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Overview of Stellenbosch University ACC Research

Hannes Pretorius

on behalf of

Department of Mechanical and Mechatronic Engineering, Stellenbosch University, Western Cape, South Africa

ACCUG 2021 – Virtual Conference

Contents

- Background
- Resources & testing facilities
- Latest research activities & major results
- Research funding & consulting opportunities
- Conclusion

Background

- Department involved in ACC research over past 5 decades
- The late Prof Detlev Kröger
  - Started research in 1970's
  - Large South African ACC design & features greatly influenced by his research
  - Strong relationship with industry

(Pretorius, 2012)

(Lennon, 2011)

(Lennon, 2011)

(Augustyn, 2017)

(https://www.power-technology.com/projects/kusilepowerstation/)

Background

- Many engineers studied under his supervision
  - Lecturers at Stellenbosch University
  - Professional engineers in power generation / cooling technology industry

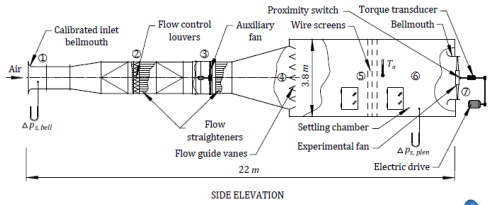
- We continue to build on this legacy
  - ACC & Dry cooling research
  - Heat exchanger bundle characteristic testing
  - ACC & fan CFD simulation
  - ACC scale fan testing
  - ACC hybrid dephlegmator design
  - ACC fan drive research
  - Post graduate course in Air-cooled Heat Exchangers and Cooling Towers

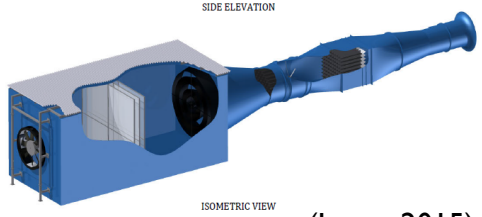
Resources & testing facilities

- Typically, 50-70 postgraduate students per year (M&M)
- Solar Thermal Energy Research Group (CSP / CST)
- Access to Center for High Performance Computing (CHPC)
  - 32832 cores
- Access to Lab for Advanced Manufacturing
- Access to the latest international research publications
- Access to multidisciplinary engineering researchers
  - Mechanical & Mechatronic
  - Civil
  - Electric & Electronic
  - Process
  - Industrial

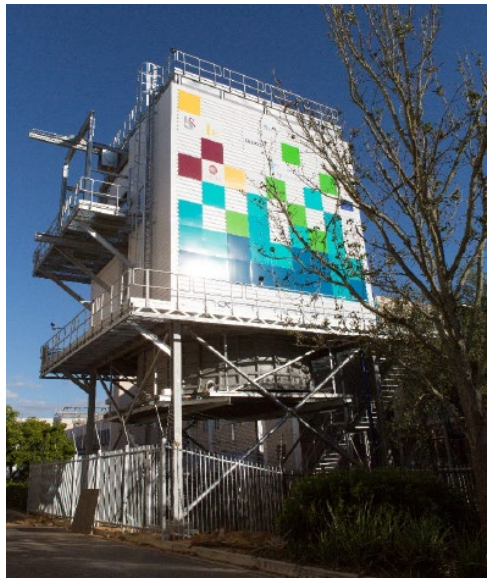
Resources & testing facilities

- ACC scale fan test facility (ISO 5801)
  - 1.542 m diameter fan
- MinWaterCSP facility
  - 24 ft fan drive with hybrid dephlegmator bundles
- ACC heat exchanger bundle test facility
  - Confidential commercial HX bundle testing
- ACC fan drive testing





(Louw, 2015)



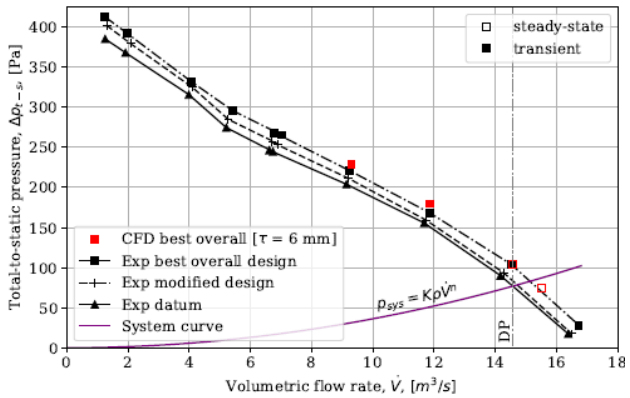
(Van der Spuy et al, 2021)

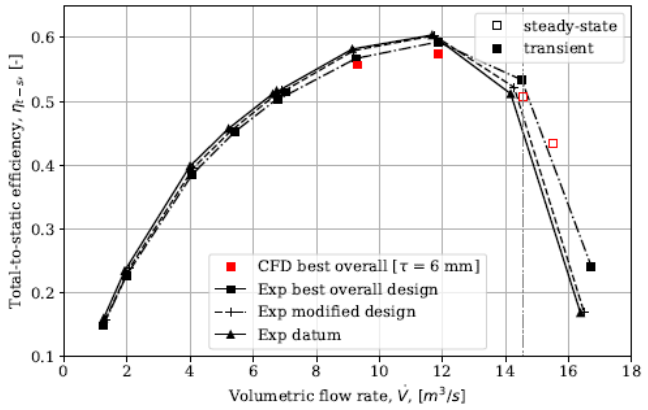
Latest research & major results

Profs Chris Meyer & Johan van der Spuy

- Axial flow fan testing and development
- ACC system improvement
- ACC modelling

- Development of tip appendage to improve fan performance at large tip clearances
  - Work done in collaboration with Sapienza URome
  - Improved performance at design and higher flow rates





Latest research & major results

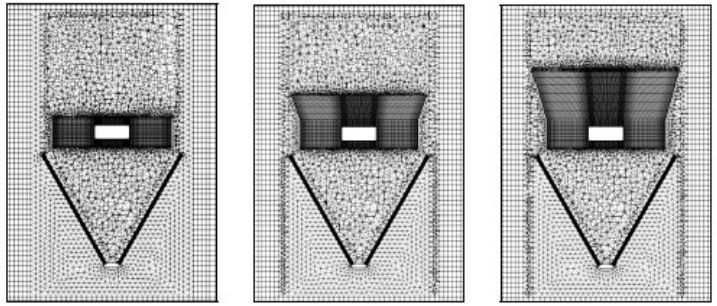
Profs Chris Meyer & Johan van der Spuy

- Further research into Reynolds-number effect on fan performance scaling
- Using free-stream turbulence to mimic high Reynolds-number operating conditions
  - Effect of turbulence on airfoil performance correlated to installed fan performance
  - Research completed, results to be published

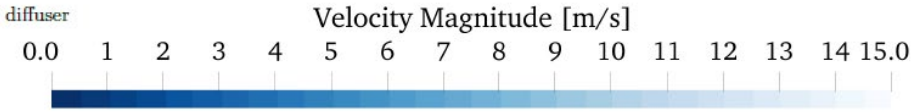
Latest research & major results

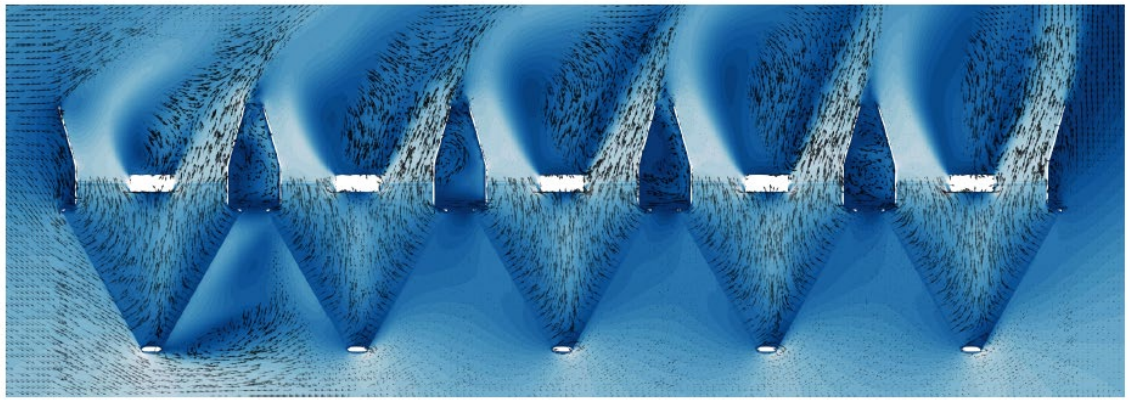
Profs Chris Meyer & Johan van der Spuy

- The development of an exhaust diffuser for and induced draught ACC
  - Specific to low pressure rise fan
  - Evaluated under wind speeds up to 9 m/s



(a) Fan only (b) $l_{dif} = 0.2d_F$ diffuser (c) $l_{dif} = 0.4d_F$ diffuser

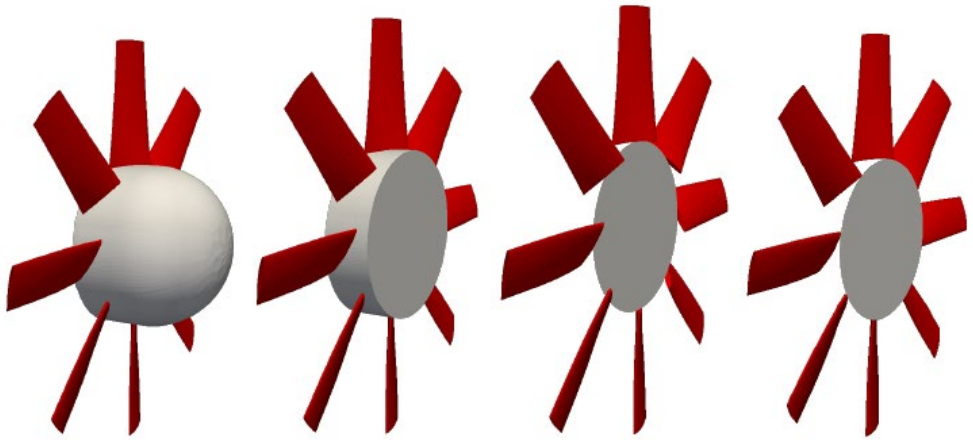




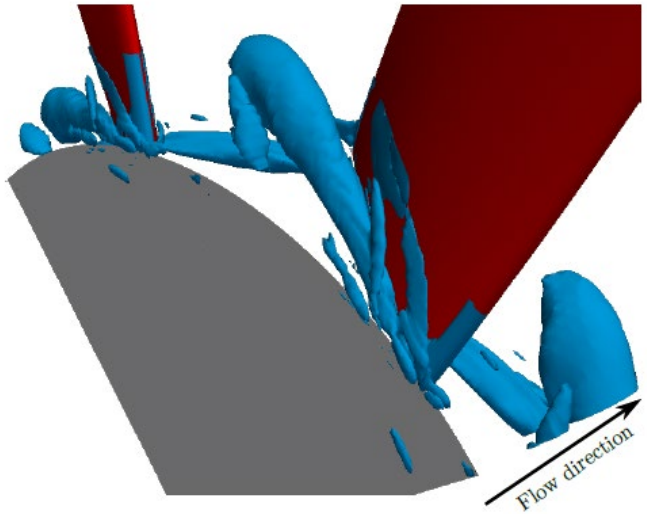
Latest research & major results

Profs Chris Meyer & Johan van der Spuy

- The effect of hub configuration on axial flow fan performance
- Role of hub vortex structures



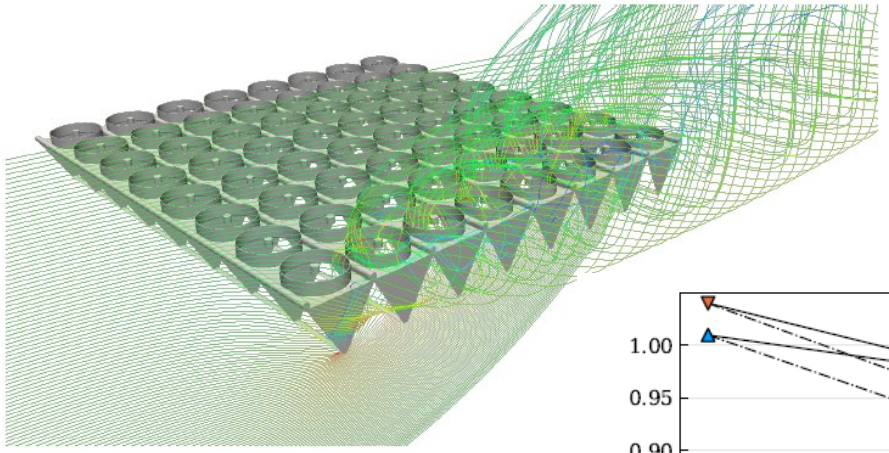
(a) R hub (b) S hub (c) CD hub (d) FD hub



Latest research & major results

Profs Chris Meyer & Johan van der Spuy

- A comparison of forced draught and induced draught ACC performance
  - Large ACC (8 x 8)
  - Combines different fan types (steep pressure gradients at sides)
  - Effect of recirculation important to consider



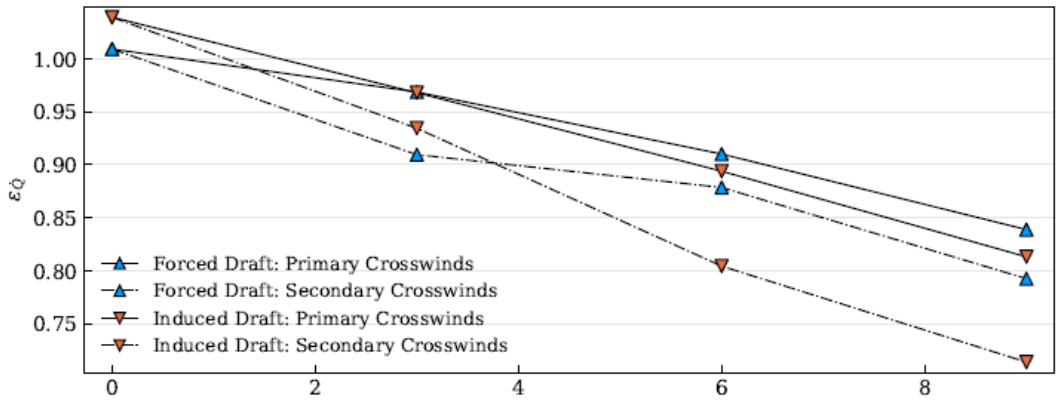
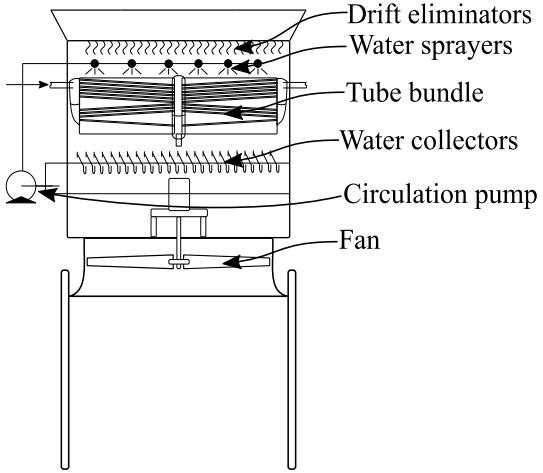


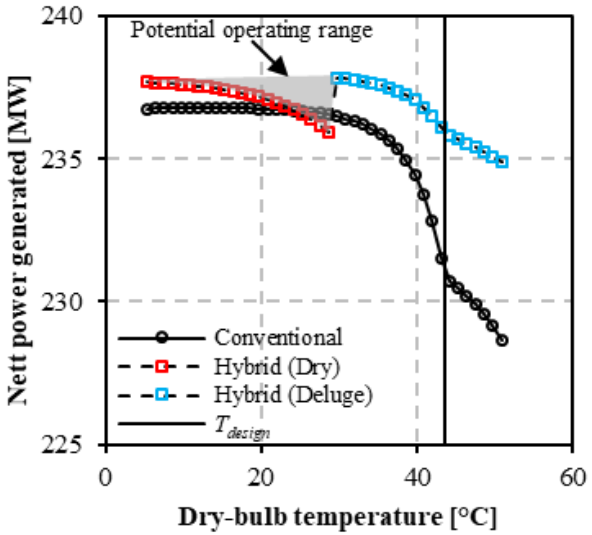
Figure 8.3: Heat Transfer Effectiveness Comparison: Forced vs Induced Draft

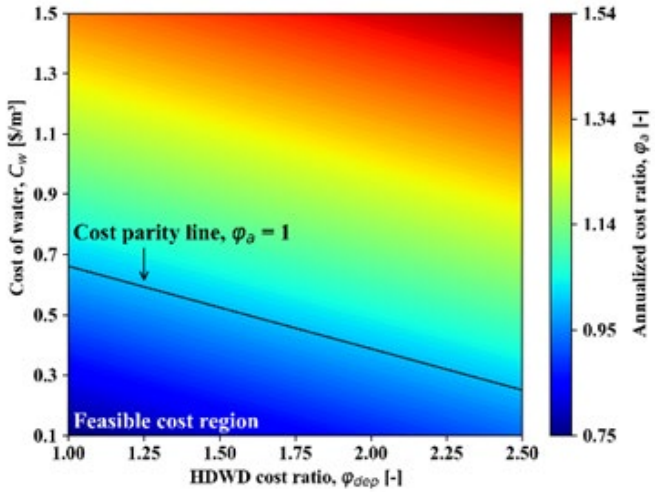
Latest research & major results

Dr Mike Owen

- Hybrid ACCs
  - Single-stage hybrid (dry / wet) dephlegmator
  - Experimental investigation of deluge bundle performance characteristics
  - Row-by-row thermal and hydraulic analysis
  - Techno-economic analysis for a variety of operating and market conditions
    - Allows for smaller ACC for similar annual performance at low specific water consumption







Jacques du Plessis
(PhD candidate)

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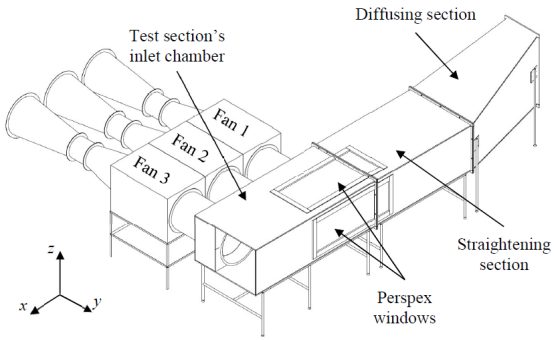
Latest research & major results

Dr Mike Owen

- ACC wind effect mitigation
  - Experimental and numerical analysis of the effect of wind screens and walkways
  - Consideration of both fan volumetric performance and dynamic blade loading
  - Single and multi-objective optimization of mitigation configuration towards a wind resistant forced draft ACCs (smaller scale ~ 6x3 units)



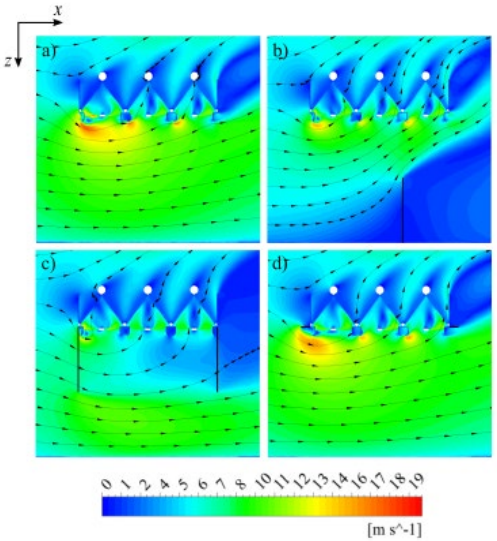


Figure 5.13: Contour plots of the velocity magnitude for (a) NM, (b) CS, (c) PS and (d) WW ($H_p/d_f = 3.5$; $v_w = 6$ m/s; $\beta_w = 0°$)

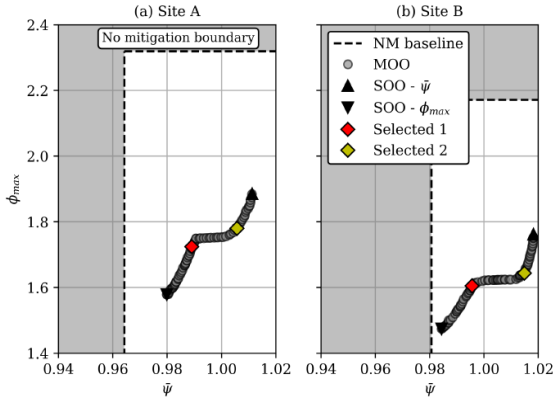


Figure 7.8: Optimisation results for (a) site A and (b) site B

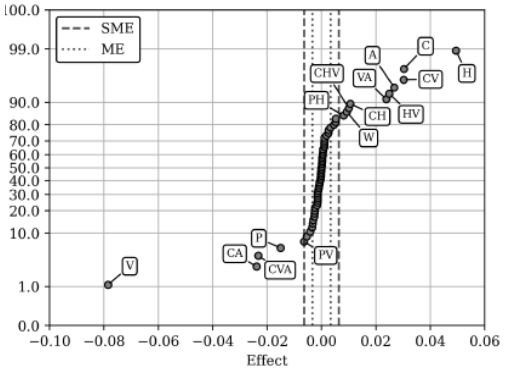


Figure 5.20: Heat transfer effectiveness normal probability plot

Dr Jacques Muiyser
(Howden Netherlands)

Simon Marincowitz
(PhD candidate)

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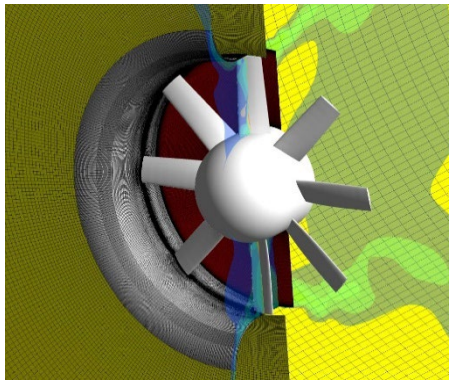
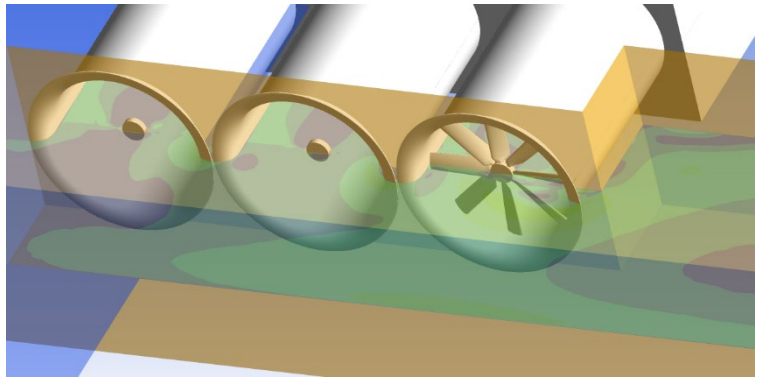
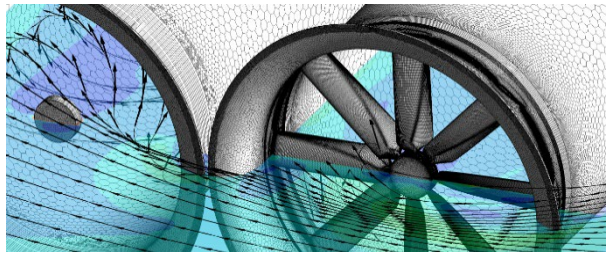
Latest research & major results

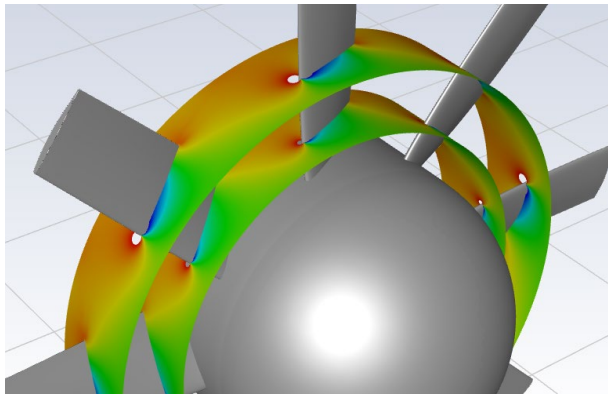
Dr Mike Owen

- Improving ACC axial flow fan performance prediction under cross-flow conditions
  - Implicit fan models provide limited accuracy under cross-flow conditions
  - Explicit fan modelling under these conditions is being used to interrogate reasons for the inaccuracies and identify / develop appropriate implicit model augmentation approaches for improved accuracy









Adam Venter
(PhD candidate)

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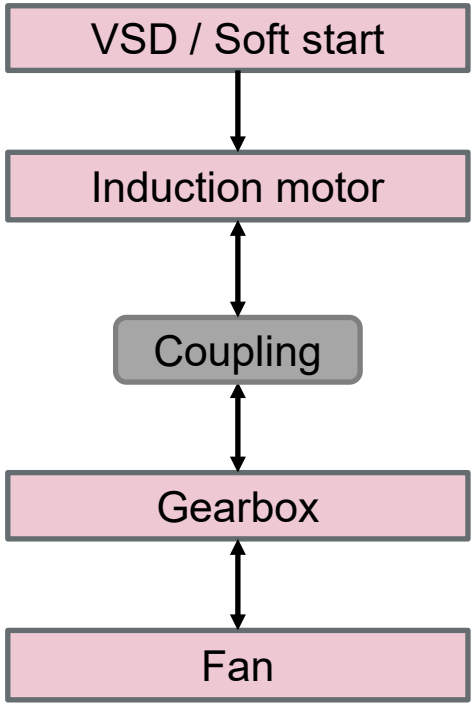
Latest research & major results

Dr Danie Els & Dr Martin Venter

- System Dynamic Modelling
- System Performance Measurements (separate presentation)

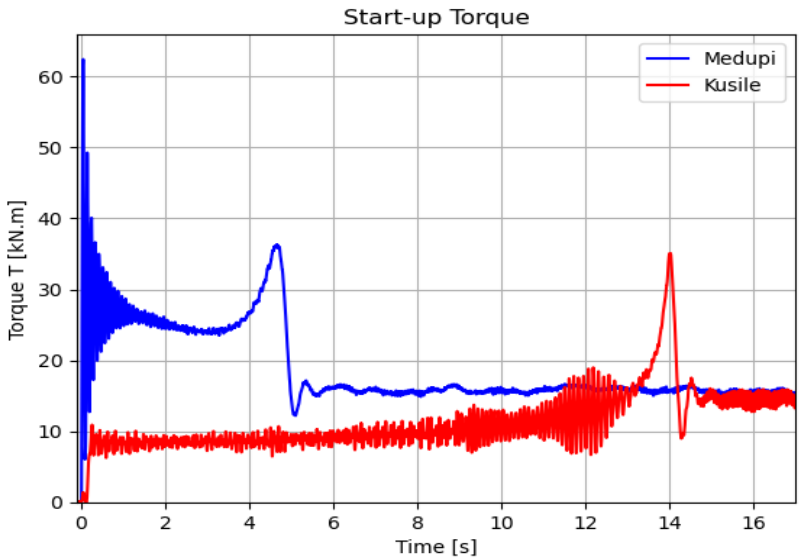
MinWaterCSP ACC test facility

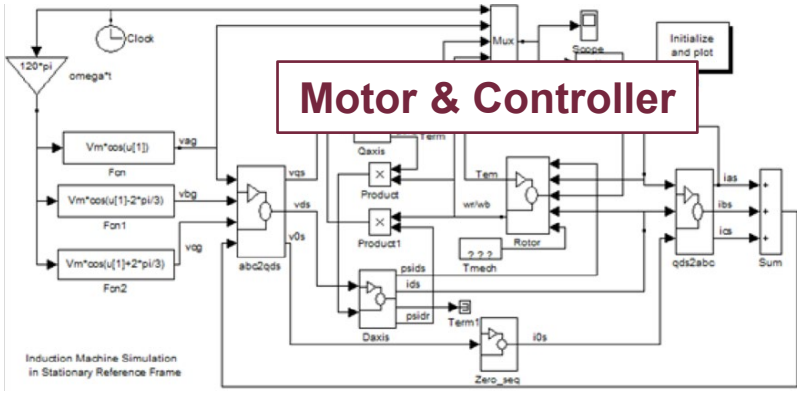


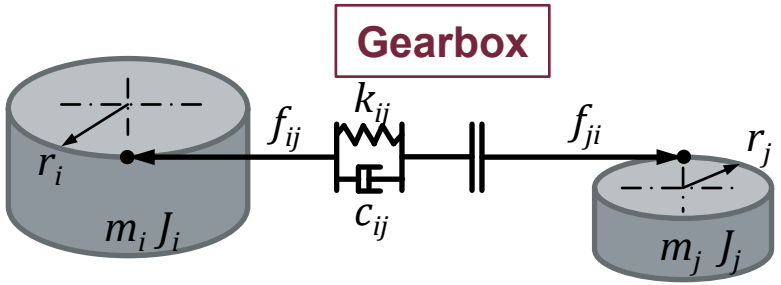
Latest research & major results

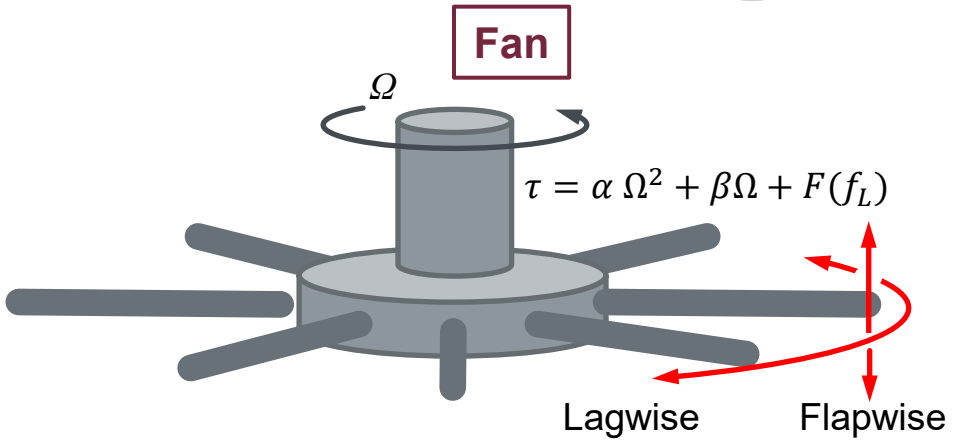
System Dynamic Modelling

- The objective is an integrated model for the torque loads through the mechanical system of an ACC.
- The main purpose of the model is to investigate and predict the start-up and steady state mechanical loads through out the system.









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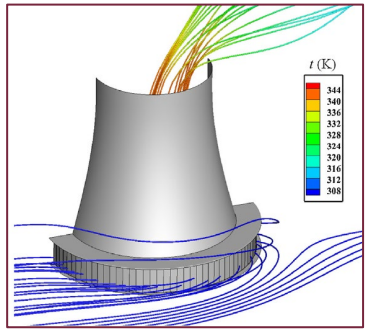
Latest research & major results

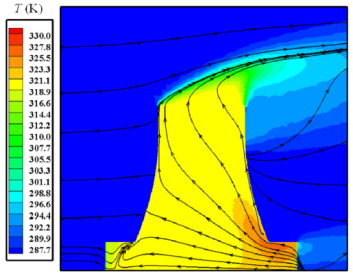
Dr Hannes Pretorius & Prof Jaap Hoffmann

- Research on Natural Draft ACC

- ACC vs Indirect dry cooling systems
  - Indirect system very reliable and relatively insensitive to wind, typically more expensive than ACC
  - ACC's typically cheaper to install, but high auxiliary power consumption, maintenance intensive and more susceptible to wind
- NDACC
  - Aims to combine the advantages of both the ACC and Indirect cooling system
  - Relatively few research publications on this topic
  - Some Contractors have already started offering such systems



Kong et al (2018)



Latest research & major results

- Research aims to:
  - Evaluate air side flows – temperature and wind effects on performance, transient effects on steam flows
  - Evaluate steam side flows – steam ducting & bundle layout configurations, air / non condensable accumulation
  - Evaluate effect of parameter variations on performance – to understand the system characteristics as part of CSP, combined cycle gas or coal application
  - Evaluate the scalability of the system – to even smaller systems for solar desalination applications
  - Transient start-up effects
  - Investigate options for more cost-effective cooling tower structures
  - Determine power station annual power output when implementing such a system and life cycle cost compared to alternative cooling systems

Research funding & consulting opportunities

- Research funding
  - Research partnerships – balance between finding real-world solutions and developing publishable research
  - Postgraduate project funding
    - M: typically $14 000 bursary & project-specific costs
    - PhD: typically $30 000 bursary & project-specific costs
  - Confidential research possible
  - IP sharing possible
- Consulting services
  - Fan design
  - CFD simulation
  - Heat exchanger bundle testing
  - ACC scale fan testing
  - ACC fan drive testing
  - ACC specification development

Conclusion

- Active research group, specializing in ACC and Dry-cooling applications
- Dedicated test facilities and simulation capabilities
- Eager to partner with industry & develop ACC and Dry-cooling solutions of the future
- Thank you for the opportunity to share our latest research results with you!

Thank you

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