Introduction to PCA Engineers Limited

Chris Robinson

PCA Engineers Limited, UK
Basic facts on PCA

• Independent consultancy based in Lincoln, UK
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• Specialists in turbomachinery design and analysis
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Basic facts on PCA

- Independent consultancy based in Lincoln, UK
- Specialists in turbomachinery design and analysis
- Established in 1989; staff have long industrial experience
- Users of ANSYS’ CAE tools for over 20 years
  - 1D Design tools from ANSYS 11
  - Vista TF in from ANSYS 12
Industries served

- Aero gas turbines
- Turbochargers
- Industrial compressors and expanders
- Industrial gas turbines
- Steam turbines
- Low speed fans
- Power generation
- Repair and overhaul
Experience in China since 2009

PCA Engineers Limited is an international engineering consultancy specialising in turbomachinery aero-mechanical design and turbomachinery design software.

Established in 1989, PCA serves many of the world’s leading manufacturers of axial and radial turbomachinery, including aerospace, energy, industrial gas turbines, steam turbines, air compressors, turbochargers, gas compressors and expanders, fans, and pumps.

The company provides the following services and products:

- Centrifugal and Axial Compressor design
- Radial and Axial Turbine design
- Fan design
- Expander design
- Pump design
- CFD analysis
- Software systems for turbomachinery design
- Finite Element structural analysis
- Field service problems in compressors or turbines
- Re-rate of in-service turbomachinery
- Training in turbomachinery design
- Expert Witness services

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PCA工程咨询有限公司是一家国际化的工程咨询专业公司，专长于透平机械的气动和结构设计以及涡轮机械设计软件的开发。

PCA公司始建于1989年，致力于为全球众多世界著名的企业提供服务。业务涉及：航空燃气轮机、工业燃气轮机、气轮机、空气压缩机、透平增压器、燃气压缩机和抽抽器、风扇以及泵类机械。

公司提供的服务及产品包括：

- 压气机设计；
- 径转设计；
- 离心设计；
- 扩散器设计；
- 收集设计；
- 计算流体分析；
- 透平机械的设计软件系统；
- 有限元分析；
- 压气机和涡轮旋转的性能分析；
- 现场透平机组的改进设计；
- 透平机组设计的培训；
- 专家论证服务；
Accurate, efficient gas turbine and turbocharger design with ANSYS products

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PCA Engineers Limited
Lincoln, UK

www.pcaeng.co.uk
Centrifugal Stage Design in ANSYS Workbench
Integrated design system

PCA's Vista CCD in ANSYS Workbench
Vista CCD and CCM
What is a 2D throughflow solution?

- Solution on a mean S2 surface
  - Solution of the pitchwise averaged equations of motion
  - Take account of the spanwise variation in parameters
  - First estimates of the performance of 3D geometry can be made
The key component in design systems

- Split-flow aero-engine LP system
What is a 2D throughflow solution?

• Simplicitic but rapid tool amenable to optimisation
• Saves time in the design process

• Brings added value:
  ◦ More complete coverage of the design space
  ◦ Assimilation of good practice from earlier designs
Vista TF solution

- Meridional velocity, Mn and loading
Vista TF solution

• Incidence and loading parameters

Vane and gas angles

\[ \lambda = \Delta H/U^2 \]

\[ \text{de Haller} = \frac{W_2}{W_1} \]

Incidence profile
VistaTF – turbocharger impeller

Inducer quite highly loaded, rapid diffusion

Loading falls to zero near splitter leading edge

Mach, Mach_ss, Mach_ps

Very low (no) diffusion of the mean flow around the axial-radial bend

Diffusion at the shroud moderate \( W_2/W_1 = 0.65 \)

Work factor \( \Delta H/U^2 = 0.6 \)

Low incidence at the shroud

Very high incidence at the hub

Needed for throat area
What VistaTF can do

- Feedback in almost real-time, for single row analysis
- Accurate representation of flows dominated by curvature effects
- Predicted Mn distributions at hub, mid and shroud
- Warnings of possible problems with choke
- Suitability of splitter location
- Predicted Euler work input ($\Delta H/U^2$) taking account of vane angles and rake
- Accurate assessment of incidence across the span
- Distribution of vane loading parameters for comparison with experience
- Possibility of automated optimisation
Comparision TF vs CFD

IGV LE meridional velocity (m/s)

TF

CFD
Comparison TF and CFD

ANSYS CFX

Vista TF

Throughflow

CFD
Design decisions

High curvature

High Mn, possible choking

Optimised design

Alternative inlet

Severe incidence profile
Typical application of throughflow

- Reduce inertia
- Maximise performance
What VistaTF cannot do

- Direct prediction of efficiency
- Surge line and choke limits in detail
- Viscous flow phenomena
- Flow phenomena driven by secondary effects such as clearance
- Transient effects

Not an alternative to CFD!
SC90 for axial compressors and turbines

Overall Performance Characteristics

Polytropic efficiency

Mass flow kg/s

Pressure ratio

Multistage compressor map predicted by SC90C
CFD Analysis
CFD calculations

- Post-processing macros are used
Transonic inlet optimisation

Conventional

Pre-compression
Fully 3D impeller design

Lean and sweep to optimise aerodynamics and structure.
Advanced impeller design

- 3D design concepts such as Lean and Sweep has been used for aerodynamic and structural reasons (Hazby et al. (2014))

better control of the shock

95% span

70% span
Transient blade row methods

- Time Transformation method in CFX is used to calculate the unsteady flow field with non-matching rotor-stator interfaces
Applications of DesignModeler
Secondary flow paths
Shrouded compressor stage
Parametric volute design

\[(A/r)_{th} = 2\pi b/\tan \alpha\]
Parameterised volute design in WB

Standard

Compact
Tip speeds of 340, 394, 525 and 550 m/s
Streaklines at the extents of the map

Near choke

Near surge
Manufacturing geometry

- Geometries which are prepared in DesignModeler can be exported in CAD formats
- Ensures consistency between the analysed and manufacturing geometries
Structural analysis
Stress analysis

Mesh

Imported temperatures

Imported pressures

Stress field
Mechanical mitigation

- Thickness necessary to achieve adequate stiffness
- Splitter can have lower thickness
- Other mitigation, axial lean of the leading edge
Relying on ANSYS products
Gas turbine capability

• Empirical knowledge
• Then relying on CFX
Industrial gas turbine mechanical design

Mode 1  Mode 2  Mode 3

Shroud 18  Shroud 18
Gas turbine aerothermal design
Relying on CFX

Dealing with excessive tip clearances

First application of Mixed Flow at high Mach number, high loading
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