched in January 2013 with an initial three year funding phase. Besides Siemens – the project coordinator - and JSC the consortium includes seven German research institutes in the fields of power plant technology and material science. Aim of the project is to develop new combustion technologies for climate-friendly power generation. The focus is on modern gas turbine technology which play an important role in the present transformation of the energy system towards a sustainable system based on renewable energy sources. The validation of the gas turbine combustion technologies will be carried out in a new test center called "Clean Energy Center" (CEC) which is currently being built by Siemens in Ludwigsfelde near Berlin.

While testing is a key step in the validation of new gas turbine combustion systems, numerical methods can provide significantly more detailed insight into the behavior of gas turbine combustion systems. The detailed insight is important since it enables engineers to derive new design hypotheses needed to achieve higher thermodynamic efficiencies and reduced pollutant emissions. A key design difficulty in the development of modern low NOx gas turbine combustion systems are thermoacoustic instabilities. Thermoacoustic instabilities can result in pressure oscillations which require the immediate shut down of a power plant to avoid mechanical failure. Avoiding these events is a high priority. Developing a modeling capability for thermoacoustic instabilities is challenging. The phenomenon involves unsteady aerodynamics, chemical reaction and acoustics resulting in a stiff multi-physics problem.

Computational fluid dynamics on massively parallel computers was found to be a suitable approach to predict thermoacoustic instabilities for single burner systems. To resolve all relevant effects simulations consuming approx. 200,000 core-hours are needed. While the behavior of a single burner is similar to the behavior of a can combustor based gas turbine, annular combustor based gas turbines require the simulation of the complete combustion system comprising up to 24 burners (see Fig. 1).

The resulting computational requirements are difficult to satisfy on PC technology based clusters – larger scale systems are needed.

Figure 1: Gas turbine with can combustion system (lhs) vs. annular combustion system (rhs)

OpenFOAM for JUQUEEN

Thus one of the aims of the CEC project is the provision of CFD software which makes efficient usage of massively parallel HPC architectures. Within the scope of this project the open source software package OpenFOAM [2] will be used.

Before the start of the CEC project OpenFOAM has already been used by Siemens for production runs on JSCs HPC cluster JUROPA. There simulations of a single combustor tube are done applying typically a few thousand cores / several hundred nodes. Within this project it is planned to compute the behavior of a complete annular combustion chamber which will lead to models where the size (number of CFD cells) is increased by at least a factor of 10. In order to keep the turnaround times acceptable it is necessary to increase the number of cores used for the calculations by a similar factor.

Thus as a first step OpenFOAM was implemented on JSCs Blue Gene/Q system JUQUEEN which is more suitable for simulations running on tens of thousands of cores. This was not straightforward since the dynamical linking strategy applied by OpenFOAM is not the first choice for highly scalable architectures like JUQUEEN. The resulting OpenFOAM installation was successfully tested and made available for use by Siemens as well as other research groups with access to JUQUEEN.

Benchmarking of OpenFOAM on JUQUEEN with a model of a single combustion tube provided by Siemens showed that the single core simulation speed is as expected less than on JUROPA due to the slower clock speed of JUQUEEN's A2 processor. But with evolving models OpenFOAM on JUQUEEN will be the only option to handle frequent production runs of the required sizes.

At present work at JSC is under way to analyze the scaling behaviour of OpenFOAM using modern performance analysis tools like Scalasca [3, 4] which is a joint development of JSC and the German Research School for Simulation Sciences. The main goal of the JSC work package is to reduce performance and scaling bottlenecks in OpenFOAM to enable large simulations on JUQUEEN.

Project Partners

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References

[1] http://www.fz-juelich.de/ias/jsc/EN/Research/Projects/_projects/cec.html

[2] http://www.openfoam.org

[3] **Geimer, M., Wolf, F., Wylie, B.J.N., Ábrahám, E., Becker, D., Mohr, B.** The Scalasca performance toolset architecture, Concurrency and Computation: Practice and Experience, 22(6):702-719, April 2010.

[4] http://www.scalasca.org

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