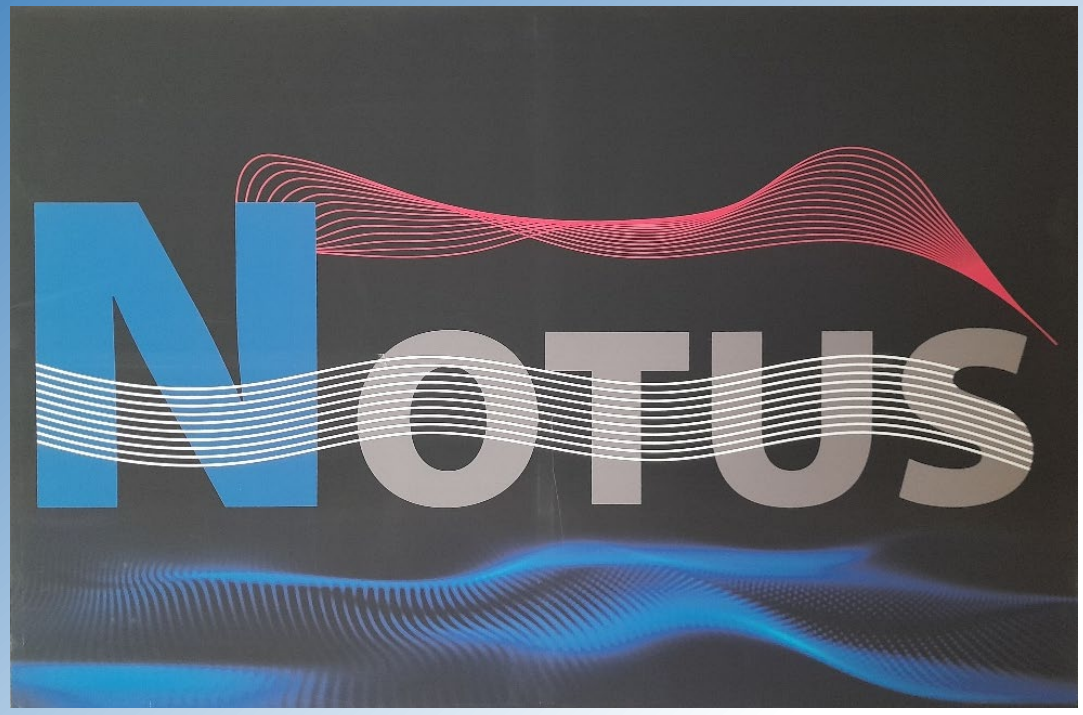


FROM ACADEMIA TO INDUSTRY

Large-scale implementation of advanced fan technology through innovation in design and manufacture

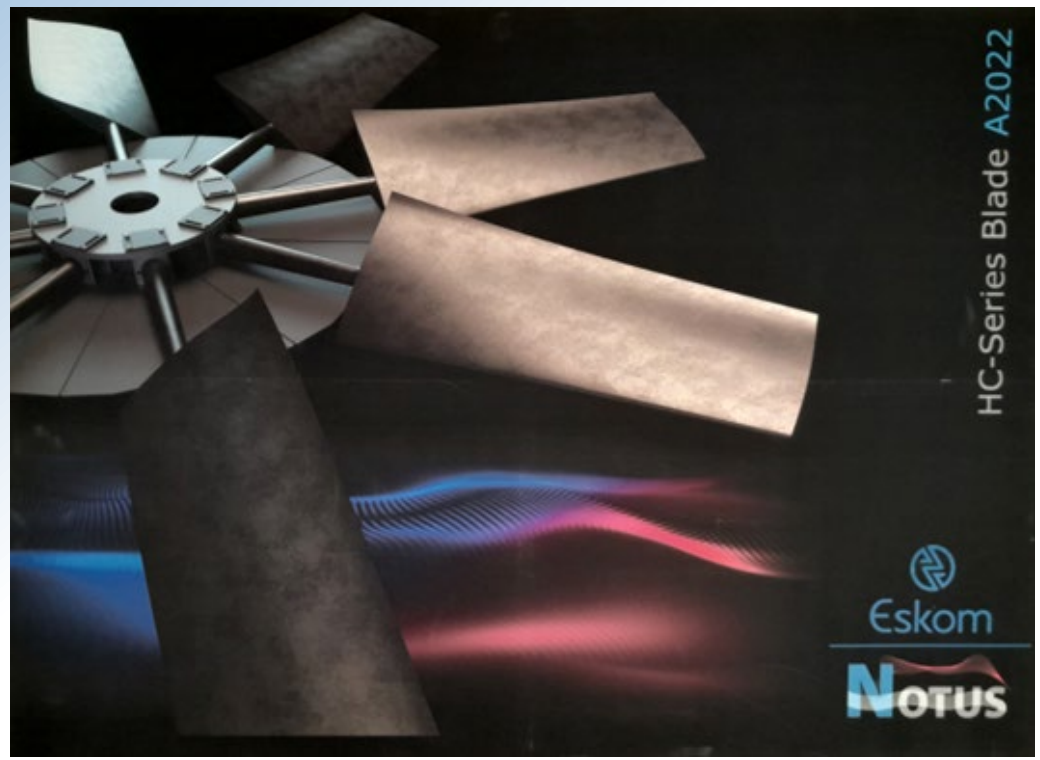
Chris Meyer

"Scientists dream about doing great things. Engineers do them." – James A. Michener

NOTUS Fan Engineering

Overview

- Company Profile
- Process Overview
- Innovation in Design
- Innovation in Manufacture
- Project: Matimba Retrofit, Unit 6



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NOTUS
Fan Engineering

Company Profile

- Since 2015
- Located in Stellenbosch, South Africa
- Close links to Stellenbosch University (SU)
  - Prof DG Kröger (†2014) – Industrial cooling
  - Prof TW von Backström (†2021) – Turbomachinery
  - 8 decades of combined research activity
  - Chris Meyer – Associate Professor at SU since 2011
  - Studied under Prof DG Kröger (1993 – 2000)
- H2020 – MinWaterCSP project (2016 – 2018)
- Design and manufacture of axial flow fans
- Primarily large-scale ACC fans
- Agricultural industry

"Scientists dream about doing great things. Engineers do them." – James A. Michener

NOTUS Fan Engineering

The Partners

Kelvion Holding GmbH
Germany
www.kelvion.com

Kelvion Thermal Solutions (Pty) Ltd
South Africa
www.kelvion.com

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., Fraunhofer Institute for Solar Energy Systems ISE
Germany
www.ise.fraunhofer.de

Universita degli studi di Roma „La Sapienza"
Italy
www.uniroma1.it

ECILIMP TERMOSOLAR S.L.
Spain
www.ecilimp.com

Stellenbosch University
South Africa
www.sun.ac.za

Notus Fan Engineering
South Africa
www.notus.co.za

Laterizi Gambettola srl - SOLTIGUA
Italy
www.soltigua.com

ENEXIO Germany GmbH
Germany
www.enexio.com

Institut de Recherches en Energie Solaire et Energie Nouvelles - IRESEN
Morocco
www.iresen.org

Steinbeis Innovation gGmbH
Steinbeis-Europa-Zentrum
Germany
www.steinbeis-europa.de

Waterleau Group NV
Belgium
www.waterleau.com

The Project

Executive Summary

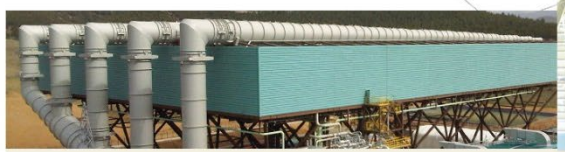
MinWaterCSP consortium will address the challenge of significantly reducing the water consumption of CSP plants while maintaining their overall cycle efficiency. Our objective is to reduce evaporation losses and mirror cleaning water usage for small- and large-scale CSP plants through a holistic combination of next generation technologies. Also, comprehensive water management plans for CSP plants in various locations will be developed. The MinWaterCSP consortium aims to make CSP more attractive for investment purposes in order to drive growth in the CSP plant business as well as job creation at European companies.

Duration

36 months (January 2016 – December 2018)

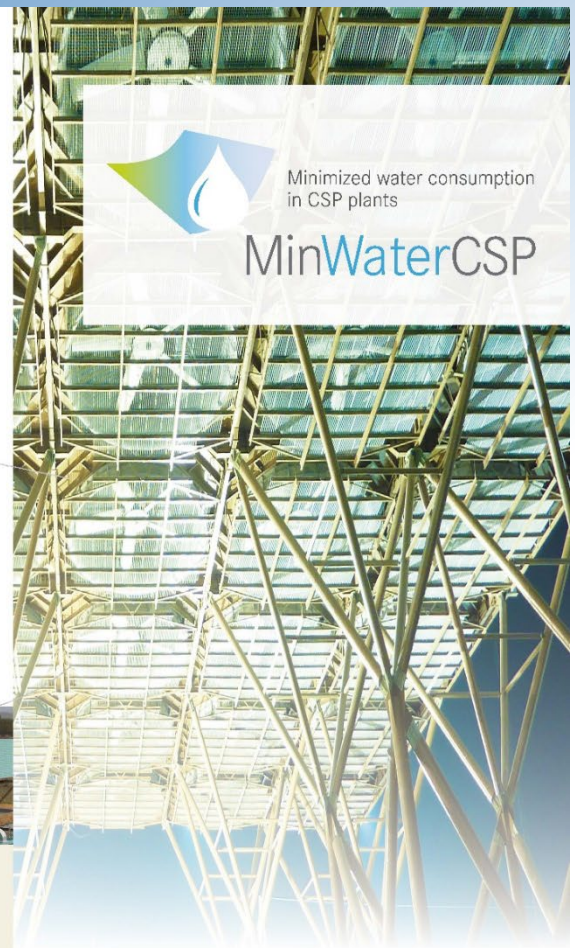
Partner

12 Partners from 6 countries
Belgium, Germany, Italy, Morocco, South Africa, Spain



Contacts

Kelvion Holding GmbH /
Kelvion Thermal Solutions (Pty) Ltd
Project coordinator / Technical coordinator
Dr. Falk Mohasseb / Dr. Albert Zapke
contact@minwatercsp.eu
www.minwatercsp.eu

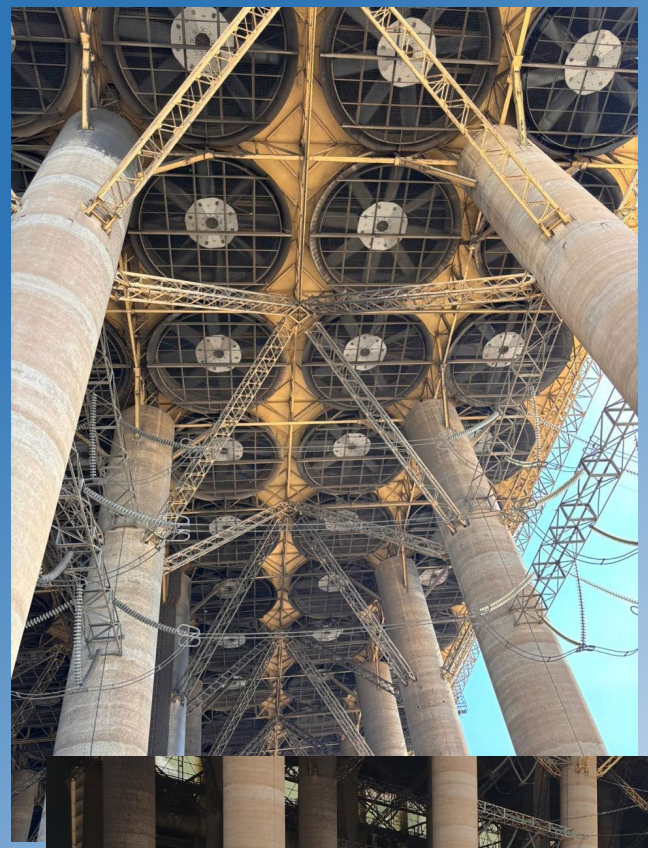


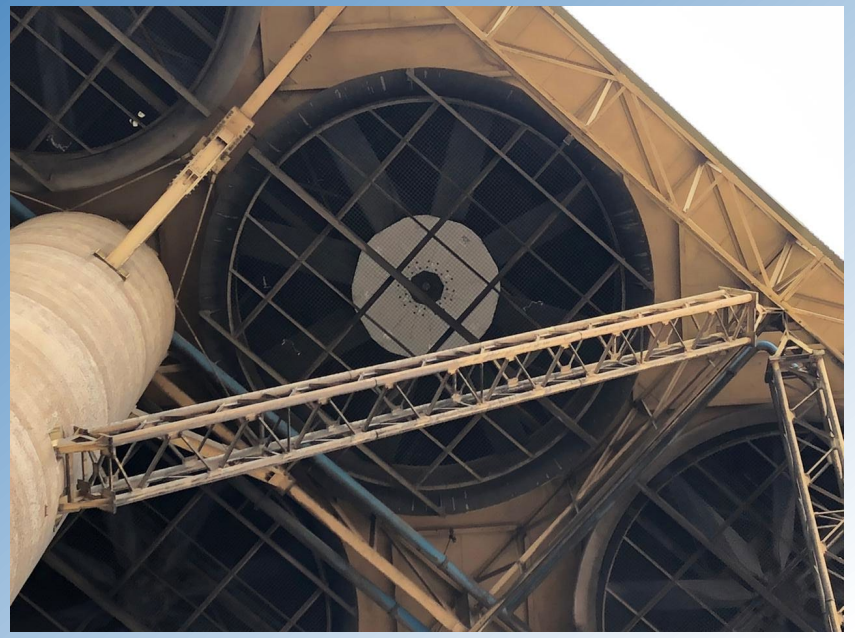
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 654443

- Origin story
- H2020 consortium
- Required - Industry partner to design and manufacture custom made fans
- 30 ft replacement for Matimba Power Station
- 24 ft for H2020 test facility (Stellenbosch)
- 1 Academic + 1 Model Glider Maker = Notus

"Scientists dream about doing great things. Engineers do them." – James A. Michener

NOTUS Fan Engineering





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NOTUS
Fan Engineering

Process Overview

- Catalogue-approach forces users to compromise on aerodynamic, dynamic and noise performance
- Notus designs and manufactures “your” fan
  - Duty point-based aerodynamic design
  - Structural design includes dynamic and strength criteria
  - Unique geometrical features are accommodated (one bladed fan?)
  - Chemical and environmental resistance via material/coating selection
  - Accuracy – blade geometry to blade setting angle
- Verification
  - Coded fan test facility tests of model scale fans
  - Structural tests of prototype fan blades

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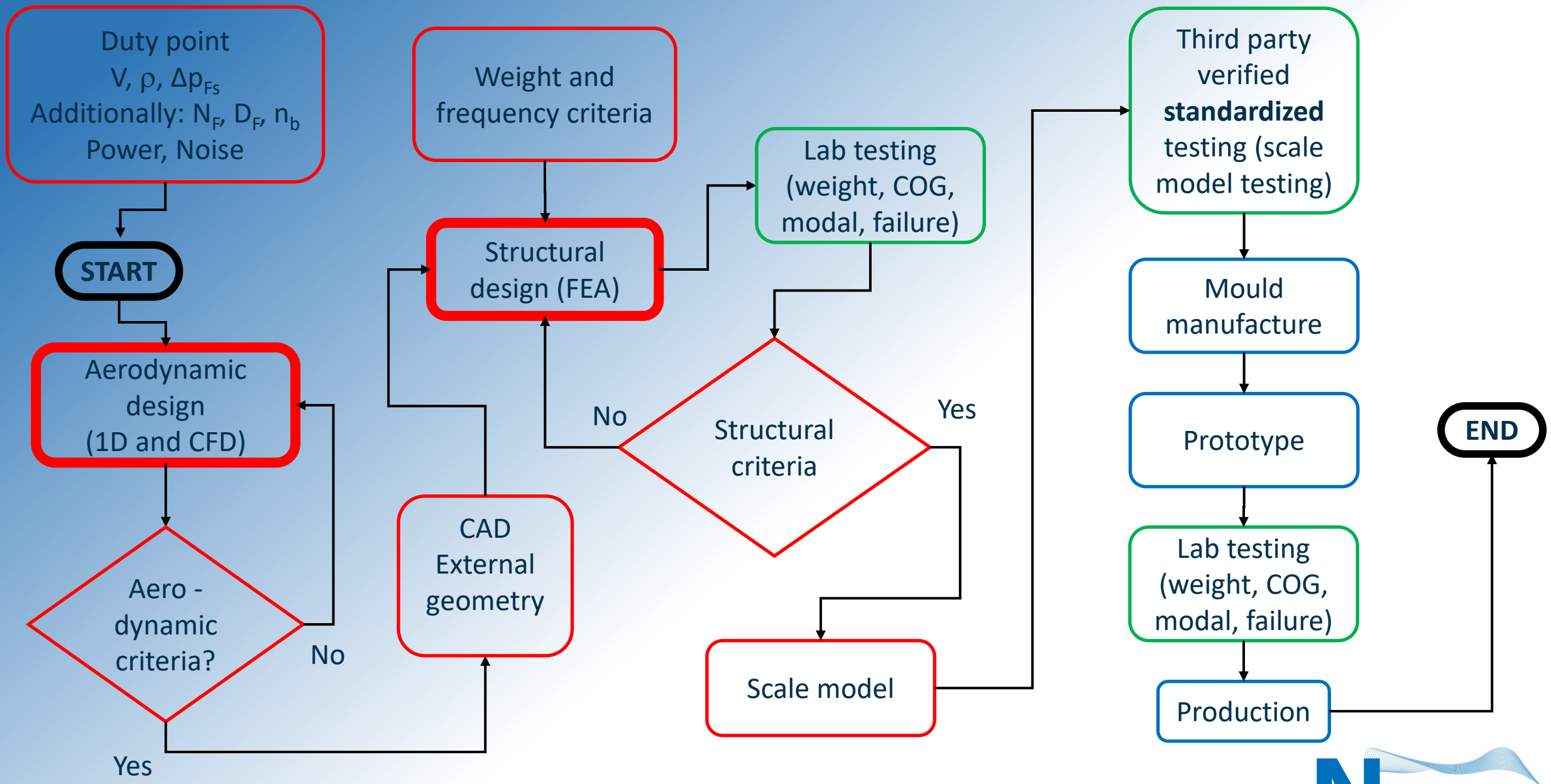
Fan Engineering



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NOTUS Fan Engineering

Innovation in Design - Aerodynamics

- Aerodynamic design pioneered by Prof TW von Backström
- Maximum efficiency

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NOTUS
Fan Engineering

Maximum Efficiency – Swirl Velocity, c_θ

- Swirl – tangential velocity

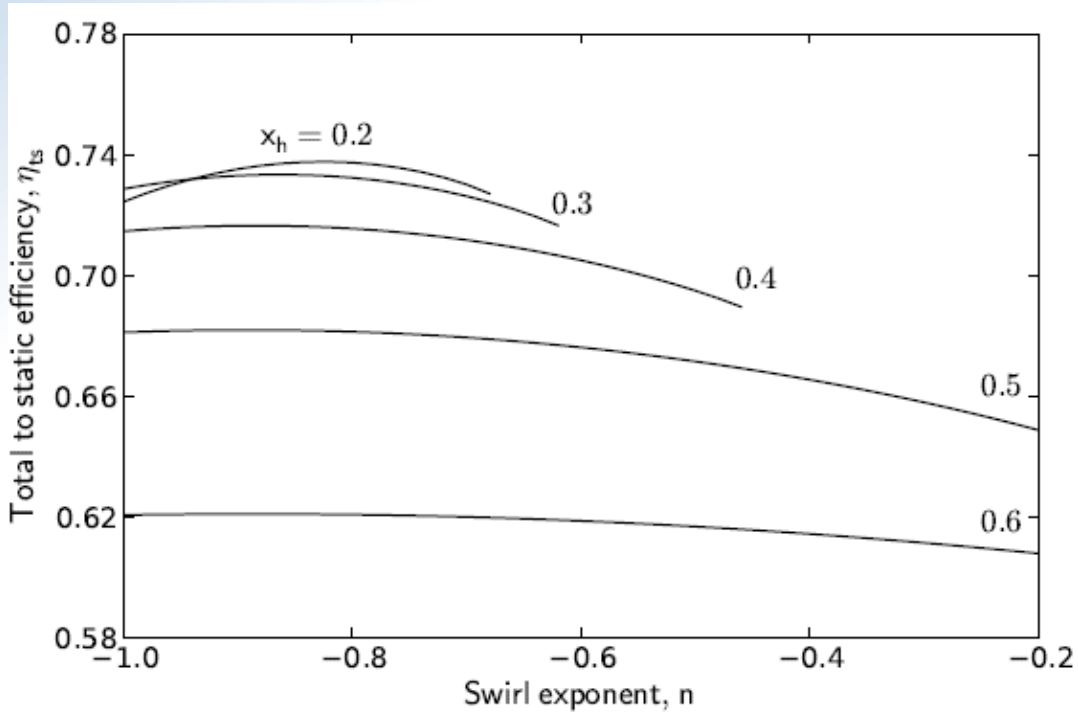
Δpressure = function(Δswirl)

  - Inlet – no swirl, $c_{\theta 1} = 0$
  - Outlet – $c_{\theta 2}$, value of "n"

- Axial flow = function($c_{\theta 2}$)
- Choice of "n" and hub-to-tip ratio determines efficiency
- It is ALL connected
- n ~ -1

$$c_{\theta_2}(r) = ar^n$$

$$c_{x_2}(r) = \sqrt{2a\Omega(r^{n+1} - r_h^{n+1}) - R(r)a^2(n+1) + c_{x_2}^2(r_h)}$$



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OTUS
Fan Engineering

Innovation in Design - Aerodynamics

- Aerodynamic design pioneered by Prof TW von Backström
- Maximum efficiency
- Uniform axial flow through fan

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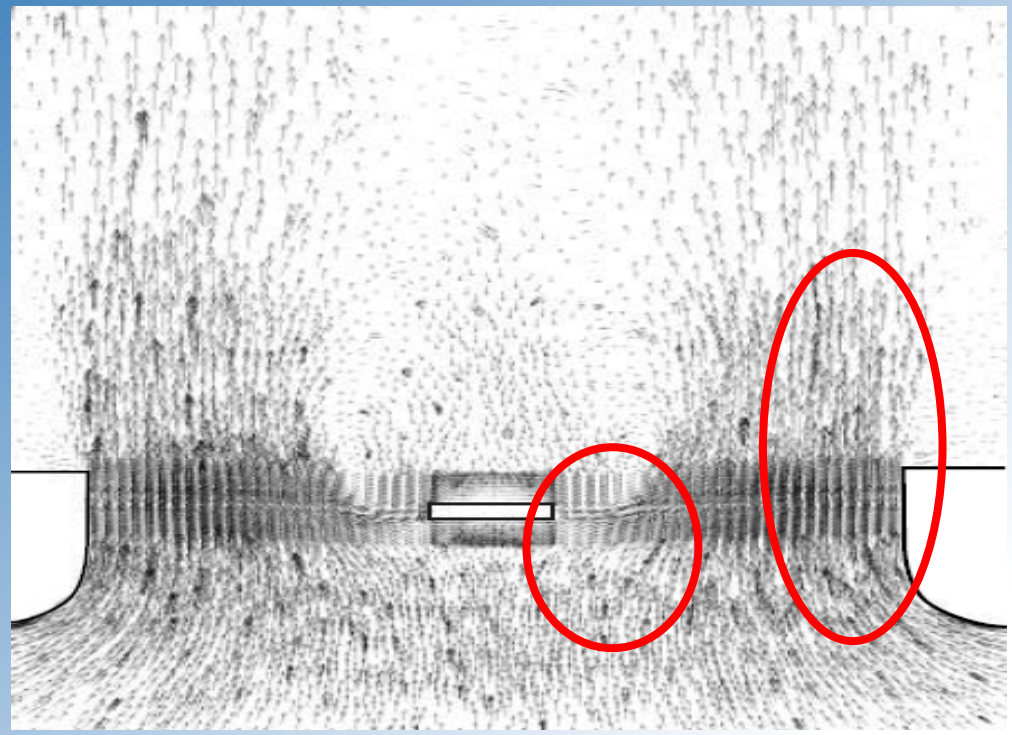
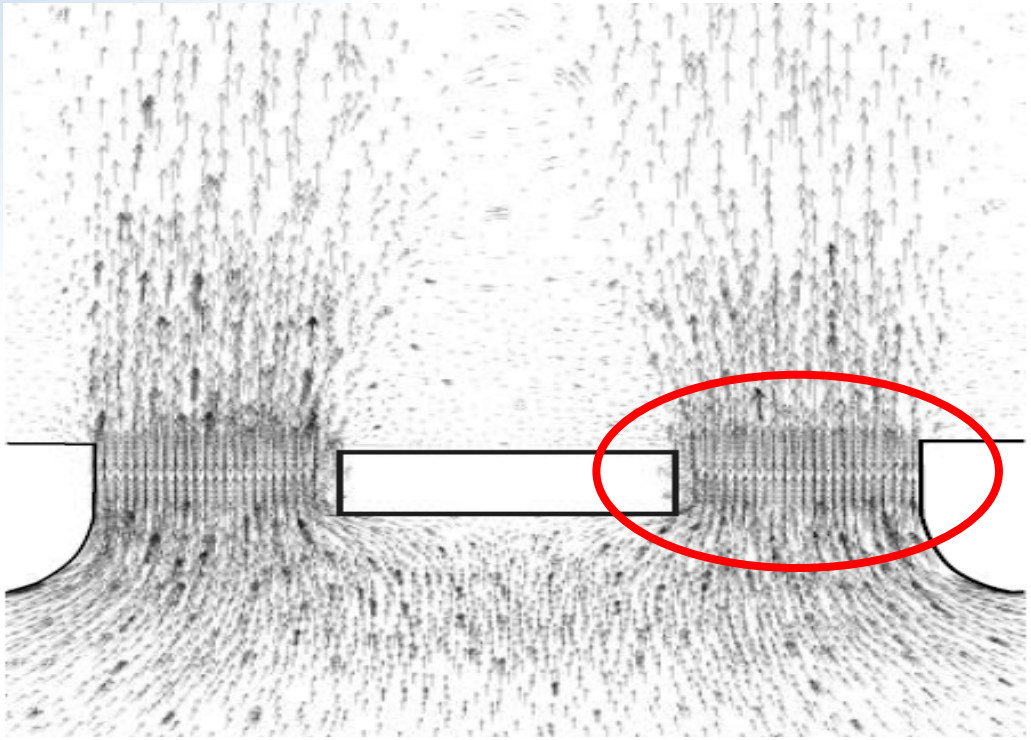
Fan Engineering

Uniform Axial Flow Velocity

Small hub-to-tip ratio



Notus Fan



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NOTUS
Fan Engineering

Innovation in Design - Aerodynamics

- Aerodynamic design pioneered by Prof TW von Backström
- Maximum efficiency
- Uniform axial flow through fan
- Hub-to-tip ratio crucial
  - Duty-point specific
  - Crucial for efficiency
  - “Large” hubs relative to industry – manufacturing challenges

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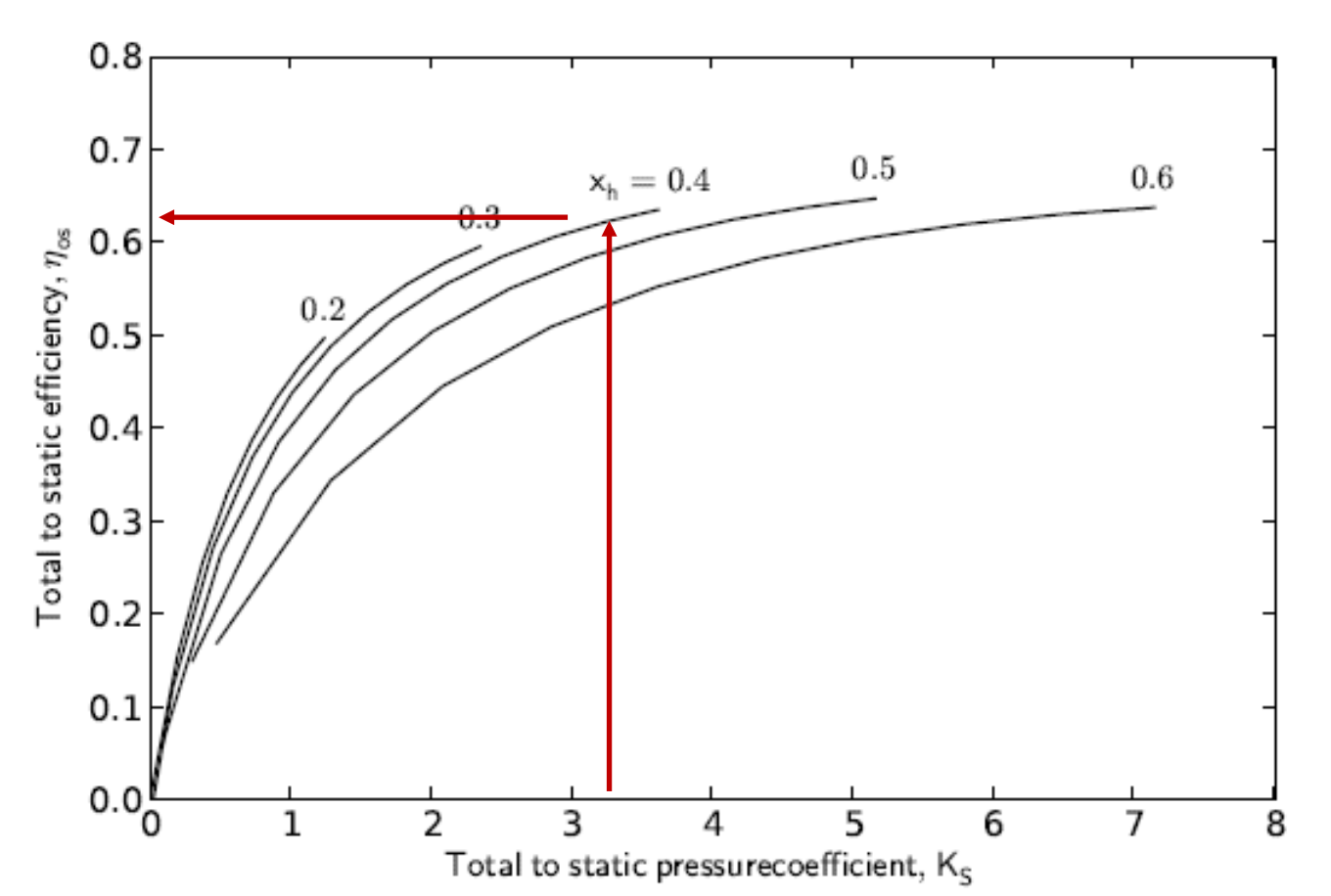
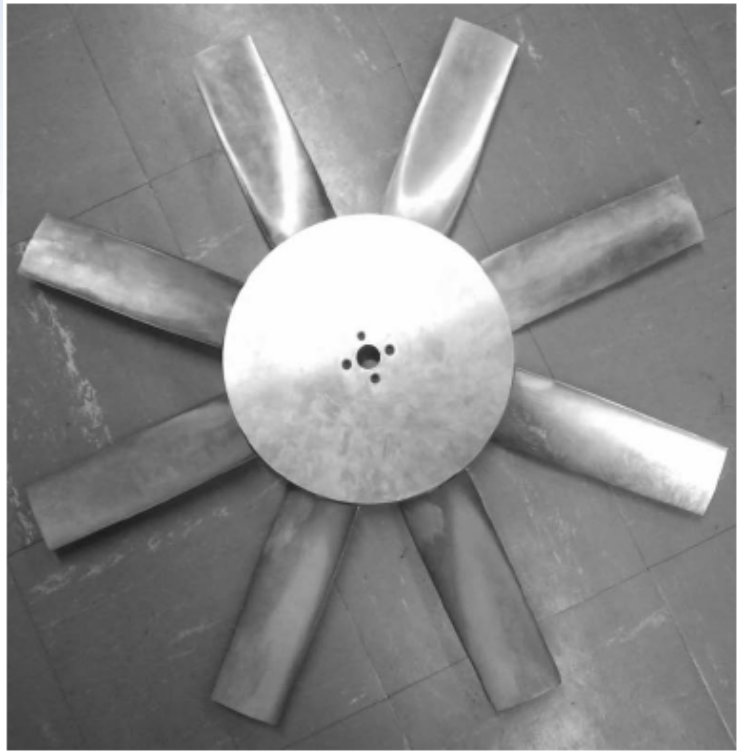
NOTUS Fan Engineering

Hub-to-tip ratio





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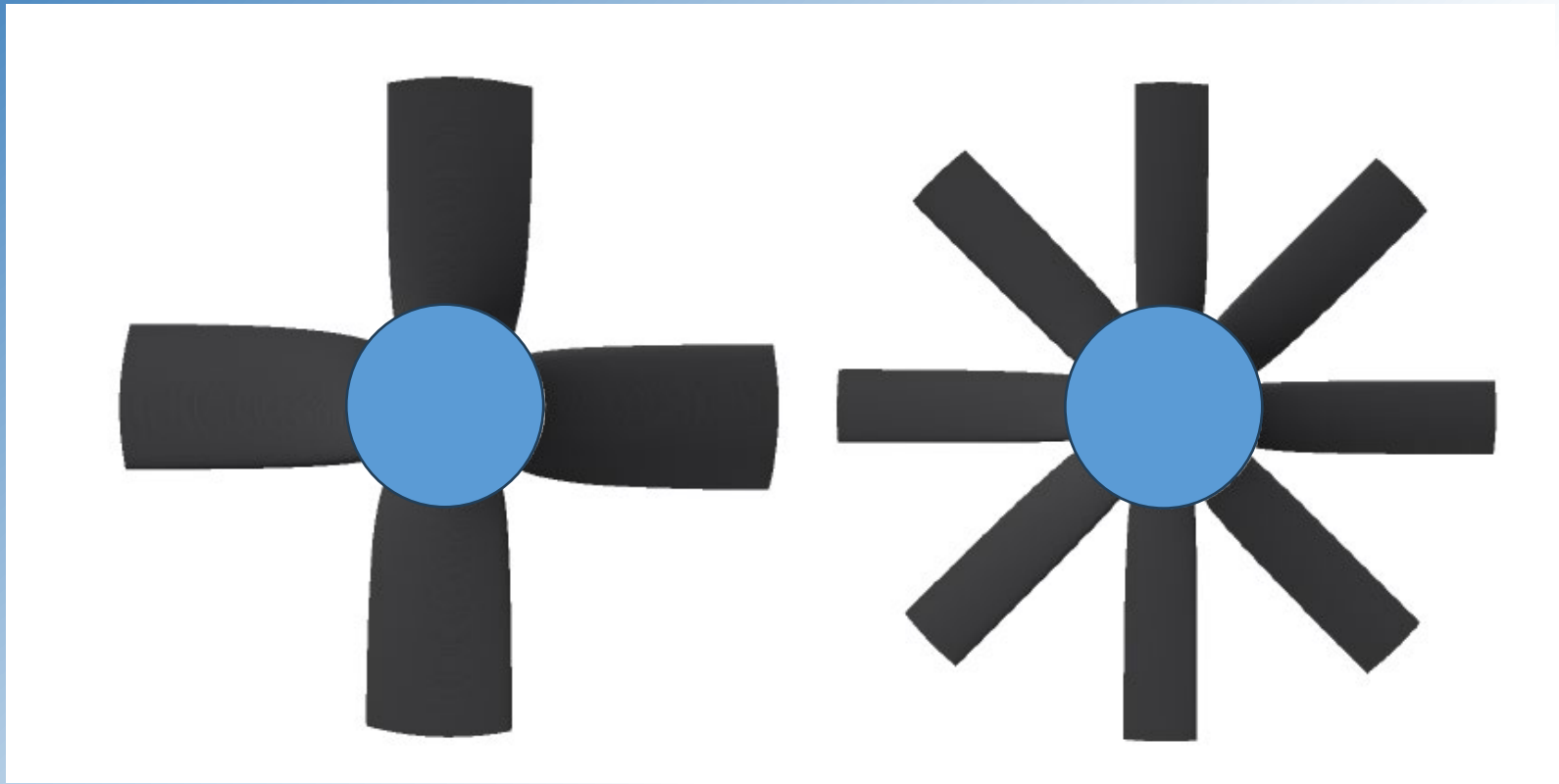
Unique Possibilities



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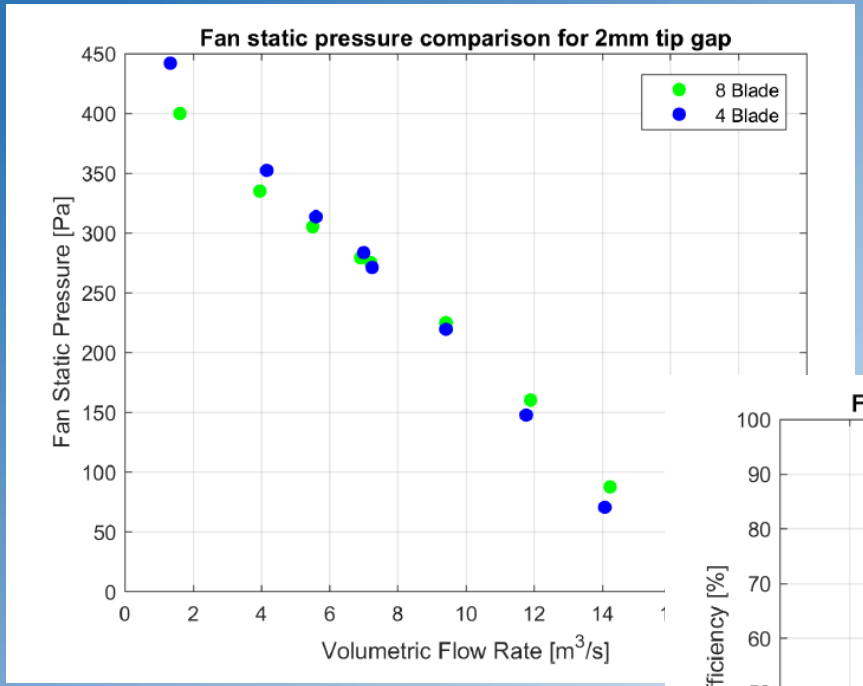
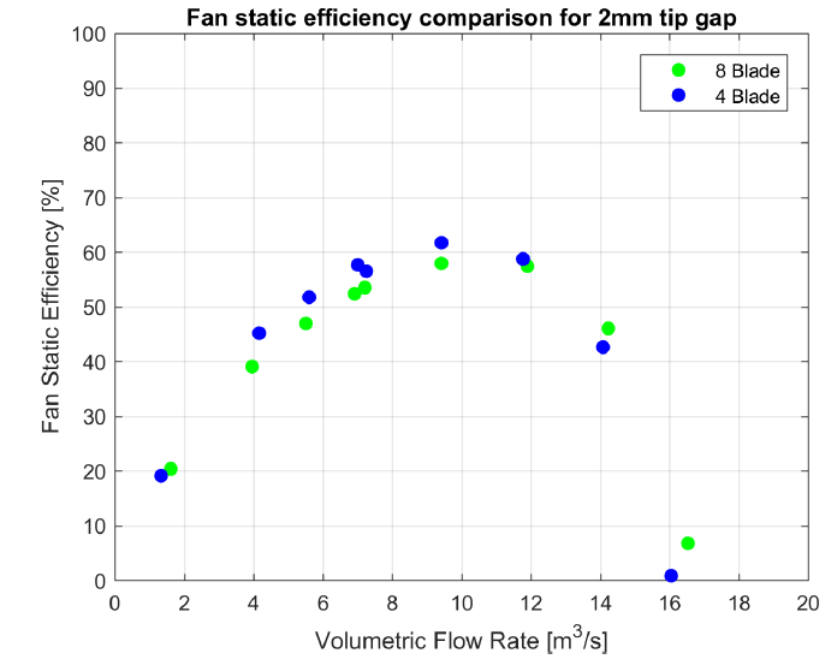
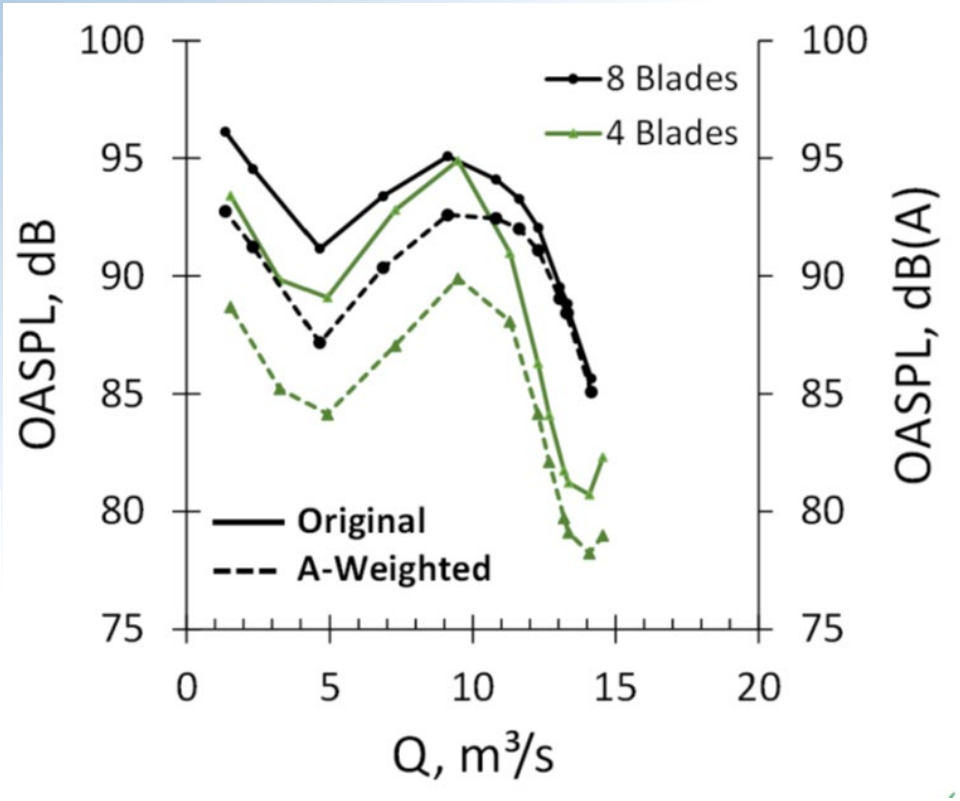
Unique Possibilities







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NOTUS Fan Engineering

Innovation in Design - Aerodynamics

- Aerodynamic design pioneered by Prof TW von Backström
- Maximum efficiency
- Uniform axial flow through fan
- Hub-to-tip ratio crucial
  - Duty-point specific
  - Crucial for efficiency
  - “Large” hubs relative to industry – manufacturing challenges
- Fan performance characteristics – coded fan test facility at model scale

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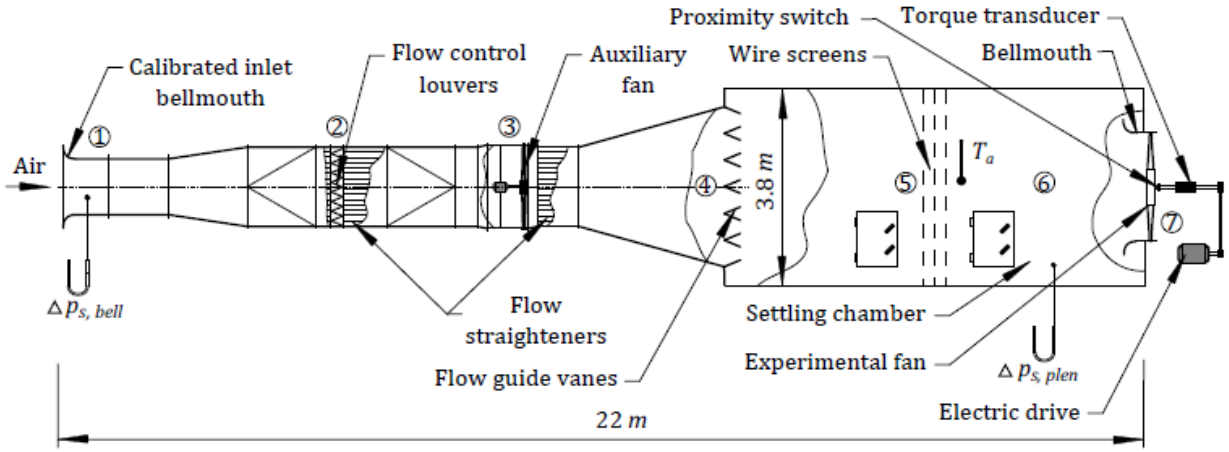
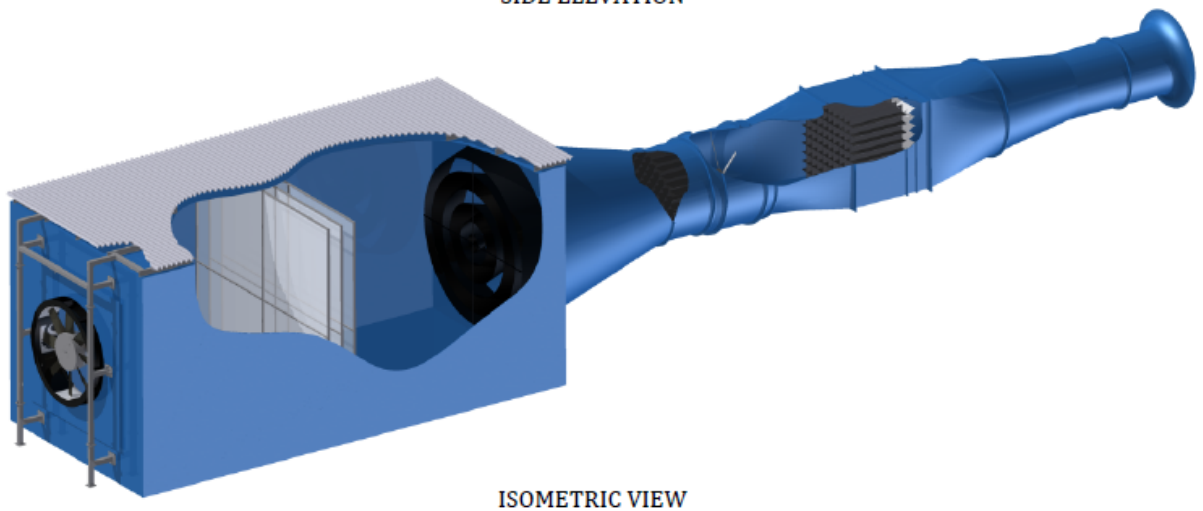
Scale model tests – ISO5801



SIDE ELEVATION



ISOMETRIC VIEW

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Innovation in Structural Design

- Aerodynamic design yields geometry of fan blades
- Structural design is from the skin, “inwards”
- Design philosophy

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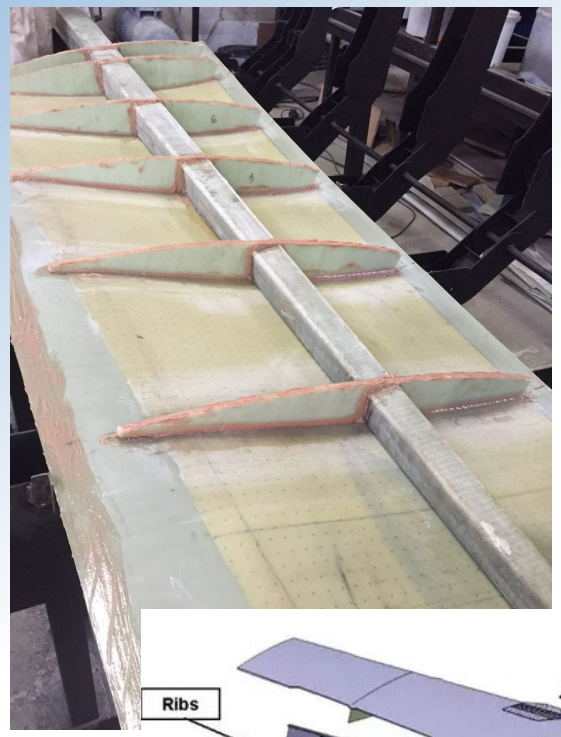
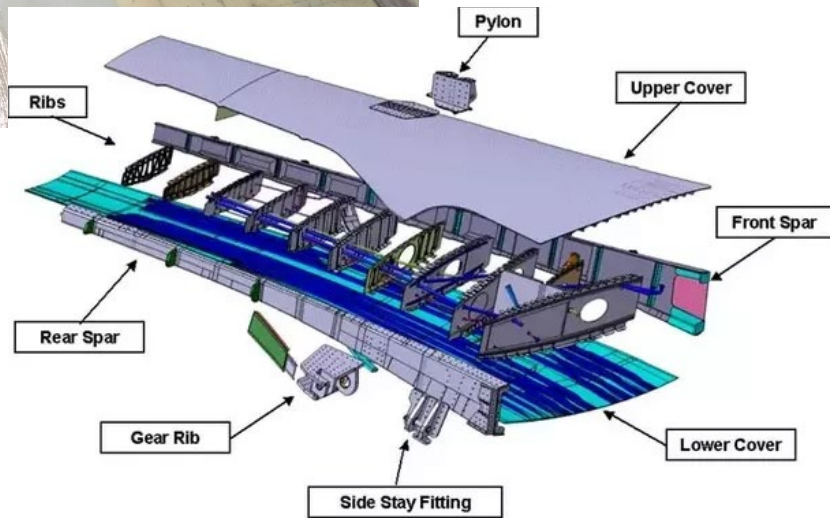
Design Philosophy

- Borrows from aircraft wing design
  - Monocoque designs lead to blades splitting
  - Spar – very stiff and takes up combined load
  - Skin – “flexible” and only resists LOCAL aerodynamic forces
- Natural frequencies can be “tuned” to avoid resonance





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Innovation in Structural Design

- Aerodynamic design yields geometry of fan blades
- Structural design is from the skin, “inwards”
- Design philosophy
- Extensive use of FEA
  - Strength of blades
  - Frequency response of blades

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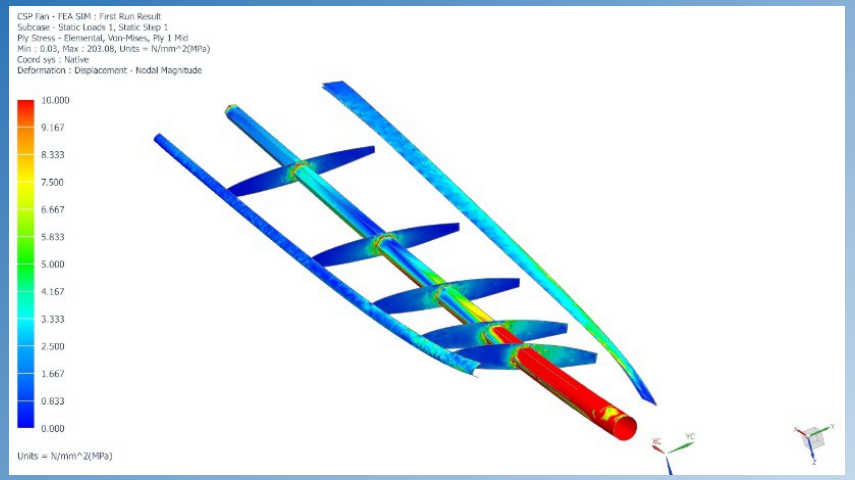
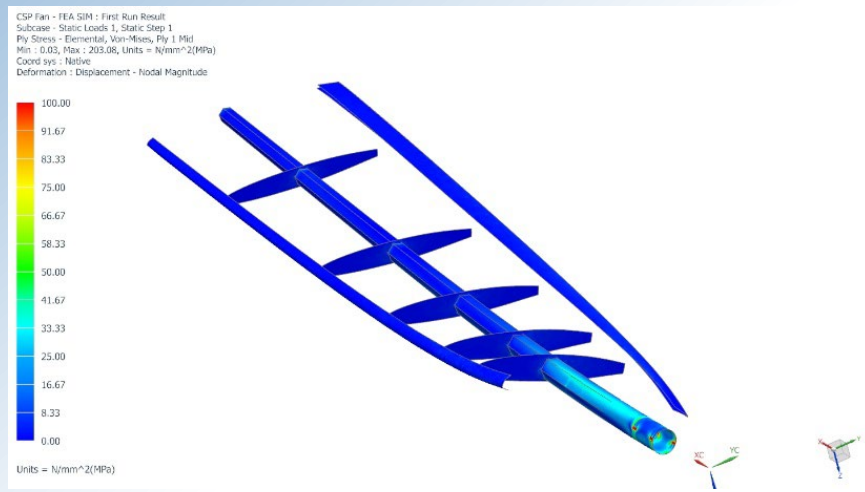
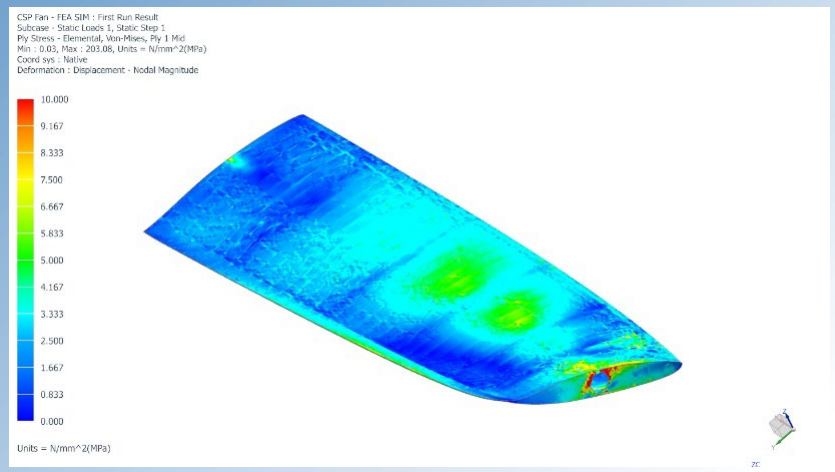
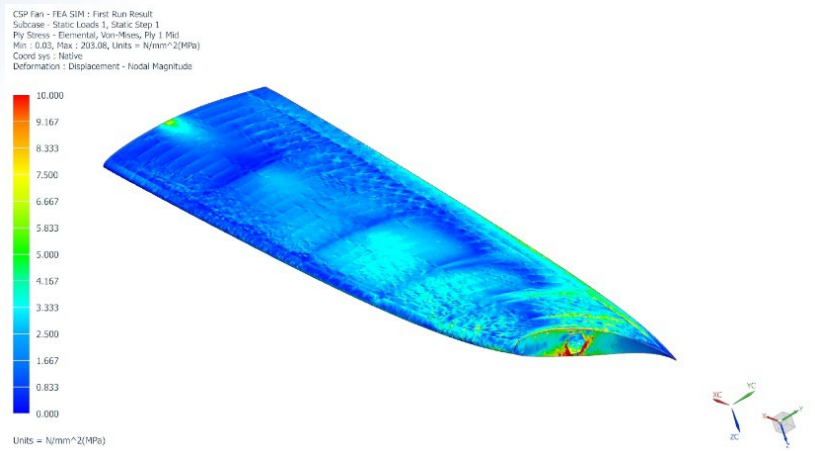
FEA – Finite Element Analysis









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Fan Engineering

Innovation in Structural Design

- Aerodynamic design yields geometry of fan blades
- Structural design is from the skin, “inwards”
- Design philosophy
- Extensive use of FEA
  - Strength of blades
  - Frequency response of blades
- Structural testing of prototype blade
  - Modal for frequency response
  - Failure test – safety factor

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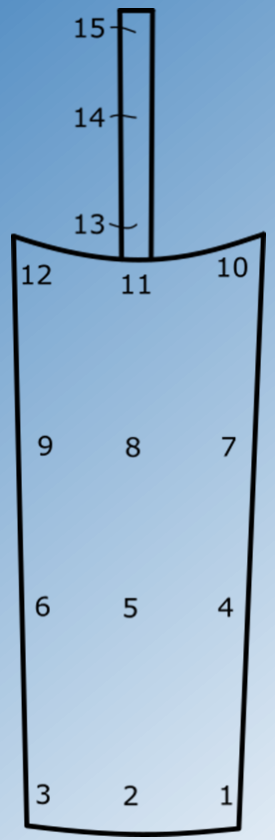
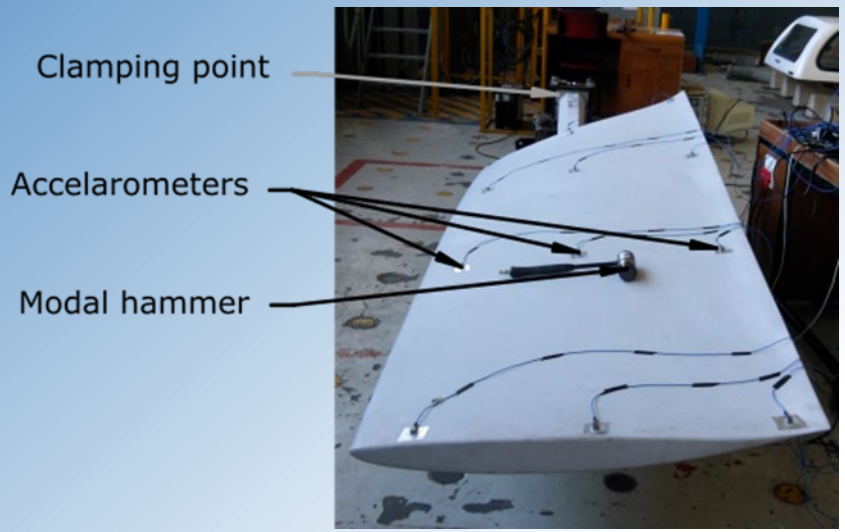
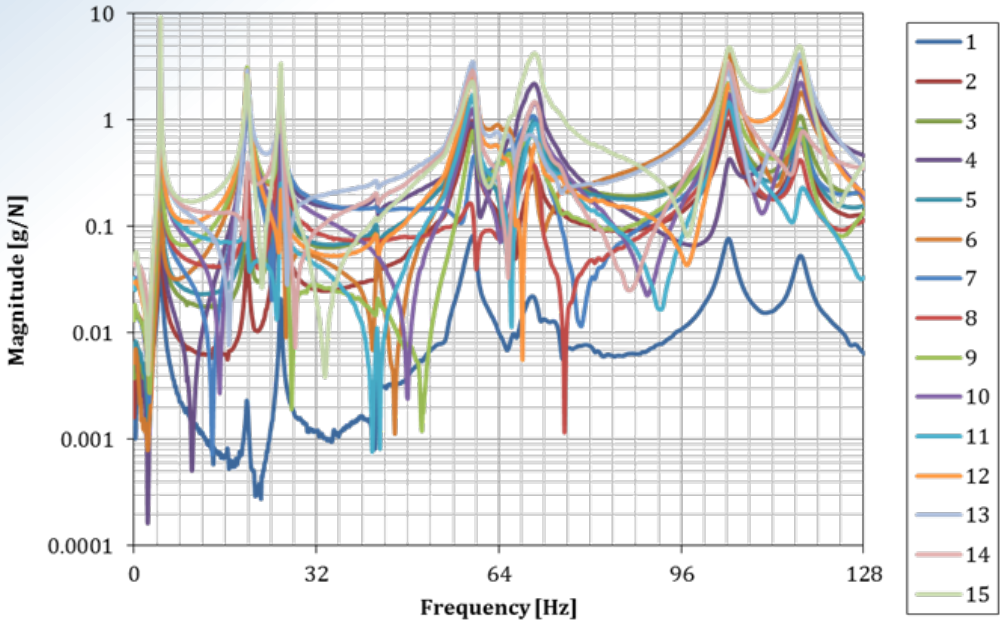
Modal Analysis – Frequency Response







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Strength Test to Failure

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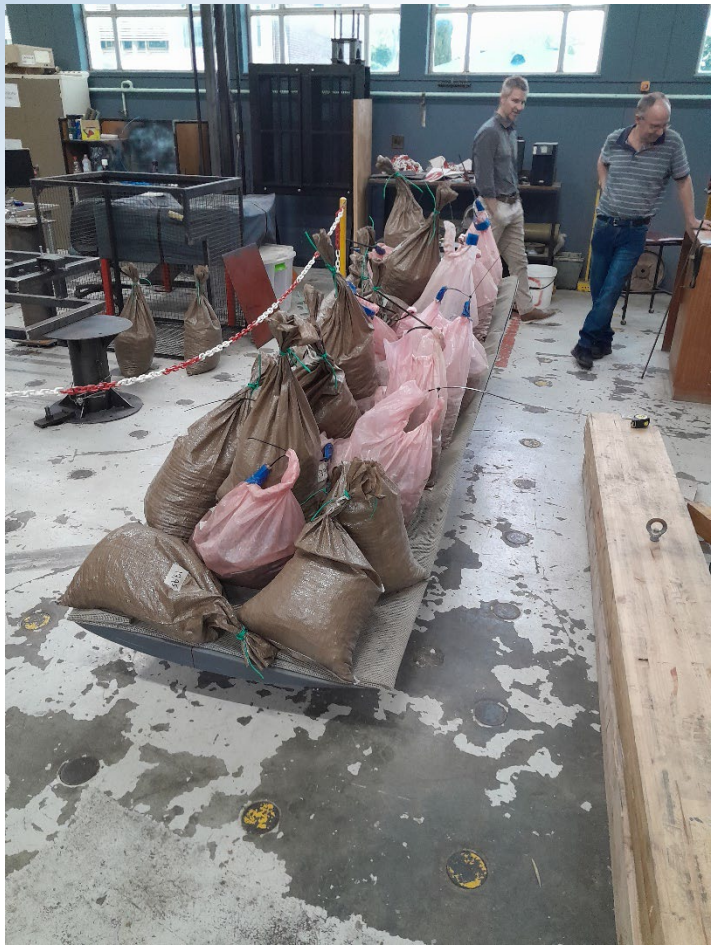
Strength Test to Failure …… sometimes



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Strength Test to Failu…. sometime

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Innovation in Manufacture

- Requirements
- Construction
- Resin Infusion
- Results

"Scientists dream about doing great things. Engineers do them." – James A. Michener

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Requirements for Manufacture

- No corrective balancing or pairing of blades
- Light weight (50% reduction in weight at Matimba Power Station)
- Blade weights must be within 1% of average blade weight
- CoG must be within 1% of average CoG of blades
- Natural frequencies must be the same
- Natural frequencies must avoid “danger zone”

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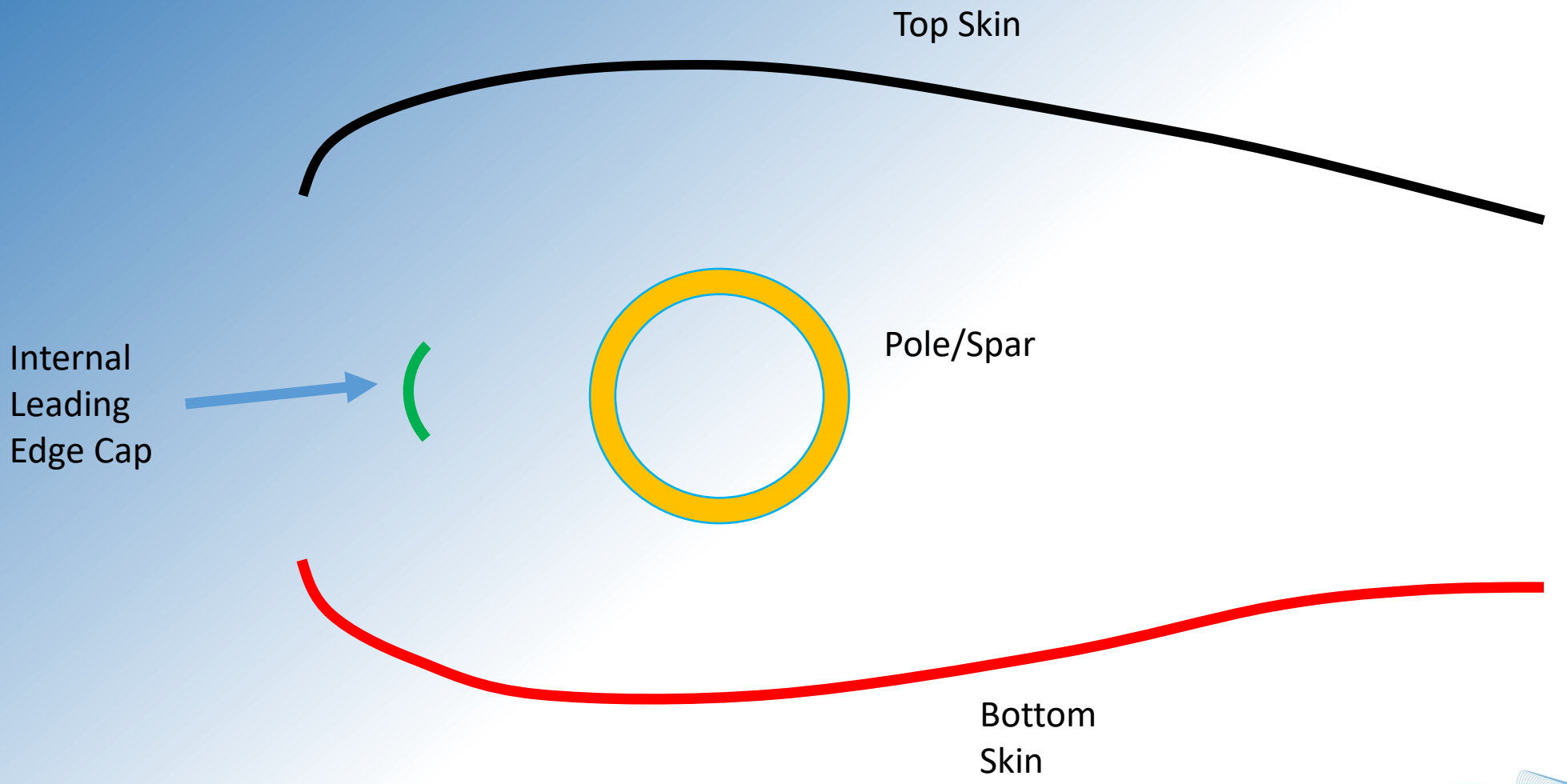
Construction



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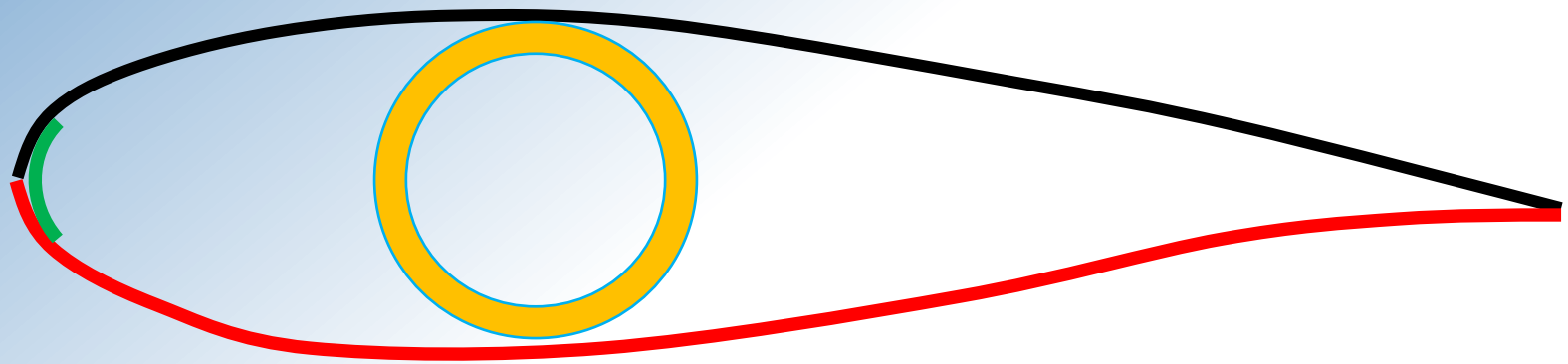
Construction



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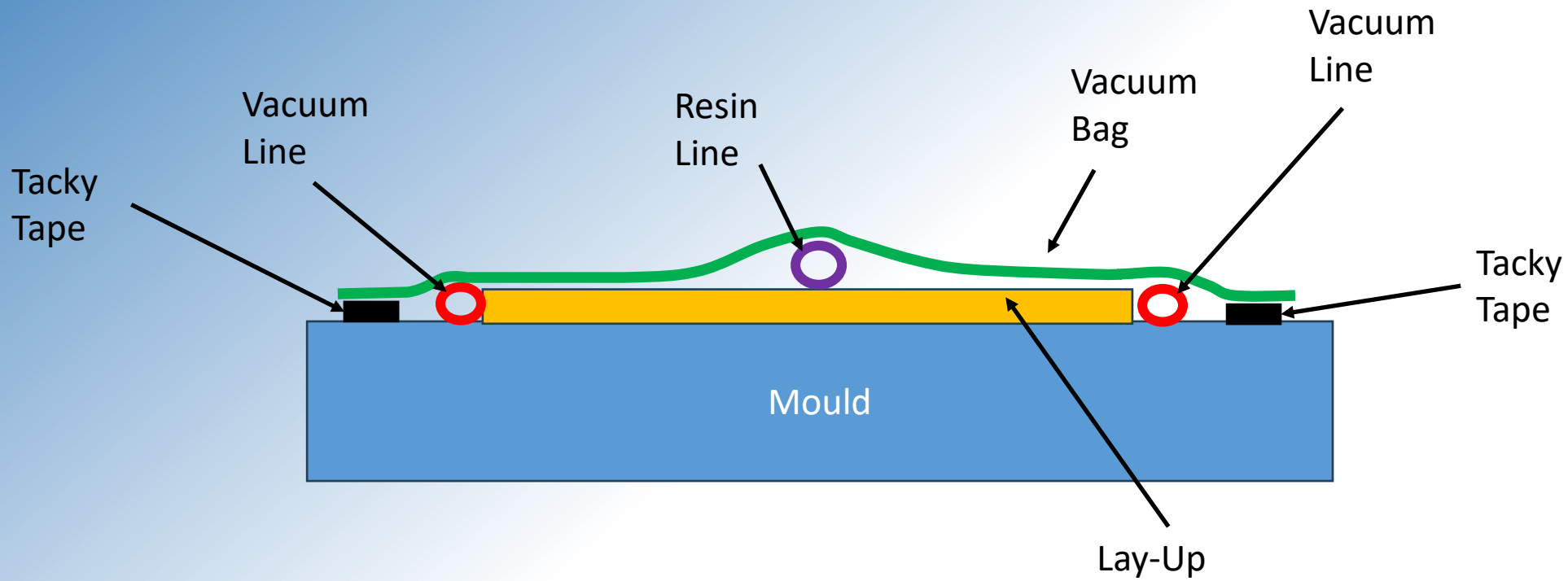
Resin Infusion - Conventional



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Resin Infusion - Conventional

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Resin Infusion - Conventional

Vacuum Line

Resin Line

Vacuum Line

Fixing Leaks

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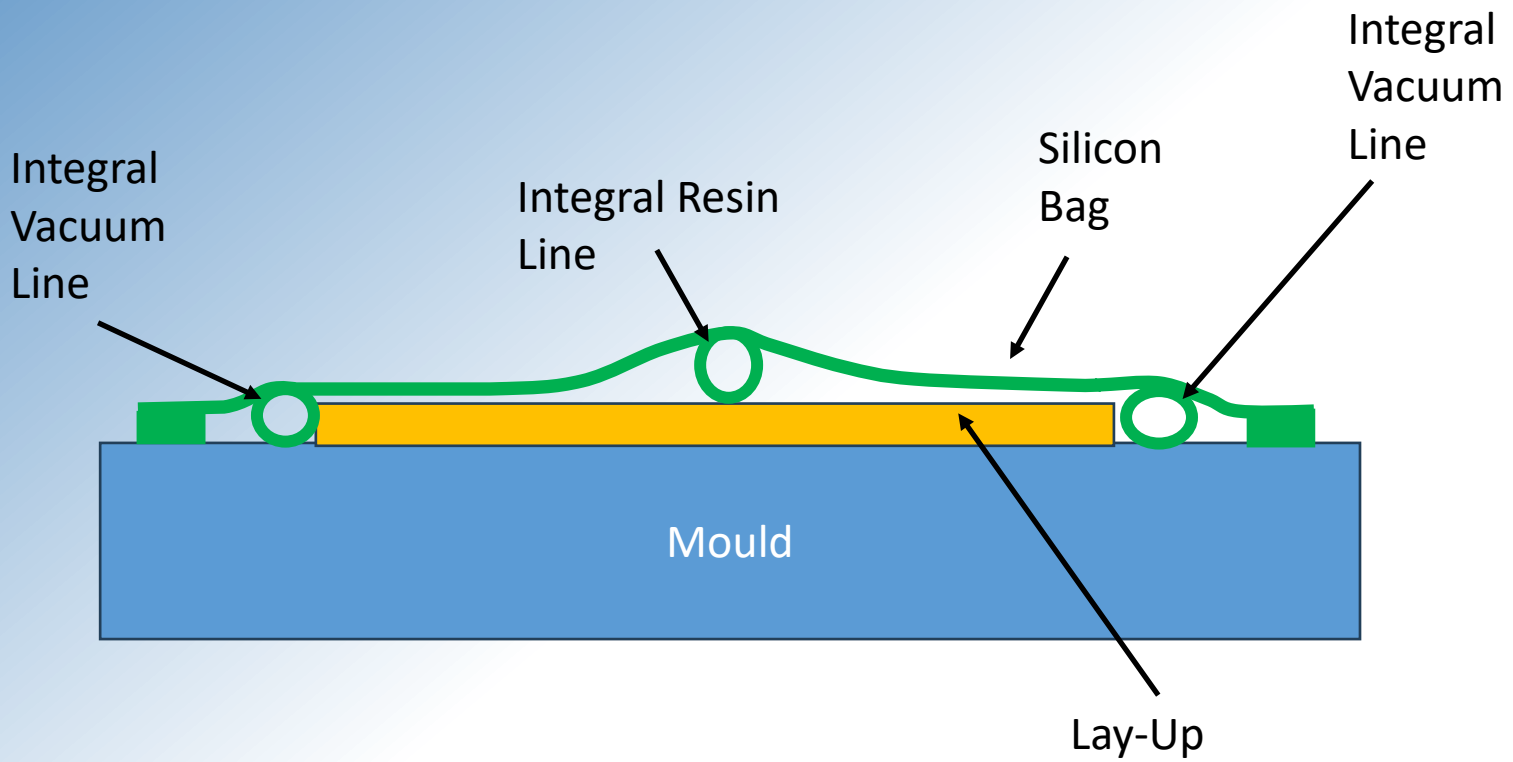
Resin Infusion – Silicon bag



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Resin Infusion – Silicon bag

- Reduces set-up time from over 2 hours to less than 5 minutes
- Removes vacuum leaks completely
- Infuses faster
- Infuses with high accuracy (morphs)
- Reduces consumables dramatically
- Reduces waste to near-zero levels

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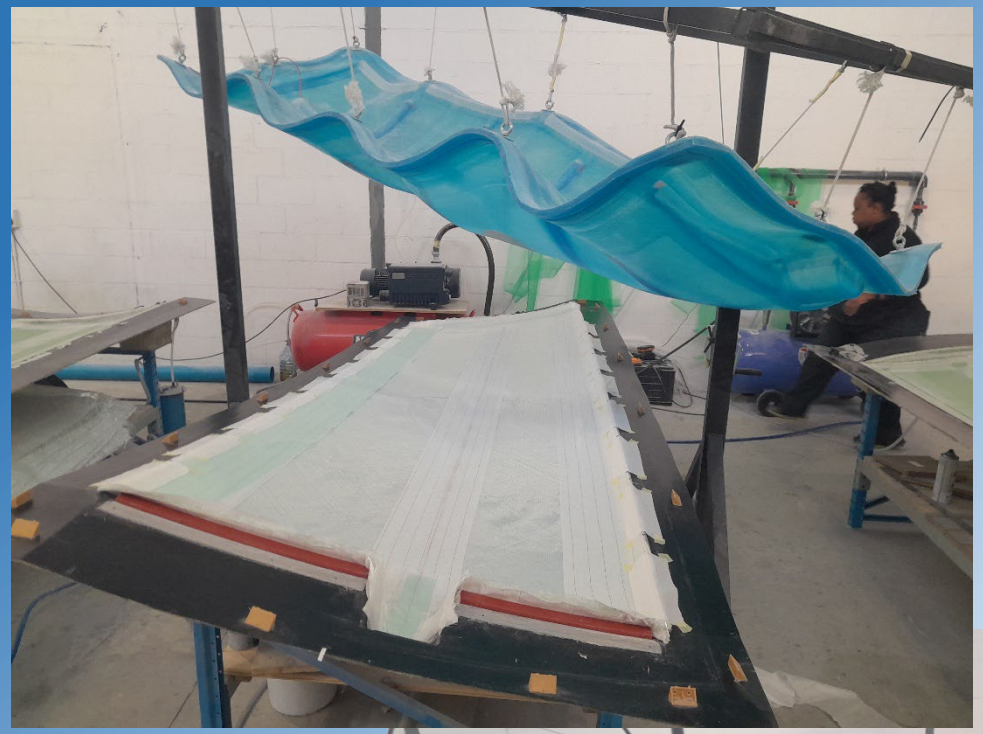

s do them." – James A. Michener

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Fan Engineering

Matimba Retrofit, Unit 6

- 6 x 665 MW
- ACC – 288 fans (48/unit)
- Gearbox failures due to fans operating in resonance
- Unit 6 – vulnerable to wind
- Supply 48 + 1 fans
- Production
  - 1 fan per week
  - 200 m^2 workshop space
  - 1 x high level technician
  - 8 x laborers

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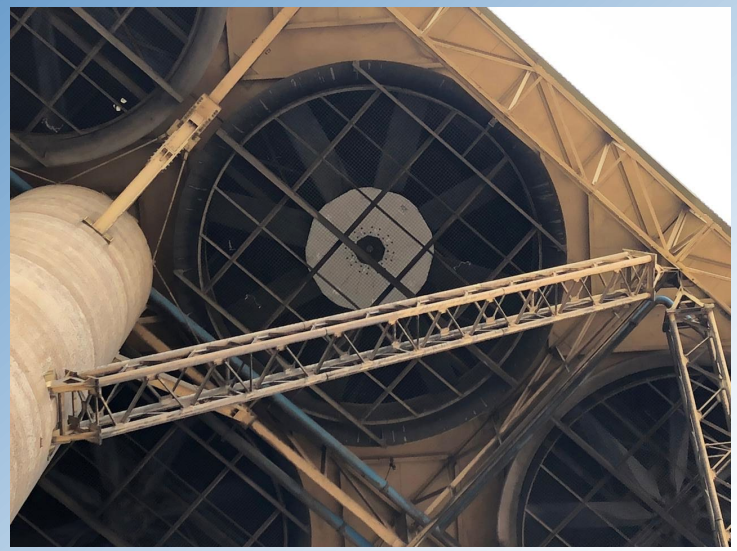

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NOTUS
Fan Engineering

Why Notus fans?

The Partners

Kelvion Holding GmbH
Germany
www.kelvion.com

Kelvion Thermal Solutions (Pty) Ltd
South Africa
www.kelvion.com

Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., Fraunhofer Institute for Solar Energy Systems ISE
Germany
www.ise.fraunhofer.de

Universita degli studi di Roma „La Sapienza"
Italy
www.uniroma1.it

ECILIMP TERMOSOLAR S.L.
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www.ecilimp.com

Stellenbosch University
South Africa
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Notus Fan Engineering
South Africa
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ENEXIO Germany GmbH
Germany
www.enexio.com

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Steinbeis Innovation gGmbH
Steinbeis-Europa-Zentrum
Germany
www.steinbeis-europa.de

Waterleau Group NV
Belgium
www.waterleau.com

The Project

Executive Summary

MinWaterCSP consortium will address the challenge of significantly reducing the water consumption of CSP plants while maintaining their overall cycle efficiency. Our objective is to reduce evaporation losses and mirror cleaning water usage for small- and large-scale CSP plants through a holistic combination of next generation technologies. Also, comprehensive water management plans for CSP plants in various locations will be developed. The MinWaterCSP consortium aims to make CSP more attractive for investment purposes in order to drive growth in the CSP plant business as well as job creation at European companies.

Duration

36 months (January 2016 – December 2018)

Partner

12 Partners from 6 countries
Belgium, Germany, Italy, Morocco, South Africa, Spain

Contacts

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Kelvion Thermal Solutions (Pty) Ltd
Project coordinator / Technical coordinator
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Minimized water consumption in CSP plants

MinWaterCSP

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 654443

"Scientists dream about doing great things. Engineers do them." – James A. Michener

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H2020 – Vibration Tests

Frequencies		Mode
Blade 1	Blade 2	
[Hz]	[Hz]	
4.63	4.60	1st global bending
19.82	20.02	1st global torsional
25.70	25.68	2nd global bending
59.39	59.02	Local mixed mode (torsion & bending)
70.27	67.30	2st global torsional
5.00	4.96	1st global bending (lag-wise)
42.74	42.27	2nd global bending (lag-wise)

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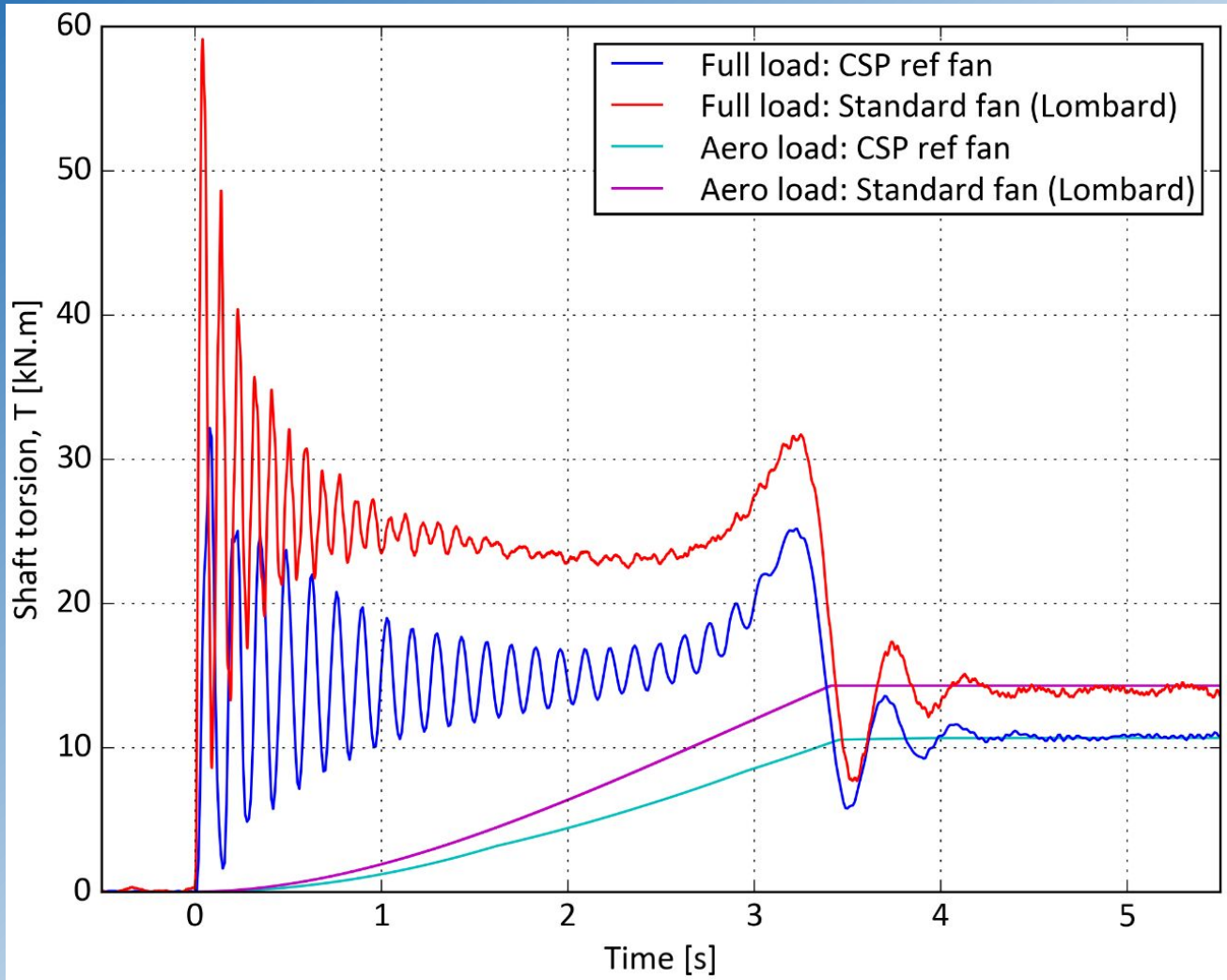
H2020 – Start-up and Running Torque



- Volume flow rates of both fans are similar
- Significant reduction in peak start-up torque: ±50%
- Running torque reduced by 20%

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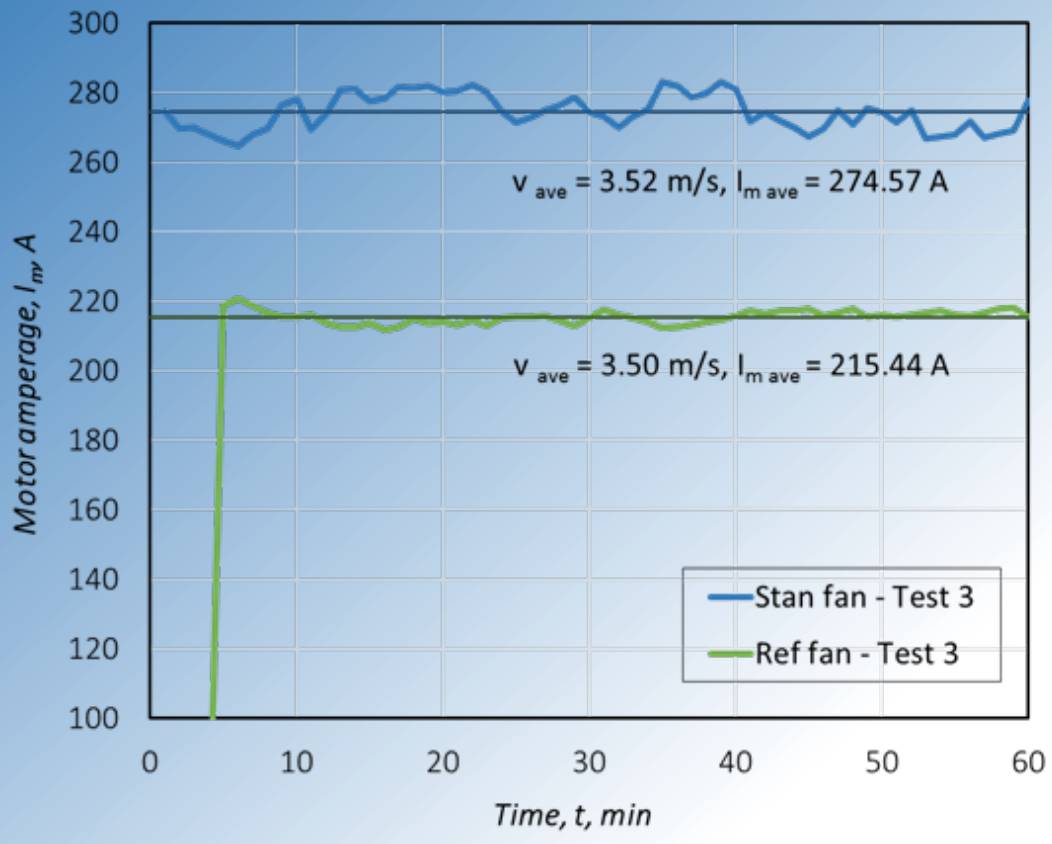
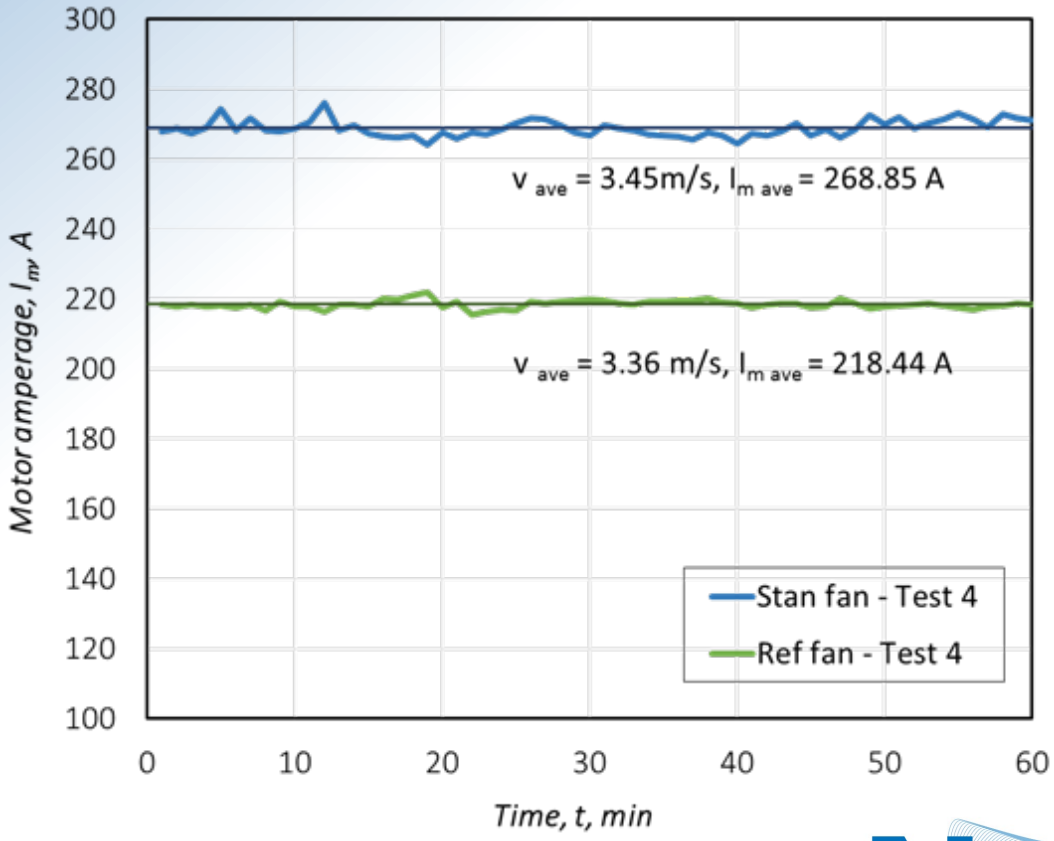
H2020 – Power Draw Reduction (20%)





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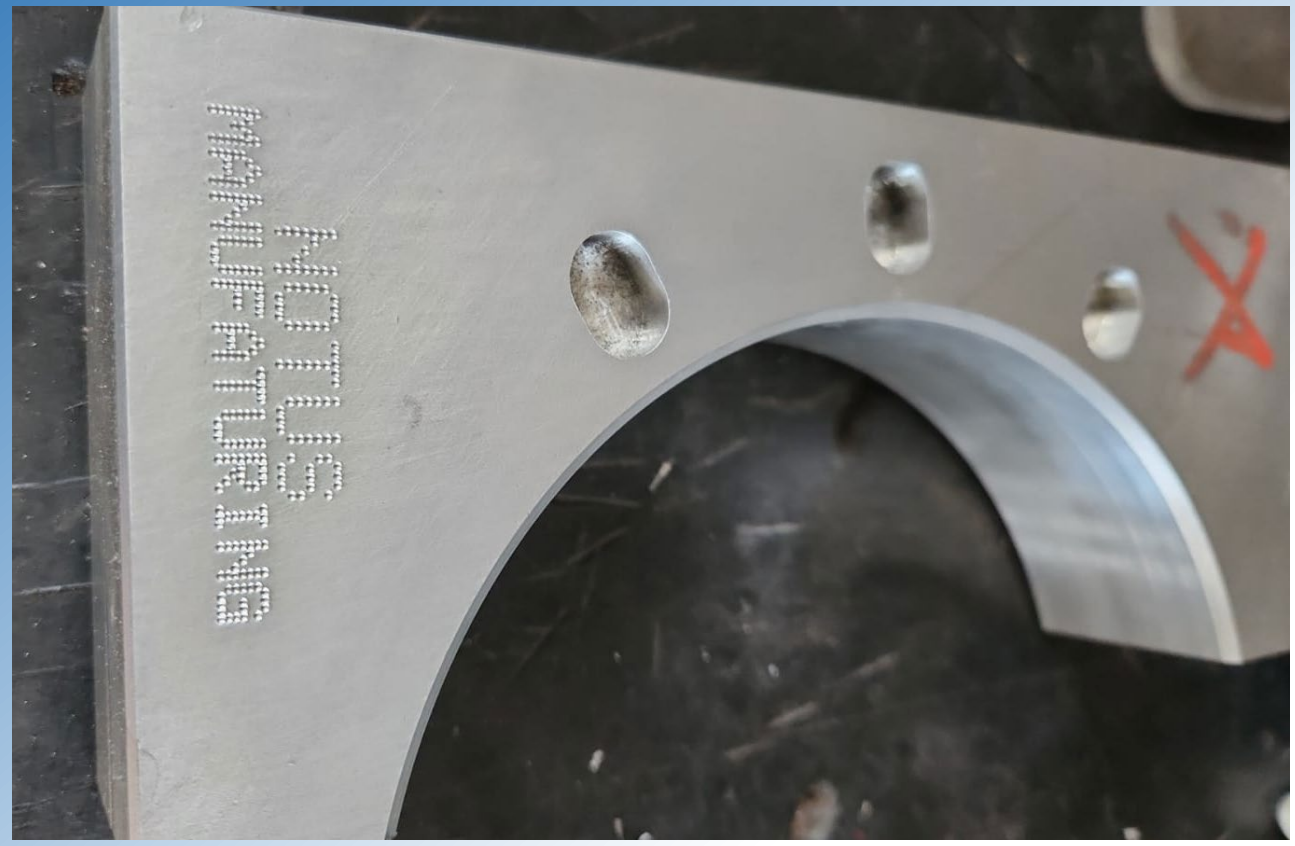
Indexing System



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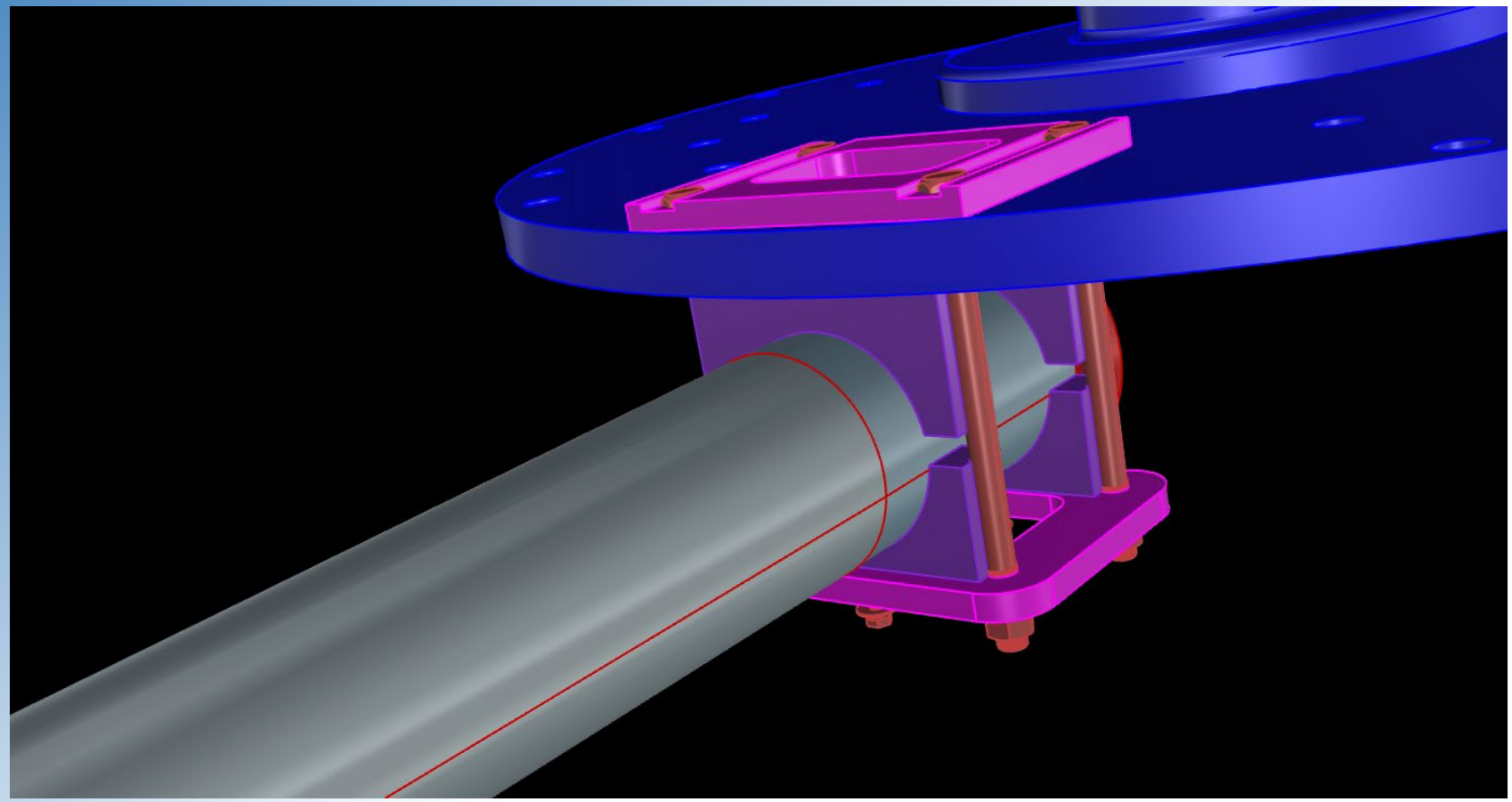
Indexing System



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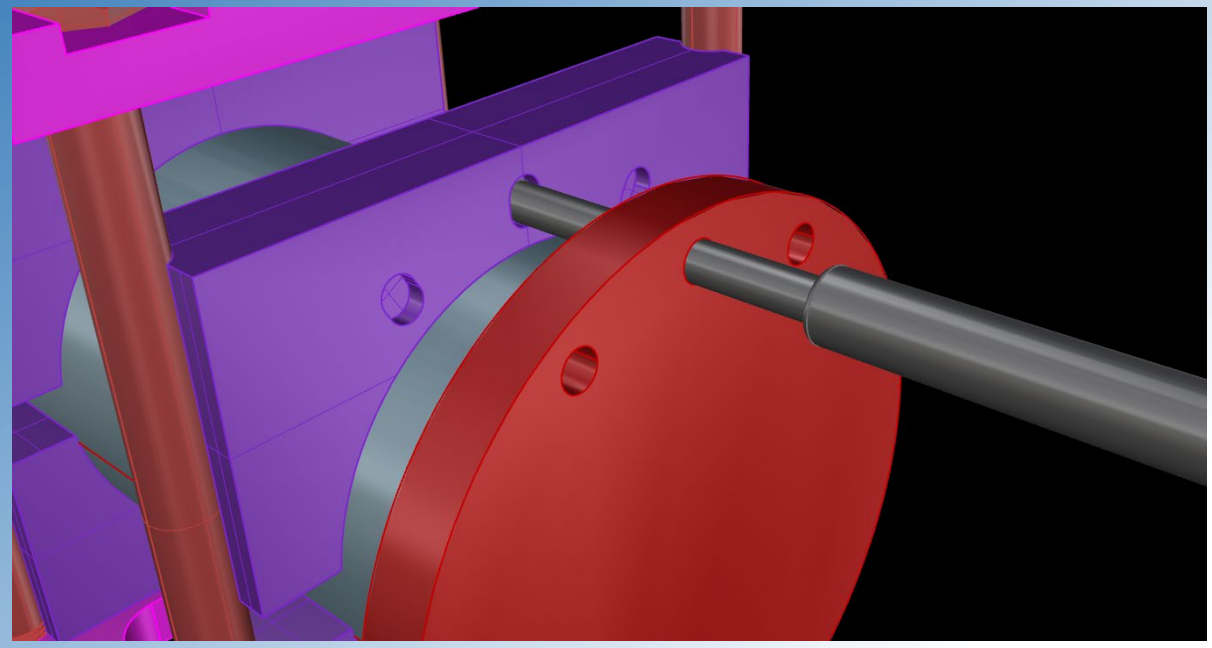

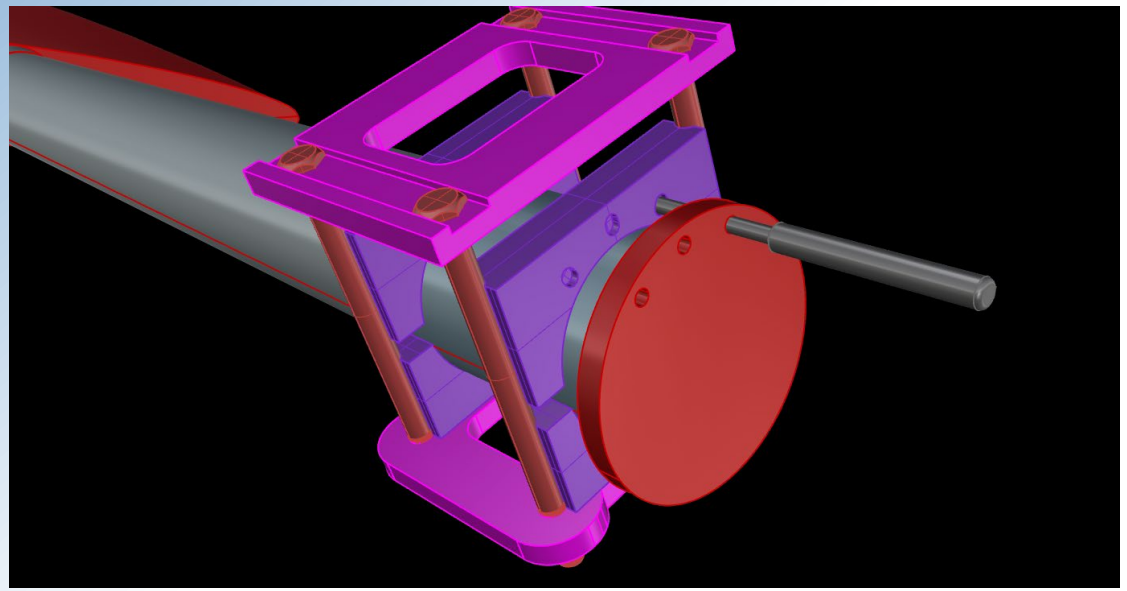

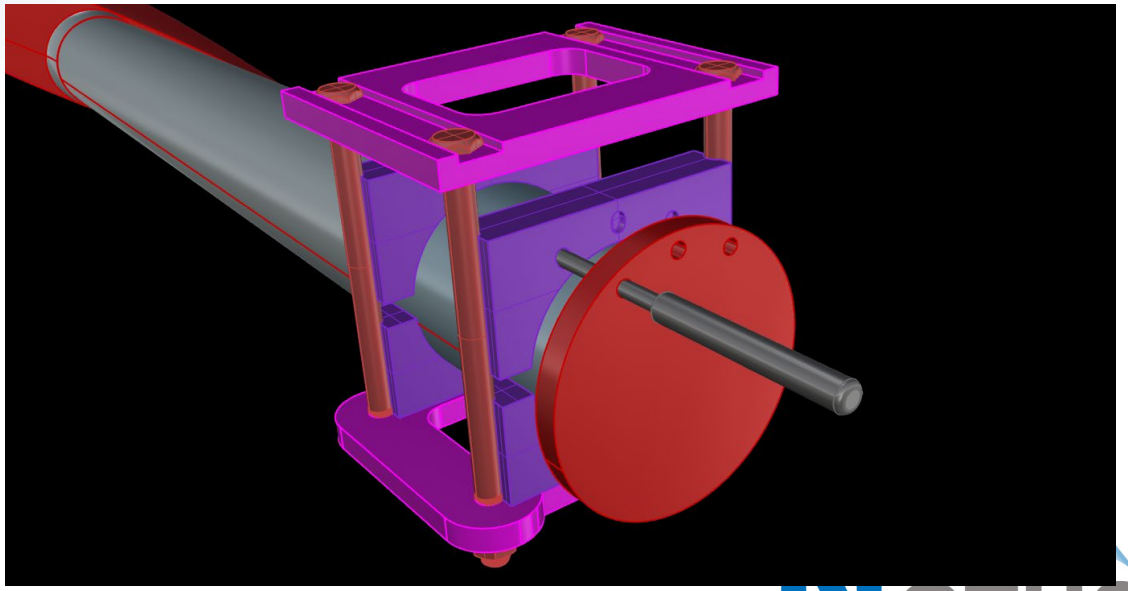

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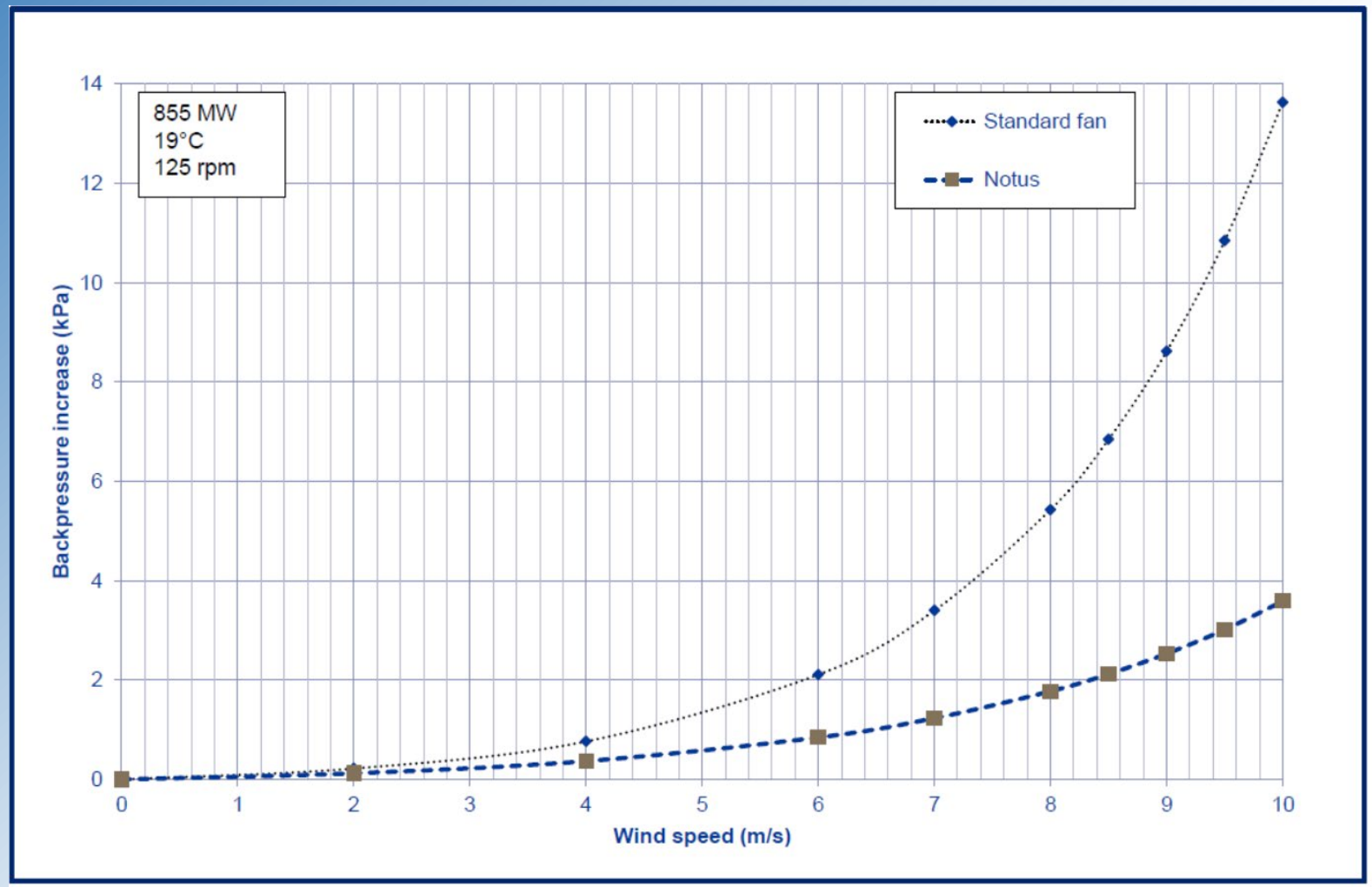
H2020 – Back Pressure Prediction (Eskom)



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THANK YOU !!!

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