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SOLAR THERMAL ENERGY RESEARCH GROUP

Numerical investigation into the effect of peripheral windscreens on air-cooled condenser fan performance under windy conditions

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Outline

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  - Background
  - Motivation
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- Experimental test facility
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- Results
- Conclusions

Introduction

Background

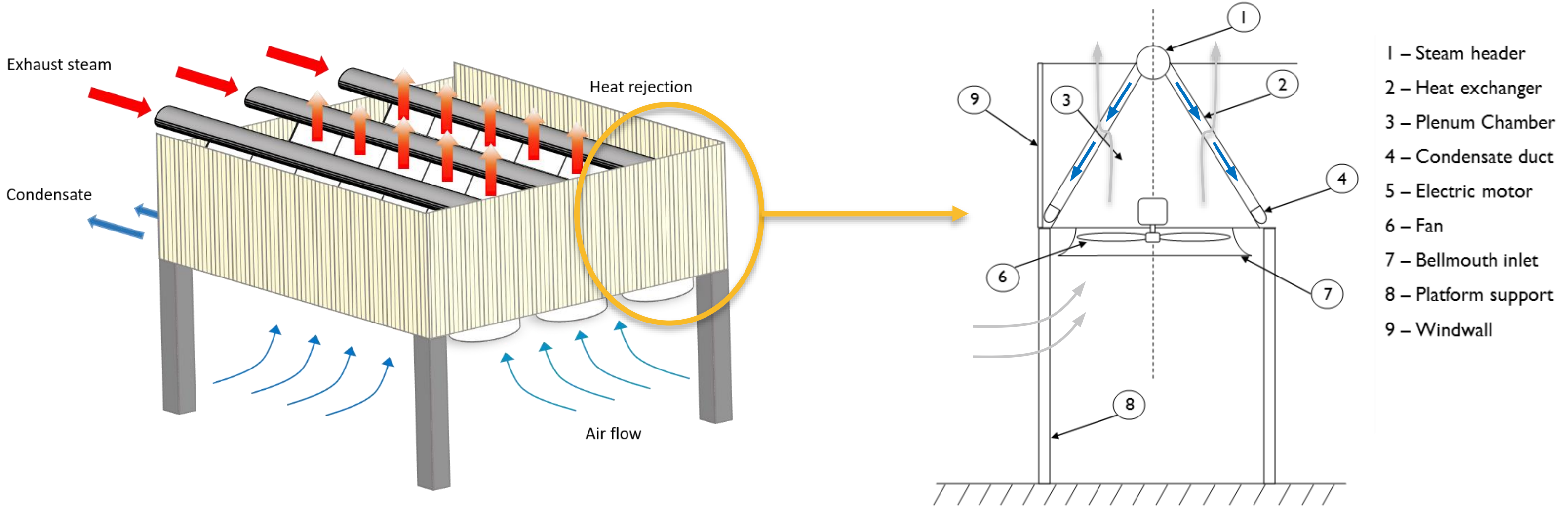
- Cooling systems
  - key feature affecting overall efficiency in thermoelectric power plants
  - 85% to 90% of the total water usage[1]
- Predominant wet cooling systems = highly water-intensive[1]
- Water usage = growing global concern
- Important that we look into means of reducing water consumption at thermoelectric power plants if we are to ensure both water and energy security into the future.

Introduction

Background

Air-cooled condensers (ACCs)

- Water-conservative alternative to predominate wet cooling systems



Introduction

Background

Air-cooled condensers (ACCs)

Cons

- × Inefficient operation
- × High operating & capital cost
- × Cost-disadvantages
  - – Poor heat transfer characteristics of air[4]
  - – Sensitivity to ambient conditions[4]
  - = Capital cost & Operating costs ~ 3x & 2x > equivalent wet cooled system[5]

Pros

- ✓ Greater locational flexibility[6]
- ✓ Complementary to concentrated solar power technologies
- ✓ Free from the environmental drawbacks[7]
- ✓ Air is available in abundance + no costs attached to its procurement or disposal[8]

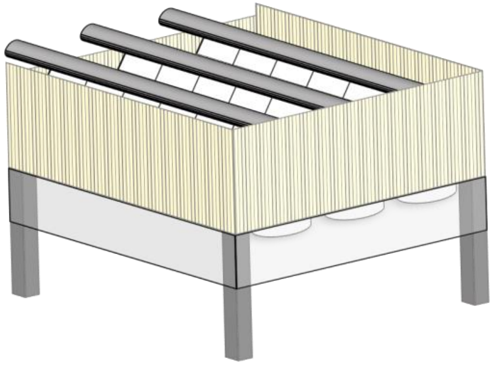
Introduction

Motivation

- Remain an unpopular option of heat sink
- Reluctance in industry to adopt ACCs = highlights the need for continued efforts to lessen their undesirable aspects

Wind

- – Most significant challenge facing ACC performance[10]
- × Deleterious effect on fan performance
- × Recirculation of hot exhaust plume
- × Imposes stresses on mechanical elements



Porous wind screens as a wind effect mitigation device

- – Uncertainty in literature
- – Lack of consistent field data/experimental case validation

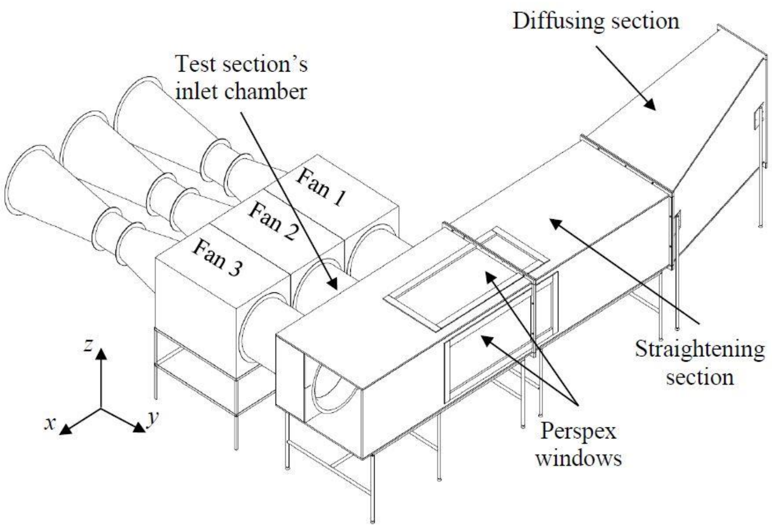
Introduction

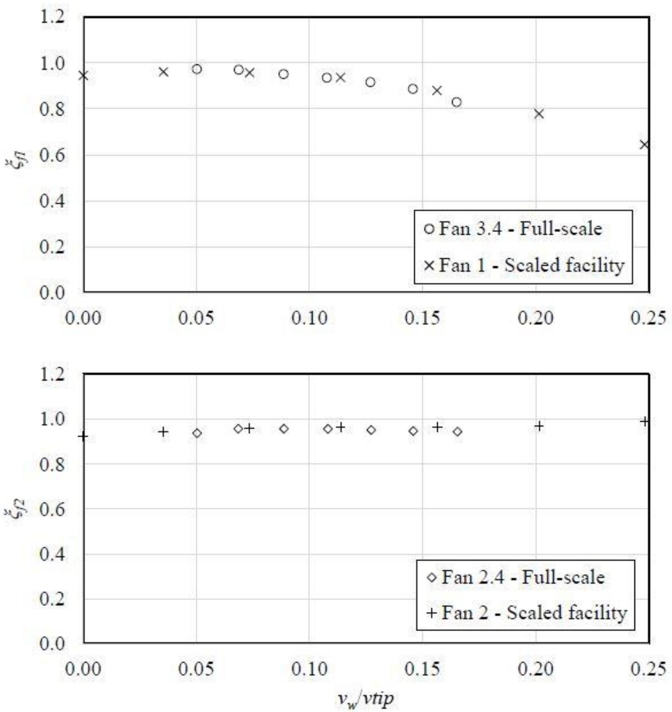
Objective

Numerically confirm the experimental measurements of Marincowitz (2018) & present a validated model that can be used to further understanding of the mechanisms that determine the effect of windscreens on ACC fan performance

- Through Computational Fluid Dynamic (CFD) simulations, using ANSYS Fluent.

Multiple fan and windscreen test facility





- Figures taken from Marincowitz (2018)
- Geometrically similar to Caithness Energy Centers' ACC

Numerical modelling

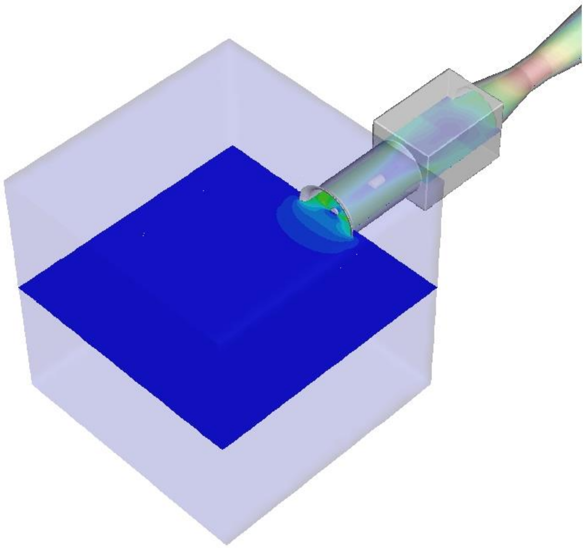
Fan models

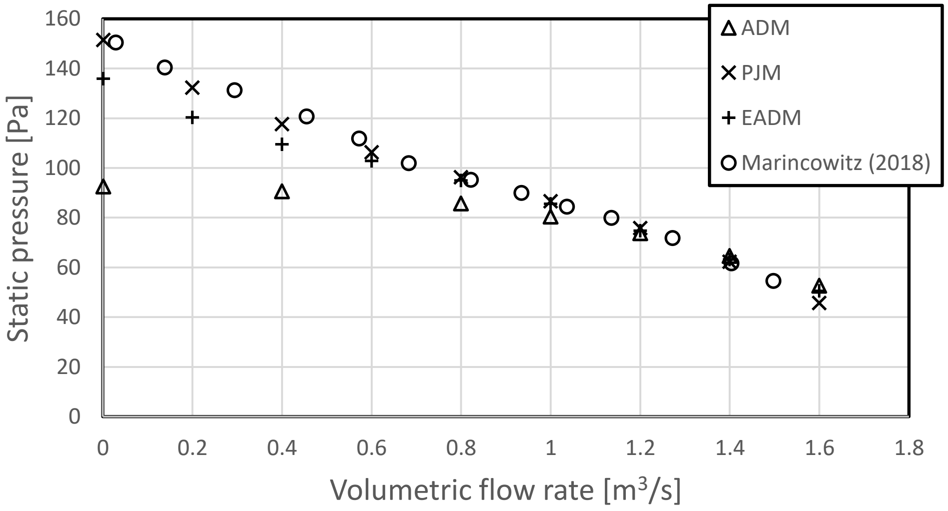
- Most accurate method = explicit modelling
  - Large complex computational grid arrangements[10]
  - Highly computationally expensive[10]
- The use of simplified, implicit fan models is motivated
  - Pressure Jump Method (PJM)
    - Static-to-static pressure rise as a function of velocity
  - Actuator Disc Method (ADM)
    - Introduction of forces into the flow field determined using blade element theory
  - Extended Actuator Disc Method (EADM)
    - Modification of lift and drag coefficients used in ADM force calculations

Numerical modelling

Single fan installation simulations

- Verification of correct fan model construction and implementation
- Single fan tunnel from multiple fan and windscreen test facility simulated



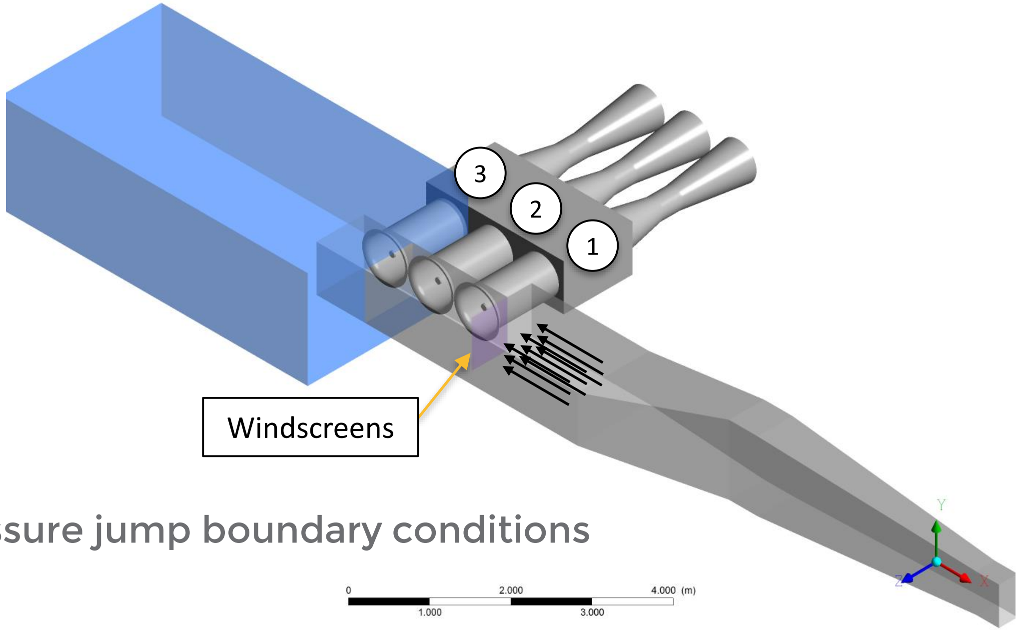


Numerical modelling

Multiple fan and windscreen test facility simulations

Fan 1 – EADM

Fan 2 & 3 - PJM



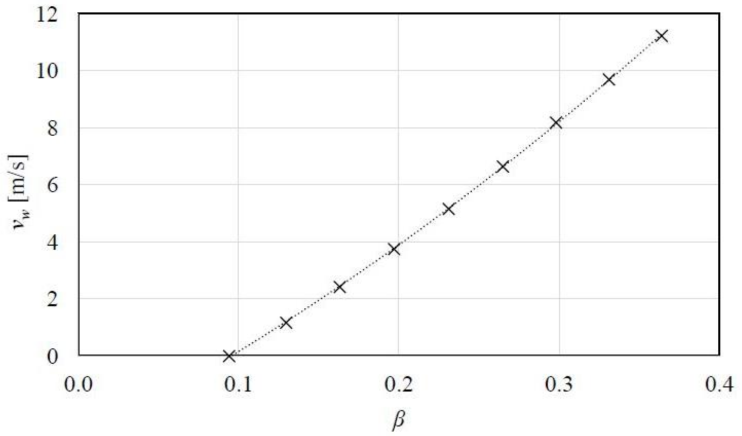
Windscreens – Pressure jump boundary conditions

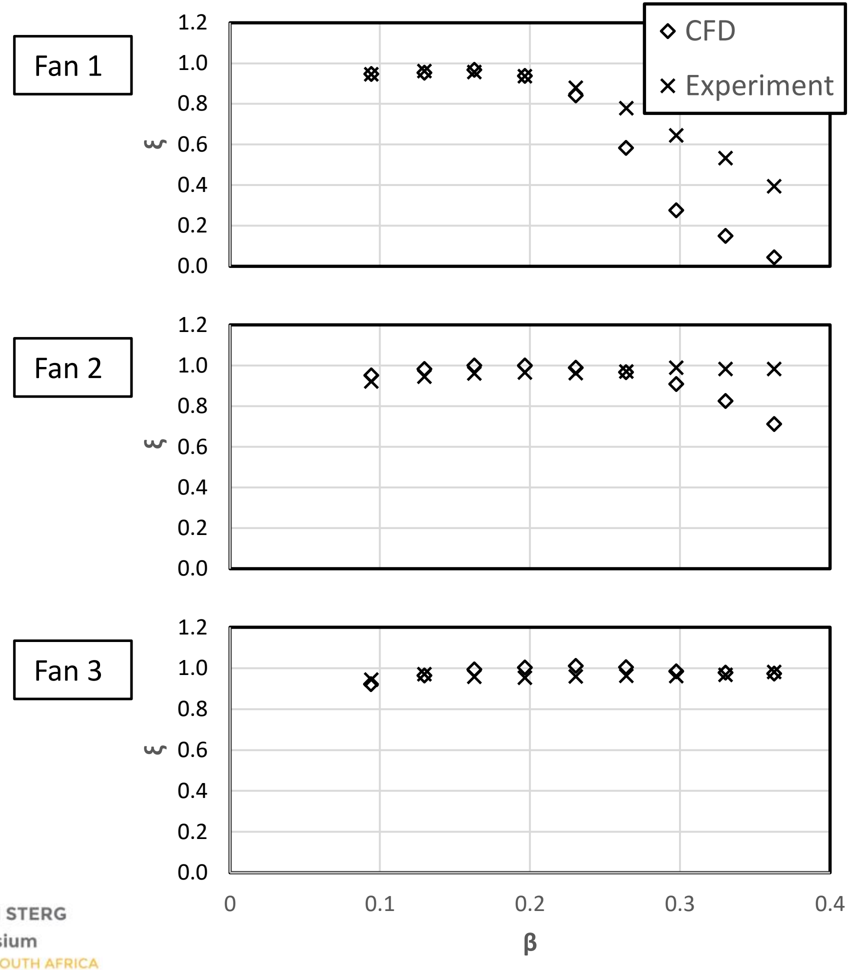
Results

Cross-flow

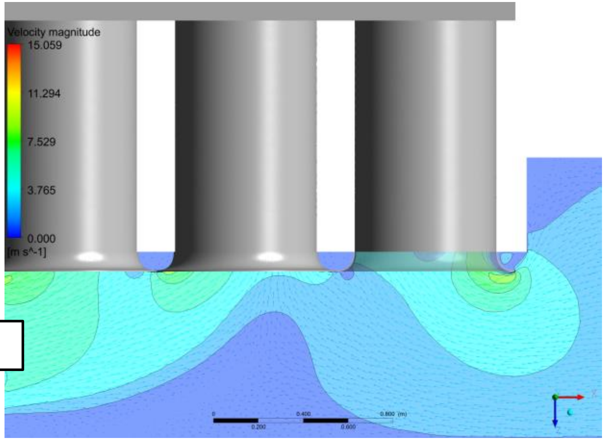
- Reduction in edge fan performance with increasing cross-flow

- Peripheral fan (Fan 1) is most affected

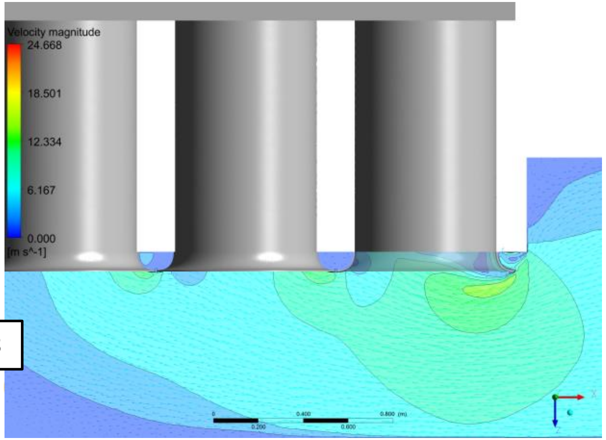




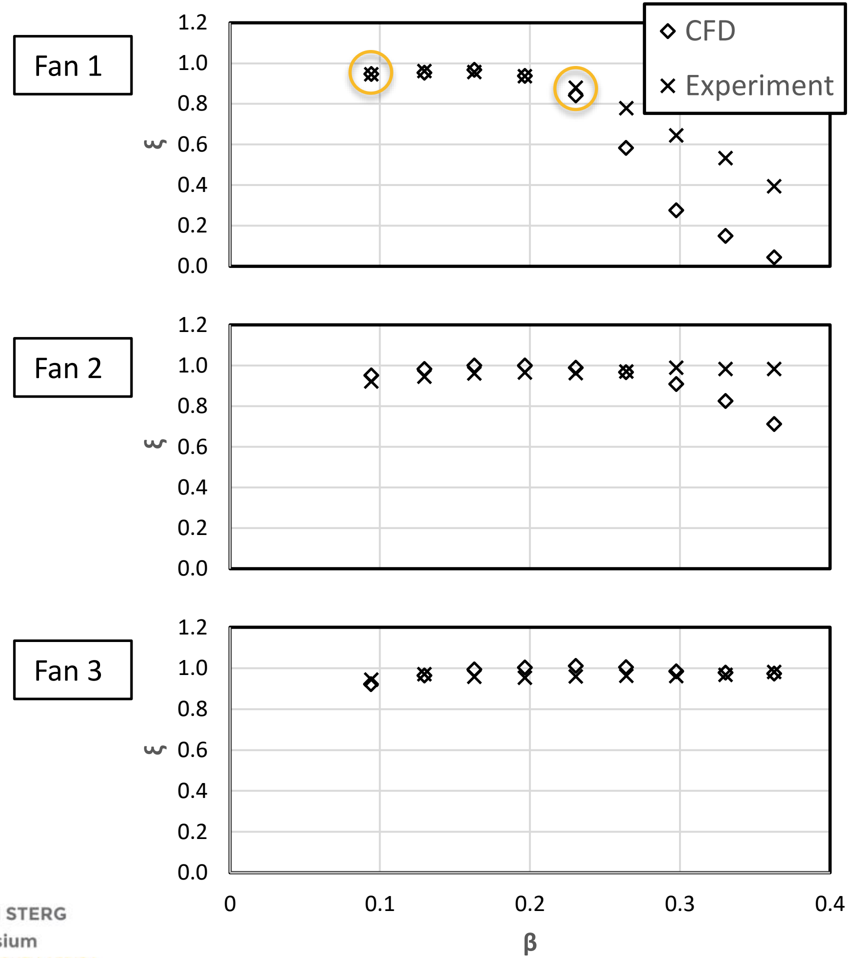
Results



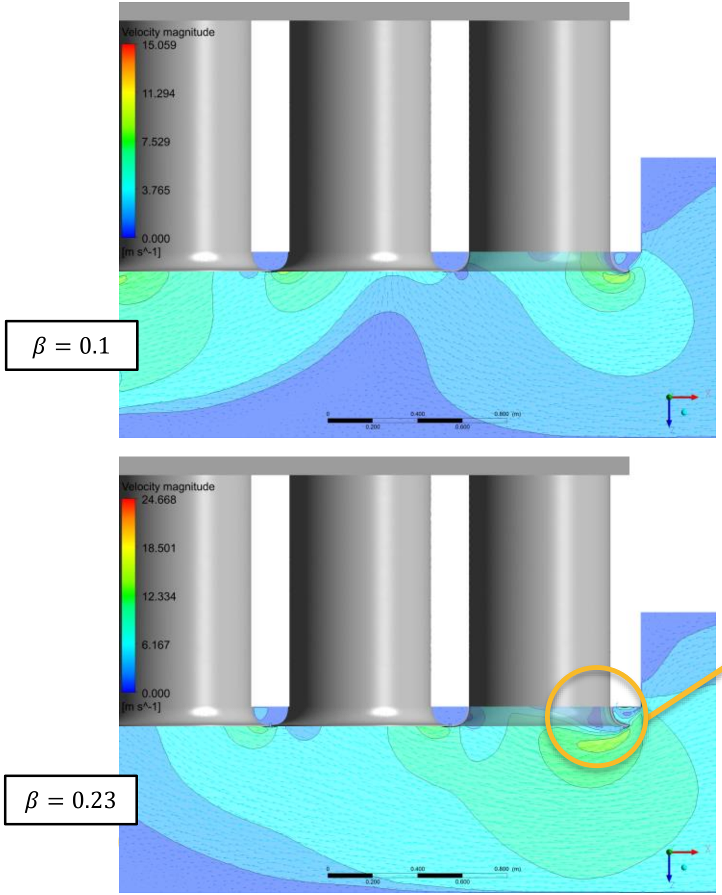
$\beta = 0.1$



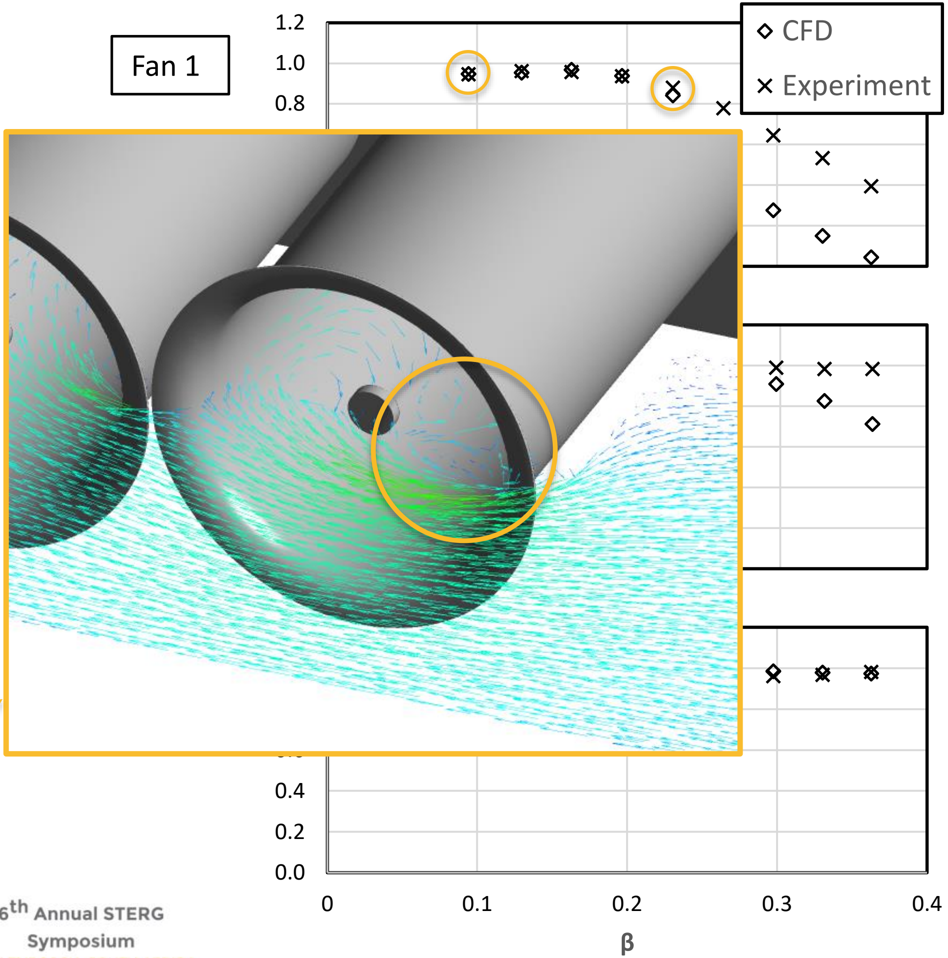
$\beta = 0.23$



Results



Velocity magnitude
15.059
11.294
7.529
3.765
0.000
[m s^-1]
β = 0.1
Velocity magnitude
24.668
18.501
12.334
6.167
0.000
[m s^-1]
β = 0.23



Fan 1
CFD
Experiment
1.2
1.0
0.8
0.4
0.2
0.0
0
0.1
0.2
0.3
0.4
β

Results

Windscreen Porosity

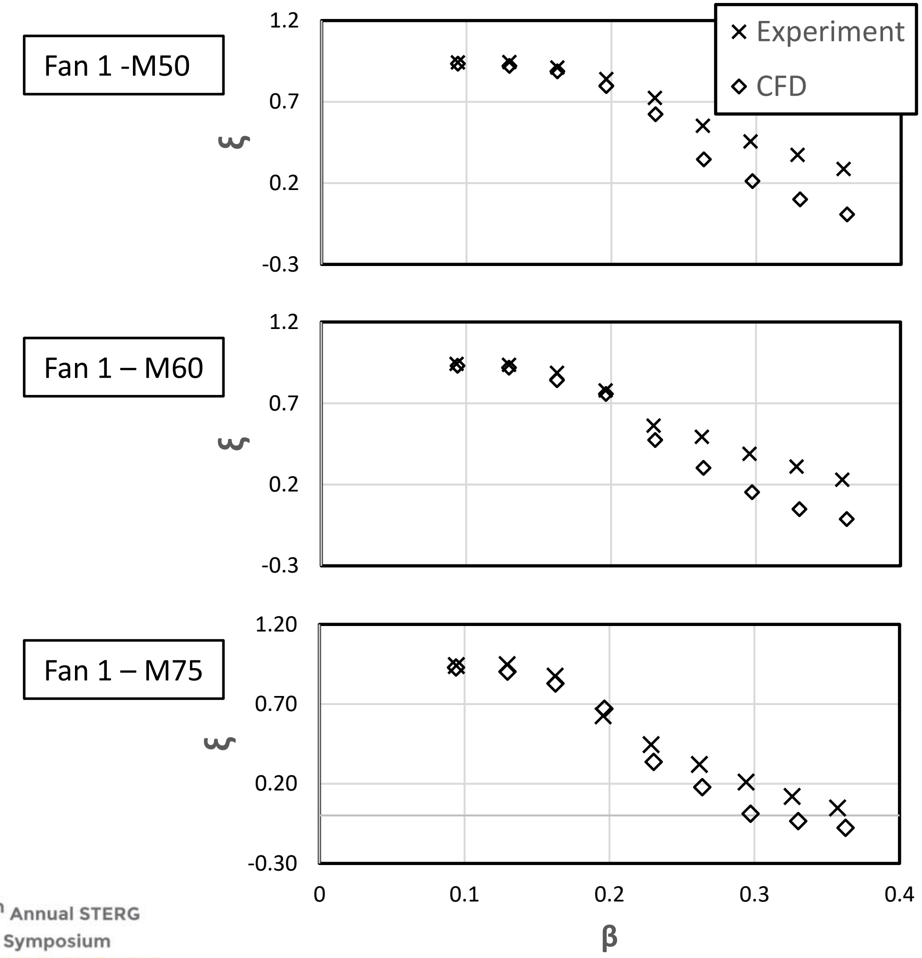
3x windscreen materials tested → M50, M60, M75

Numeric designates porosity according to

$$\alpha = \left(\frac{d_{ws}}{P_{ws}}\right)^2$$

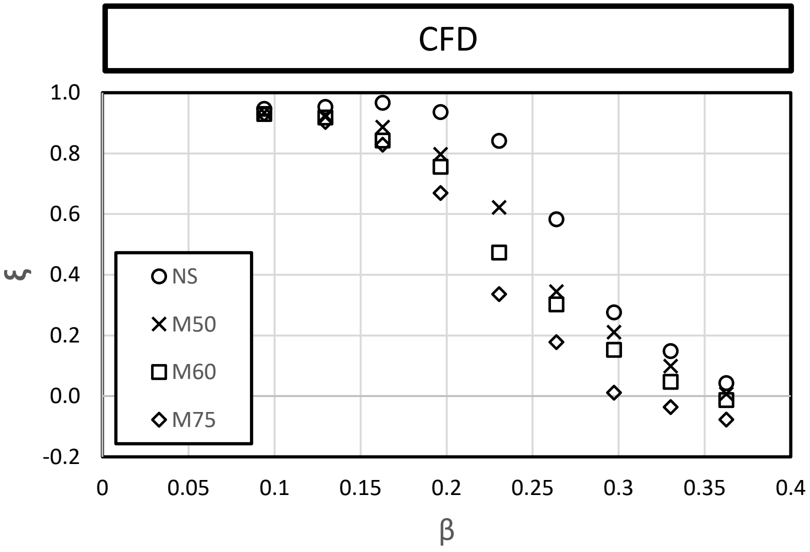
d_{ws} → Diameter of wire

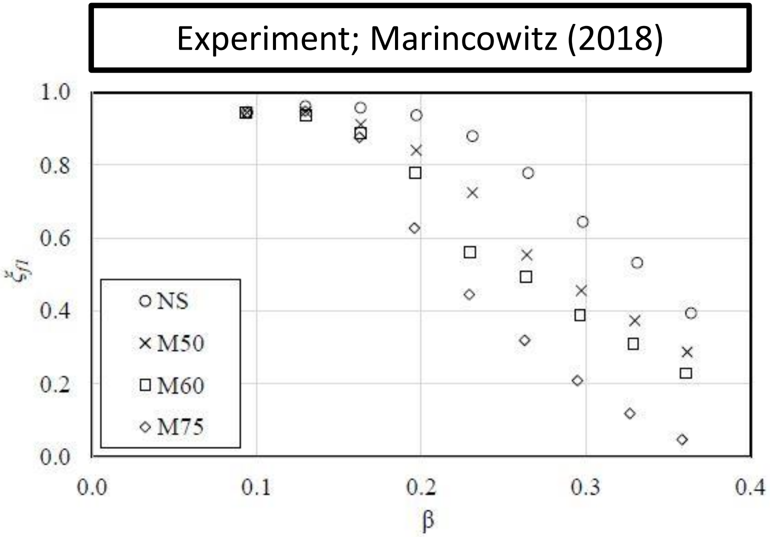
P_{ws} → Dimension of square opening



Results

Windscreen Porosity





Results

Windscreen Length

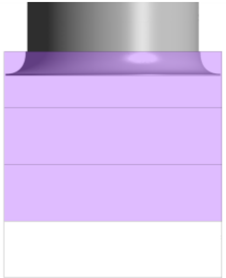
25% coverage

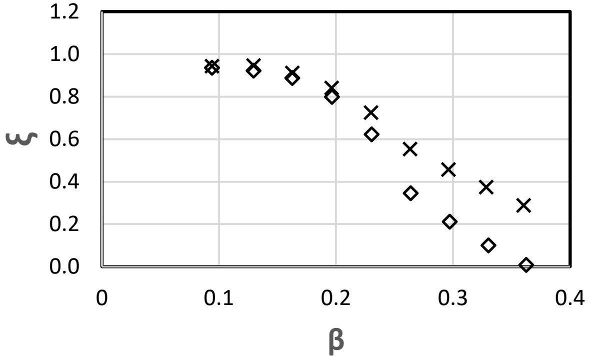
Peripheral fan (Fan 1)

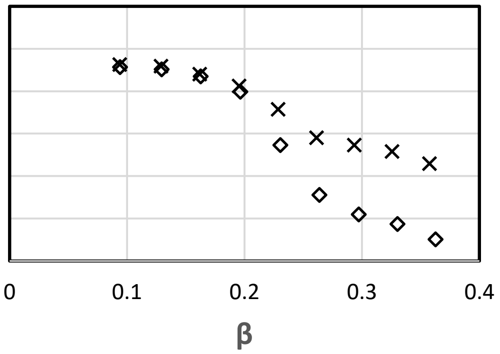
M50 material

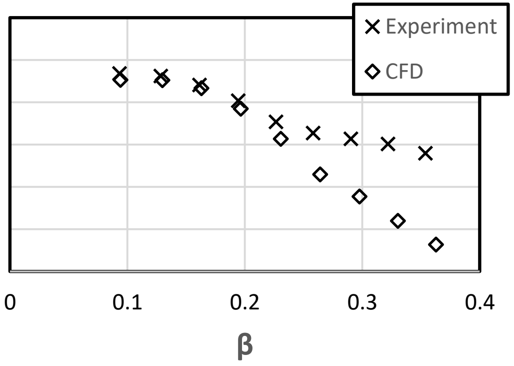
50% coverage

75% coverage



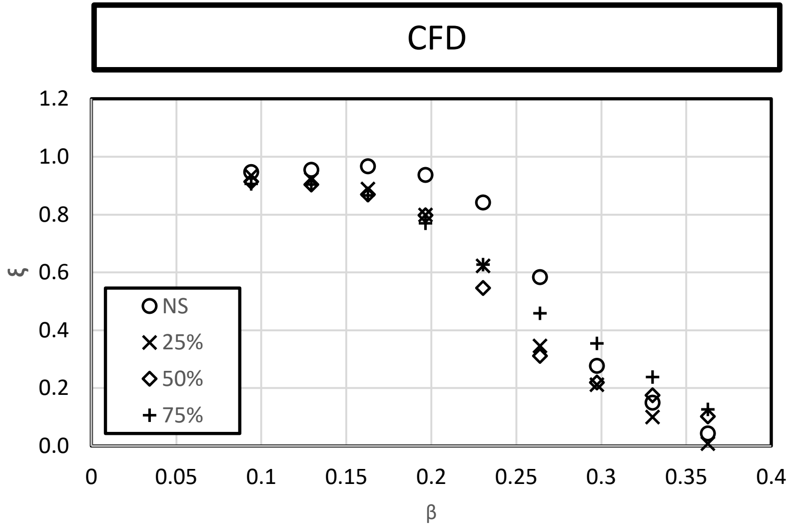


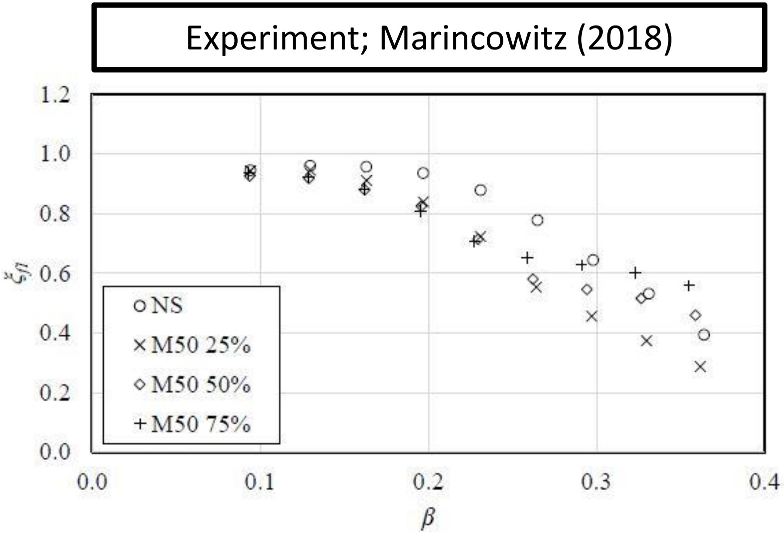




Results

Windscreen Length





Conclusions

- The numerical model is capable of quantitatively predicting the experimental results for low cross-flow cases, & qualitative trends for higher cross flow cases.
- For the particular case; windscreens hurt fan performance although slight improvement is possible in very high cross-flow situations, depending on the screen length.
- Results limited by the two dimensional flow assumption
- Model can be confidently used to unpack the mechanisms that determine windscreen effects

Conclusions

- Next steps
  - Use the validated modelling techniques to investigate the influence of windscreens in conjunction with:
    - Platform height
    - Fan row edge effects
    - Full-scale simulations

Thank you

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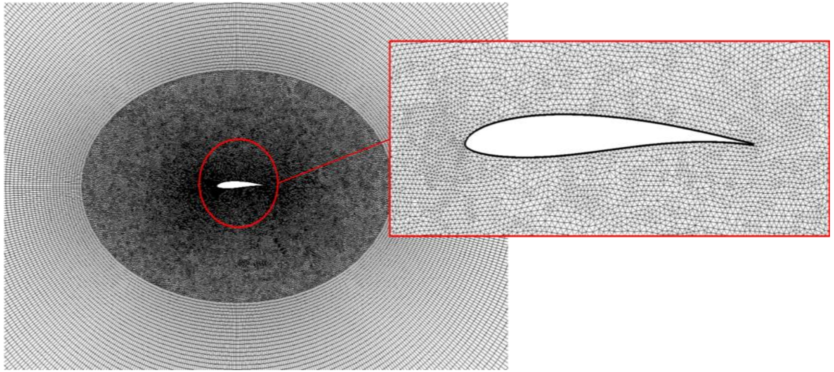
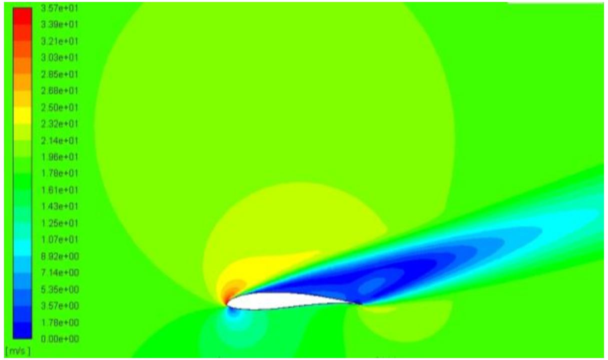
Questions

Fan models

- Angles of attack ranging from -90° to 90 ° can be expected in an axial flow fan
- Lift and drag coefficients in force calculations are determined through isolated 2D air foil profile tests

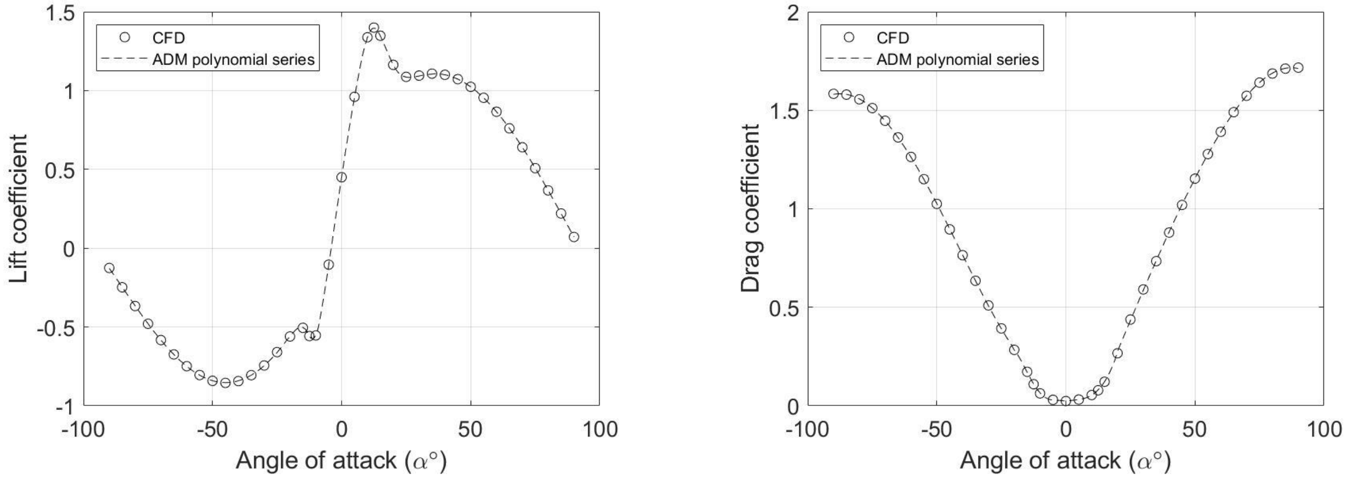




Questions

Fan models

- L2 Fan – FX 60-126 air foil

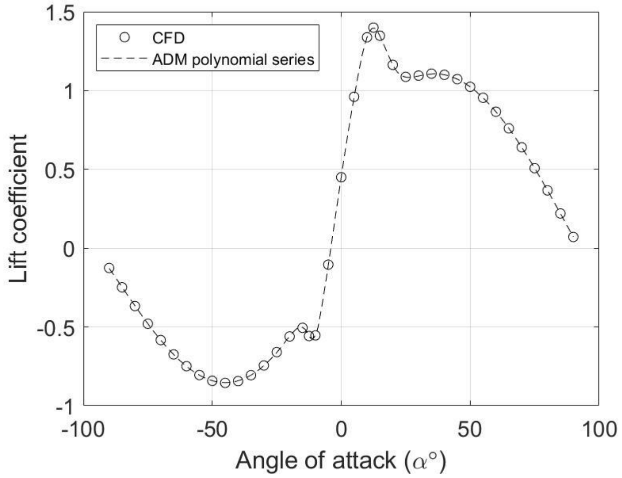


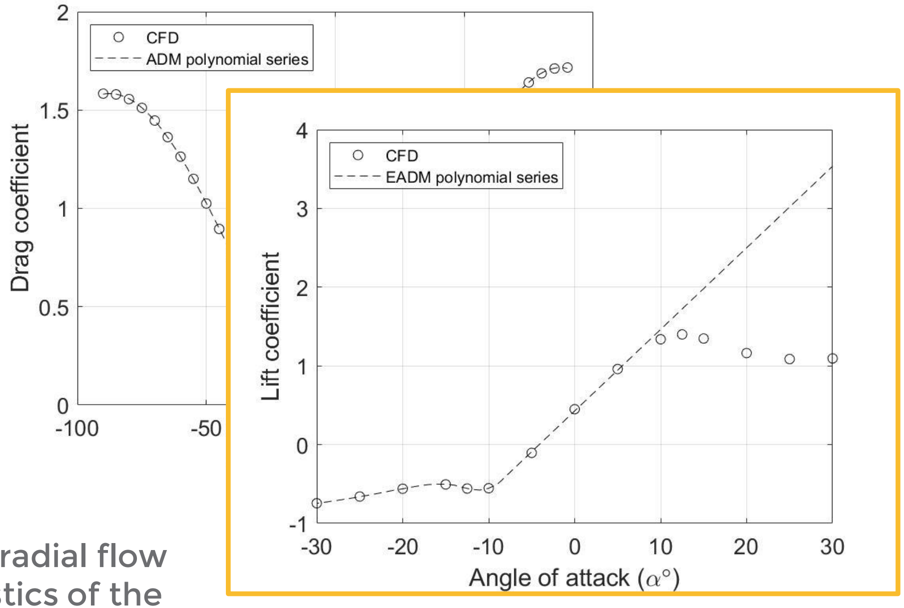
- Low flow rates
  - Centrifugal loading initiates an absolute radial flow path = alters the lift and drag characteristics of the fan blade

Questions

Fan models

- L2 Fan – FX 60-126 air foil





- Low flow rates
  - Centrifugal loading initiates an absolute radial flow path = alters the lift and drag characteristics of the fan blade