ACC research at Stellenbosch University: capabilities and new insights

Department of Mechanical & Mechatronic Engineering

ACCUG Clarksville, USA

14-16 July 2026

Prof Hannes Pretorius

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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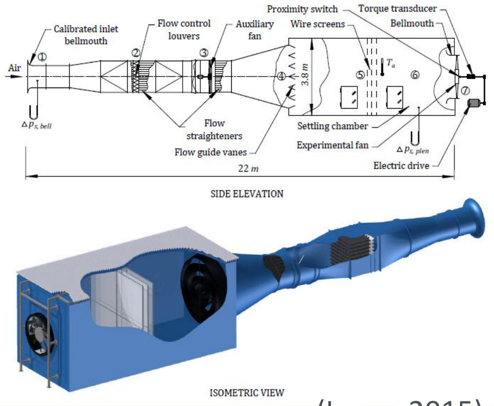
- We aim to continue to build on the legacy of ACC research at Stellenbosch University through academic and commercial research in:
  - ACC, dry and hybrid cooling research
  - Heat exchanger bundle characteristic testing
  - ACC fan development
  - ACC & fan CFD simulation
  - ACC scale fan testing
  - ACC hybrid dephlegmator development
  - ACC fan drive research

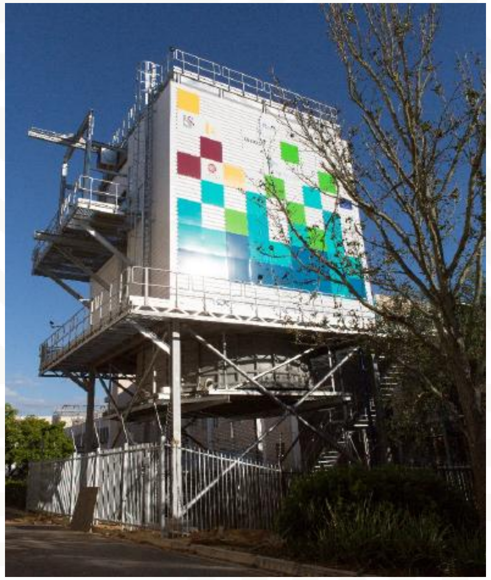
- Post graduate course Industrial Heat Exchangers 814 (based on Kröger's "Air-cooled Heat Exchangers and Cooling Towers")

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, Star CCM+)
- 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 results

ACC gearbox behaviour

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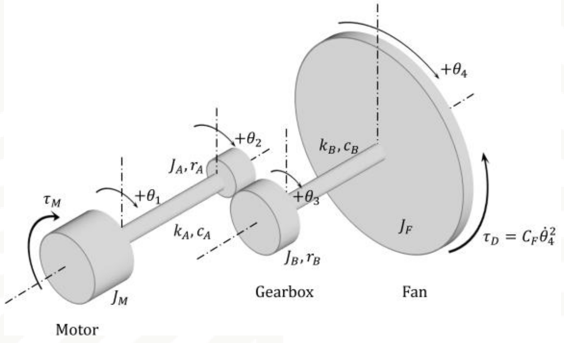
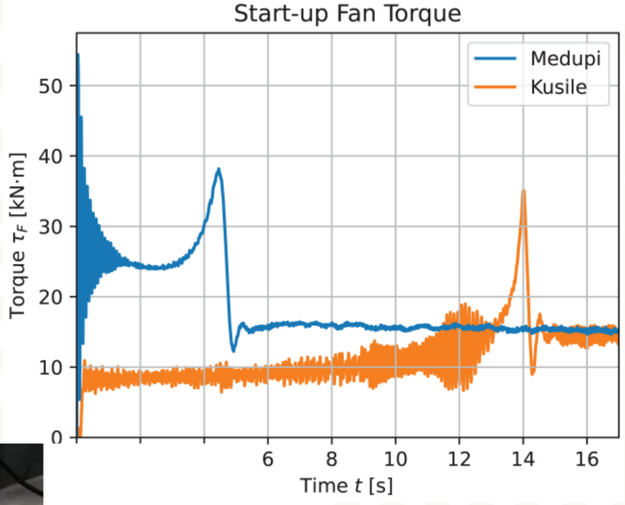
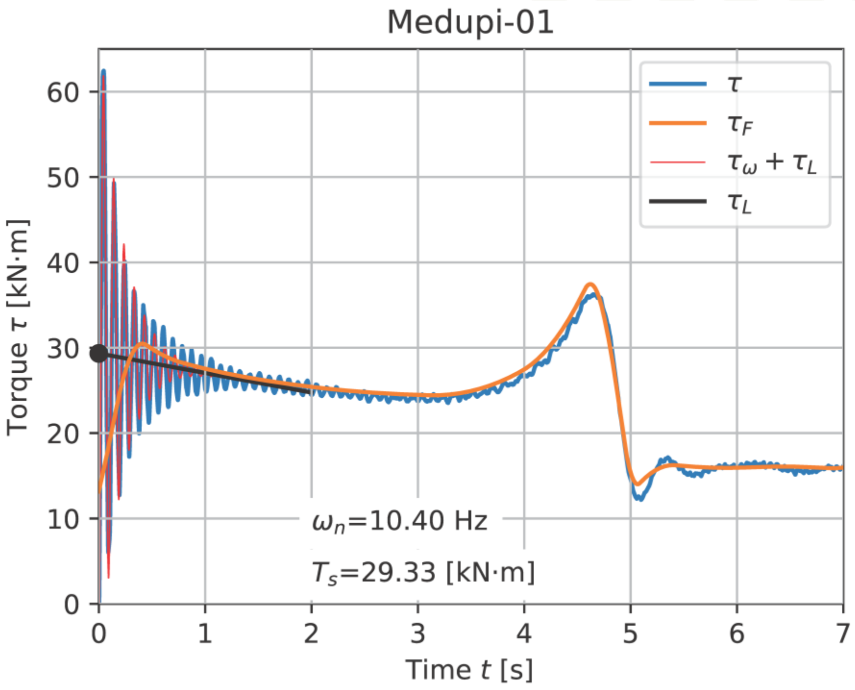
Sumitomo Drive Technologies

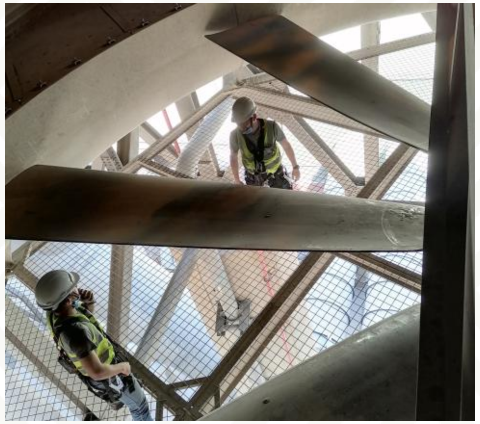
Hansen Industrial Transmissions NV

- Fan drivetrain dynamics
  - Supported by Sumitomo as part of collaborative work
  - High start-up loads on gearboxes during direct start-up
  - Lumped mass modelling is now at the point of capturing the effects









Recent gearbox-related research outputs

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Journal & conference papers

1. Els, D.N.J., and Venter M.P., 2024, “Investigation of large, air-cooled condenser drive-train torque oscillations during startup”, 31st International Conference on Noise and Vibration Engineering, ISMA 2024 and 10th International Conference on Uncertainty in Structural Dynamics

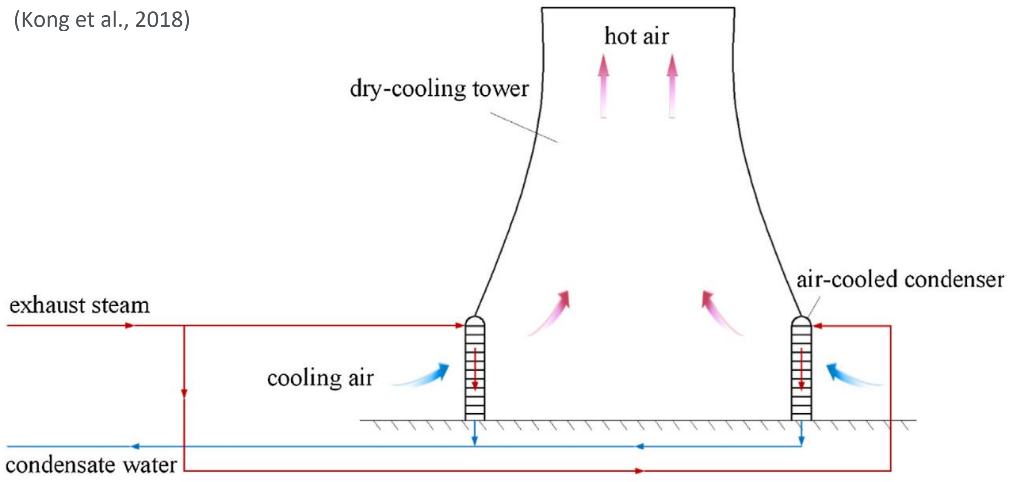
Latest research results

Natural draft ACCs: finned tube design for optimal system performance

NDACC operating principle

- NDACC is made up of tower with steam-carrying finned tube heat exchangers around perimeter of base
- Buoyancy-driven airflow
- Heat exchanger provides driving potential to move airflow through tower
- However, it is also the primary source of resistance to airflow
- Optimal condenser operation depends on tradeoff between frictional losses and heat transferred to the air
- Current finned tubes were developed for mechanical ACC operation — may not be optimal for NDACC application

(Kong et al., 2018)



(spgdrycooling.com)

Latest research results

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Aims and objectives

- Masters study by Johan van der Spuy (jnr), co-supervised by Prof Mike Owen

Aim of research

- Develop validated parametric model of thermohydraulic performance of finned tubes, to determine optimal geometry for NDACC application

Objectives of study

- Develop validated CFD model of finned tubes
- Investigate and compare existing analytical and numerical models for finned tube performance against experimental data
- Develop a parametric reduced-order finned tube thermohydraulic performance model

Latest research results

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Wavy-finned flat-tube heat exchanger

Origin

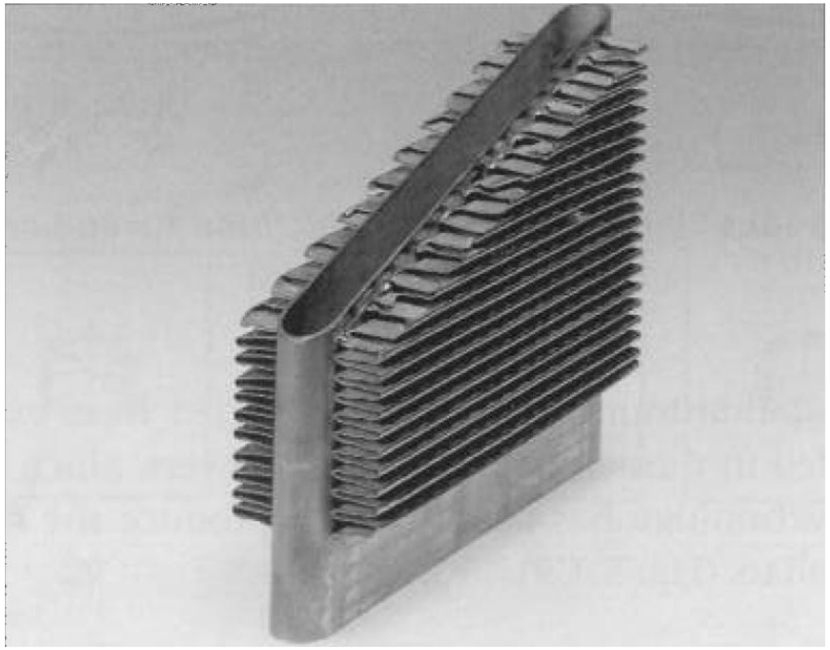
- Industry standard originally developed by Hamon-Lummus company in 1980's

Description

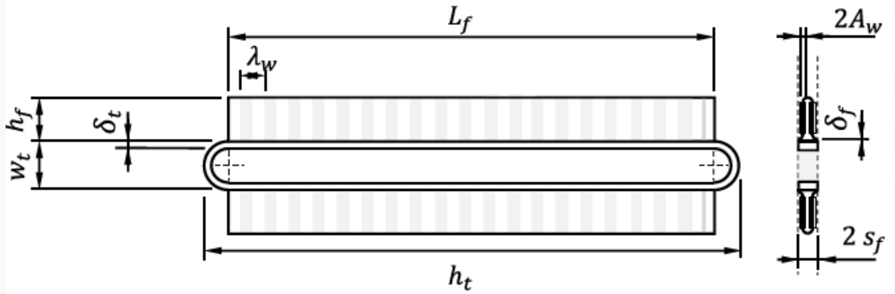
- Steam is condensed in flattened tubes under vacuum
- Aluminium fins brazed to steel tubing
- Fins may be corrugated or straight

Operation

- Airflow typically varies from fully laminar ($Re \ll 1800$) to fully turbulent ($Re \gg 2300$) flow regimes
- Characterized by a dimensionless apparent friction factor (f_{app}) and a dimensionless Colburn-j factor (j_a)
- Smaller face area with larger finned body reduces total losses whilst maintaining higher heat transfer rate (Webb, 1980)



(Kröger, 2004)



Latest research results

Theoretical models for heat exchanger performance

Classical

- Power-law relationship as function of Re
- Empirical constants and coefficients (a, b, c, d, n)

$$f_{app} = aRe^{b}$$

$$j = cRe^{d}$$

Asymptotic-composite

- Suitable for processes displaying uniform variation between limiting physical cases
- Applied to low-Re compact heat exchangers by (Churchill & Usagi, 1972)

$$f_{app}Re = \left((f_{dev}Re)^{n} + (f_{fd}Re)^{n}\right)^{\frac{1}{n}}$$

$$j = \left(j_{dev}{}^{n} + j_{fd}{}^{n}\right)^{\frac{1}{n}}$$

Modern geometric

- More data-driven approach
- Power-law formulation with additional terms representing geometry
- Applied to compact heat exchangers by (Muzychka, 1999)

$$f_{app} = aRe^{b}\left(\frac{c_1}{d_1}\right)^{n_1}\left(\frac{c_2}{d_2}\right)^{n_2}\left(\frac{c_3}{d_3}\right)^{n_3}$$

$$j = aRe^{b}\left(\frac{c_1}{d_1}\right)^{n_1}\left(\frac{c_2}{d_2}\right)^{n_2}\left(\frac{c_3}{d_3}\right)^{n_3}$$

Latest research results

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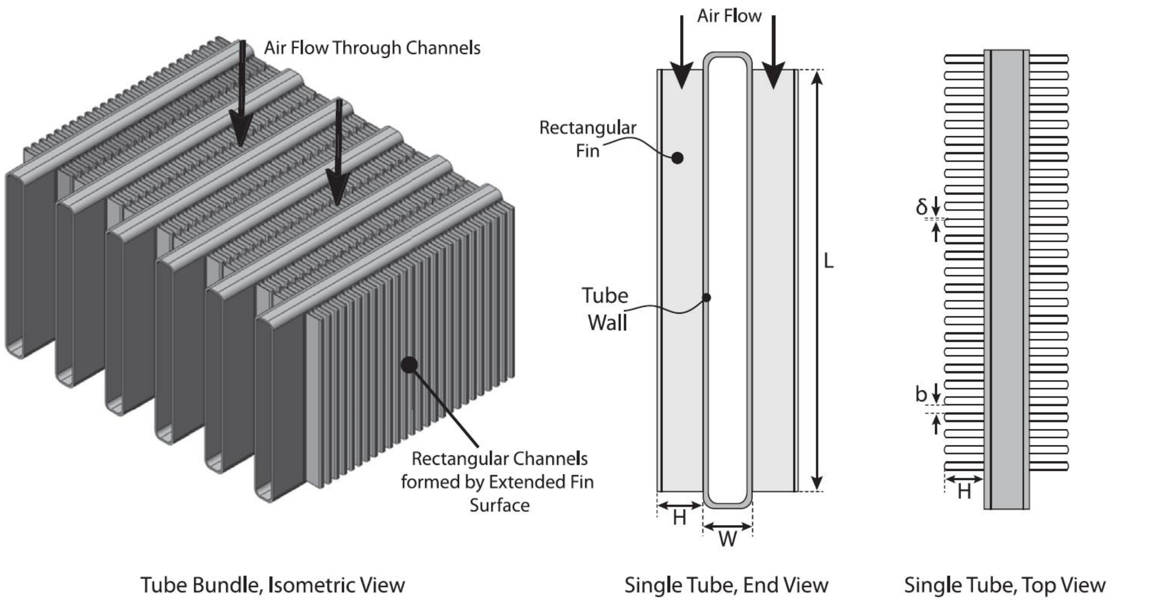
Theoretical models for heat exchanger performance

Existing performance models for flat tube heat exchanger

- Awad & Muzychka (2011) proposed modifications to asymptotic model to account for fin waviness effects
- Unmodified composite model utilized by Moore et al. (2014) to model rectangular tubes with straight fin
- Duan et al. (2016) simulated wavy-finned flat tubes and developed a power law model

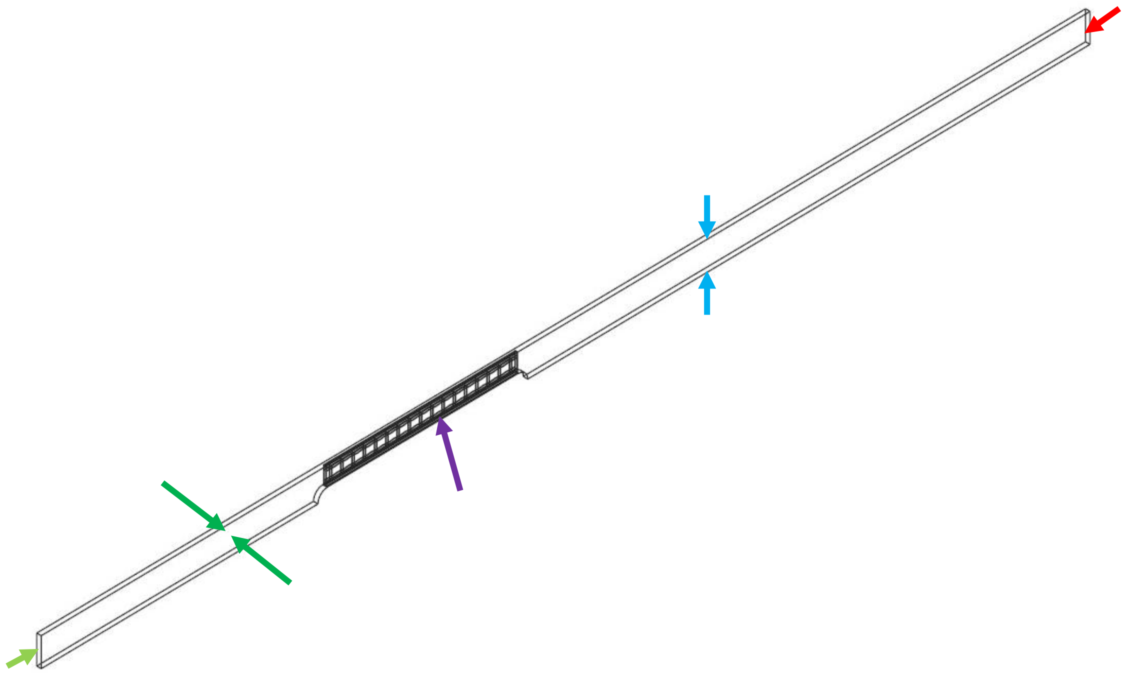


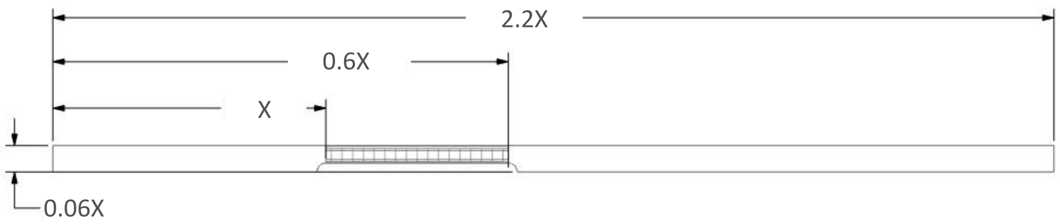
(Muzychka, 1999)

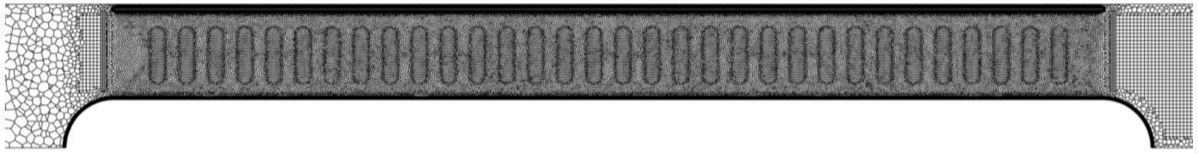
Latest research results

Computational fluid dynamics (CFD) model

- Numerical model created using Ansys Fluent 2023 R1
- Computational domain as periodic-symmetric section of fin pair and half-tube
- 11 million poly-hexcore cells
- Boundary conditions include mass flow inlet, static pressure outlet, periodic sides and symmetric top and bottom, as well as a no-slip wall with constant temperature boundary condition
- For anticipated NDACC $500 \leq Re \leq 4000$ operating range, transition SST $(\gamma - Re_\theta)$ turbulence model was utilized

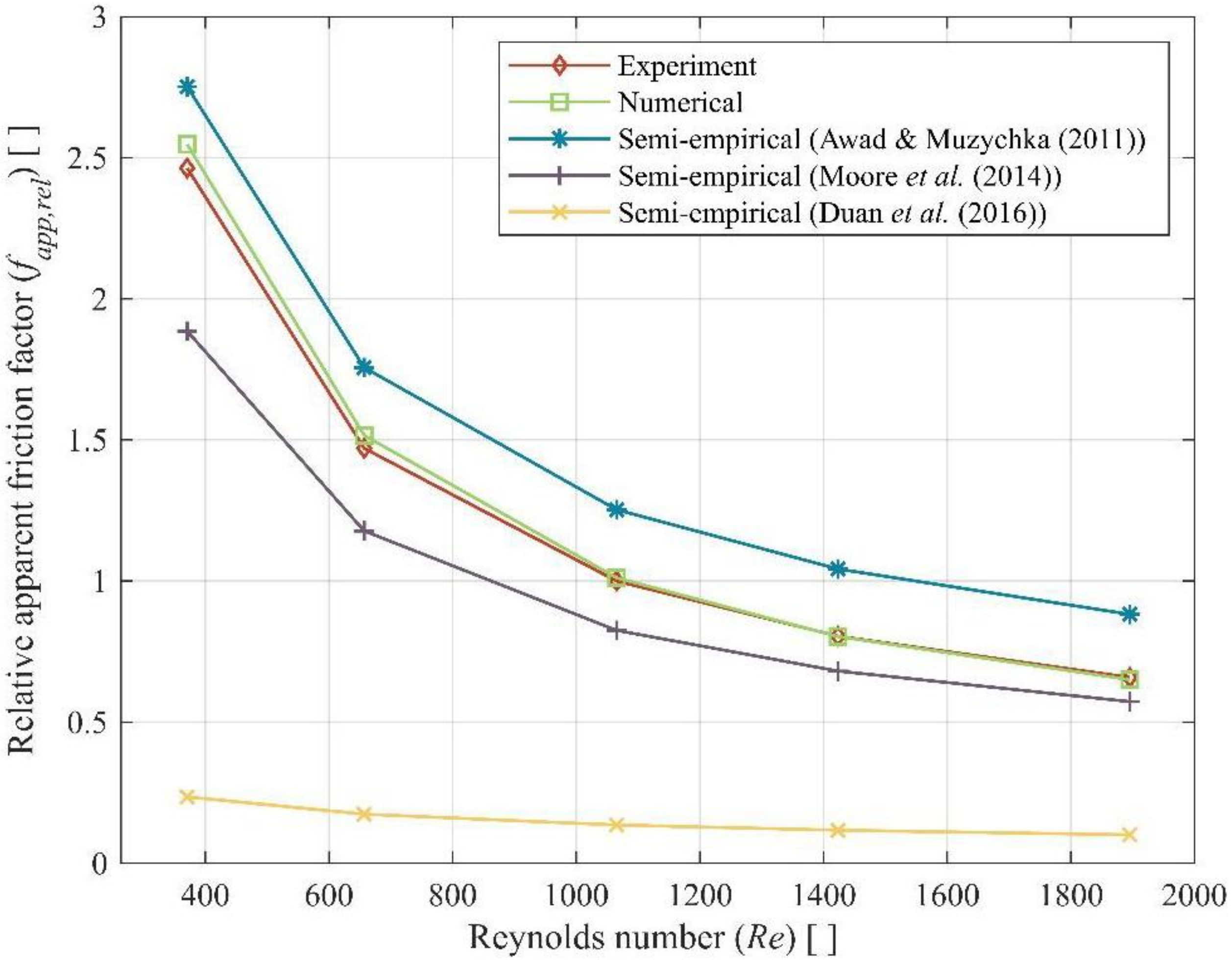






Latest research results

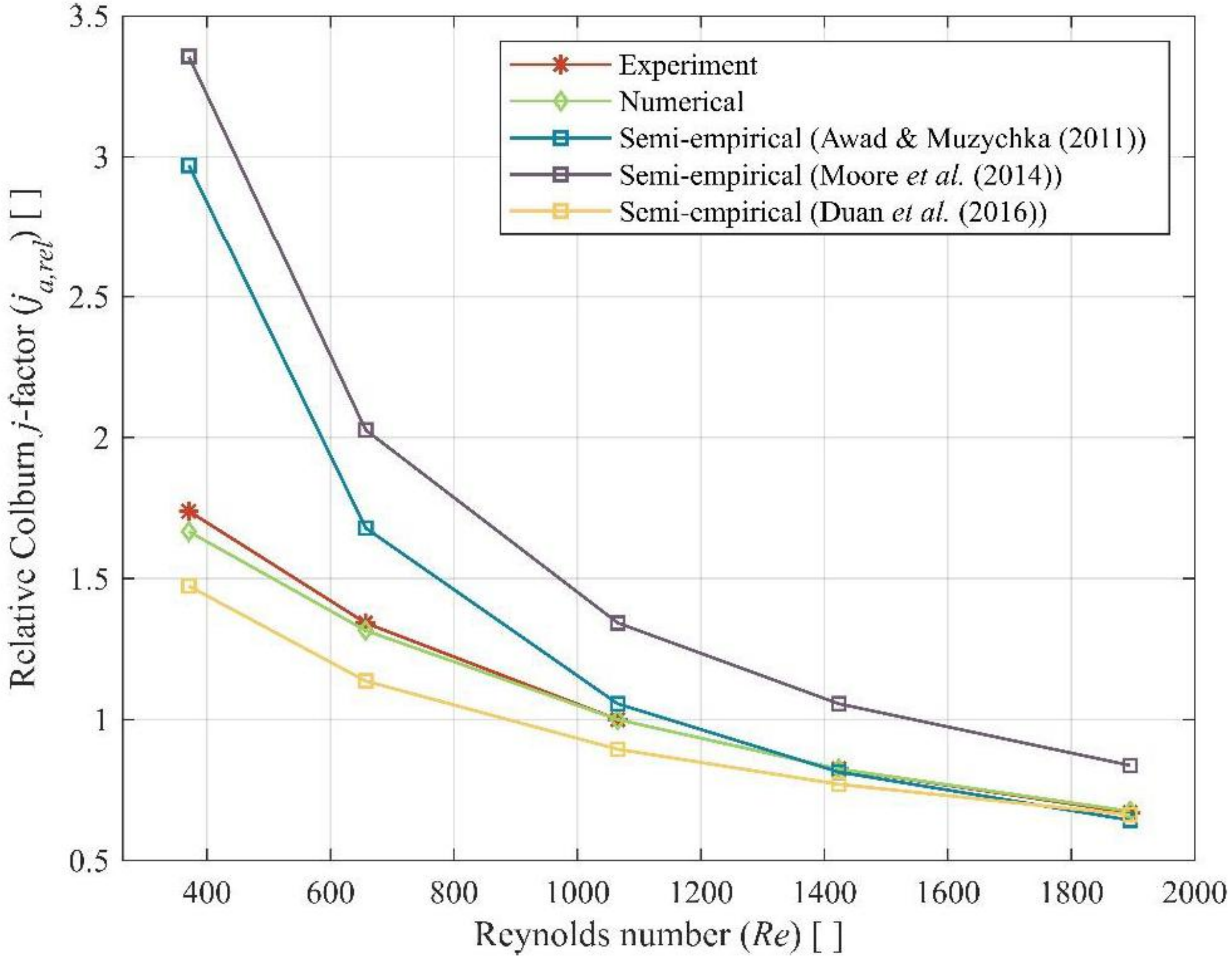
CFD model validation: pressure drop



Model	*RMSE* [%]	Maximum relative error [%]
Semi-empirical (Awad & Muzychka, 2011)	25.2	+34.0
Semi-empirical (Moore *et al.*, 2014)	18.2	−23.5
Semi-empirical (Duan *et al.*, 2016)	87.1	−90.5
Numerical	2.19	+3.41

Latest research results

CFD model validation: heat transfer



Model	*RMSE* [%]	Maximum relative error [%]
Semi-empirical (Awad & Muzychka, 2011)	33.7	+70.8
Semi-empirical (Moore *et al.*, 2014)	52.6	+93.0
Semi-empirical (Duan *et al.*, 2016)	11.2	−15.3
Numerical	2.09	−4.16

Latest research results

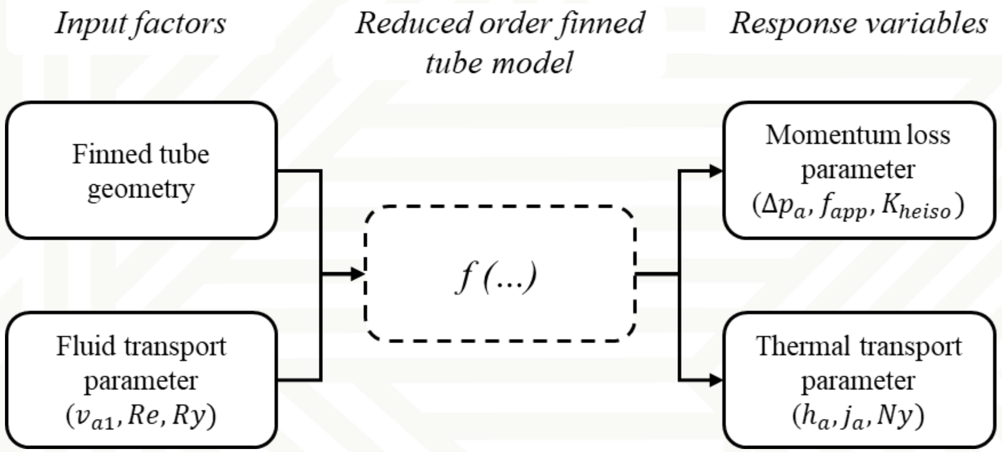
Factor screening study overview

Motivation

- Heat exchangers may be modelled as dual-input (geometry & flow), dual-output (pressure drop & heat transfer) systems
- Complex thermohydraulic interactions are simplified to reduced order models (ROM) of finned tube performance (the system response)
- A prerequisite in ROM construction is to determine important design parameters in a factor sensitivity study

Overview

- Applicable parameters and ranges were identified by reviewing the relevant literature
- A 2^k factorial study allows us to quantify the mean effect of each geometric factor (i.e. $k = 4$) and their interactions
- $\therefore 2^4 = 16$ CFD simulation cases performed



Type	Parameter	Range
Fin	Spacing/pitch $[mm/fin]$ (s_f)	$1.5 - 3$
	Thickness $[mm]$ (δ_f)	$0.1 - 0.24$
Wave	Amplitude $[mm]$ (A_w)	$0 - 1.35$
	Wavelength $[mm]$ (λ_w)	$10 - 20$
Flow	Reynolds number [ ] (Re)	$500 - 4000$

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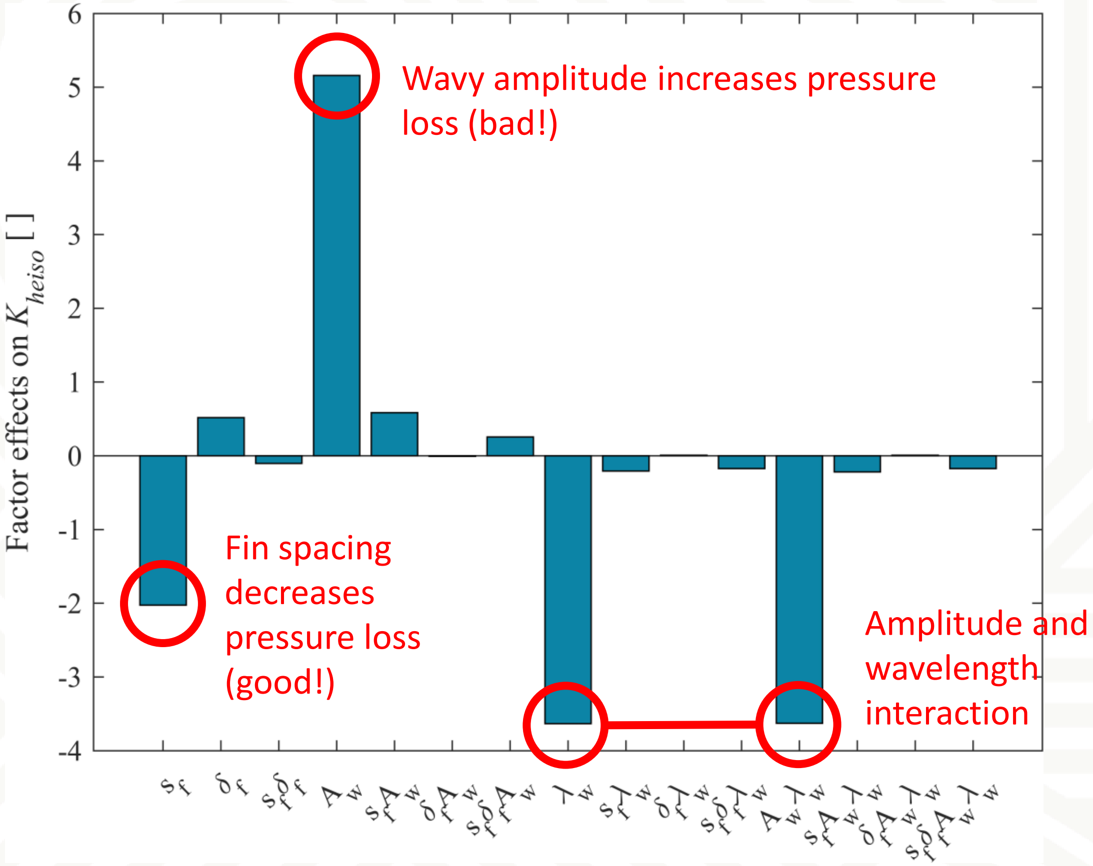
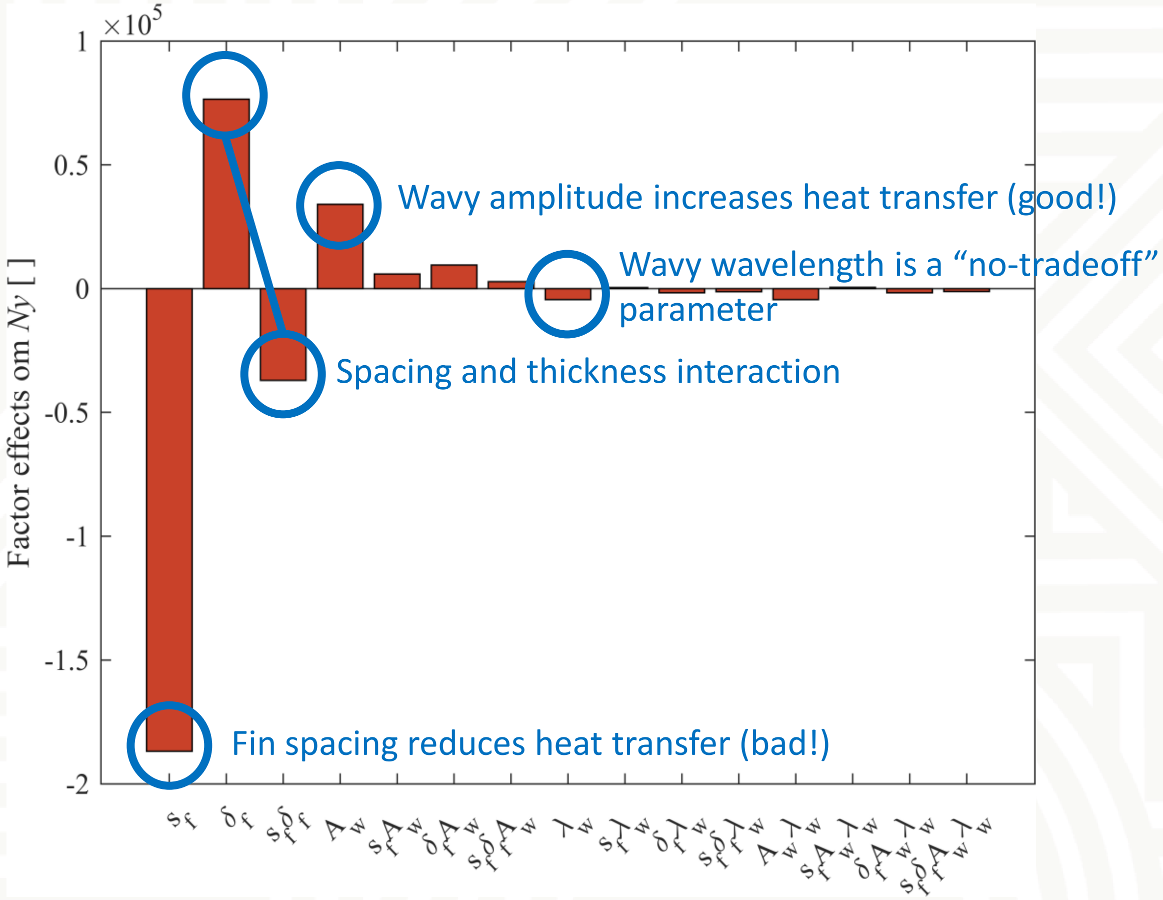
Factor screening study CFD results





Latest research results

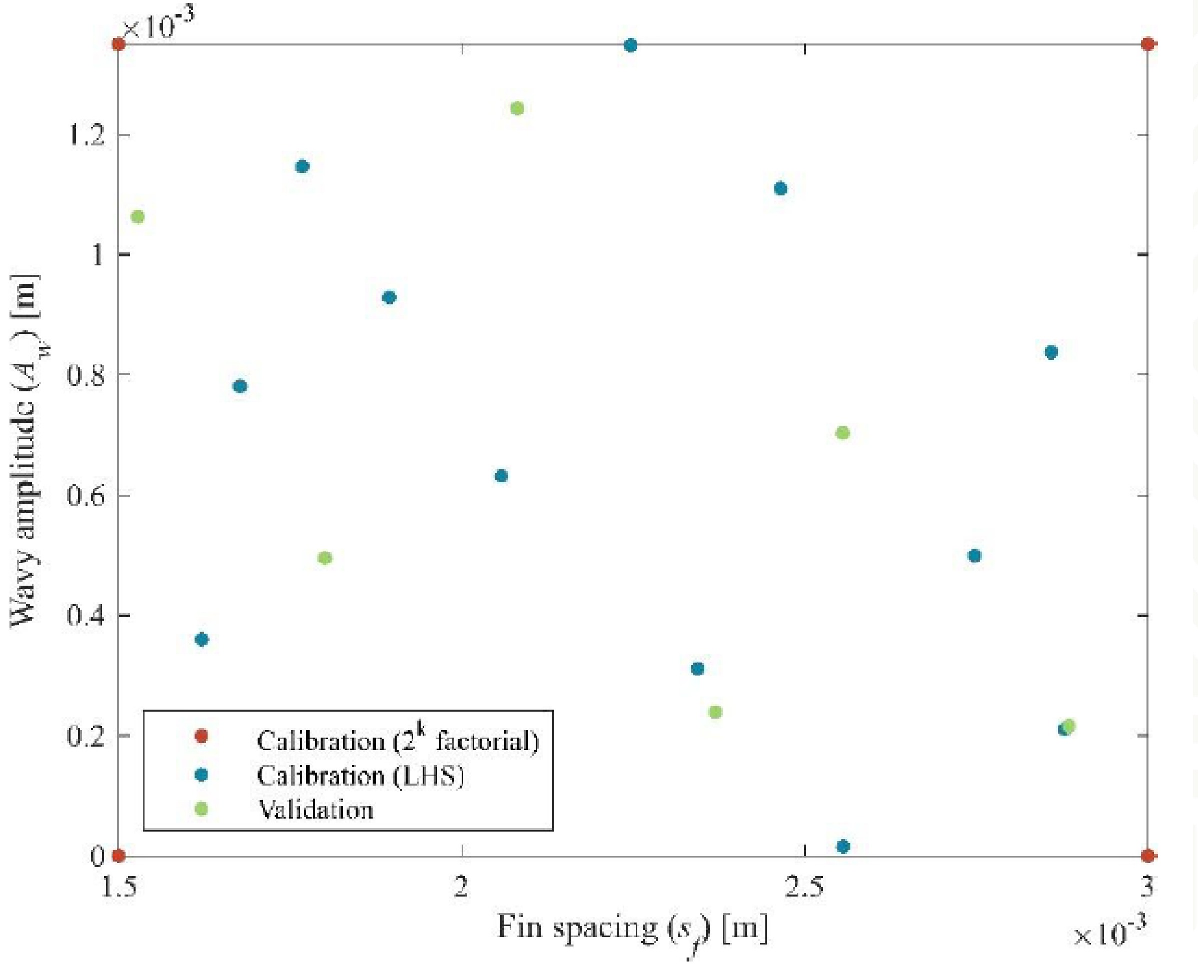
Factor screening study conclusion

- Fin spacing, amplitude and wavelength have significant effects on pressure drop
- Fin spacing and amplitude have significant effects on heat transfer
- Fin thickness shows some effect on heat transfer, but less so on pressure drop
  - Practical and cost implications
  - Use constant minimum fin thickness within range
- Increased wavelength decreases pressure drop and has no impact on heat transfer, and dominates interactions
  - Use maximum wavelength within range
- Fin spacing and wavy amplitude parameters of interest for ROM

Latest research results

Parametric CFD: selecting simulation cases

- We want to:
  - Run CFD simulations for variations in fin spacing and wavy amplitude
  - Fit a response surface to results
- Method:
  - Random sampling in design space using Latin Hypercube (LHS) sampling method
- Cases:
  - 4 cases from previously run 2^k factorial study (red)
  - 12 additional cases using LHS (blue)
  - 6 validation cases (green)
- All cases run at 5 different Re numbers
  - 72 calibration cases
  - 30 validation cases



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Model fit to response surface

- From parametric CFD, we produced a response surface
- We fit different correlations to the response surface data, evaluated errors in fit
  - Simple power law
  - Conditioned geometric power law
  - First order polynomial with interactions
  - Second order polynomial with interactions
- Best fit: geometric power law
  - This is our ROM of finned tube performance

Model	f_{app} R^2	f_{app} Adjusted-R^2	j_a R^2	j_a Adjusted-R^2
Simple power law	0.940	0.939	0.865	0.863
Conditioned geometric power law	0.966	0.964	0.959	0.957
First-order polynomial with interactions	0.746	0.722	0.847	0.833
Second-order polynomial with interactions	0.936	0.927	0.970	0.966

$$f_{app} = 2.78\, Re^{-0.698} e^{0.00776/\alpha+6.56\,\gamma-0.355/\varepsilon}$$

$$j_a = 0.2509\, Re^{-0.53} e^{-0.0409/\alpha+3.56\,\gamma-0.204/\varepsilon}$$

$$K_{heiso} = 14851\, Ry^{-0.853}\, e^{0.226/\alpha+9.26\,\gamma-0.515/\varepsilon}$$

$$Ny = 719.91\, Ry^{0.339}\, e^{0.111/\alpha+2.59\,\gamma-0.143/\varepsilon}$$

Latest research results

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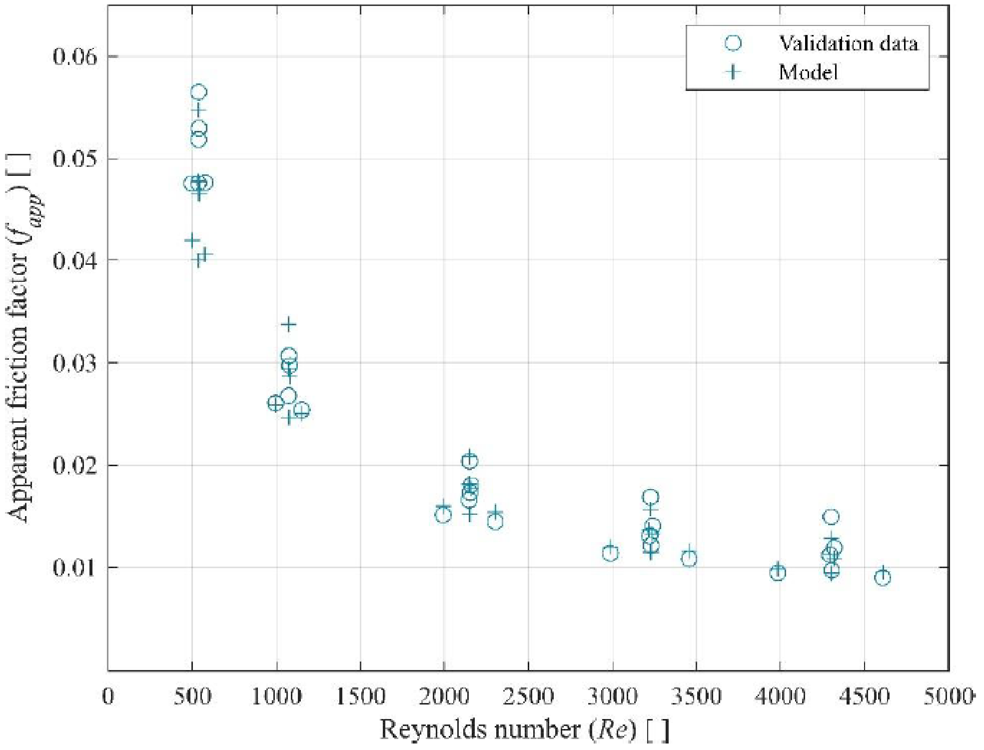
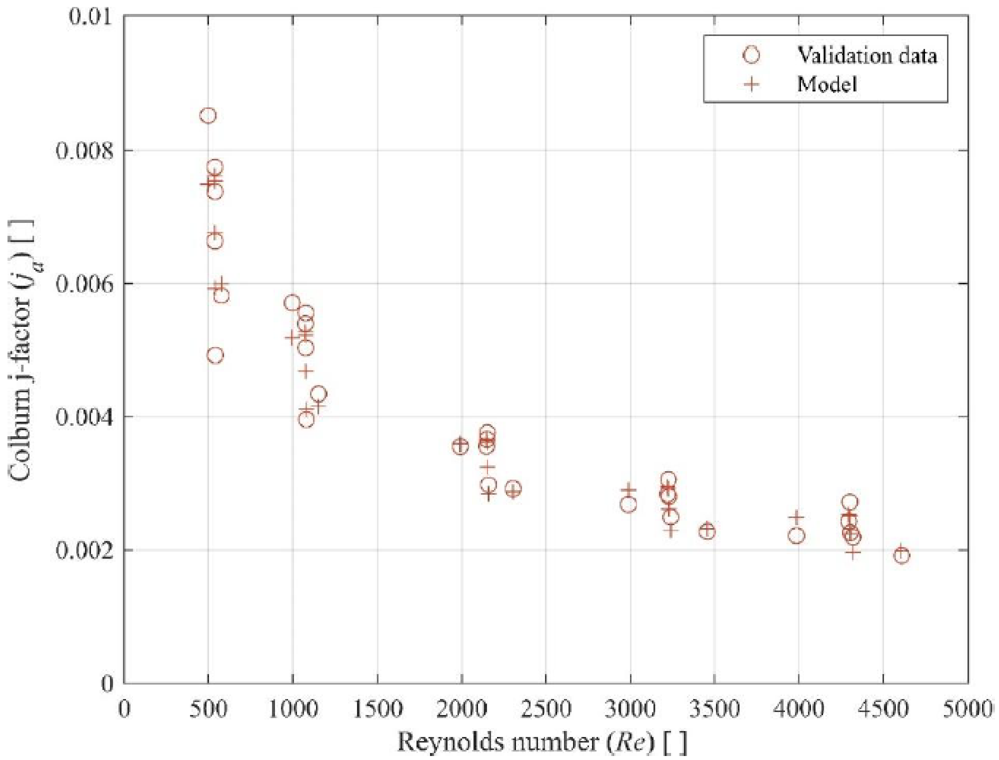
ROM accuracy compared to CFD data

- Compare outputs of ROM to calibration and validation data to determine accuracy

Reference data	Error parameter	f_{app}	j_a
Calibration	$RMSE$	±9.01%	±7.38%
	E_{max}	26.1%	−16.7%
Validation	$RMSE$	±9.76%	±8.17%
	E_{max}	29.1%	−20.4%





Recent NDACC-related research outputs

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Journal & conference papers

1. Van der Spuy, S.J. (jnr), Owen, M.T.F., and Pretorius, J.P., 2025, "Parametric CFD and Reduced Order Modelling of Wavy-Finned Flattened Tube Thermohydraulic Performance in Laminar and Transitional Flow," Results in Engineering, 105054, DOI: https://doi.org/10.1016/j.rineng.2025.105054
2. Van der Spuy, S.J. (jnr), Owen, M.T.F., and Pretorius, J.P., 2025, “Numerical Modelling of Heat Transfer and Pressure Drop in a Wavy-finned Flat-tube Heat Exchanger,” Proceedings of ASTFE 10th Thermal and Fluids Engineering Conference, Washington DC, USA, ISSN Online: 2379-1748, pp. 95-106, DOI: 10.1615/TFEC2025.cmd.055320

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 $15 000 bursary & project-specific costs
    - PhD: typically $33 000 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. Mike Owen – mikeowen@sun.ac.za (Division head: thermofluids, general enquiries)
  - Prof Hannes Pretorius – jpp@sun.ac.za
  - Prof Martin Venter – mpventer@sun.ac.za
  - Prof Chris Meyer – cjmeyer@sun.ac.za
  - Prof. Ryno Laubscher – rlaubscher@sun.ac.za

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Questions?

Thank you

Photo by Stefan Els

References

- Awad, M.M. & Muzychka, Y.S. 2011. Models for Pressure Drop and Heat Transfer in Air Cooled Compact Wavy Fin Heat Exchangers. *Journal of Enhanced Heat Transfer*. 18(3):191–207.
- Churchill, S.W. & Usagi, R. 1972. A General Expression for the Correlation of Rates of Transfer and Other Phenomena. *American Institute of Chemical Engineers Journal*. 18(6).
- Kong, Y., Wang, W., Huang, X., Yang, L. & Du, X., "Annularly arranged air-cooled condenser to improve cooling efficiency of natural draft direct dry cooling system". International Journal of Heat and Mass Transfer, 118:587–601, 2017. DOI: 10.1016/j.ijheatmasstransfer.2017.11.031.
- Kröger, D.G., 2004. *Air-cooled Heat Exchangers and Cooling Towers*. vol. 1. Tulsa: Penwell Corporation
- Louw, F.G. "Investigation of the flow field in the vicinity of an axial flow fan during low flow rates". PhD thesis, Stellenbosch University, 2015
- Moore, J., Grimes, R., Walsh, E. & O'Donovan, A. 2014. Modelling the thermodynamic performance of a concentrated solar power plant with a novel modular air-cooled condenser. *Energy*. 69:378–391. DOI: 10.1016/j.energy.2014.03.028.
- Muzychka, Y.S. 1999. Analytical and Experimental Study of Fluid Friction and Heat Transfer in Low Reynolds Number Flow Heat Exchangers. PhD. University of Waterloo.
- 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 MinWaterCSPlarge cooling systems test facility". ASME Turbo Expo 2021 Virtual conference, GT2021-59130, 2021
- Van der Spuy, S.J. (jnr). 2025. Parametric modelling of wavy-finned flattened tube performance for application in air-cooled heat exchanger optimization. Master's thesis, Stellenbosch University.
- Webb, R.L., 1980. Air-Side Heat Transfer in Finned Tube Heat Exchangers. *Heat Transfer Engineering*. 1(3):33–49.