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Numerical simulation of the flow field in the vicinity of an axial flow fan

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Fakulteit Ingenieurswese
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Faculty of Engineering

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Question

Can the flow field in the vicinity of an axial fan be modeled, using a RANS/U-RANS approach?

If we can, how does it look?

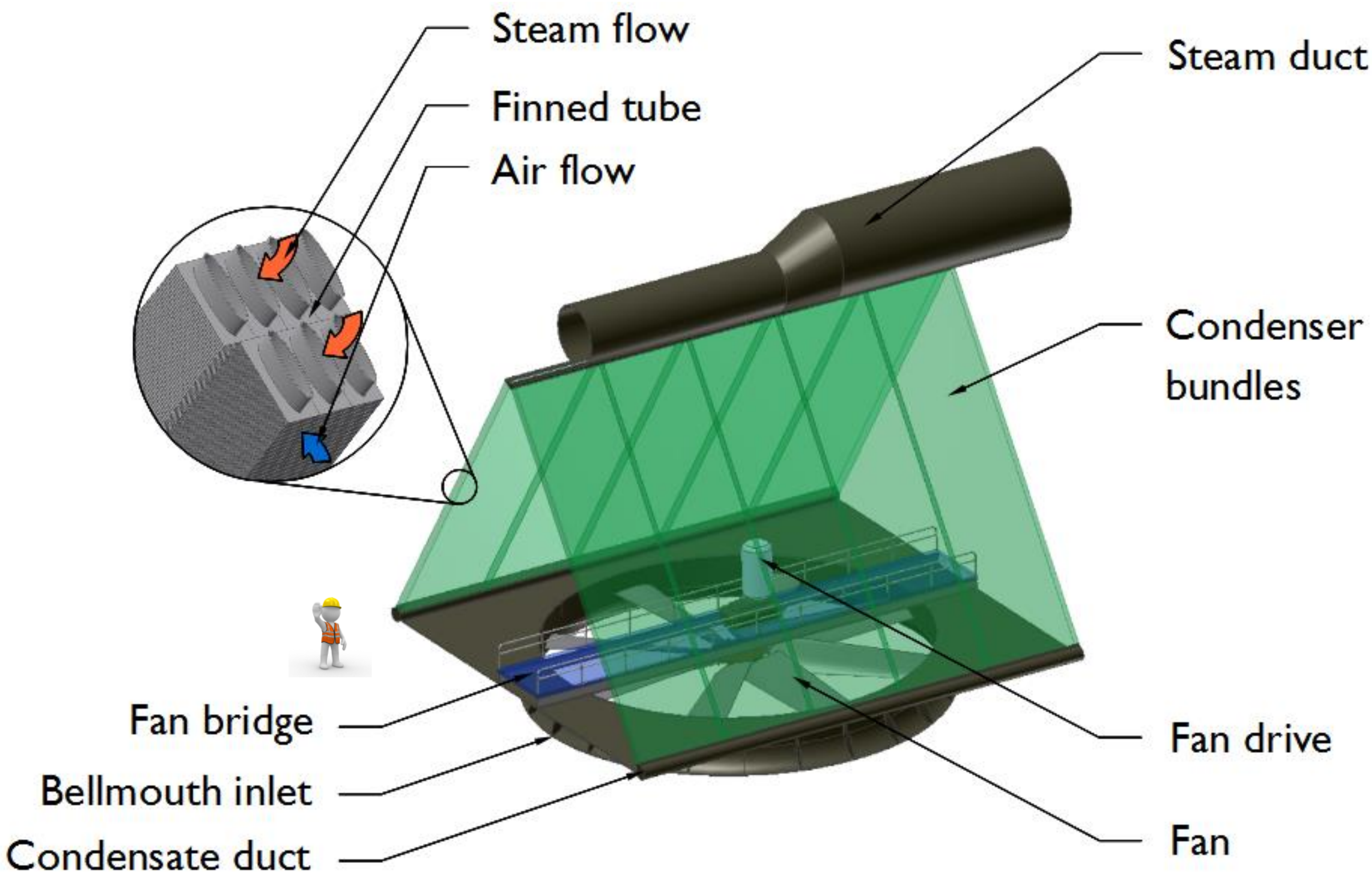
(especially at low flow rates)

Question

Why?

- Impress people with colorful CFD pictures…
- RANS is computationally cheap
- If successful: Advantages for development of simplified fan models
- Implementation: Modeling of large scale fan systems (ACHEs)

Introduction: ACHEs



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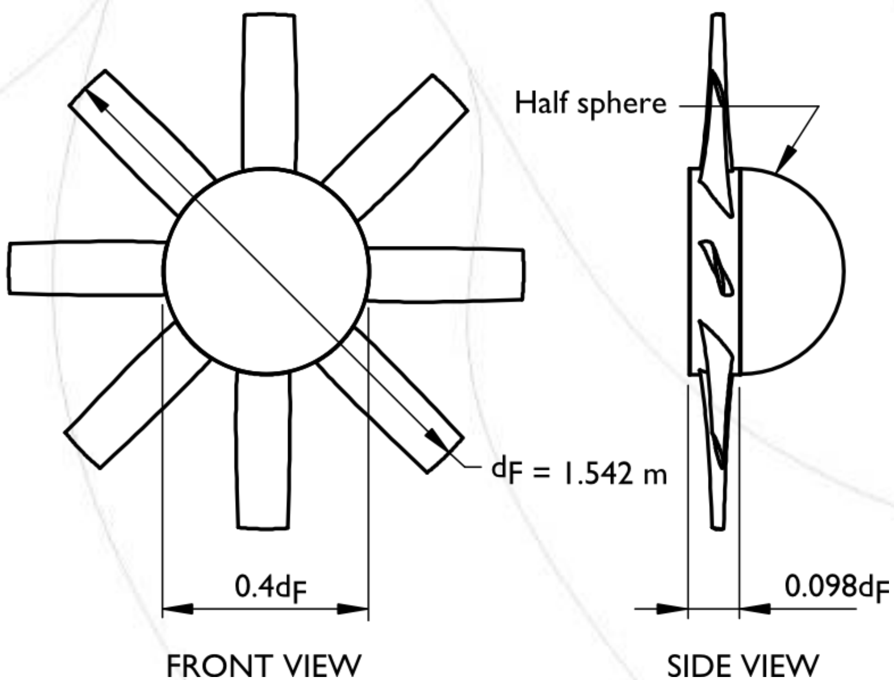
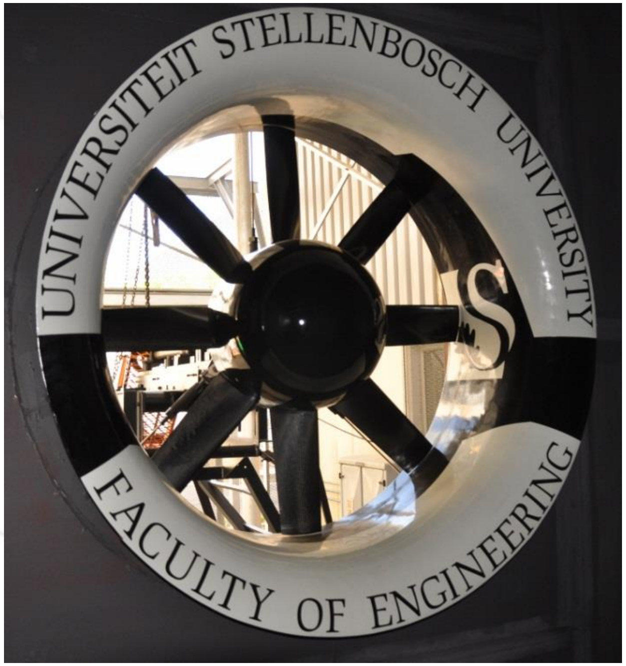
Introduction: Present study

- Numerical modelling of flow for a range of flow rates
- Test subject: 8 bladed, ACHE fan (B2a-fan)





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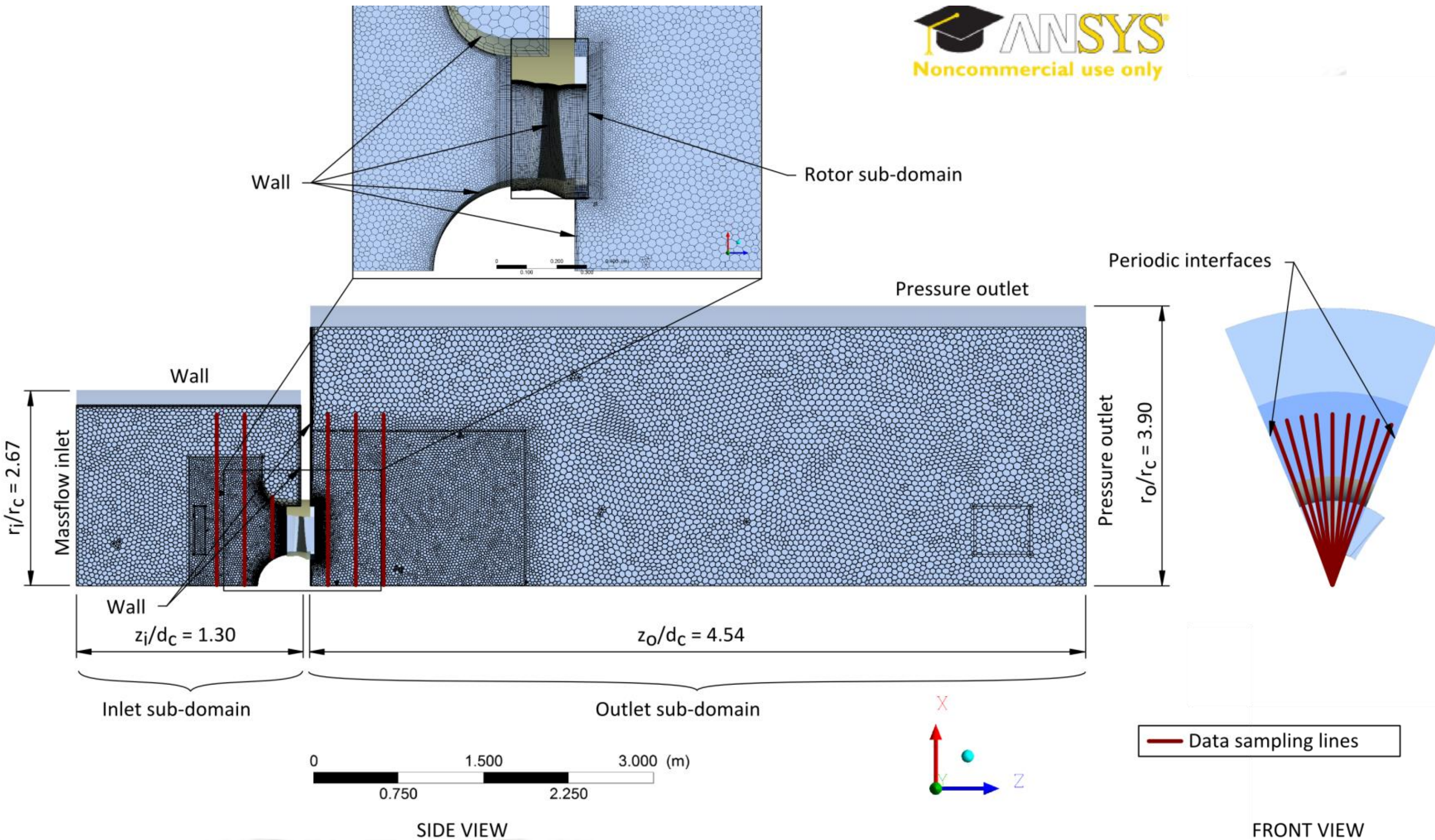
Numerical: Computational technique

- 1/8th sector modeled (assume rotational symmetry)
- Solving: ANSYS Fluent 14
- Realizable k-ε model with Standard wall function
- Steady simulations for $\varphi > 0.137$ (13 m^3/s)
  [$\varphi_D = 0.168$ (16 m^3/s)]
- Unsteady simulations for $\varphi < 0.137$

Numerical: Computational domain



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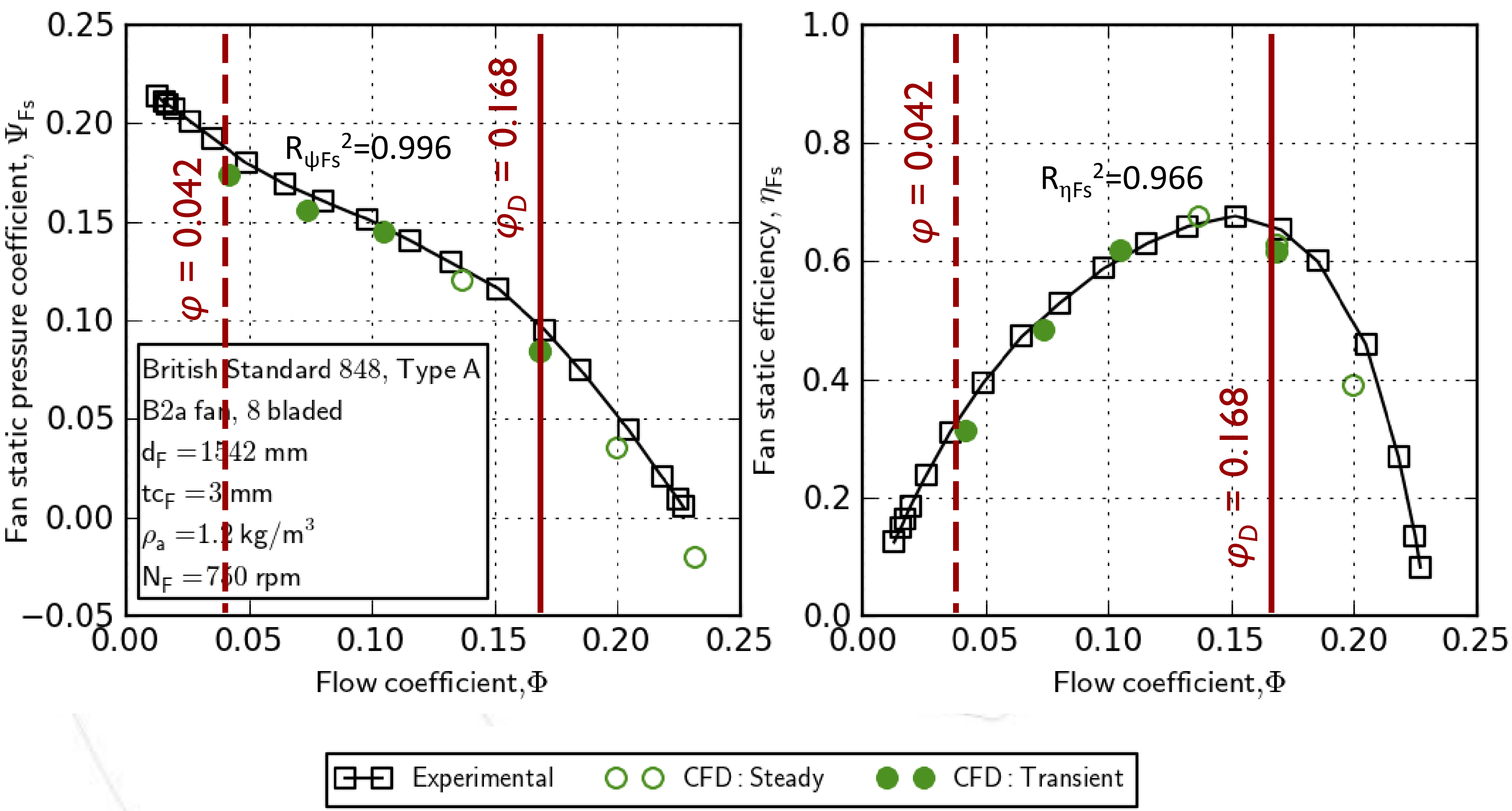
Numerical: Results verification



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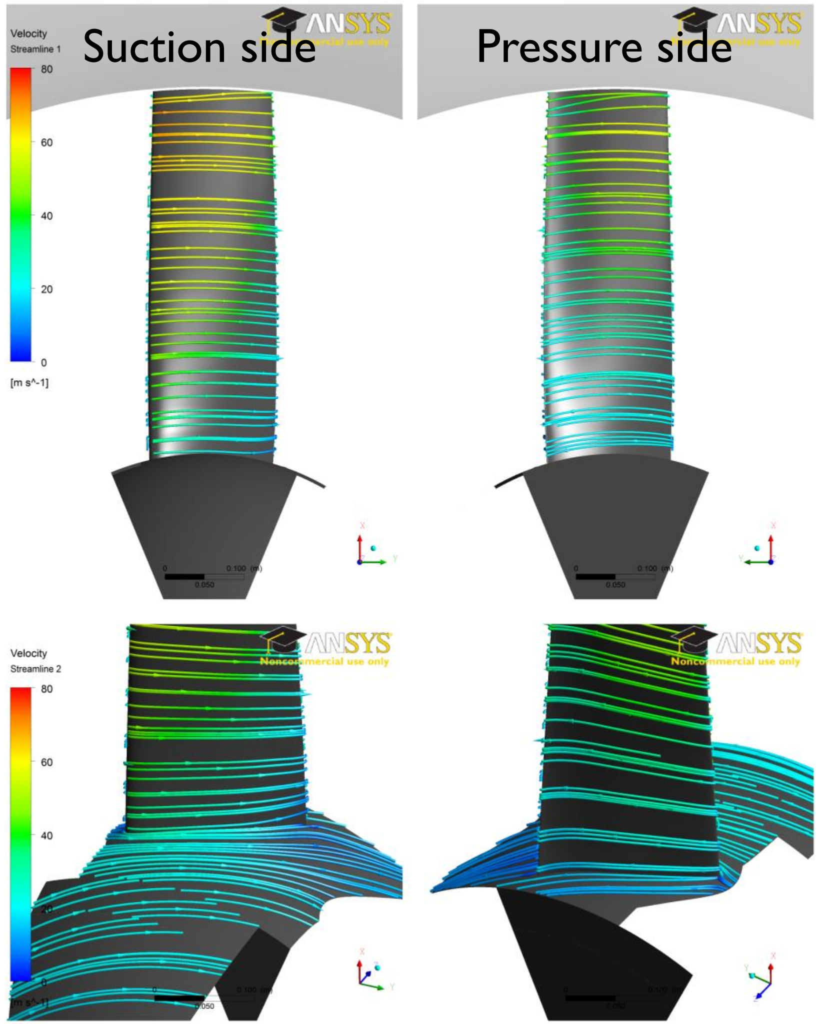
Results: $\varphi_D = 0.168$ (16 m^3/s)



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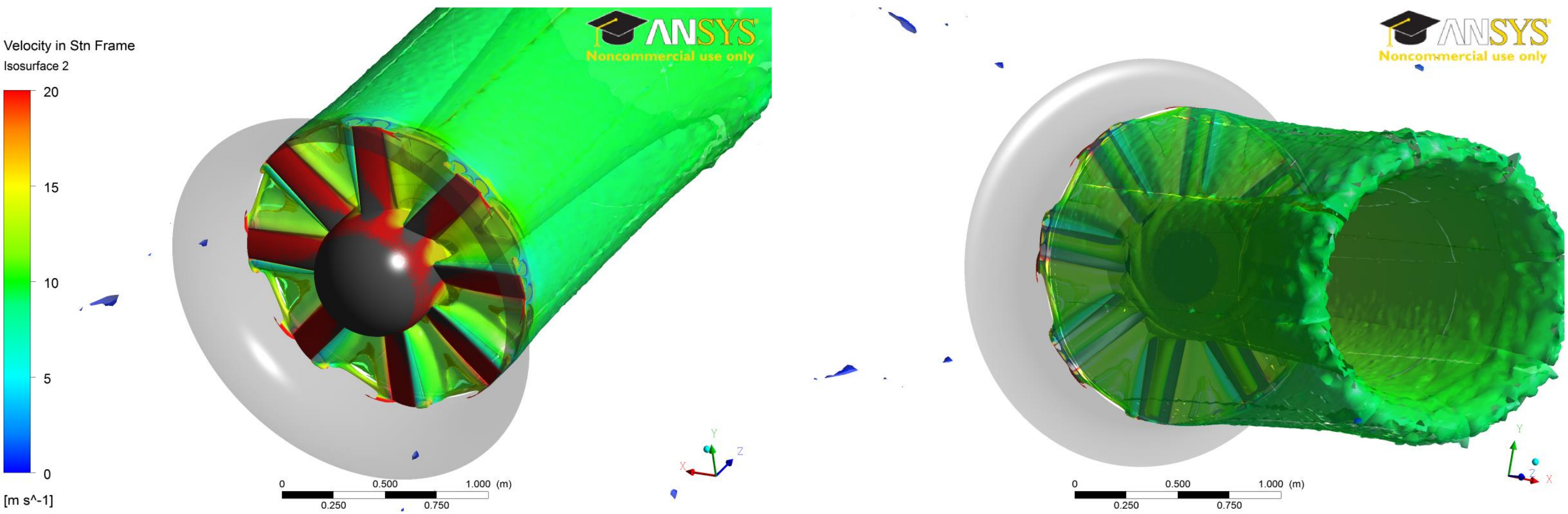
Results: $\varphi_D = 0.168$ (16 m^3/s)



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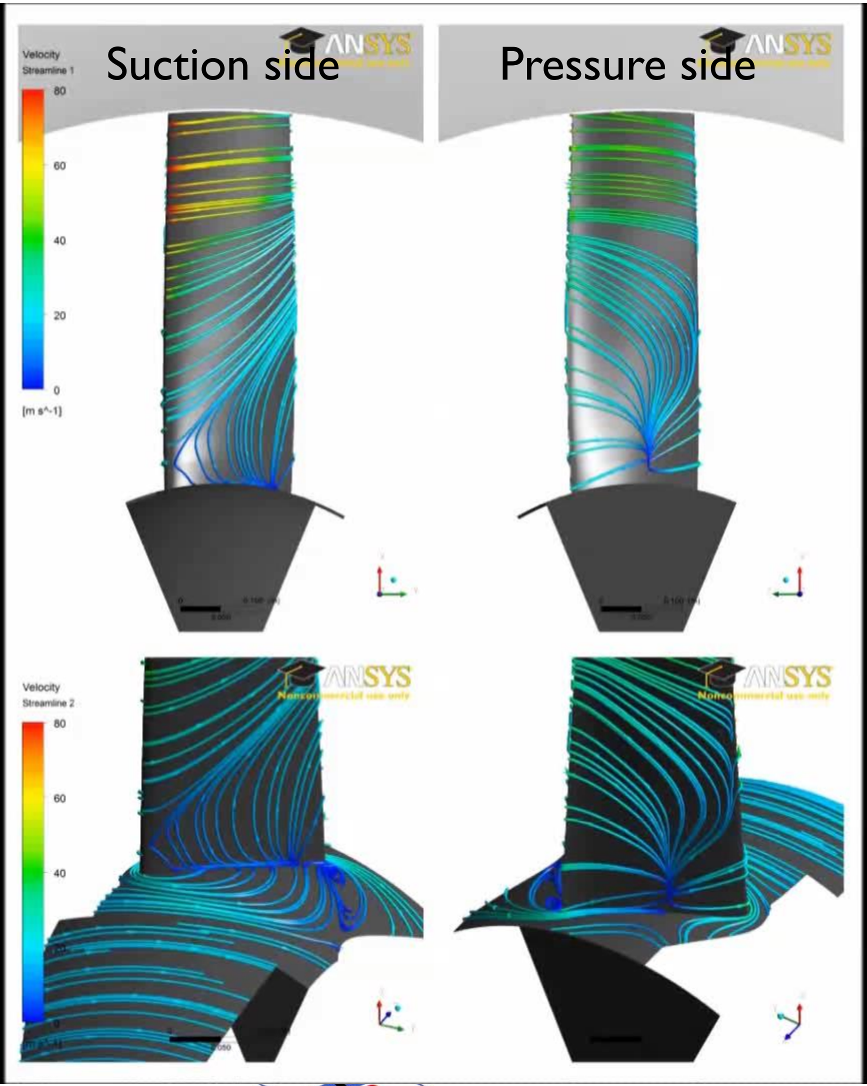
Results: φ = 0.042 (4 m^3/s)



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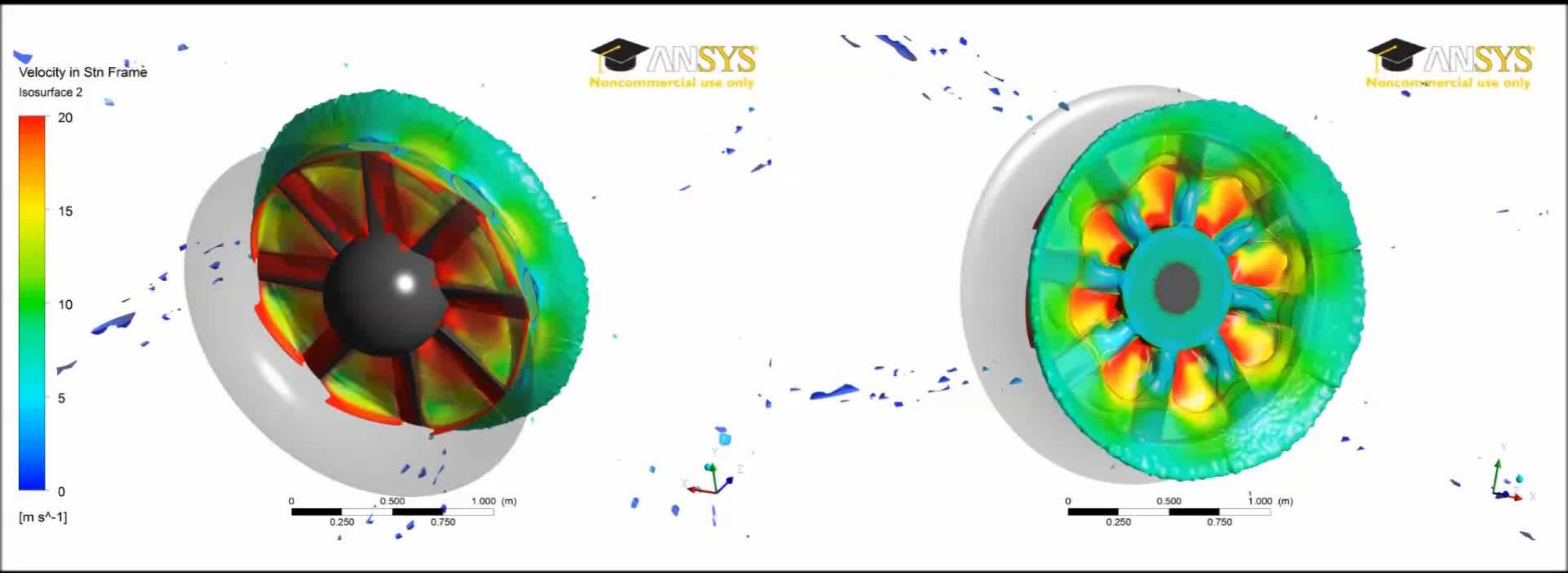
Results: $\varphi = 0.042$ (4 m^3/s)



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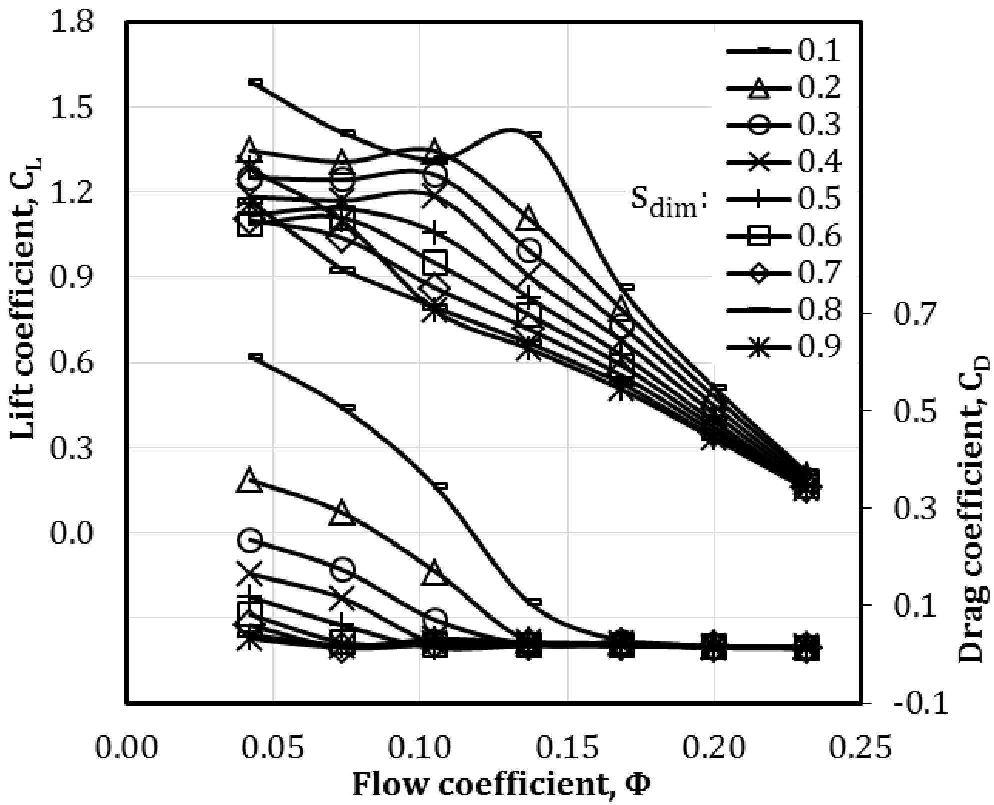
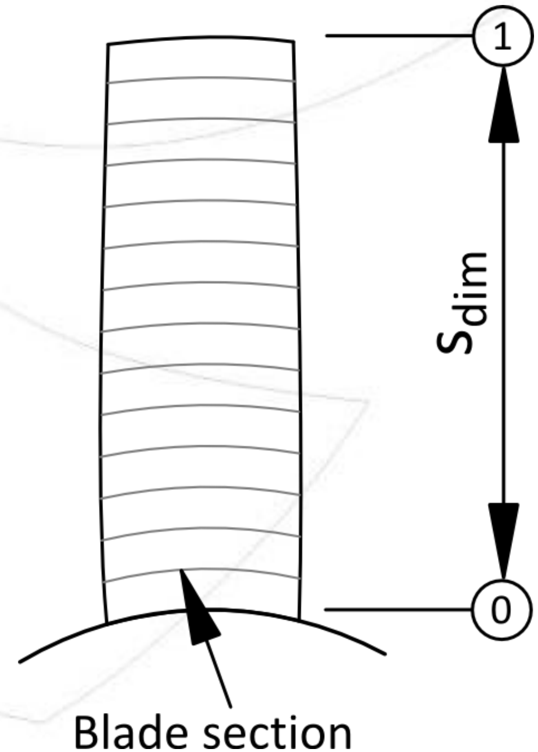
Results: Lift/Drag coefficients





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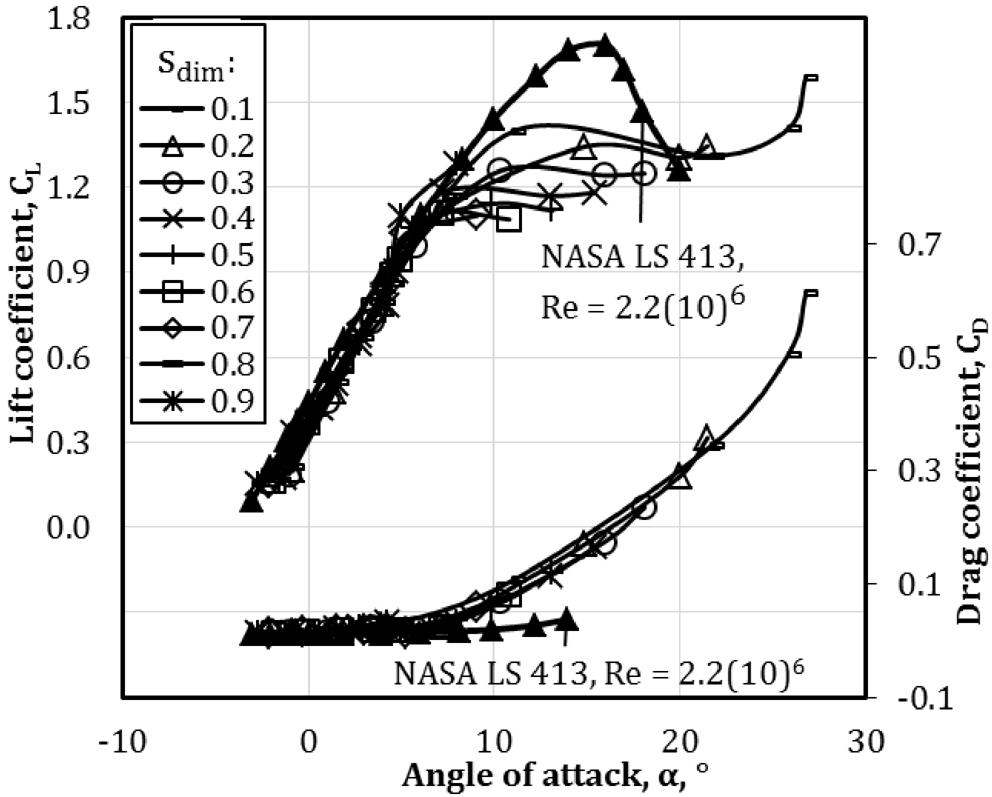
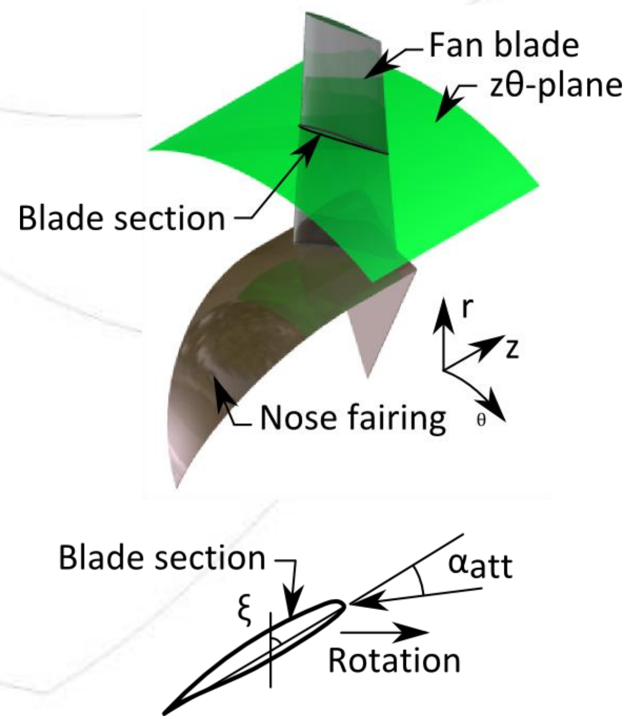
Results: Lift/Drag coefficients





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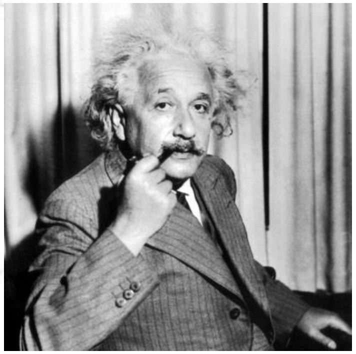
Conclusions

Can the flow field in the vicinity of an axial fan be modeled, using a RANS/U-RANS approach?

Depends…

"Everything should be made as simple as possible, but not simpler" - Albert Einstein



Conclusions

Yes

- Comparison between experimental and numerical results are fair with $R_{\psi FS}^2$=0.996 and $R_{\eta Fs}^2$=0.966.
- Practical engineering estimation
- Further development of simplified fan model

But also, no…

- No solution for $\varphi < 0.042$ (maybe due to symmetry assumption)
- Scientific view: Some flow phenomena are 'missed' due to RA approach

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Thank you

- Supervisors/Other personel
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  - Department of M&M Engineering, Dr. vd Spuy (Eskom, GEA)
  - National Research Foundation (NRF)
  - Solar thermal energy research group (STERG)

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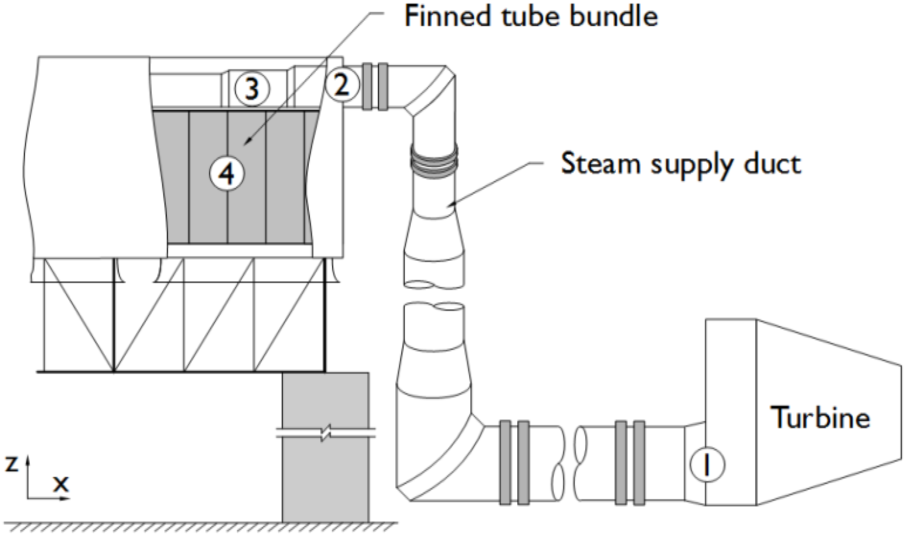
ACHEs



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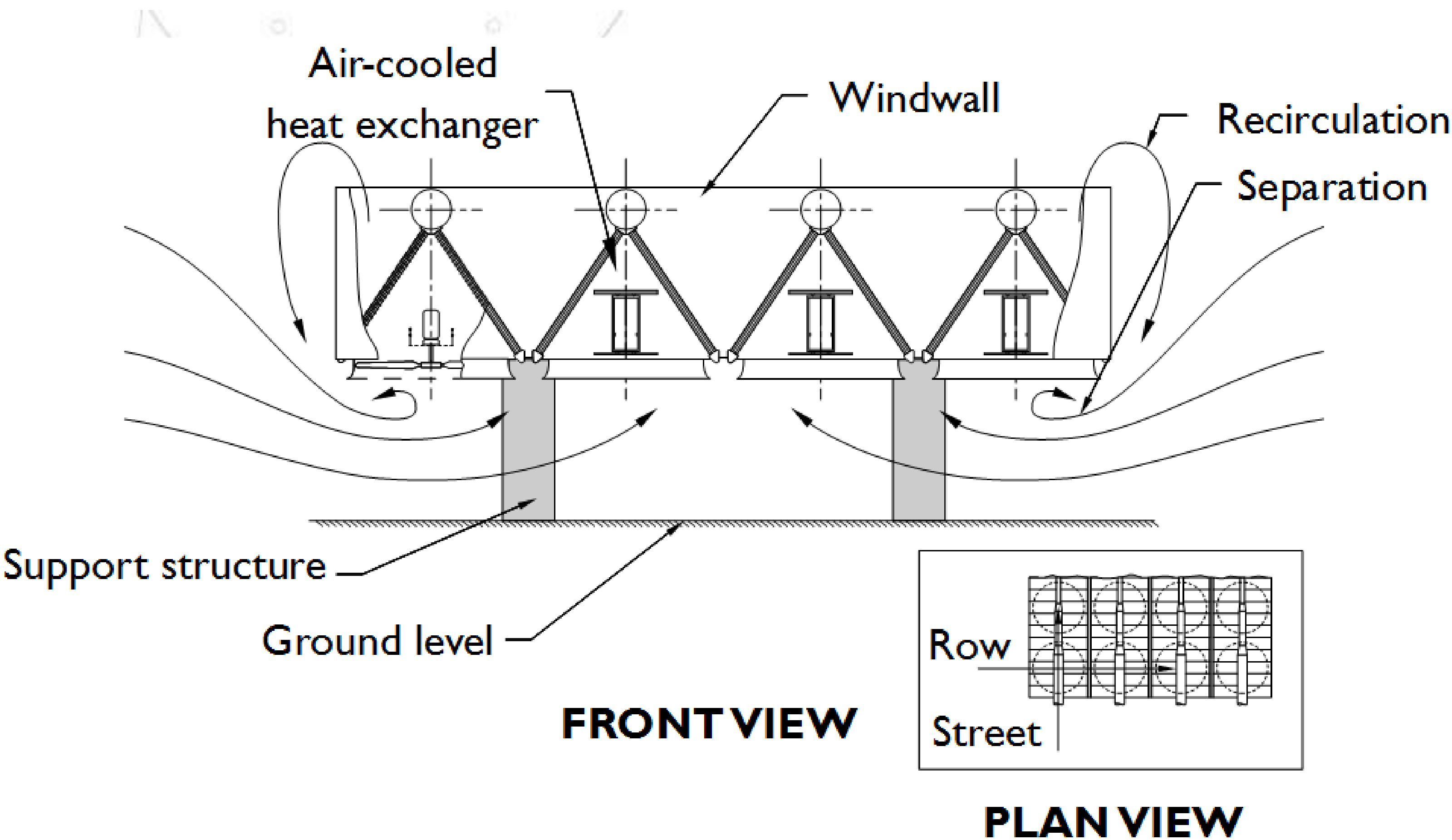
Low flow problem



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Numerical: Computational technique

- Solver settings:

Setting	Steady state simulations	Transient simulations
Discretization scheme (Gradient)	Least squares cell based	Least squares cell based
Discretization scheme (Pressure)	PRESTO!	PRESTO!
Discretization scheme (Other)	QUICK	QUICK
Pressure-velocity coupling	SIMPLE	PISO
Convergence	10^{-5}	10^{-3}

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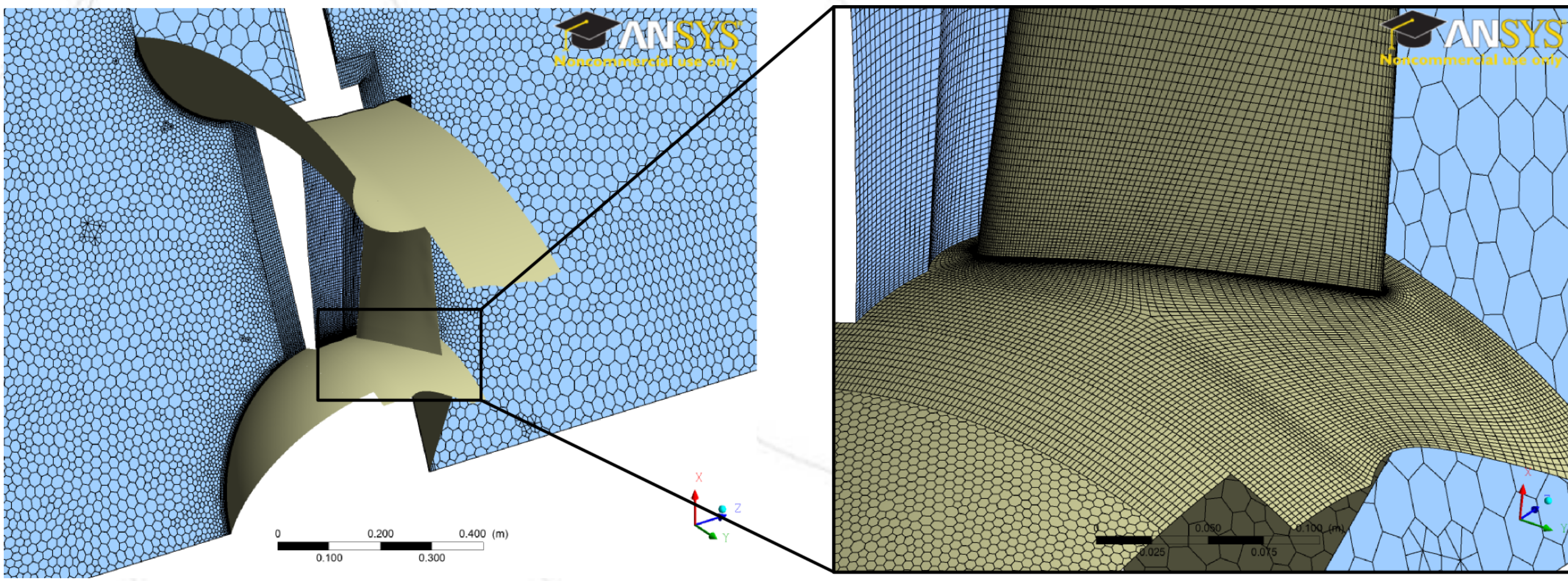
Numerical: Computational domain

- Combination of three domains: *Inlet, Rotor and Outlet*
- Grid size: $2.5(10)^6$ cells ($y^+>30$)



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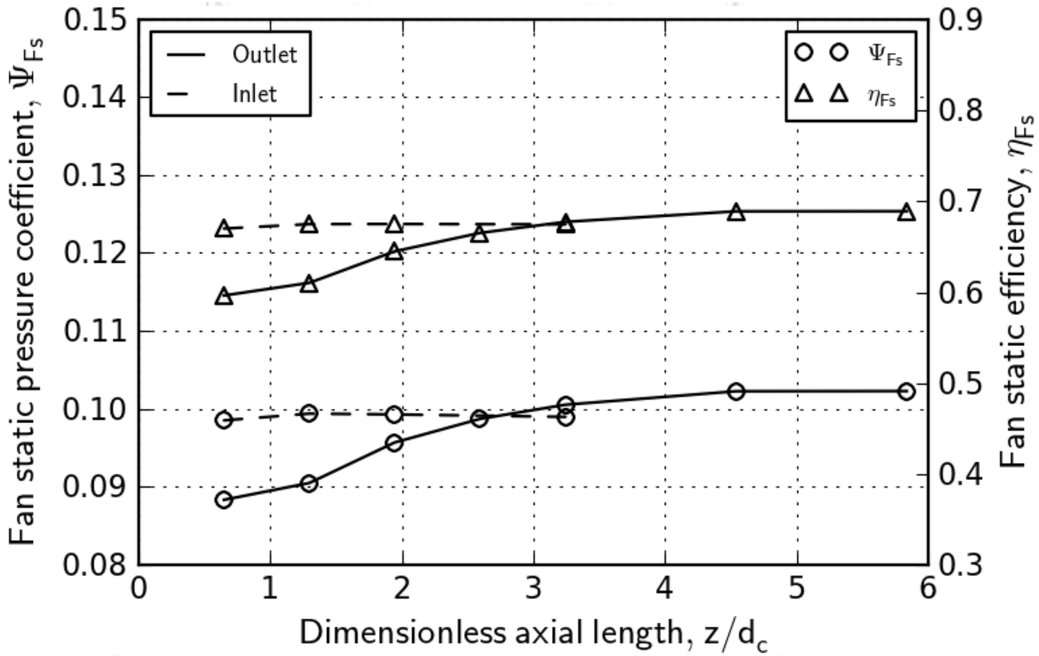
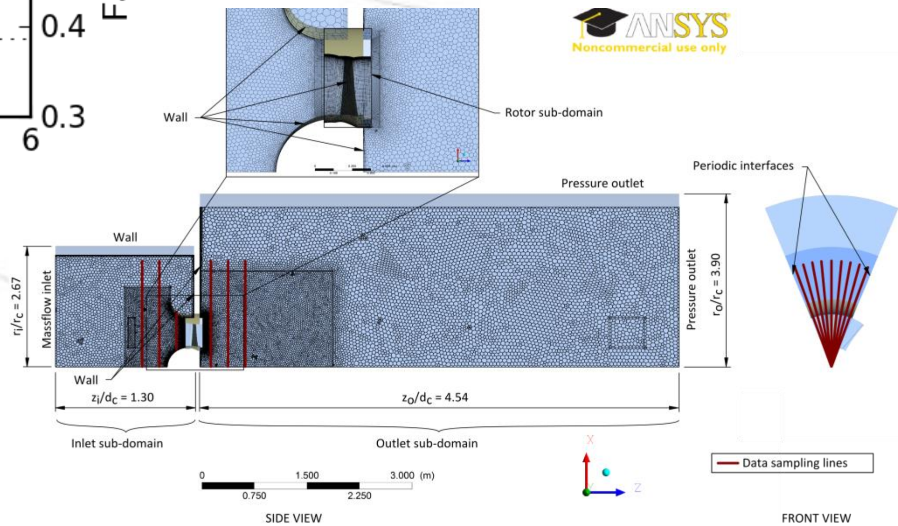
Numerical: Boundary proximity analyses





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Numerical: Time step independence analyses

φ	$\Delta t, (10)^{-3}s$	ψ_{Fs}	η_{Fs}
0.168	0.5	No result	No result
	0.2	0.084	0.617
	0.1	0.084	0.618
	0.05	0.084	0.618
	0.025	0.084	0.618
0.042	0.2	No result	No result
	0.1	0.174	0.313
	0.05	0.173	0.313
	0.025	0.174	0.314

Numerical: Grid independence

- Conducted at $\varphi_D = 0.168$
- Rotor domain axial length: $z_r = 0.1d_c$
- Convergence obtained between $1(10)^6$ and $2(10)^6$ cells

Cell count	**Fan static pressure coefficient, ψ_{Fs}**
$240(10)^3$	0.119
$500(10)^3$	0.101
$990(10)^3$	0.106
$2000(10)^3$	0.106

φ	*Cell count*	ψ_{Fs}	η_{Fs}
0.168	$2.5(10)^6$	0.084	0.627
	$5.5(10)^6$	0.084	0.617
0.042	$2.5(10)^6$	0.174	0.313
	$5.5(10)^6$	0.175	0.307

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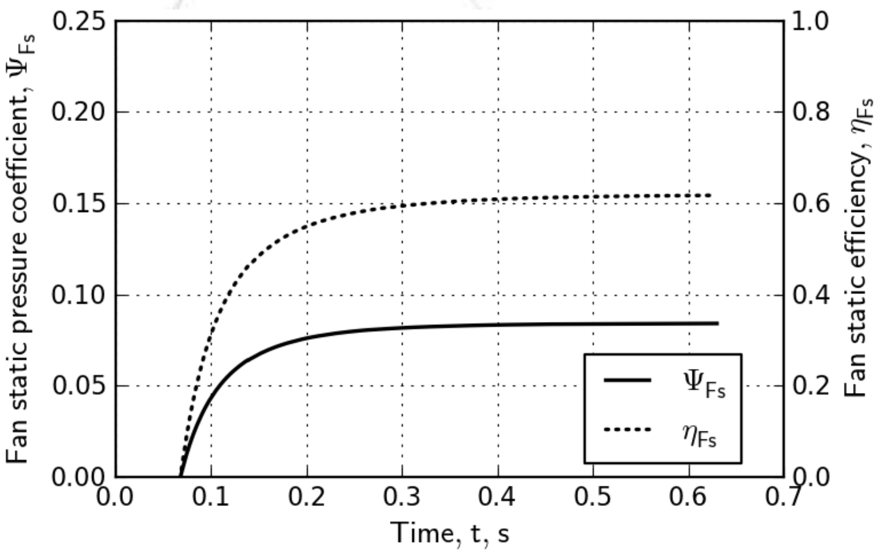
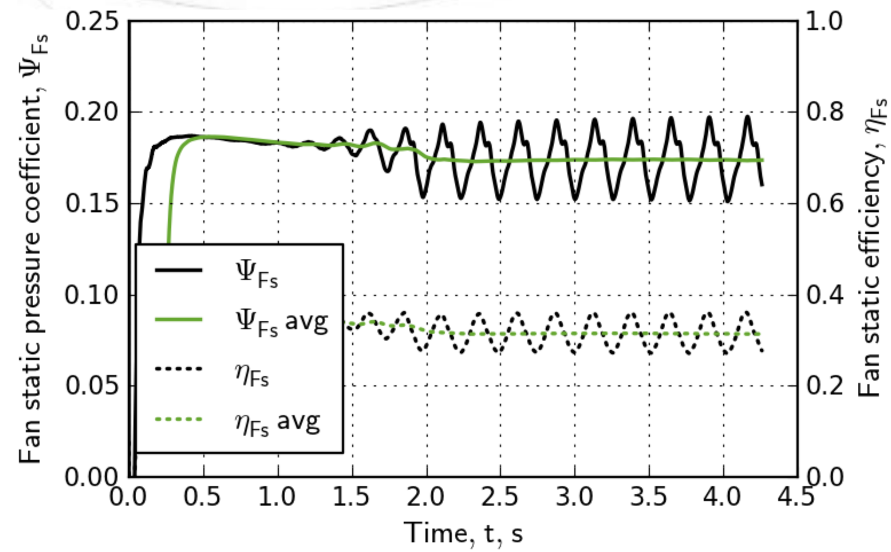
Numerical: Convergence

φ_D = 0.168



φ = 0.042



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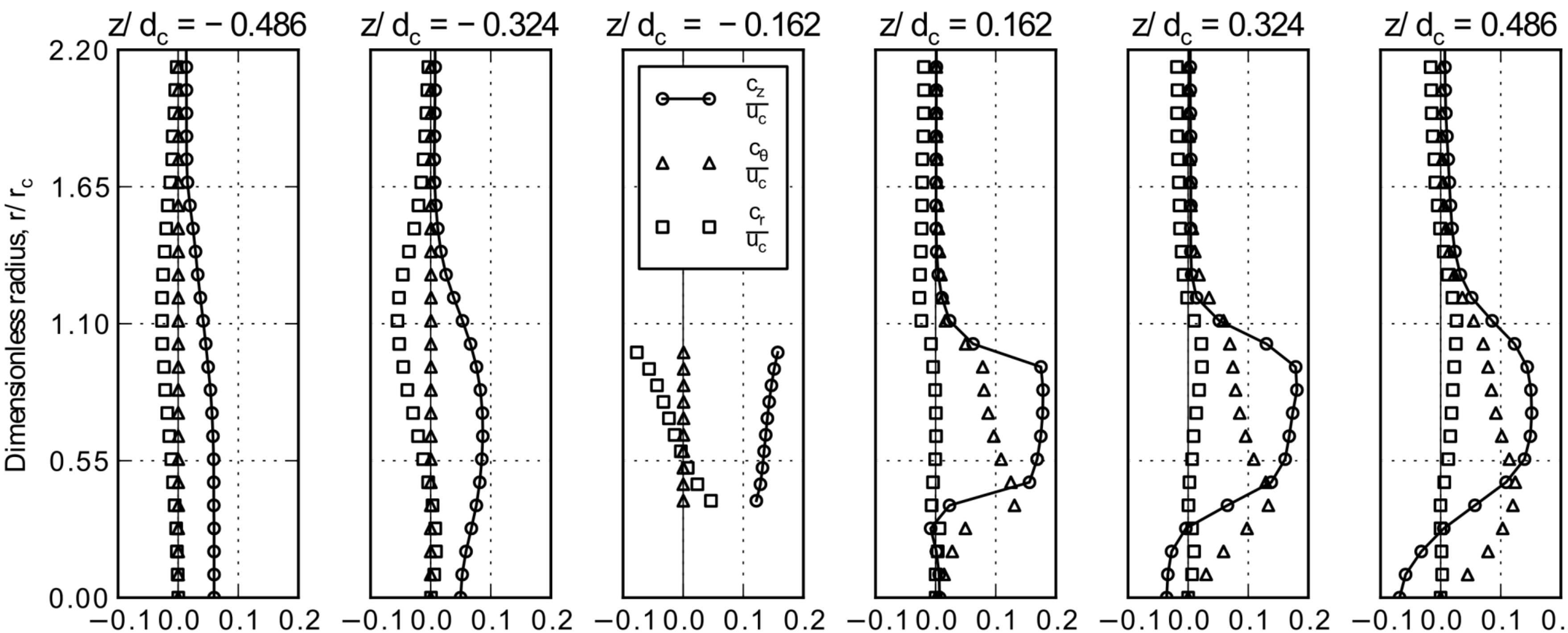
Results: $\varphi_D = 0.168$ (16 m^3/s)



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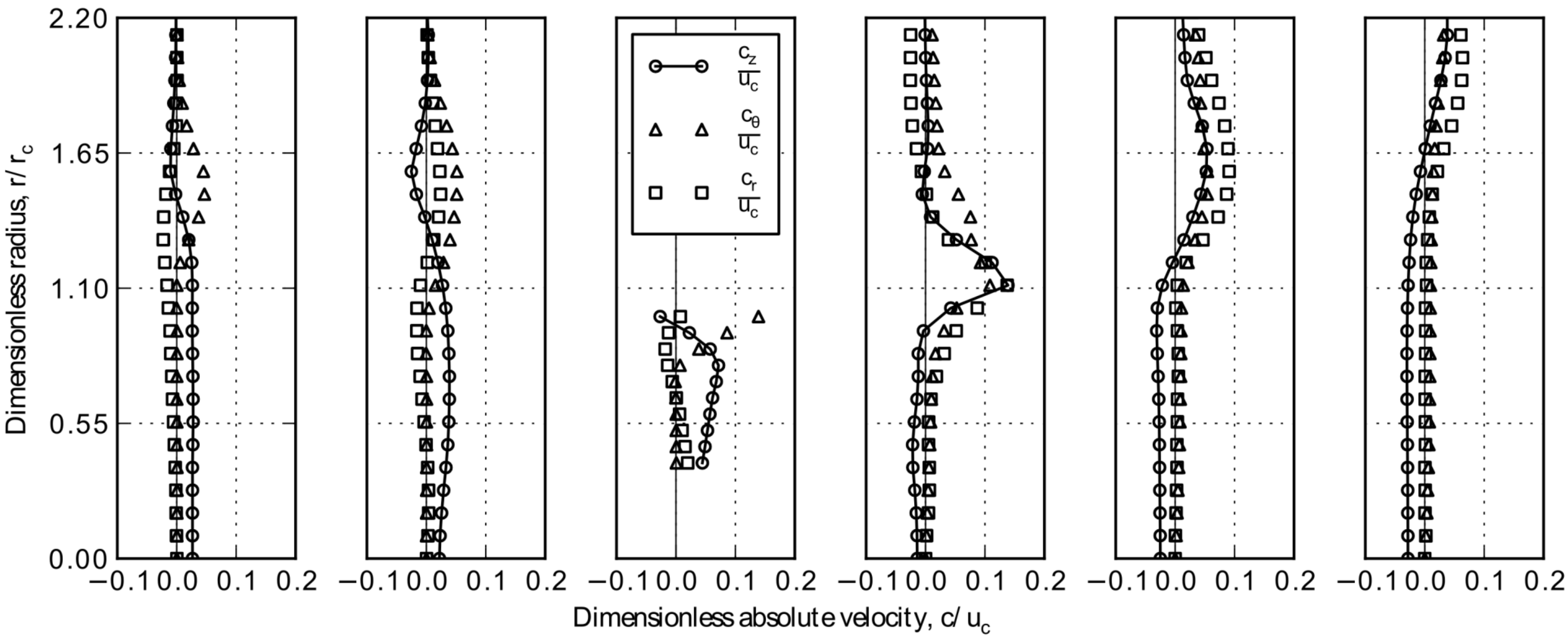
Results: $\varphi = 0.042$ (4 m^3/s)



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