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3D SHAPE OPTIMISATION OF A LOW PRESSURE TURBINE STAGE

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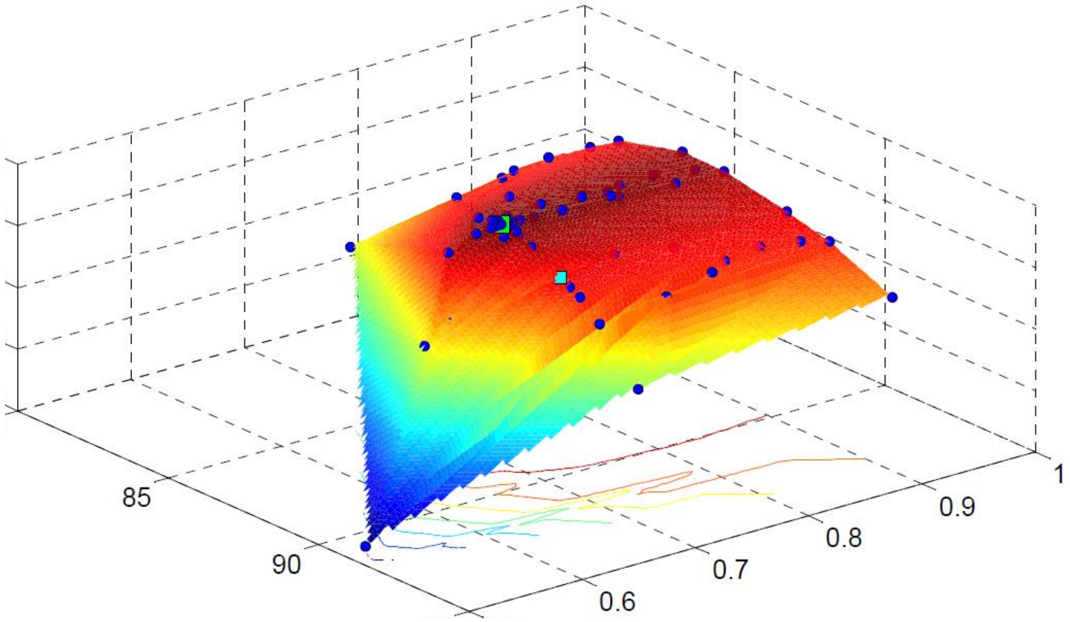
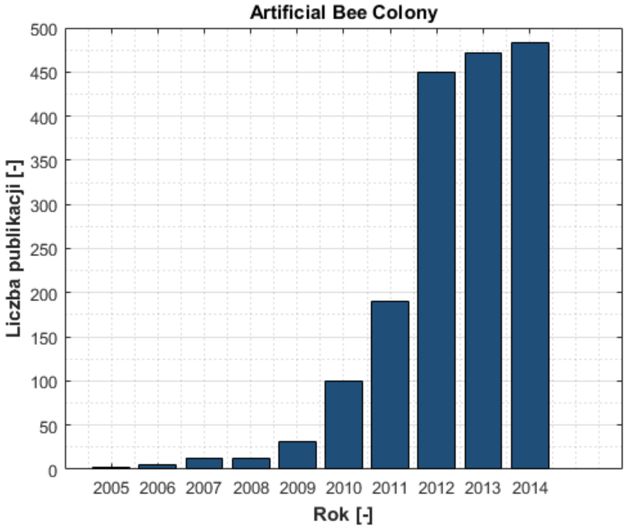
Optimisation

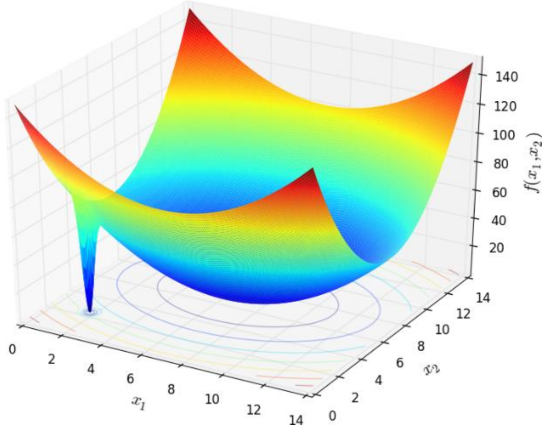
- Optimisation allows us to improve efficiency of the machines
- Procedure for finding maximum/minimum of objective function
- Objective function, penalty function, boundaries
- Methods of optmisation – wide range
- Reduction of flow losses:
  - profile loss
  - boundary loss
  - exit kinetic energy losses

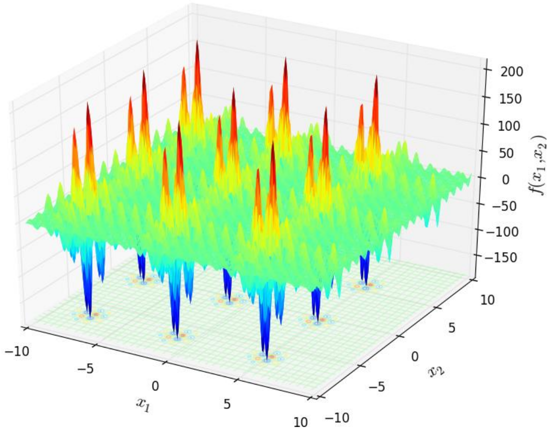


Methods of optimisation

- Deterministic Methods: Nelder-Mead, Hooke-Jeevesa.
- Stochastic methods: Swarm intelligence, Genetic methods.







- Hybrid methods:

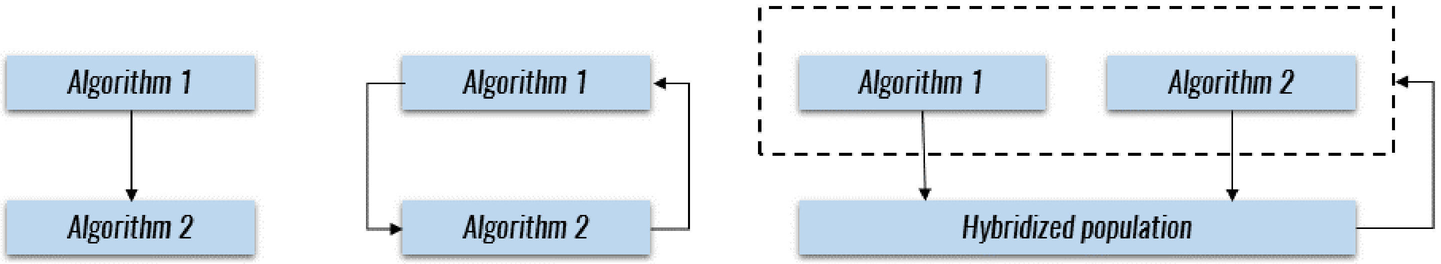
Bat algorithm
Cuckoo Search
Glowworm swar optimization
Grey wolf optimizer
Spider Monkey Optimization

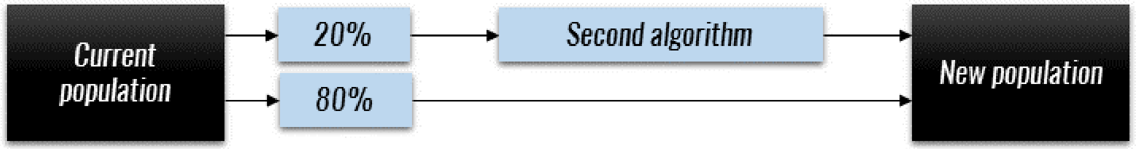
\+

Nelder Mead
Hooke-Jeeves

Hybrid algorithms

- Collectively and cooperatively solving a predefined problem
- Collaborative Hybrids: multi-stage, sequential, paralel structures
- Integrative Hybrids: full manipulation, partial manipulation
- Chalanges: namin convention, complexity, computational speed





Hybrid algorithms

- A NEW METAHEURISTIC BAT-INSPIRED ALGORITHM - Xin-She Yang, Nature Inspired Cooperative Strategies for Optimization (NISCO 2010), (Eds. J. R. Gonzalez et al.), Studies in Computational Intelligence, Springer Berlin,284, Springer, 65-74 (2010)
- A SIMPLEX METHOD FOR FUNCTION MINIMIZATION - Nelder, J.A. and Mead, R. , Comput. J., 7, pp. 308 – 313

1. Initialize the bat population x
2. Define pulse frequency
3. Initialize pulse rates (r) and loudness (A)
4. While (t < Max number of iterations

   Generate new solutions by adjusting frequency and updating velocitiec and locations
   - If rand > r

   Select a solution among the best solutions. Generate a local solution around the best solution.
   - End if

   Generate a new solution by flying randomly
   - If rand < A and f(x_new < x_new_previous)

   Accept the new solution.
   - Elseif

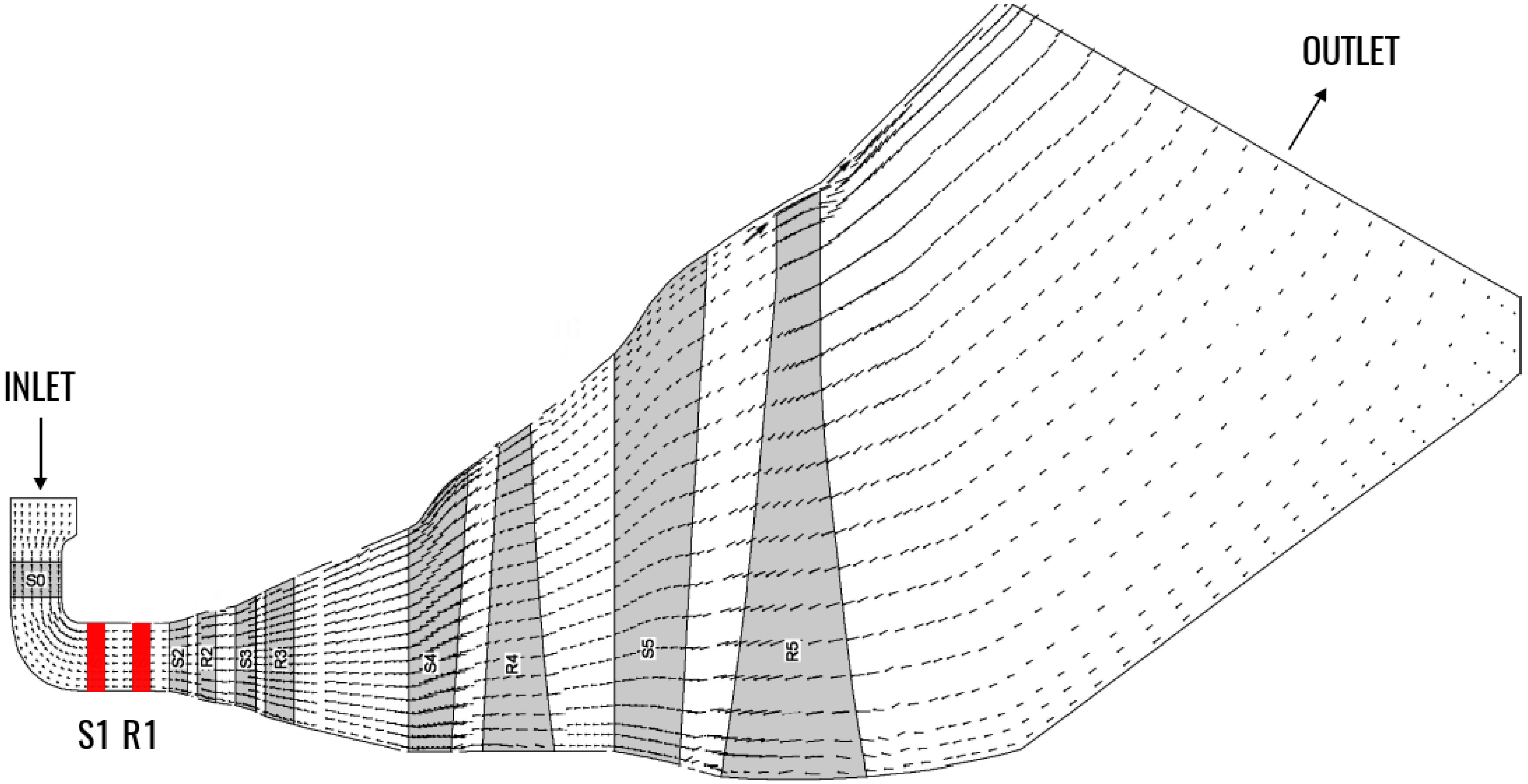
   Neldera – Mead Method
   - End if

   Rank the bats and find current best

5. End while

Case study

- LP part of steam axial turbine
- Number of stator blades - 202
- Number of rotor blades - 227
- Design parameters:
  - Rotational speed – 3000 rpm
  - Inlet pressure – 514 kPa
  - Inlet temperaturę – 537 K
  - Outlet pressure – 9 kPa
  - Mass flow – 135 kg/s
  - Working fluid - water

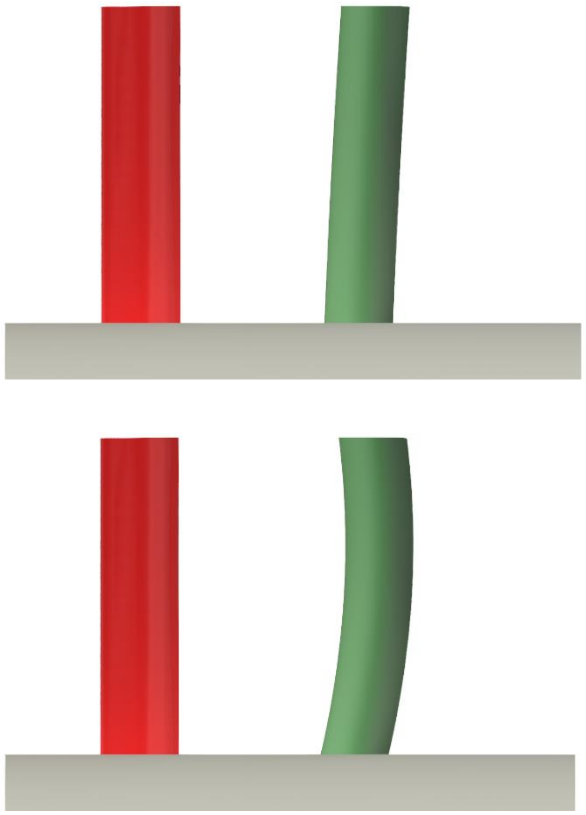


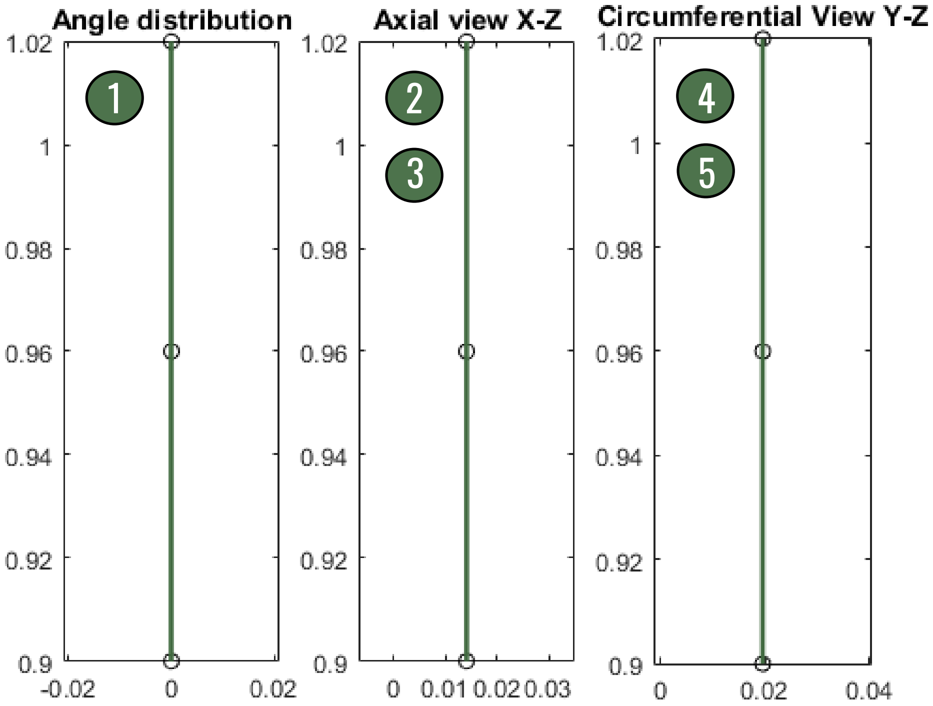
Parametrization

- Parametrization is a **key to success** of optimisation
- B-spline function with control point at the medium height of blade and blade tip
- 12 changing points (6 stator, 6 rotor)

2

3





1 Blade twist angle

2 Blade simple axial lean

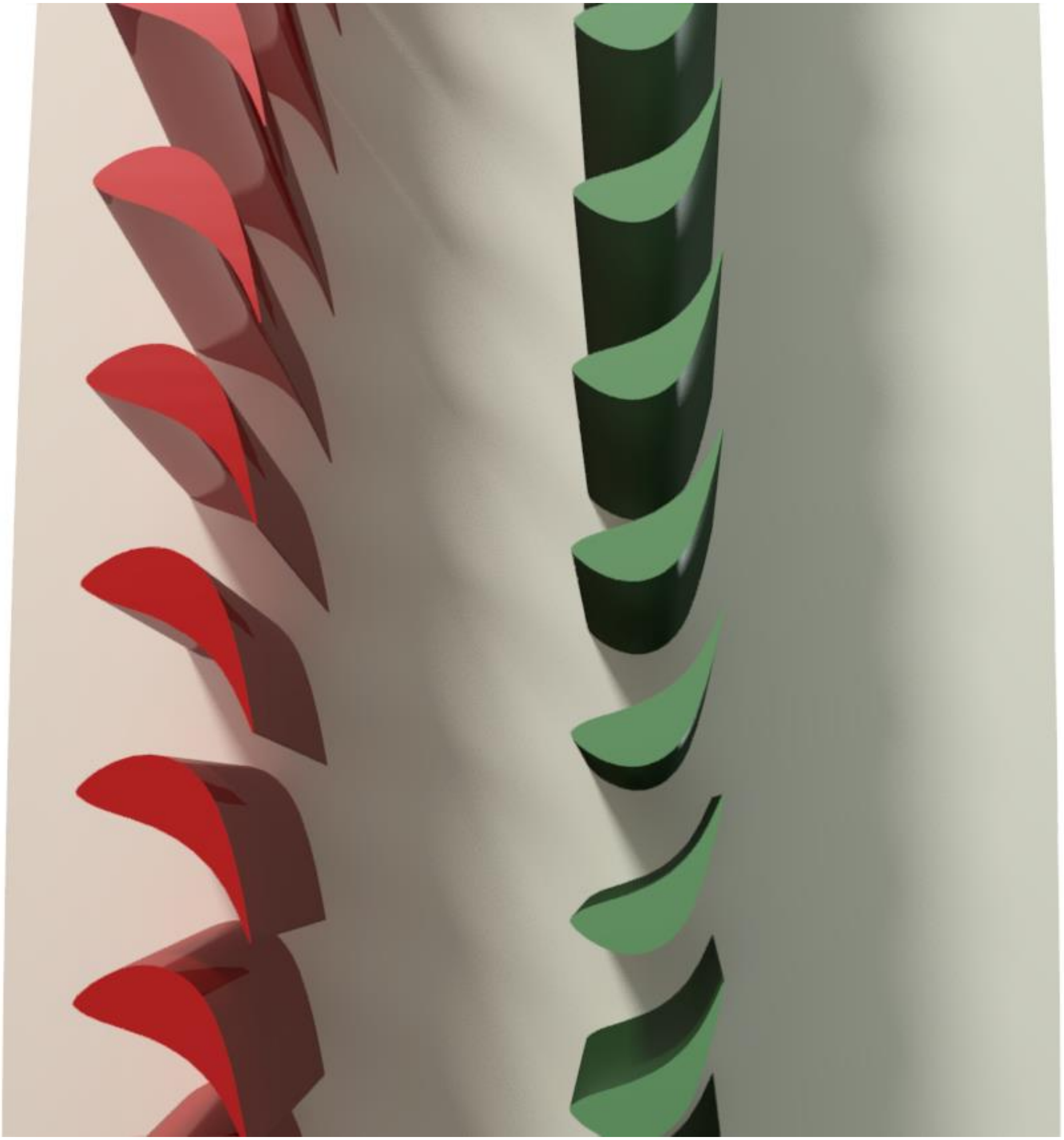
3 Blade compound axial leand

4 Blade simple circuferential lean

5 Blade compound circuferential lean

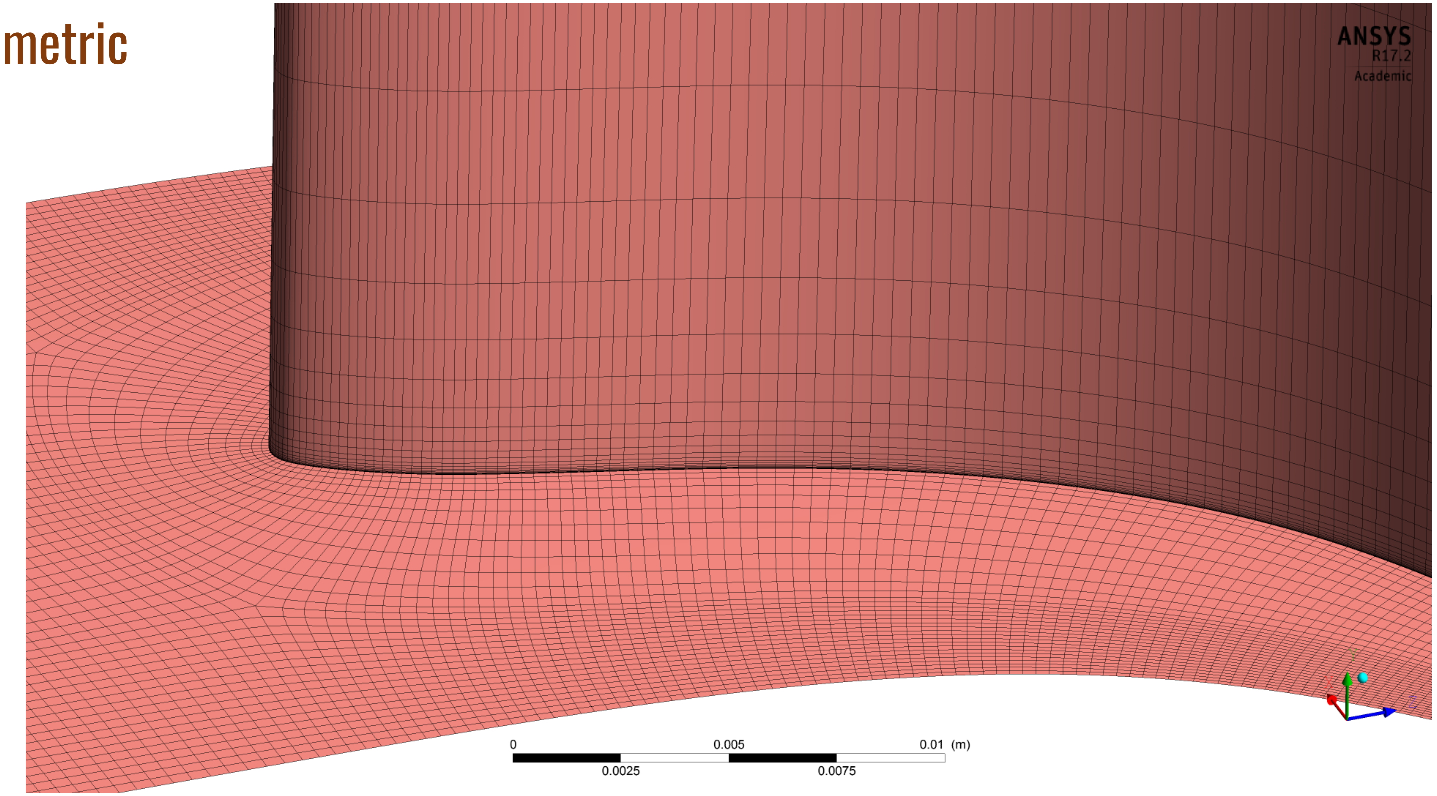
Methodology

- RANS (Reynolds-averaged Navier-Stokes) stationary simulations in ANSYS CFX v.17
- *k-ω* SST turbulence model
- Periodicity conditions
- ANSYS Turbogrid v.17 software is used for meshing
- Boundary conditions:
  - inlet – total pressure , total temperature
  - outlet – static pressure
  - other – rotational speed



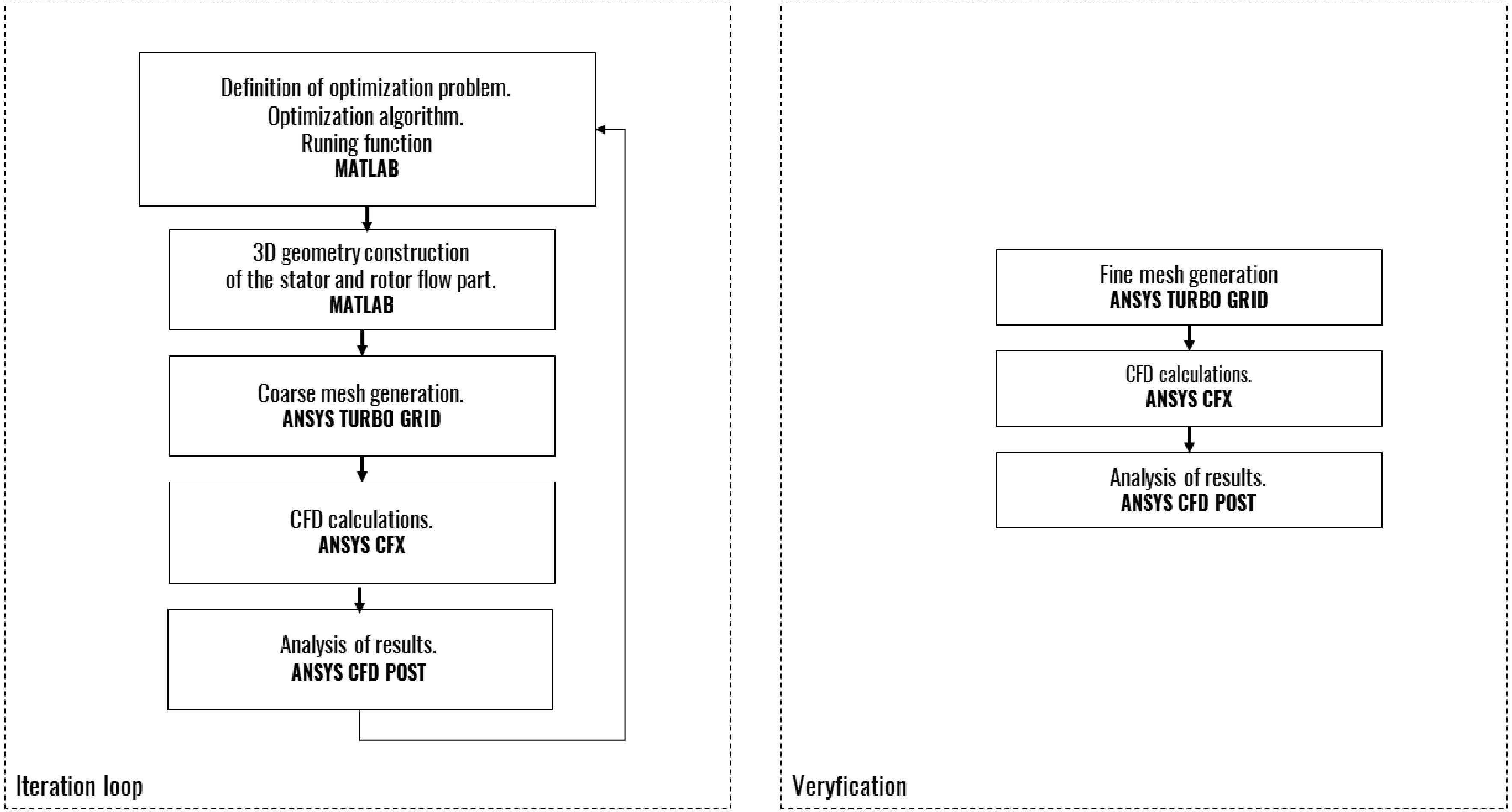
Discretization

- Topology definition – Single Round Round Symmetric
- Mesh limits:
  - Maximum face angle - 165°
  - Minimum face angle - 15°
  - Maximum volume ratio - 20
  - Edge lenth ratio – 1000
- Number of elements:
  - Optimisation task – 0.5 mln
  - Verification task – 2 mln

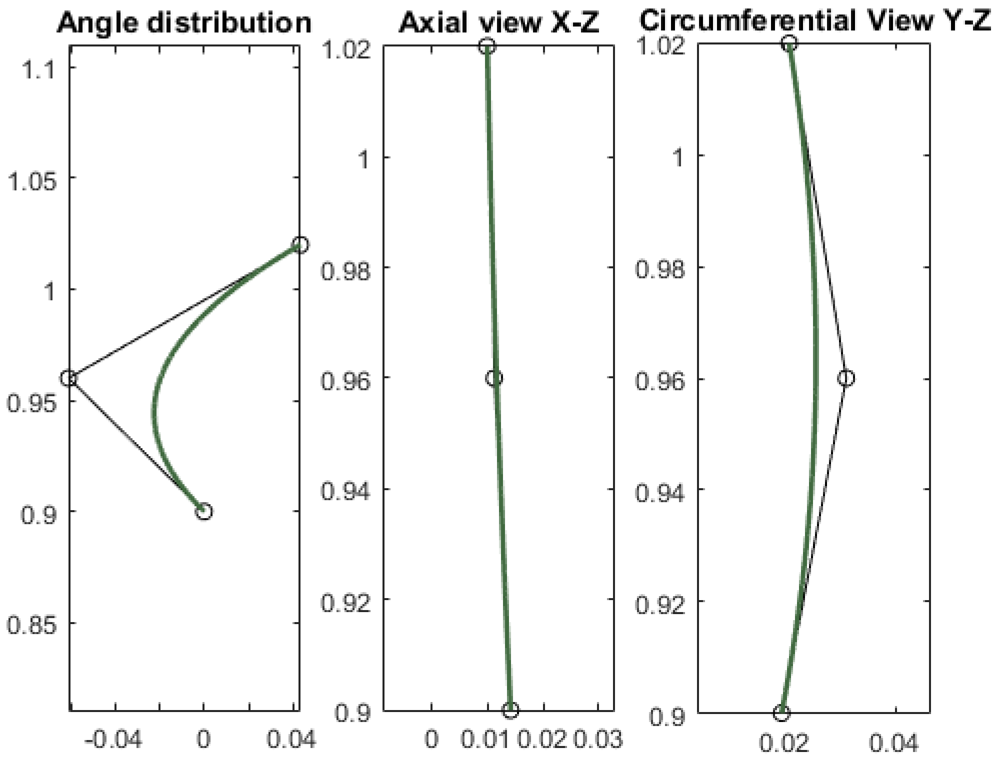


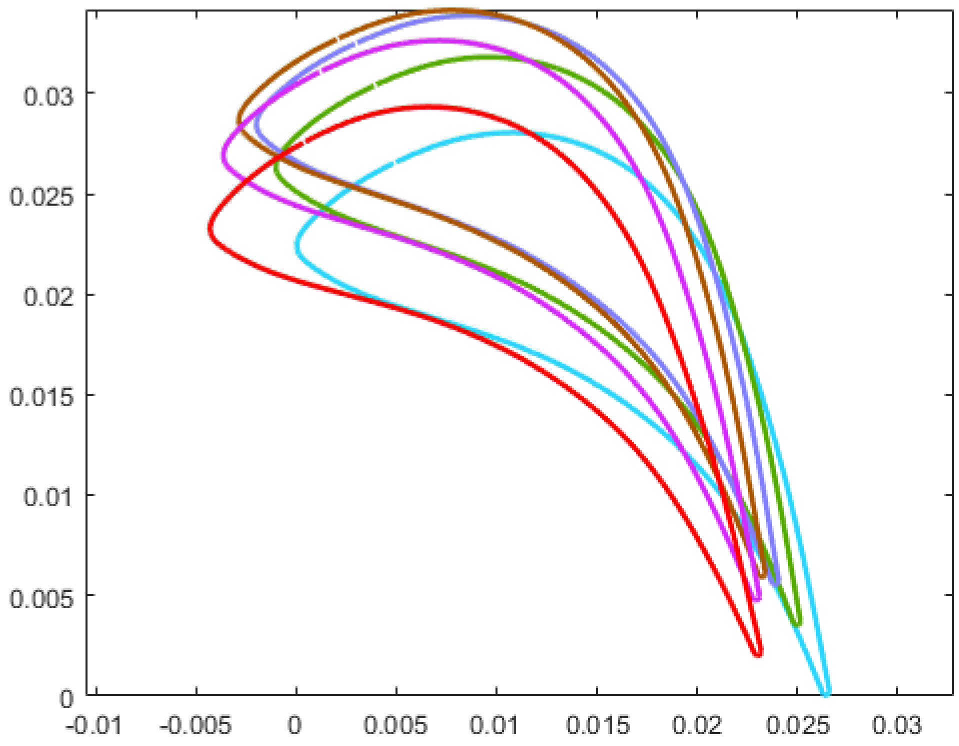
Mesh – 2 mln elements in stage

Scheme of optimization & verification



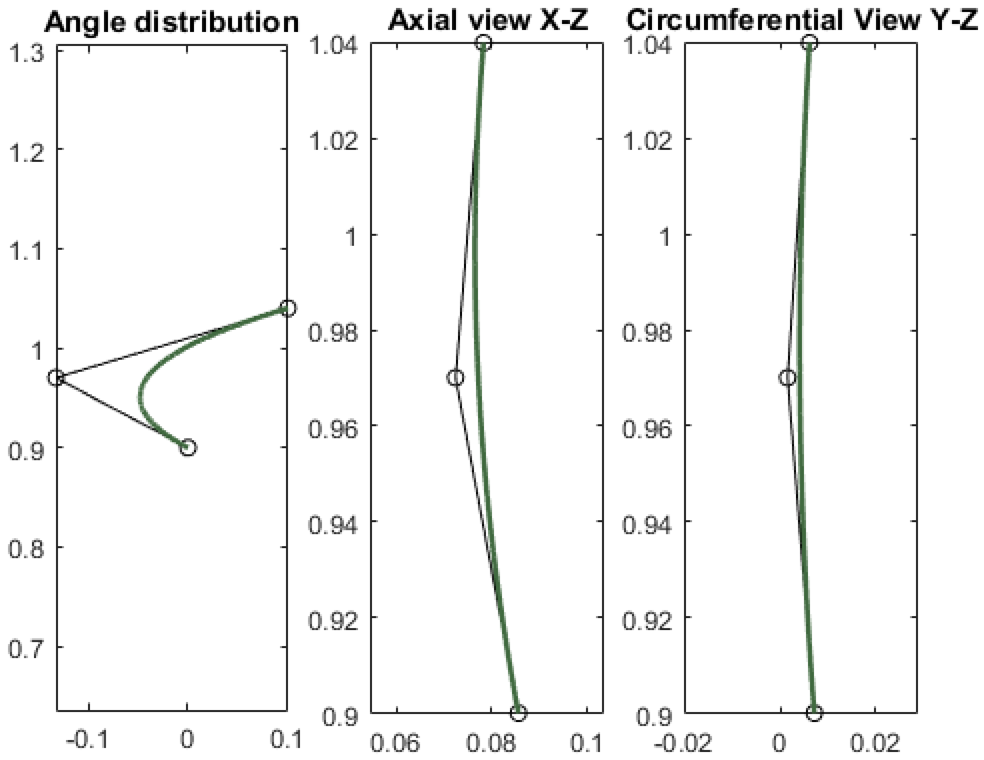
Results

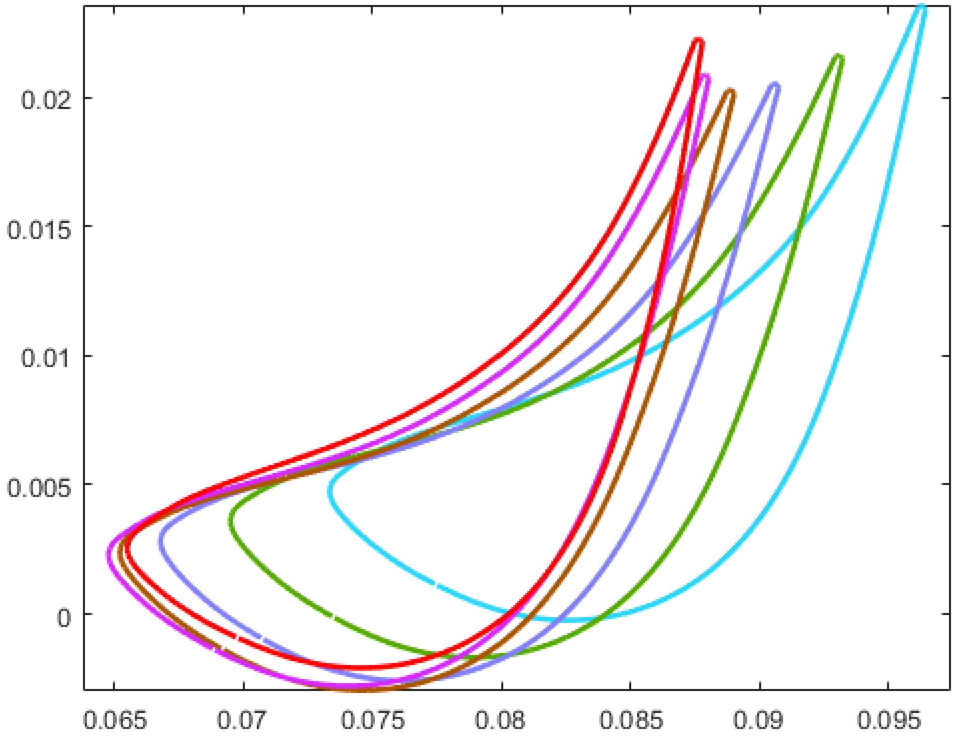




Stator airfoils

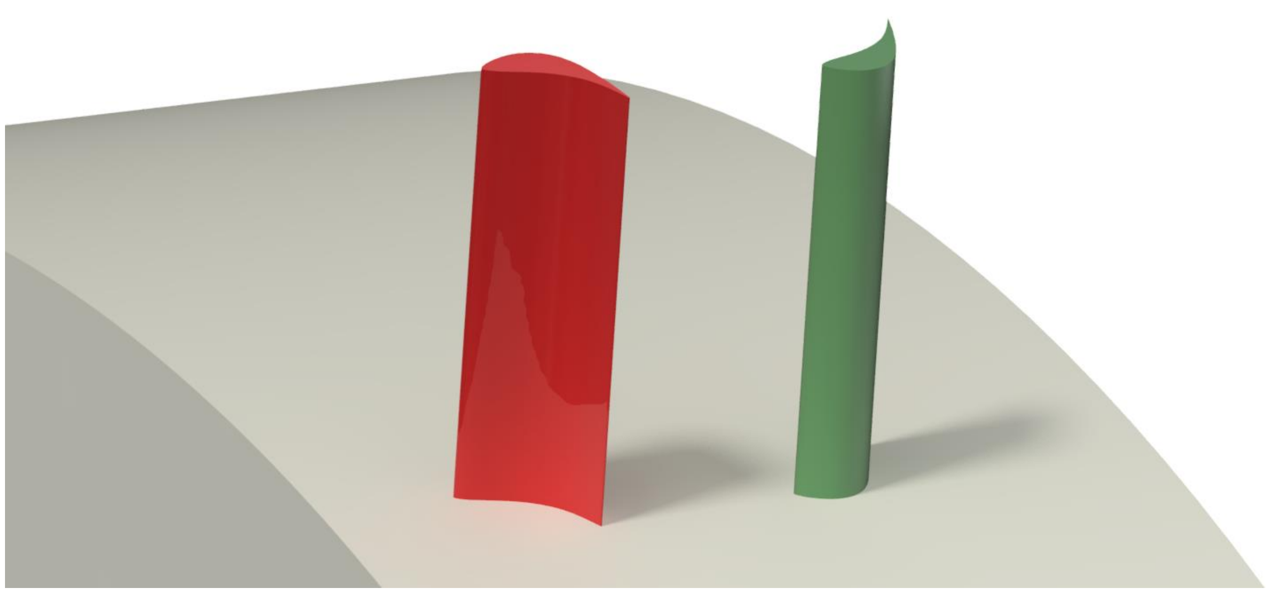
Results



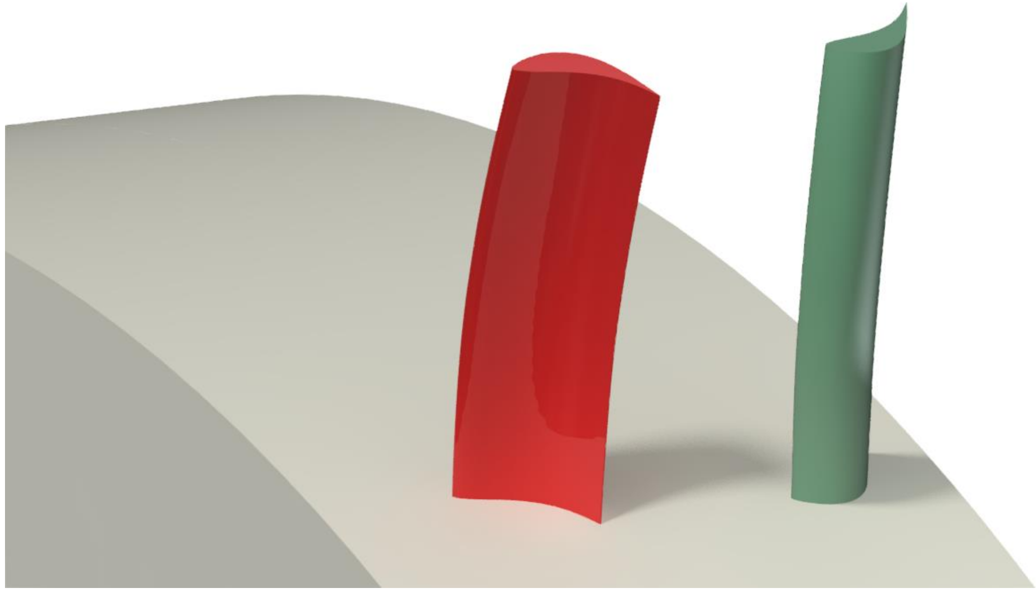


Rotor airfoils

Results

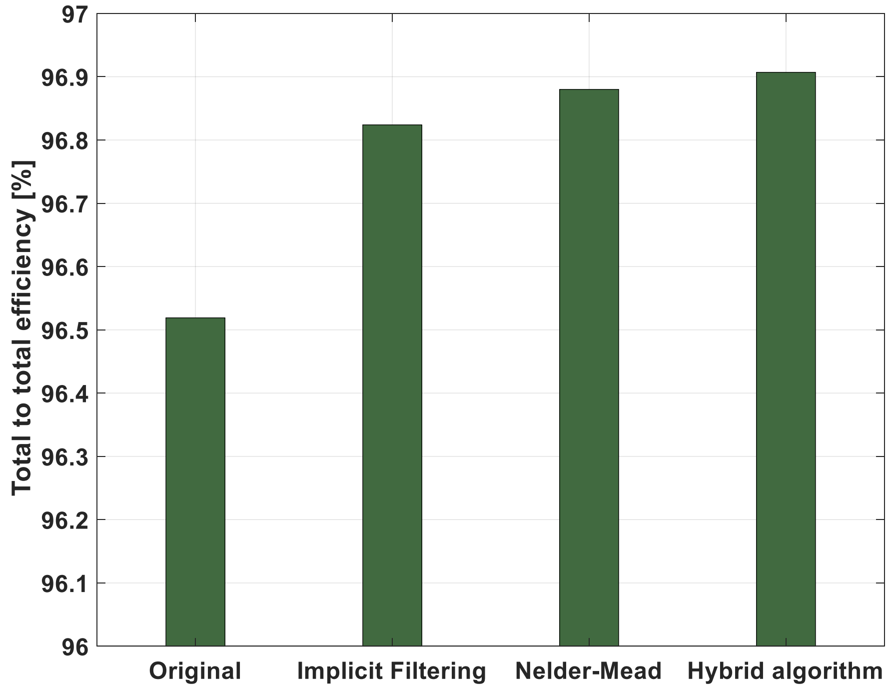


Original geometry

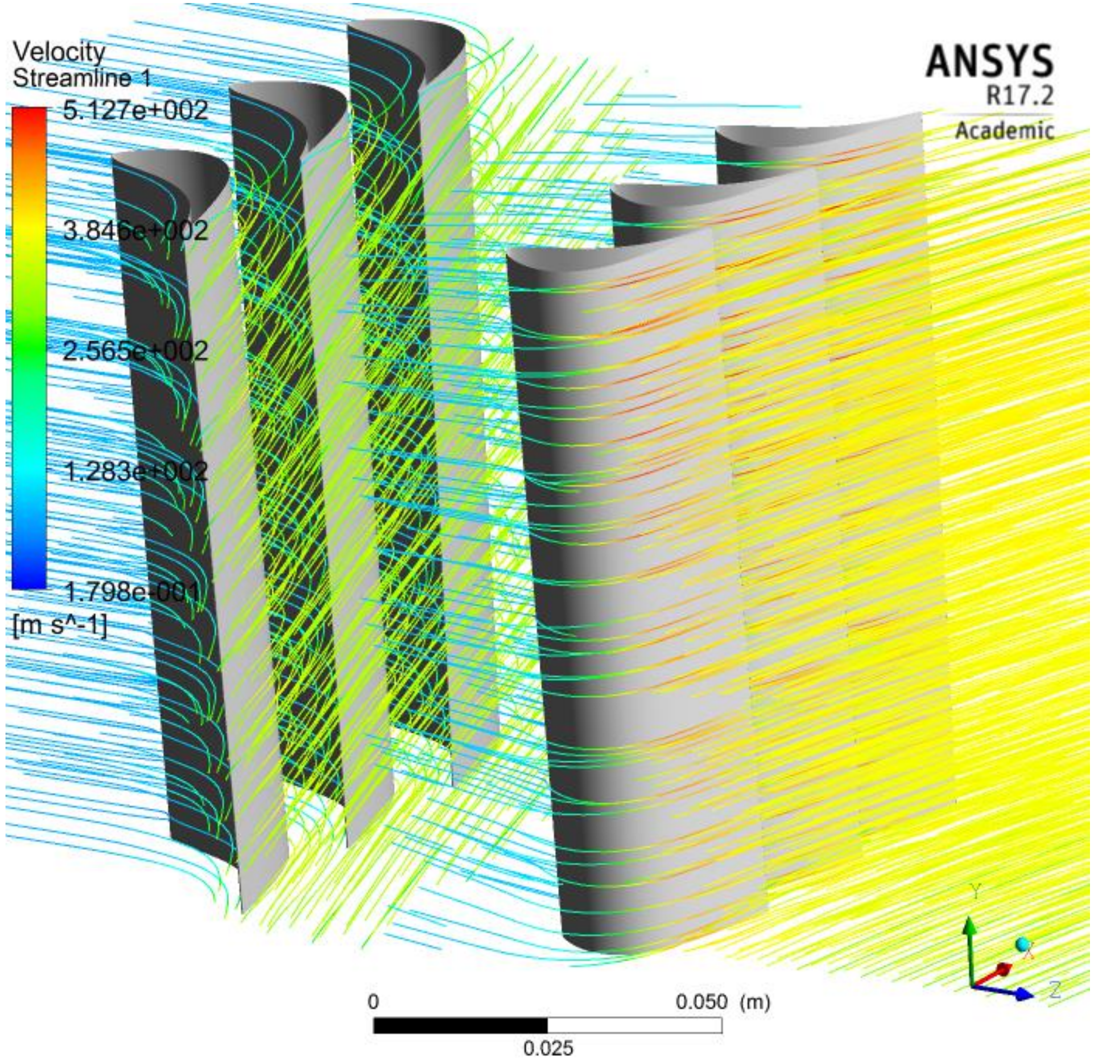


Optimised geometry

Results



Comparison of total to total efficiency of orginal and optimized geometries



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Conclusion

- The results show an improvement of objective function
- The hybrid algorythm are suitable for turbine optimization
- Finding the global minimum is very difficult and time-consuming
- The algorithm needs some changes to avoid unnecessary calculation of objective function
- Future studies should take into account new parametrization:
  - number of blades
  - meridional contour
- New algorithms will be implemented

Thank you!

Acknowledgements

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