RENUDA
FLUID SOLUTIONS

PRACE days 2018

29 May 2018

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

N. Tonello[a], P. Asproulis[a], K. Stratford[b], N. Banglawala[b], P.Graham[b]
[a]Renuda, UK Ltd
[b]EPCC, University of Edinburgh, UK

Acknowledgements:

SHAPE
EPCC, the HPC centre at the University of Edinburgh
EDF

Contact

For further information, please contact:

Nicolas Tonello
Director
RENUDA

nicolas.tonello@renuda.com

T: +44 (0)20 3371 1709

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)

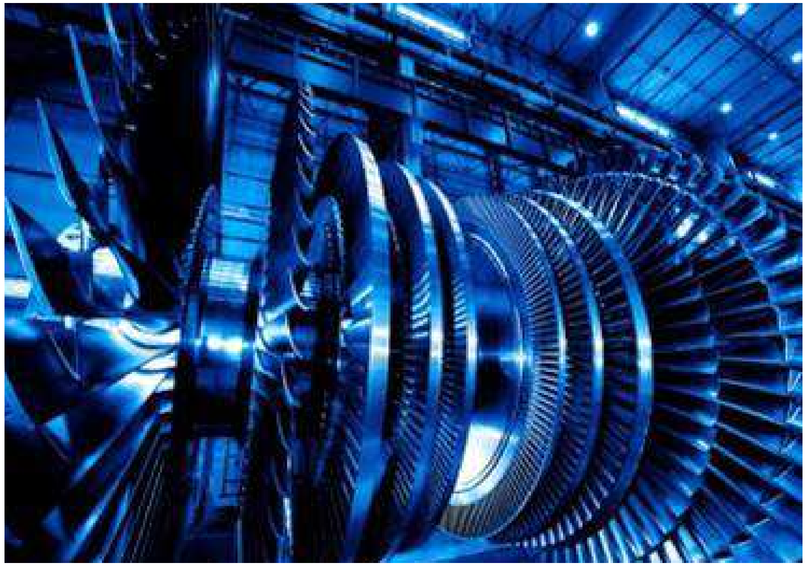
Illustrative Projects

- 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

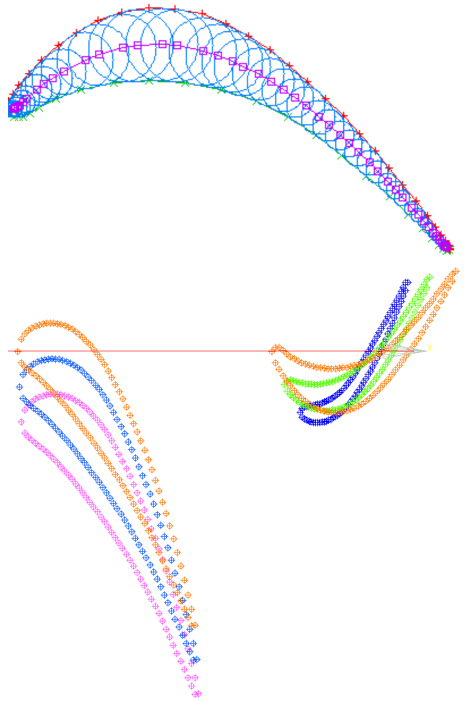
- Power generation



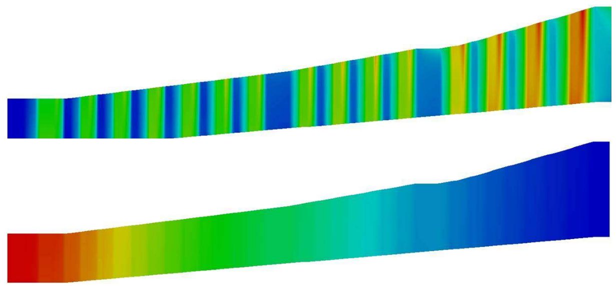
- Predicting the performance of steam turbines: power, losses, efficiency, etc.
  - Retrofits, modifications, optimisation, operating conditions, etc.
- Challenge: Quick tool for decision making by non-CFD specialists

CodeX

- 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 parallelistion
  - 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

		Original	Modified: 1 core		Modified: 8 core		Modified: 16 core	
Case	Iterations	Time (s)	Time (s)	Speedup v Original	Time (s)	Speedup v Original	Time (s)	Speedup v Original
Mesh1	10000	1142	1030	1.1	189	6.0	139	8.2
Mesh2	10000	4137	3696	1.1	526	7.9	345	12.0
Mesh3	14178	14670	12370	1.2	1768	8.3	973	15.1
Mesh4	30000	59620	48430	1.2	6546	9.1	3544	16.8

  - Steam

		Original	Modified: 1 core		Modified: 8 core		Modified: 16 core	
Case	Iterations	Time (s)	Time (s)	Speedup v Original	Time (s)	Speedup v Original	Time (s)	Speedup v Original
Mesh1	10000	3287	1328	2.5	304	10.8	216	15.2
Mesh2	10000	10850	4597	2.4	713	15.2	493	22.0
Mesh3	20000	49240	22320	2.2	3233	15.2	1919	25.7
Mesh4	30000	134000	60790	2.2	8822	15.2	4940	27.1

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