Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT

forward together
sonke siya phambili
saam vorentoe

An overview of ACC research at Stellenbosch University

Presented by Prof. Hanno Reuter *on behalf of*

Department of Mechanical and Mechatronic Engineering, Stellenbosch University, South Africa.

ACCUG Annual Conference, Stamford, CT. 12 - 15 September 2022

Background

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

- Our department has been actively involved in ACC research for over 5 decades.
- Prof. Detlev Kröger
  - Initiated ACC research at SUN in the 1970s
  - South Africa's large ACC design and features are greatly influenced by his research
  - Established a strong relationship with industry


(Pretorius, 2012)


(Lennon, 2011)


(Lennon, 2011)


(Augustyn, 2017)


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

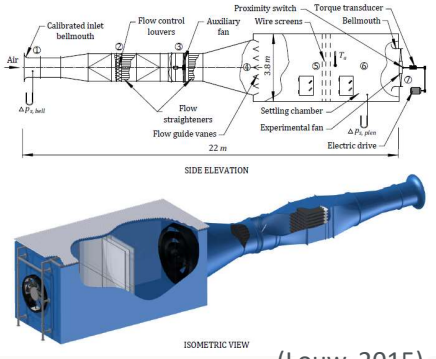
Background (cont.)

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together
sonke siya phambili
saam vorentoe

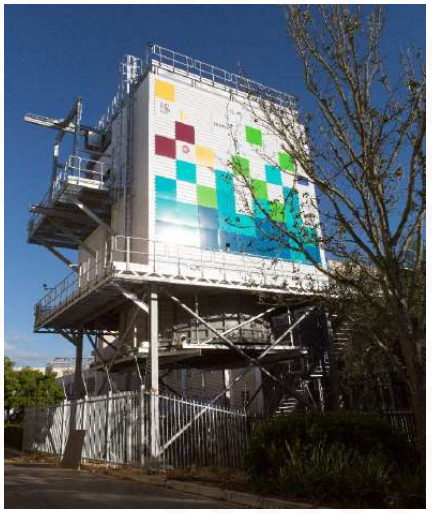
- Many engineers studied under Prof. Kröger's supervision:
  - Professional engineers in power generation / cooling technology industry
  - Researchers at Stellenbosch University
- We aim to continue to build on the legacy of ACC research at Stellenbosch University through academic and commercial research in:
  - ACC, dry and hybrid cooling research
  - Heat exchanger bundle characteristic testing
  - ACC fan development
  - ACC & fan CFD simulation
  - ACC scale fan testing
  - ACC hybrid dephlegmator development
  - ACC fan drive research
- Post graduate course Industrial Heat Exchangers 814 (based on Kröger's "Air-cooled Heat Exchangers and Cooling Towers")

Experimental facilities

- MinWaterCSP facility
  - 24ft fan
  - Water reticulation system for use in testing droplet collectors associated with deluge bundles in a hybrid cooling system
- ACC scale fan test facility (ISO 5801)
  - 1.542 m dia. fan
  - Ability to investigate fan noise
- ACC heat exchanger test facility
- ACC fan drive testing
- Cross and counterflow cooling tower test facility
- Well-equipped heat transfer and wind tunnel laboratories



(Louw, 2015)



(Van der Spuy et al, 2021)

Other resources

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together
sonke siya phambili
saam vorentoe

- Typically 50-70 postgraduate students per year (department wide)
- Licenses for several commercial simulation tools (e.g. ANSYS FLUENT)
- Access to National Centre for High Performance Computing (CHPC) super computer
  - ~33000 compute cores
- Access to Advanced Manufacturing laboratory
- Access to the latest international research publications
- Access to multidisciplinary engineering researchers
  - Mechanical & Mechatronic
  - Civil
  - Electric & Electronic
  - Process
  - Industrial
  - Solar Thermal Energy Research Group (CSP / CST)

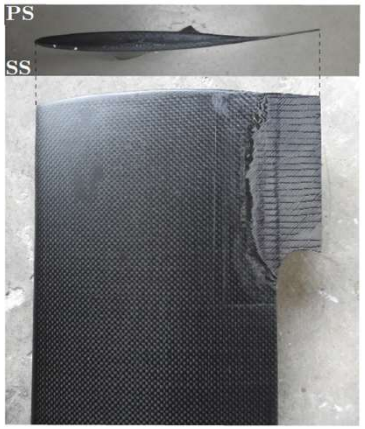
Latest research & major results

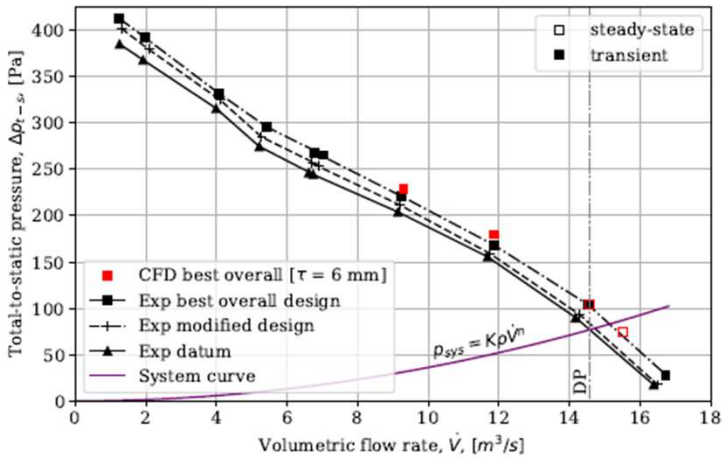
Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

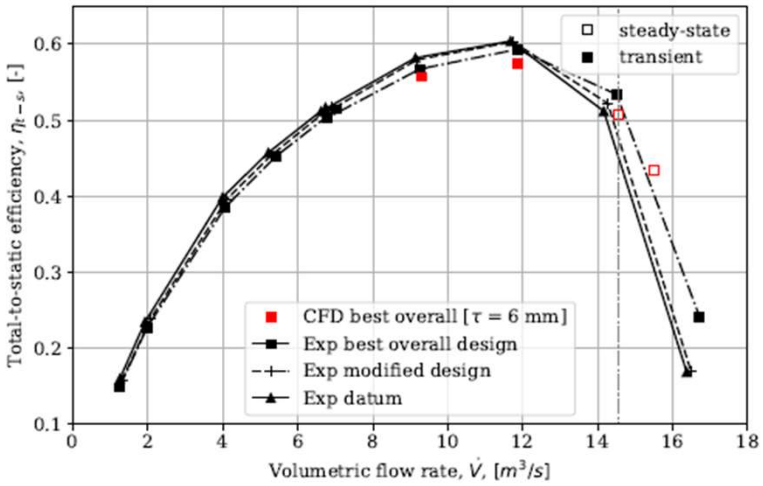
Profs Chris Meyer and Johan van der Spuy


- 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





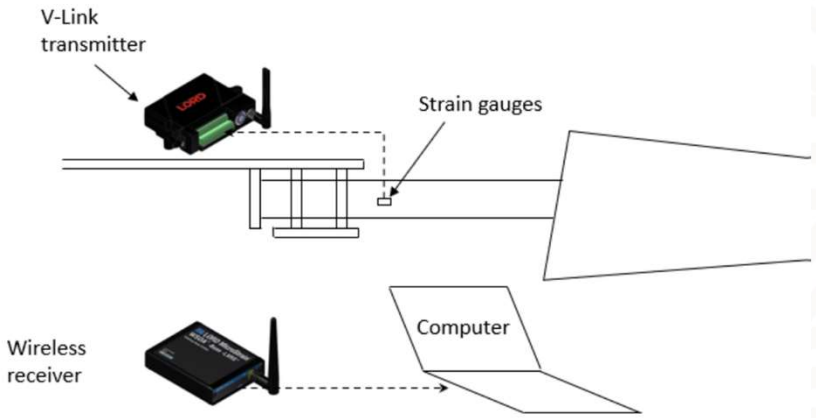


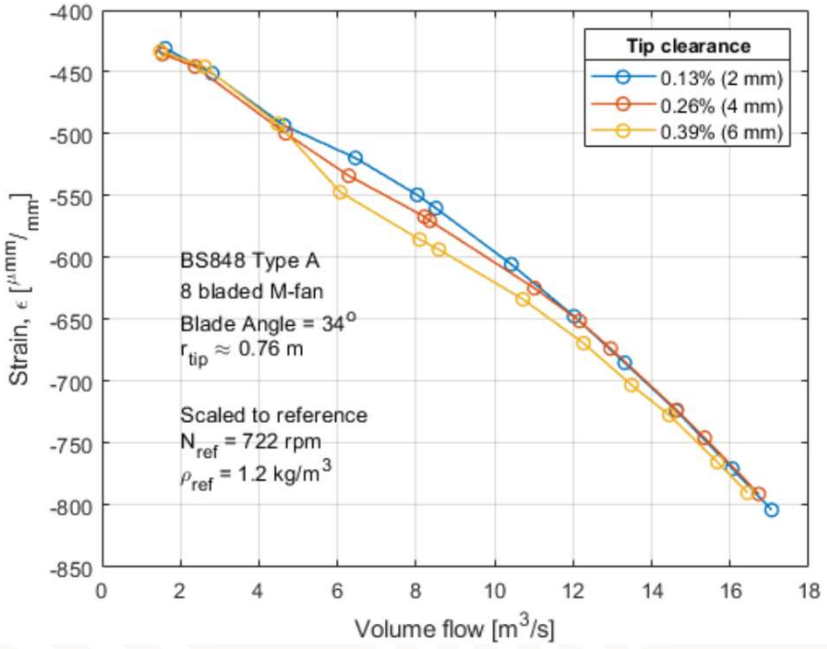
Latest research & major results

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Profs Chris Meyer and Johan van der Spuy

- Measurement of installed fan performance
- Using blade flap-wise strain gauge measurements



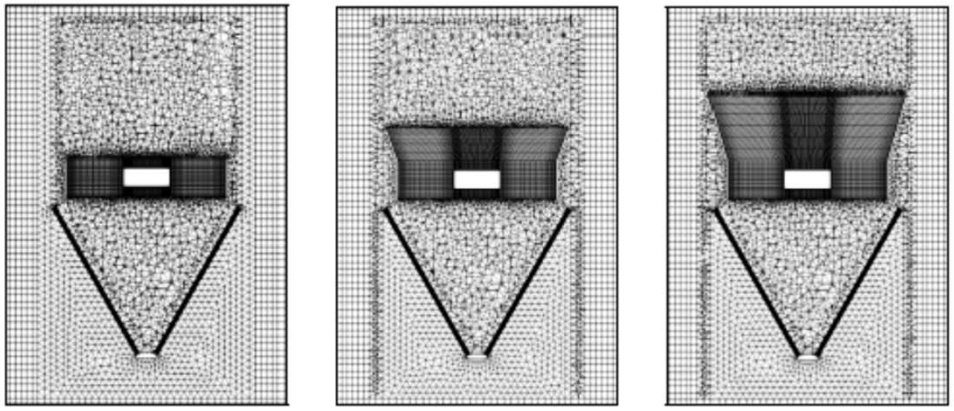


Latest research & major results

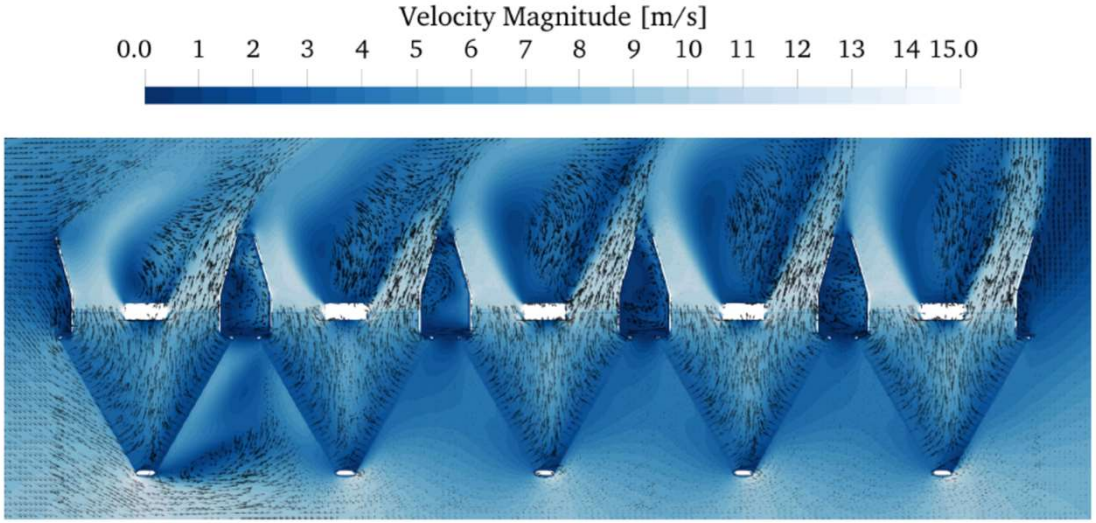
Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Profs Chris Meyer and Johan van der Spuy


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



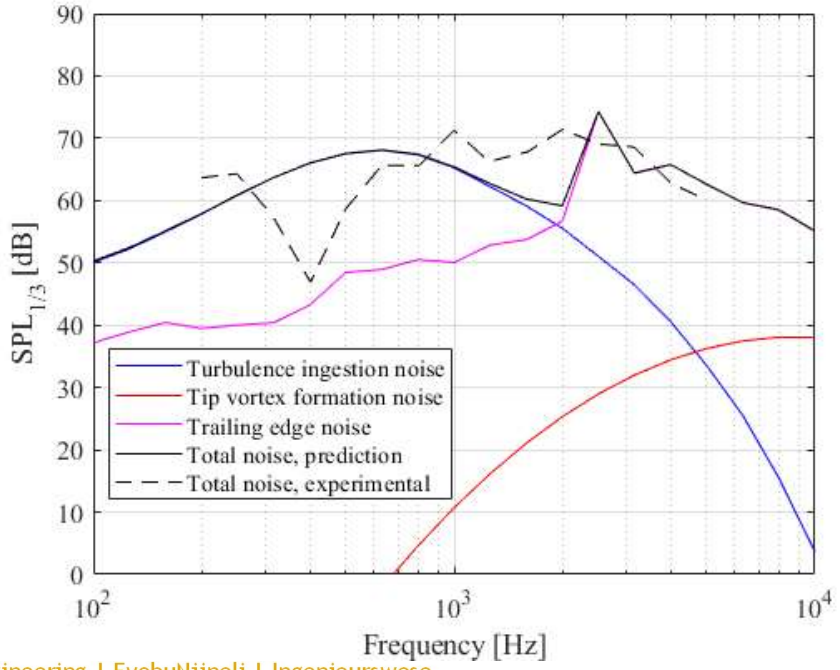
(a) Fan only (b) $l_{dif} = 0.2d_F$ diffuser (c) $l_{dif} = 0.4d_F$ diffuser

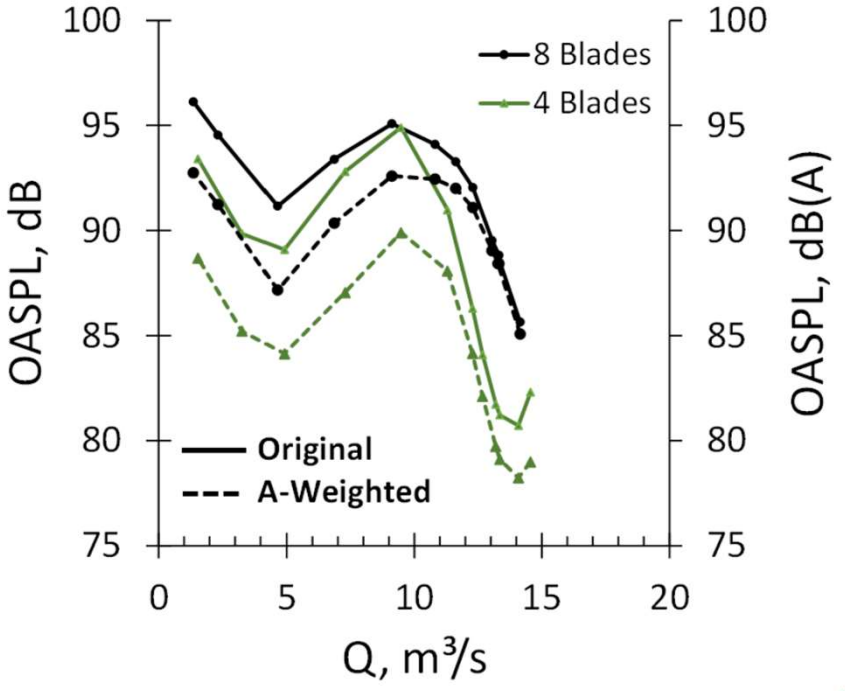


Latest research & major results

Profs Hanno Reuter and Johan van der Spuy

- Prediction of large diameter axial flow cooling fan noise
  - 8-blade Mfan: Numerically (OASPL = 77.59 dB(A)) and experimentally (OASPL = 78.73 dB(A))
  - Experimental evaluation of 4-bladed vs 8-bladed M-fan.



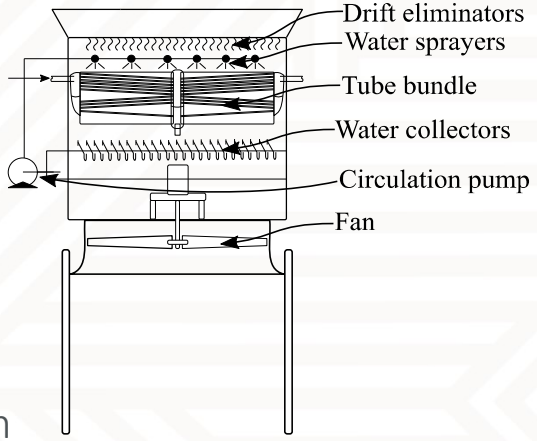


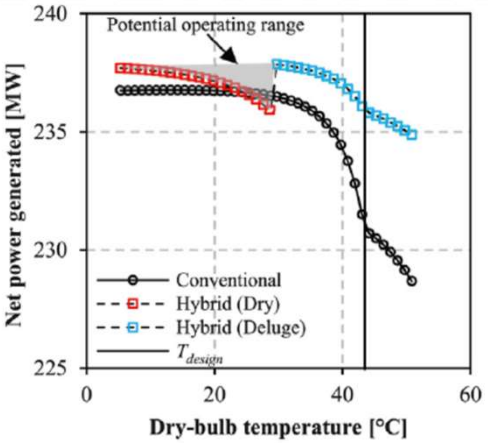
Latest research & major results

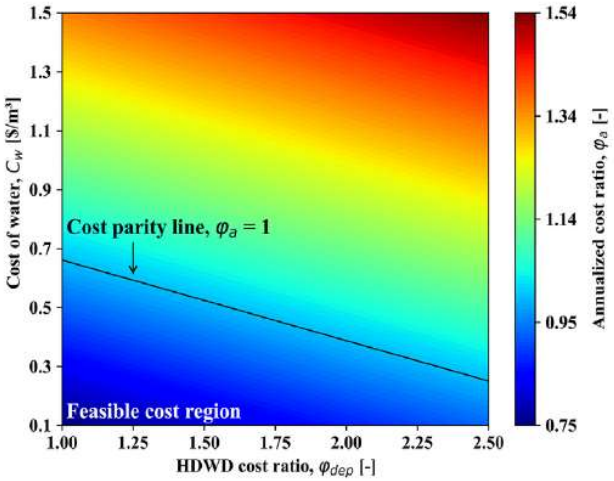
Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Dr Mike Owen

- Hybrid ACC with single stage dry/wet dephlegmator
  - Techno-economic feasibility analysis
  - Hybrid ACC can be 1/3rd smaller than a conventional ACC
  - Specific water consumption
    - 0.31 kL/MWh to 0.69 kL/MWh
    - Potential for much lower through oversizing the hybrid system
  - Wide regions of cost-competitiveness.







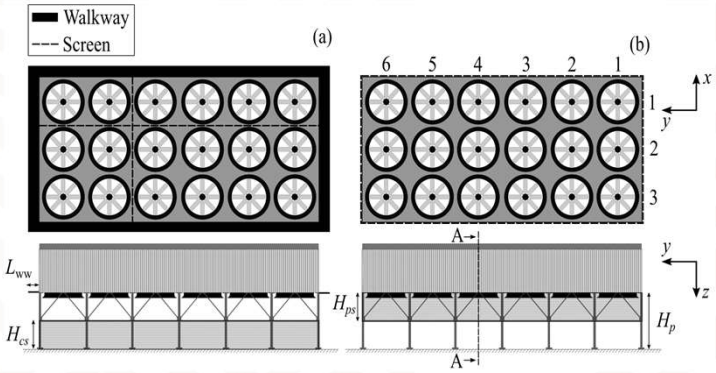
Jacques du Plessis
(PhD)

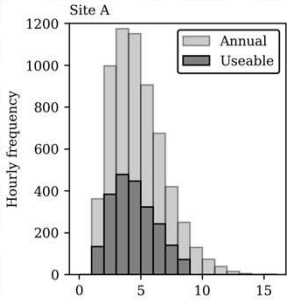
Latest research & major results

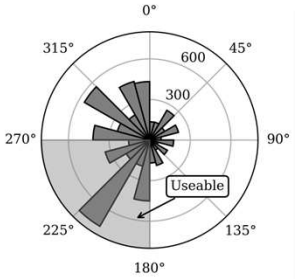
Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

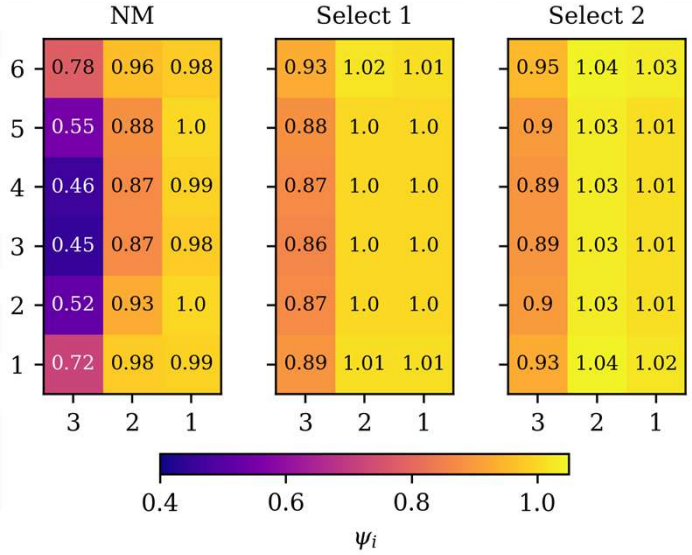
Dr Mike Owen

- ACC wind effect mitigation
  - Multi-objective optimization of windscreen and walkway configuration
  - Aiming for improved thermal performance and reduced dynamic blade loading
  - Consideration to wind distributions rather than singular wind conditions
  - General guidelines for the “best” configurations recommended









Simon Marincowitz
(PhD)

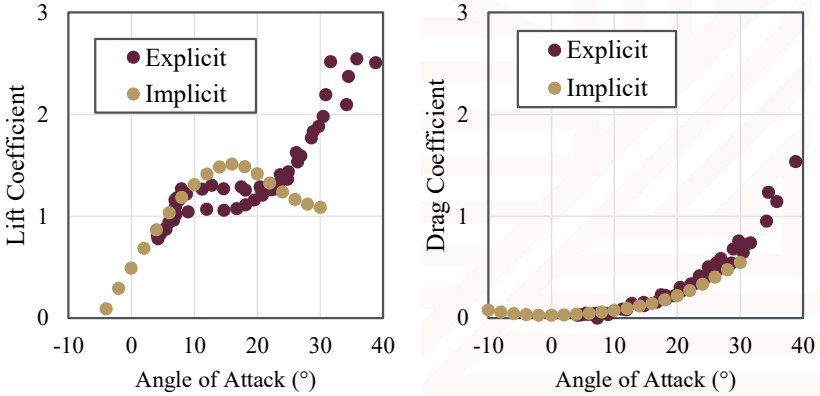
Dr Jacques Muiyser
(Howden Netherlands)

Latest research & major results

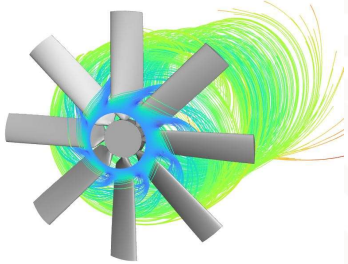
Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Dr Mike Owen

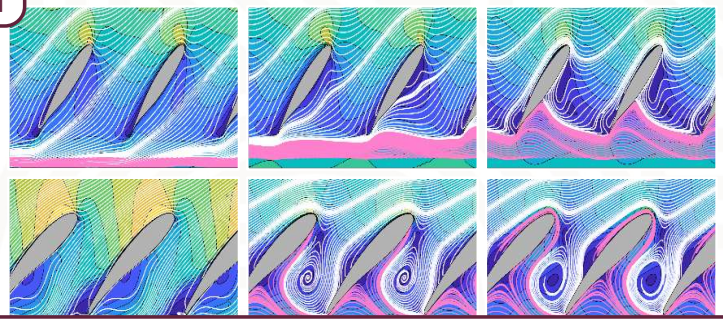
- Improving ACC axial flow fan modelling in CFD
  - Implicit fan models provide a limited approximation of actual ACC fan performance
  - Explicit fan modelling is being used to identify the flow mechanisms at play and derive augmented formulations for blade element-based actuator disk-type fan models for large-scale ACC CFD applications



Actual ACC vs. implicit fan model behaviour



Explicit model



Flow contours to unpack fan behaviour mechanisms

Adam Venter
(PhD candidate)

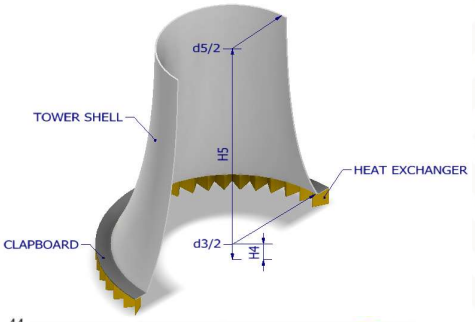
Engineering | EyobuNjineli | Ingenieurswese

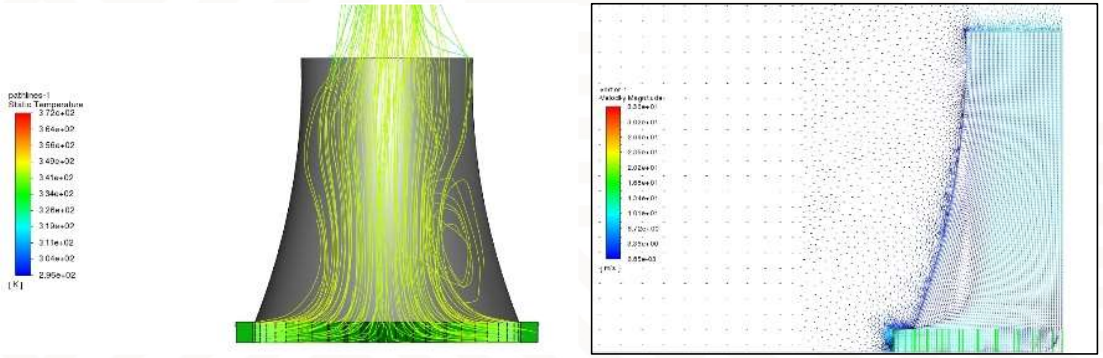
Latest research & major results

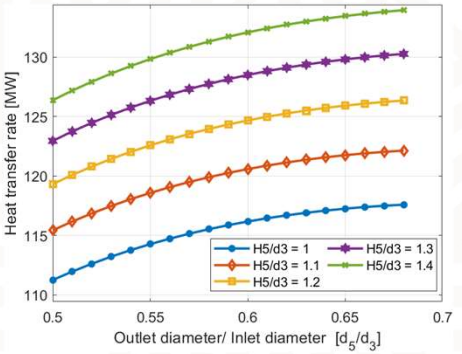
Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

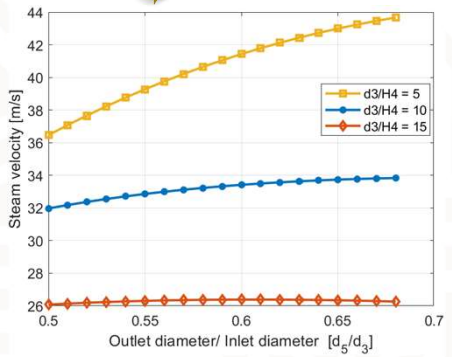
Dr Hannes Pretorius and Prof. Jaap Hoffman

- Natural draft ACCs
- Air-side performance evaluation
  - 1D model and 3D CFD model
  - Investigate scalability of system for large (coal), medium (combined cycle, CSP) or small (solar desalination) applications
  - Effect of geometric parameter variation on performance
  - Evaluate effects of wind on performance of system at various scales









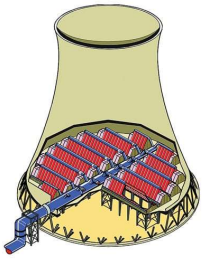
Strydom et al. (2022)

Latest research

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Drs Hannes Pretorius and Mike Owen


- Natural draft ACCs
  - Steam-side performance evaluation (starting 2023)
    - 1D model and 3D CFD model
    - Steam ducting & bundle layout configurations
    - Air / non-condensable accumulation



powermag.com (SPX Cooling Technologies)

- FAC in ACCs
  - Towards FAC alleviation by numerical analysis of two-phase steam flow in ACCs
  - Liquid extraction for alleviation of FAC in ACCs
  - Research partners wanted!

Dooley & Lister (2018)

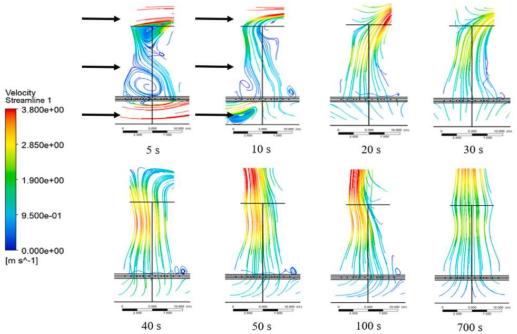
Latest research

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT

forward together
sonke siya phambili
saam vorentoe

Dr Hannes Pretorius and Mr Matthew Meas

- Natural draft ACCs
- Transient effects on NDACC (starting 2023)
  - Start-up characteristics
  - Transient wind effects
  - Coupled steam-side and air-side performance
- Future research
  - Cost-effective cooling tower structures
  - Annual power station output with NDACC
  - Life-cycle costs compared to alternative systems



Zhang et al. (2022)

www.sbp.de

ACC-related research outputs (2021/22)

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Journal papers

- Bekker, GJ, Meyer, CJ, van der Spuy, SJ, The Effect of Wind Screens on the Performance of an Induced Draft Air-Cooled Condenser Under Windless and Windy Conditions, Journal of Thermal Science and Engineering Applications, published online, 2022.
- Bekker, GJ, Meyer, CJ, van der Spuy, SJ, Influence of pressure recovery on the performance of an induced draught air-cooled condenser under windless and windy conditions, Applied Thermal Engineering, 213, 2022.
- Bekker, GJ, Meyer, CJ, van der Spuy, SJ, Pressure R.ecovery Discharge Configurations for an Induced Draught Axial Flow Fan, R&D Journal, 38, 2022
- Bekker, GJ, Meyer, CJ, van der Spuy, SJ, Performance Enhancement of an Induced Draught Axial Flow Fan Through Pressure Recovery, R&D Journal, 37, 2021.
- Du Plessis, C, van der Spuy, SJ, Reuter, HC, On the effect of the correction of modelled airfoil tonal noise for a spanwise extension, Aerospace Science and Technology, 118, 2021.
- Du Plessis, J., Owen, M., Techno-economic analysis of hybrid ACC performance under different meteorological conditions, Energy, 255, 2022.
- Du Plessis, J., Owen, M., A single-stage hybrid (dry/wet) dephlegmator for application in air-cooled steam condensers: Performance analysis and implications, Thermal Science and Engineering Progress, 26, 2021.
- Marincowitz, F., Muiyser, J., Owen, M., The effect of windscreens and walkways on air-cooled condenser performance and fan blade dynamic loading, J. Eng. Gas Turbines Power, 2021.
- Meyer, TO, van der Spuy, SJ, Meyer, CJ, Design of a tip appendage for the control of tip leakage vortices in axial flow fans; ASME Journal of Turbomachinery, Volume 143, 2021.
- Pretorius, J. P., and Erasmus, J. A. (September 29, 2021). "Effect of Tip Vortex Reduction on Air-Cooled Condenser Axial Flow Fan Performance: An Experimental Investigation." ASME. J. Turbomach. March 2022; 144(3): 031001.
- Venter, A., Muiyser, J., Owen, M., A numerical analysis of windscreen effects on air-cooled condenser fan performance, Applied Thermal Engineering, 186, 2021..

ACC-related research outputs (2021/22)

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Conference papers

- Boshoff, F.D., Van der Spuy, S.J., Pretorius, J.P., and Meyer, C.J., 2022, "Design of an axial flow fan for a unique cooling application," Proceedings of ASME Turbo Expo 2022, GT2022-80256, Rotterdam, Netherlands.
- Louw, D, Meyer, CJ, van der Spuy, SJ, Numerical Investigation of an Induced Draft Air-Cooled Condenser Under Crosswind Conditions, ASME 2021 Heat Transfer Summer Conference, June 2021.
- Marincowitz, F., Holkers, P., Muiyser, J., Owen, M., Uniformity index as an universal air-cooled condenser fan performance metric, International Conference on Fan Noise, Aerodynamics, Applications and Systems, Senlis, France, June 2022.
- Meyer, TO, van der Spuy, SJ, Meyer, CJ, Optimization of a Tip Appendage for the Control of Tip Leakage Vortices in Axial Flow Fans, ASME TurboEXPO, June 2021.
- Pretorius, J.P., Van der Spuy, S.J., and Strümpfer, M. 2022, "Tip vortex effects on air-cooled condenser axial flow fan performance," Proceedings of ASME Turbo Expo 2022, GT2022-82283, Rotterdam, Netherlands.
- Strydom, W., Pretorius, J.P., and Hoffmann, J.E. 2022, "Natural draft direct dry cooling system scaling for diverse applications,", 16th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT), virtual conference.
- Van der Spuy, SJ, Els, DNJ, Thieghi, L, Delibra, G, Corsini, A, Zapke, A, Louw, FG, Meyer, CJ, Preliminary Evaluation of the 24 Ft. Diameter Fan Performance In the MinWaterCSP Large Cooling Systems Test Facility, ASME TurboEXPO, June 2021.
- Venter, A., Muiyser, J., Owen, M., Towards the improvement of numerical air-cooled condenser fan models, International Conference on Fan Noise, Aerodynamics, Applications and Systems, Senlis, France, June 2022.

ACC-related research outputs (2021/22)

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

Academic dissertations

- PhD
  - Bekker, G.J., Numerical Investigation of Pressure Recovery for an Induced draught Air-cooled condenser for CSP Applications, 2021.
  - Du Plessis, J., A single-stage dry/wet dephlegmator: development, performance evaluation and application in a hybrid ACC at CSP or NGCC scale, 2021.
  - Louw, D., Evaluation of the Modelling strategy for a large Air-cooled condenser, 2021.
  - Marincowitz, F.S., Optimisation towards a wind-resistant air-cooled condenser for the modern energy sector, 2021.
- MEng
  - Siavhe, A, Numerical Investigation of a Large Air-Cooled Steam Condenser, 2021.
  - Steenkamp, GJ, Reynolds Number Scaling of Axial Flow Fans, 2021.
  - Waters, D. MEng, A parametric analysis of hybrid (dry/wet) cooling system configuration for thermal power plants, 2022.

- Publically available via SUN Scholar

Collaboration opportunities and services

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together
sonke siya phambili
saam vorentoe

- Academic research
  - 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 and contact details

Stellenbosch UNIVERSITY IYUNIVESITHI UNIVERSITEIT
forward together sonke siya phambili saam vorentoe

- We are an active research group, specializing in ACC and dry-cooling applications
- We have dedicated test facilities and simulation capabilities
- We are very eager to partner with industry to solve ACC and dry-cooling related problems and develop solutions for the future.
- We would love to engage more actively with the ACC industry and encourage ACCUG members to contact researchers directly:

  - Prof. Johan van der Spuy - sjvdspuy@sun.ac.za (Dept. head: M&M engineering)
  - Prof. Jaap Hoffman - hoffmaj@sun.ac.za
  - Prof. Chris Meyer - cjmeyer@sun.ac.za
  - Prof. Hanno Reuter - hreuter@sun.ac.za
  - Dr Hannes Pretorius - jpp@sun.ac.za
  - Dr Mike Owen - mikeowen@sun.ac.za (Division head: thermofluids, general enquiries)
  - Mr Matthew Meas – mmeas@sun.ac.za

Stellenbosch
UNIVERSITY
IYUNIVESITHI
UNIVERSITEIT

forward together
sonke siya phambili
saam vorentoe

Thank you
Enkosi
Dankie

Photo by Stefan Els

References

- Augustyn, O.A., “Medupi Power Station ACC Performance During Windy Conditions,” ACC User’s Group Conference 2017, Las Vegas, USA.
- Dooley, R.B., and Lister, D. 2018. “Flow-Accelerated Corrosion in Steam Generating Plants”, PowerPlant Chemistry, 20(4), pp. 194-244.
- Lennon, S., “Advanced in Dry Cooling Deployed at South African Power Stations,” EPRI Summer Seminar 2011, Marina Del Rey, California, USA.
- Pretorius, J.P., “Eskom perspective on specifications for large ACC’s,” ACC User’s Group Conference 2012, Gillette, USA.
- Kröger, D.G., “Air-cooled heat exchangers and cooling towers: Thermal-flow performance evaluation and design”, PennWell Corporation, Tulsa, 2004.
- Van der Spuy, S.J., Els, D.N.J., Tieghi, L., Delibra, G., Corsini, A., Louw, F.G., Zapke, A., Meyer, C.J., “Preliminary evaluation of the 24-ft. diameter fan performance in the MinWaterCSP large cooling systems test facility”. ASME Turbo Expo 2021 Virtual conference, GT2021-59130, 2021.
- Strydom, W., Pretorius, J.P., and Hoffmann, J.E. 2022, “Natural draft direct dry cooling system scaling for diverse applications,” 16th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT), virtual conference.
- Zhang, L., Li, X., Zhou, J., Yu, Y., and Feng, J. 2022, “Numerical study of the dynamic response of the natural draft dry cooling tower under crosswind condition,” Case Studies in Thermal Engineering, 34, 102027.