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Latest ACC research at Stellenbosch University

Presented by Assoc. Prof. Chris Meyer *on behalf of*

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

ACCUG Annual Conference, London 23 - 25 July 2024

Photo by Stellenbosch

Engineering | EyobuNjineli | Ingenieurswese

Background

- 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
- Prof TW von Backström
  - Industry: Uranium enrichment and gas turbines (1980s)
  - Turbomachinery and Renewable Energy
  - 4 decades of research

Background (cont.)

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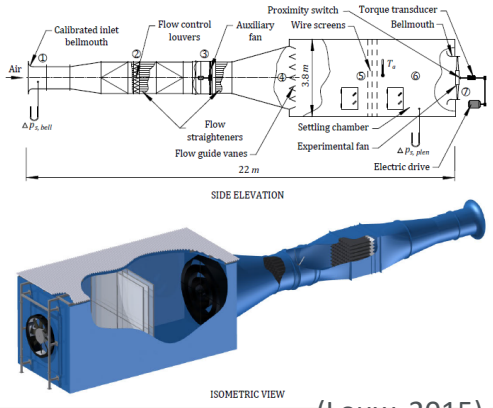
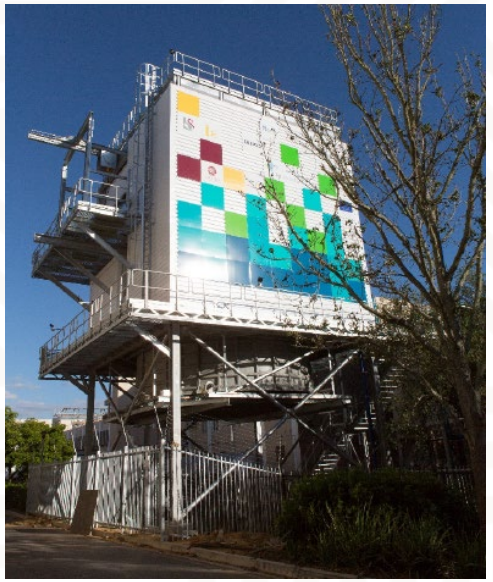
- Many engineers studied under Prof. Kröger's and Prof von Backström's supervision:
  - Professional engineers in power generation / cooling technology industry
  - Researchers at Stellenbosch University
- We aim to continue to build on the legacy of ACC research at Stellenbosch University through academic 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

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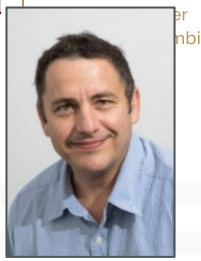
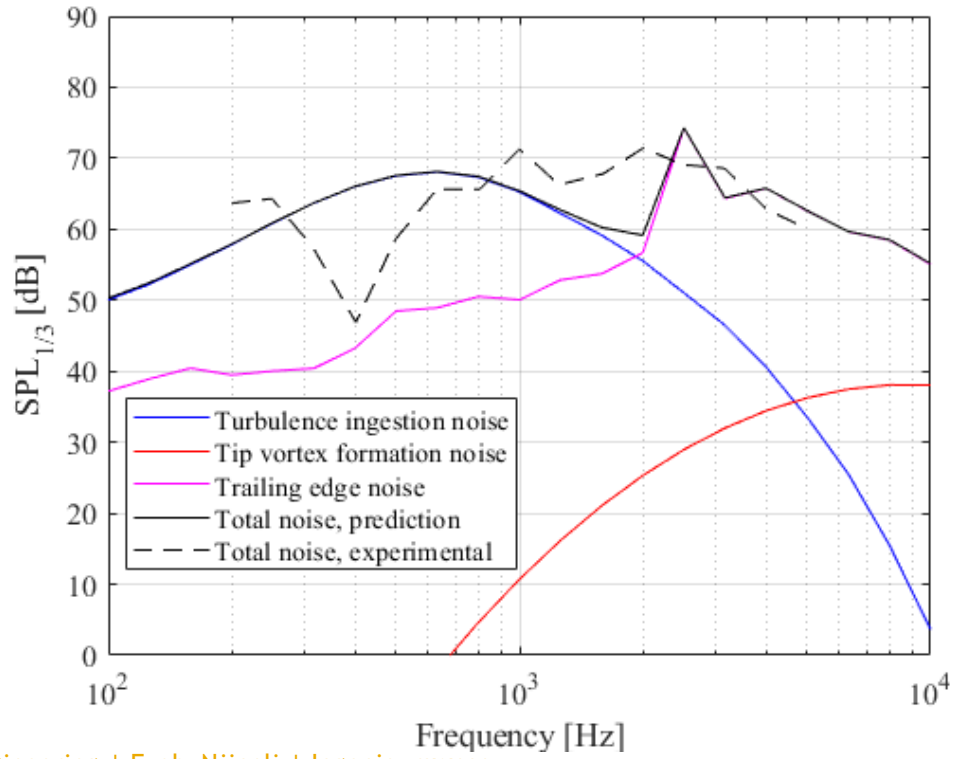
- Typically, 50-70 postgraduate students per year (department wide)
- Licenses for several commercial simulation tools (e.g. ANSYS FLUENT)
- Access to National Centre for High Performance Computing (CHPC) supercomputer
  - ~33000 compute cores
- Access to Advanced Manufacturing laboratory
- Access to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

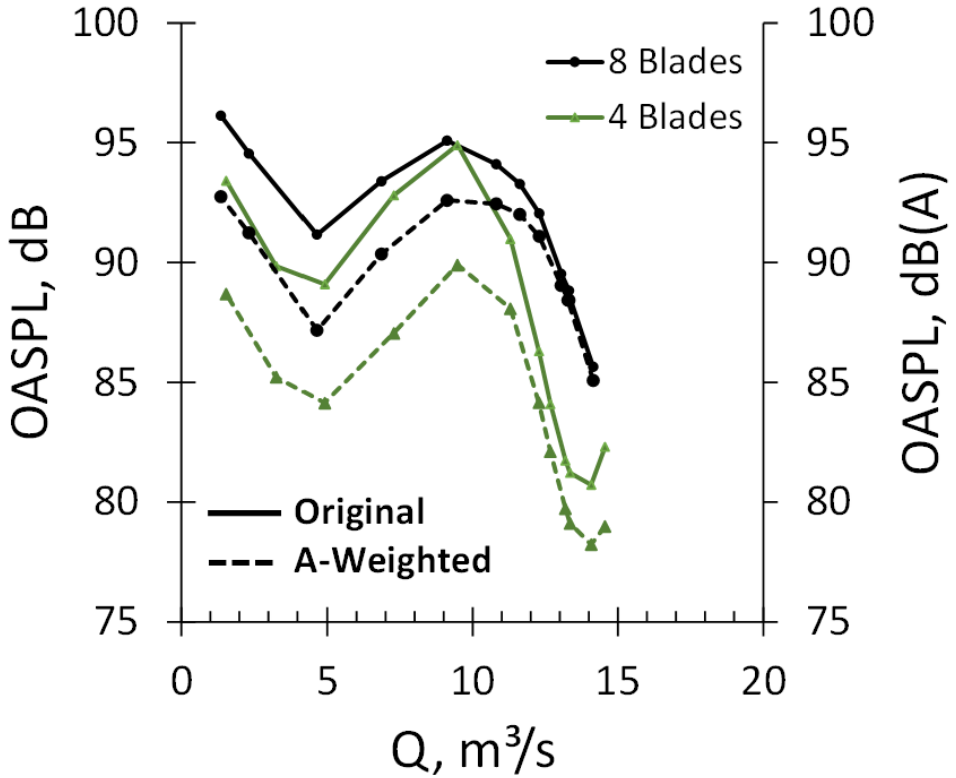
Latest research & major results



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

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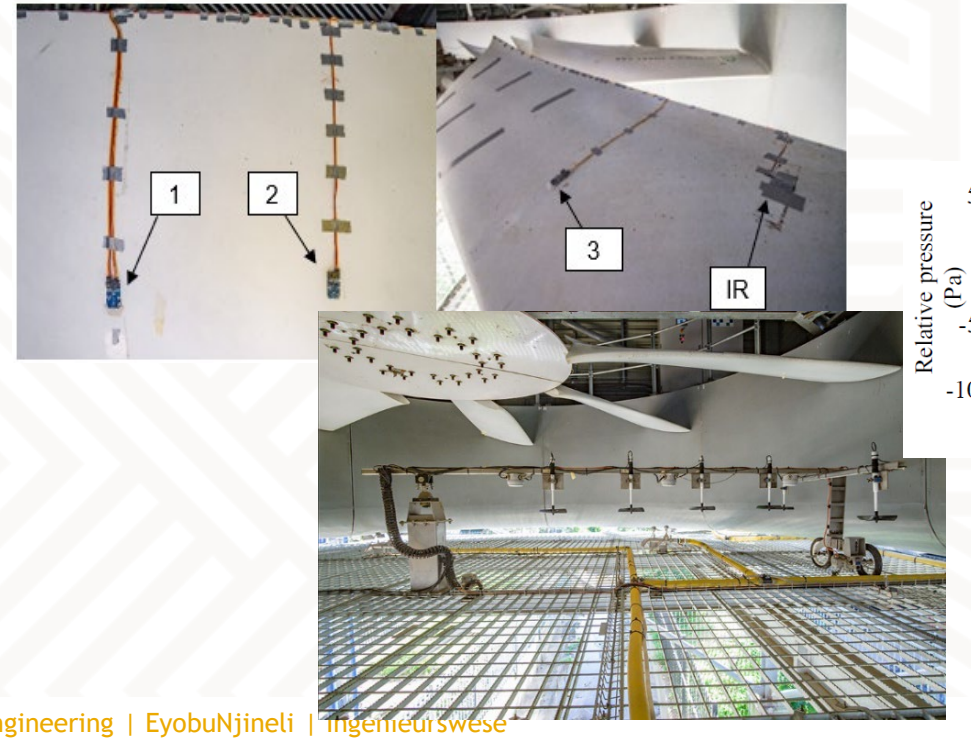
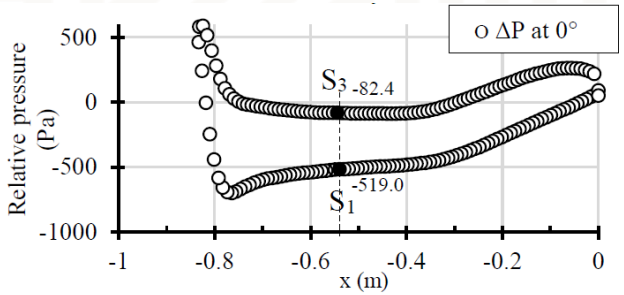
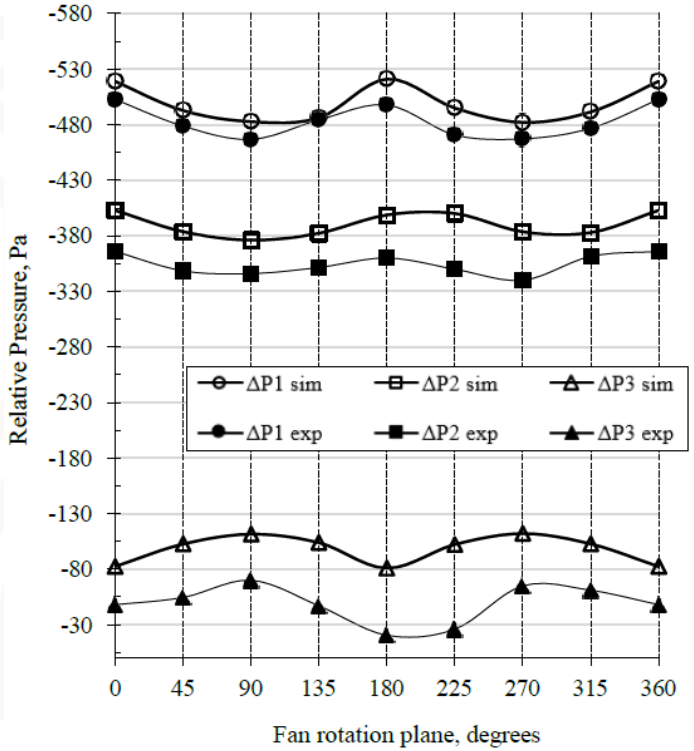
Prof Johan van der Spuy

- Prediction of installed axial flow fan performance
  - Measure pressure at discrete locations on rotating M-fan blade.
  - Compare measurements to results obtained from actuator disk simulation of the same fan.



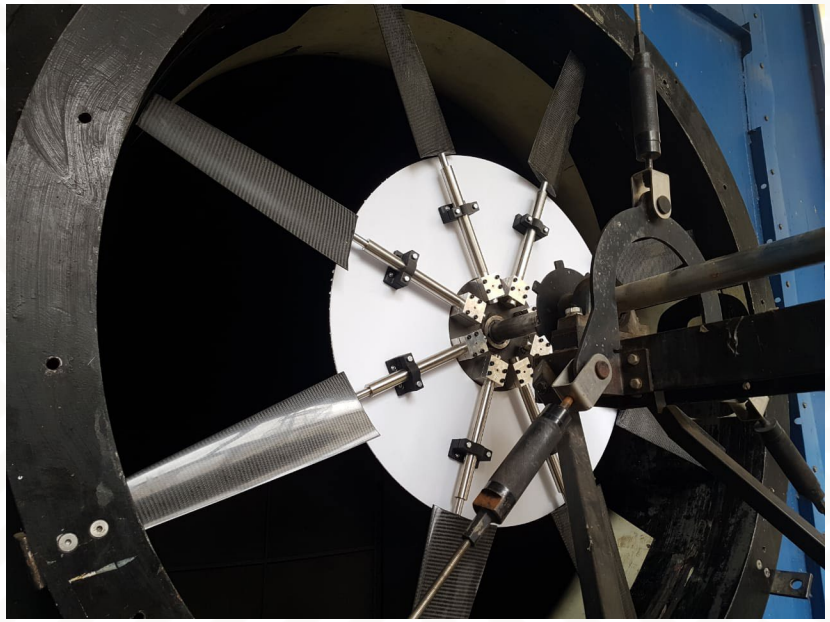




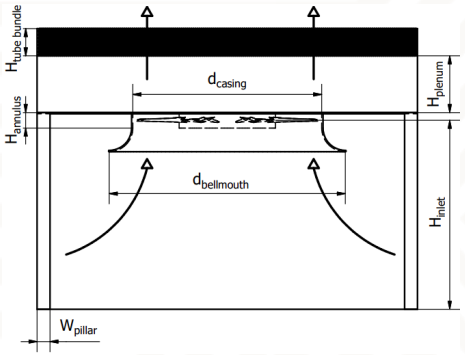
Latest research & major results

Prof Johan van der Spuy & Dr Hannes Pretorius

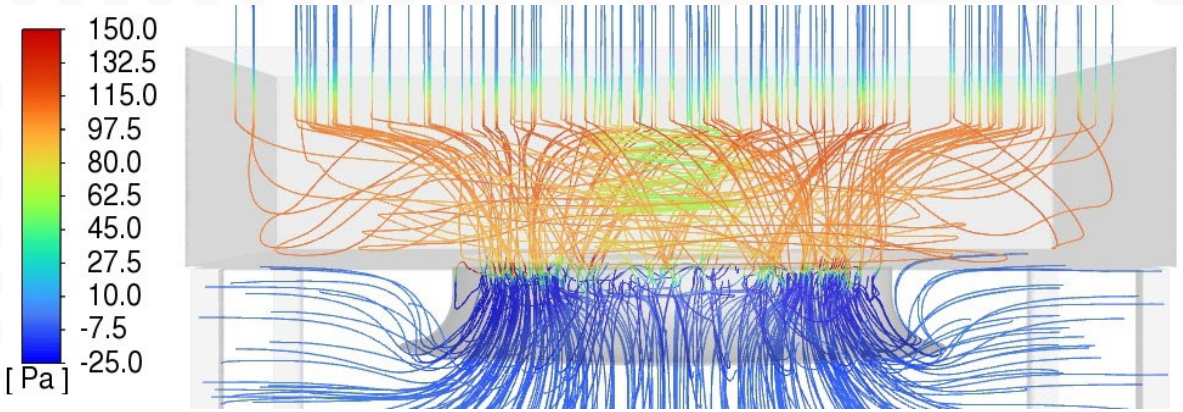
- Development of a fan for sCO2 cooling
  - What would a cooling fan for an sCO2 cycle look like?
  - Fan based on design point of ASME paper.
  - Large hub-tip ratio, low solidity.
  - Currently performing coupled analysis.



Height	$\dot{V}_F$ (m^3/s)	Δp_{ts} (Pa)	P_F (kW)	η_{ts} (%)
$0.25 \times d_{Fc}$	168.8	110.5	31.99	58.32
$0.3 \times d_{Fc}$	169.4	110.5	31.91	58.66
$0.4 \times d_{Fc}$	170.1	110.6	31.79	59.15
$0.5 \times d_{Fc}$	169.9	110.2	31.76	58.94
$1 \times d_{Fc}$	166.7	106.8	31.76	56.05



Path lines coloured by static pressure



ACC-related research outputs (2023/24)

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Journal papers

1. Investigation into the predicted performance of a cooling fan for an sCO2 CSP plant, Francois D. Boshoff1, Sybrand J. van der Spuy, Johannes P. Pretorius, Christiaan J. Meyer, IMEchE Journal of Power and Energy, accepted for publication, January 2024.
2. Measuring the Installed Performance of the 24 ft diameter MinwaterCSP Fan, Cesar C. Thiry, Sybrand J. van der Spuy, Giovanni Delibra, Lorenzo Tieghi, Periodica Polytechnica Mechnical Engineering, submitted, 2023.
3. Design of sinusoidal leading edge for low-speed axial fans operating under inflow distortion, Lorenzo Tieghi, Giovanni Delibra, Johan van der Spuy, Alessandro Corsini, Energies, submitted, 2023.
4. Experimental noise reduction of a large diameter axial flow cooling fan through a reduction in blade tip clearance, PC Swanepoel, TM Biedermann, SJ van der Spuy, International Journal of Aeroaccoustics, AOP, 2023.
5. Leading Edge Bumps for Flow Control in Air-Cooled Condensers, Lorenzo Tieghi, Giovanni Delibra, Johan van der Spuy and Alessandro Corsini, International Journal of Turbomachinery Propulsion and Power, 2023, 8, 9
6. The Effect of Wind Screens on the Performance of an Induced Draft Air-Cooled Condenser Under Windless and Windy Conditions, G.M. Bekker, C.J. Meyer, S.J. van der Spuy, ASME Journal of Thermal Sciences and Engineering Applications, 15(1), 2023

ACC-related research outputs (2023/24)

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Conference papers

- Boshoff, F.D., Van der Spuy, S.J. and Pretorius, J.P., “Axial flow fan performance in a forced draught air-cooled heat exchanger for a sCO2 Brayton cycle”, ASME Turbo Expo 2024, London, UK.
- Stephan, G, van der Spuy, SJ, Meyer, CJ, 2023, “Development of a custom mesh generation tool for low solidity axial flow fans”, ASME Turbo Expo 2023, Boston, USA.

Latest research & major results

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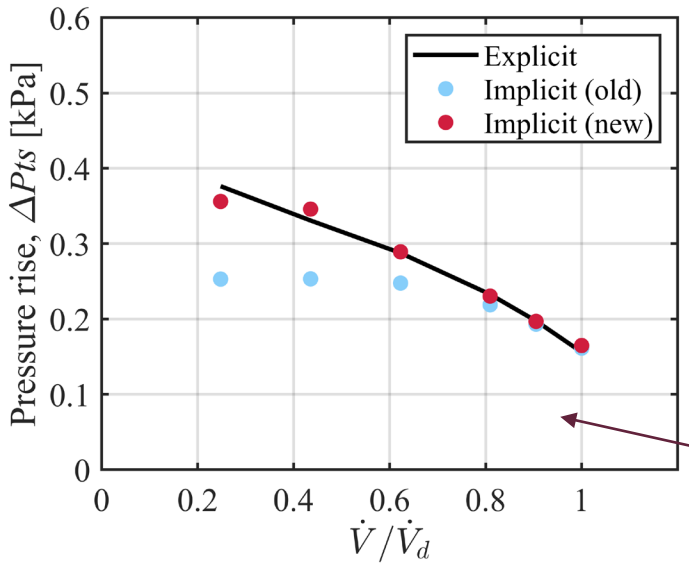
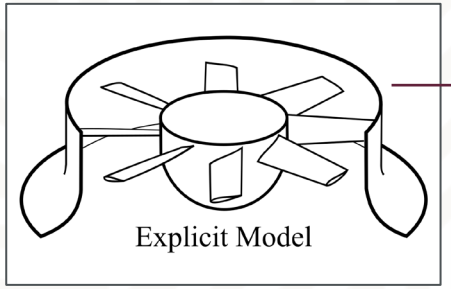
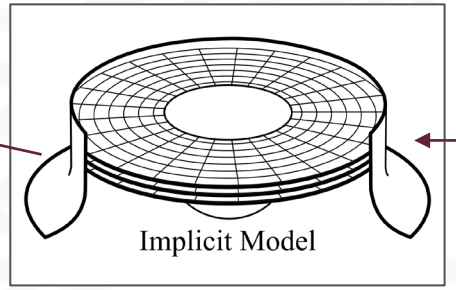
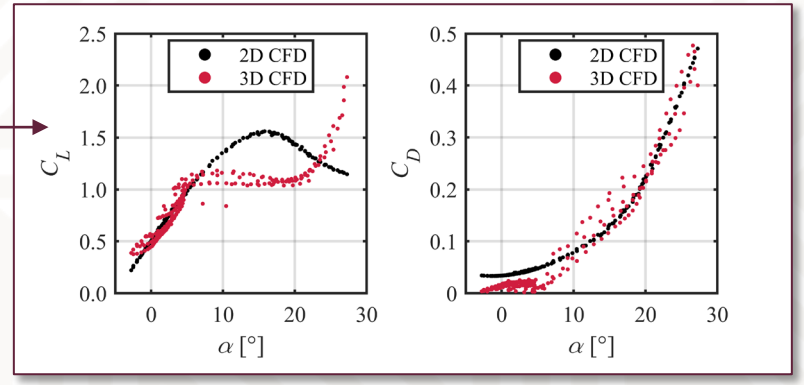
Prof. Mike Owen

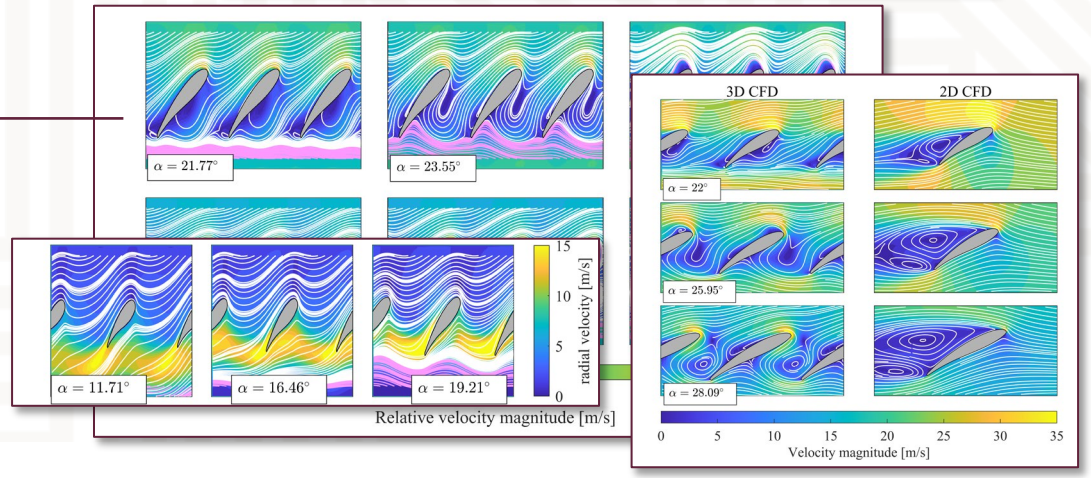
- Improving axial flow fan modelling in CFD
  - Explicit fan modelling was used to improve cost-effective implicit fan model codes for large-scale, resource-heavy ACC CFD applications











Dr Adam Venter (PhD)

Dr Jacques Muiyser (Howden Netherlands)

Latest research

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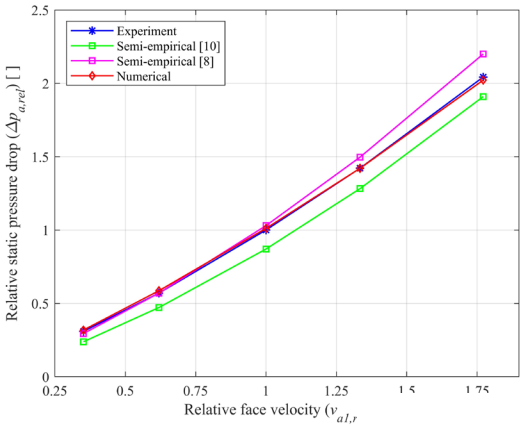
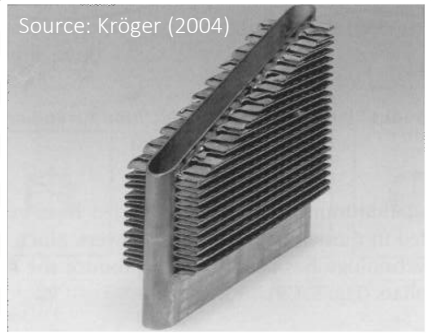
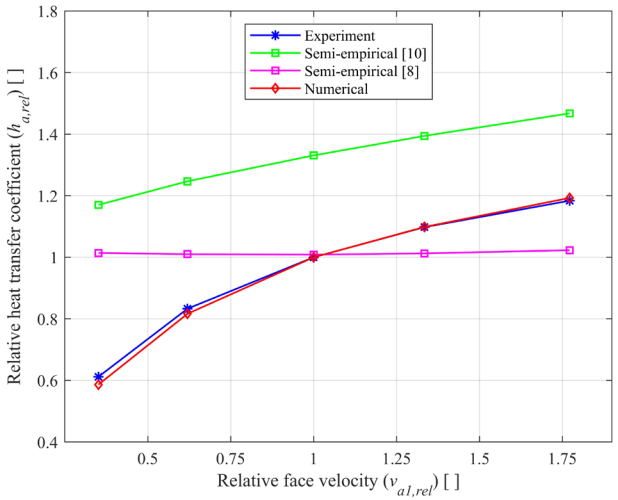
Dr Hannes Pretorius and Prof. Mike Owen

- Natural draft ACCs: HX design for optimal system performance
  - Hypothesis: current finned tubes may not be optimal for the NDACC context.
  - Methodology:
    - Parametric CFD model of tube
    - Generate reduced order model (ROM) of tube characteristics
    - Apply in 1D NDACC model to determine optimal tube configuration
  - Results to date:
    - CFD model of wavy-finned flattened tube has been validated against experimental data & compared to existing analytical models
    - Maximum error of 5% for pressure drop and 4% for heat transfer aligns well with experimental uncertainty
    - Existing analytical models struggle particularly to predict heat transfer accurately -> new ROM thus motivated







ACC-related research outputs (2023/24)

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Journal papers

1. The effects of rotation and solidity on the aerodynamic behaviour of low-pressure axial flow fans, Venter, A., Owen, M., Muiyser, J., ASME Journal of Fluids Engineering, Vol. 146, 2024.
2. Multi-objective optimisation for wind resistant air-cooled condenser operation, Marincowitz, F., Owen, M., Muiyser, J., Applied Thermal Engineering, 218, 2023.

ACC-related research outputs (2023/24)

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Conference papers

1. Venter, A., Owen, M., and Muiyser, J., 2024, “A new implicit fan model for robust air-side heat exchanger simulation”, Proceedings of the 6th African Conference on Computational Mechanics, Cape Town, South Africa.
2. Van der Spuy, S., Owen, M., Pretorius, J., 2024, “Numerical Simulation of Laminar and Transitional Flow and Heat Transfer for a Wavy-finned Flat-tube Heat Exchanger”, 6th African Conference on Computational Mechanics, Cape Town, South Africa.
3. Venter, A., Owen, M., and Muiyser, J., 2023, “Understanding the aerodynamic behaviour of rotating axial flow fan blades”, Aeronautical Society of South Africa: Annual Conference, Pretoria, South Africa.

ACC-related research outputs (2023/24)

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Academic dissertations

- PhD
  - Venter, A., Augmentation of the actuator-disk method for low-pressure axial flow fan simulation, 2024.
- MEng

- Publically available via SUN Scholar

Latest research and major results

Assoc. Prof. Ryno Laubscher

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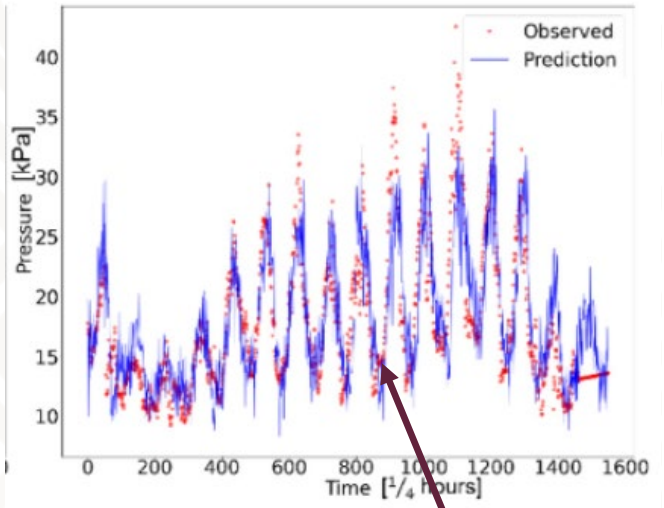
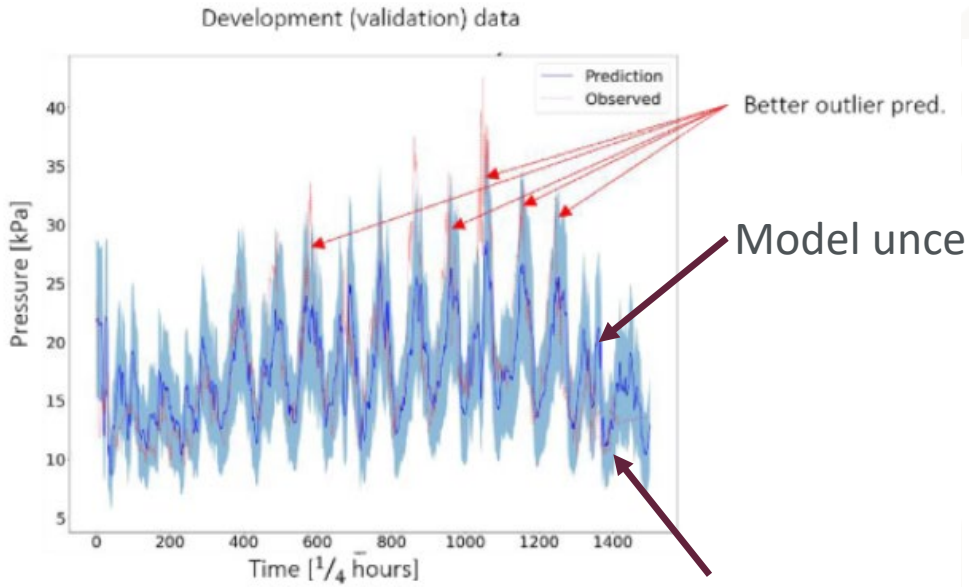
- Application of machine learning for ACC performance monitoring
  - Development of a time-series based back pressure prediction model using actual plant data (weather data and plant measurements).
  - Extension of above model to include model confidence via the inclusion of predictive probabilities.
  - Model uses the previous 6 hours of data to forecast the upcoming 4 hours of performance with model confidence intervals.



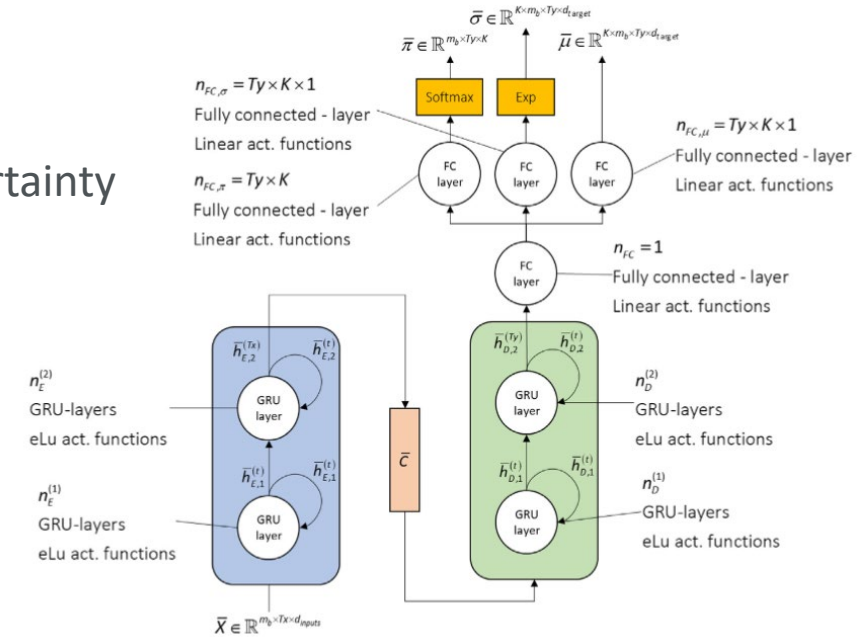
Mean predictions

No model uncertainty included



Mean predictions

Model uncertainty included



Novel neural network architecture

Latest research & major results

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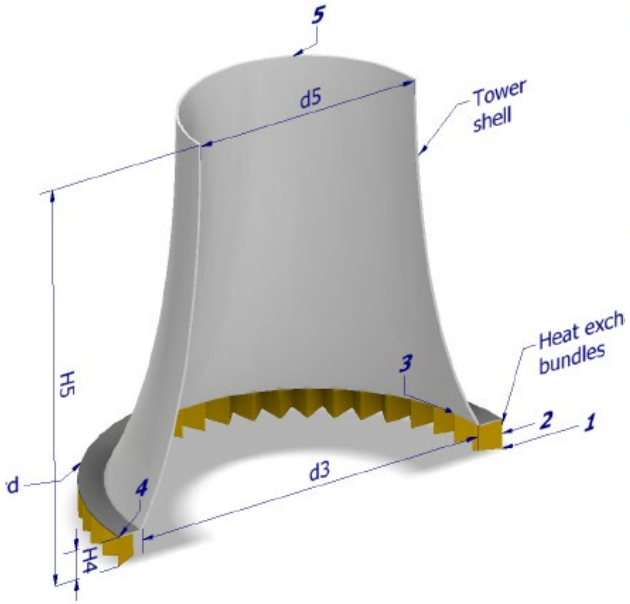
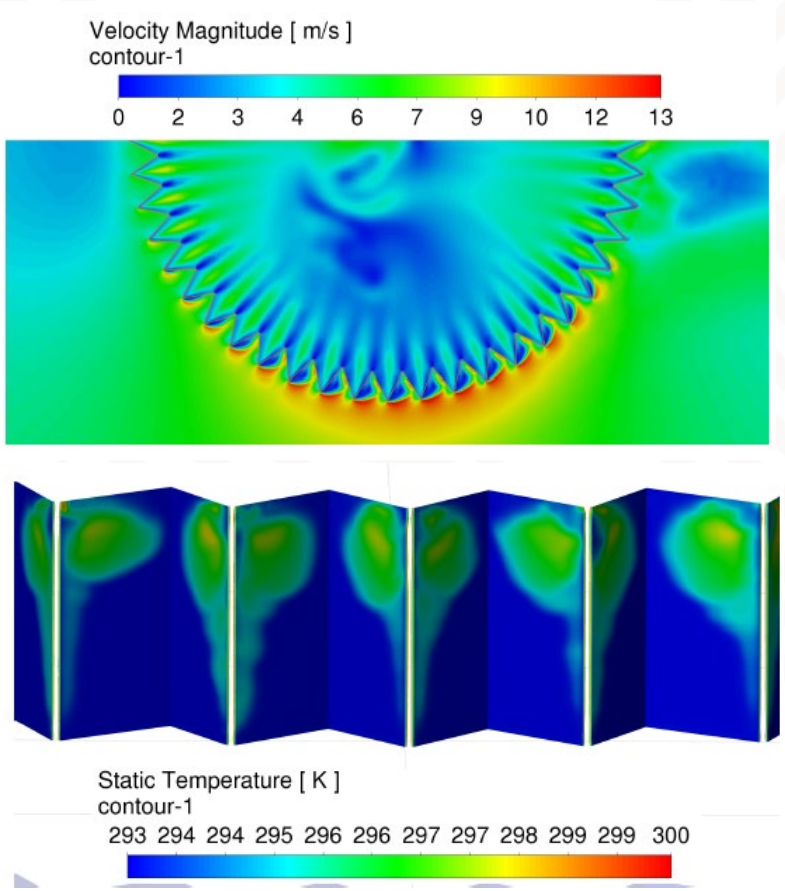
Dr Hannes Pretorius

- Natural draft ACCs: Steady state air-side performance evaluation using 3D CFD
  - Large (900 MWt), medium (100 MWt) and small (1 MWt) systems simulated
  - Similar wind sensitivity to forced draft ACCs at large scale
  - Wind causes recirculation at heat exchanger inlets
  - Wind sensitivity increases as scale reduces
  - Wind mitigation essential, as for forced draft ACCs
  - Performance recovery occurs at very high wind speeds

news.cgtn.com





Latest research & major results

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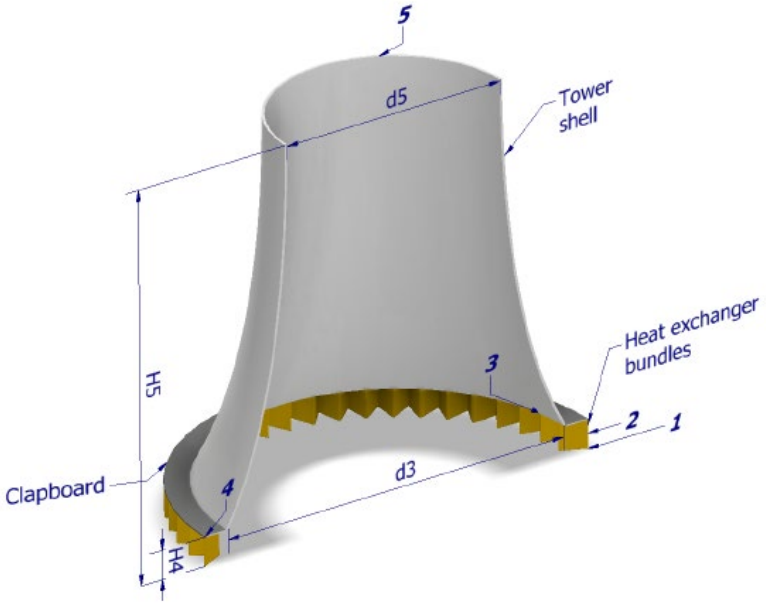
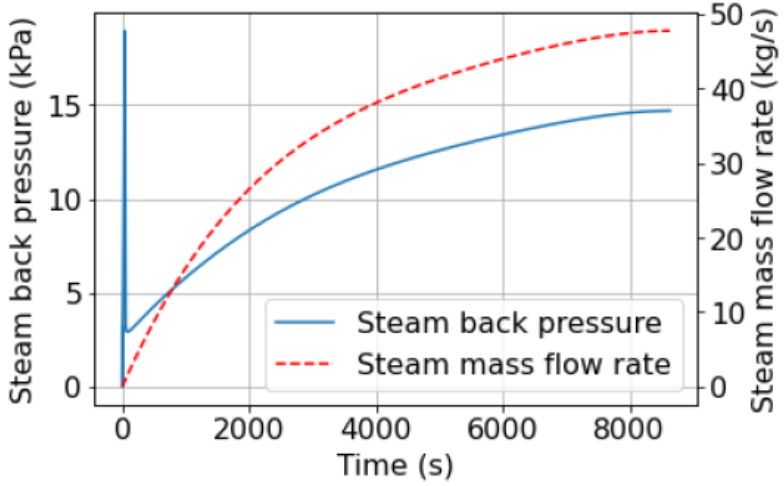
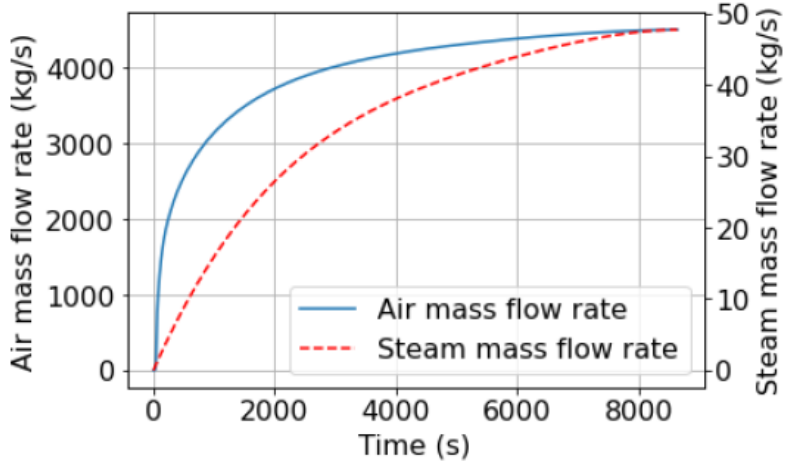
Dr Hannes Pretorius

- Natural draft ACCs: Transient air-side performance evaluation
  - 1D model calculations
    - Evaluation of transient response times on steam and air side: steam-side responds much faster than air-side
    - System transient response for coal-fired and CSP plant start-ups: NDACC responds fast enough to avoid turbine performance limitations
  - 3D CFD simulations ongoing







ACC-related research outputs (2023/24)

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Journal papers

1. Boshoff, F.D., Van der Spuy, S.J., Pretorius, J.P., and Meyer, C.J., 2024, “Investigation into the predicted performance of a cooling fan for an sCO2 CSP plant,” IMechE Journal of Power and Energy, Vol. 10, No. 2, pp. 1-11. DOI: 10.1177/0957650924123784O.
2. Pretorius, J.P., and Van der Spuy, S.J. (jnr), 2024, “Enhancing axial flow fan performance in air-cooled condensers: tip vortex manipulators and comparative analysis of numerical simulation and experimental testing,” ASME Journal of Fluids Engineering (available online). DOI: 10.1115/1.4064854.

ACC-related research outputs (2023/24)

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Conference papers

1. Strydom, W., Pretorius, J.P., and Hoffmann, J.E. 2023, “Sensitivity Analysis on the performance of a natural draft direct dry cooling system for a 50 MWe CSP application”, 8th World Congress on Momentum, Heat and Mass Transfer, Lisbon, Portugal, Paper no. ENFHT 138, DOI: 10.11159/enfht23.138.
2. Boshoff, F.D., Van der Spuy, S.J., and Pretorius, J.P., 2024, “Axial flow fan performance in a forced draught air-cooled heat exchanger for a sCO2 Brayton cycle,” Proceedings of ASME Turbo Expo 2024, GT2024-120962, London, UK.

Latest research

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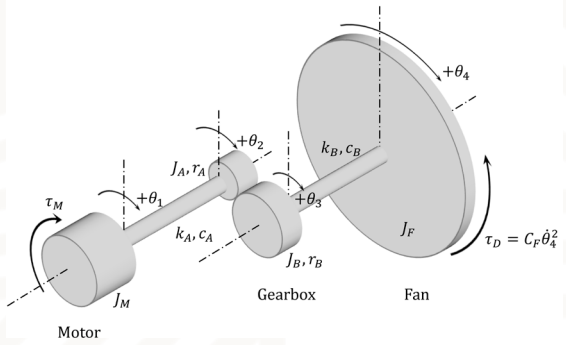
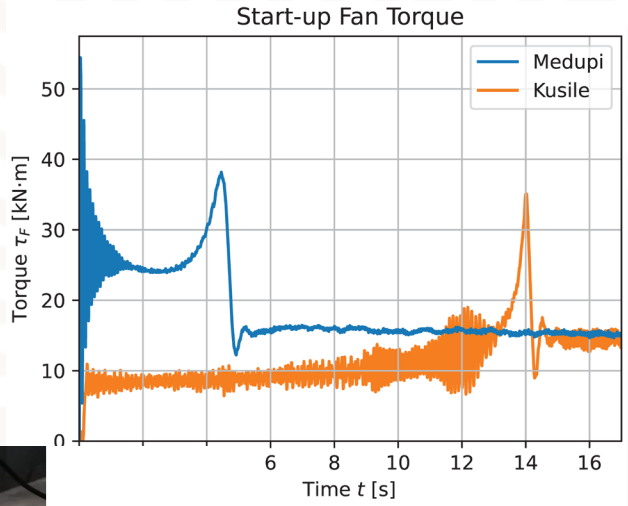
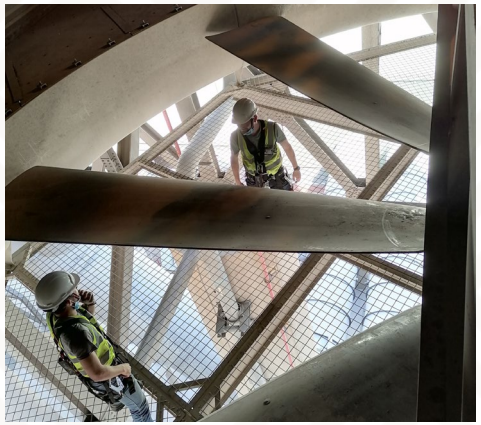
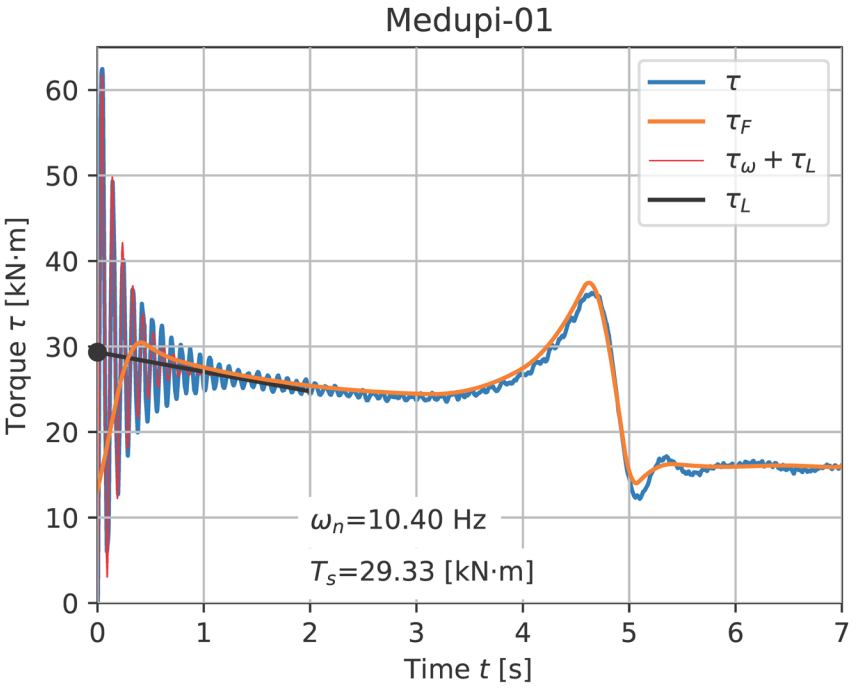
Dr Danie Els

- Fan drivetrain dynamics
  - High start-up loads on gearboxes during direct start-up
  - Lumped mass modelling is now at the point of capturing the effects









Latest research

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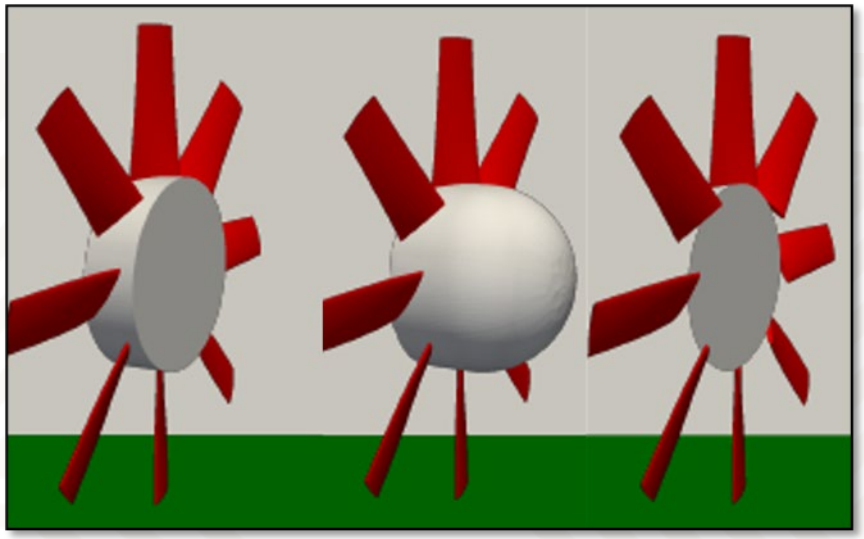
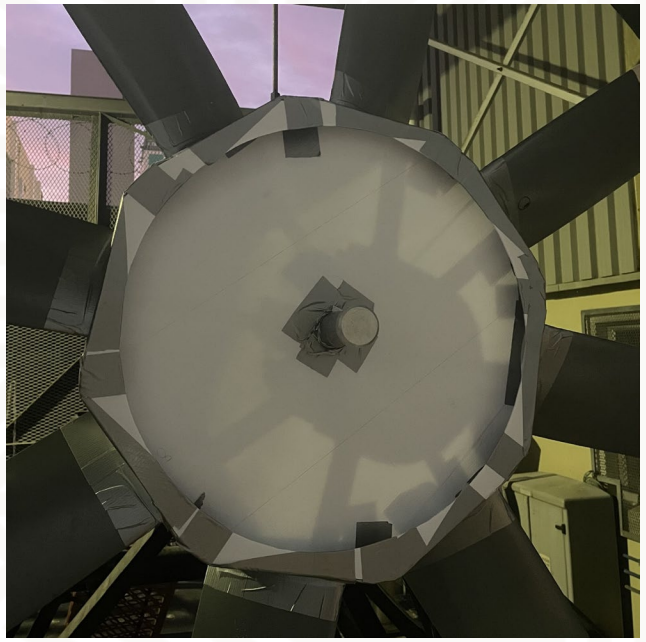
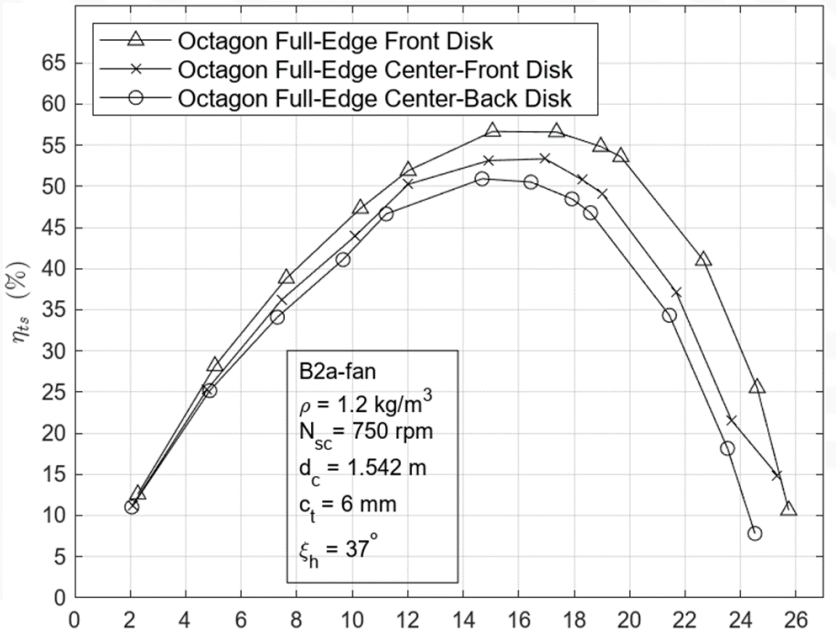
Prof Chris Meyer

- Axial flow fan hub geometries
- “Academic” does not translate well into “industrial”
- Flat root hub intersection (octagon) vs round
- Approximating “perfection”







Collaboration opportunities and services

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- 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

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- 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. Hanno Reuter - hreuter@sun.ac.za (extraordinary appointment)
  - Ass. Prof. Ryno Laubscher – rlaubscher@sun.ac.za
  - Ass. Prof. Mike Owen - mikeowen@sun.ac.za (Division head: thermofluids, general enquiries)
  - Dr Hannes Pretorius - jpp@sun.ac.za
  - Dr Danie Els – dnjels@sun.ac.za
  - Prof Chris Meyer – cjmeyer@sun.ac.za

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Thank you
Enkosi
Dankie

Photo by Stefan Els