CFD OF AIR FLOW IN HYDRO POWER GENERATORS FOR CONVECTIVE COOLING, USING OPENFOAM

ECCOMAS CFD 2010

Pirooz Moradnia, Håkan Nilsson

Lisbon-Portugal

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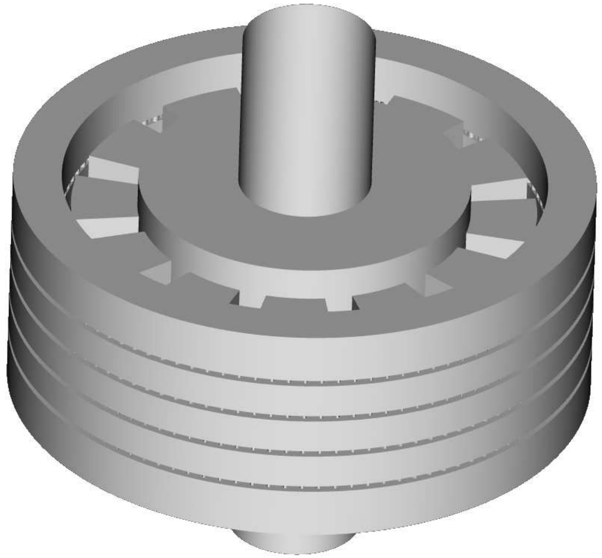
Importance of cooling in generators

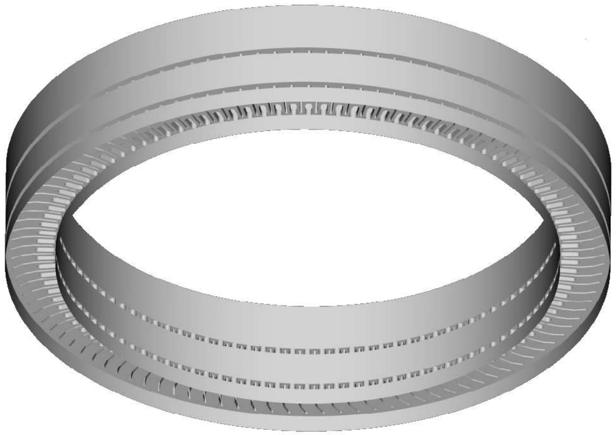
- Hydroelectric power generation stands for about half of the electricity generation in Sweden
- Modifications to the existing units would lead to significant contributions to the total energy production
- An increased power output leads to more heat that needs to be removed
- The two large sources of energy losses in the generators: thermal and ventilation losses:

  - Production of heat by the electric resistance in the generator coils (should be removed)
  - The rotor and stator are cooled by air, which causes ventilation losses
- The stators should be cooled by air flowing through the stator air channels
- Focus of the present work: Axially cooled generators

Geometry

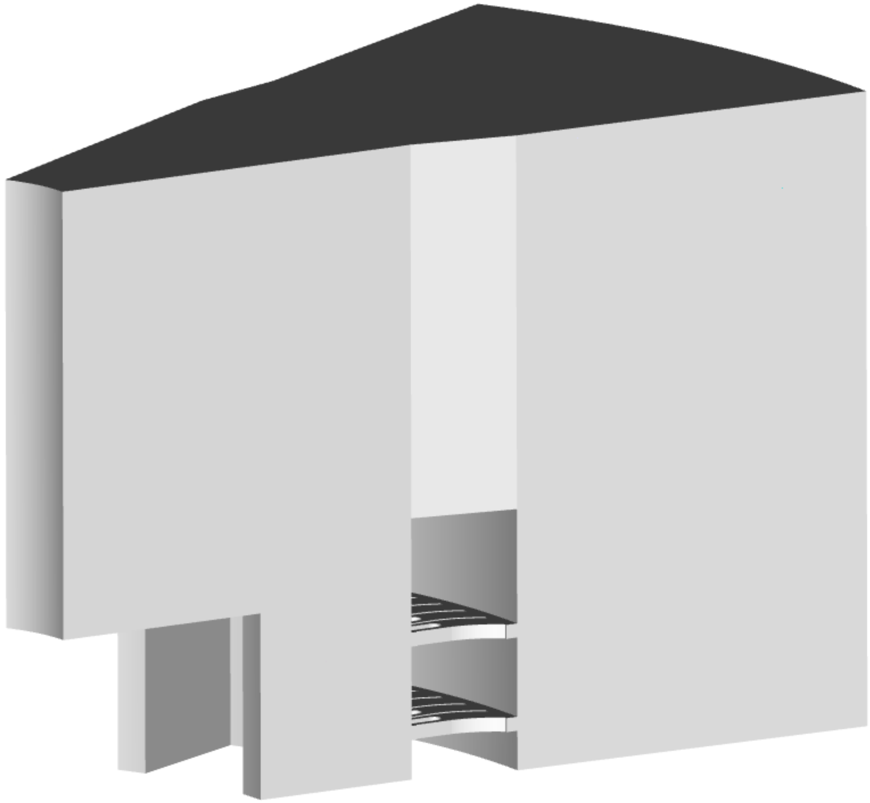
- A small generator at Uppsala University, Sweden
- 4 cooling-channel rows
- 108 cooling channel in each row
- 12 poles
- Rotational speed: 500 rpm
- The flow is driven by the rotation of the rotor, axially into the rotor and radially out through the stator



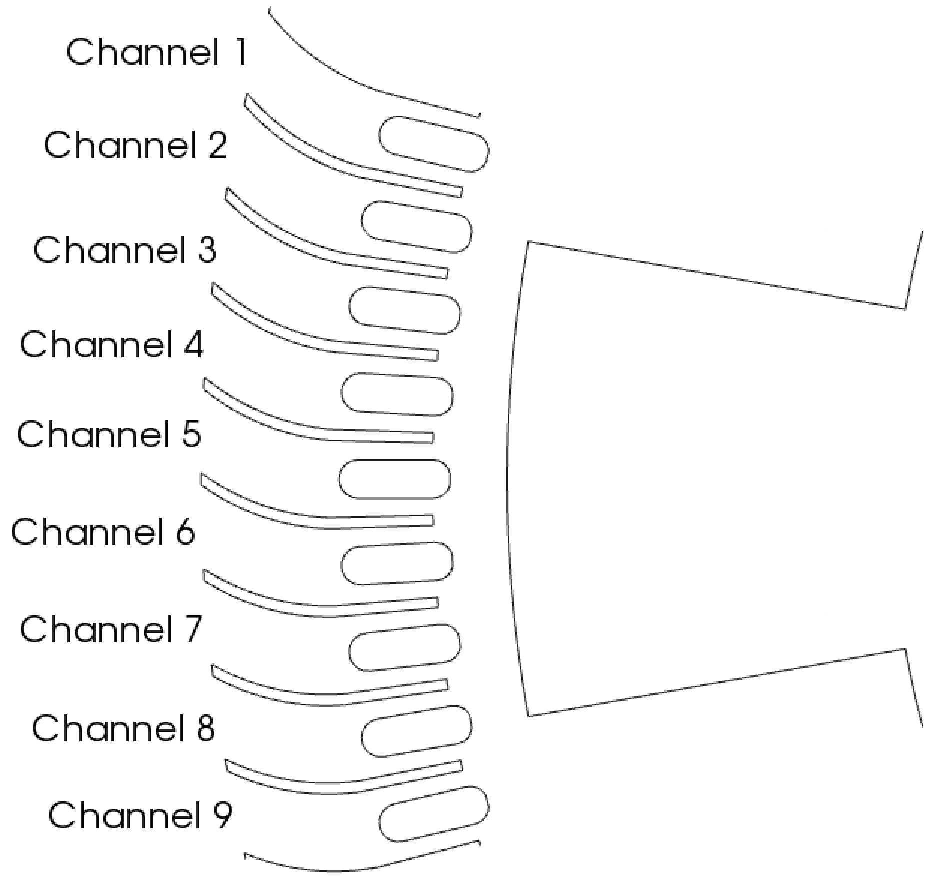


Modelling in OpenFOAM

- A periodic 1/12 sector in the tangential direction since there are exactly 9 channels per pole
- Symmetry plane in the middle of the generator (lower boundary in figure)
- No inlet and outlet boundaries, no prescribed mass flow
- Recirculating flow without inlet and outlet, thus no prescribed mass-flow
- The mass flow is given by the rotation of the rotor



Stator cooling channels

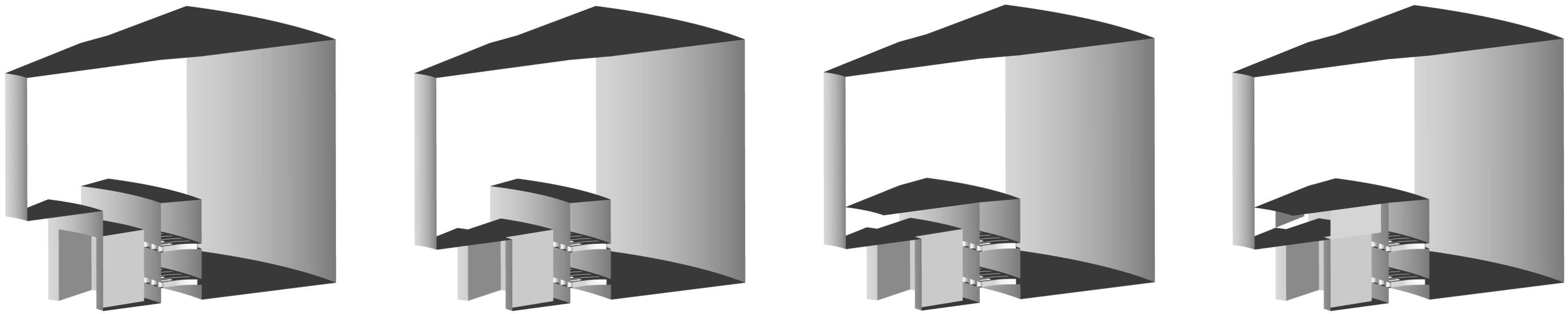


The rotor rotates clockwise. The channel numbers will be shown again in the results section

Cases

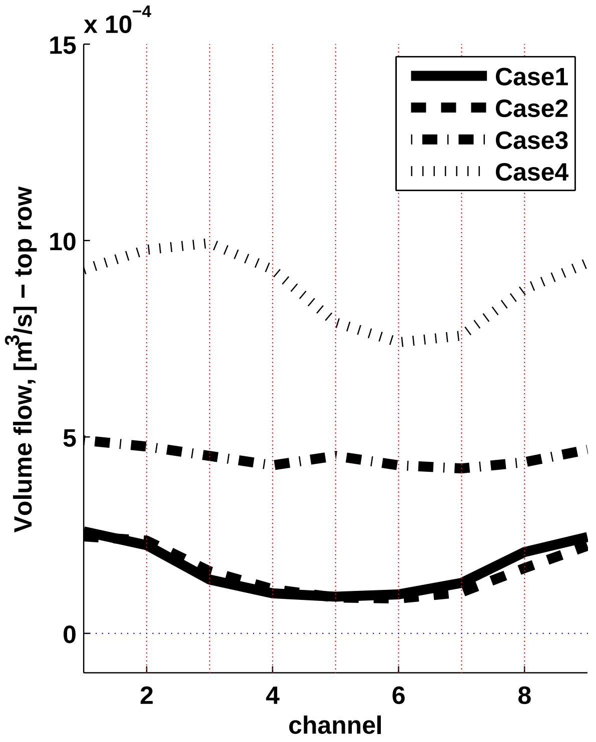
- Frozen rotor concept: MRFSimpleFOAM (MRF = Multiple Reference Frames)
- Low-Re Launder-Sharma turbulence model
- Mesh generated with blockMesh (parameterized m4 script)
- 1 base case + 3 cases with one-at-a-time geometry modifications

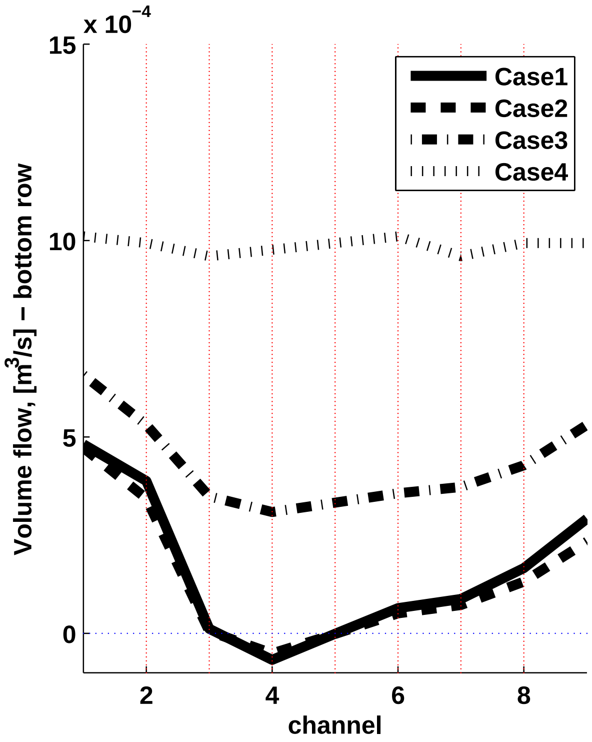
- Case 1: The base case (7.2 M cells)
- Case 2: Case 1 with modified rotor body (9.1 M cells)
- Case 3: Case 2 with stator baffle (9.1 M cells)
- Case 4: Case 3 with radial fan blades (9.1 M cells)

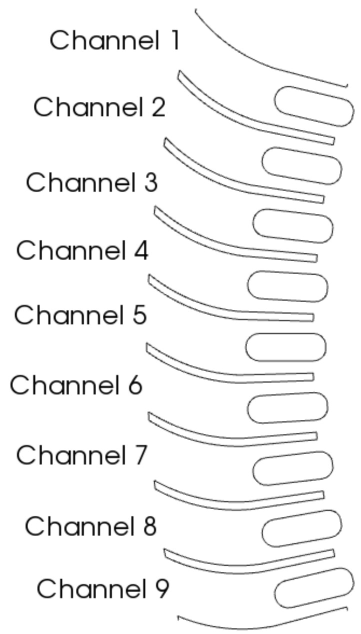


Distribution of volume flows in the channels, (m^3/s)

- The stator baffle and fan blades help making the distribution of the flow more uniform
- The volume flow decreases at the center of the pole (lower pressure)

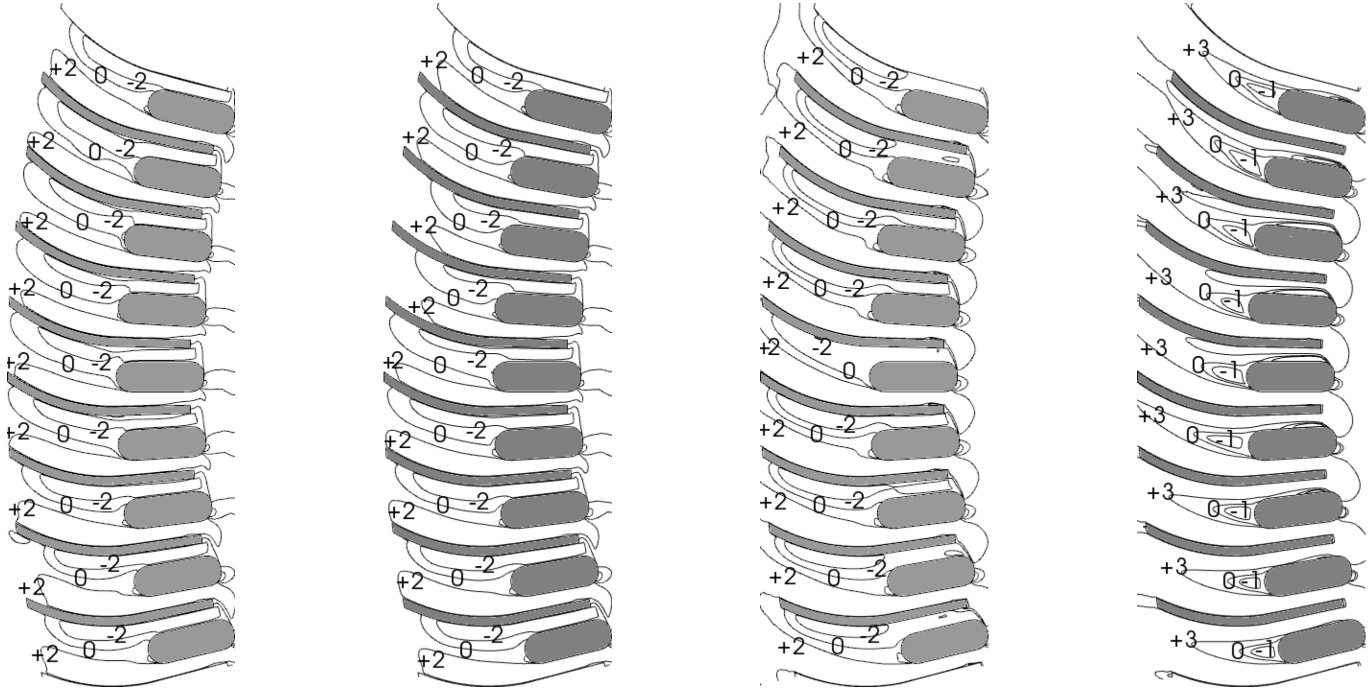




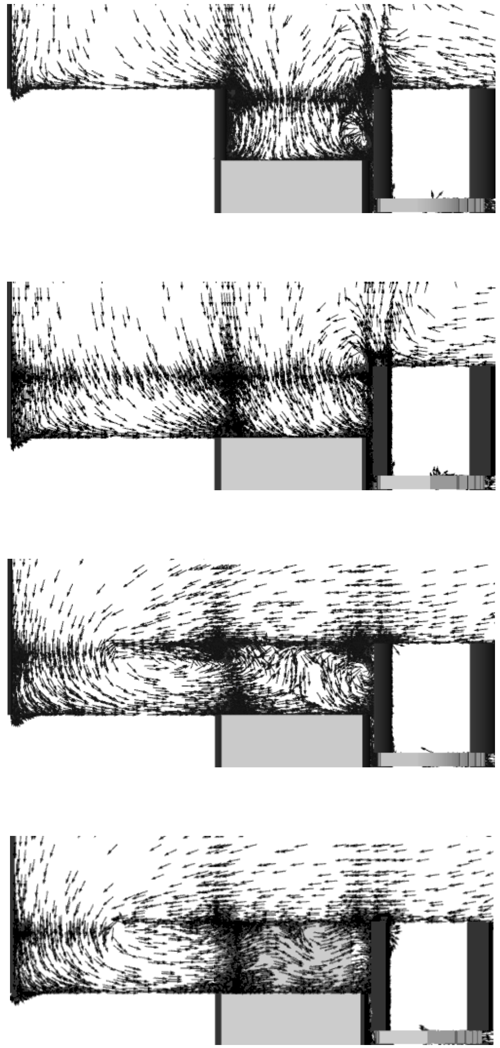


Flow structure in the channels

- Contours of zero radial velocity seperate the recirculation area from the outgoing flow
- In the cases without the fan blade, the reversed flow covers the entire downstream side of the stator windings
- The fan blades minimize the reversed flow region

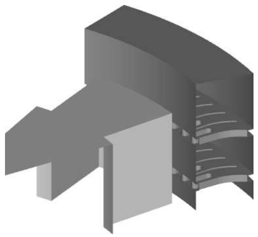
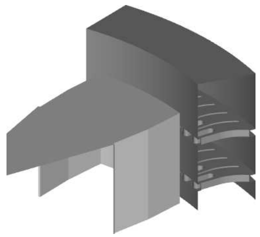
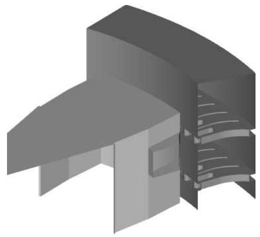
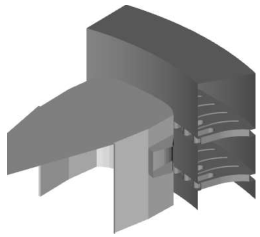
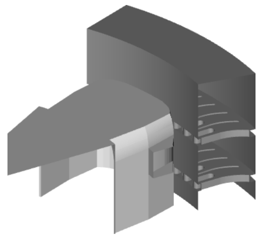
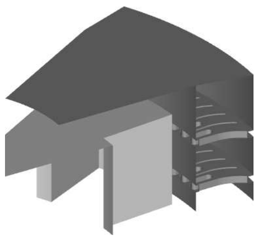
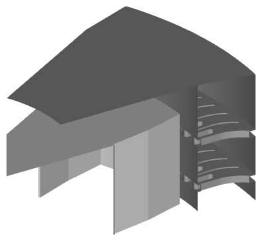
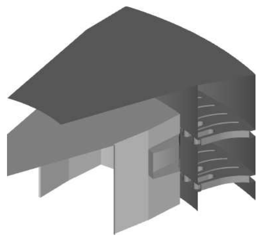
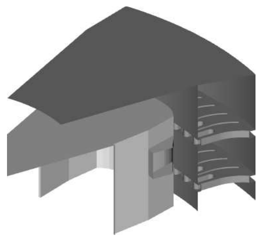
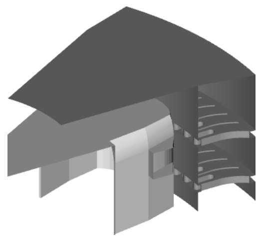
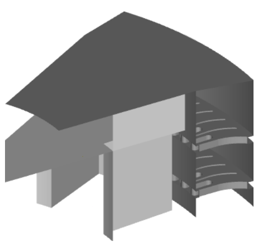
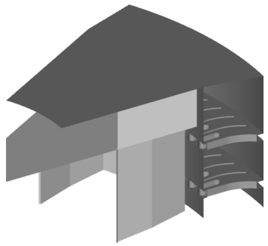
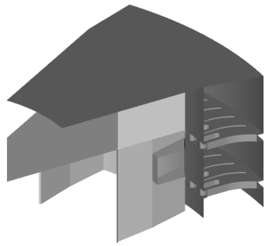
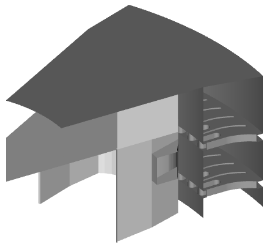
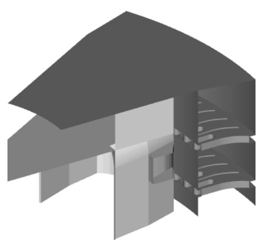


Unit vectors of meridional flow

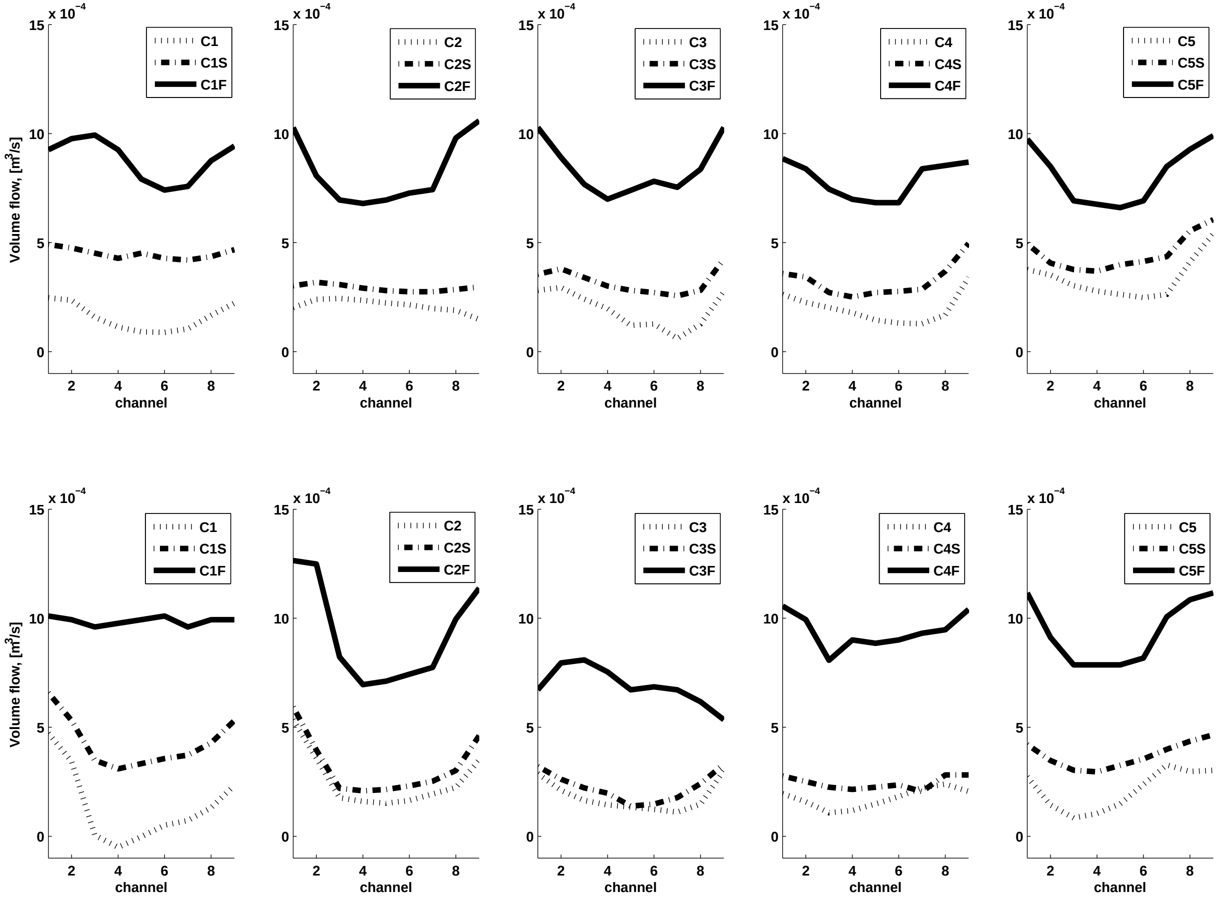


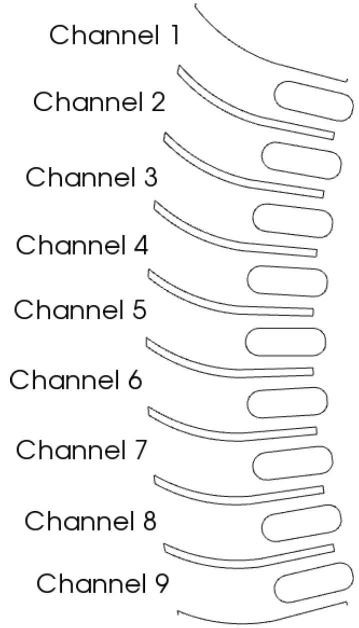
- Regions with upward velocity near the stator inner wall
- Higher pressure make-up by the stator baffle and rotor fan blades give more downward flow
- Separation just at the inlet in cases with stator baffle (less powerful separation with fan blades)
- Purely inward flow at the inlet to the stator baffle

Further parametric studies

	Rotor design C1	Rotor design C2	Rotor design C3	Rotor design C4	Rotor design C5
Base					
Baffle					
Blade					

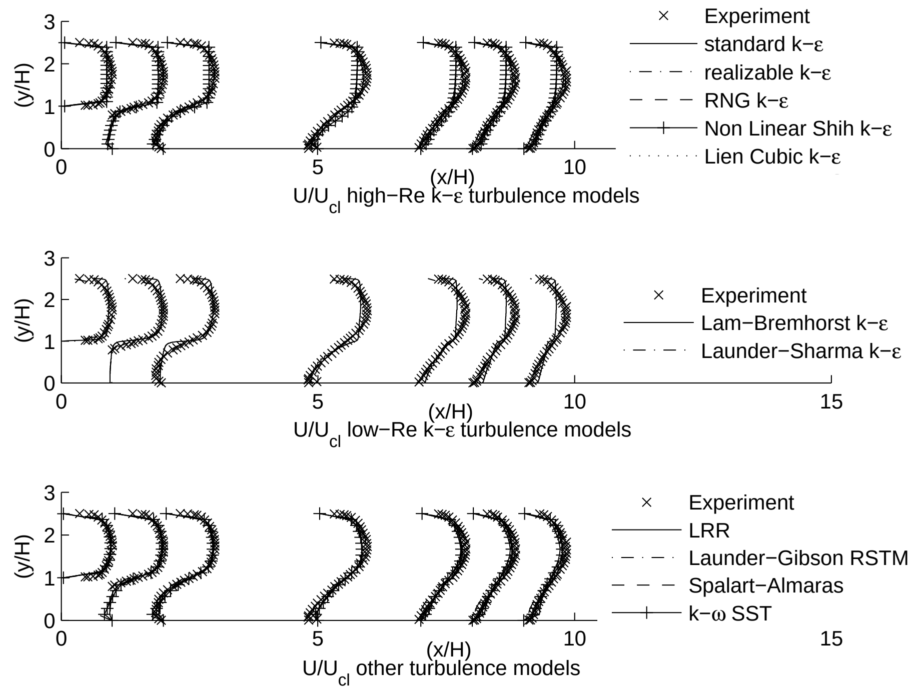
Distribution of volume flows, (m^3/s), further studies

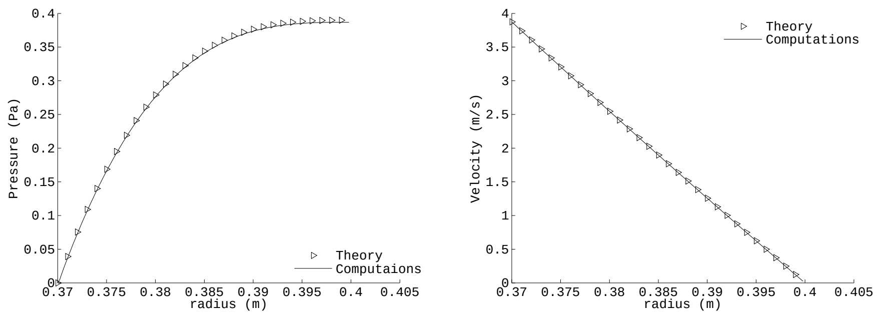




Validation cases

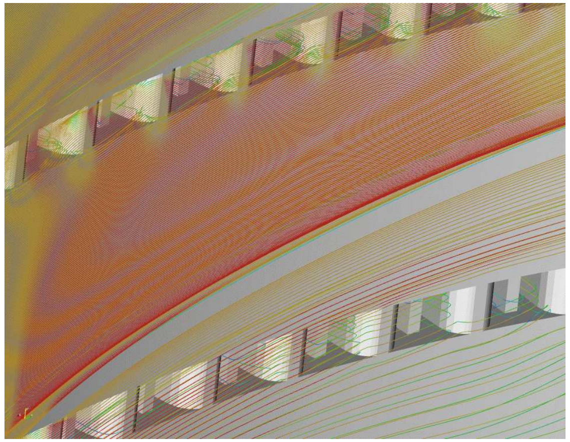
- Two well-known test cases - backward facing step and Couette flow
- Comparisons with experiments and theory
- Backward Facing step: A detailed study of turbulence models in OpenFOAM, led to the selection of the Launder-Sharma turbulence model
- Laminar Couette flow, to verify the pressure and velocity distributions

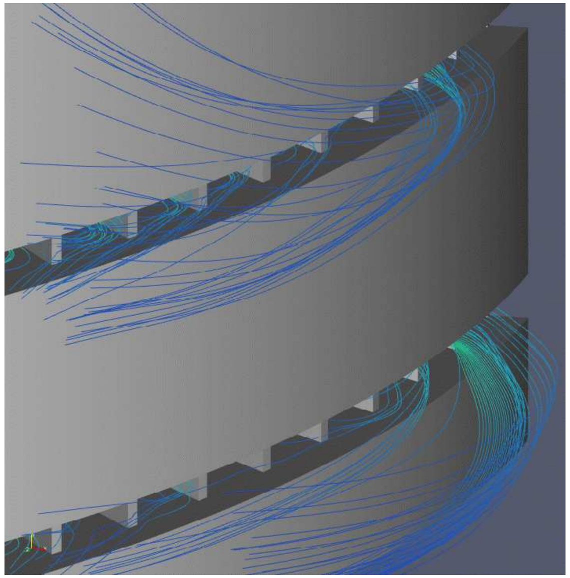




Conclusions

- Modification of the height of the rotor body did not affect the results considerably
- Use of stator baffles to avoid outward flow at the inlet
- Higher and more even pressure distribution in the machine, achieved by stator baffles
- Fan blades increase the pressure inside the machine even more, leading to a higher pressure difference between the inside and outside
- Higher pressure difference between inside and outside the machine leads to a higher volume flow
- Higher pressure difference between inside and outside the machine leads to a decreased recirculation in the stator channels





Thank you!

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