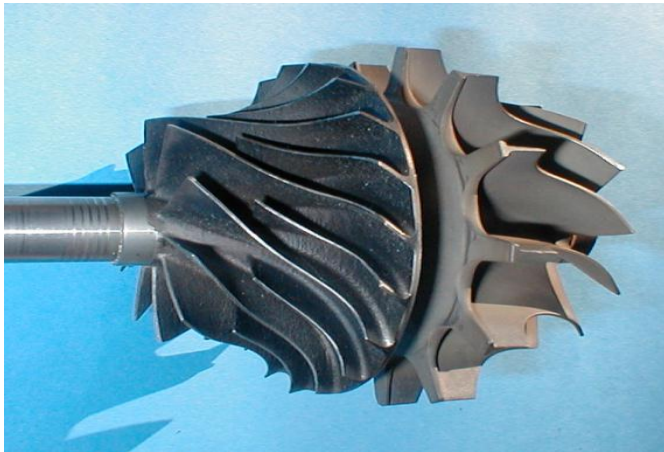


ANSYS®



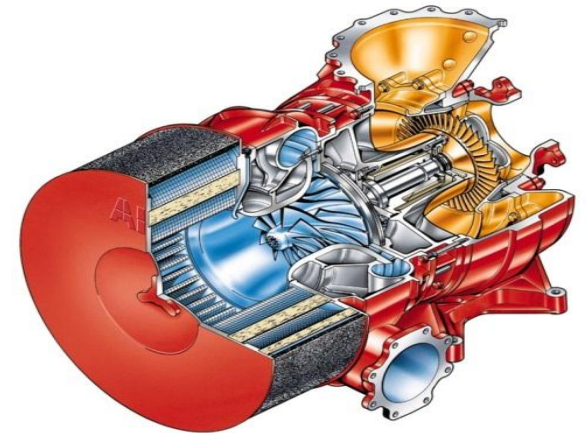
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Introduction to PCA Engineers Limited



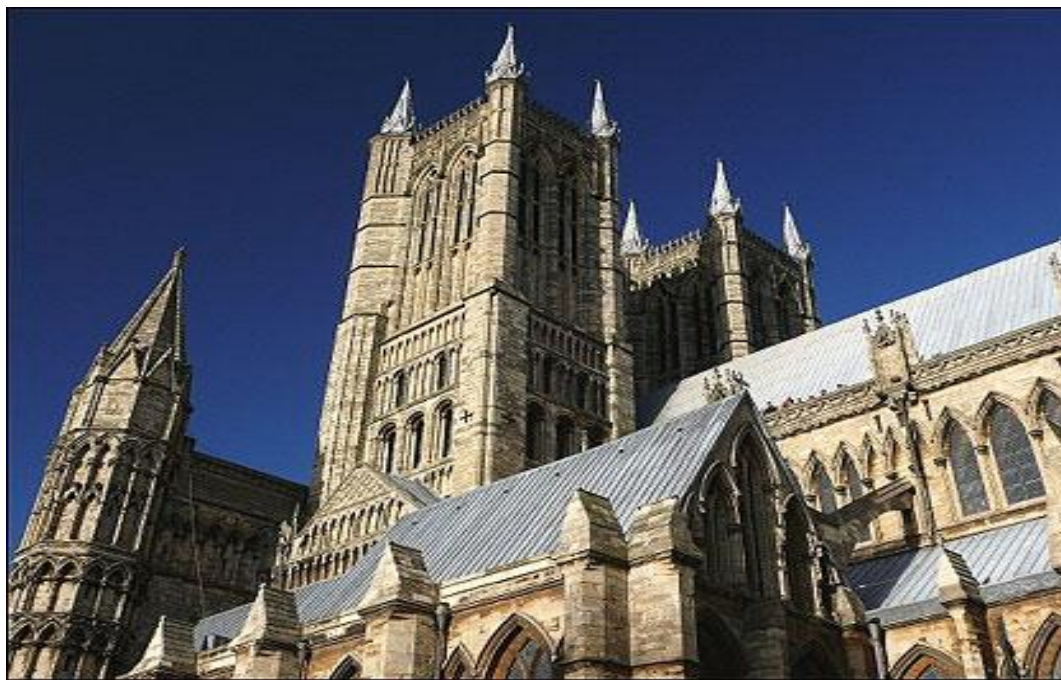
Chris Robinson

PCA Engineers Limited, UK



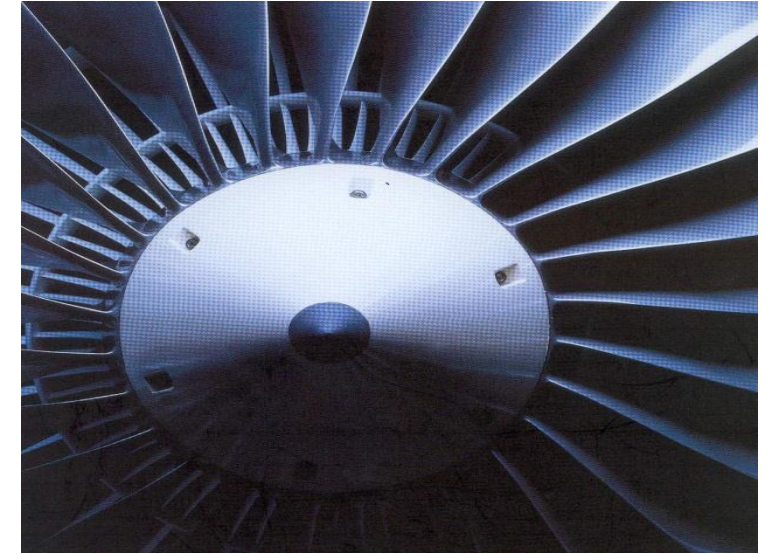
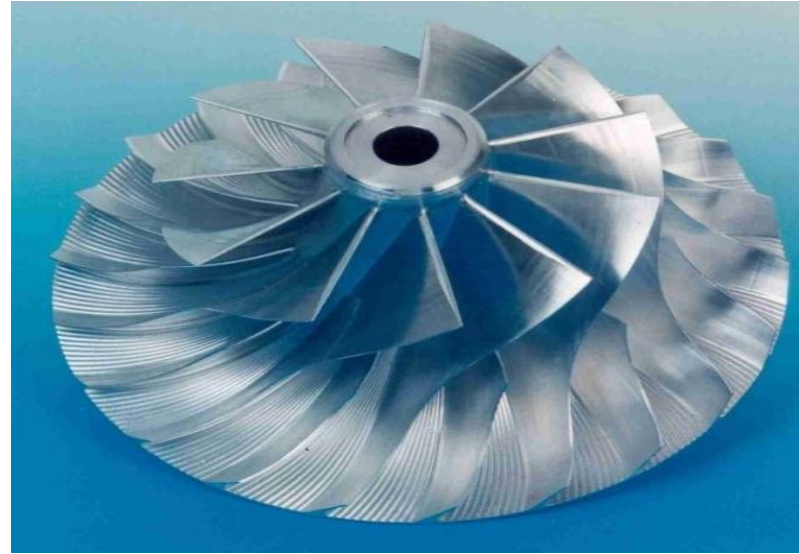
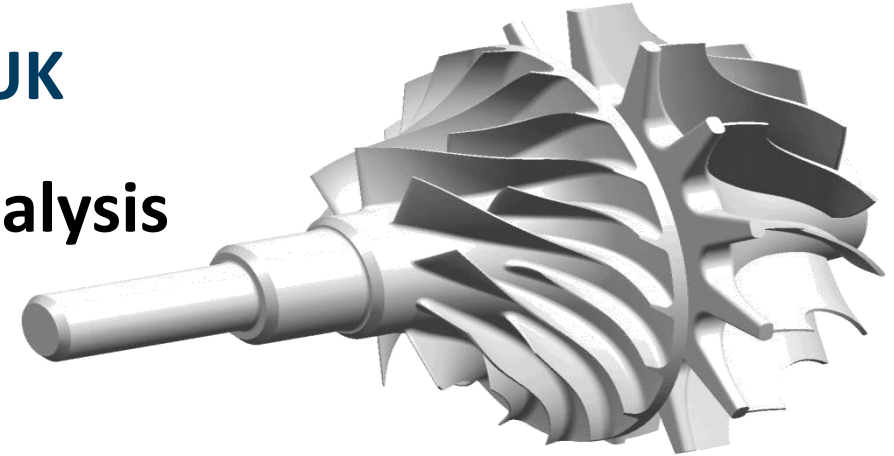
Basic facts on PCA

- Independent consultancy based in Lincoln, UK



Basic facts on PCA

- Independent consultancy based in Lincoln, UK
- Specialists in turbomachinery design and analysis



Basic facts on PCA

- Independent consultancy based in Lincoln, UK
- Specialists in turbomachinery design and analysis
- Established in 1989; staff have long industrial experience

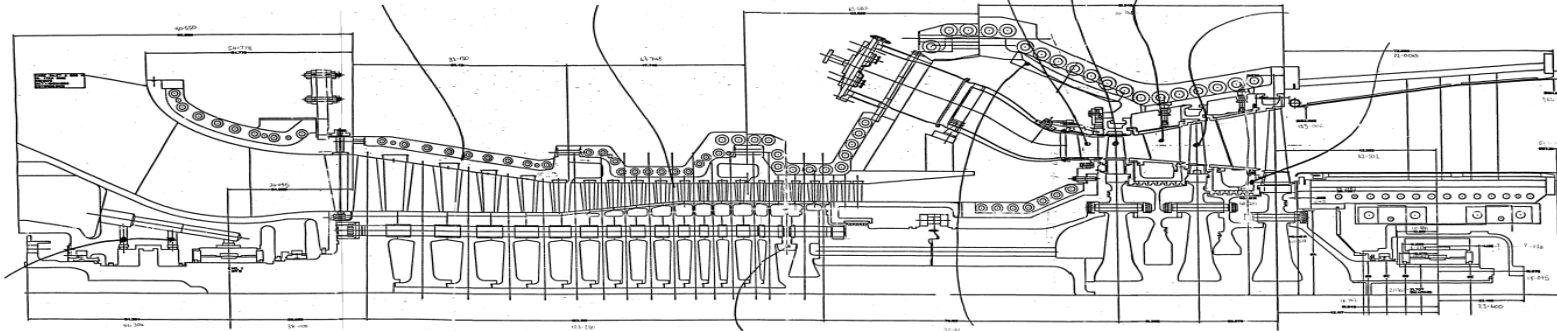


Rolls-Royce

SIEMENS

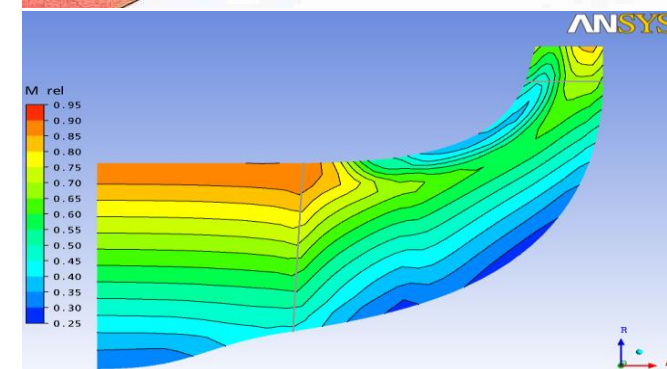
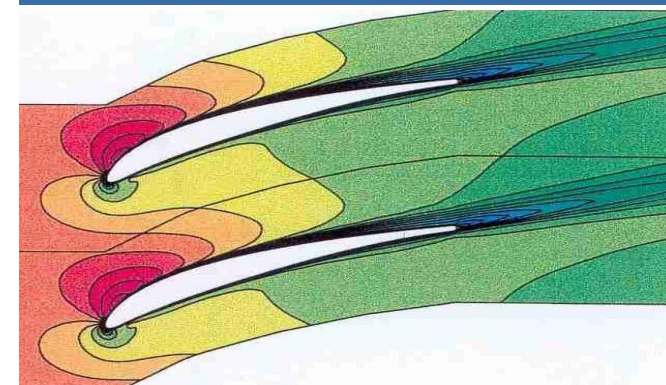
SULZER
TURBO

QinetiQ



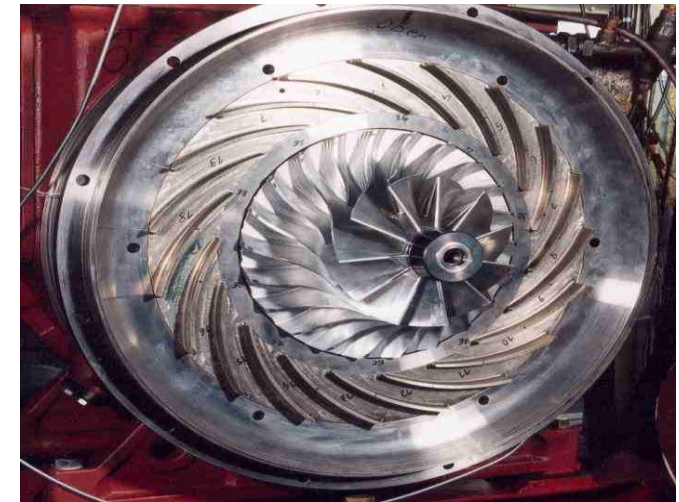
Basic facts on PCA

- 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



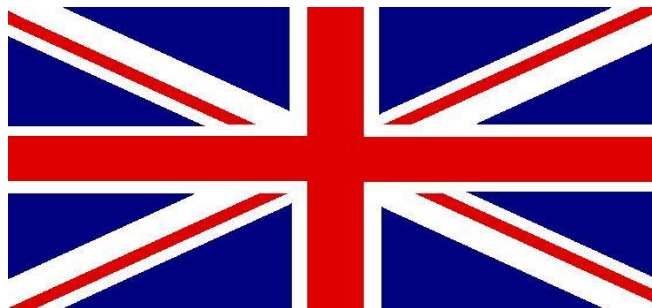
Experience in China since 2009

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 aero gas turbines, 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 compressor or turbines
- Re-rate of in-service turbomachinery
- Training in turbomachinery design
- Expert Witness services



欢迎来到PCA工程咨询有限公司（PCA Engineers Limited）的网站。

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公司创建于1989年，致力于为众多世界著名的轴流式、径流式涡轮机械制造商提供服务。业务涉及：航空燃气轮机、工业燃气轮机、气轮机、空气压缩机、涡轮增压器、燃气压缩机和扩压器、风扇以及泵类机械。

公司提供以下的服务及产品：

- 压气机设计；
- 涡轮设计；
- 风扇设计；
- 扩压器设计；
- 泵设计；
- 计算流体动力学分析；
- 涡轮机械的设计软件系统；
- 有限元结构分析；
- 压气机和涡轮现场故障诊断；
- 现装透平机械的改进设计；
- 涡轮机械设计的培训；
- 专家见证服务；



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Accurate, efficient gas turbine and turbocharger design with ANSYS products

Chris Robinson

PCA Engineers Limited, UK

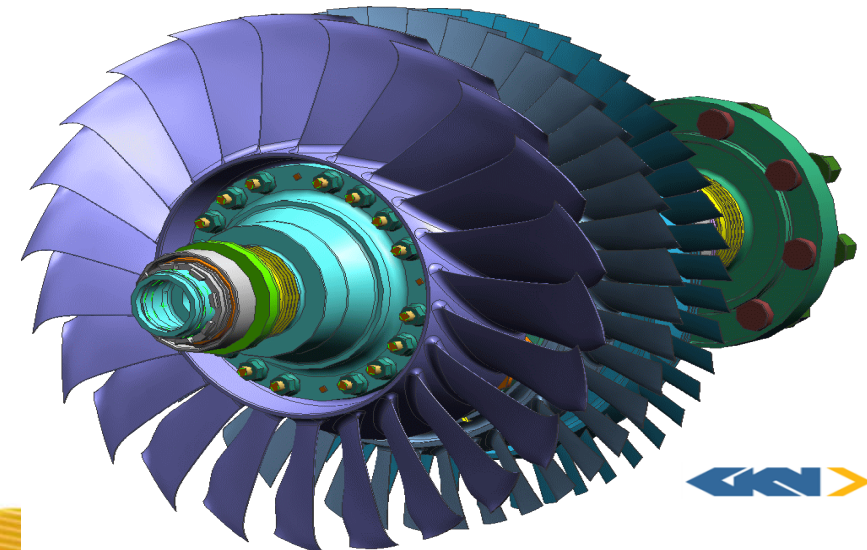
Accurate, efficient gas turbine and turbocharger design with ANSYS products

Chris Robinson

PCA Engineers Limited

Lincoln, UK

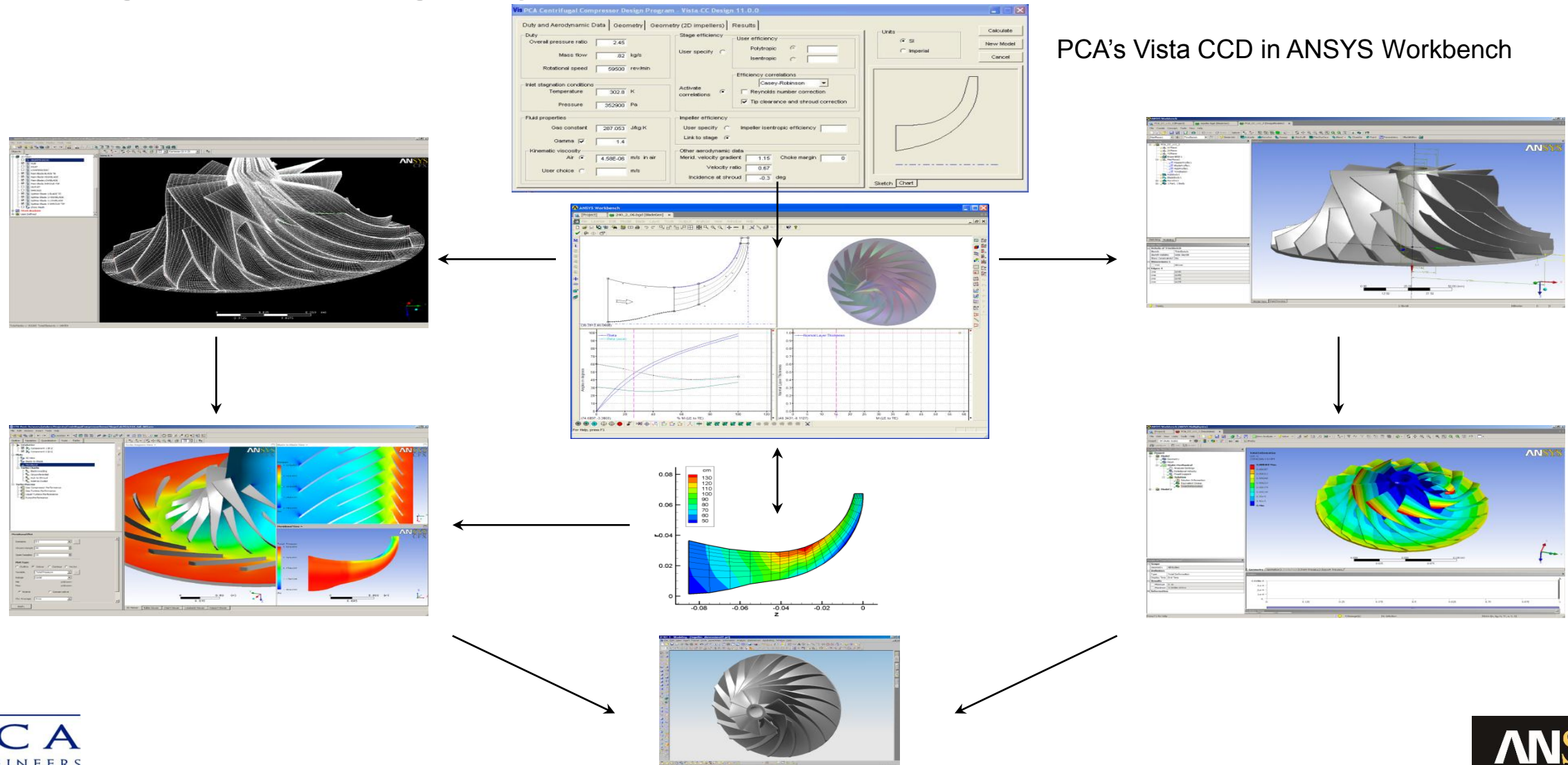
www.pcaeng.co.uk



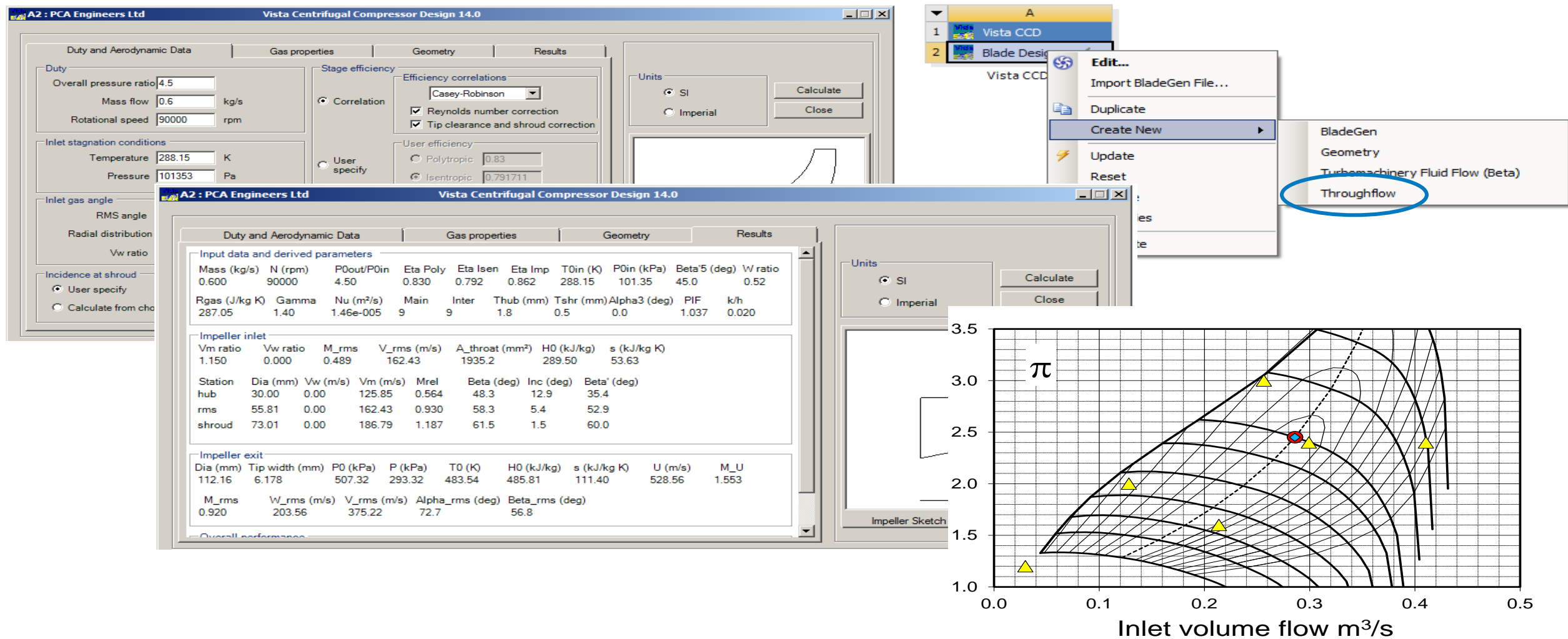
Centrifugal Stage Design in ANSYS Workbench

Integrated design system

PCA's Vista CCD in ANSYS Workbench

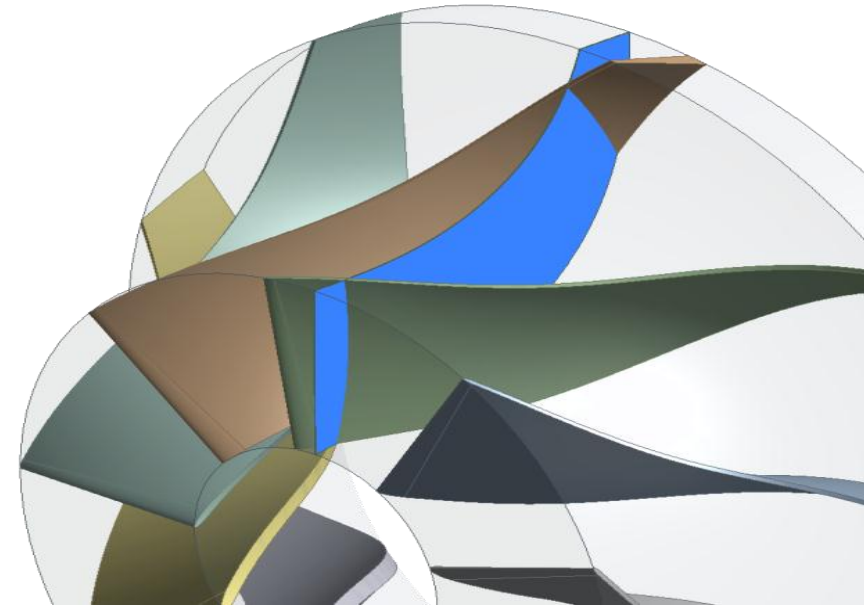
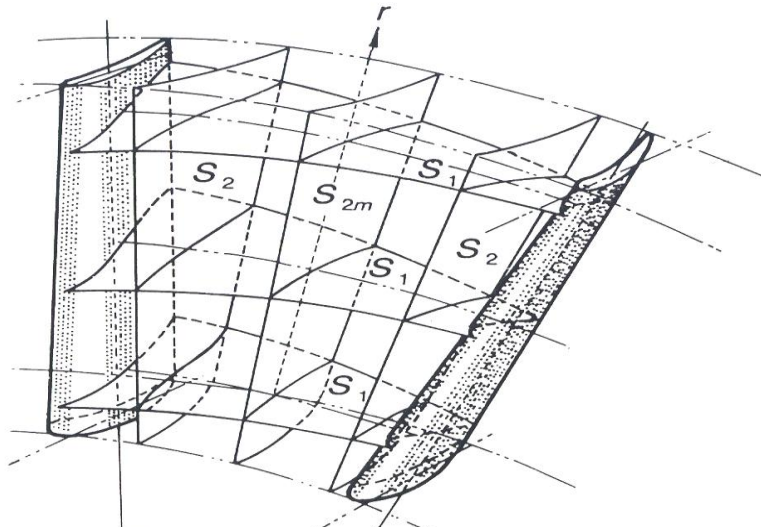


Vista CCD and CCM



What is a 2D throughflow solution?

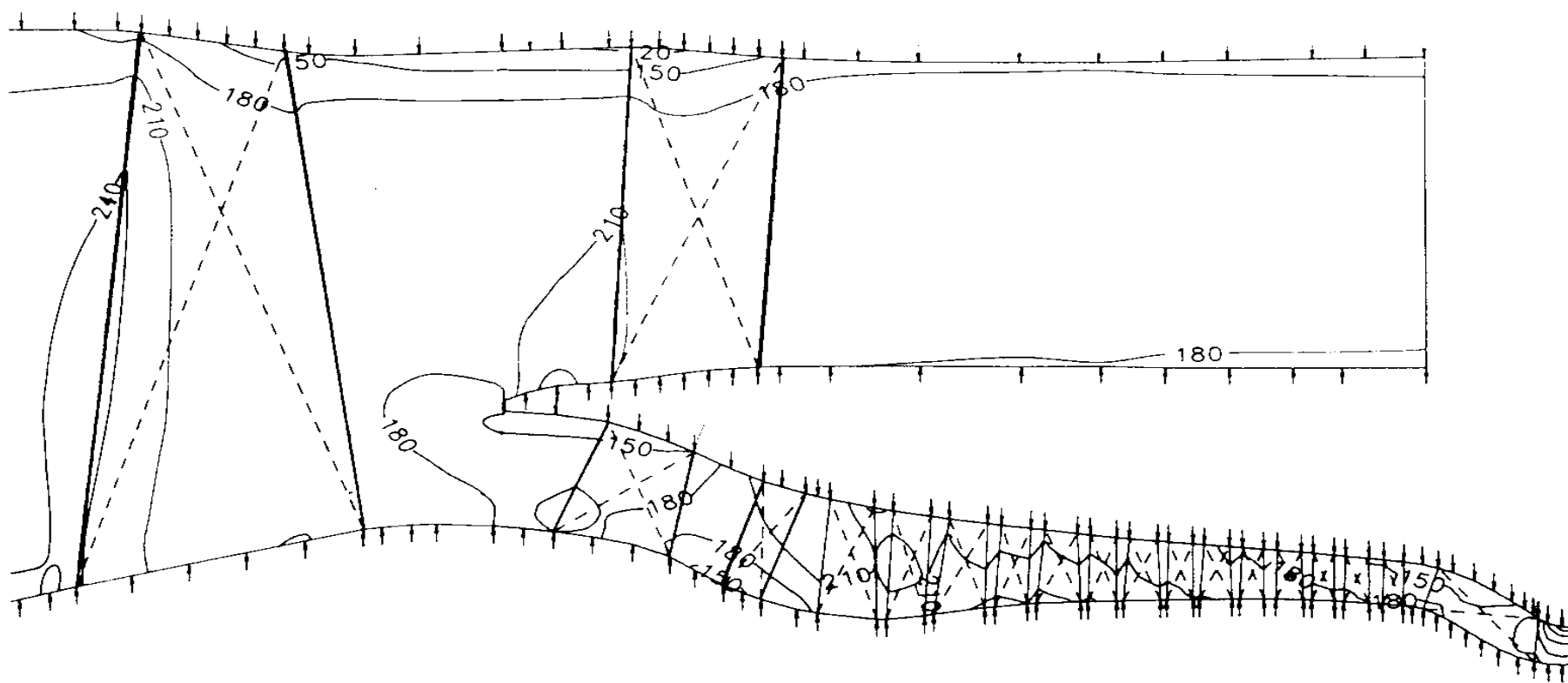
- **Solution on a mean S2 surface**
 - Solution of the pitchwise averaged equations of motion
 - Take account of the spanwise variation in parameters
 - First estimates of the performance of 3D geometry can be made



S1-S2

The key component in design systems

- Split-flow aero-engine LP system



AXIAL-VELOCITY (M/SEC)

What is a 2D throughflow solution?

- Simplistic but rapid tool amenable to optimisation
- Saves time in the design process

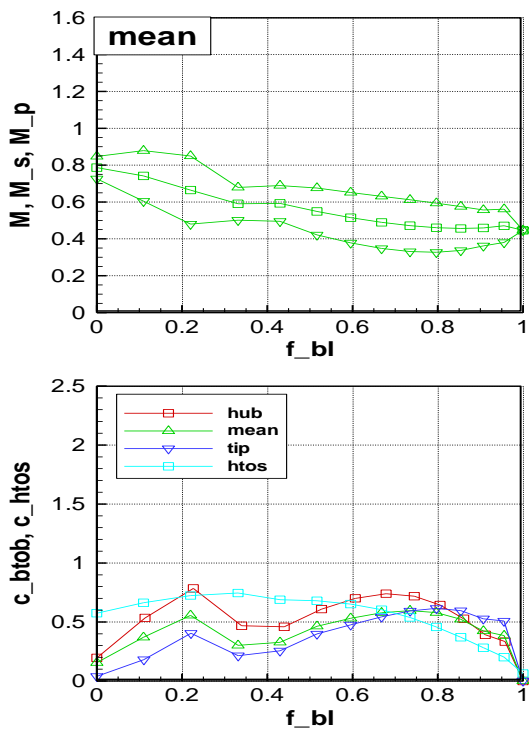
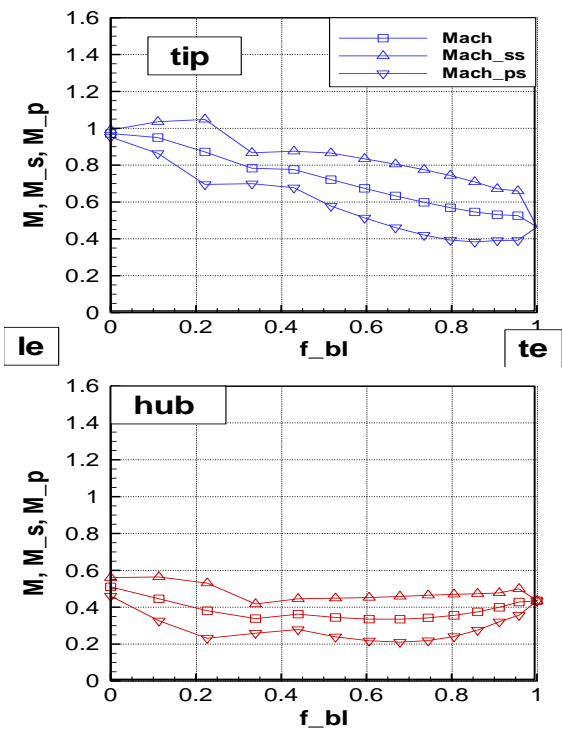
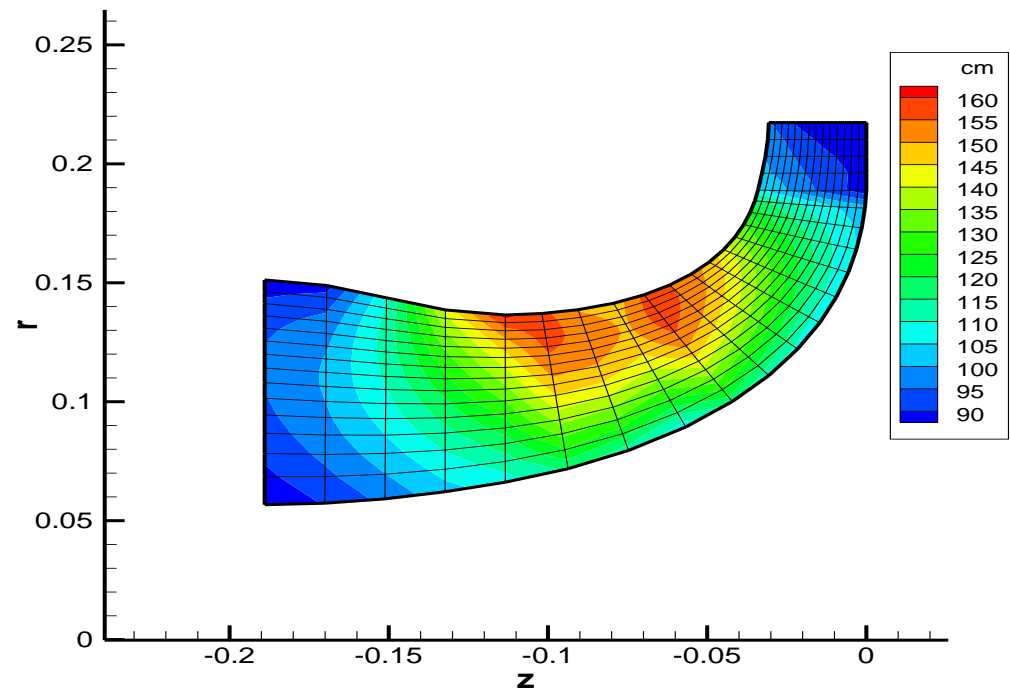
1D Design	Vista CCD		
Development of the 2D design	BladeGen and Vista TF		
Refinement and confirmation with CFD	CFX		

1D Design	Vista CCD		
Definition of vane shape	BladeGen		
Development and confirmation with CFD	CFX		

- Brings added value:
 - More complete coverage of the design space
 - Assimilation of good practice from earlier designs

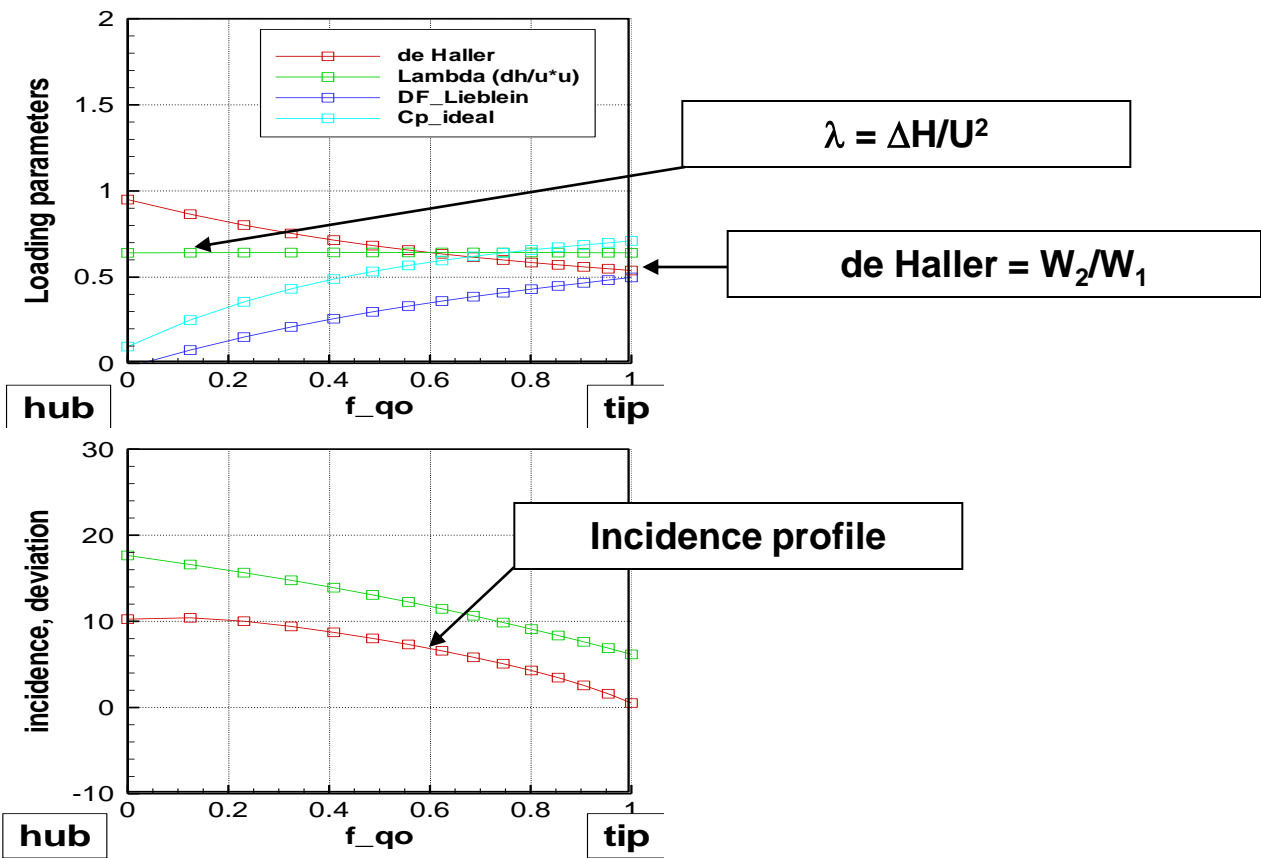
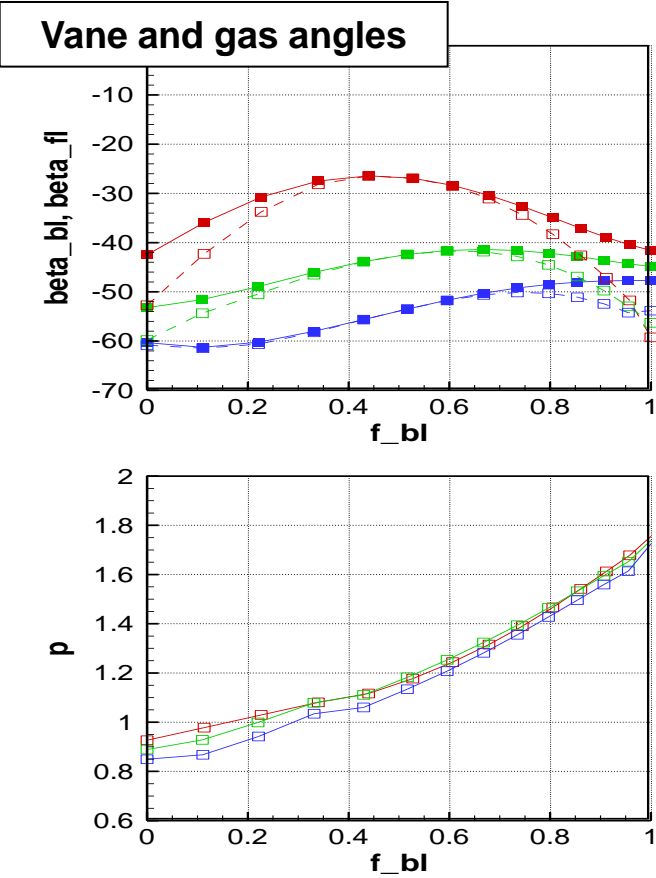
Vista TF solution

- Meridional velocity, Mn and loading



Vista TF solution

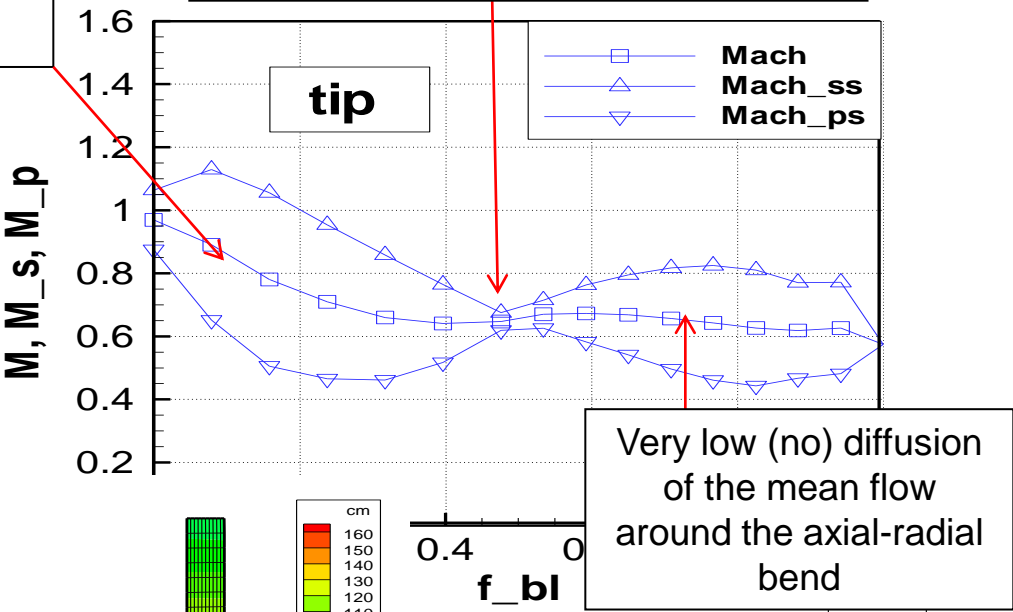
- Incidence and loading parameters



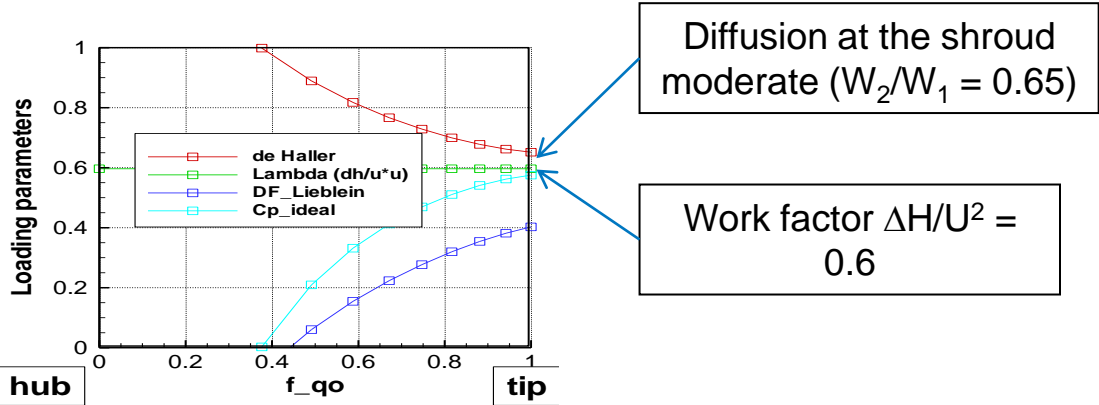
VistaTF – turbocharger impeller

Inducer quite highly loaded, rapid diffusion

Loading falls to zero near splitter leading edge

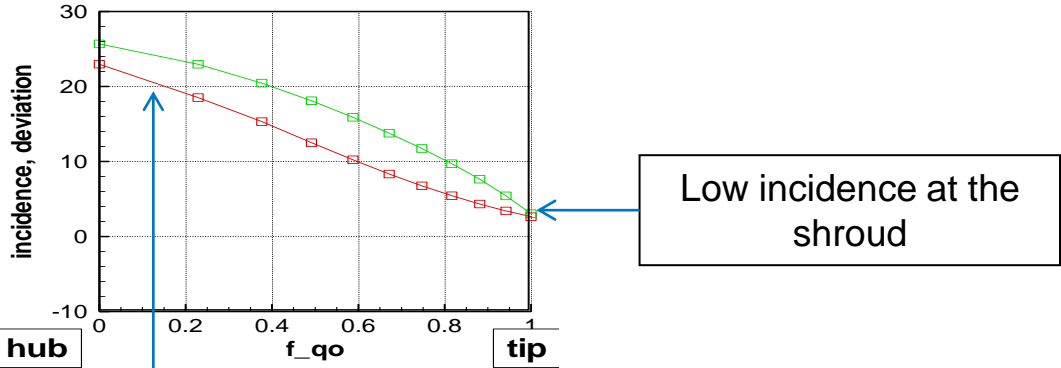


Very low (no) diffusion of the mean flow around the axial-radial bend



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

Work factor $\Delta H/U^2 = 0.6$



Low incidence at the shroud

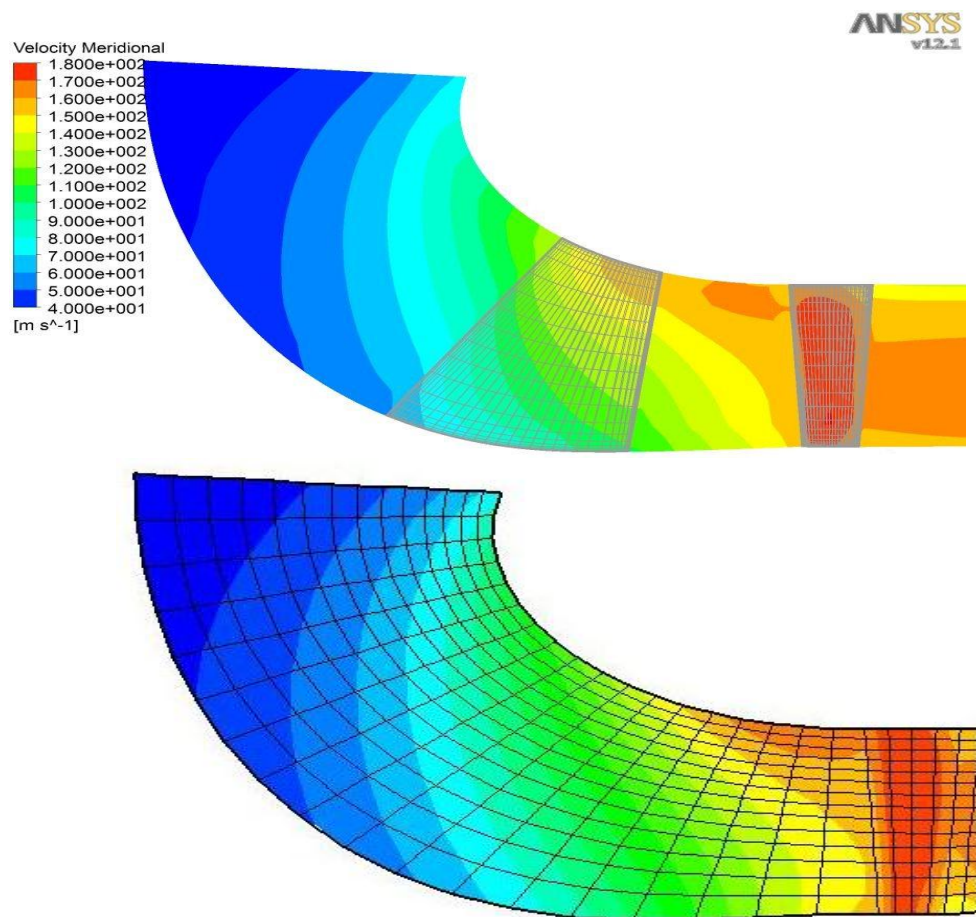
Very high incidence at the hub

Needed for throat area

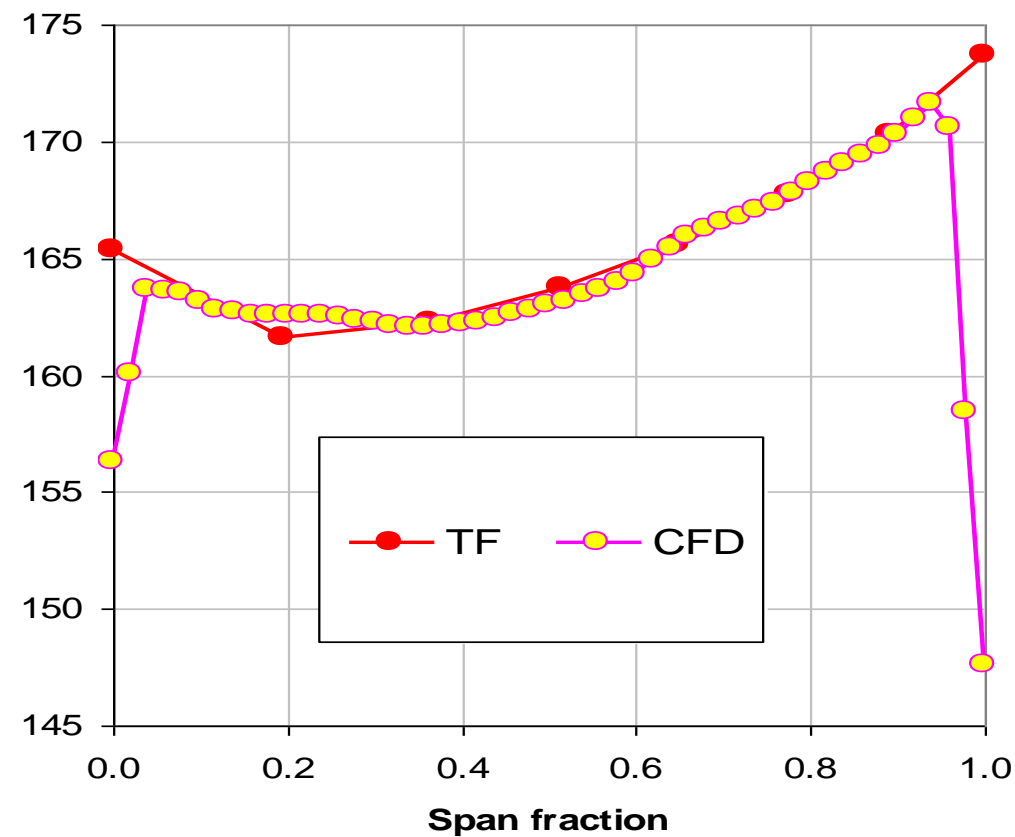
What VistaTF can do

- 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

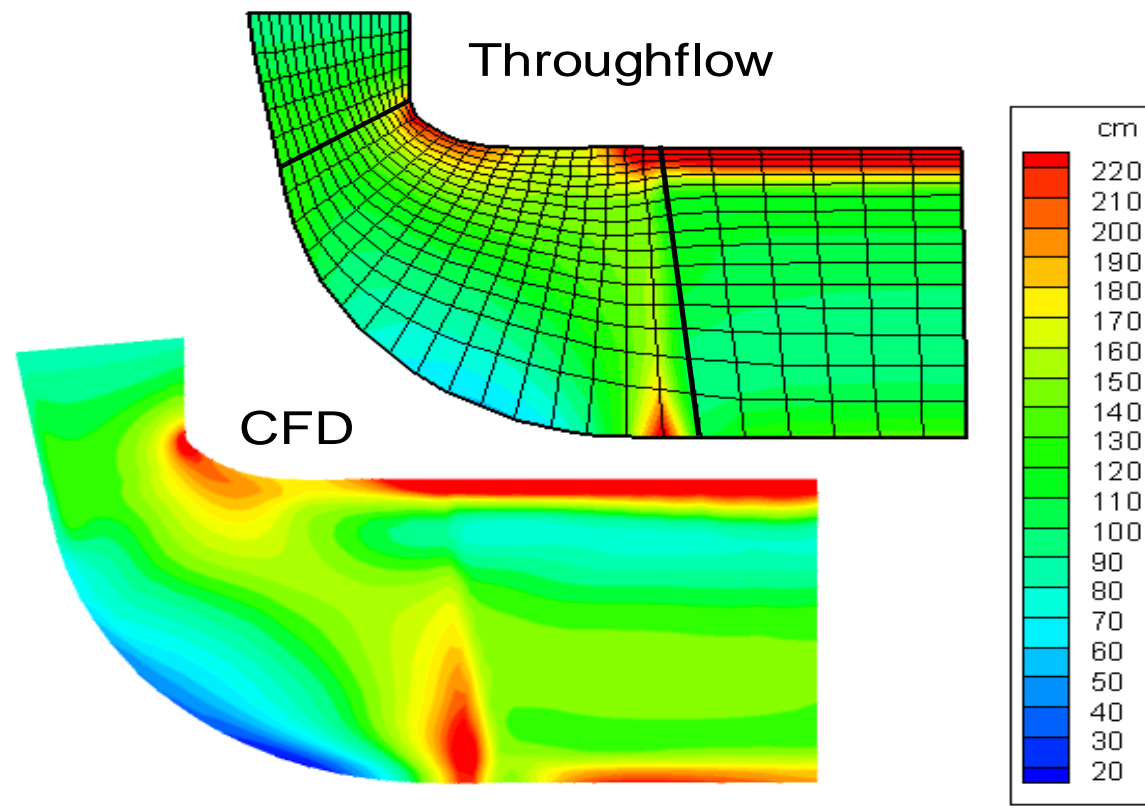
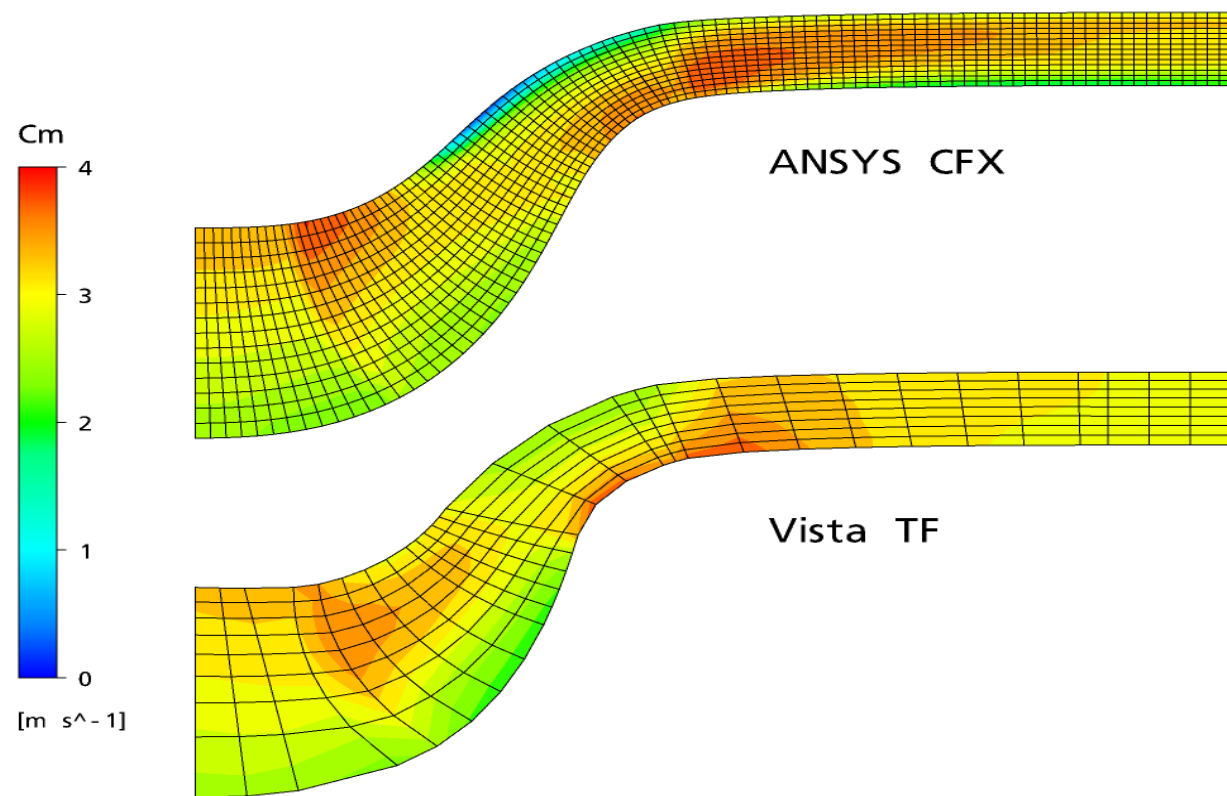
Comparison TF vs CFD



IGV LE meridional velocity (m/s)

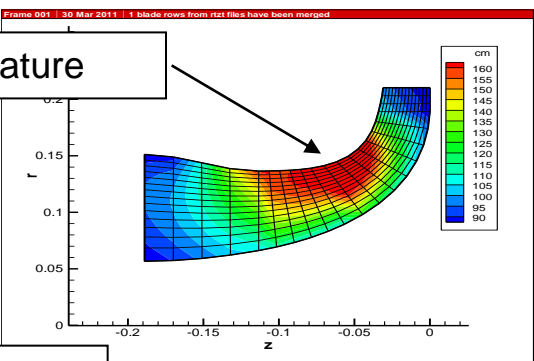


Comparison TF and CFD

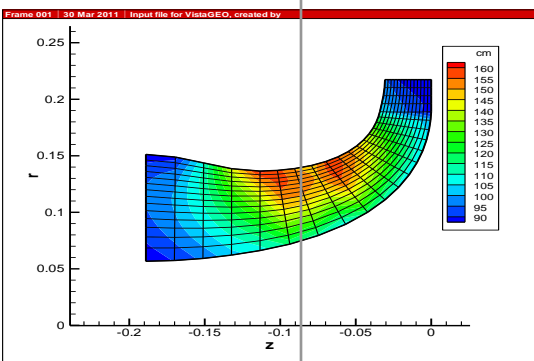


Design decisions

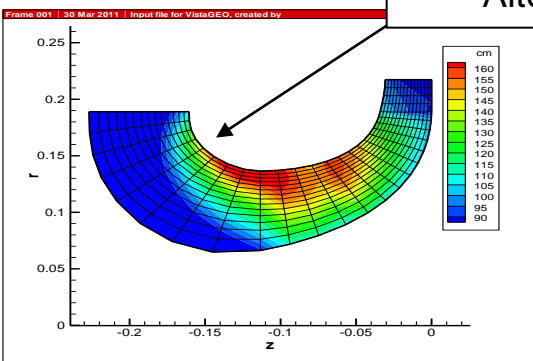
High curvature



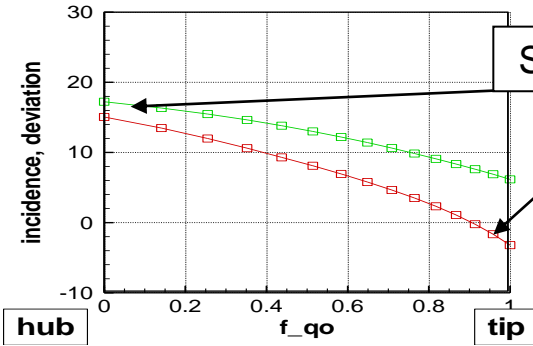
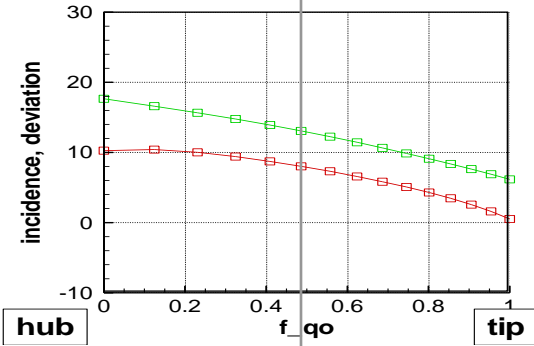
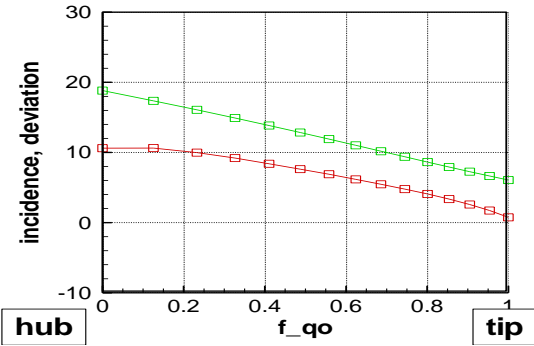
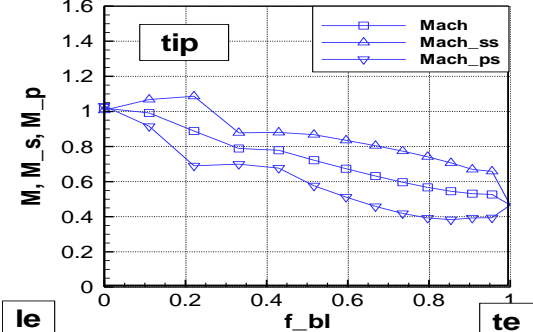
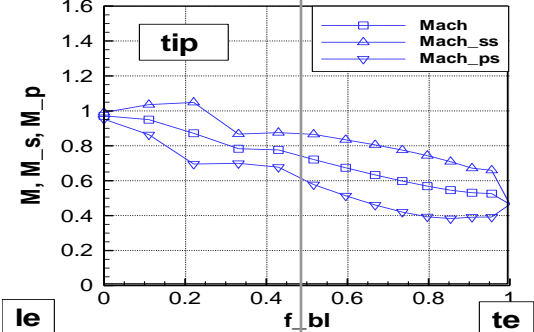
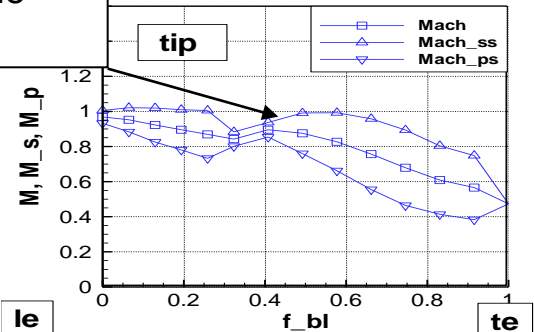
Optimised design



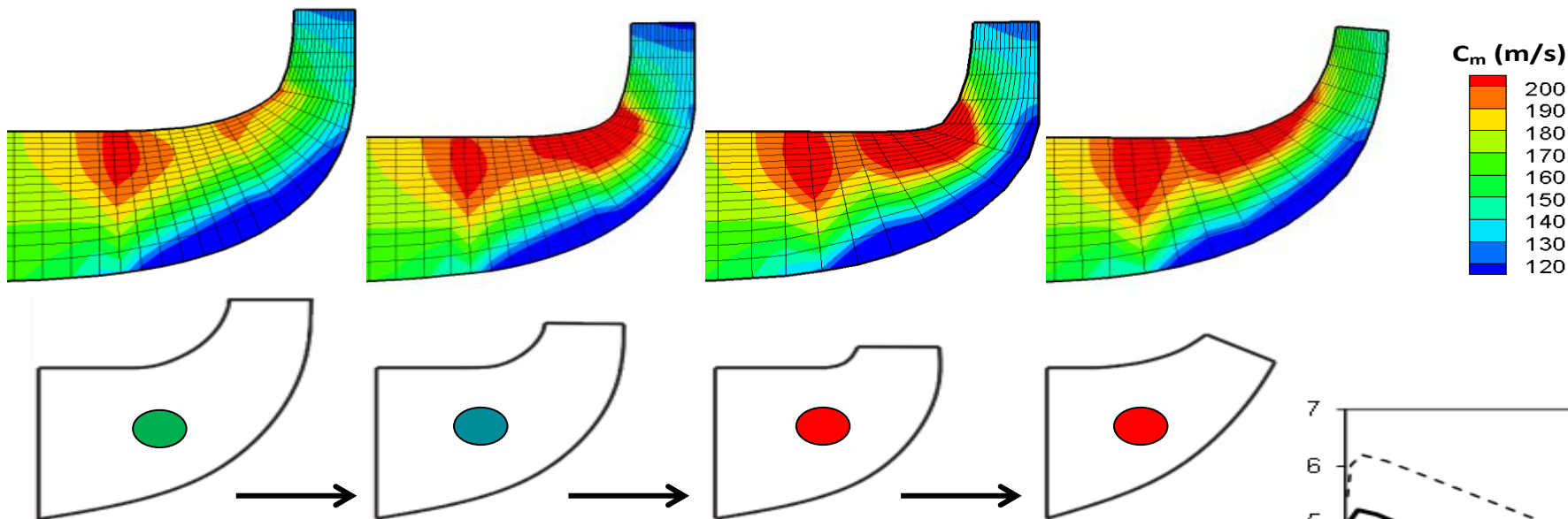
Alternative inlet



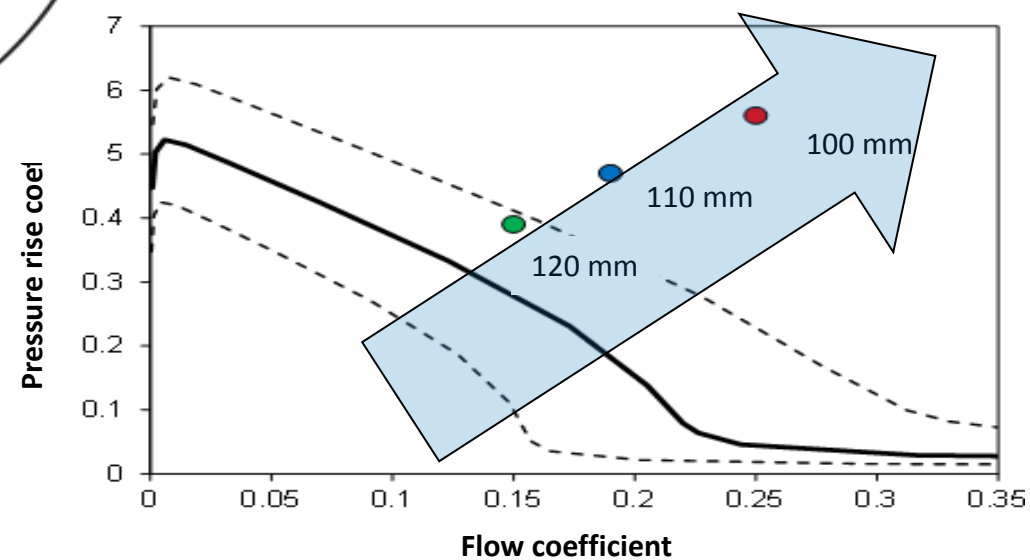
High Mn, possible choking



Typical application of throughflow



- Reduce inertia
- Maximise performance



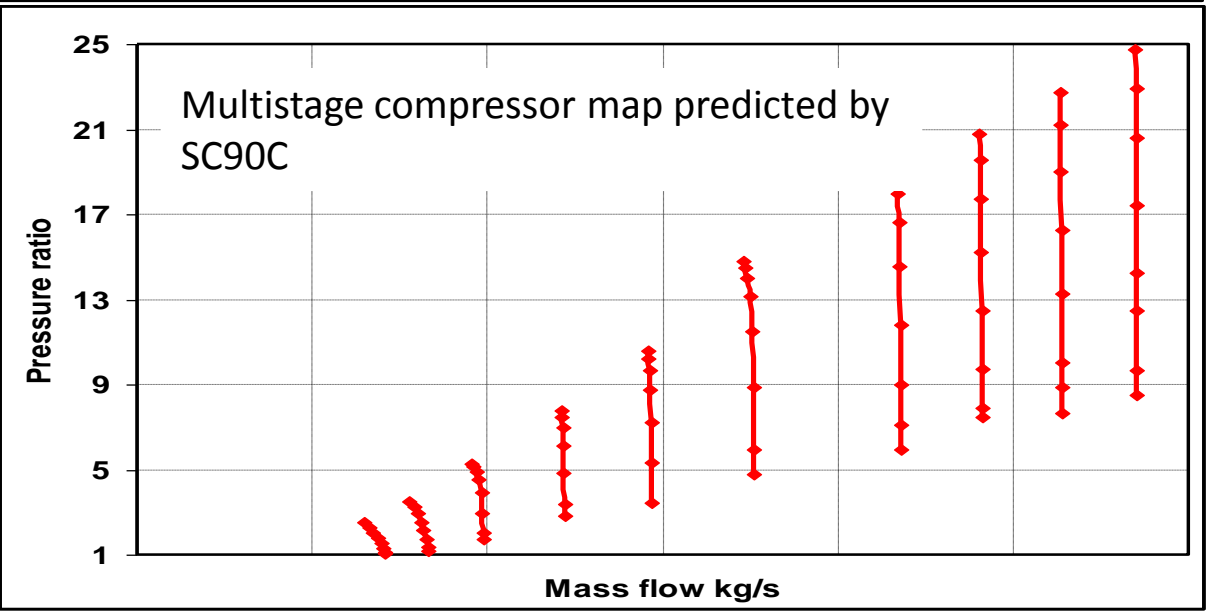
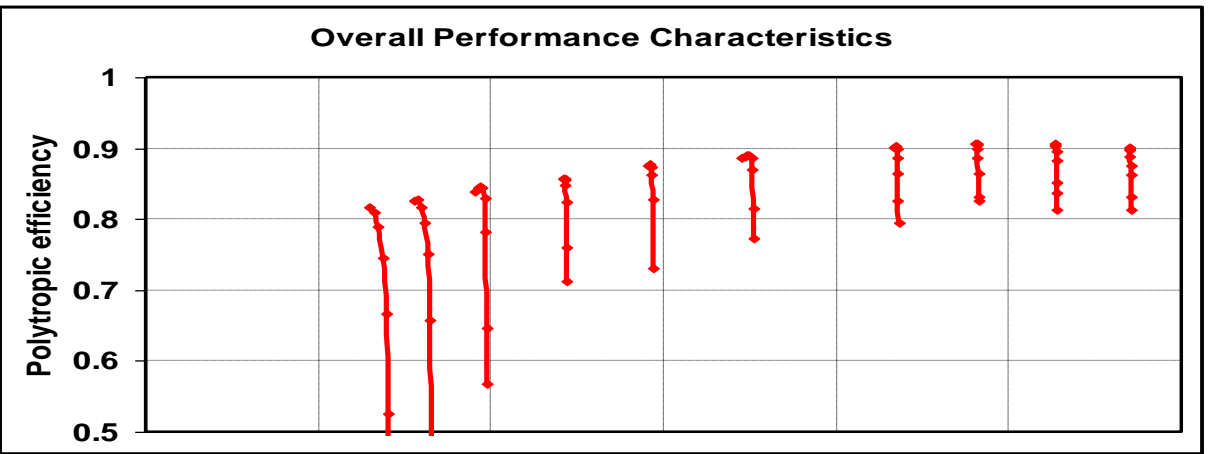
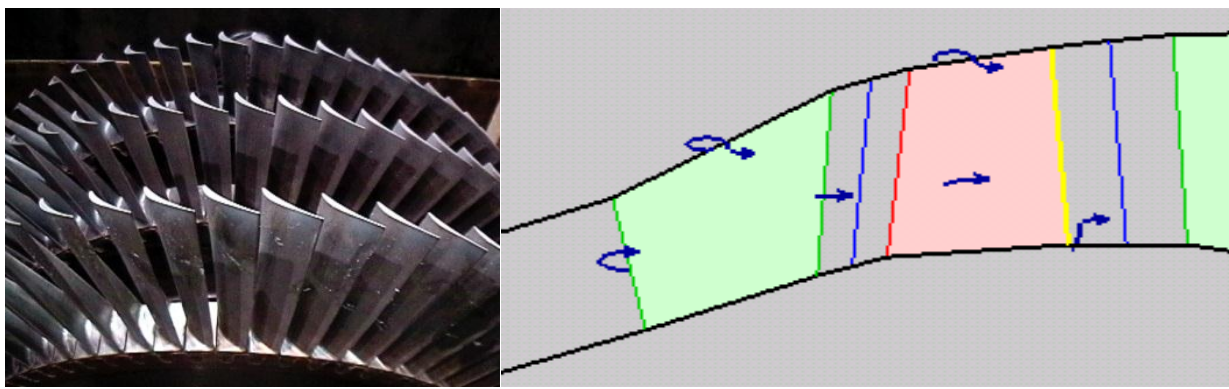
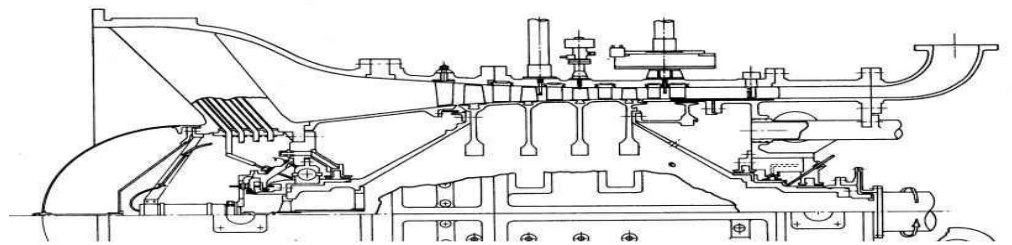
What VistaTF cannot do

- 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



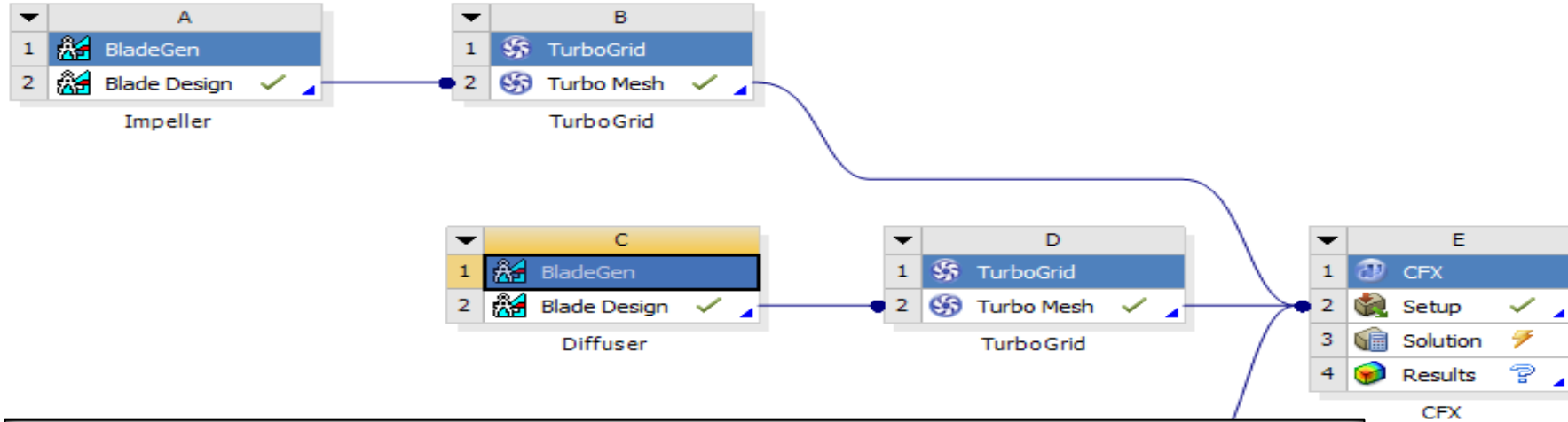
Not an alternative to CFD!

SC90 for axial compressors and turbines

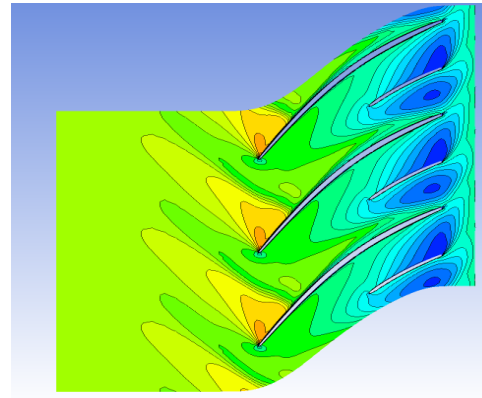
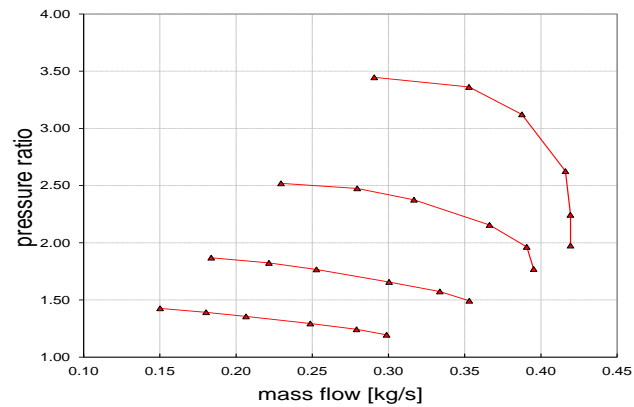


CFD Analysis

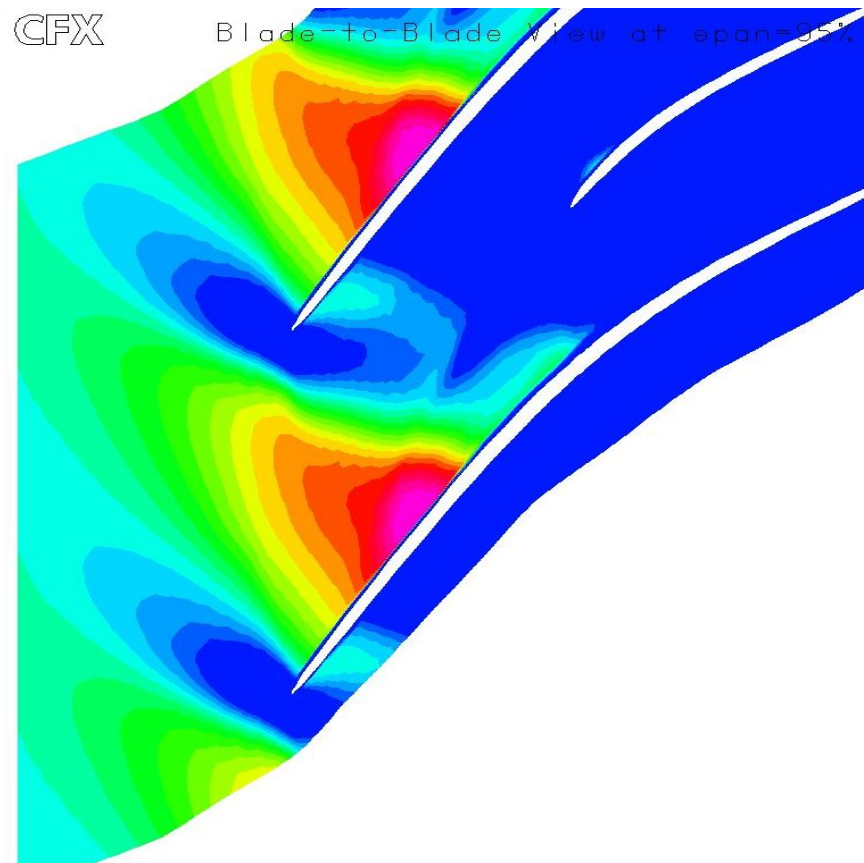
CFD calculations



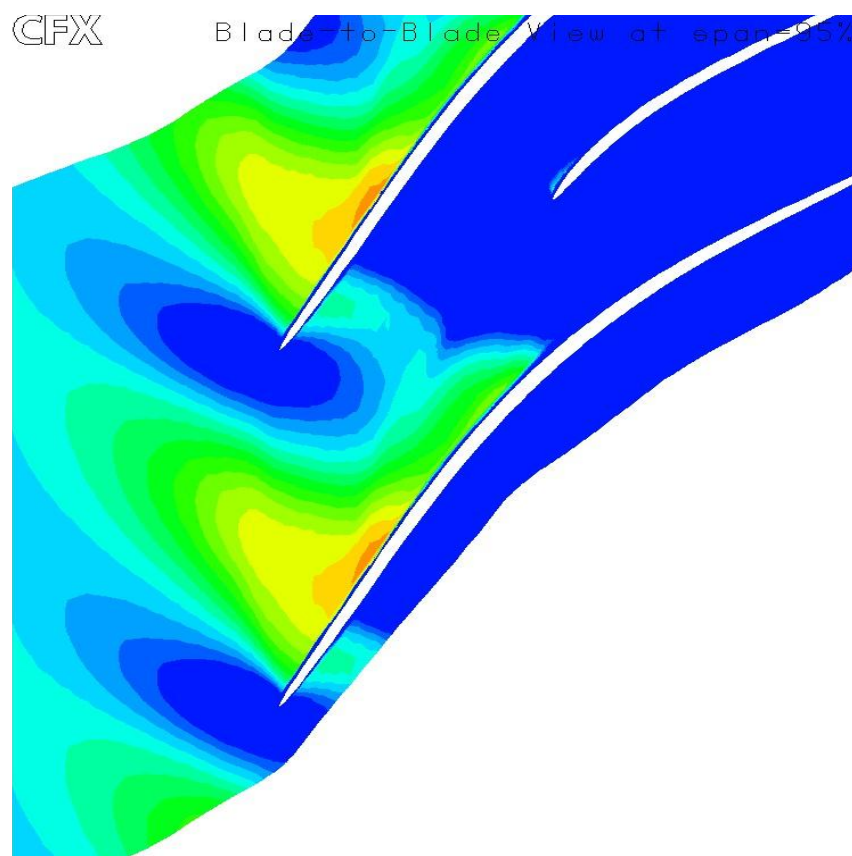
- Post-processing macros are used



Transonic inlet optimisation

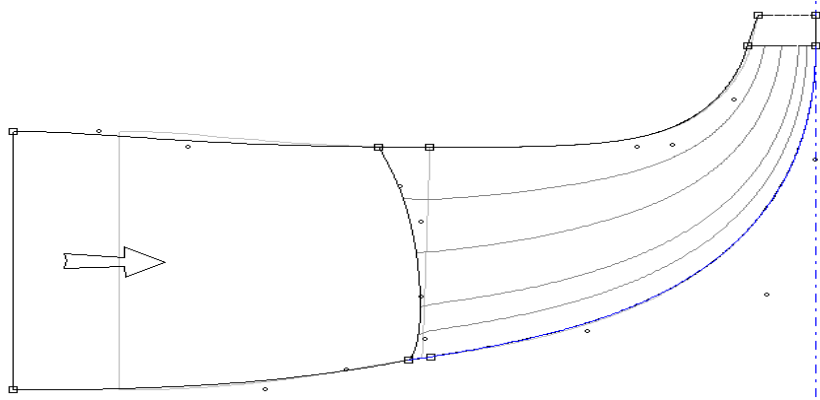


Conventional

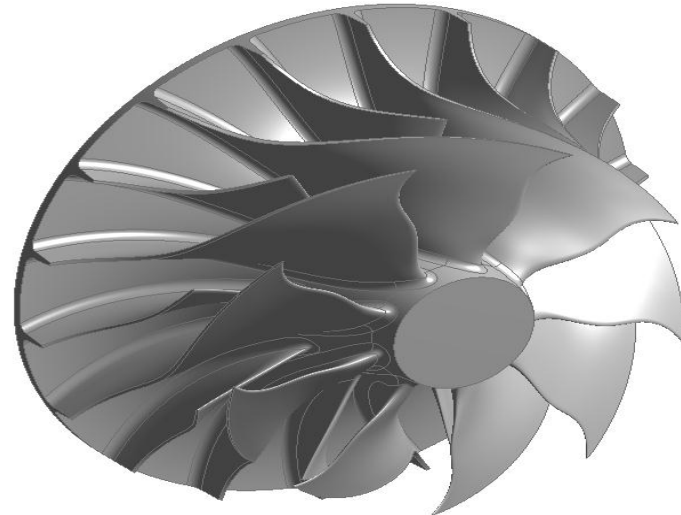
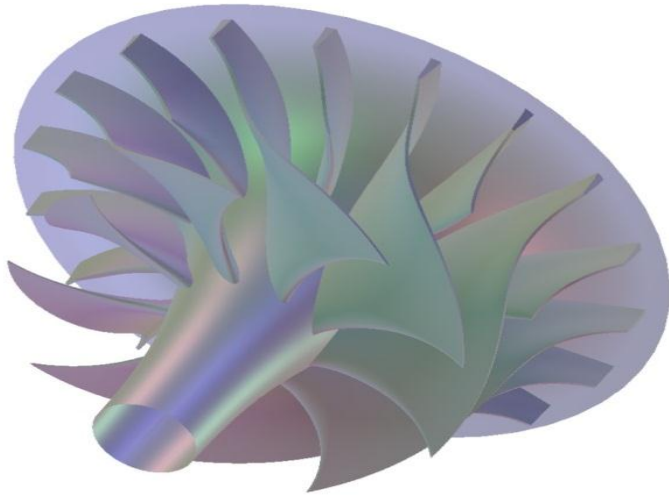
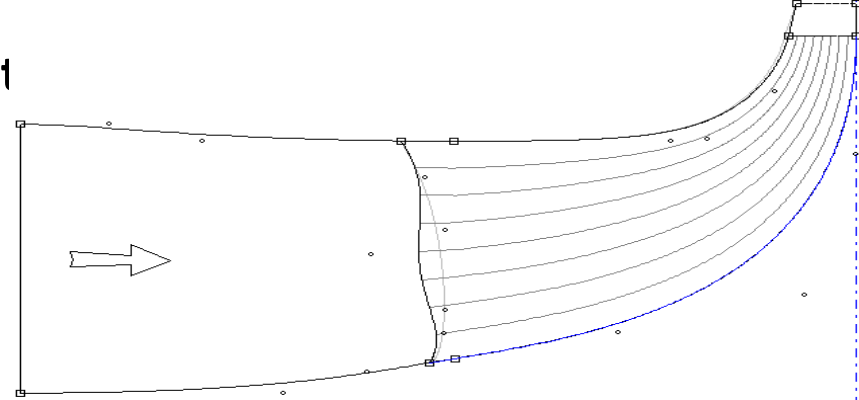


Pre-compression

Fully 3D impeller design

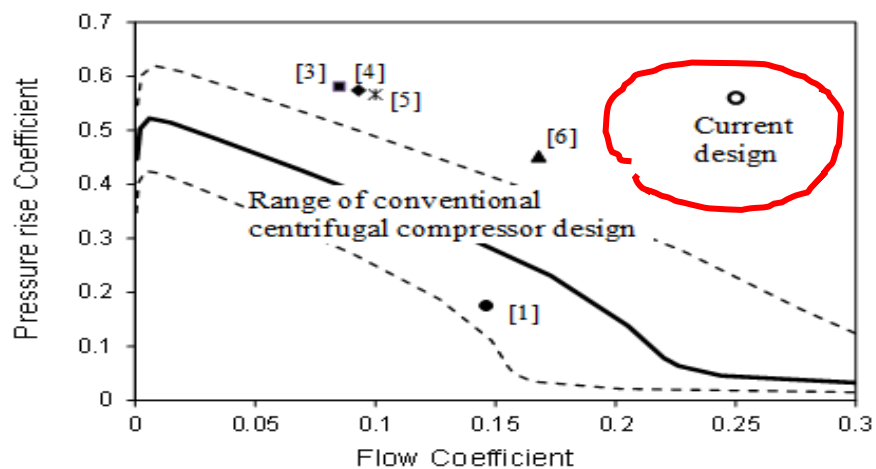
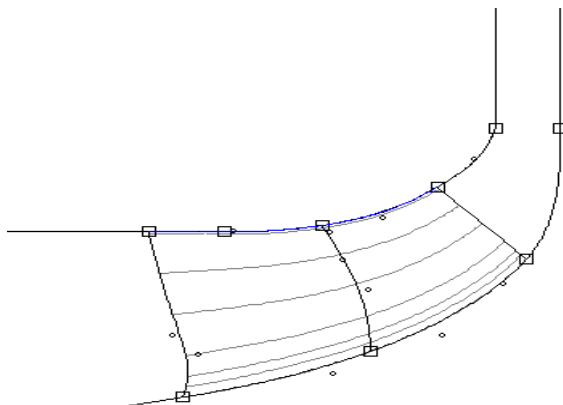


imics and st

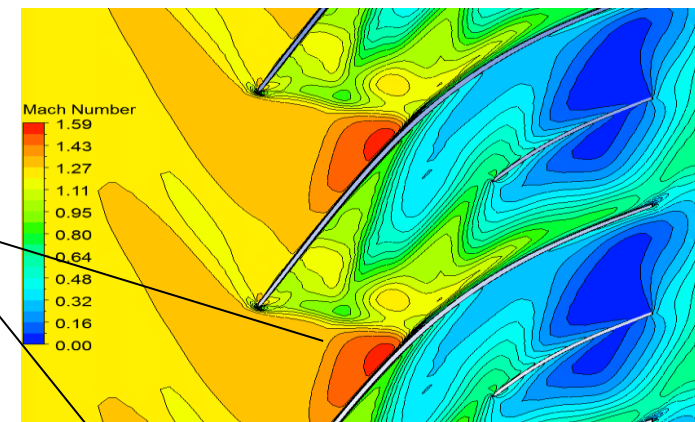


Advanced impeller design

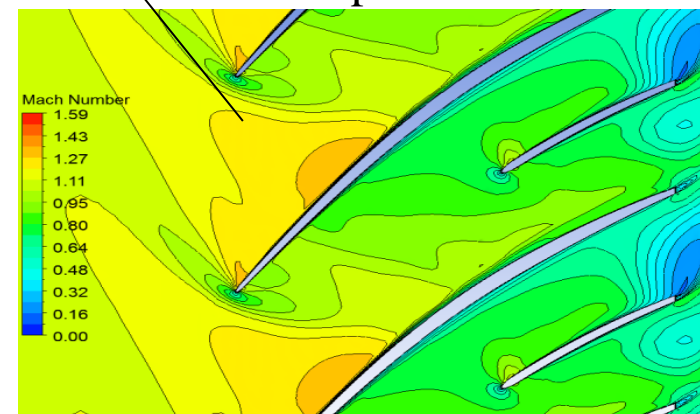
- 3D design concepts such as Lean and Sweep has been used for aerodynamic and structural reasons (*Hazby et al. (2014)*)



better control of the shock



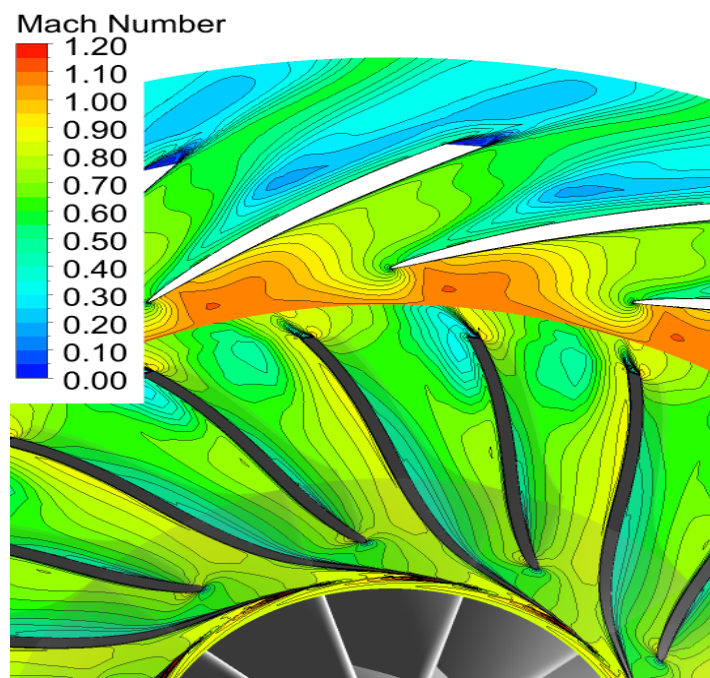
95% span



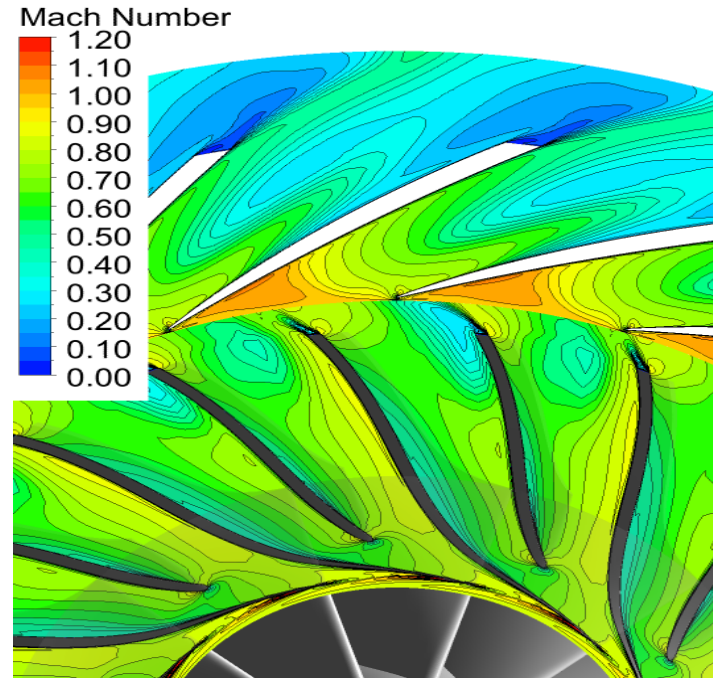
70% span

Transient blade row methods

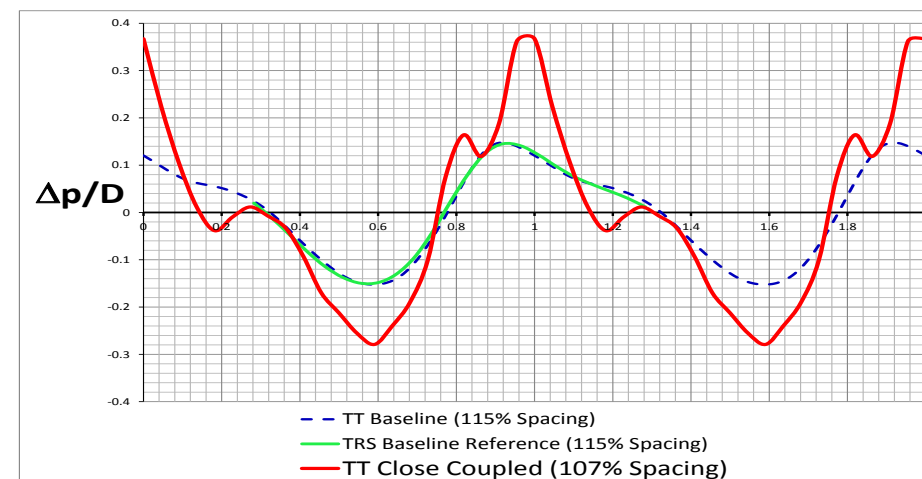
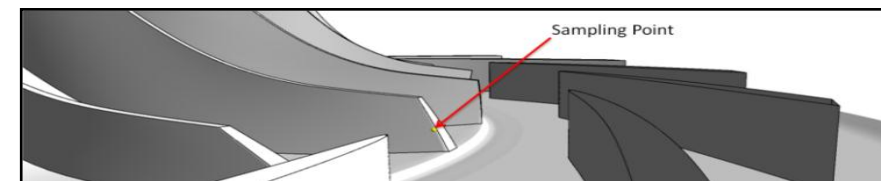
- Time Transformation method in CFX is used to calculate the unsteady flow field with non-matching rotor-stator interfaces



Baseline (115%)

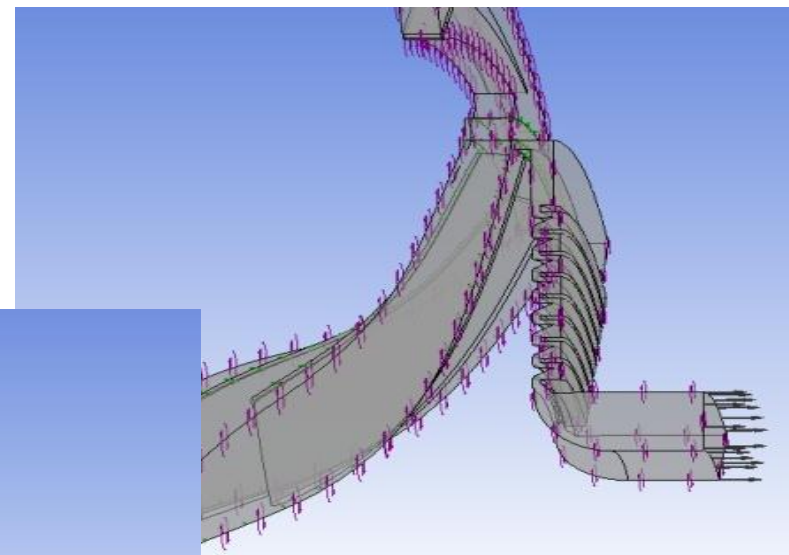
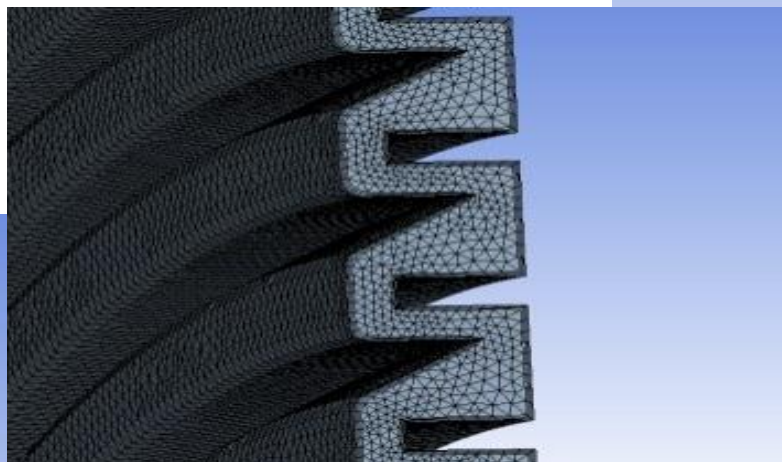
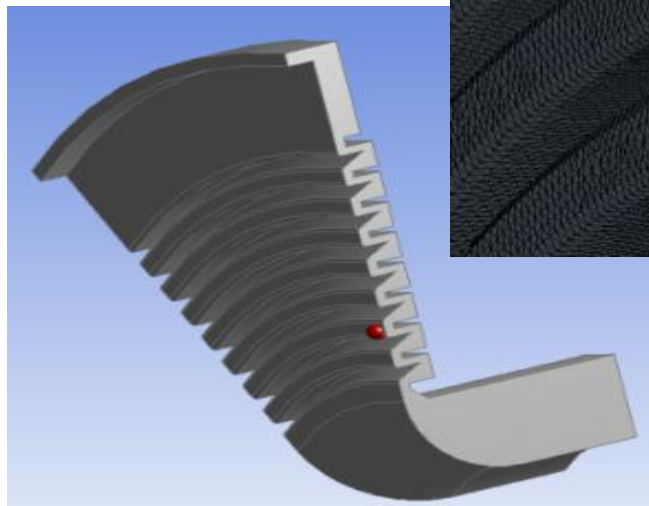
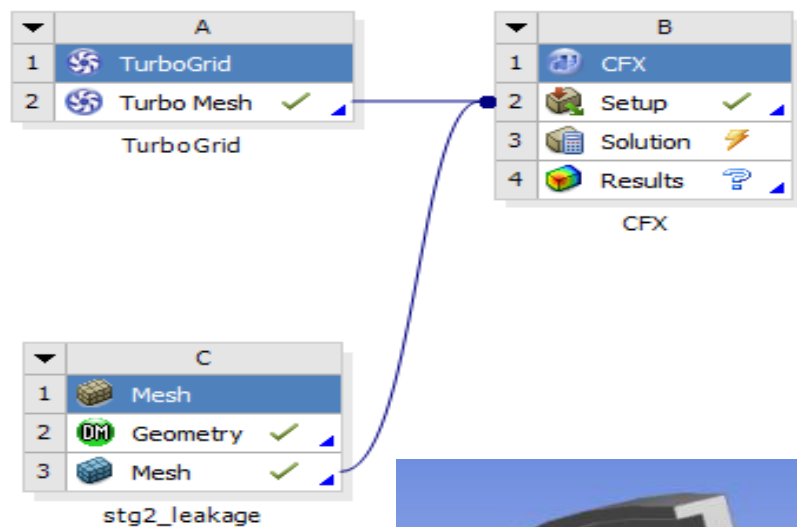


Close-coupled (107%)

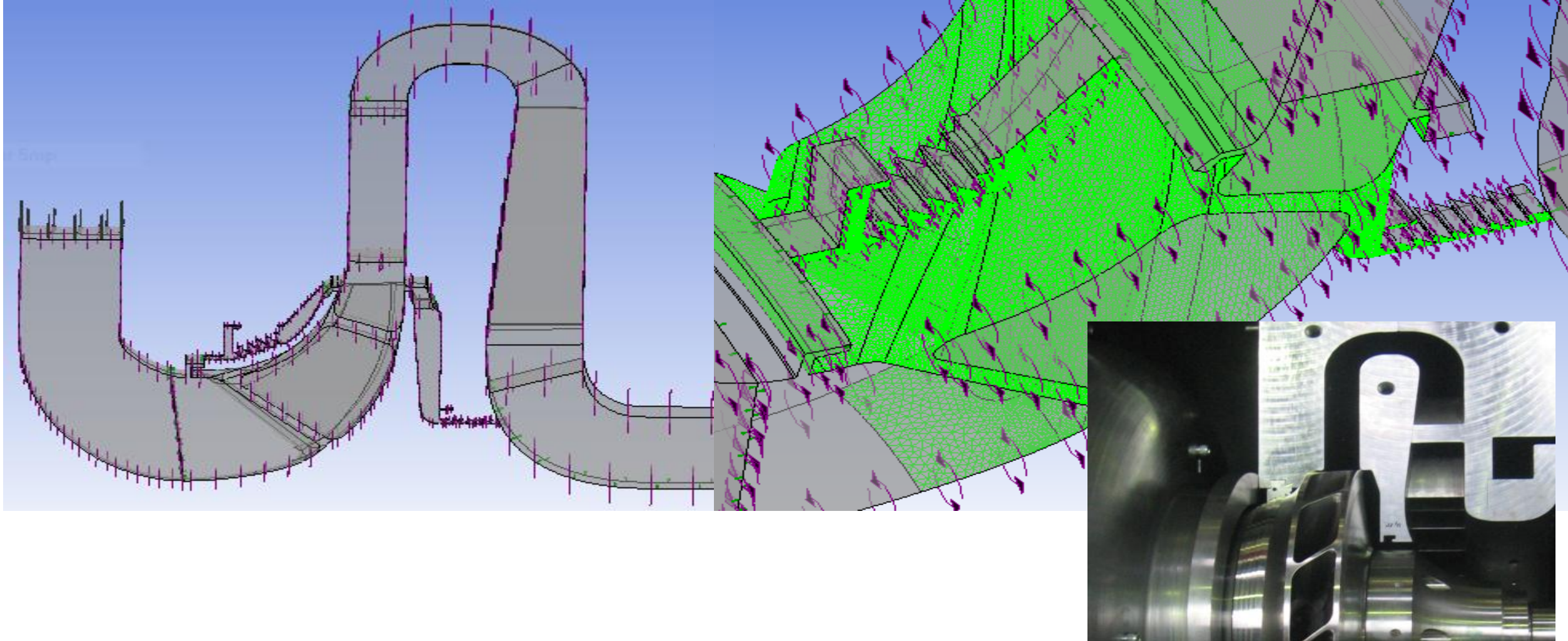


Applications of DesignModeler

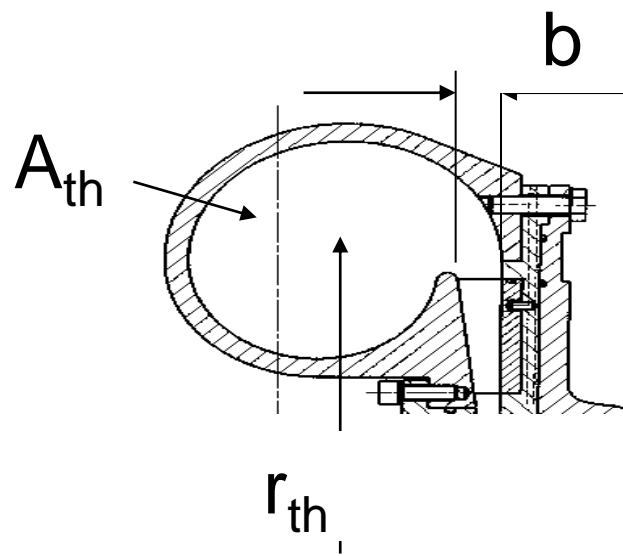
Secondary flow paths



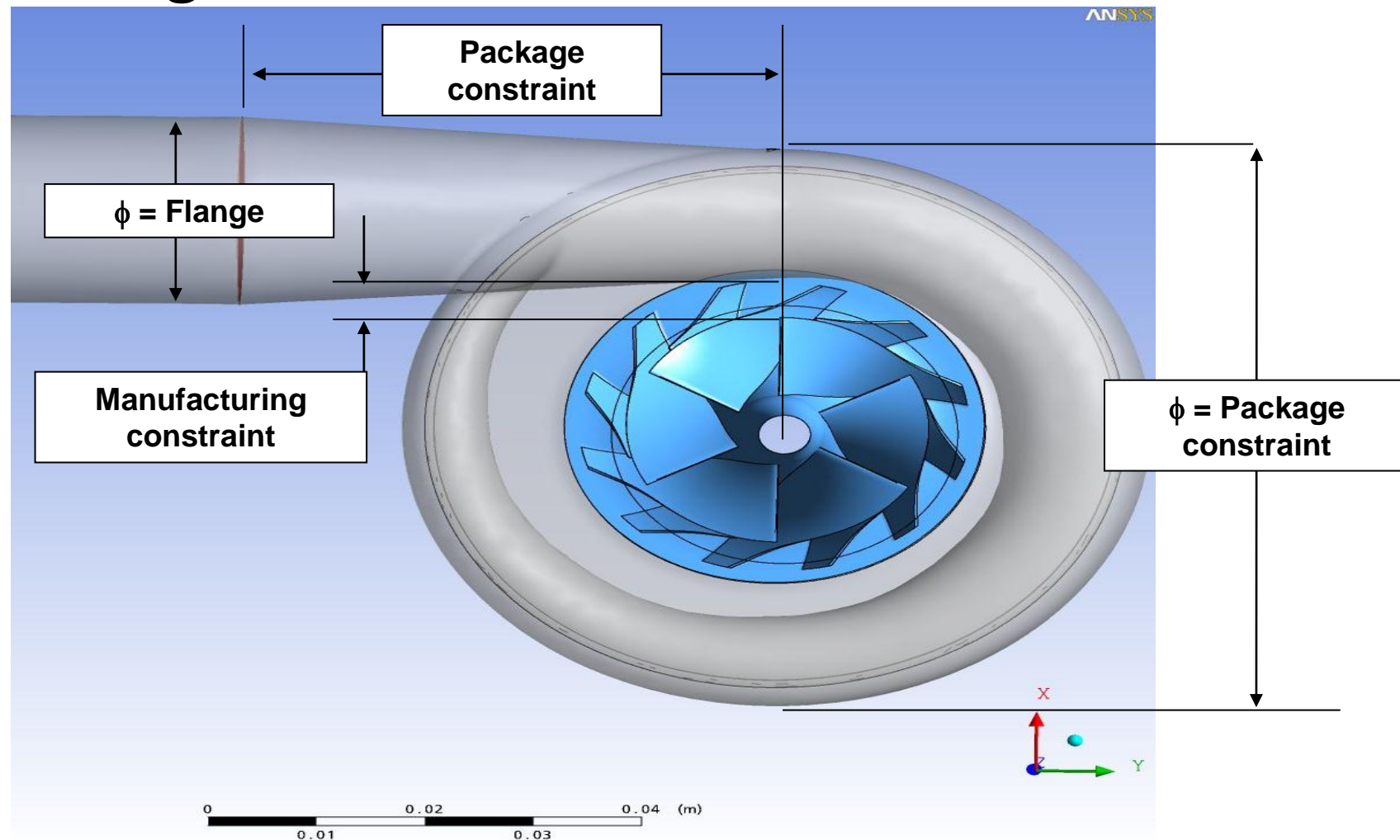
Shrouded compressor stage



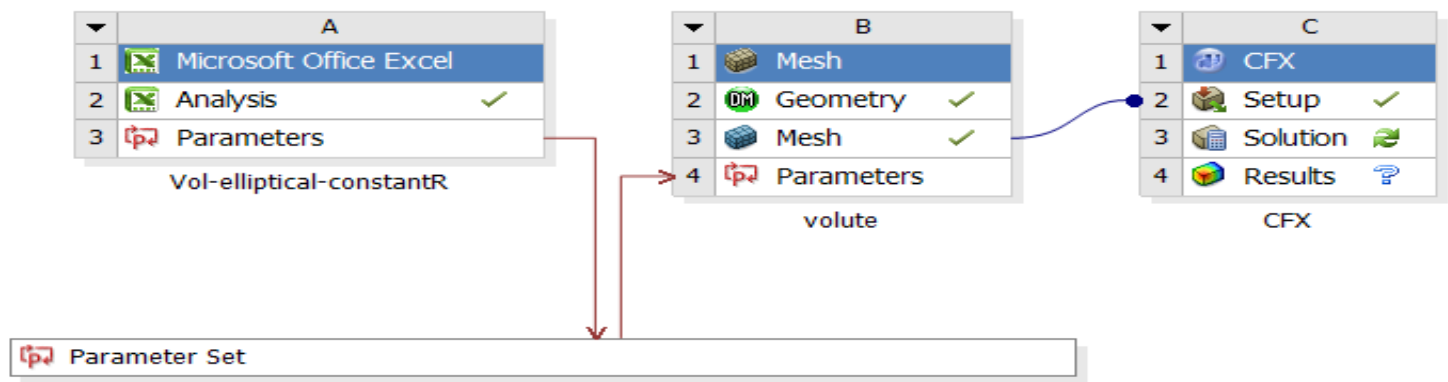
Parametric volute design



$$(A/r)_{th} = 2\pi b / \tan\alpha$$

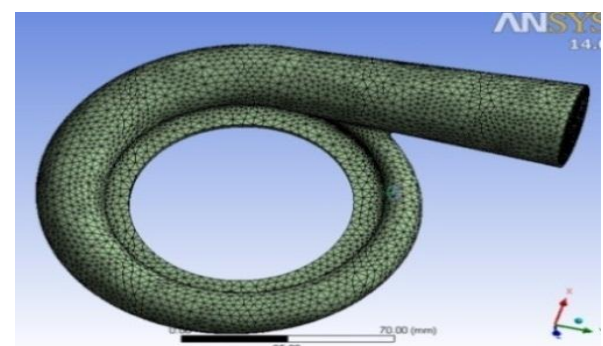
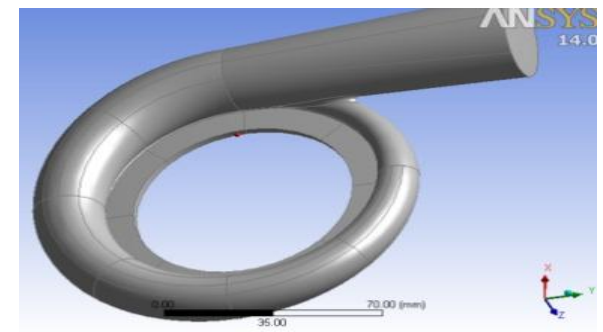
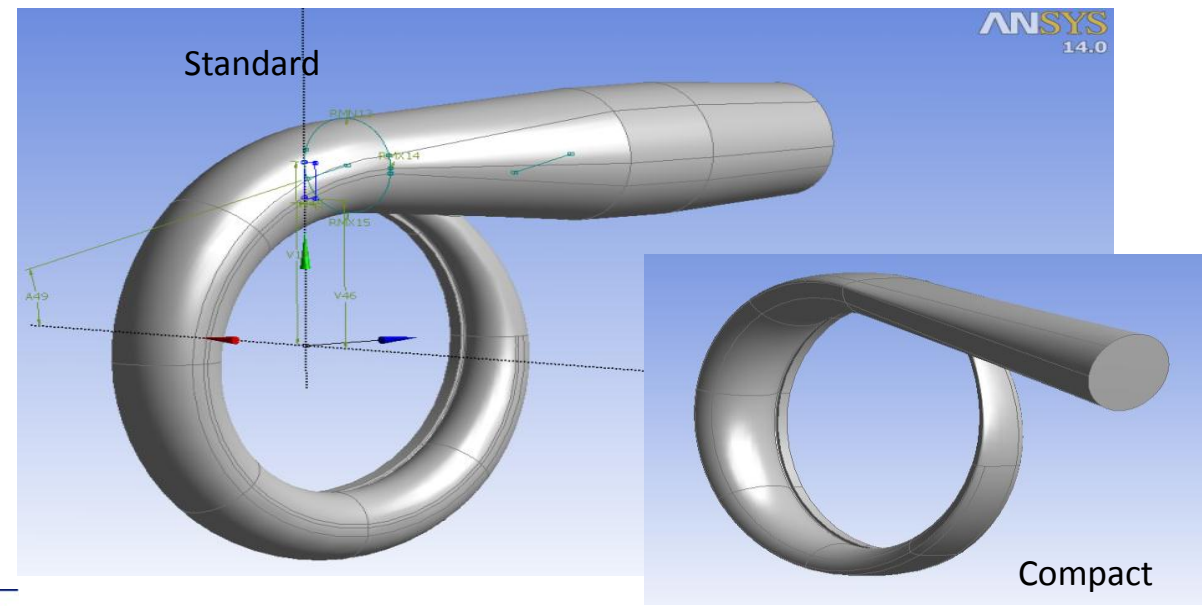


Parameterised volute design in WB

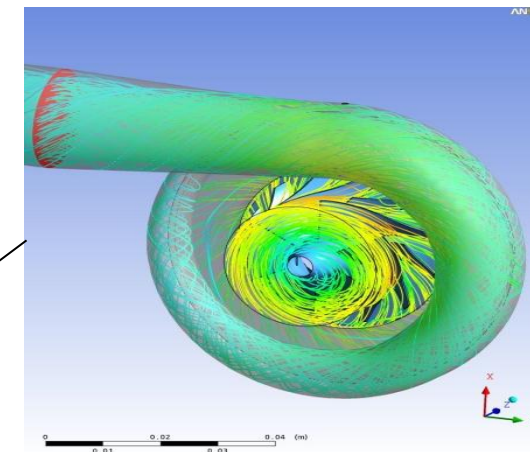
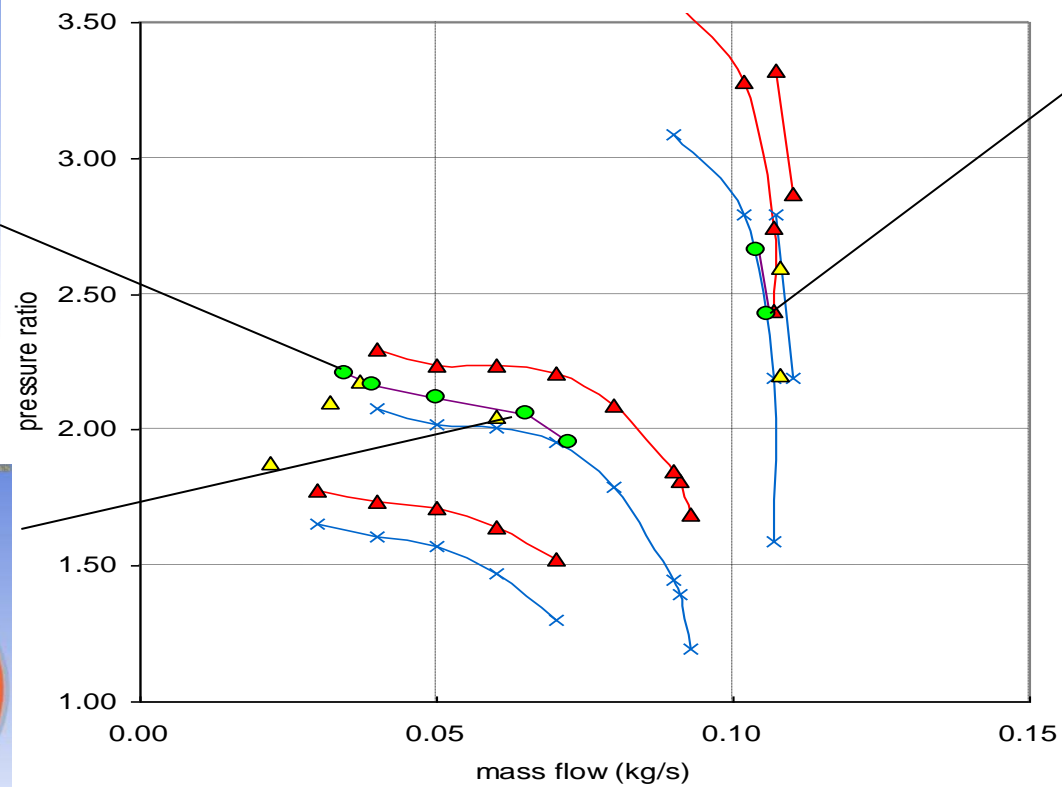
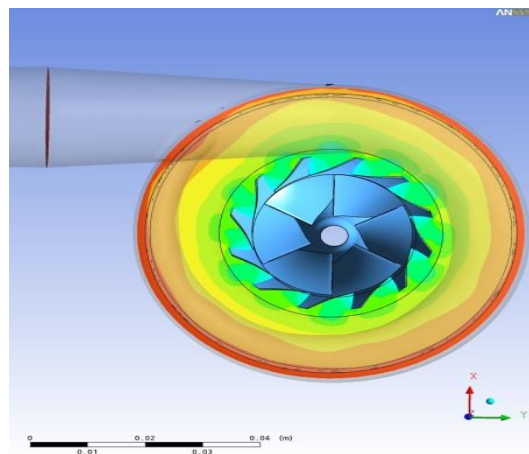
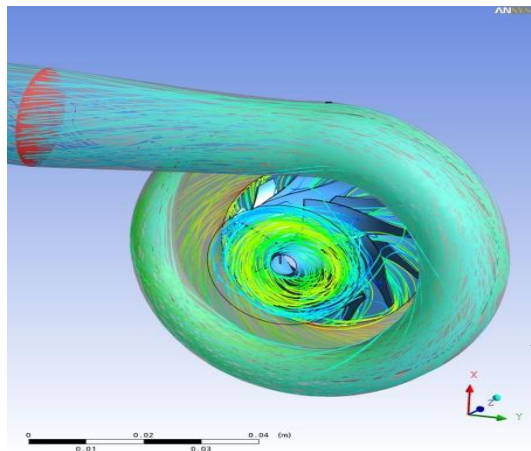


Outline of Schematic A3: Parameters

	A	B	C	D
	ID	Parameter Name	Value	Unit
1				
2	Input Parameters			
*	New input parameter	New name	New expression	
4	Output Parameters			
5	Vol-elliptical-constantR (A1)			
6	P1	a.0	0.37125	
7	P2	a.135	2.0147	
8	P3	a.180	2.3264	
9	P4	a.225	2.601	
10	P5	a.270	2.8492	
11	P6	a.315	3.0775	
12	P7	a.360	3.29	

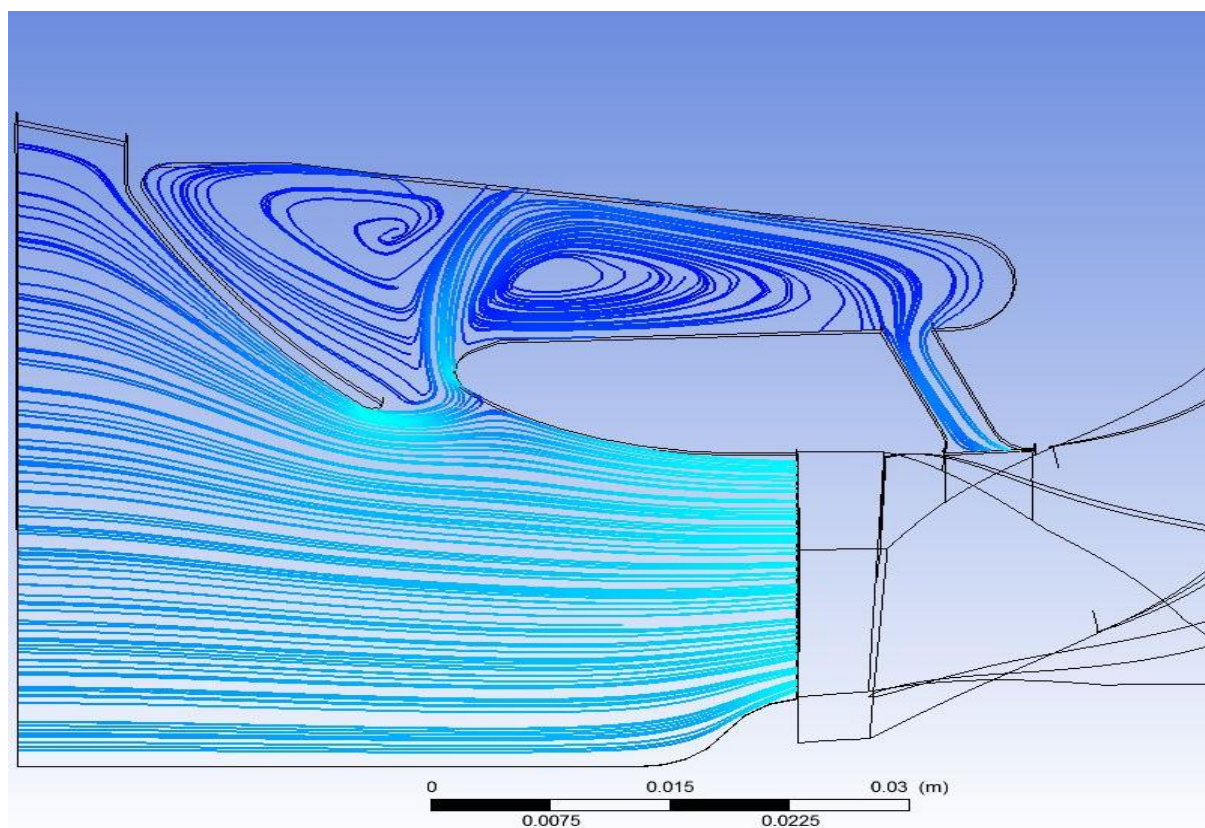


Full 360° model

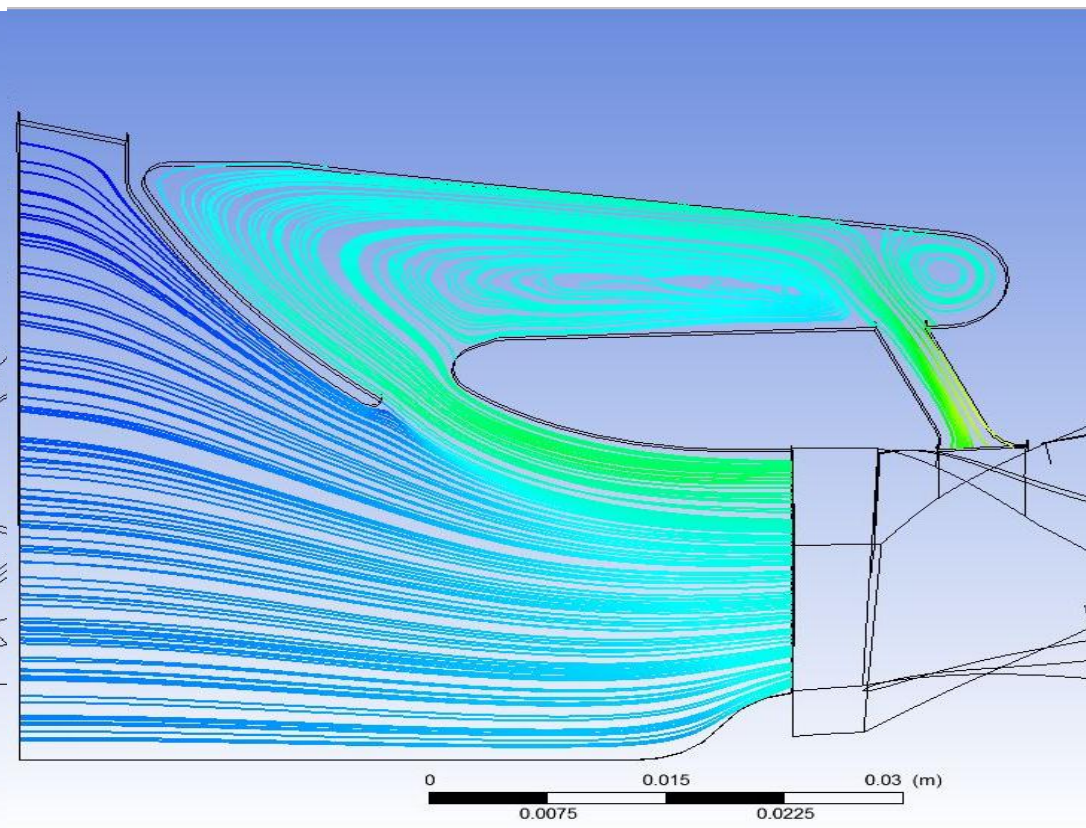


Tip speeds of 340, 394, 525 and 550m/s

Streaklines at the extents of the map



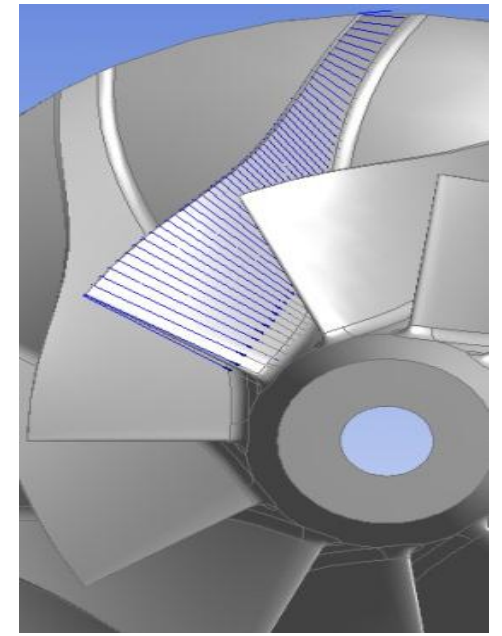
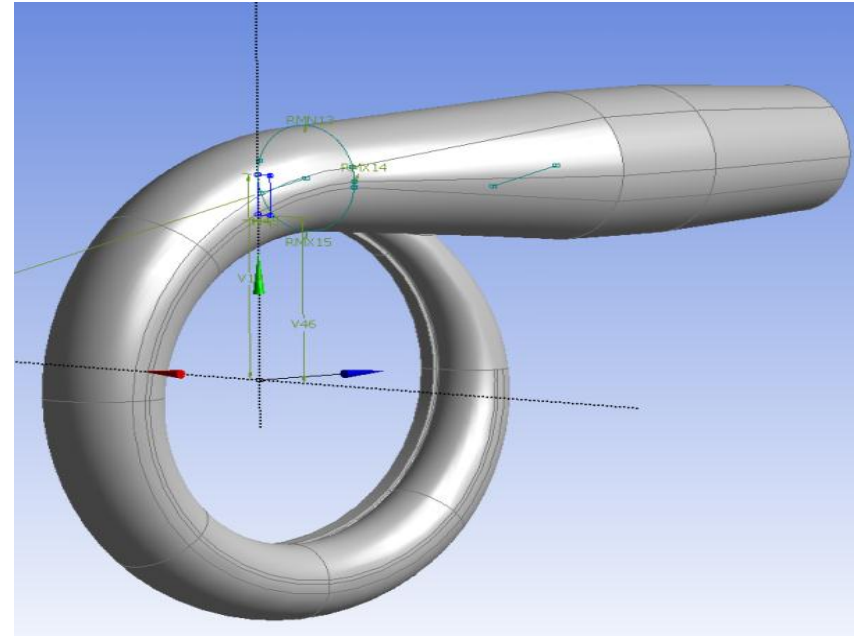
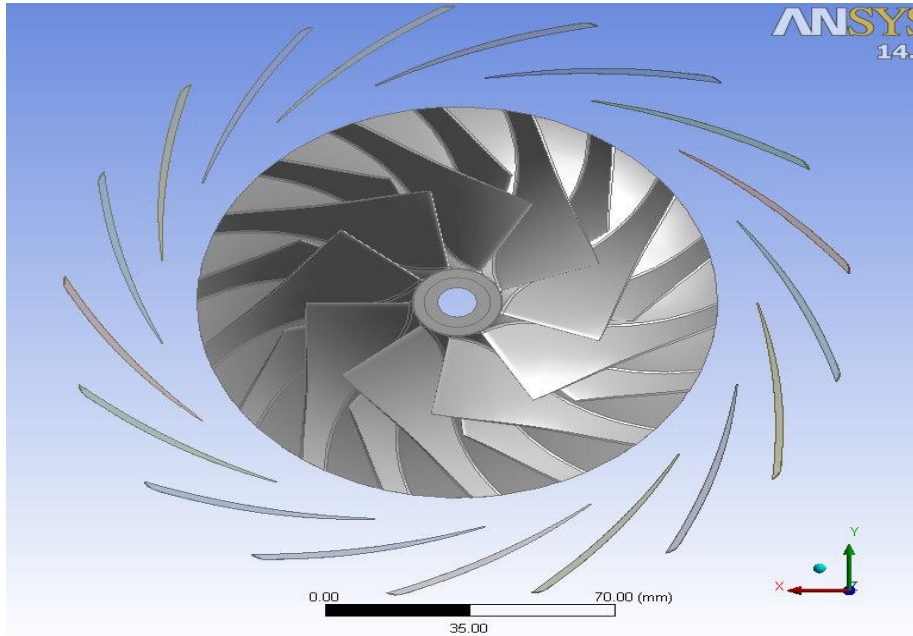
Near choke



Near surge

Manufacturing geometry

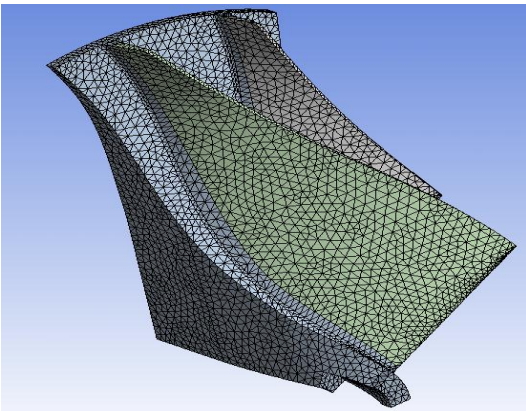
- Geometries which are prepared in DesignModeler can be exported in CAD formats
- Ensures consistency between the analysed and manufacturing geometries



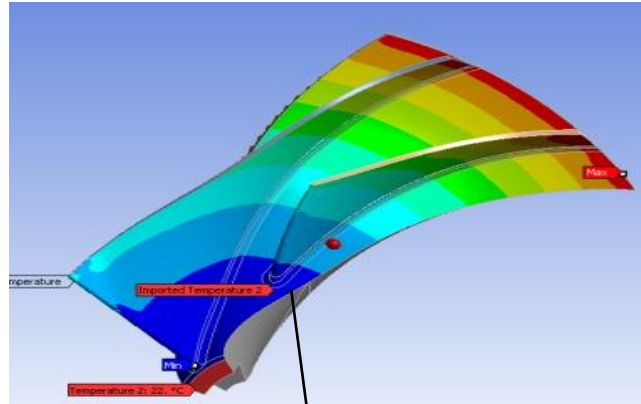
Structural analysis

Stress analysis

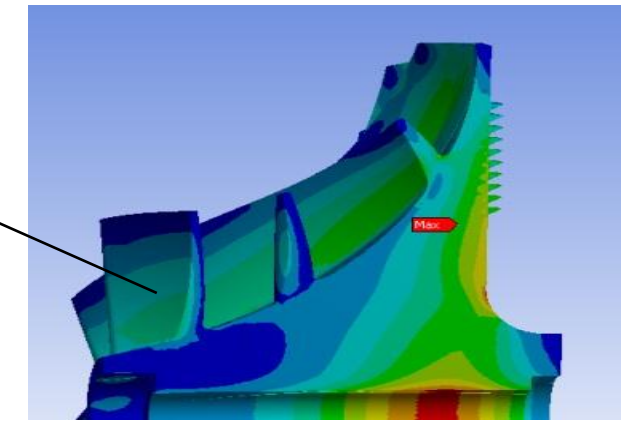
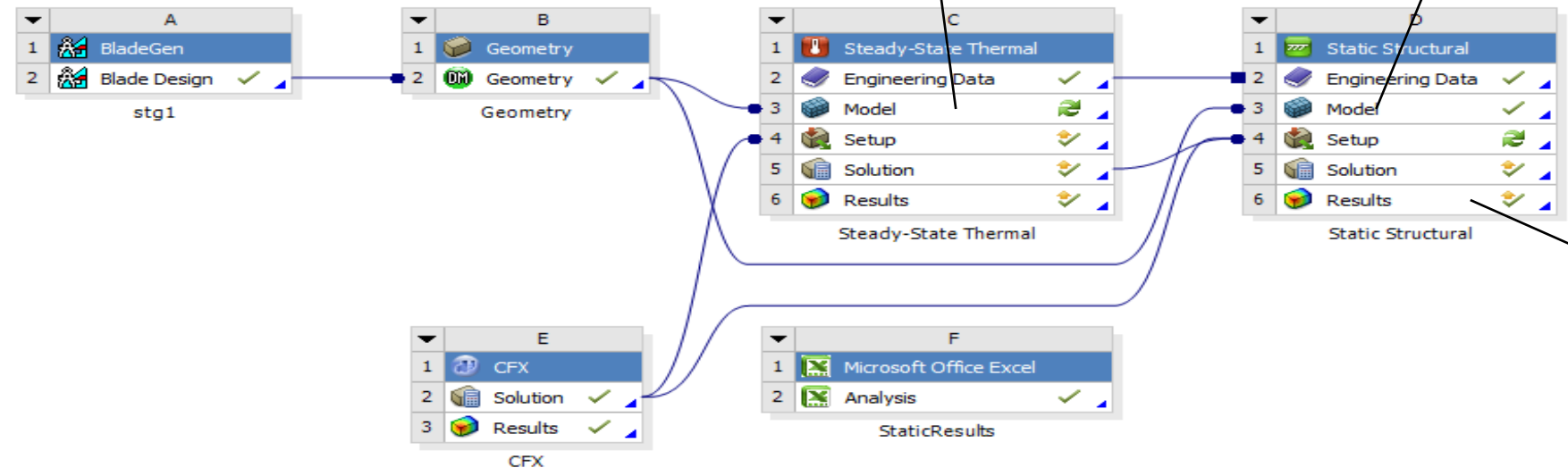
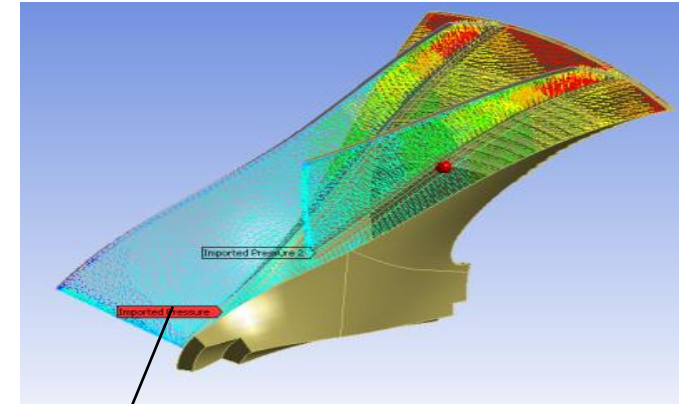
Mesh



Imported temperatures



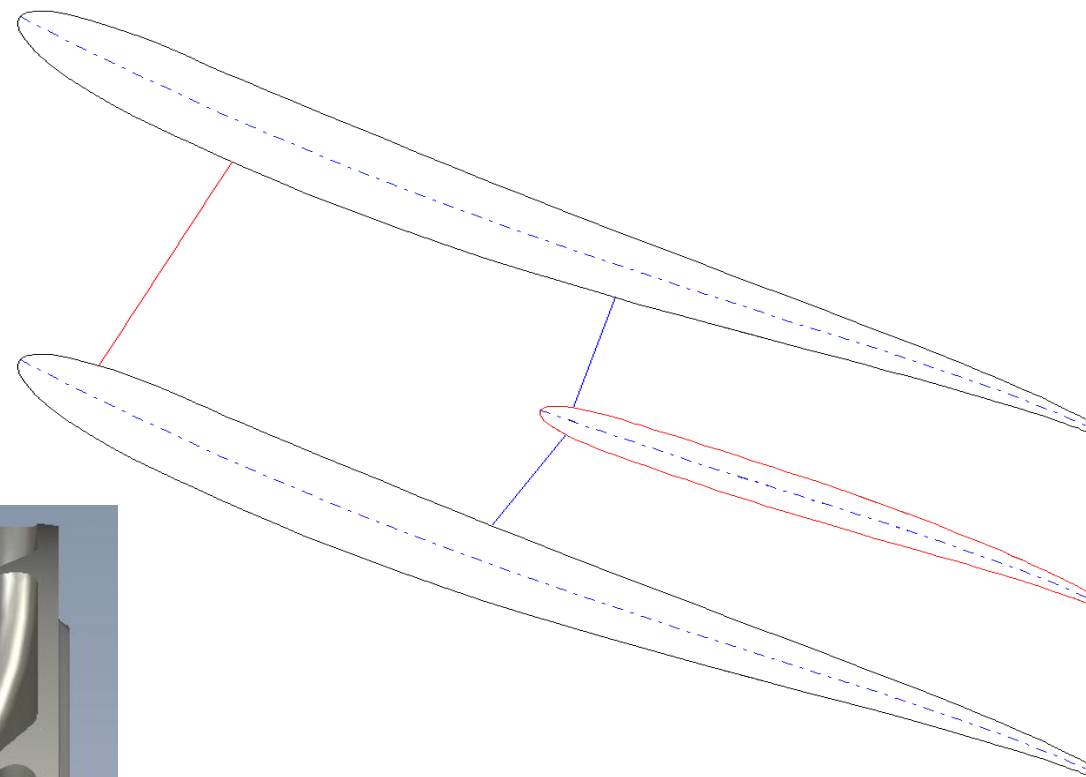
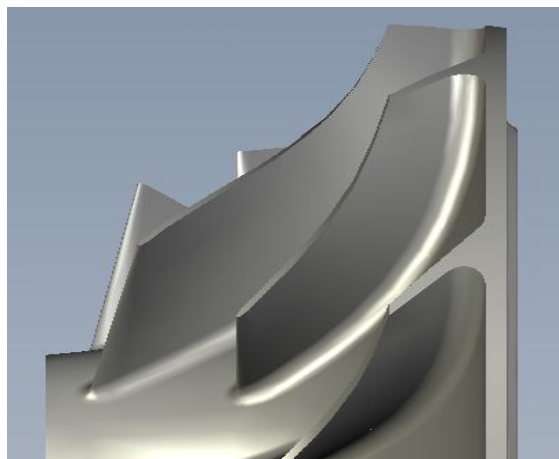
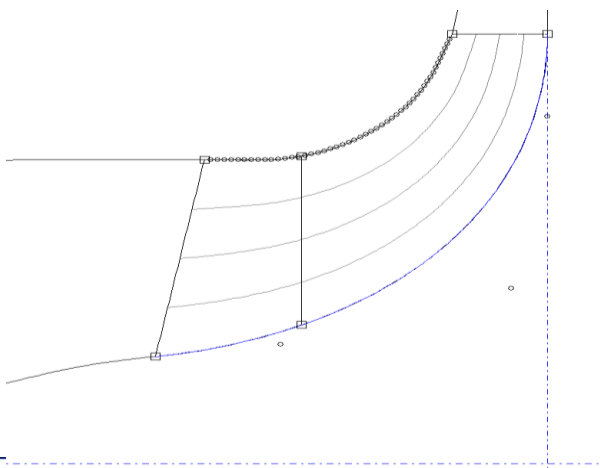
Imported pressures



Stress field

Mechanical mitigation

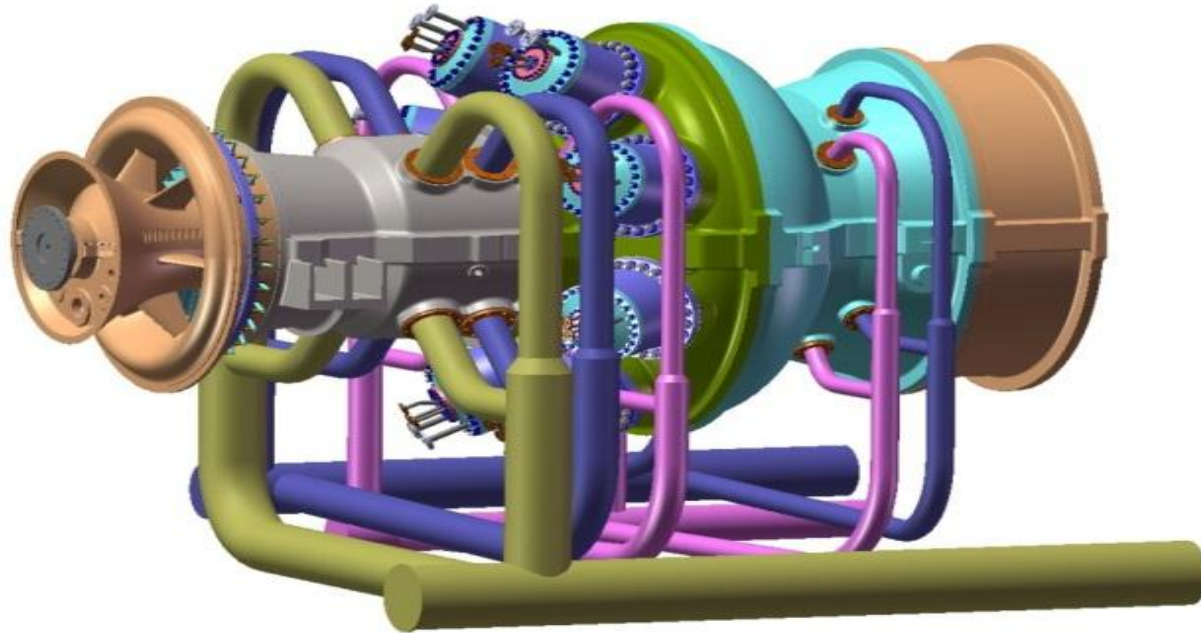
- Thickness necessary to achieve adequate stiffness
- Splitter can have lower thickness
- Other mitigation, axial lean of the leading edge



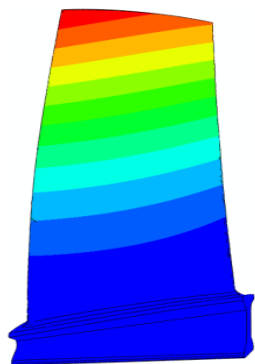
Relying on ANSYS products

Gas turbine capability

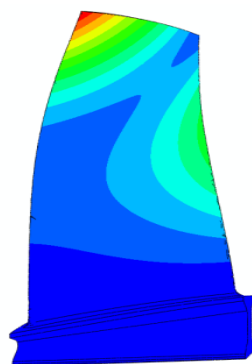
- Empirical knowledge
- Then relying on CFX



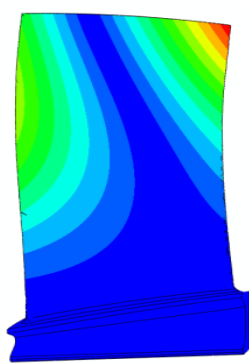
Industrial gas turbine mechanical design



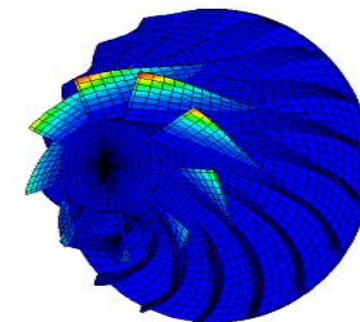
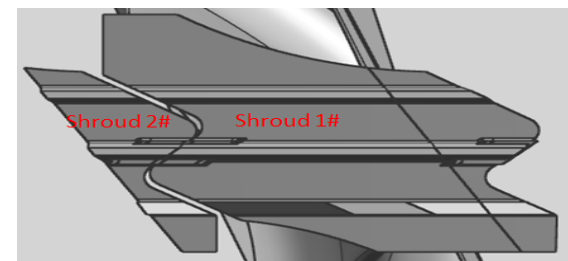
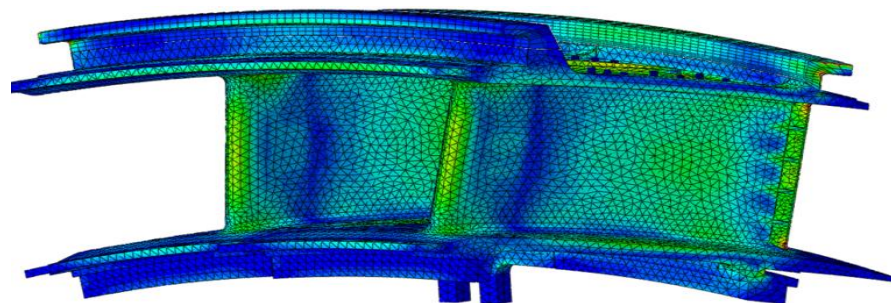
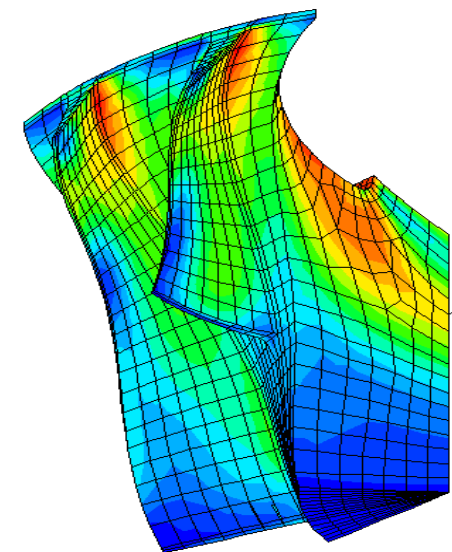
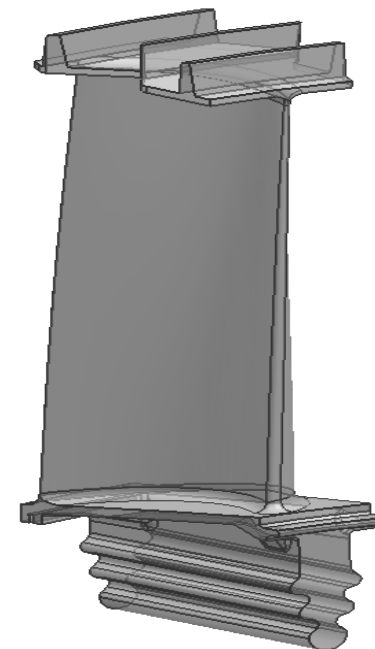
Mode 1



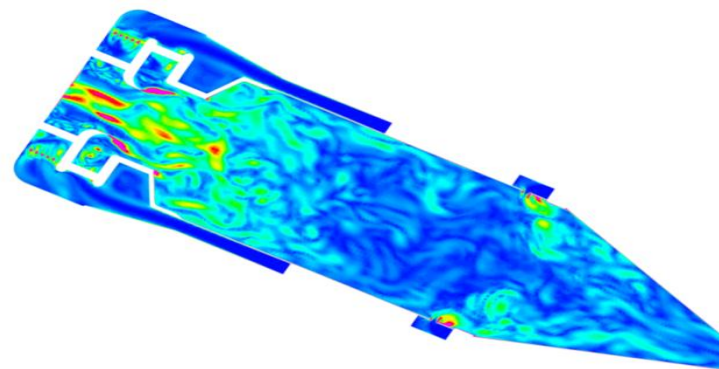
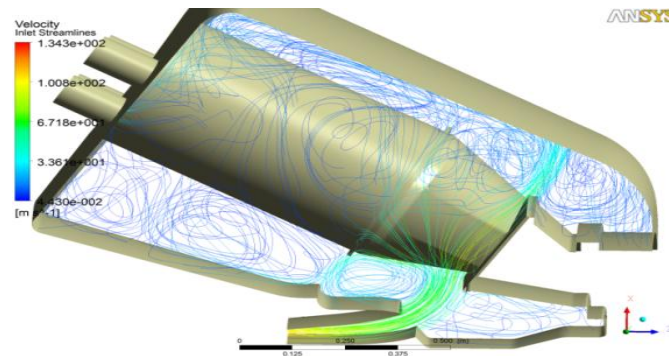
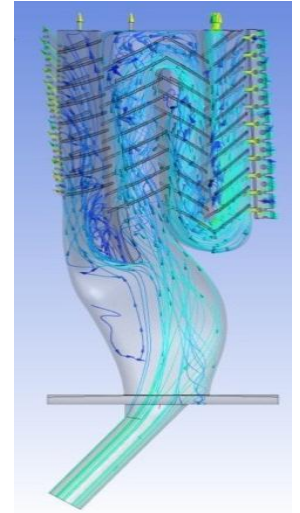
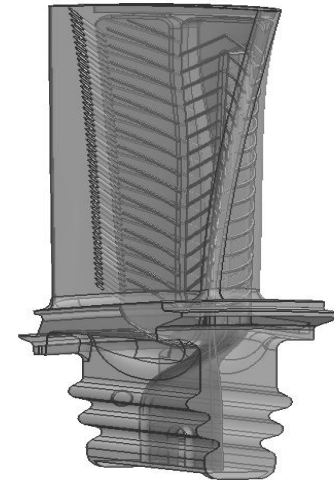
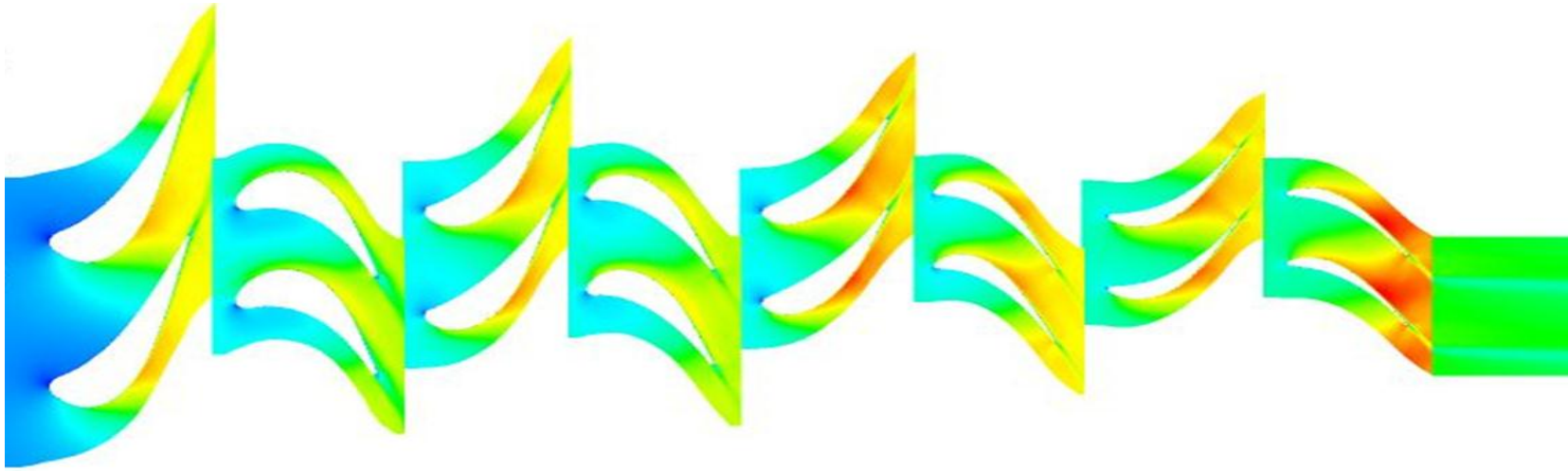
Mode 2



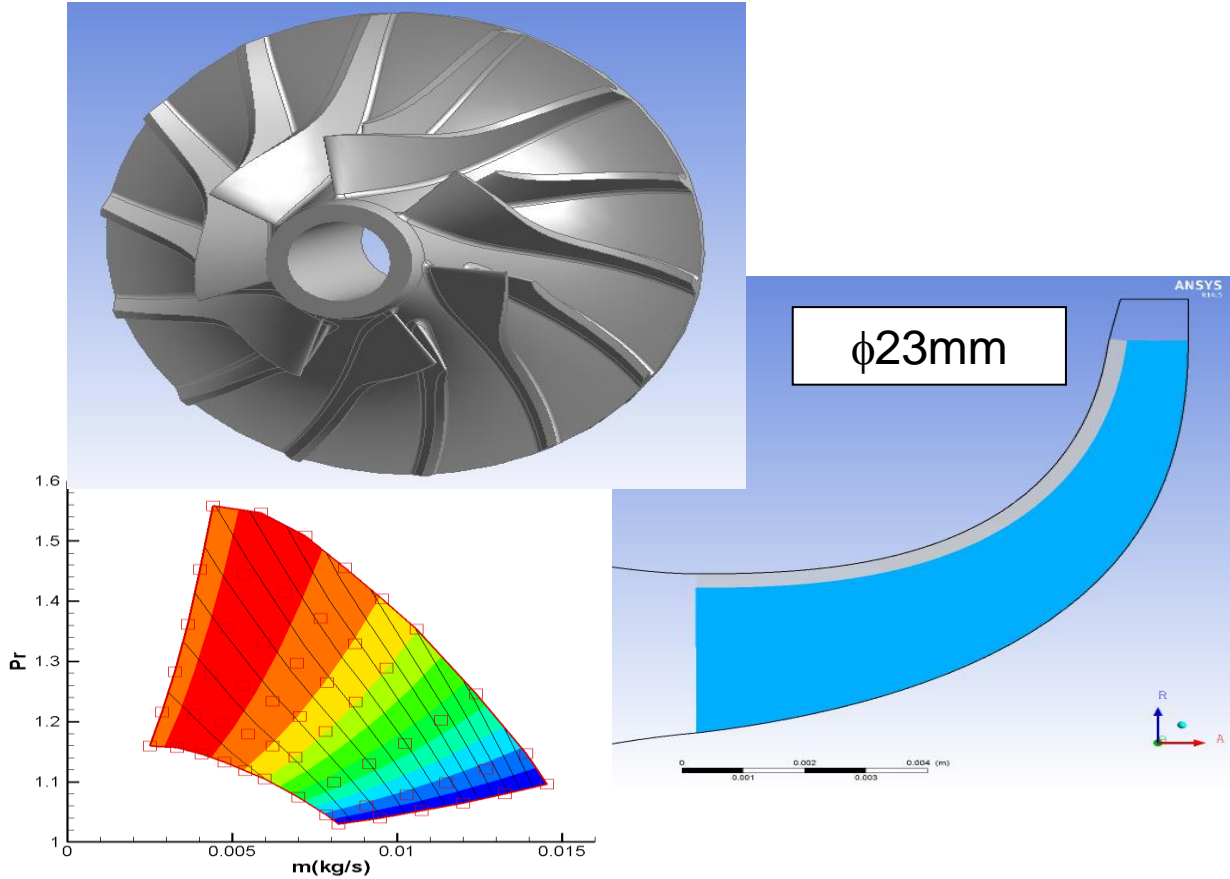
Mode 3



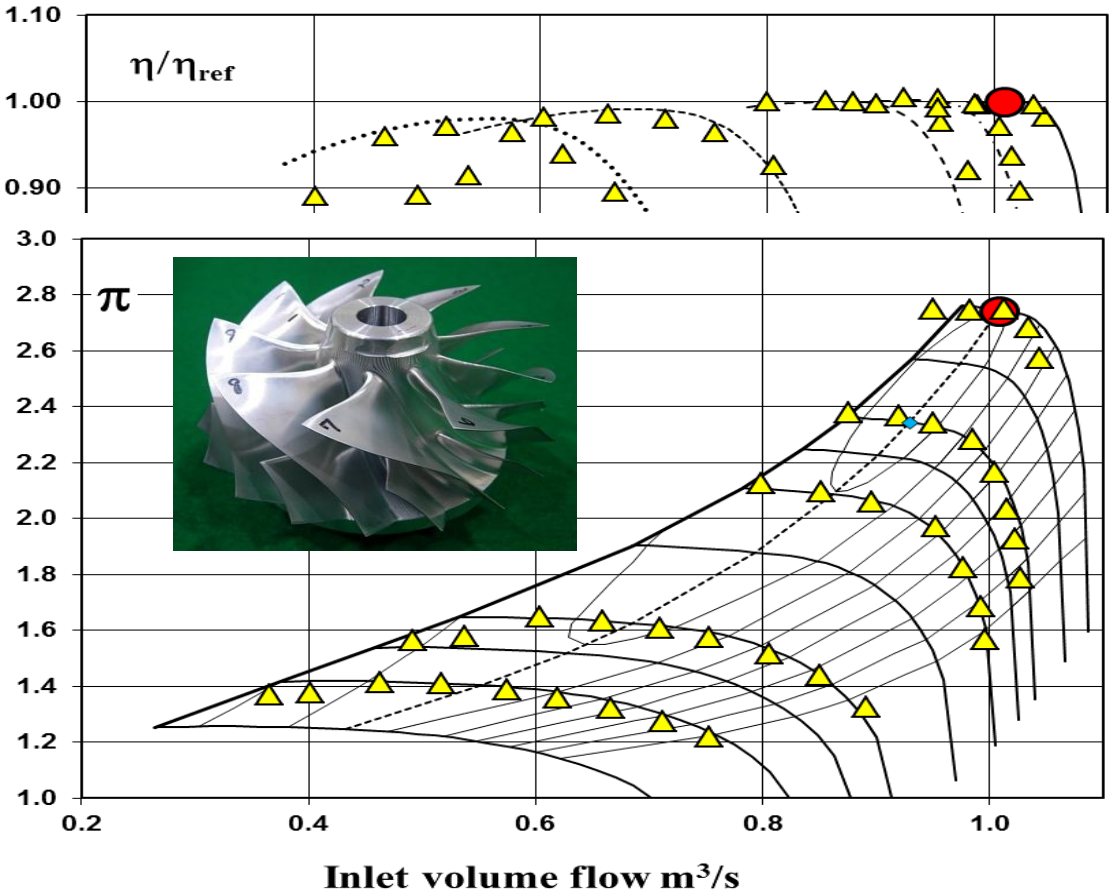
Gas turbine aerothermal design



Relying on CFX



Dealing with excessive tip clearances



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

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