



Numerical Investigation of the Performance of an ACC

Presenter: RA Engelbrecht

Academic Mentor: Prof. S.J. van der Spuy

Industrial Mentor: AF Du Preez

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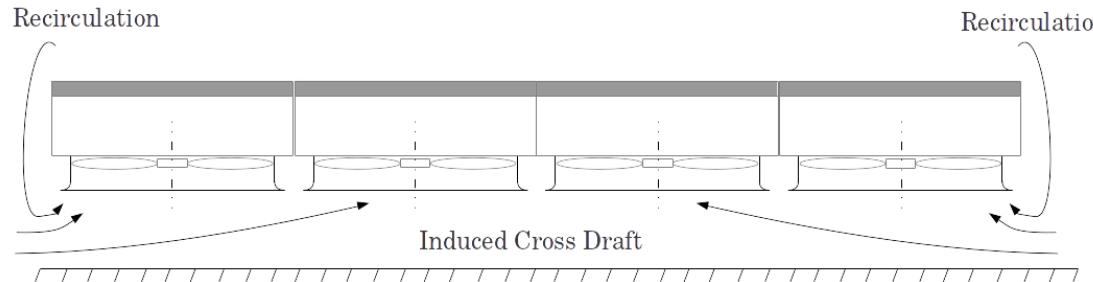


Outline

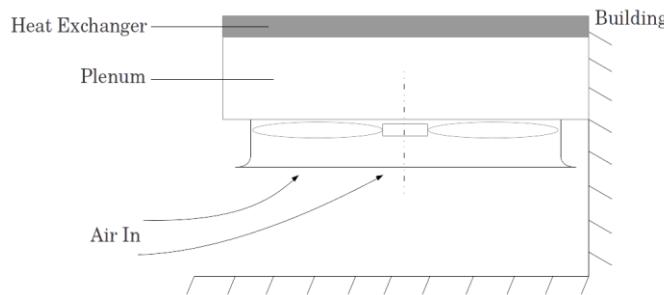


- Project Background
- Model Implementation & Validation
- Future/Planned Research

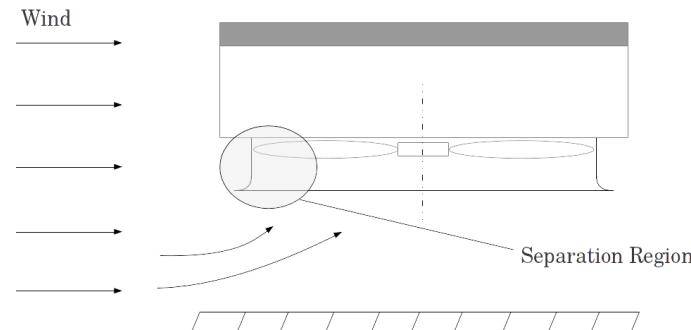
- Recirculation at periphery fans



- Effects of buildings



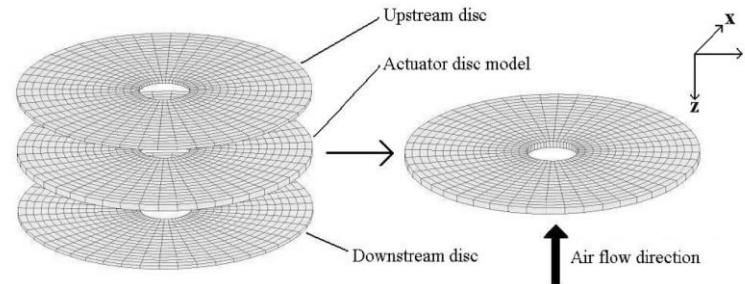
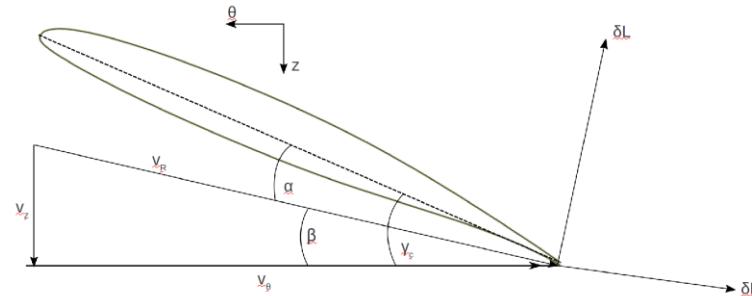
- Separation Effects



- Effects on fan volume flow and performance

- Objectives
 - Implement axial flow fan and A frame heat exchanger model
 - Validate Models
 - Determine operating points
 - Model 30 fan ACC bank with different fan configurations and different environmental effects
- Outcomes
 - Determine effect of environmental conditions on performance of ACC through power requirements

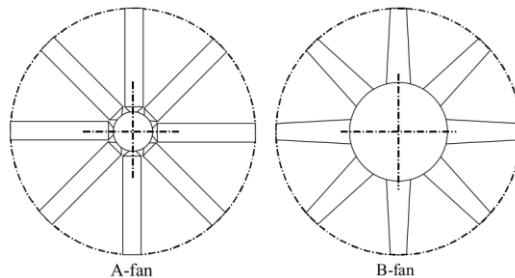
- Actuator Disk Model (ADM) developed by Thiart and von Backström (1993)
- Implemented in Open source Field Operation and Manipulation (OpenFOAM) software package
- Blade element theory



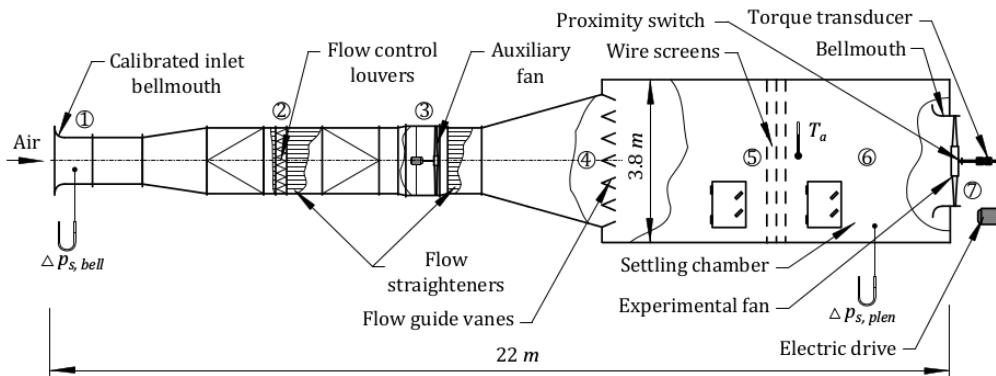
- Uniform disk grid spacing

- Actuator Disk Model was chosen for:
 - Accurate flow representation downstream of fan
 - Power can be measured
 - OpenFOAM implementation
- Two fans used in this study

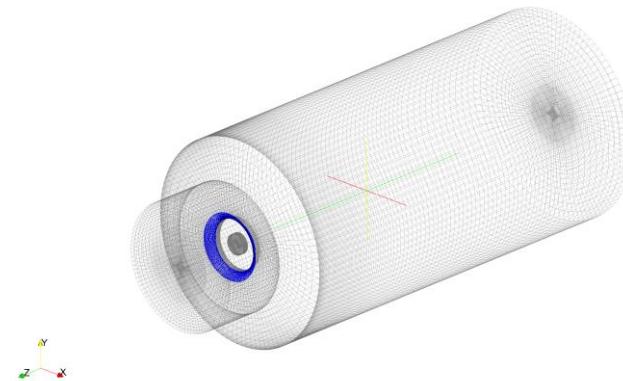
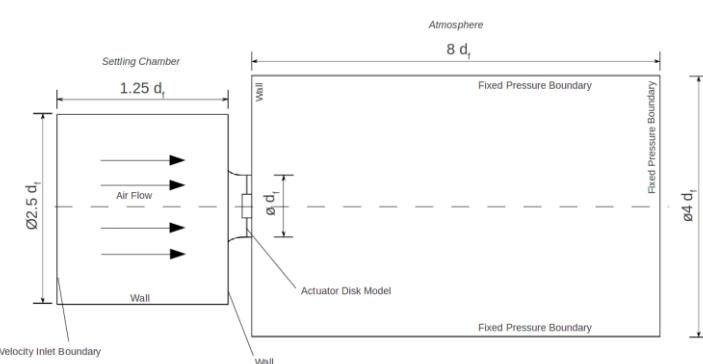
| Fan Designation | Fan Diameter (m) | Hub-to-tip Ratio | No. of Blades |
|-----------------|------------------|------------------|---------------|
| A Fan | 9.145 | 0.153 | 8 |
| B2 Fan (small) | 1.542 | 0.4 | 8 |



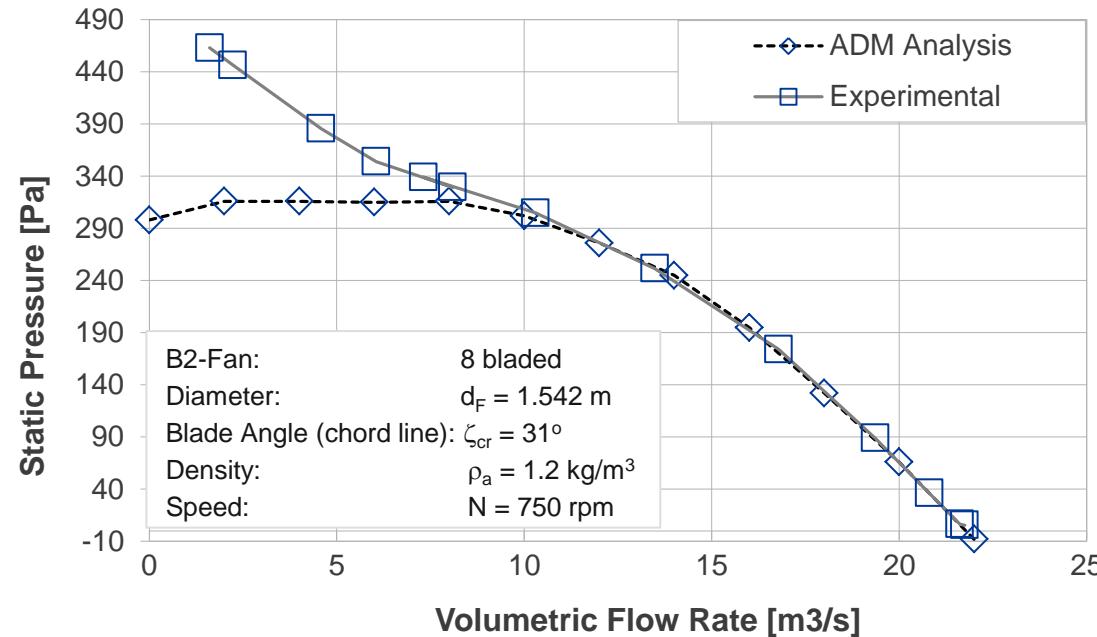
- BS848 Type-A test facility at Stellenbosch



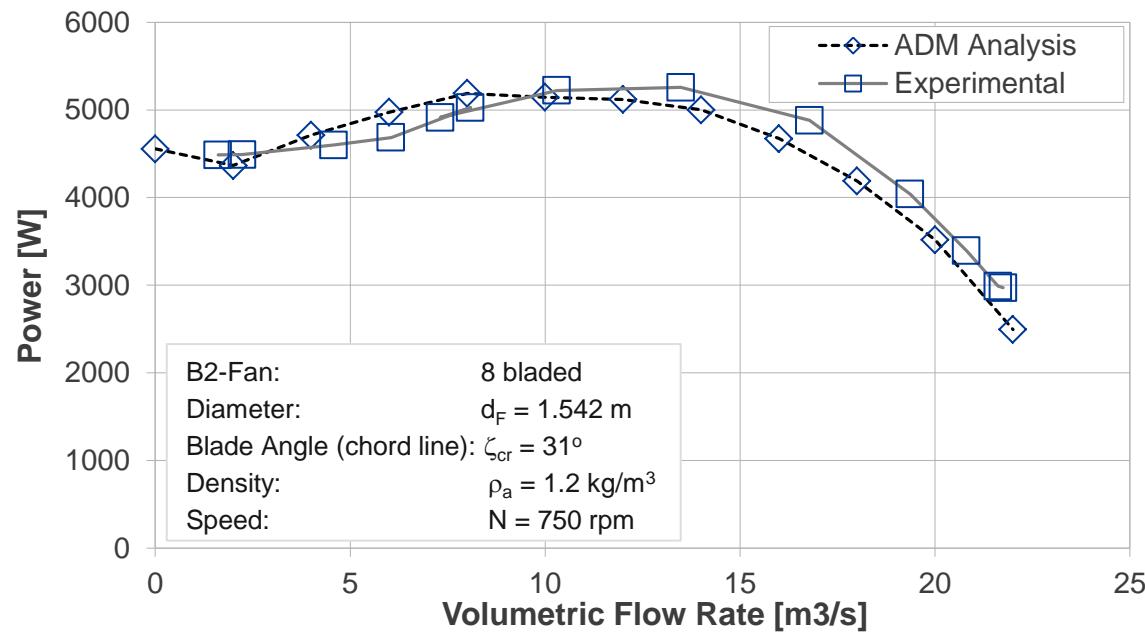
- Computational Domain



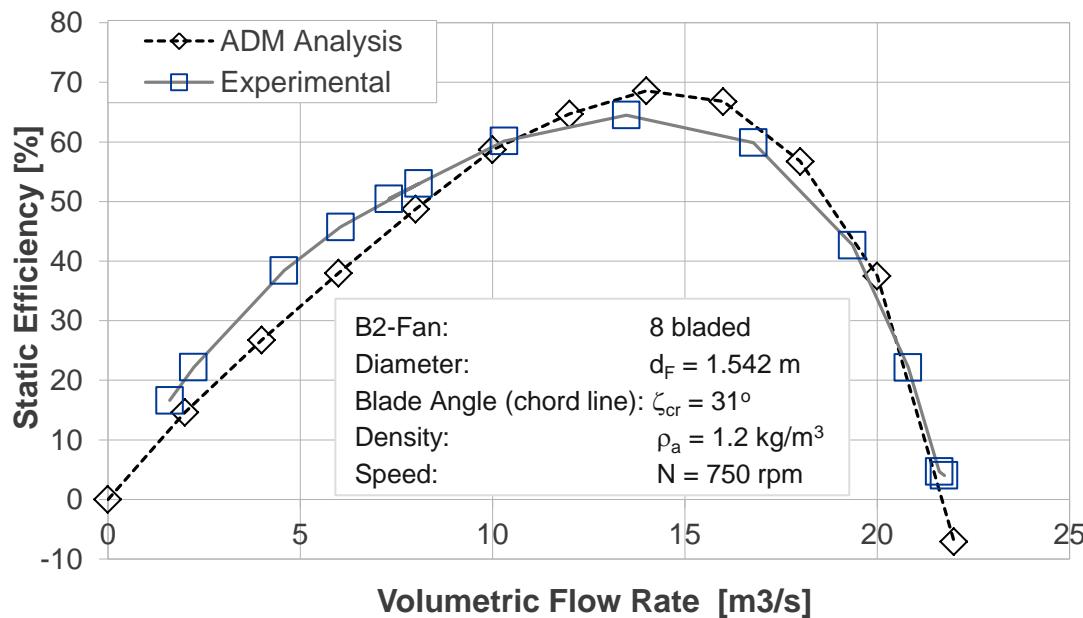
- Performance Characteristics
 - Static Pressure vs. Flow Rate



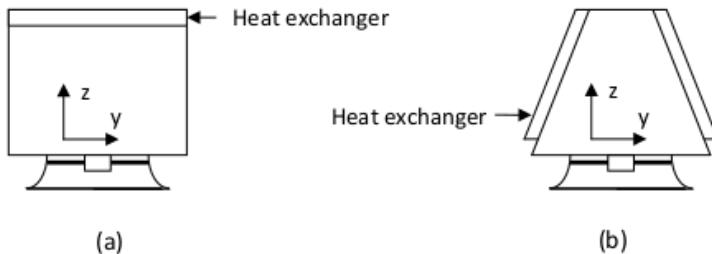
- Performance Characteristics
 - Power vs. Flow Rate



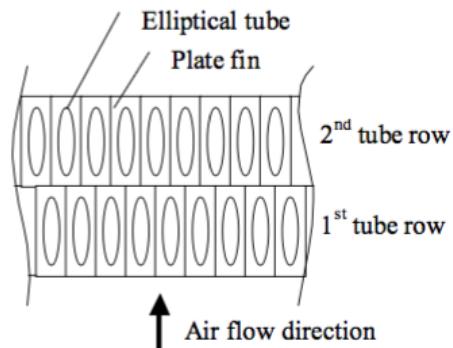
- Performance Characteristics
 - Static Efficiency vs. Flow Rate



- Heat Exchanger Models



- Elliptical, double row finned tubes



| Designation | Loss Parameter | Heat Transfer (1 st Row) | Heat Transfer (2 nd Row) |
|------------------------|-----------------------------------|-------------------------------------|-------------------------------------|
| Finned Elliptical Tube | $K_{he} = 4464.831Ry^{-0.439275}$ | $Ny_{(1)} = 583.8307Ry^{0.4031}$ | $Ny_{(2)} = 1277.72Ry^{0.3806}$ |

- Pressure Drop
 - One Dimensional Draft Equation without fan pressure recovery term

$$p_{a1} - p_{a7} \approx K_{ts} \frac{1}{2\rho_{a1}} \left(\frac{m_a}{n_b A_{fr}} \right)^2 + (K_{up} + K_{do}) \frac{1}{2\rho_{a3}} \left(\frac{m_a}{A_e} \right)^2 + K_{\theta t} \frac{1}{2\rho_{a56}} \left(\frac{m_a}{n_b A_{fr}} \right)^2$$

- Flow Conditioning
 - Darcy-Forccheimer Porous Medium

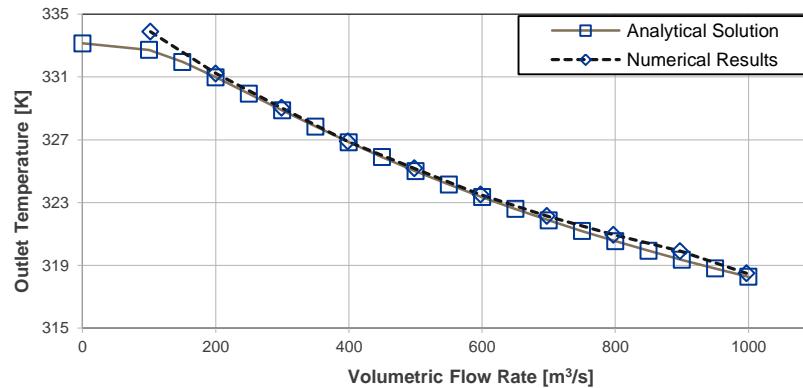
$$F_i = - \left(C_i \frac{1}{2} \rho |v| v_i + \frac{\mu_i}{\alpha} v_i \right)$$

- Heat Transfer
 - ϵ -NTU

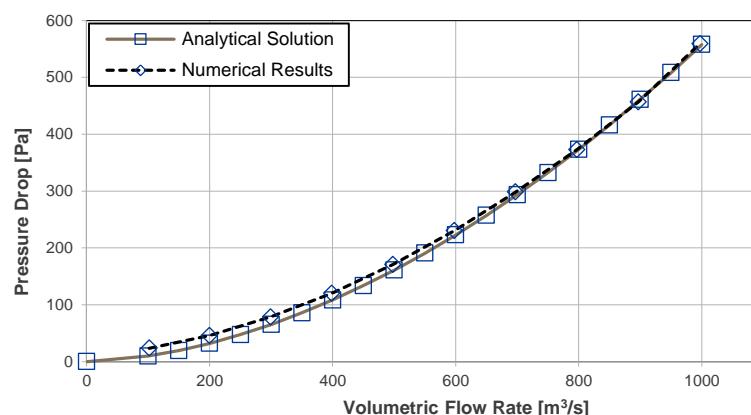
$$Q_{(i)} = m_a c p_a (T_{ao(i)} - T_{ai(i)}) = e_{(i)} m_a c p_a (T_s - T_{ai(i)})$$

Heat Exchanger Model Validation

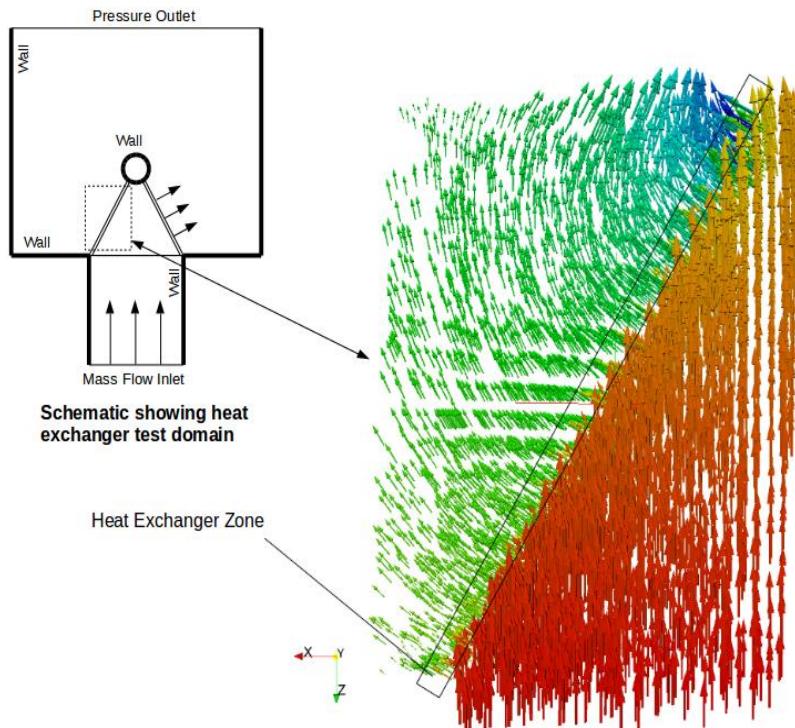
- Heat Transfer



- Pressure Drop

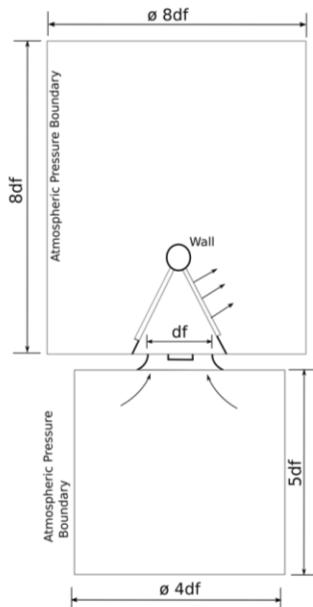


- Flow Conditioning



Operating Point

- Computational Domain

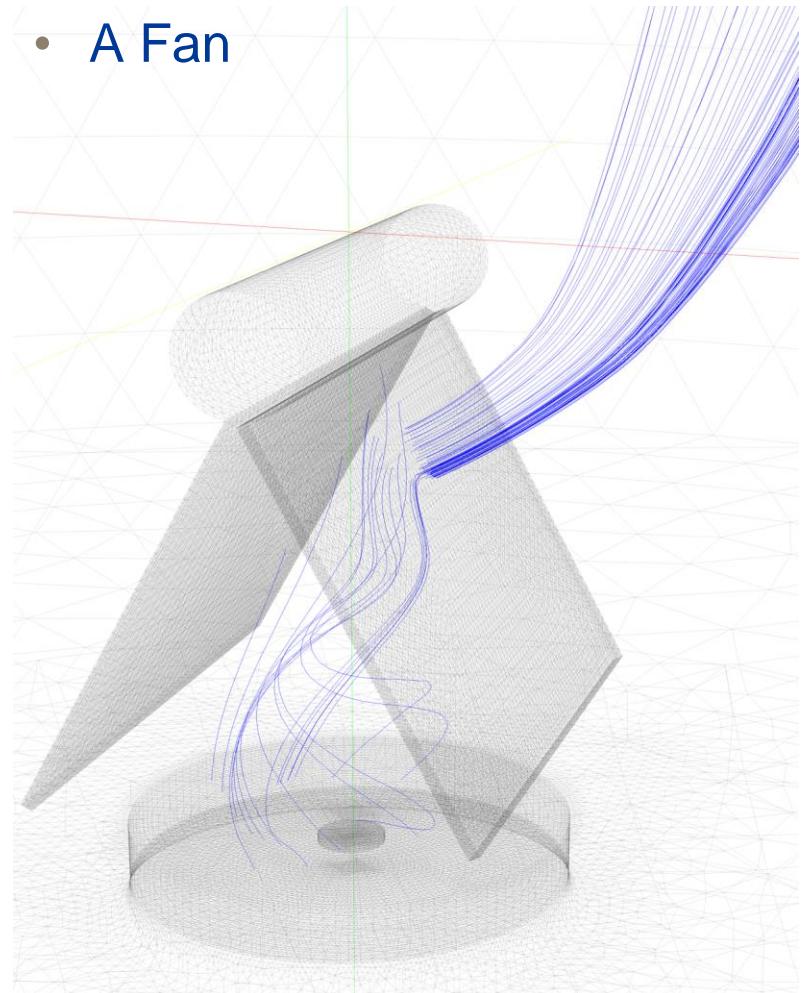


- Operating Point

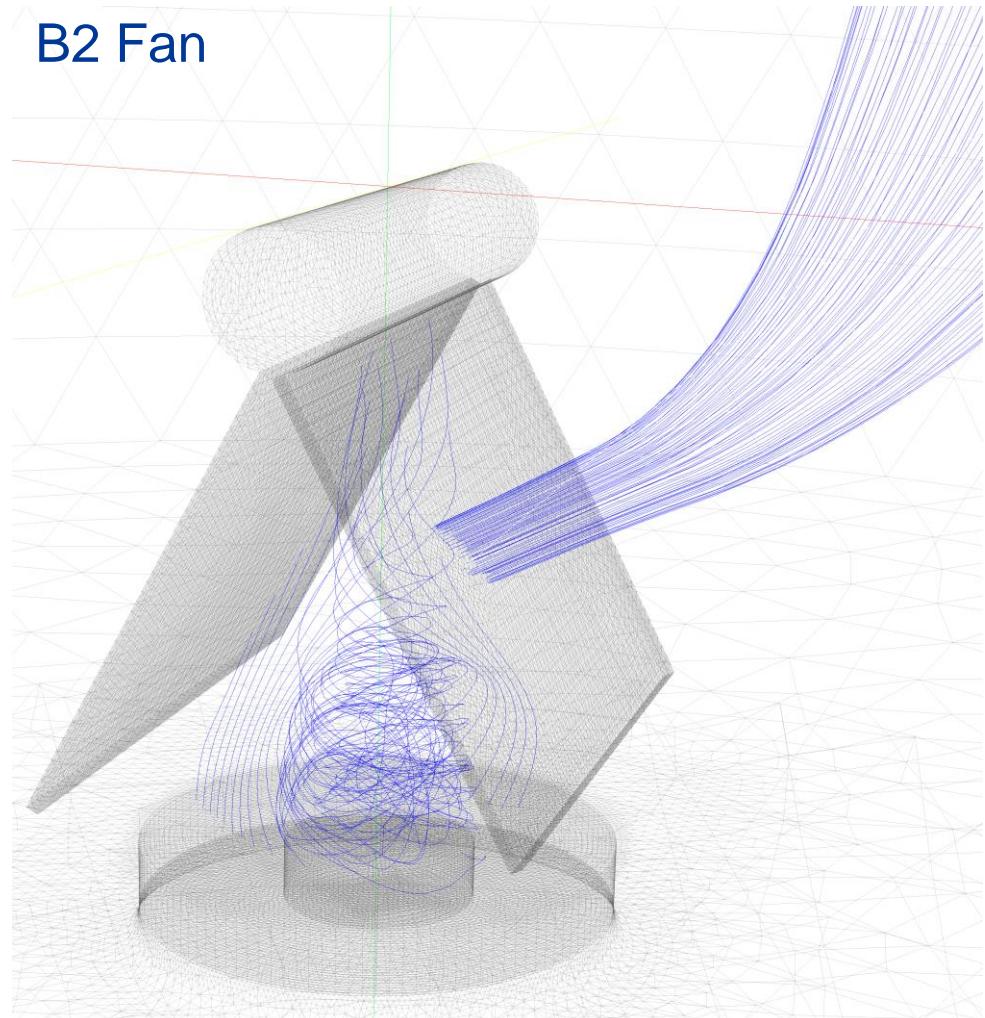
| Fan Designation | Analytical (m^3/s) | Numerical (m^3/s) | Power (W) |
|-----------------|--------------------------------------|-------------------------------------|-----------|
| A Fan | 631.1685 | 620.193 | 207 814 |
| B2 Fan | 631.1685 | 625.923 | 203 281 |

Operating Point

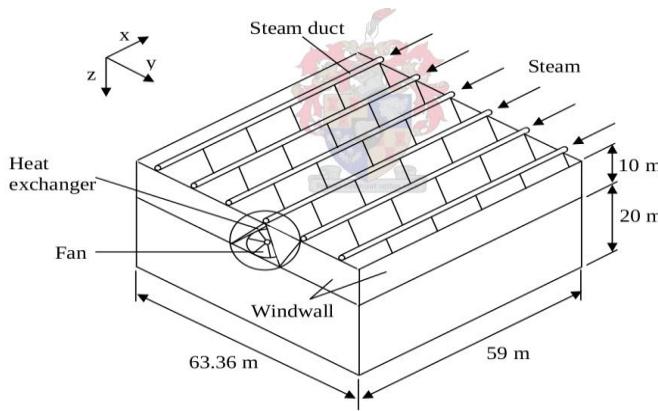
- A Fan



- B2 Fan



- Generic ACC with B2 Fans for validation



- Validation will be done by comparing the volumetric effectiveness to previous literature
- $$V_{eff} = V/V_{id}$$
- Different fan configurations will be tested under differing environmental conditions to determine the effect on power output of the bank



Thank you

