Investigating physical ways of Improving the performane of Air-Cooled Steam Condensors under Adverse wind conditions.

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CENTRE FOR RENEWABLE AND SUSTAINABLE ENERGY STUDIES

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Introduction

> Air-Cooled Steam Condensors (ACSC) are used for rejection of waste heat in power generations industries.

> Pros: Minimum water consumption thus flexibility in plant location.
: Consequently, low water-use costs.

> Cons: Performance deterioration during unfavourable wind conditions.
: Consequently, lower net-power plant output with unplanned shutdown for extreme cases.

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Introduction

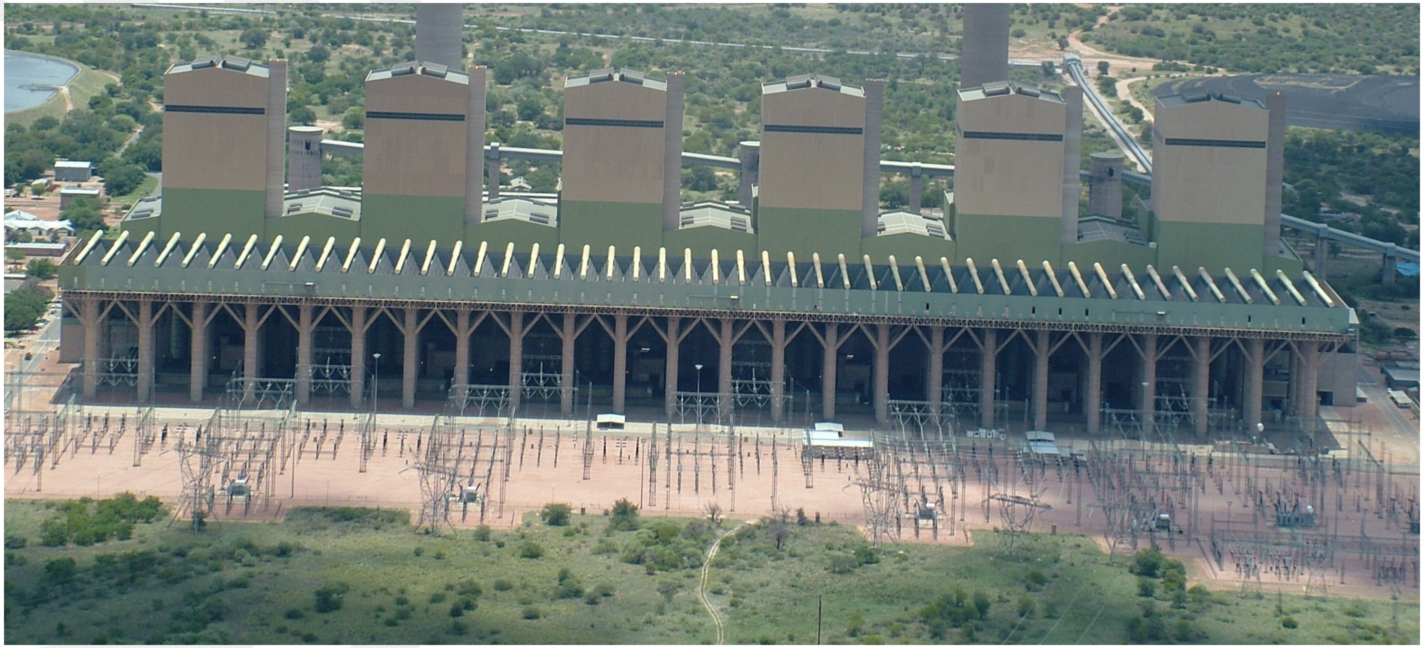


Figure 1: Matimba Dry-Cooled Power Station with the ACSC backend against the turbine hall (Source: eskom.co.za)

> ~4000 MW of net electic power output (rated)

> A total of 6 x 48 = **288** axial flow fans

Factors causing deterioration

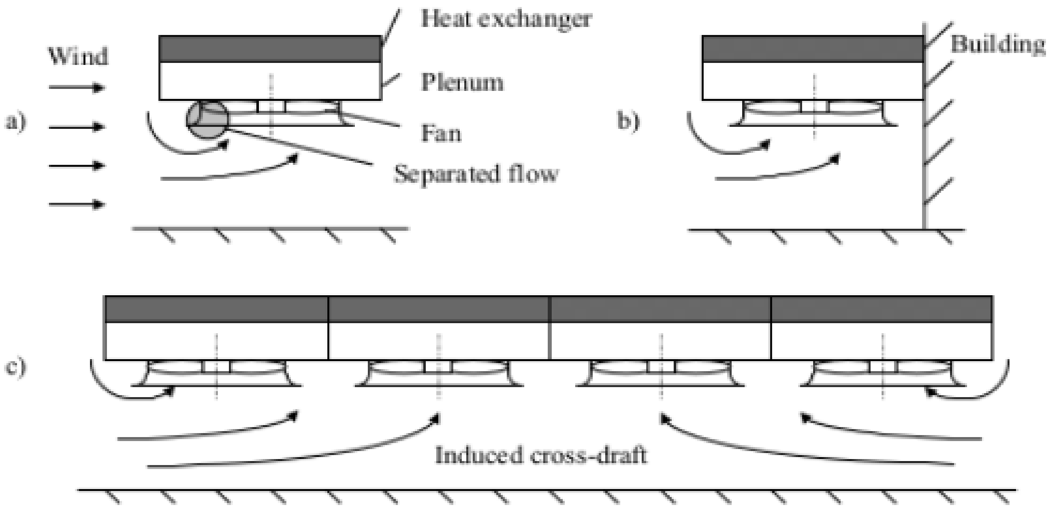


Figure 2.1: Factors causing ACSC performance deteriation
(Source: Bredell, 2005)

Consequence of high turbine back pressure

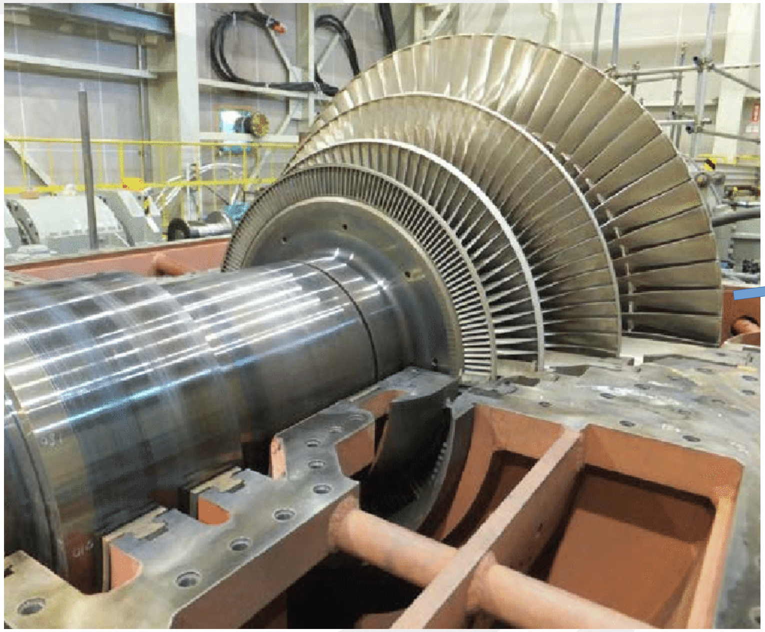


Figure 2.2: Low pressure steam turbine

Research Objectives

> Develop a CFD model of an ACSC with turbine hall taken into account.

> Investigate wind effects on performance of the ACSC.

> Compare numerical results to previous work and customer data (if available).

> Interpret results to evaluate physical ways of improving the performance of the ACSC subjected to windy conditions.

Examples

Figure 3: Gale breakers deployed (Source: galebreakercooling.com)

Figure 4: Cruciform walls (Source: Maulbetsch and DiFilippo)

Axial flow fan model: The big debate
To **Pressure jump** or to **Actuator disk** ?

> Pressure jump: Uses the draft equation (fan curve) to specify **uniform** pressure at the fan exit region.

> Actuator Disk: Uses experimentally determined aerofoil data with **2D flow assumption** to determine lift and drag force components.

> Pressure distribution is non-uniform across the fan rotor.

> As result, the Actuator disk approach is used in this project.

> 3D explicit fan blade model: Not yet feasible for ACSC CFD simulations. Too computational expensive.

Fan validation: Facility

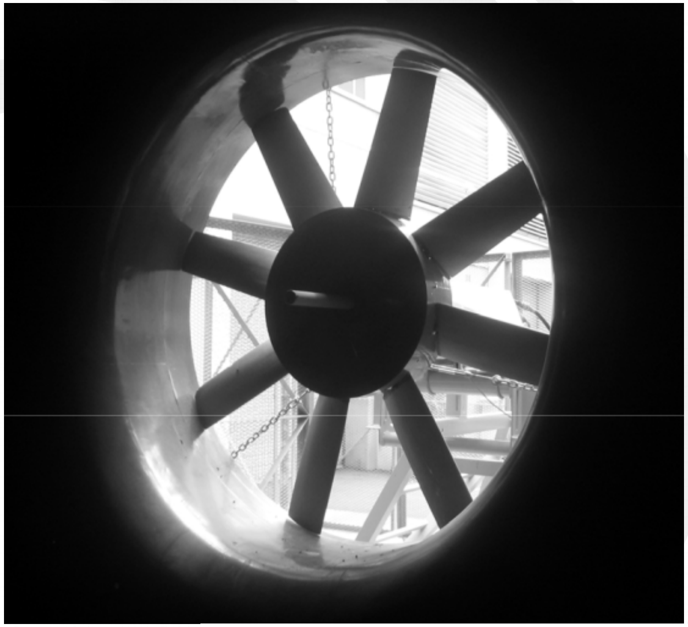
> The BS 8484 type A facillity of Stellenbosch University is used for testing scaled fans of diameter 1.542 m.

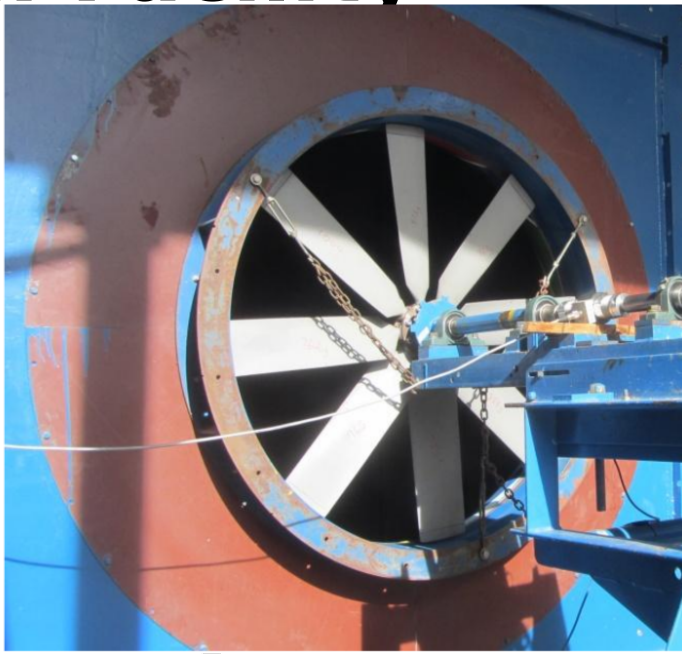
> Fan validation CFD domain is based on this facility.

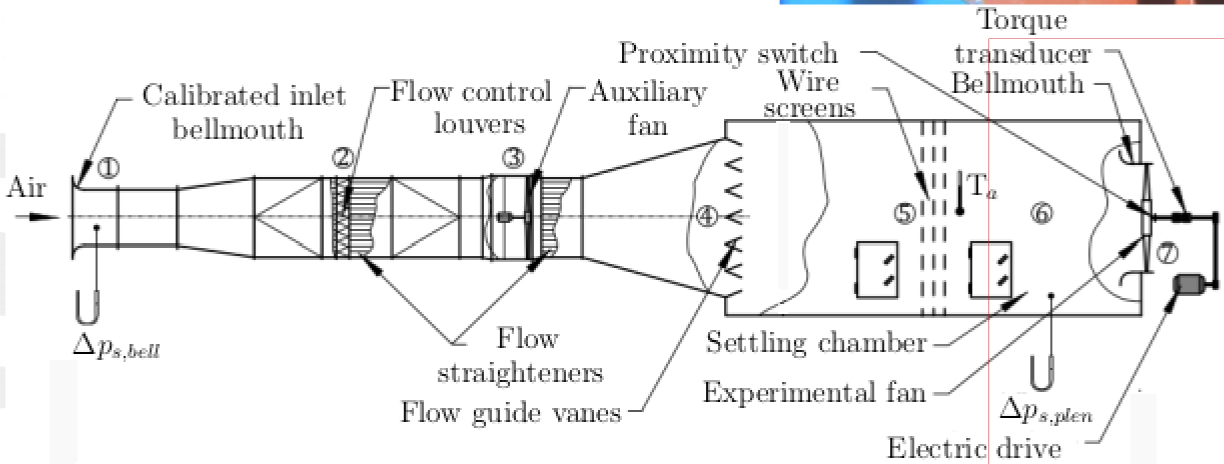
> The CFD model only includes the settling chamber, bellmouth, fan rotor and fan discharge zone.

> The inlet venturi ducts and auxilliary fan are not taken into account.

Fan validation: Facility







CFD solvers: To Open-Source or to Commercial ?

> Using OpenFOAM (Open-Source but ..).

> Written in c++.

> In-house (**SU**) developed fan and heat exchanger code.

> All Mesh (Computanional Domain) developed using Salome (Also Open-source).

> No **Ansys CFX or Fluent** / **STARCCM** (Commerical) used in this project. Why? $$$

Fan validation: Results(design point)

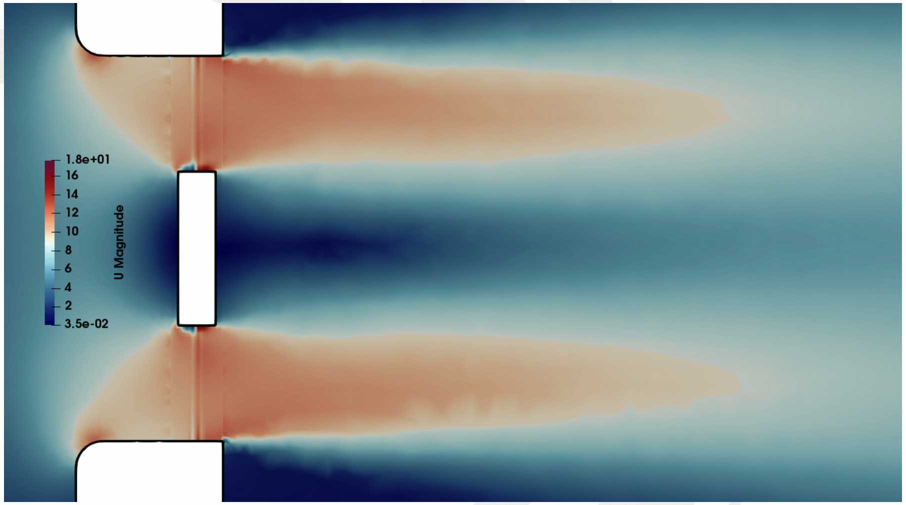


Figure 7: B2a-fan: Velocity field at design flow rate (**SU design**)

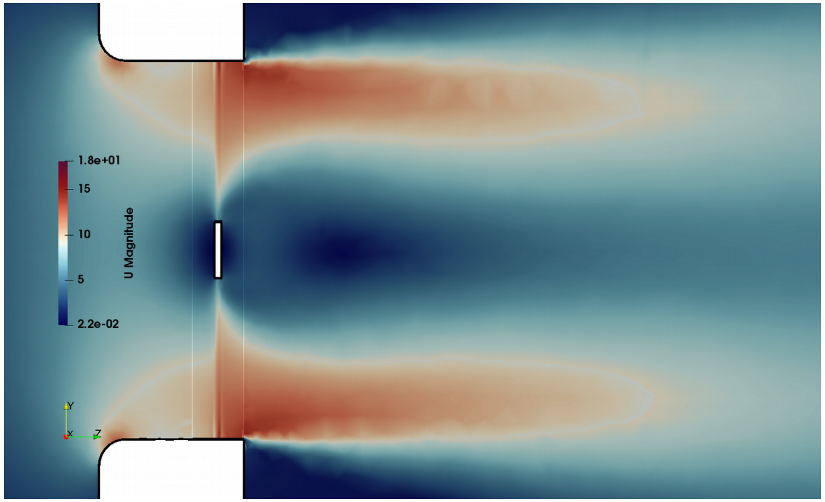


Figure 8: Afan: Velocity field at design flow rate (**Industry design**)

	SU design	Industry design
Static pressure rise [Pa]	151	159
Shaft Power [kW]	3.57	4.61
Efficiency [%]	67.7	55.2

Fan validation: Results (design point

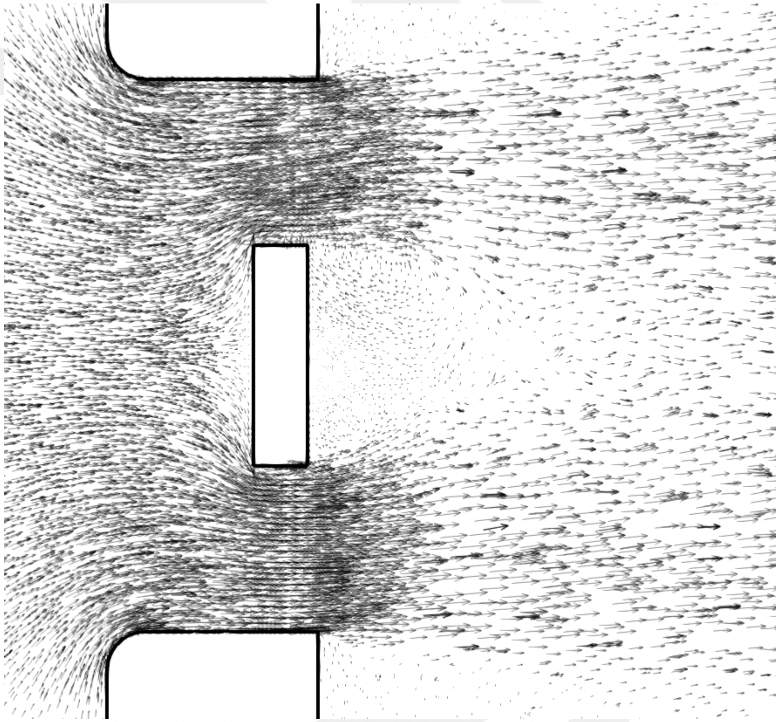


Figure 9: B2a-fan: Velocity vector field at design flow rate (**SU design**)

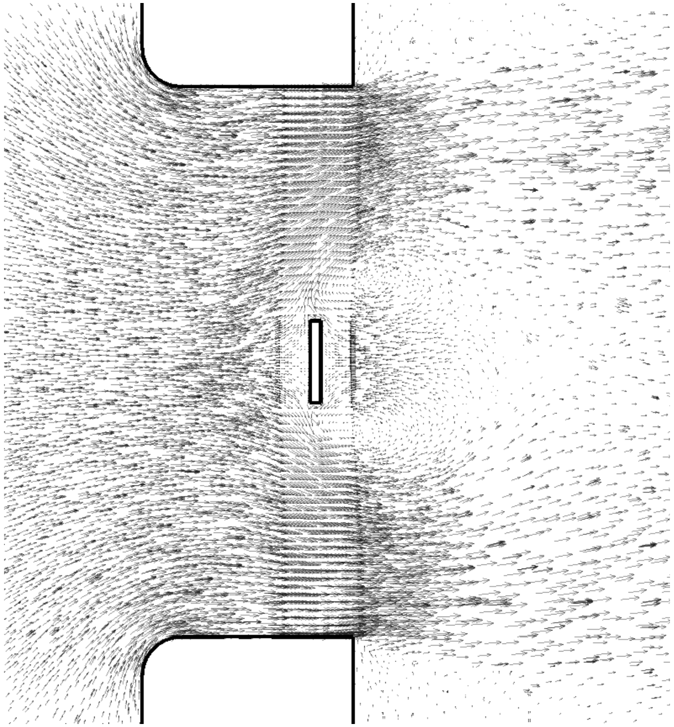


Figure 10: Afan: Velocity vector field at design flow rate for (**Industry design**)

Fan validation: Results

Himmelskamp effect

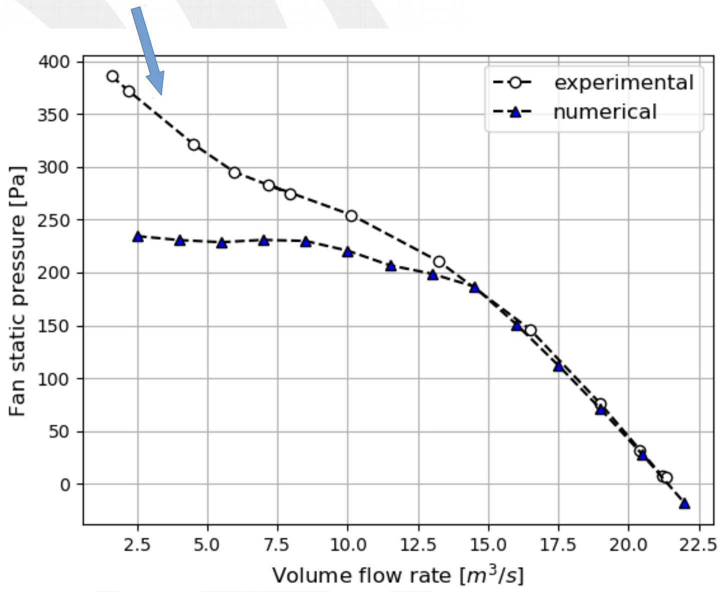


Figure 11: B2a-fan: Fan static pressure rise (SU design)

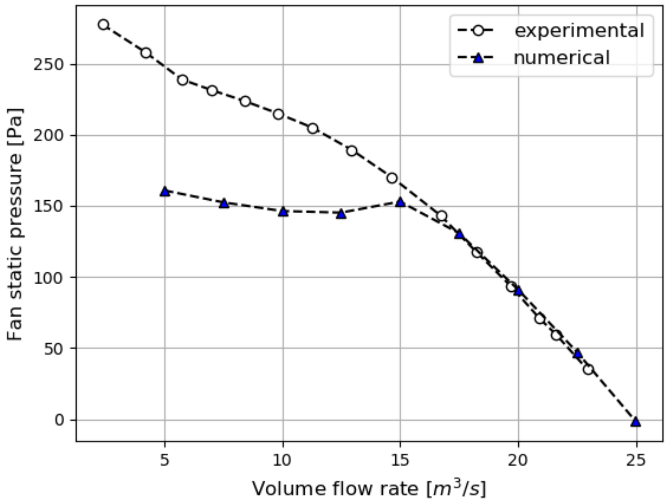


Figure 12: Afan: Fan static pressure rise (Industrial design)

Heat exchanger validation: Mesh

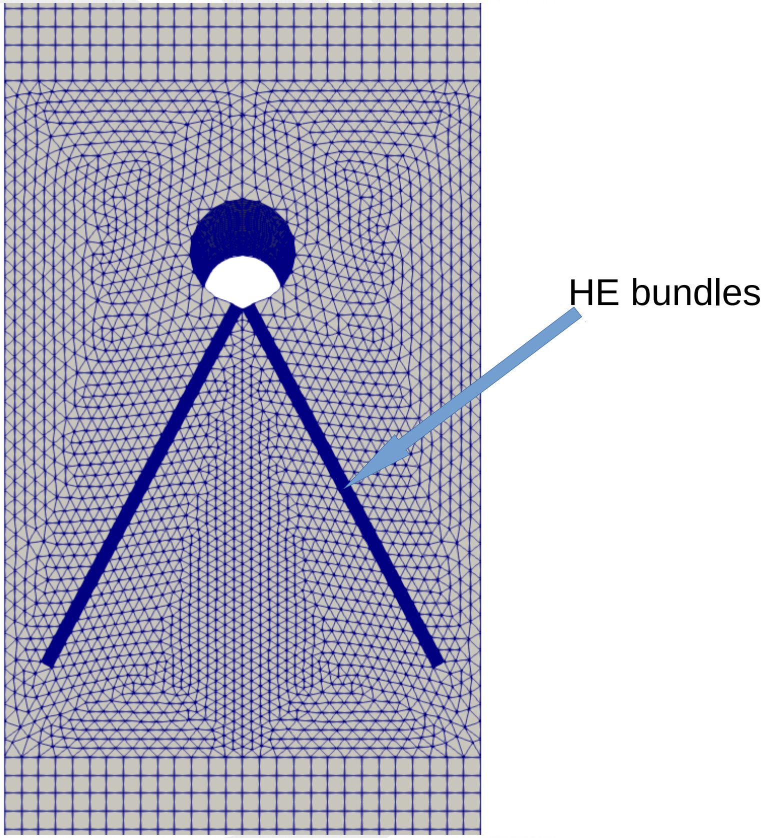
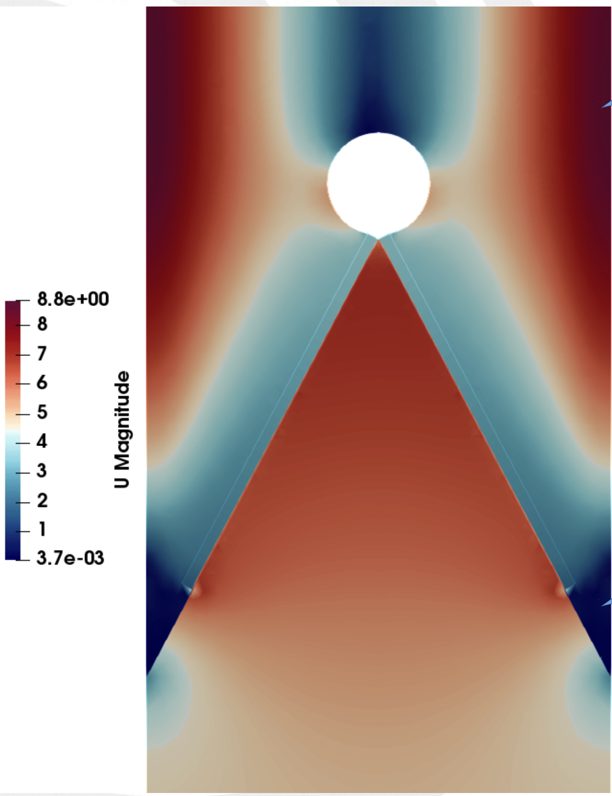


Figure 13: A-frame HE mesh
(Close-up view)

Figure 14: A-frame HE bundles
Source: Cotrell

Heat exchanger validation: Results



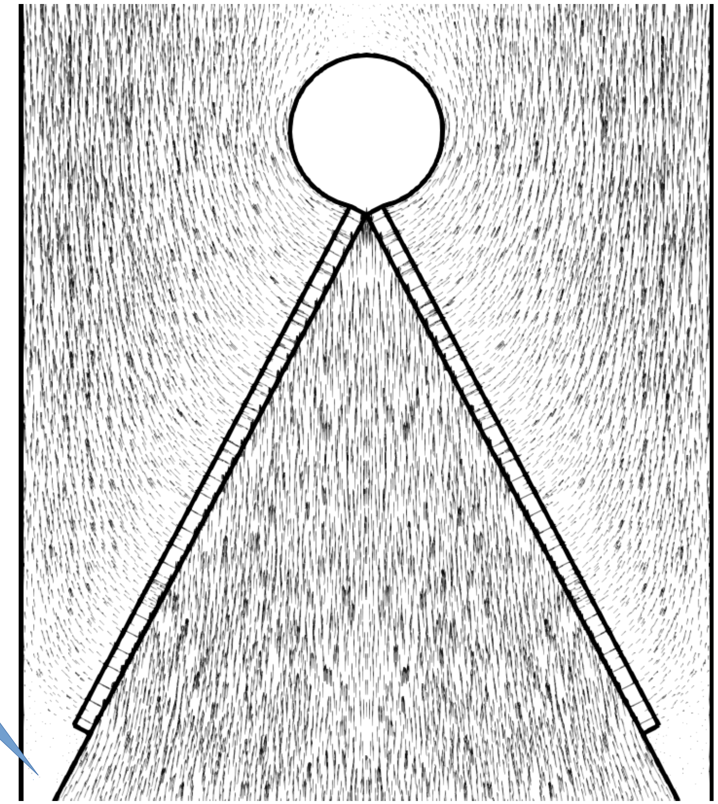
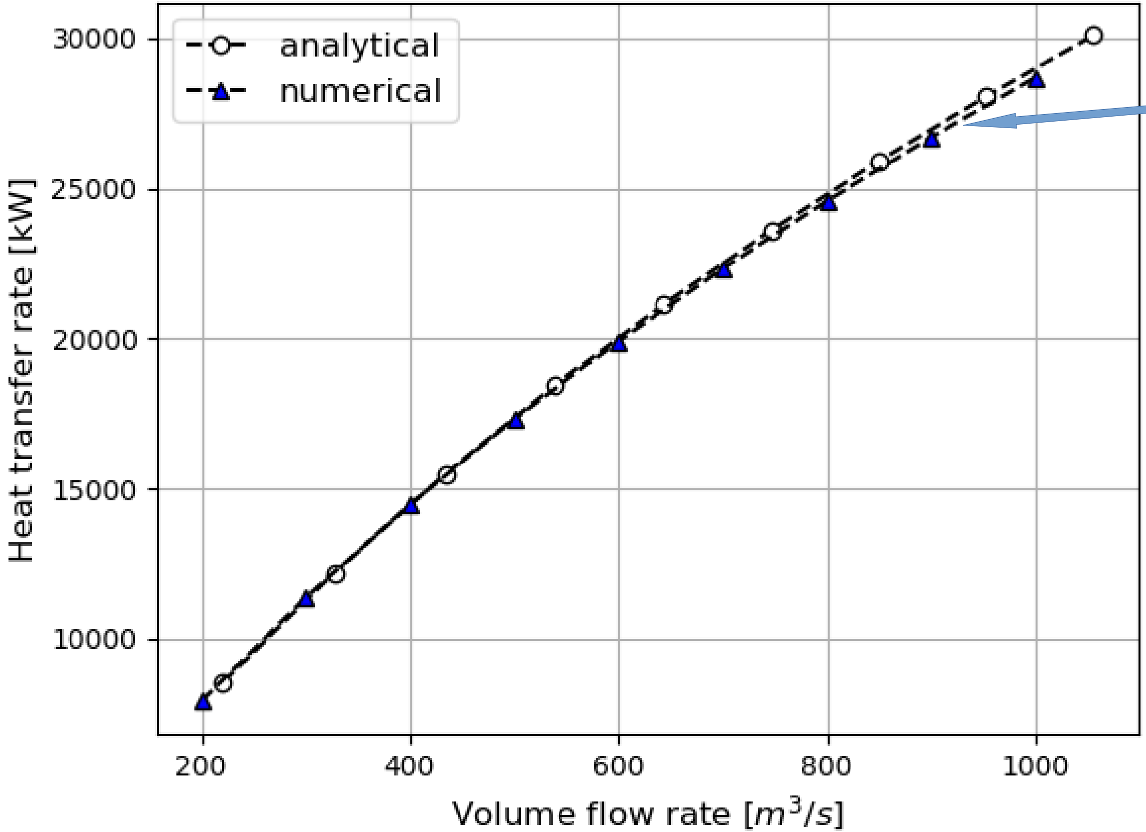


Figure 15: Velocity field at design point(smoothed plot)

Figure 16: Velocity vector field at design point

Heat Exchanger validation: Results



Less than 5% difference

Figure 17: A-frame HE validation: Numerical vs analytical data

ACC single unit: Geometry

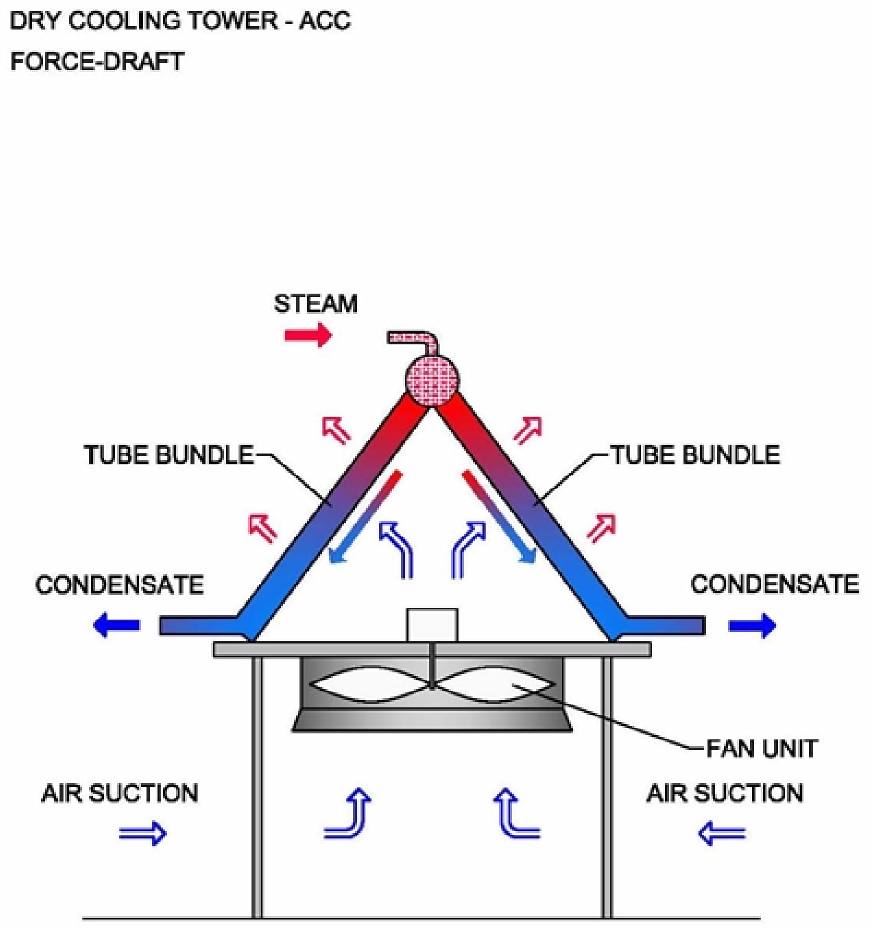


Figure 18: ACC single unit set up
Source: fans complete techonology

ACC single unit validation: Mesh

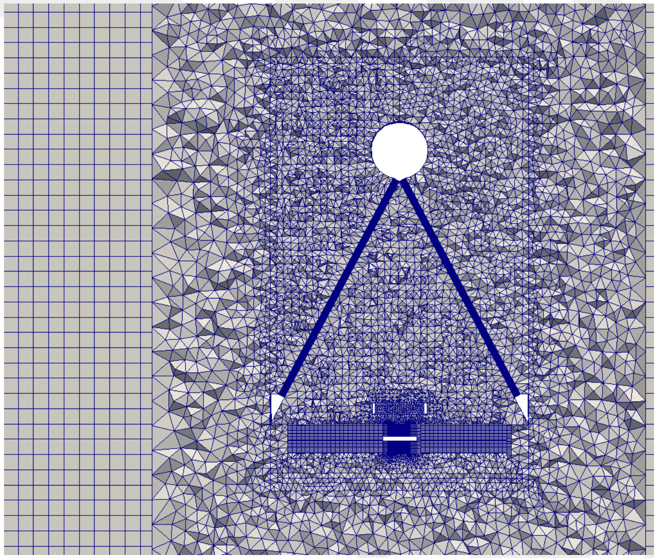


Figure 19: ACC single unit mesh (Close-up view)

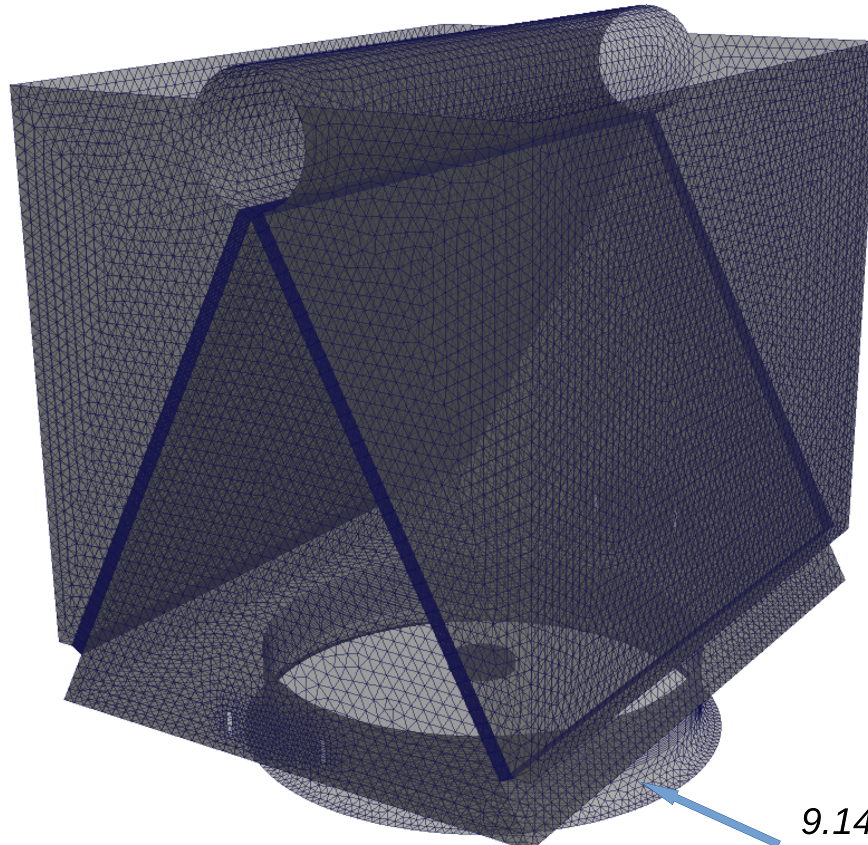
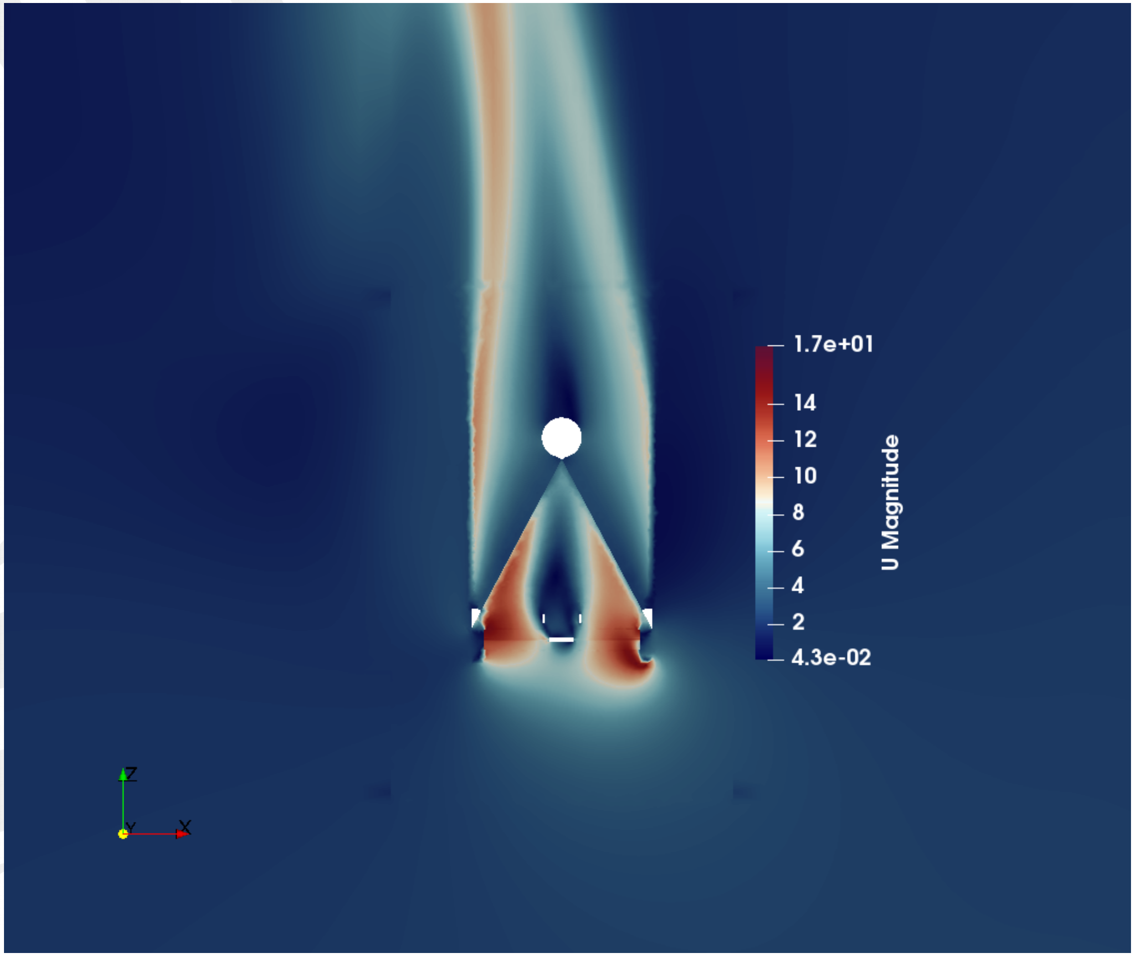


Figure 20: ACC single unit mesh wireframe view

Nearly there...but



Pending work

> 5 x 6 ACC Array.

> Cross walls/Wind breakers/Replace peripheral fans(Numerical).

> Hand-in (Obviously).

Challenges so far

> The learning curve of OpenFOAM.

> Stable convergence in OpenFOAM .

> Previsously, load-shedding (By the way, not because of the ACSC).

Q and A

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