Implementation of a Virtual Turbine - Towards interactive design of hydraulic turbomachinery

Hubert Hérenger

High Performance Computing Centre
Stuttgart

Abstract:

The current standard design process for hydraulic turbines is a complex iterative procedure. It consists of geometry definition for a single turbine component, usually using a CAD tool. The CAD model subsequently is imported into a meshing tool to create a computational mesh for this component. Using the mesh a simulation is performed for the component. Postprocessing the simulation results quality of the component design is assessed. If the quality is insufficient the geometry has to be adjusted and the previous steps have to be repeated. Once a satisfactory design for all components (spiral casing with stay vanes, wicked gate with guide vanes, runner, and draft tube) has been found a coupled simulation has to be performed in order to resolve interactions of the single components and assess overall performance and quality of the turbine. Results of the coupled simulation might lead to further iterations of the initial design process for single components.
In order to shorten the development cycles for hydraulic turbines a Virtual Turbine (VT) currently is being developed. A VT is understood as a numerical model of a real turbine embedded in a Virtual Reality (VR) environment. The goal of the VT is to allow interactive manipulation of a turbine like geometry adaptation, changing operational parameters such as discharge, guide vane and runner blade angel, speed etc.. Ideally the changed flow conditions immediately should be available and visualized.
To realize a VT OpenFOAM is connected to COVISE. COVISE is an extendable distributed software environment developed at the High Performance Computing Centre (HLRS) to integrate simulations, postprocessing and visualization functionalities in a seamless manner. COVISE provides mesh generator modules for gate, runner and draft tube thus satisfying parts of the pre- and postprocessing requirements for interactive turbomachinery simulations.
The other important requirement for interactive simulations is to obtain short latencies. To realize required latencies simplifications need to be applied to the underlying simulation problem. Possible simplifications can be classified as either model simplifications or simplifications through reduction of the problem size. Model simplifications hereby are turbomachinery specific simplifications (simulation of one blade passage with periodic boundary conditions in the most simple case against full 360° coupled simulation of all components as most complex case) or simplifications of the physical model (Navier-Stokes, Euler or Potential

flow simulations).
The VT target system will allow an engineer to reduce complexity of the underlying simulation problem such that it bests fits requirements for accuracy and latency during all design phases. Results obtained with a simpler model will consistently will be used to create as good initial solutions as possible for simulations of the next level of complexity up to the coupled simulation of the entire turbine.
The full paper discusses results of parallel OpenFOAM Navier-Stokes, Euler and Potential flow simulations for different turbine components performed on different HPC resources of HLRS with respect to scalability followed by a discussion of viability and usability of Euler and Potential flow simulations compared to Navier-Stokes simulations.