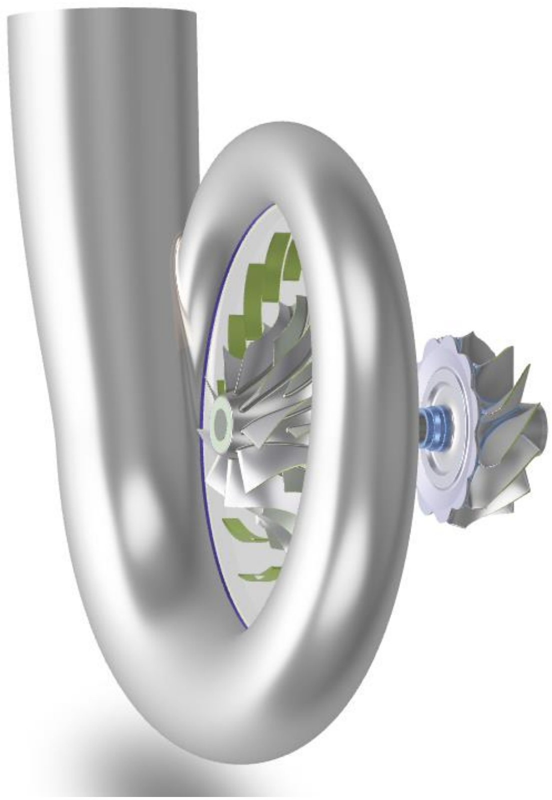
EUROPEAN

USERS' MEETING 2017

Parametric design of turbomachinery components for fully automated shape optimization with CFD and stress analysis



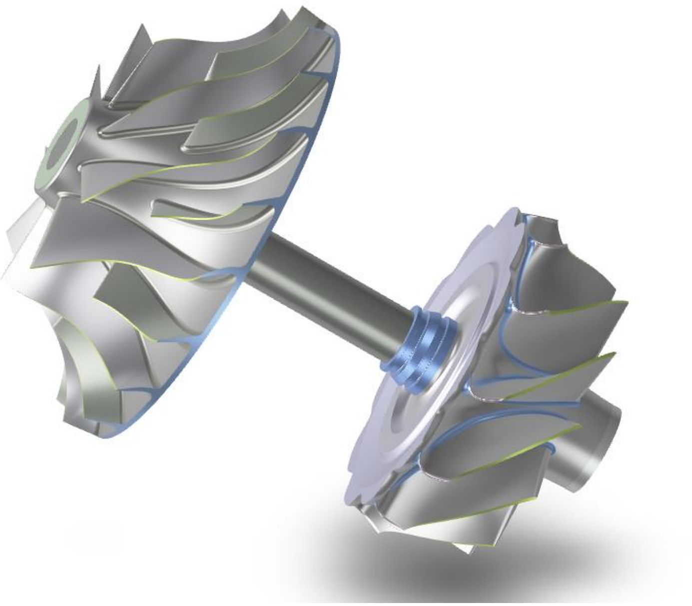
CARSTEN FÜTTERER

EUROPEAN USERS’ MEETING 2017

CAESES®

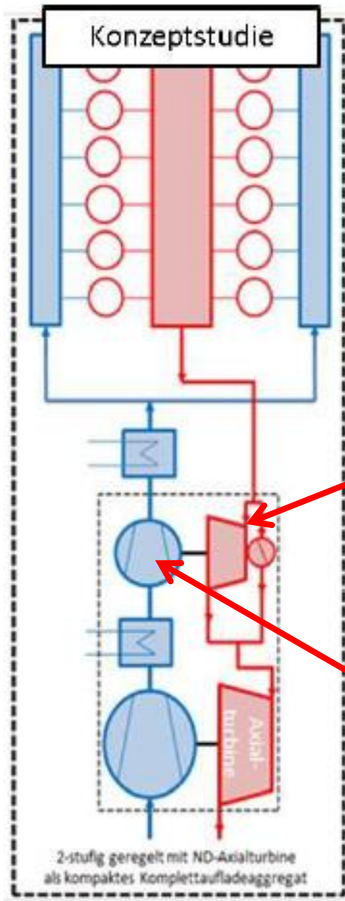
Introduction to GAMMA

- Research project
- GAMMA = Effiziente **GA**smotoren für **M**ariti**M**e **A**nwendungen
- Goal:
  - Investigate new technologies of turbo charger for fast running high efficient Gas (LNG / Natural) engines
  - Increase efficiency, reduce carbon emissions (~7% in first project phase) , stay profitable and reduce complexity of engine parts
- Field of application
  - Engines of 0.5 -10 MW
  - Yards, offshore supply vessel, patrol boats, trains, large trucks
- Project partners:
  - MTU Friedrichshafen GmbH, Numeca Ingenieurbüro, Friendship Systems AG, TU Darmstadt Fachgebiet Gasturbinen, Luft- und Raumfahrtantriebe

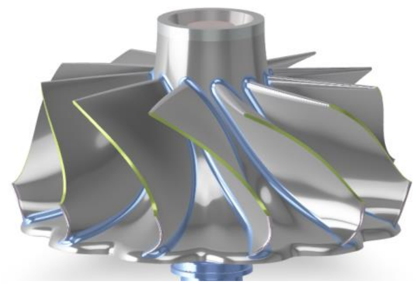


Introduction to GAMMA

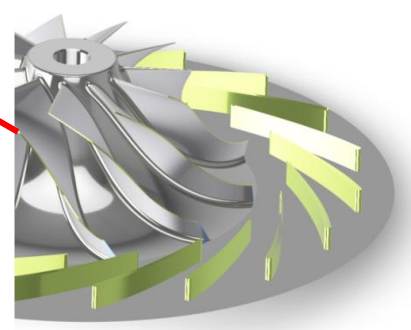
- Engine concept
  - Two stage design
  - High pressure turbine and compressor
  - Low pressure axial turbine
  - High pressure bypass
  - Compact design
  - Modular parts



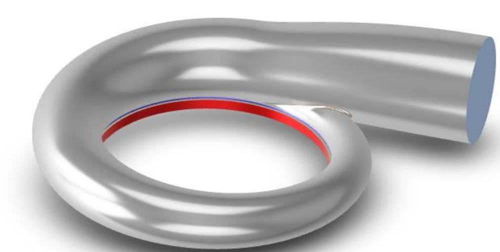
Radial turbine



Compressor blades + diffusor



Compressor volute

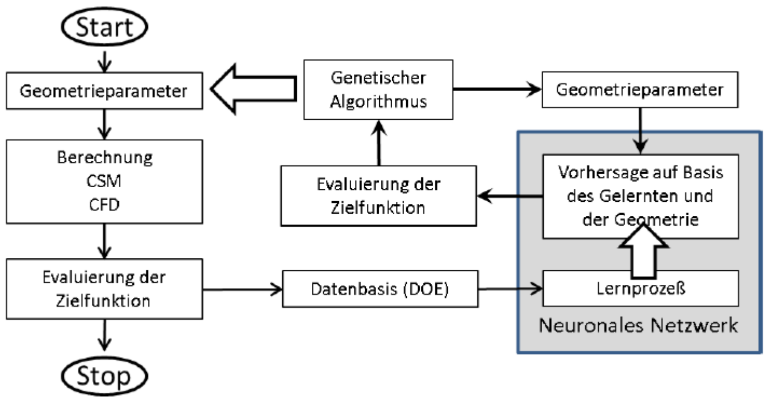


source: MTU Friedrichshafen GmbH

Workflow

- Important part of the workflow is the combination of structural mechanics (CSM) and CFD
  - Geometry -> CSM -> CFD
  - If the design fails because of structural constraints, the CFD is not calculated

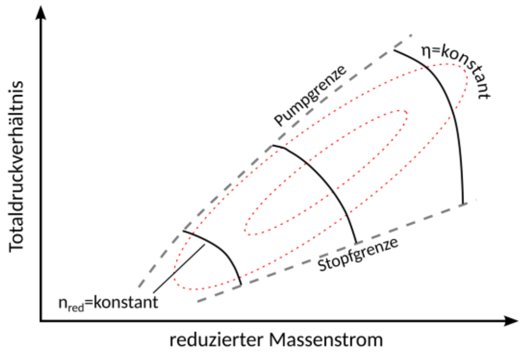
- CAESES has to provide
  - Quality solid segment and fluid domain
  - Geometry, which produces good quality volume cells
  - Geometry, which does not need any modification
  - Geometry, which is robust for a large design space

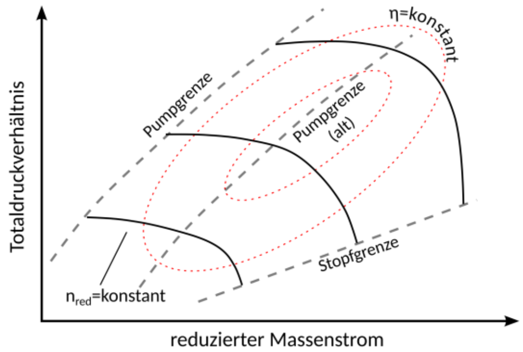


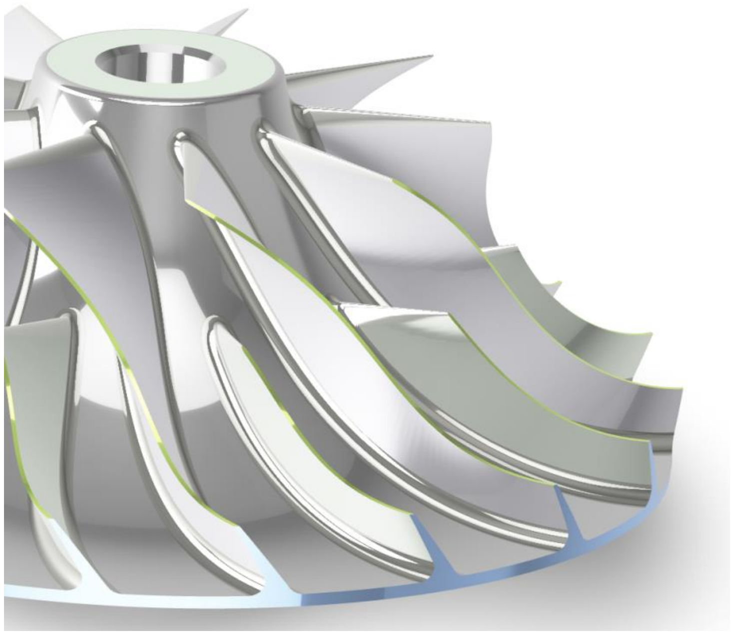
Quelle: Projektbeschreibung zum Programm des BMWi: “6. Energieforschungsprogram”. Verbundvorhaben GAMMA-1

Compressor blades

- Current baseline model has good efficiency but very narrow compressor map
- Target
  - increase operation range
  - Increase the efficiency
- Constraints
  - Pressure ratio
  - Eigen frequency
  - Stresses
- Software:
  - Geometry: CAESES
  - Mesh CFD: AutoGrid (Numeca)
  - CFD: FineTurbo
  - Mesh CSM: SimLab
  - CSM: Calculix
  - Optimization: ModeFrontier

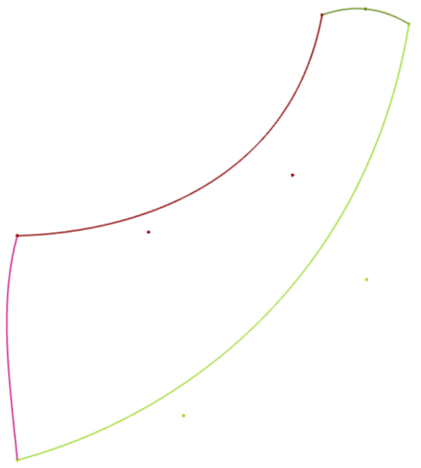




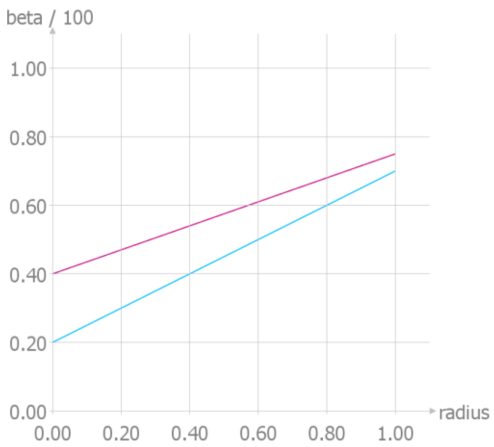


Compressor blades

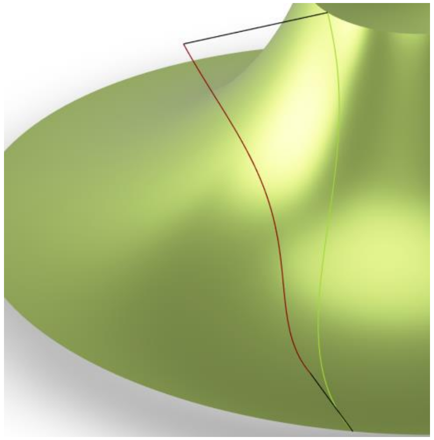
Meridional Contours



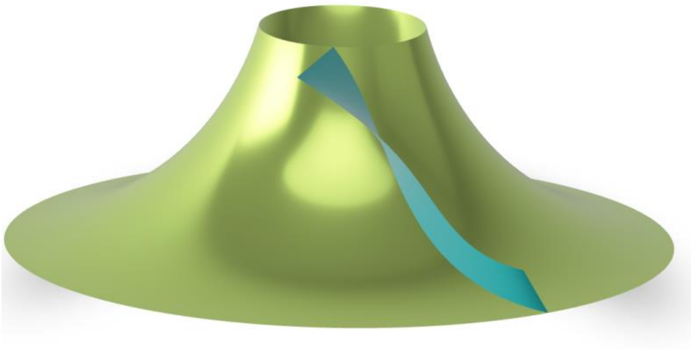
Beta Distribution for hub



Streamsection

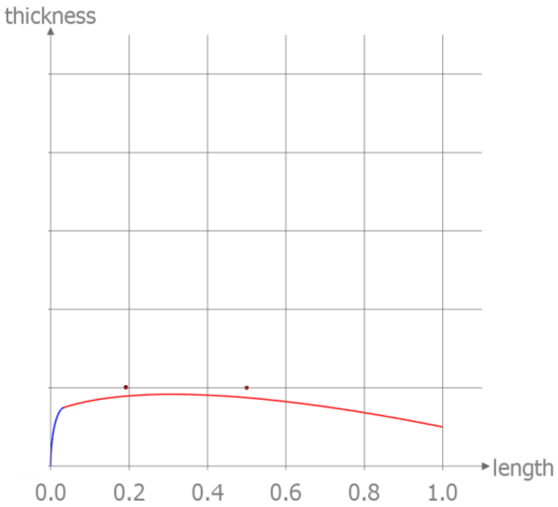


Camber surface

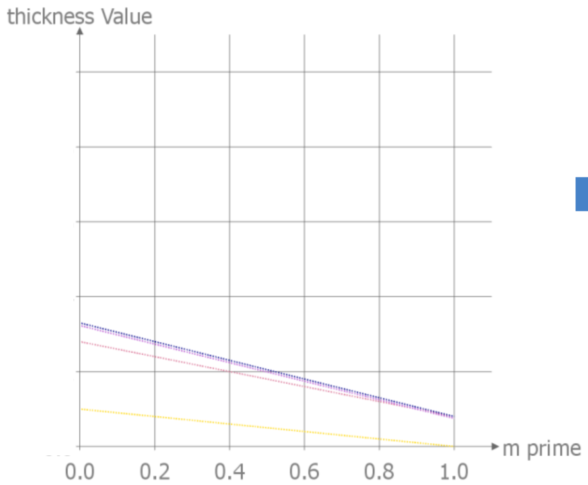


Compressor blades

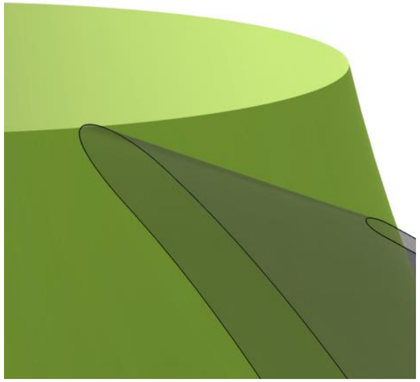
Thickness 2D profile



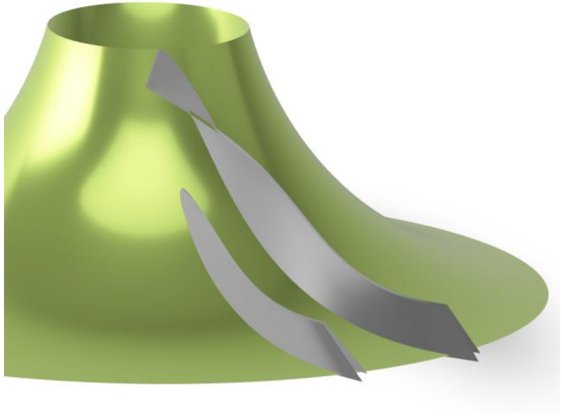
Thickness Distributions



Blade surface

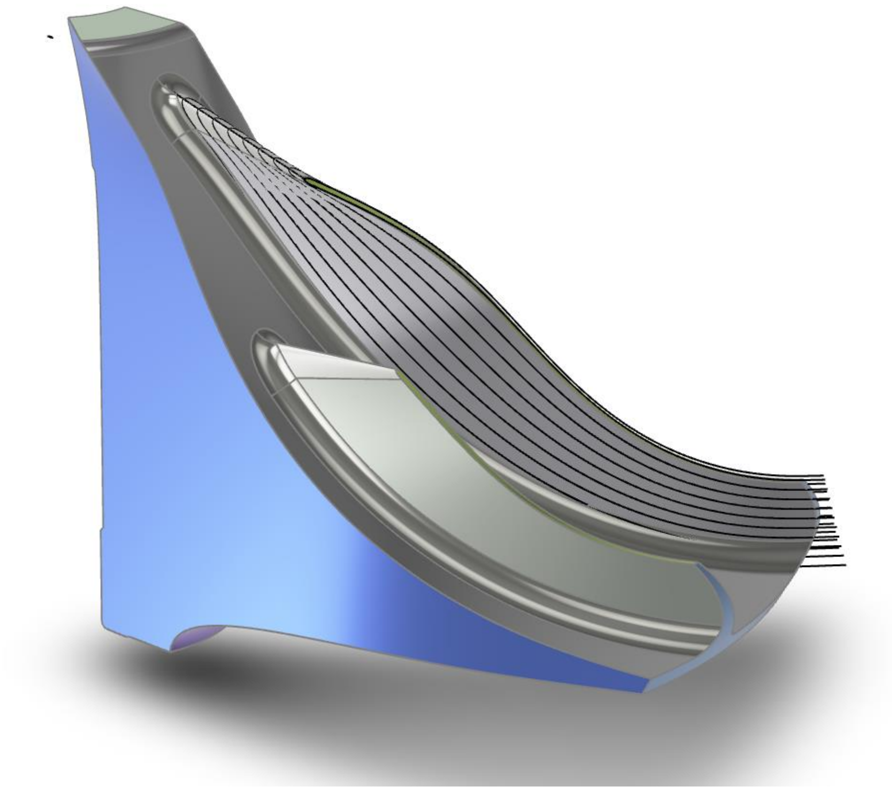


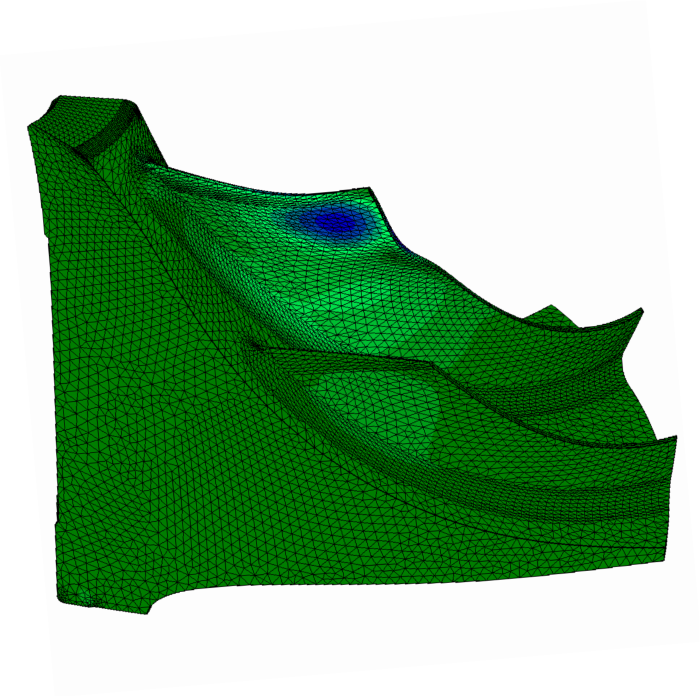
Splitter Blade



Compressor blades

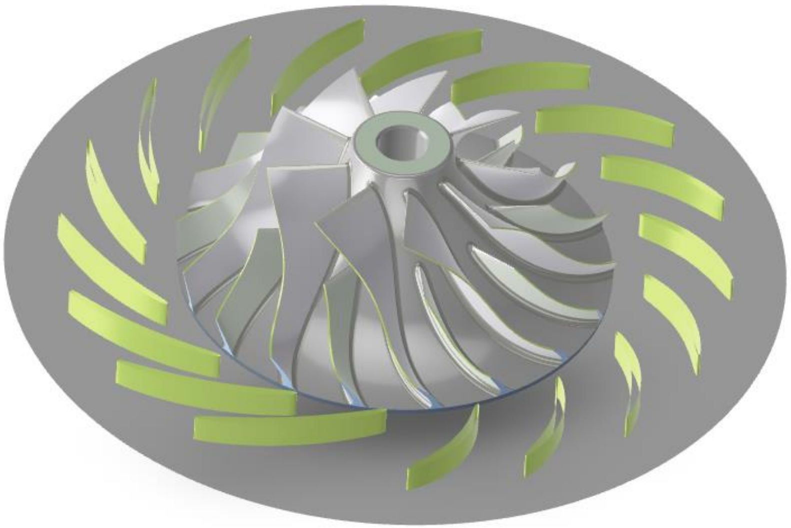
- Exports
  - For CFD: in blades in geomTurbo format
  - FOR CSM: Solid segment

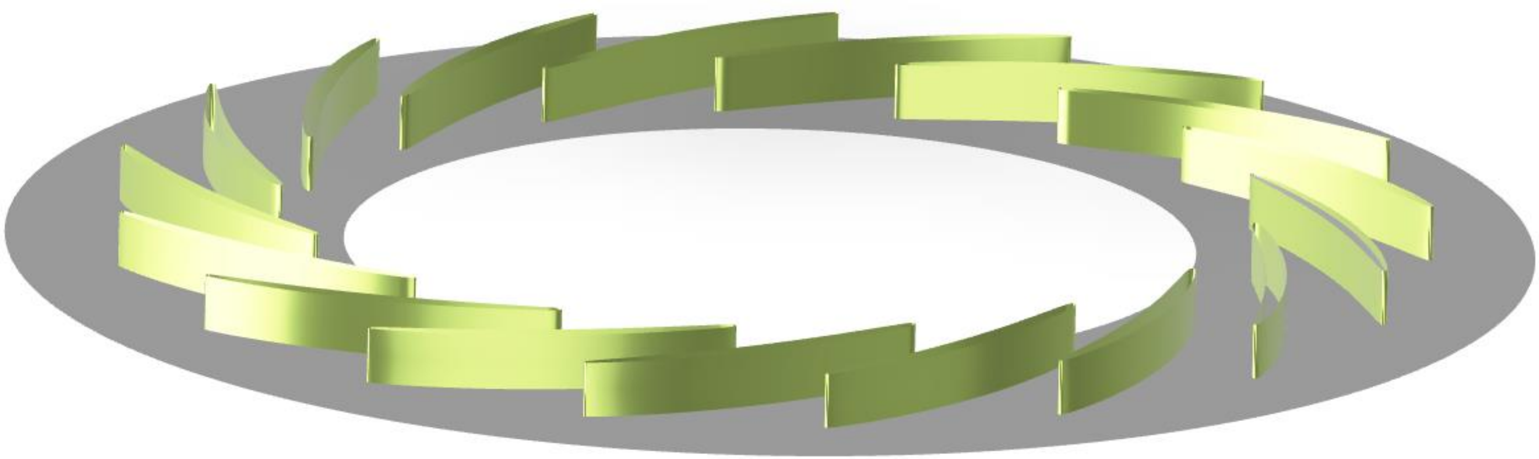




Diffusor Blades

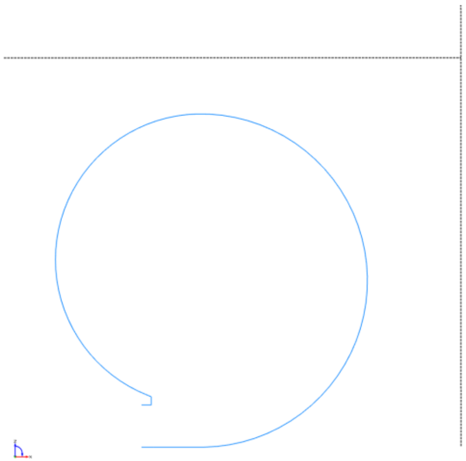
- Meta surface for each blade
- Setup is the same as rotor blades
- Each parameter of the meta surface can also be varied in circumferential direction
  - Curve engine and meta surface will be completely generated inside a feature
  - Inputs to the feature are value distributions or constant values for each parameter

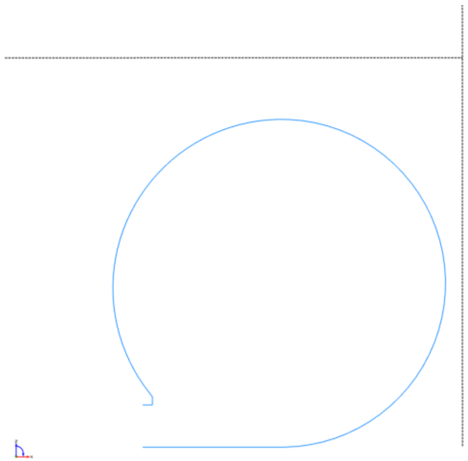


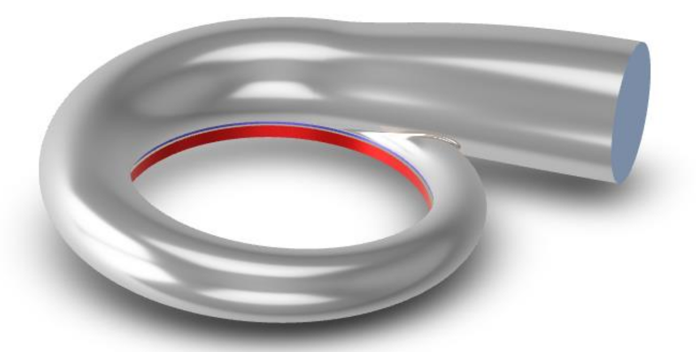


Compressor Volute

- Basic profile is modeled with circular segments
- The board angle and the A2R ratio can be varied
- If space constraint for the max radius is reached, then the profile is getting higher
- If the max height is reached, then the profile moves inwards



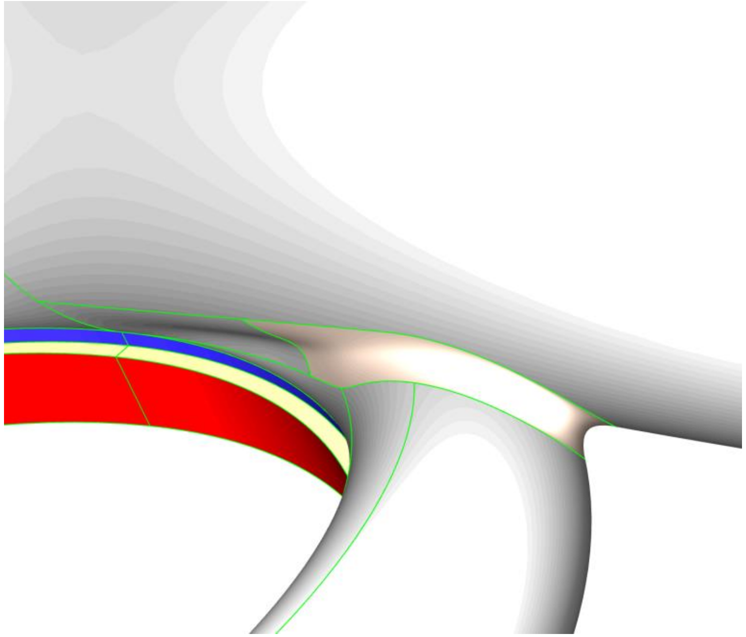




Compressor Volute

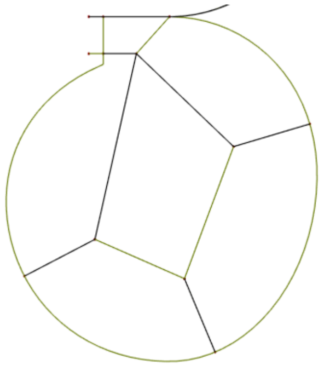
- The tongue is model with a custom fillet surface
- Advantages:
  - Very robust
  - Highly flexible
  - Very good quality of the exported solid (no open edges or intersecting faces)

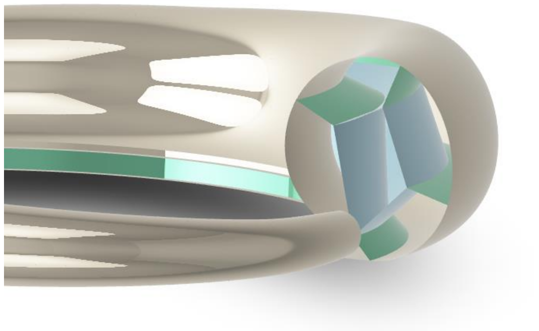
- Volute export format
  - Parasolid

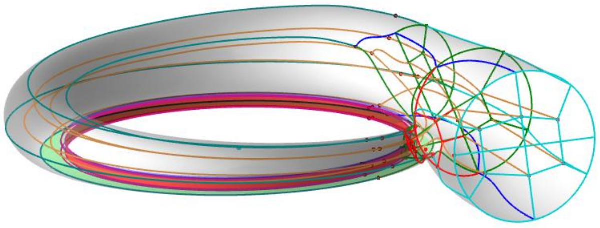


Compressor Volute – support geometry

- Motivation
  - Robust structured meshing for variable and complex geometries like volutes is very difficult
- Idea:
  - Create parametric support geometry inside CAESES
  - Export the curves to IGG
  - All blocks are well defined, which make the generation of the block mesh much more easy
- Testing if support geometry generated from CAESES can handle this
- Method
  - Included in profile definition
  - Create a meta surface for each line
  - Connect curves from volute and outlet

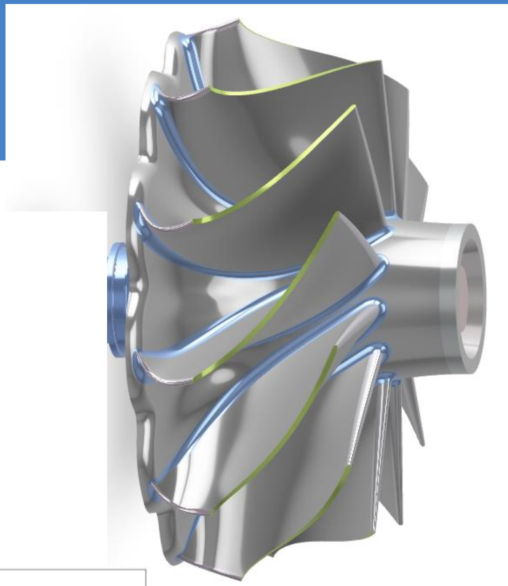


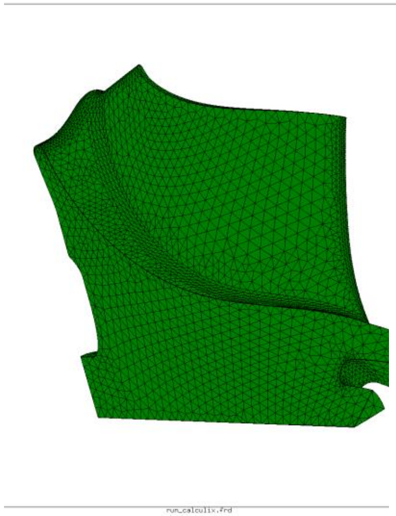


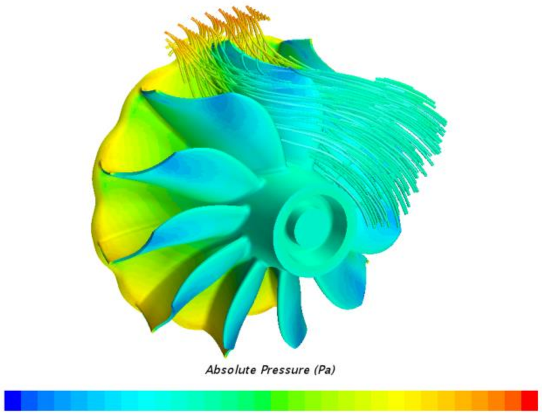


Turbine blades

- Target
  - Increase the efficiency
- Constraints
  - Eigen frequency
  - Stresses
  - Fatigue life
- Software:
  - Geometry: CAESES
  - Mesh CFD: STARCCM+
  - CFD: STARCCM+
  - Mesh CSM: SimLab
  - CSM: Calculix
  - Optimization: ModeFrontier



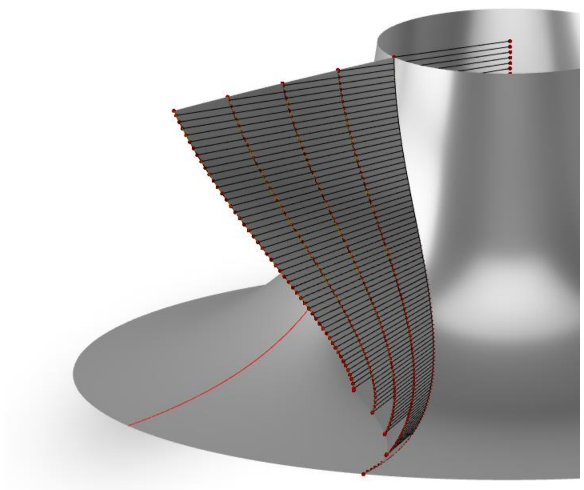




Turbine blades – Interesting features

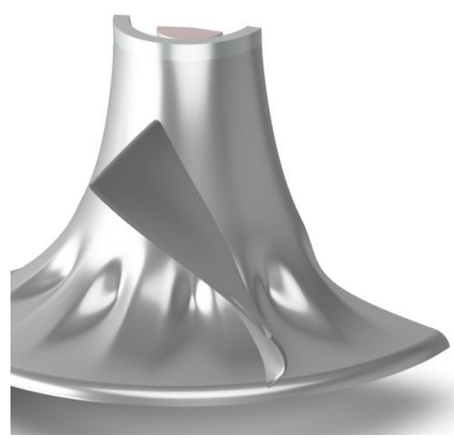
Camber surface

- All points p of the camber surface are dependent on the hub streamline
- p(theta,z)
- Structural beneficial
- Reduces number of design variables



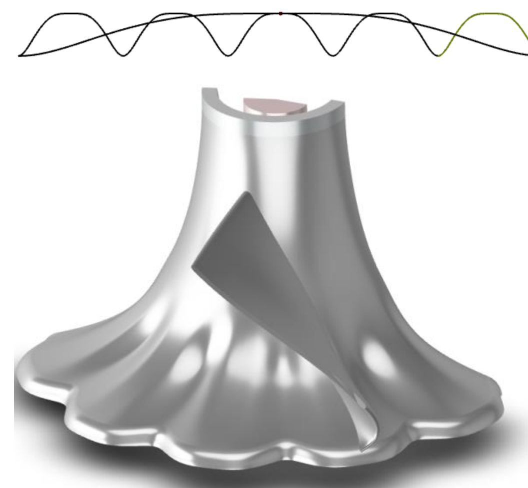
Hub endwall contouring

- Hub contour can be changed in circumferential direction
- Additional changes are possible, to apply endwall contouring
- Beneficial to reduce rotating mass



Hub Scallops

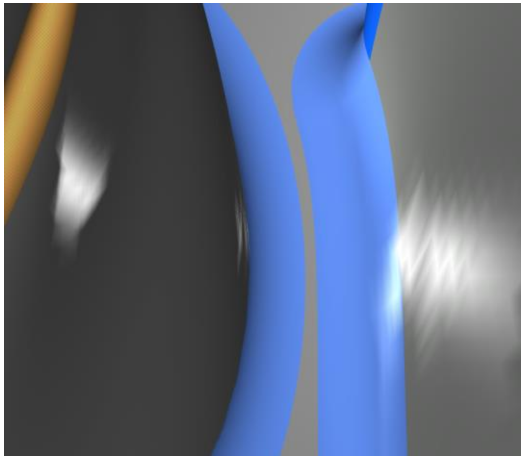
- Scallops are also directly included inside the hub surface



Turbine blades – Interesting features

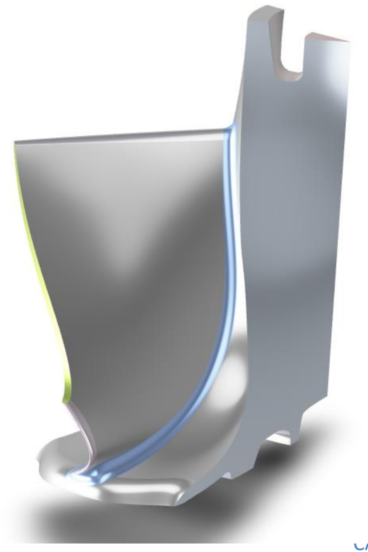
Max fillet radius

- For mechanical reasons it is beneficial, when the fillet radius between the blades is as large as possible
- Maximum fillet radius and position is automatically calculated
- Internal optimization is used



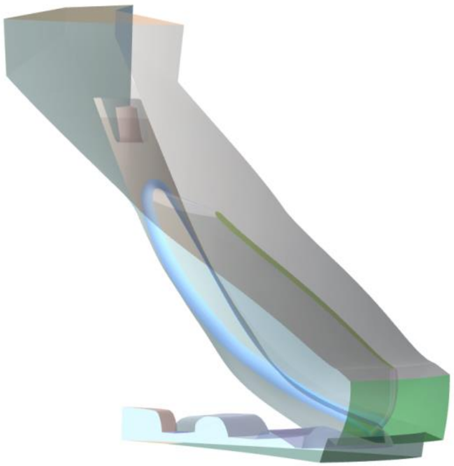
Periodic segment

- Periodic cut out is crucial between blades
- Working in domain space is very useful
- Care about good quality volume cells

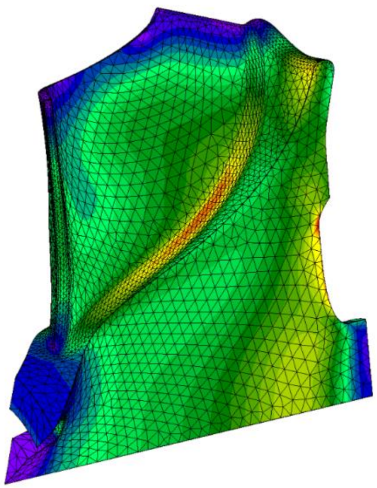


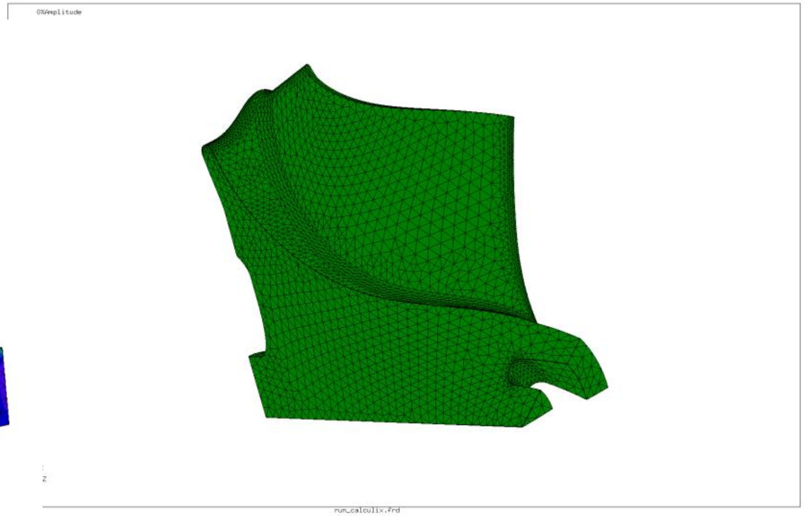
Flow domain

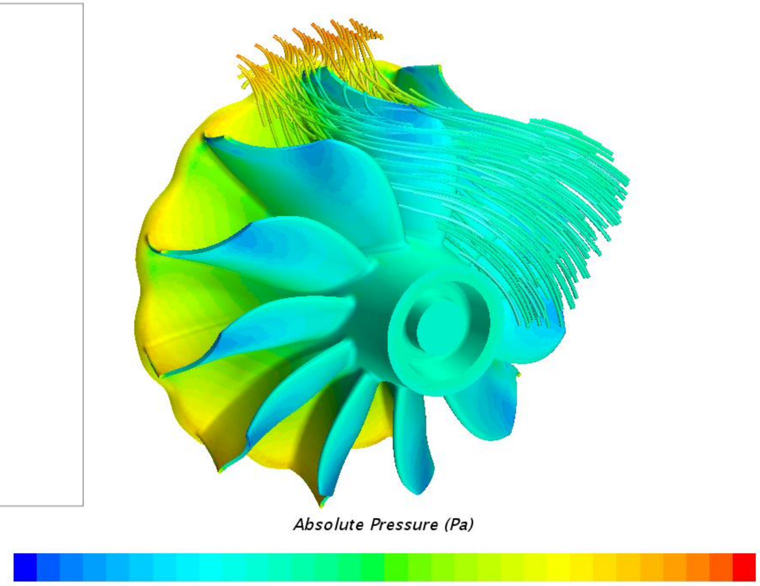
- For CFD
- Fluid and solid domain have to fit exactly on each other



Turbine blades







Thank You!

www.CAESES.com