PRACE days 2018

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Optimising 2D simulations for faster, better steam turbine design

A SHAPE Project collaboration between Renuda UK Ltd and EPCC, the High Performance Computing centre at the University of Edinburgh

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Outline

1. Renuda and Projects
2. Turbine Simulations and CodeX
3. CodeX HPC
4. Conclusions
1. Renuda and Projects
• CFD Specialists
  • Consulting, Software development, Training
  • Fully independent
  • UK, France, Germany

• Blue Chip Clients
  • Applications from single phase pipe flow to turbomachinery, multiphase flow, coupled heat transfer, mechanical calculations
  • Industries: transport, automotive, processing, nuclear, power generation, civil engineering

• Compete on
  • Skills
  • Difficult problems
Research Partnership And Collaborations

• Research and development is very important
• Collaborative research relationship with EDF R&D on the development of *Code_Saturne*
• Collaboration with the Salome teams:
  ▪ Development of GUI for CodeX
    • From CAD to Analysis
• Part of the UK Consortium on Turbulent Reactive Flow
• Collaboration with different universities and research labs
  ▪ University of Manchester
  ▪ Daresbury Laboratory (Science and Technology Facilities Council) – HPC research and application
  ▪ EPCC (SHAPE project)
Illustrative Projects

• Different applications to a wide range of industries
  ▪ Waste water treatment
  ▪ Machine and plant engineering
  ▪ Auto industry
  ▪ Process industry
  ▪ Energy: Nuclear, Hydro
  ▪ Turbomachines
• Mesh motion
• Multiphase
  ▪ Lagrangian
  ▪ Drift flux
  ▪ VOF
• Application and development
2. Steam Turbine Modelling and CodeX
Industrial Context

- Power generation

- Predicting the performance of steam turbines: power, losses, efficiency, etc.
  - Retrofits, modifications, optimisation, operating conditions, etc.
- Challenge: Quick tool for decision making by non-CFD specialists
• Throughflow code: the Navier-Stokes equations are projected in the meridian plane of the (axial) turbine and reduced to two-dimensions
• Solve for mass, momentum and energy conservation
• Fewer dimensions means faster solution, but complex physics
  ▪ Compressible flow with heat transfer
  ▪ Steam and real gas thermodynamics
  ▪ Large machines with important number of stages (e.g 15)
  ▪ Rotor-stator pairs, rotating flows with complex blade shapes
  ▪ Blade modelling
  ▪ Correlations and specific models for turbomachinery losses
  ▪ Bleeds
• Validated for a number of single-stage test turbine and multi-stage high-pressure and low-pressure industrial turbines against other, 3D CFD software

• Development of a GUI for non-CFD specialists, turbine engineers to allow
  ▪ Creation of the turbine
  ▪ Meshing
  ▪ Solution
  ▪ Analysis with pertinent output data
    • E.g. power per stage and Mollier diagrams

• Serial code may still require of the order of days for large turbines and difficult operating conditions

SHAPE Project with EPCC to parallelise CodeX
3. CodeXHPC
SHAPE Project

- Collaboration with EPCC
  - Expertise with parallelisation and supercomputers
- With the necessary confidentiality agreements in place, file sharing through repository
  - Excellent for collaboration and exchanges, real time collaboration
- Multi-stage, iterative project with regular conference calls
  1. Extensive code review and benchmarking
  2. Development of an implementation strategy
    1. Prioritisation of the target procedures
    2. Choice of parallelisation
  3. Implementation and validation
  4. Book keeping
Scope

• Phase 1: Review and benchmarking
  ▪ Already achieved benefits
  ▪ Code restructuring to prepare for parallelisation
  ▪ Speed up through reorganisation
  ▪ Speed up of the tabulated methods for steam thermodynamics
• Phase 2: Priorities and choice of parallelisation
  ▪ Timing of the different components of the code
  ▪ Different cases and both perfect gas and steam thermodynamics
  ▪ Choice of OpenMP implementation
    • Did not require to restructure for domain decomposition
    • Directly beneficial even on smaller machines
• Phase 3: Implementation
  ▪ Application of OpenMP directives
Results

- Excellent speed up demonstrated on a range of cases, for example for the HP1300 turbine:
  - Perfect gas

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- Steam

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4. Conclusions and Future Work
Conclusions and Future Work

- Successful collaboration through the SHAPE project with EPCC
- Successful introduction of OpenMP in CodeXHPC, with the added benefit of the code restructuring and optimisation
- The level of performance achieved in SHAPE, opens up the utilisation of CodeXHPC
  - As a useful tool in industrial settings
  - For more advanced modelling: larger models, added physics
- On-going activities to
  - Install and validate CodeXHPC on different machines, local machines and clusters
  - Finalise the GUI