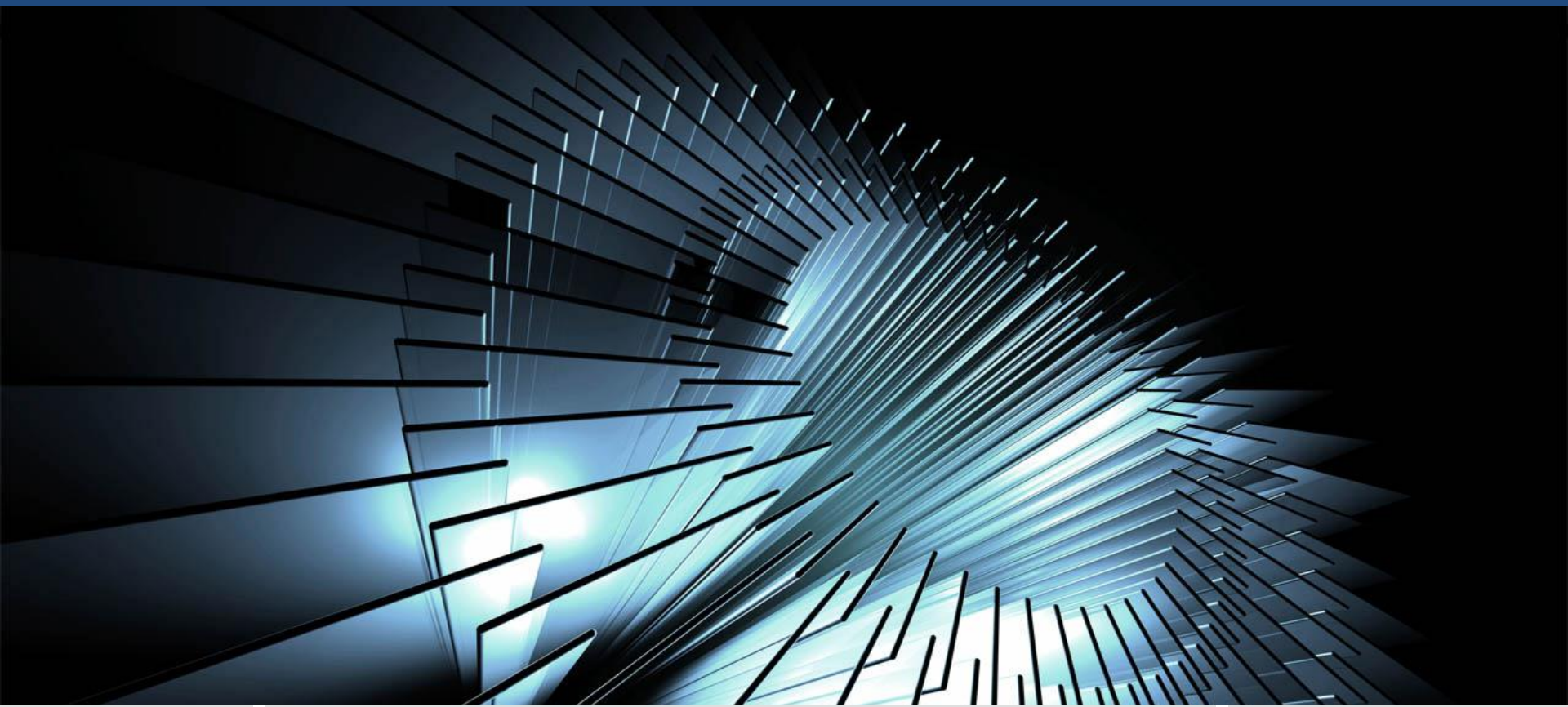


2012

5. Dresdner Probabilistik Workshop

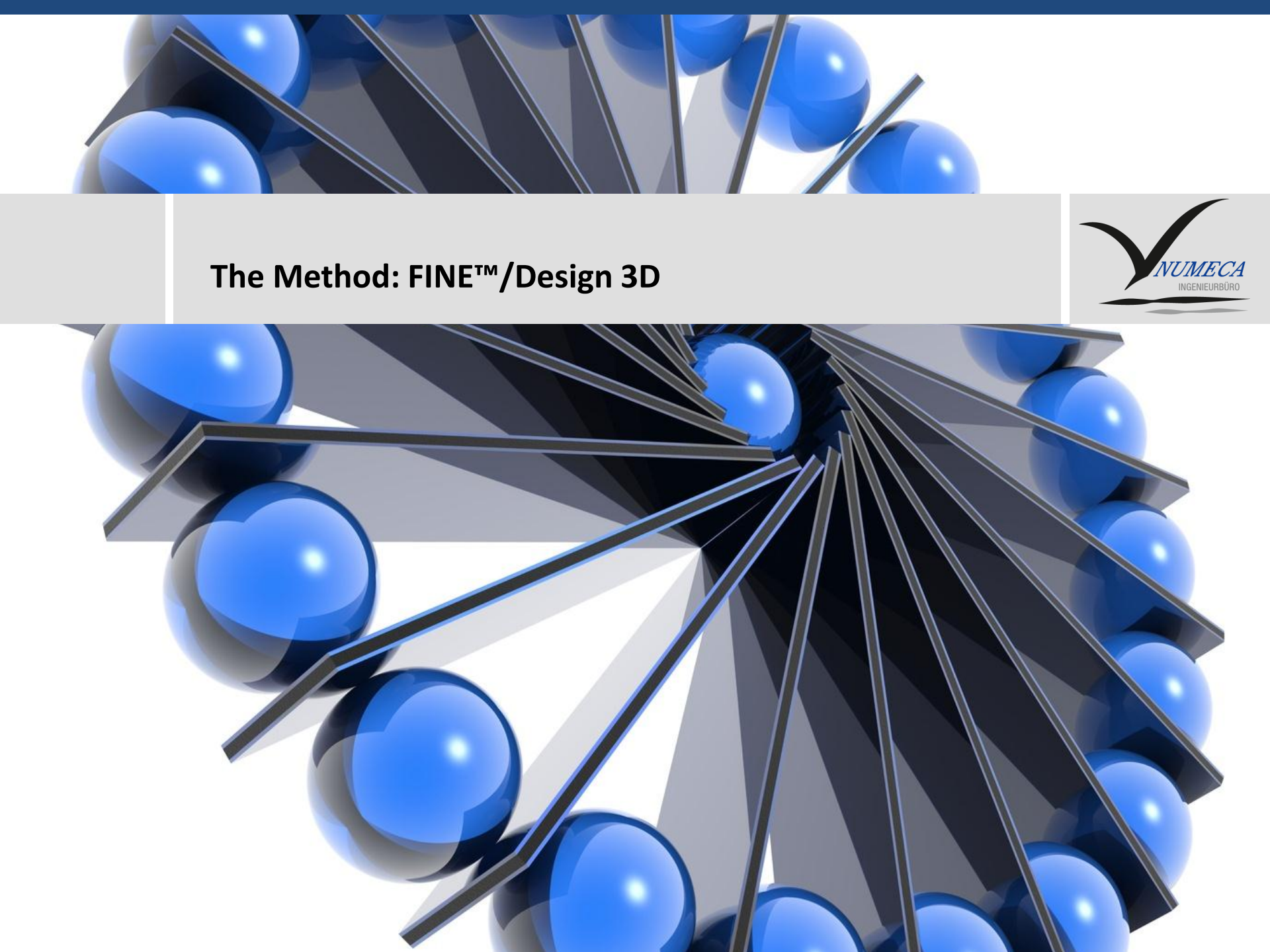
"Optimisation of Industrial Fans Using NUMECA FINE/Design 3D"

NUMECA INGENIEURBÜRO

Overview

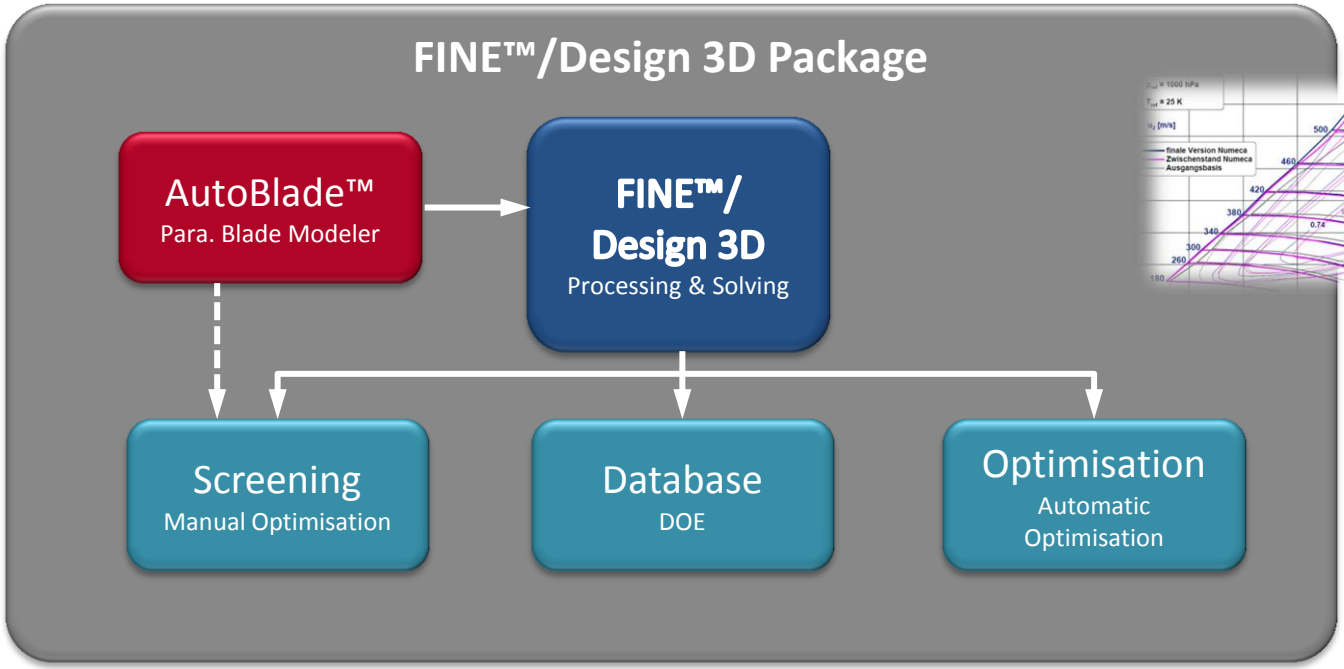
01	The Method: FINE™/Design 3D
02	Multi-Disciplinary Optimisation: Reversible Axial Flow Fan

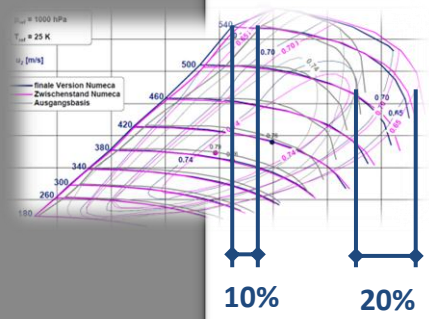
The Method: FINE™/Design 3D



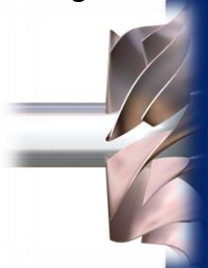
The Method: FINE™/Design 3D

FINE™/Design 3D Package





Original

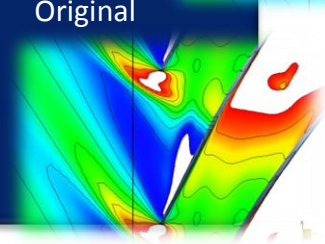


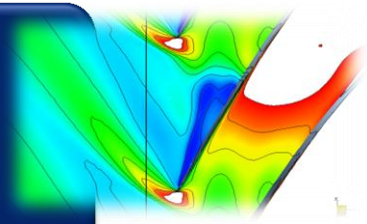
Optimization

Application for:

- Aerospace
- Power Generation & Propulsion
- Hydro Engineering
- Wind Energy
- …

Original

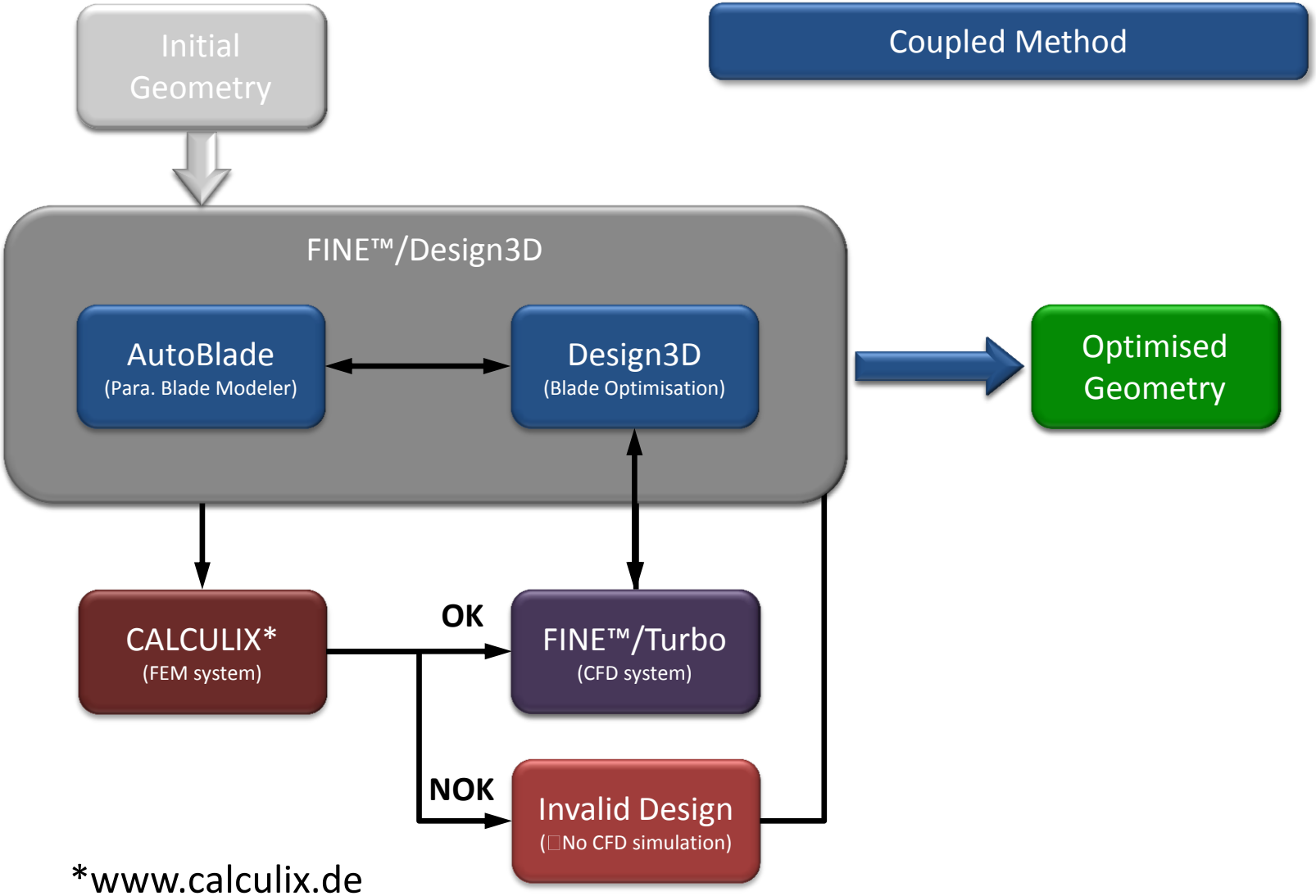




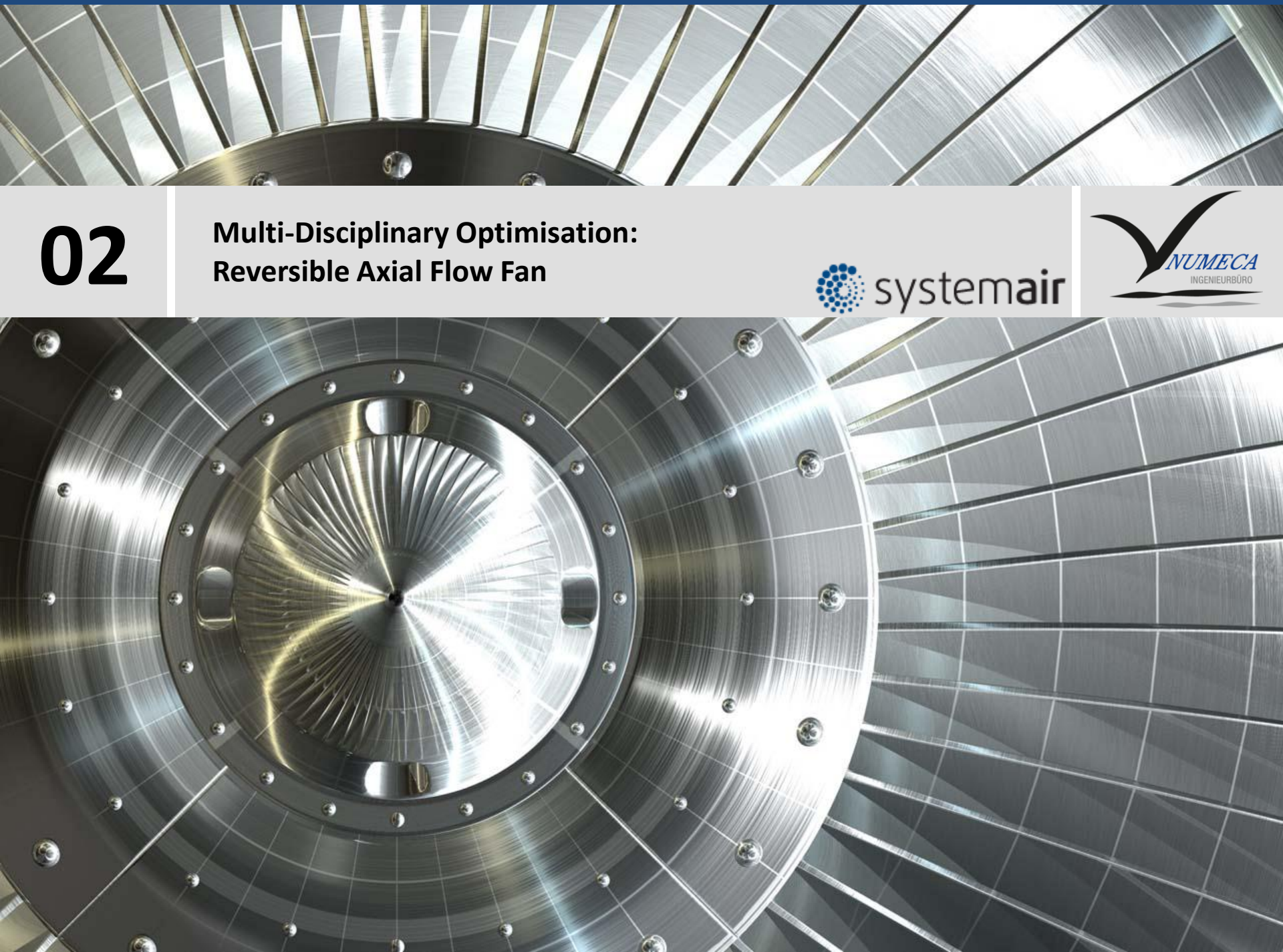
Optimization

The Method: FINE™/Design 3D

Extension to Multi Disciplinary Optimisation MDO



*www.calculix.de



02

Multi-Disciplinary Optimisation: Reversible Axial Flow Fan

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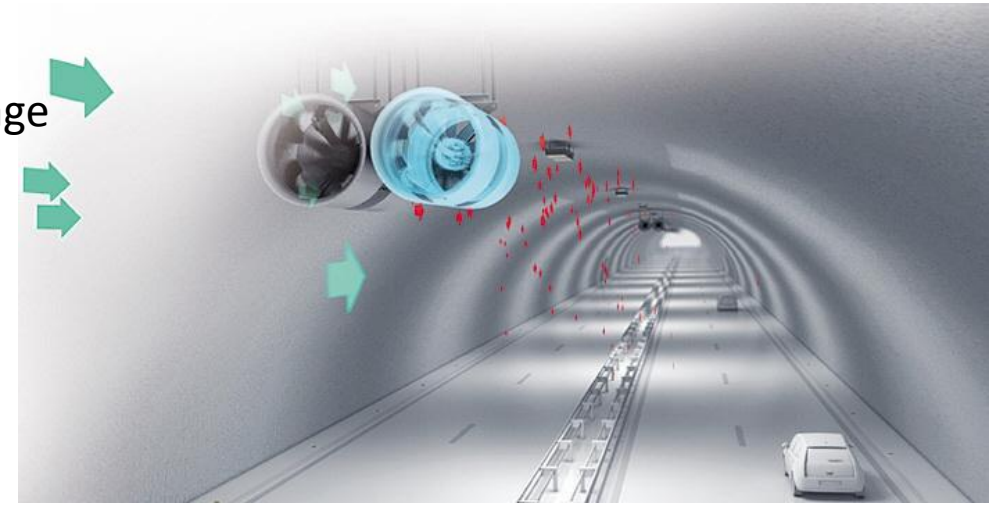
MDO Optimisation: Reversible Axial Flow Fan
Objective & Constraints

Optimisation towards:

- Reduced materials usage
- Increasing thrust
- Maintaining efficiency



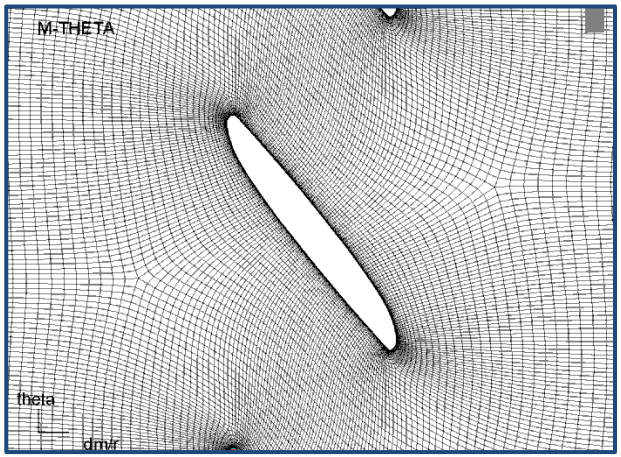
Requirements:

- Two volume flows
- Two design sizes (ø 800mm, ø 1000mm)
- Two stagger angles (30°, 40°)
- Two flow directions (reversible flow) equal performance in both flow directions

2 (flow directions) * 2 (volume flows) * 2 (design sizes) * 2 (staggers) = 16 operating points

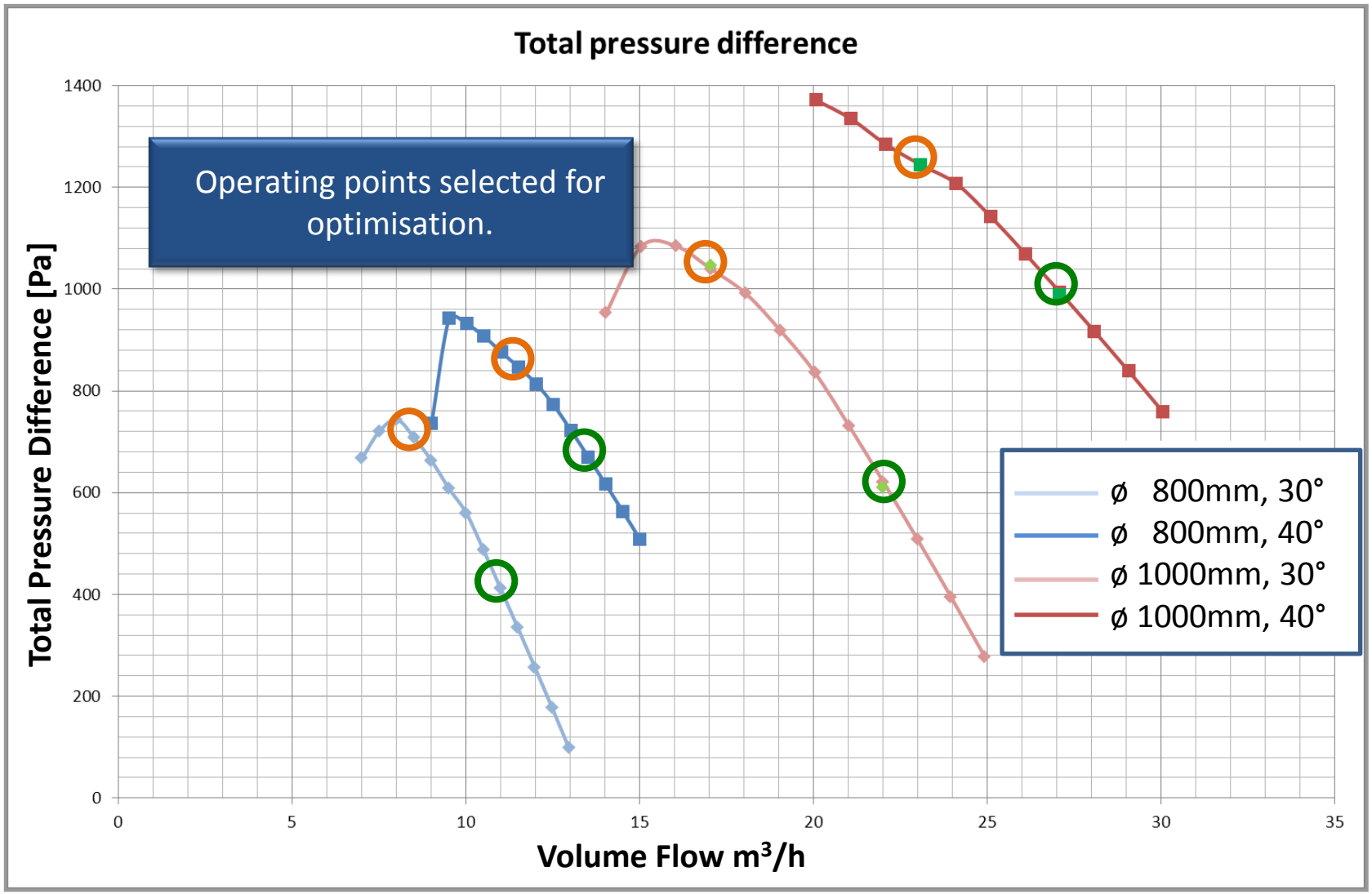
MDO Optimisation: Reversible Axial Flow Fan
Objective & Constraints

How to deal with two flow directions?



2 (flow directions) * 2 (volume flows) * 2 (design sizes) * 2 (staggers) =
8 operating points

MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Operating points



MDO Optimisation: Reversible Axial Flow Fan
Parameterisation of Blade Section

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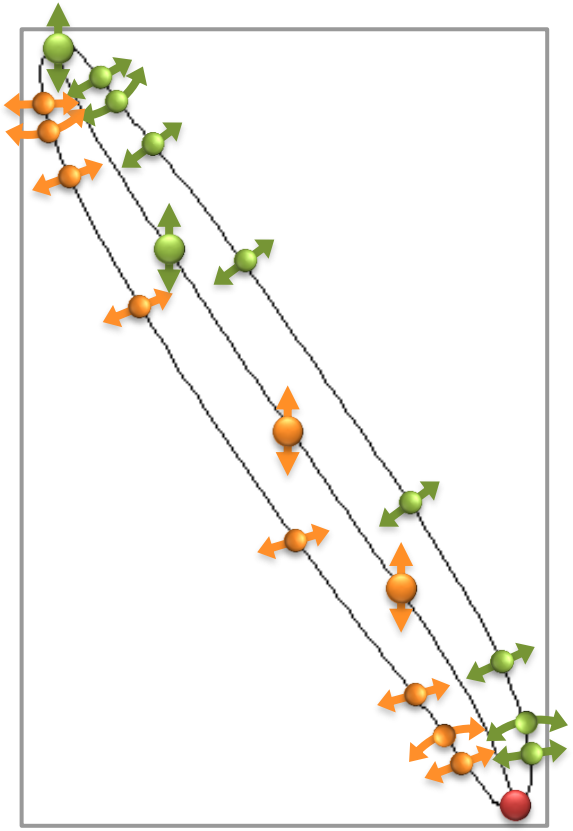
Point symmetric:
Camber & Blade Thickness Distribution



Parameters:

- Fixed
- Free
- Dependent

MDO Optimisation: Reversible Axial Flow Fan
Camber Curve & Blade Thickness

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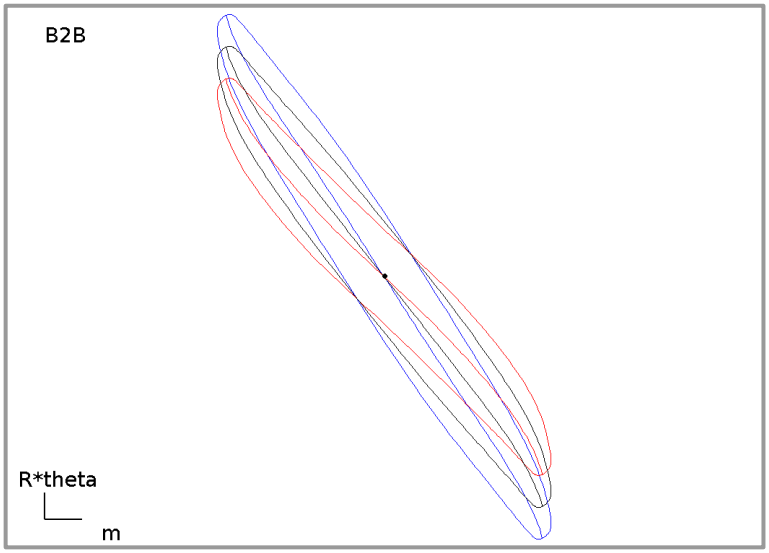
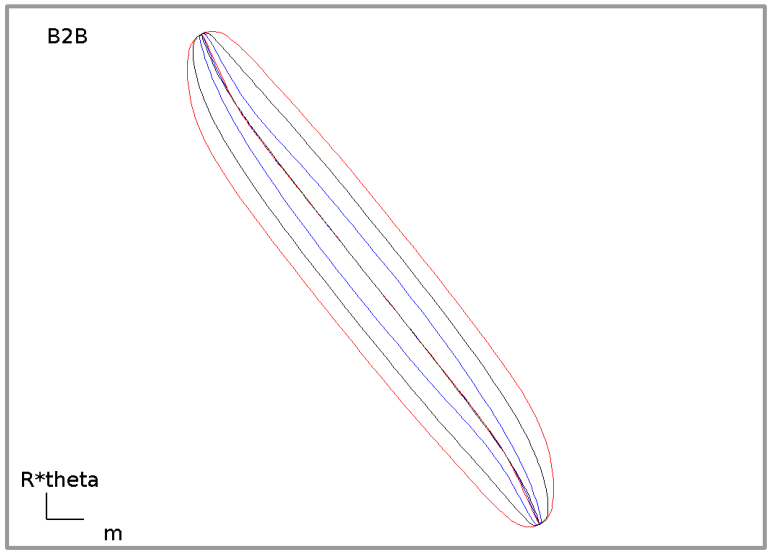


	Free Parameters
Camber curve	3 x 2 = 6
Thickness distribution	3 x 8 = 24
Tangential location	2
Others	4
Sum	36
Number of designs in Database ≥	108



MDO Optimisation: Reversible Axial Flow Fan
From Model to Mesh

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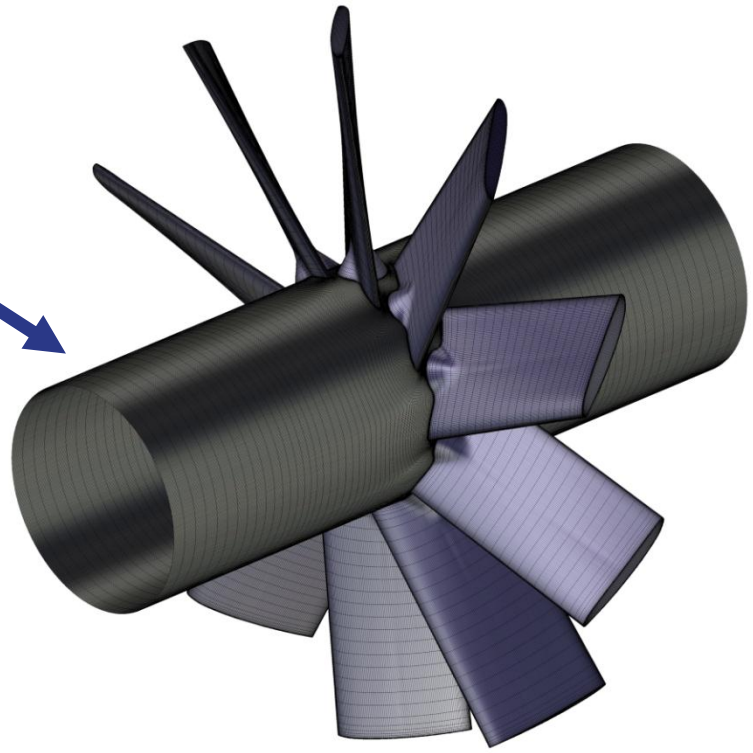
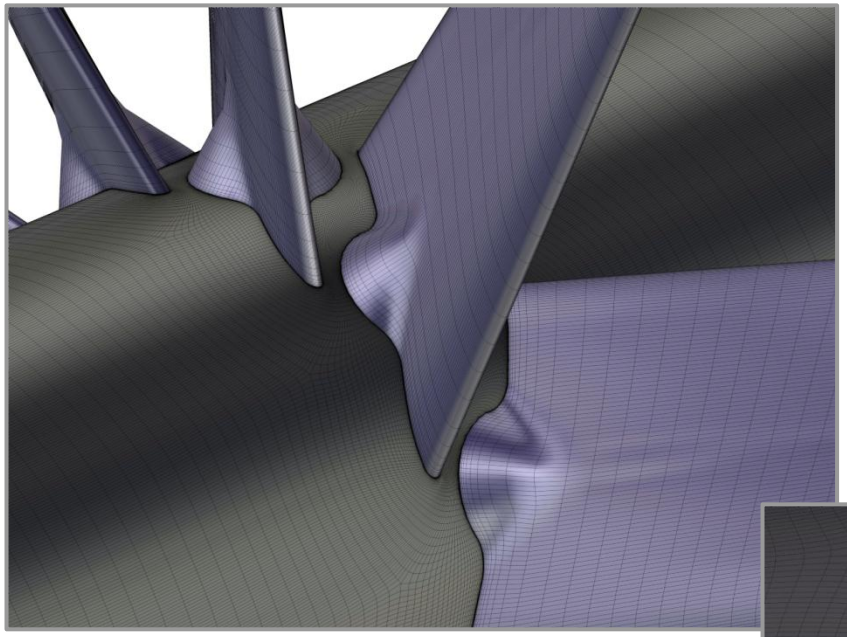
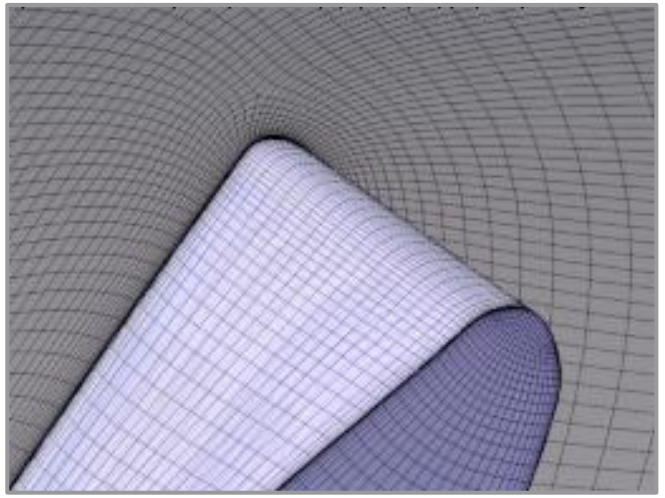


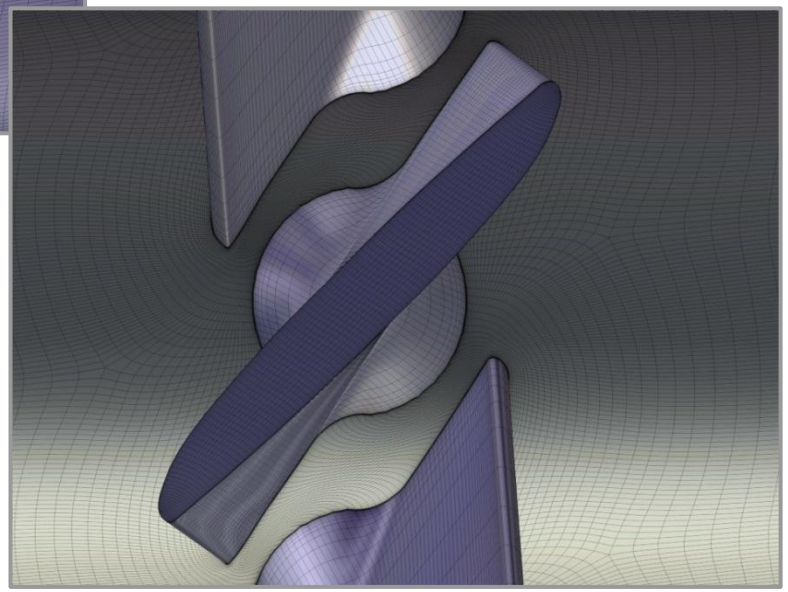
Boundary Conditions

$\dot{V} = \pm 8.5 \ \ldots \ 27 \ \ m^3/s$

MDO Optimisation: Reversible Axial Flow Fan
Numerical Mesh

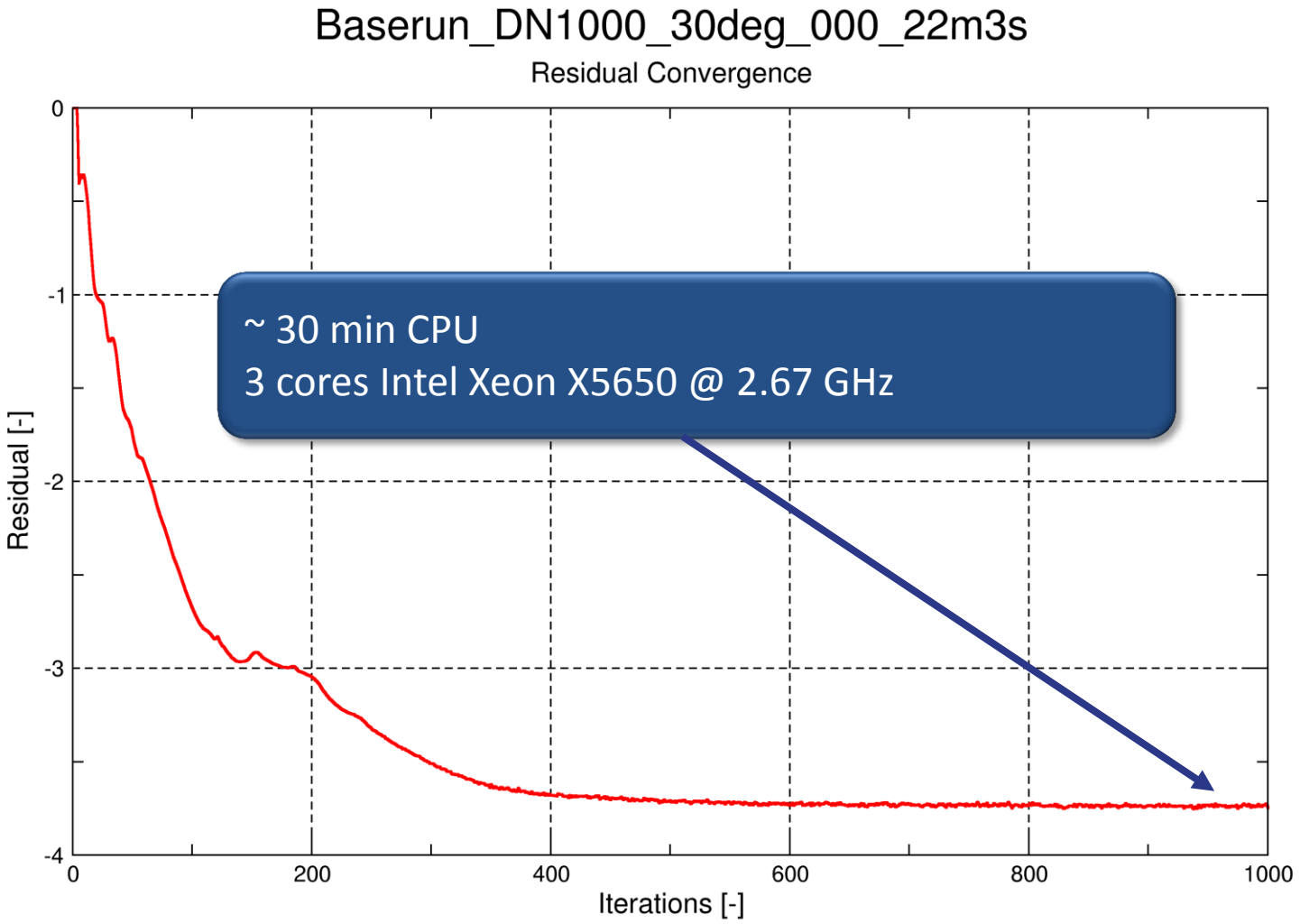




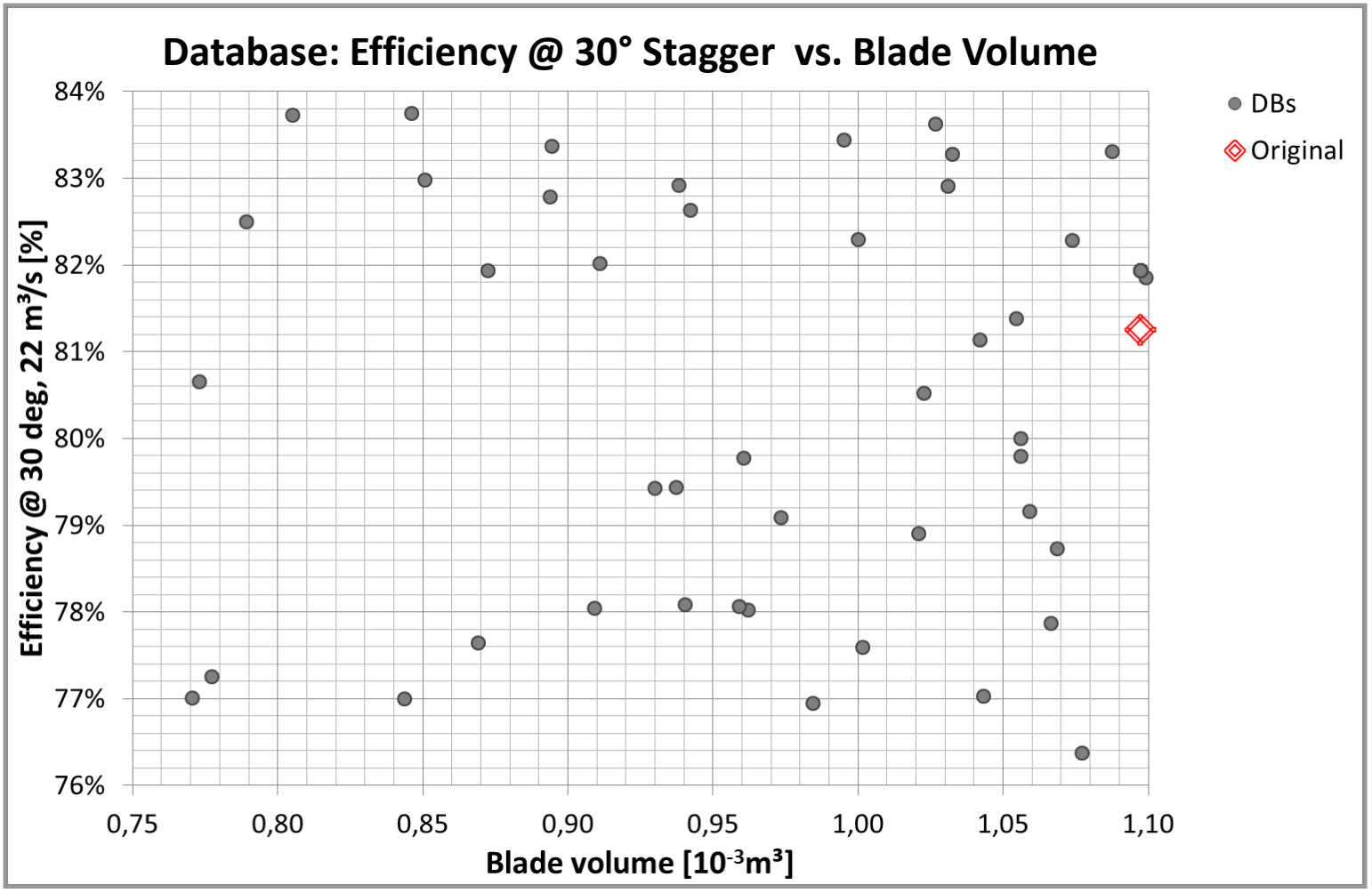


Numerical grid	
Type	structured, multi-block
	Rotor
Total # of points	~ 1.000.000

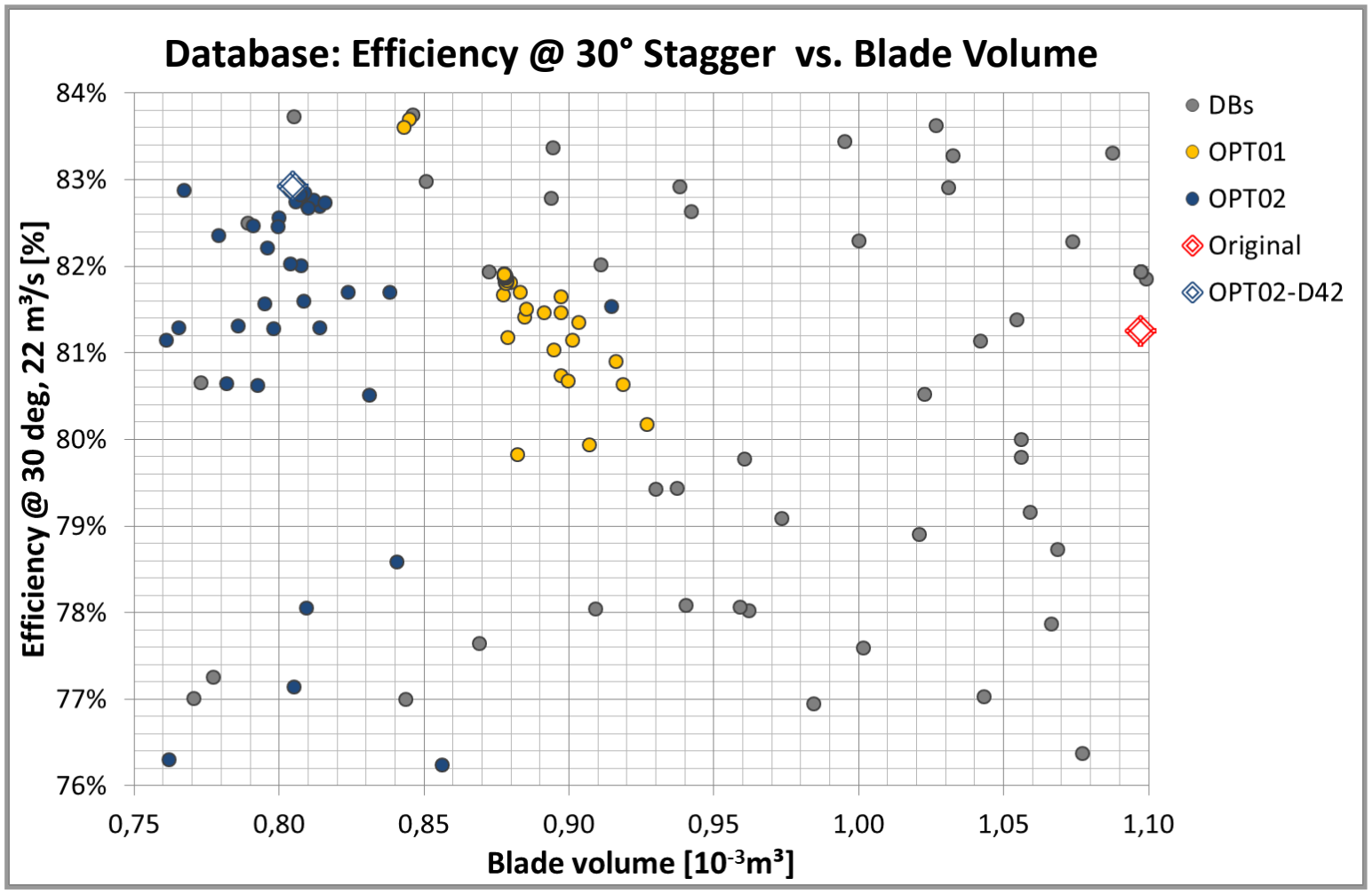
MDO Optimisation: Reversible Axial Flow Fan
Convergence – global residuals



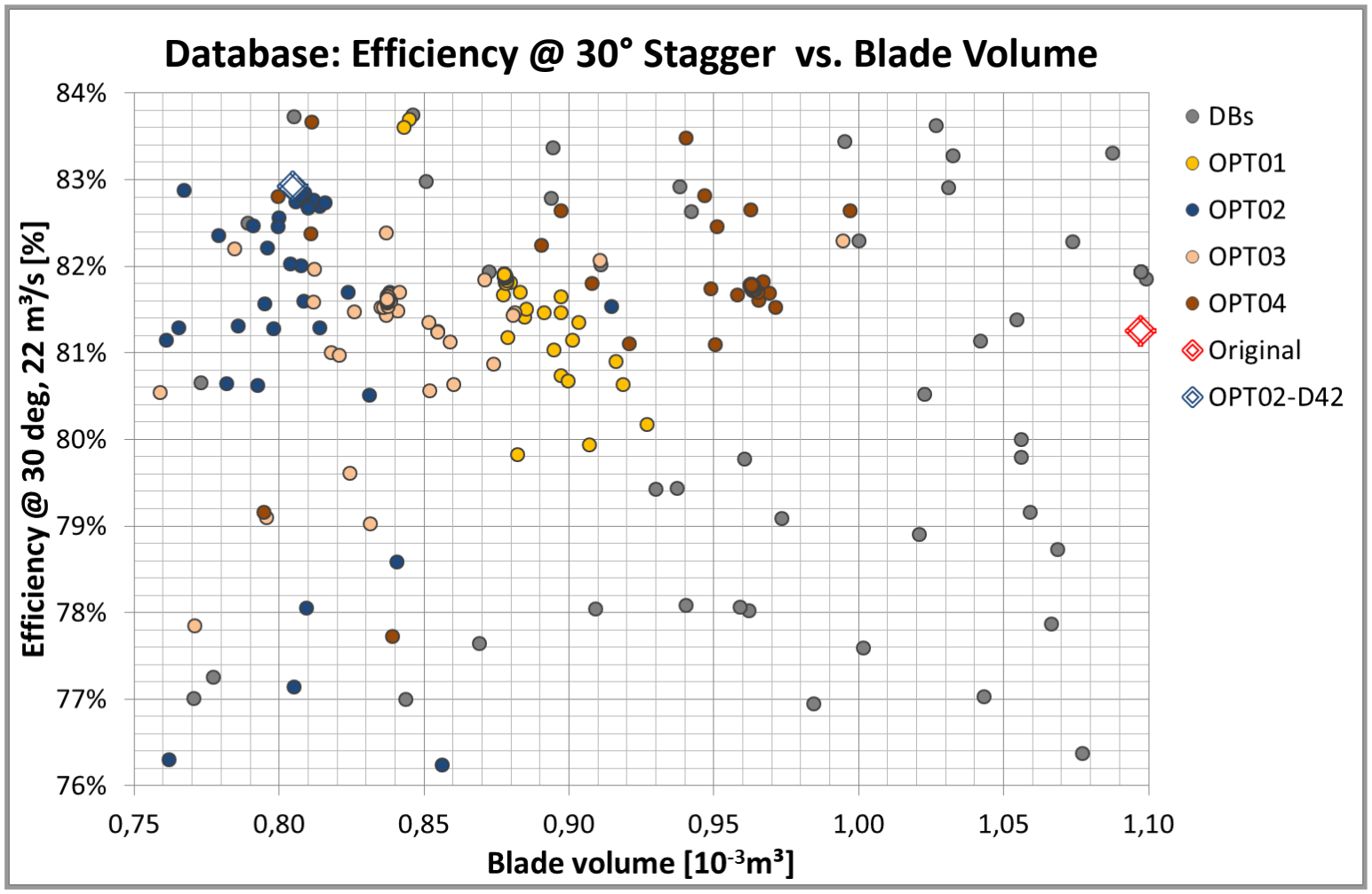
MDO Optimisation: Reversible Axial Flow Fan Optimisation – Progress



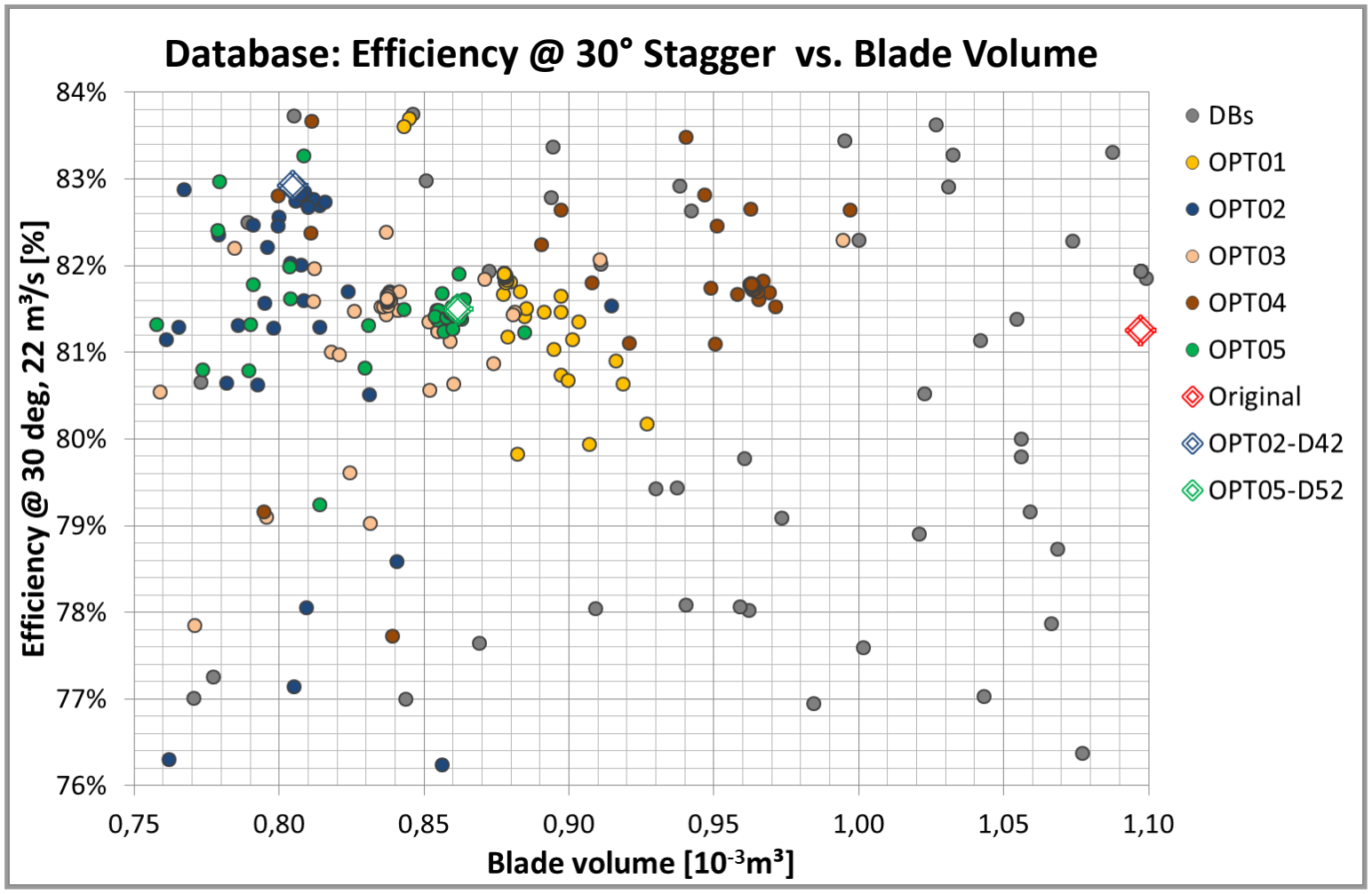
MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Progress



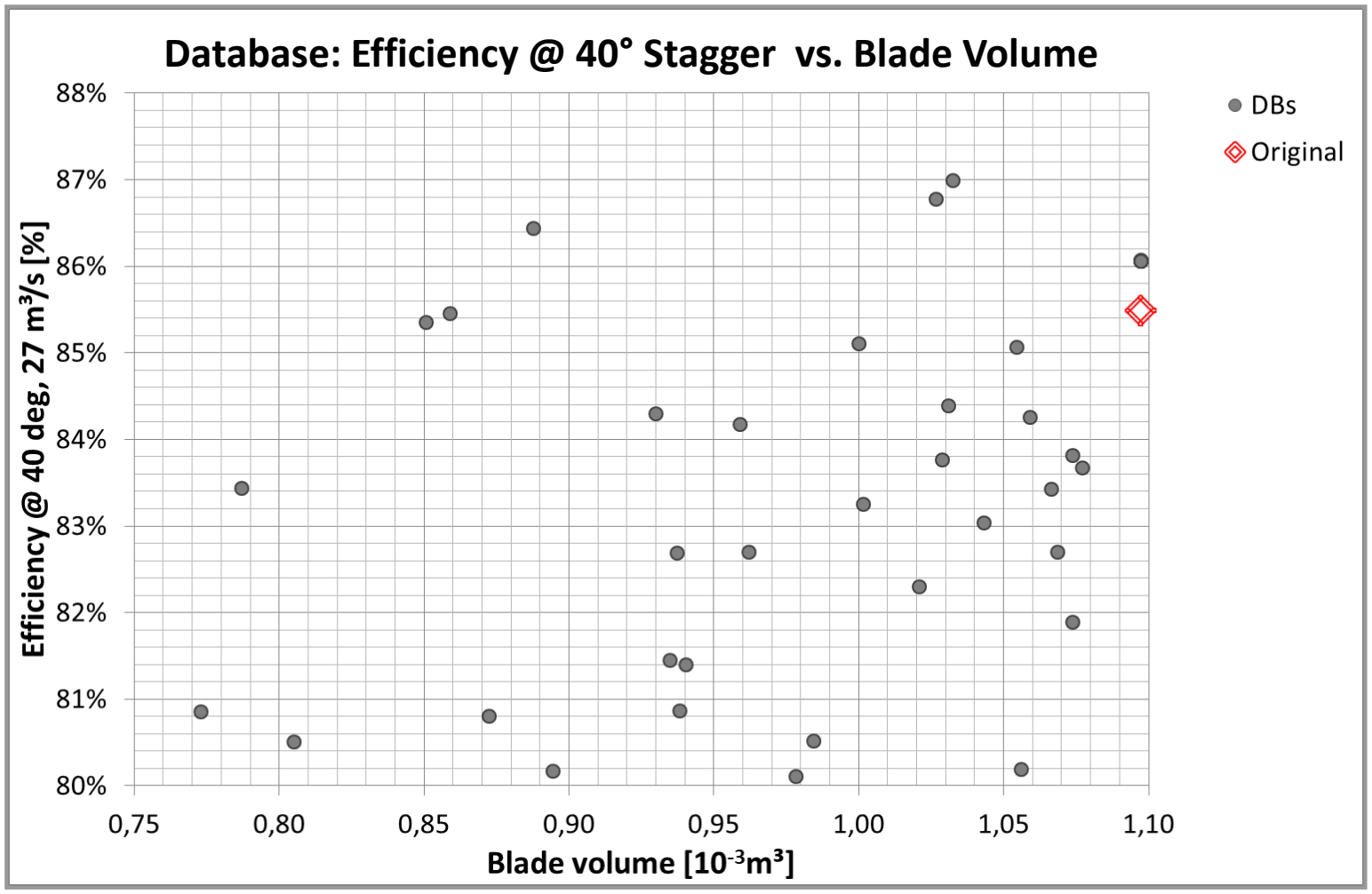
MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Progress



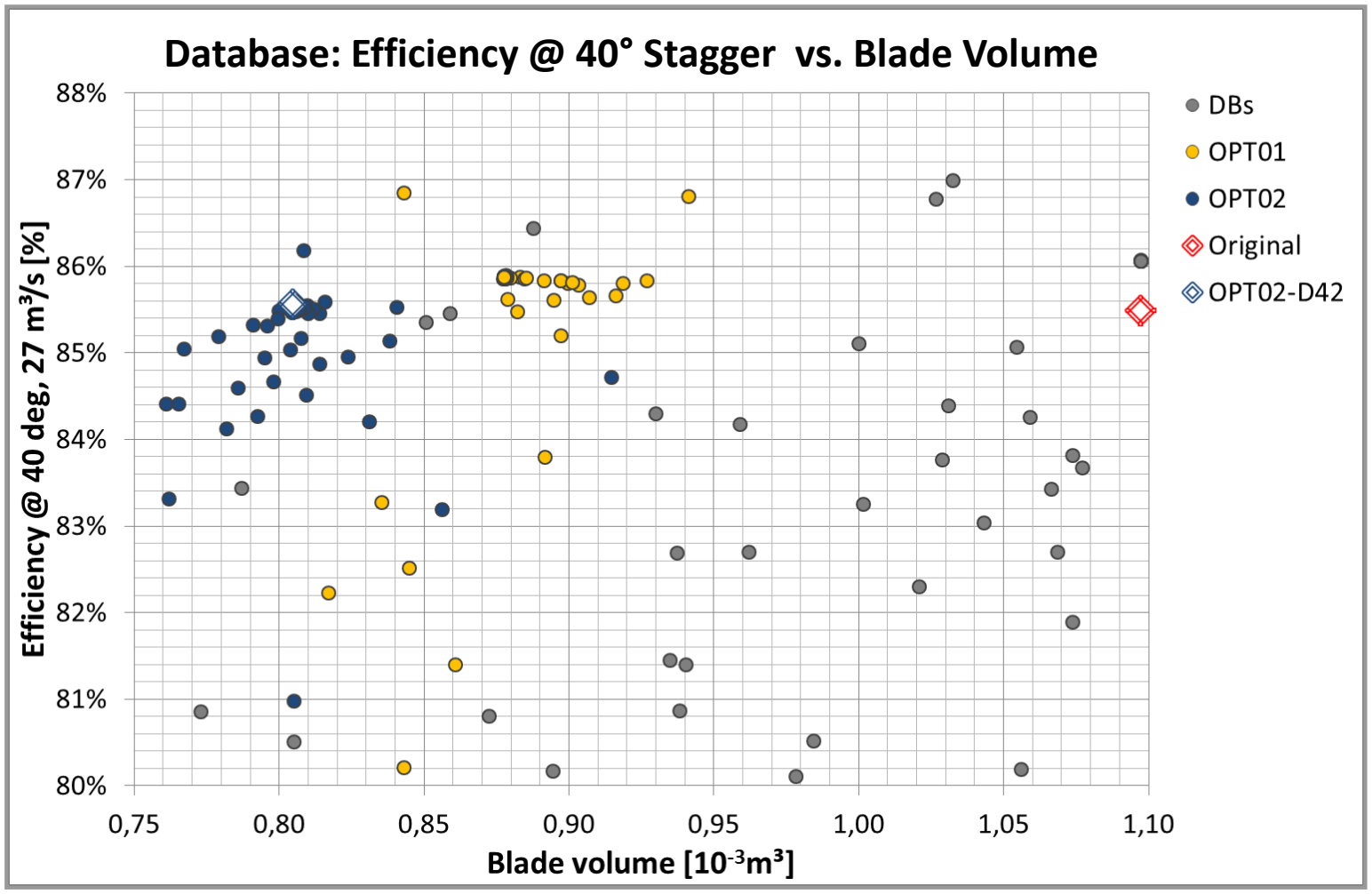
MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Progress



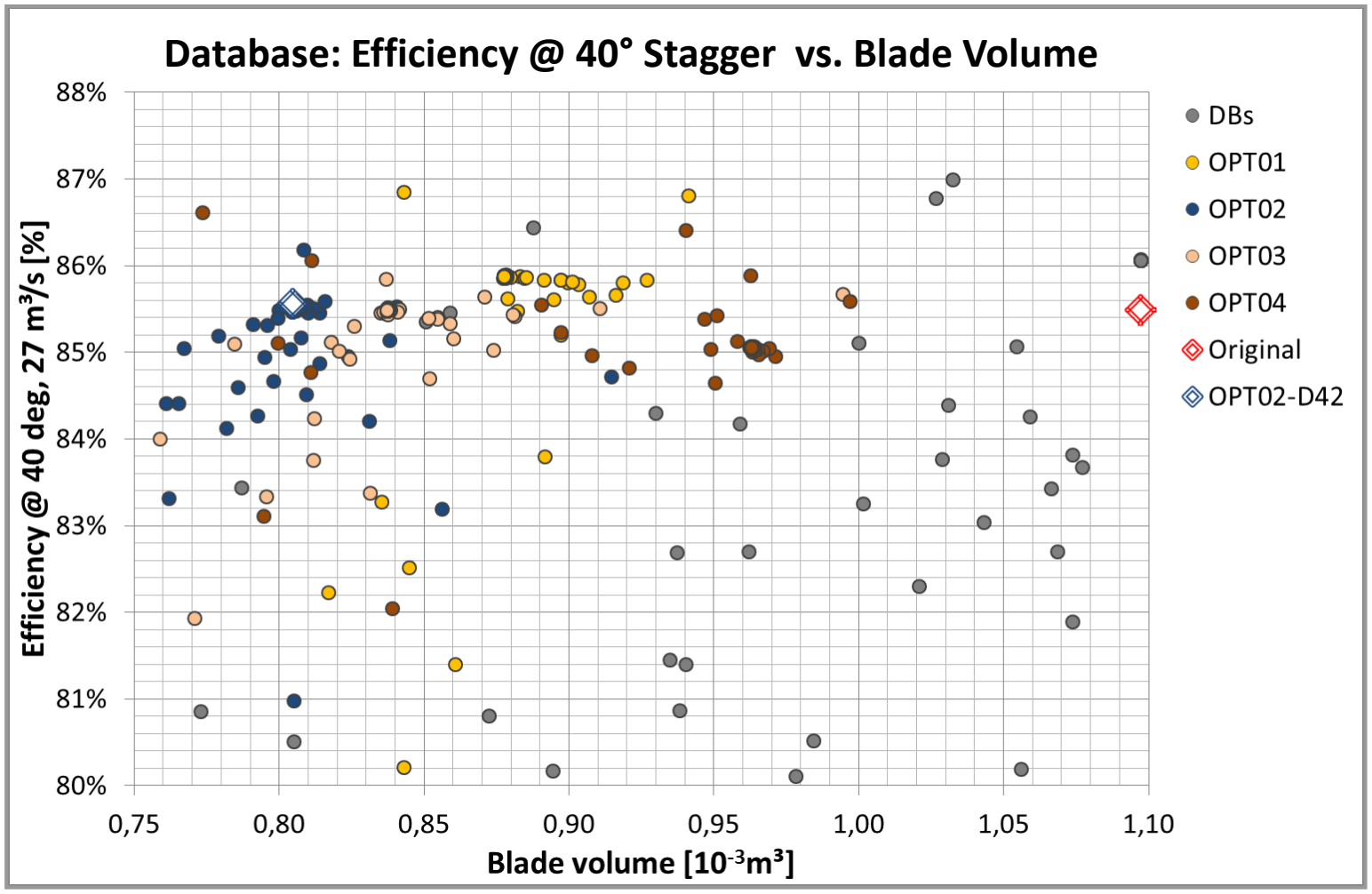
MDO Optimisation: Reversible Axial Flow Fan Optimisation – Progress



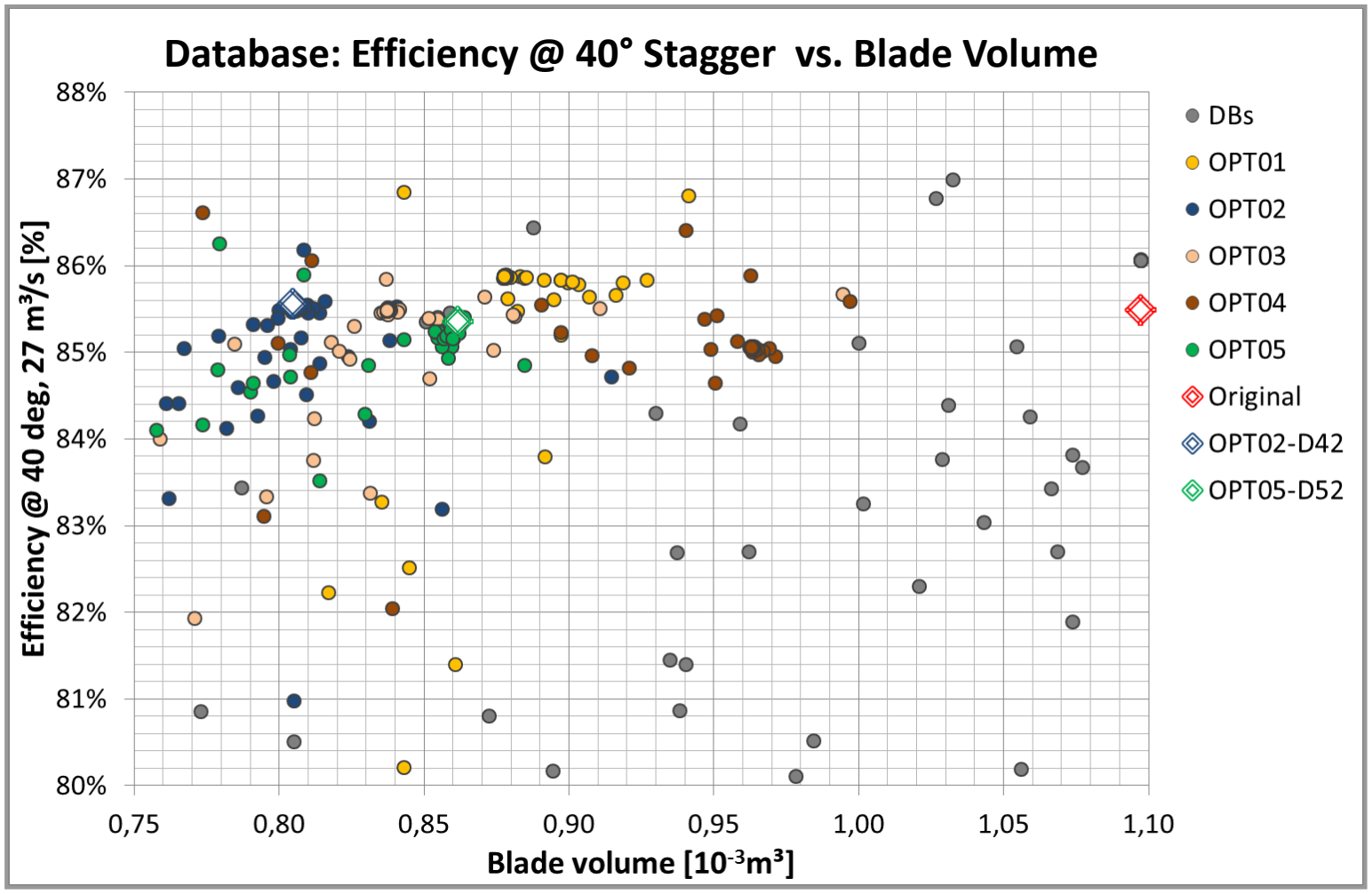
MDO Optimisation: Reversible Axial Flow Fan Optimisation – Progress



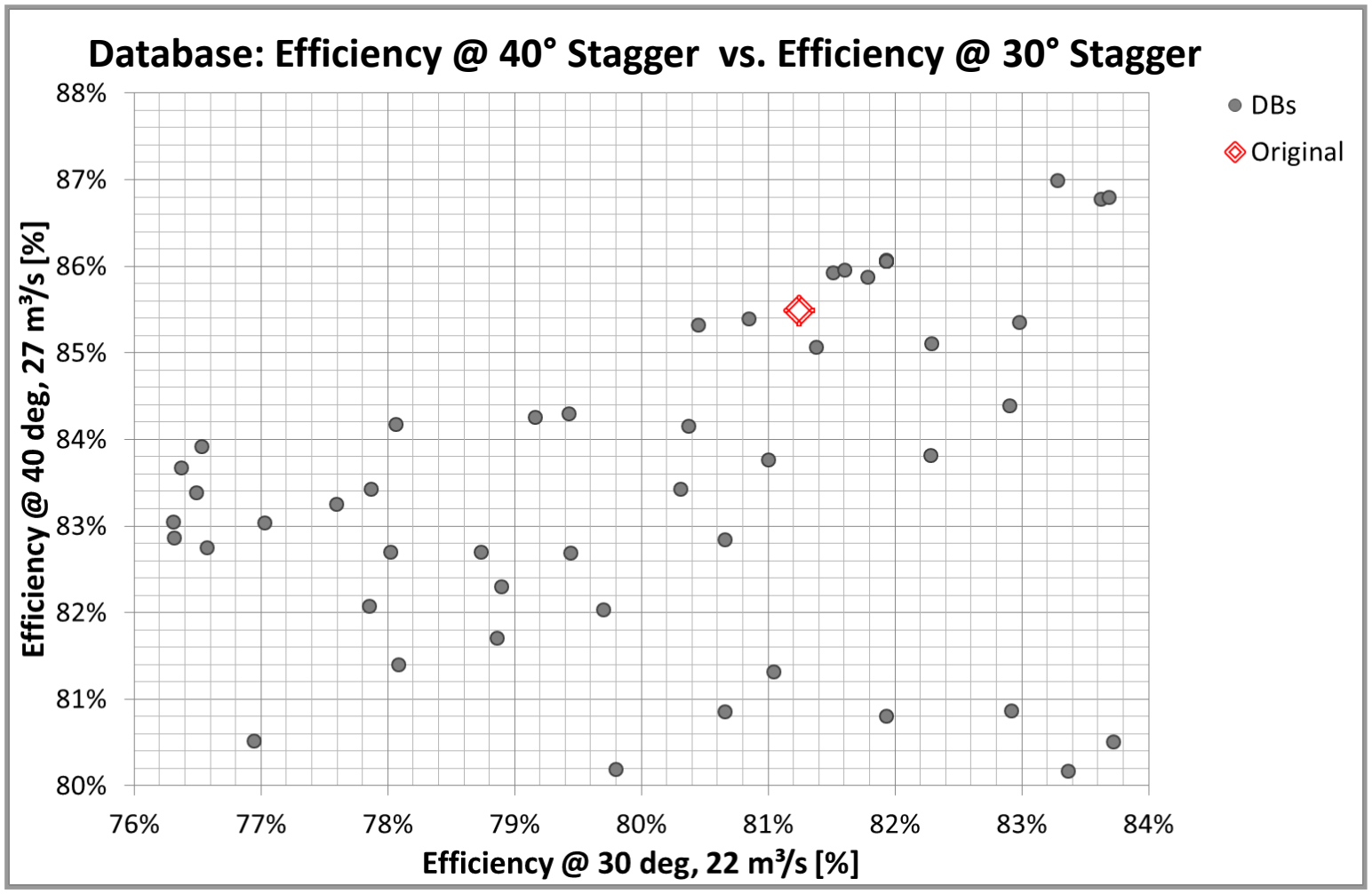
MDO Optimisation: Reversible Axial Flow Fan Optimisation – Progress



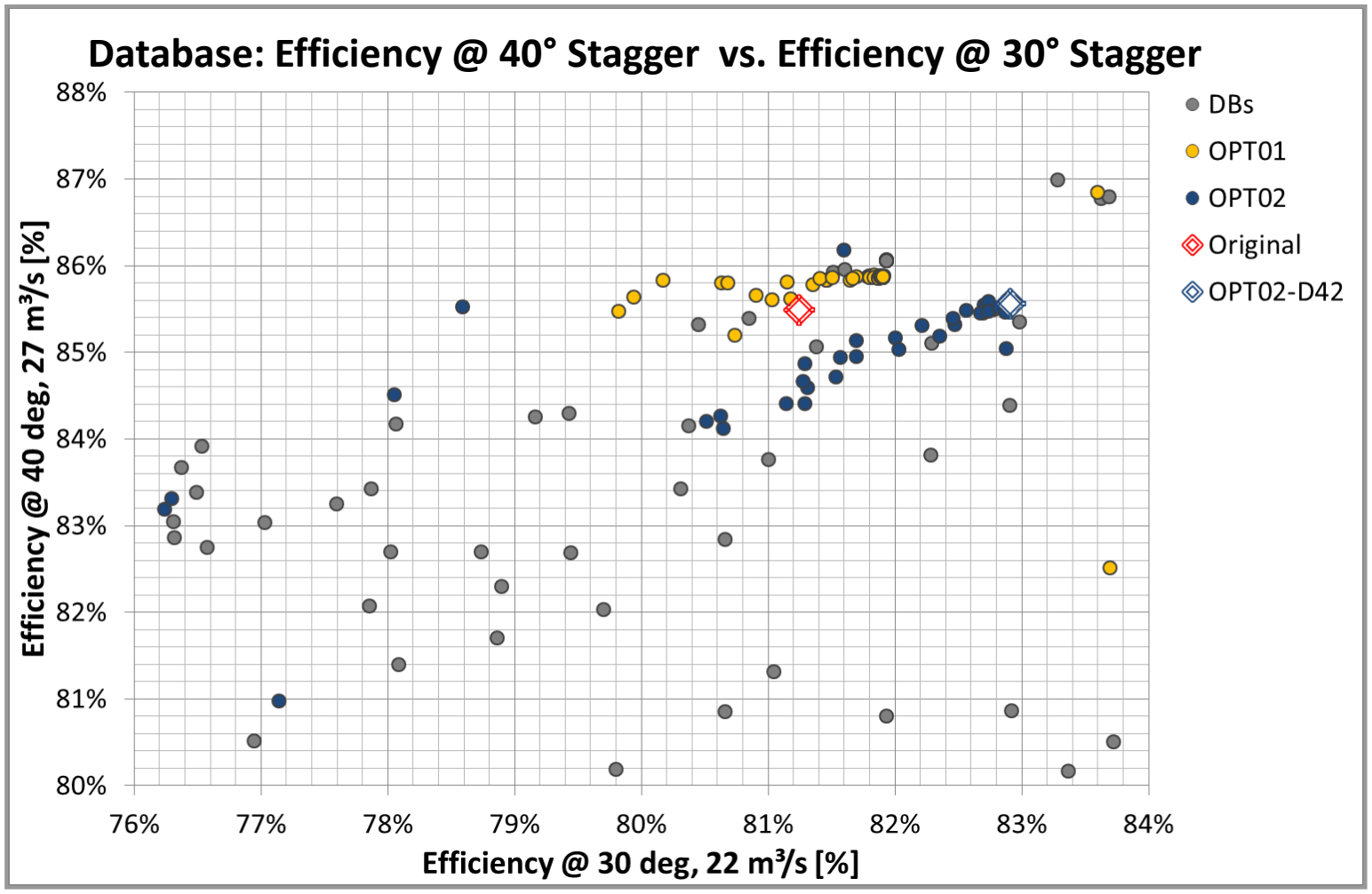
MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Progress



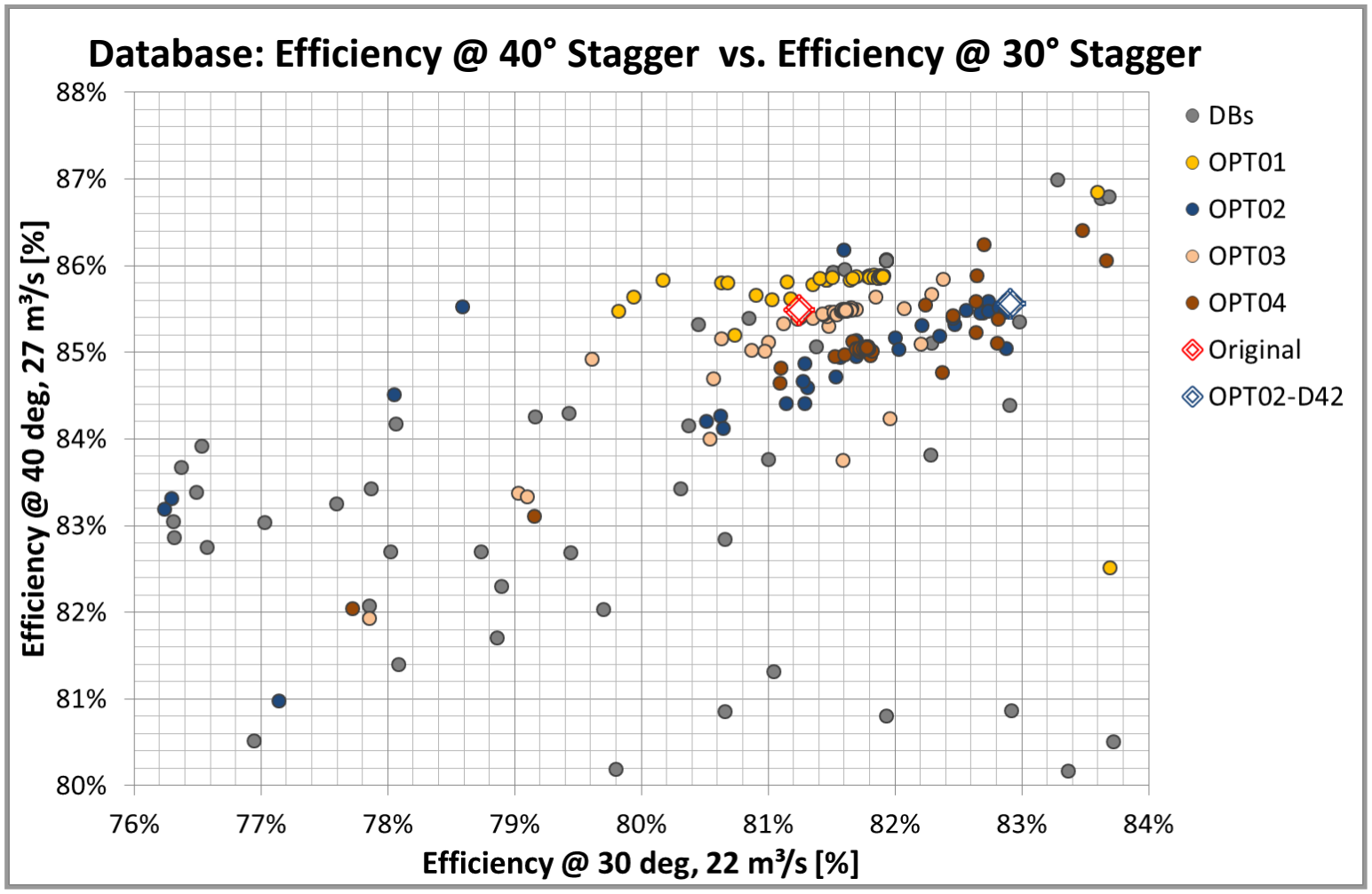
MDO Optimisation: Reversible Axial Flow Fan Optimisation – Progress



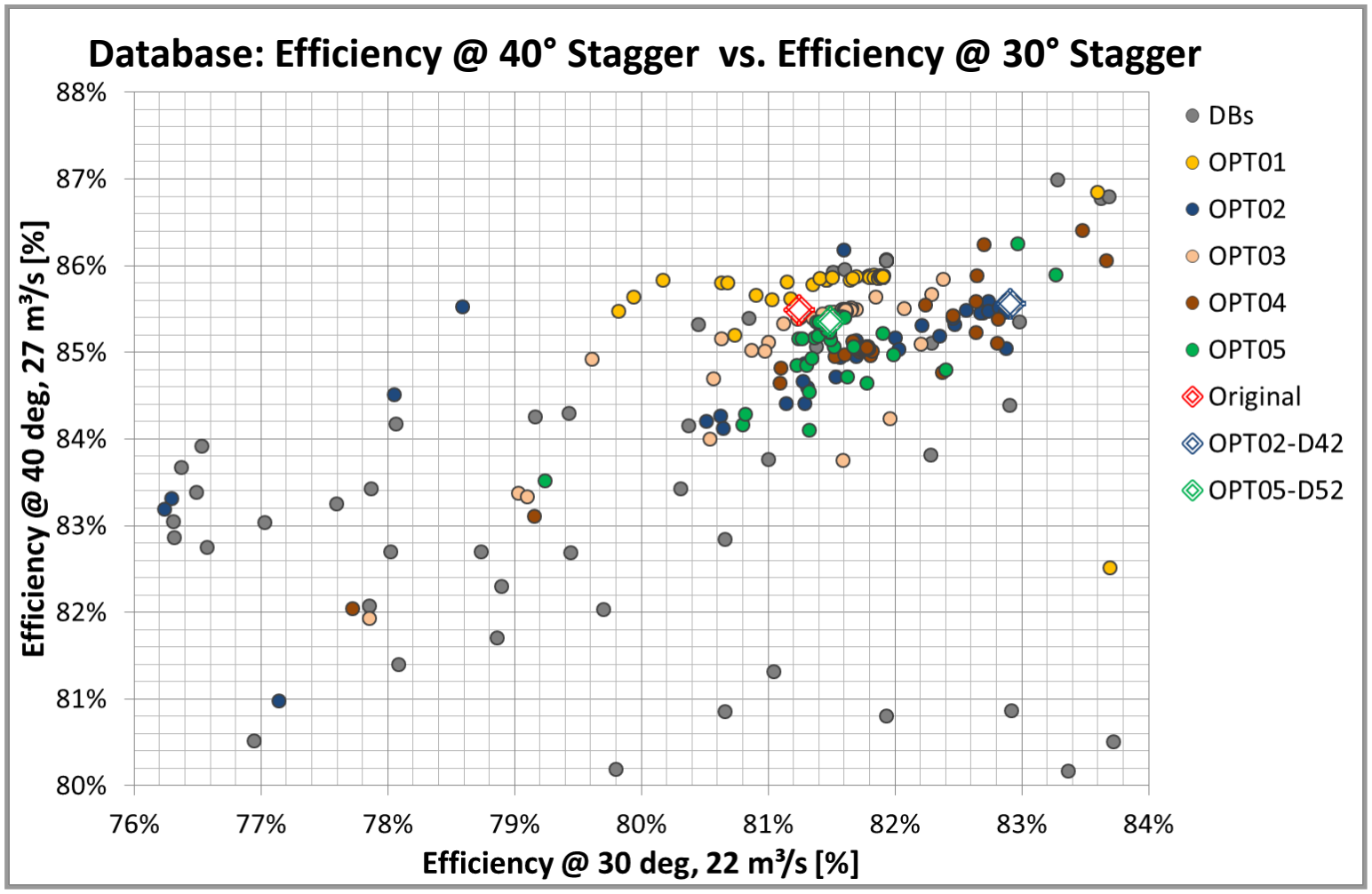
MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Progress



MDO Optimisation: Reversible Axial Flow Fan Optimisation – Progress

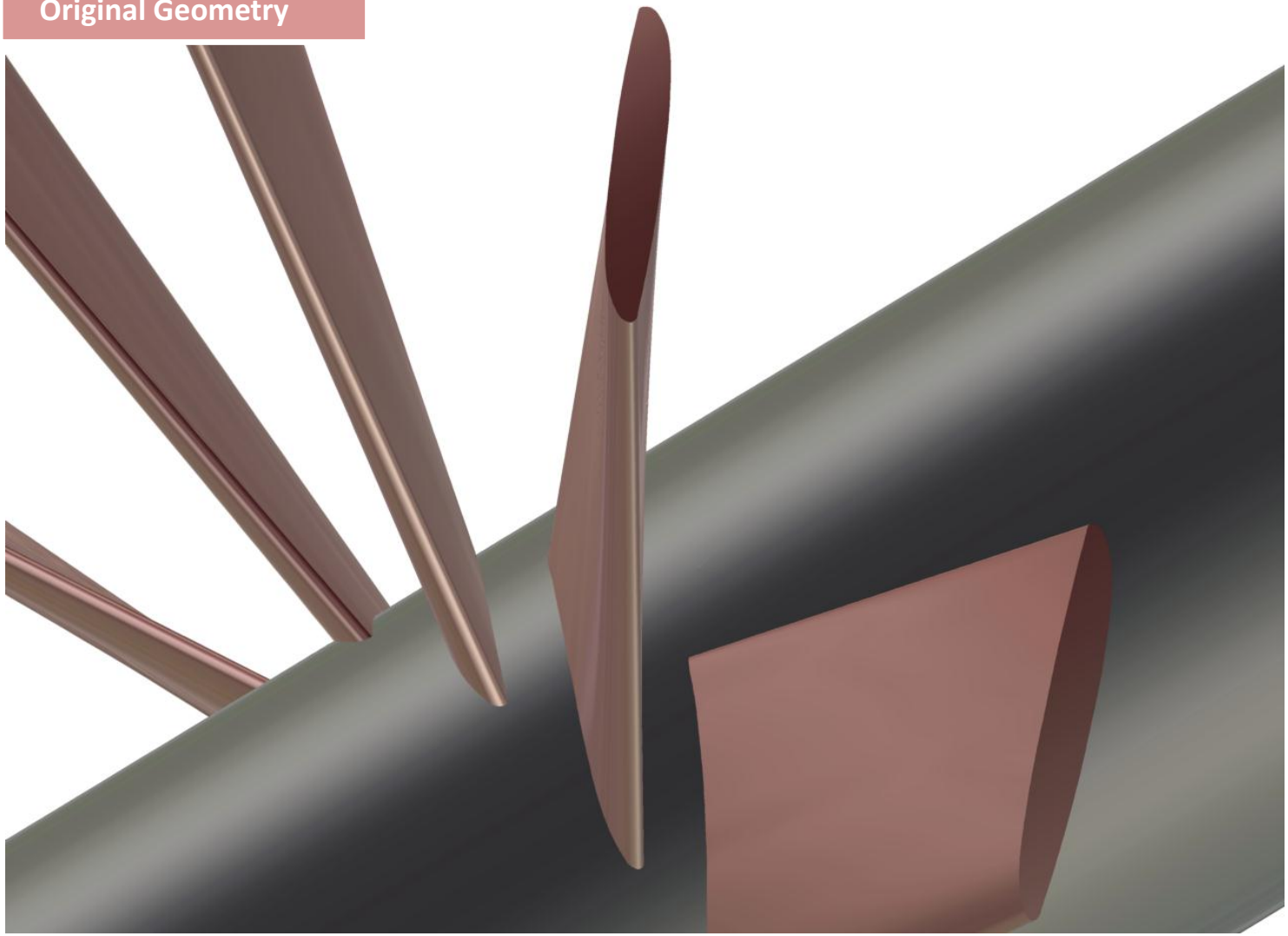


MDO Optimisation: Reversible Axial Flow Fan Optimisation – Progress



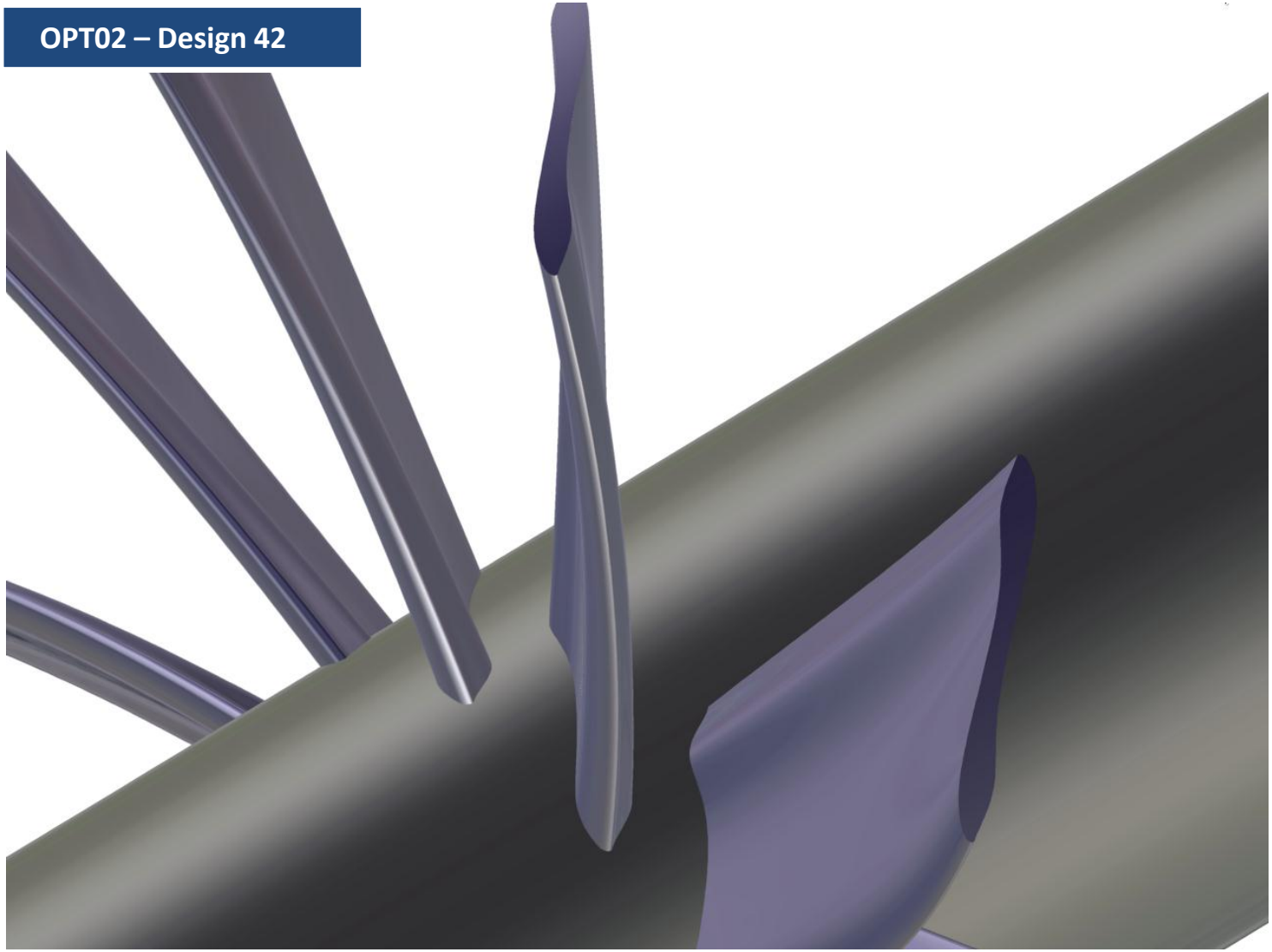
MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Geometrical comparison

Original Geometry



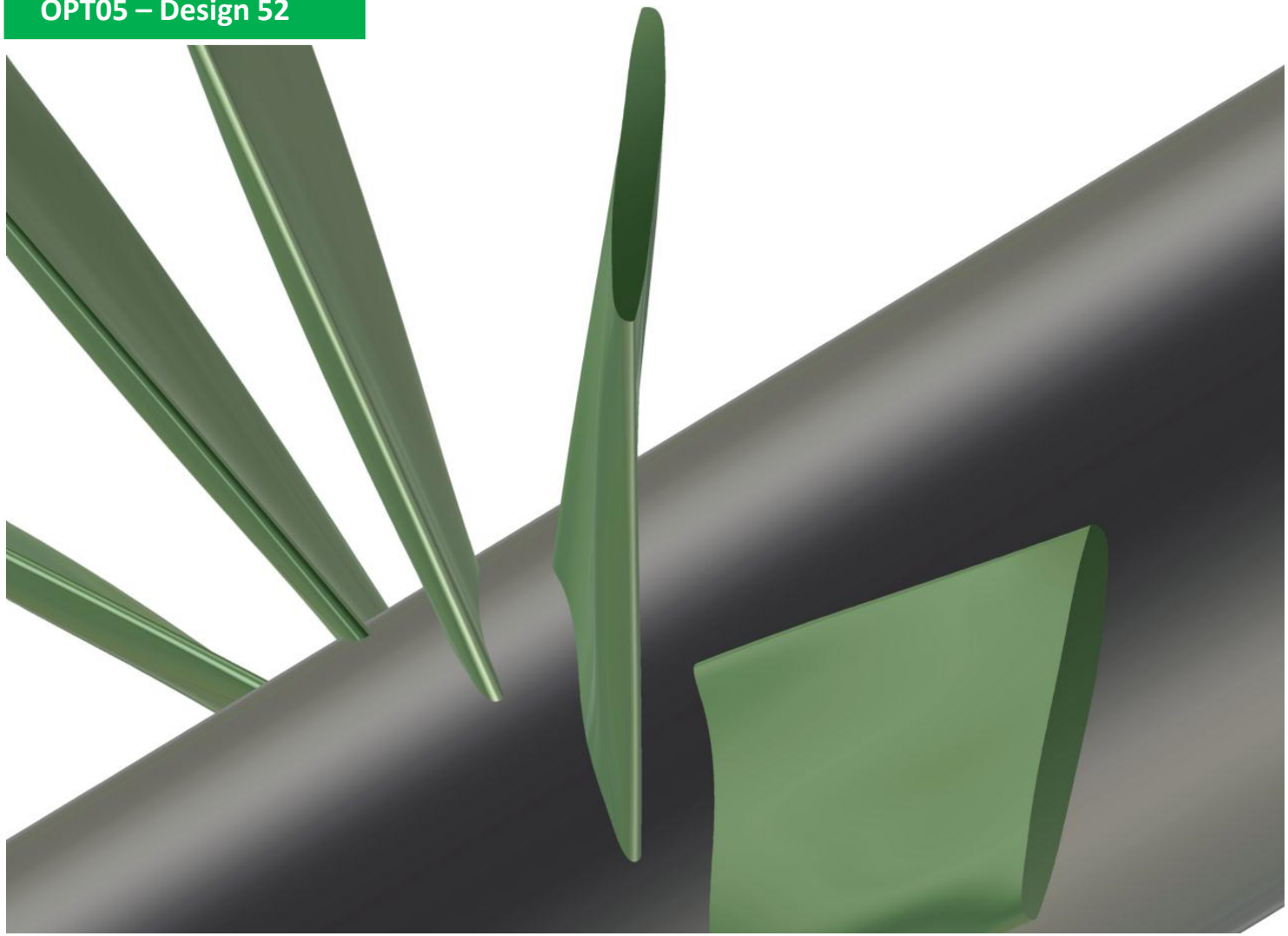
MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Geometrical comparison

OPT02 – Design 42

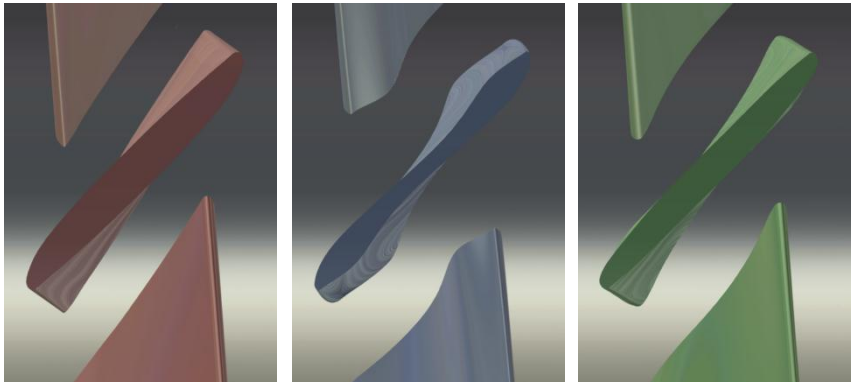


MDO Optimisation: Reversible Axial Flow Fan
Optimisation – Geometrical comparison

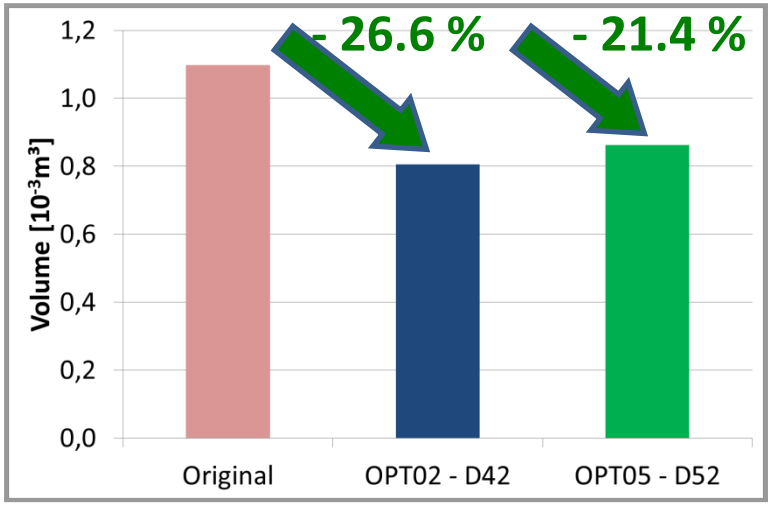
OPT05 – Design 52



MDO Optimisation: Reversible Axial Flow Fan
Results: Volume Reduction



Volume	Original geometry	OPT02 – Design 42	OPT05 – Design 52
[$10^{-3}m^3$]	1.097	0.805	0.862



MDO Optimisation: Reversible Axial Flow Fan
Results: Mechanical Integrity

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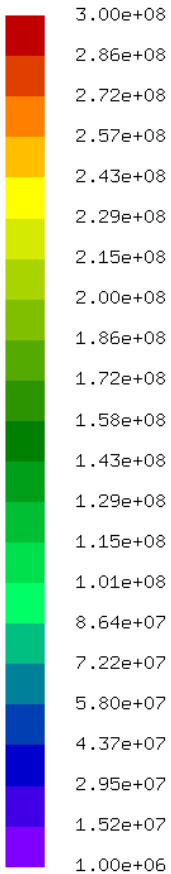
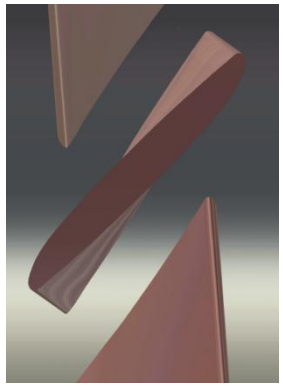
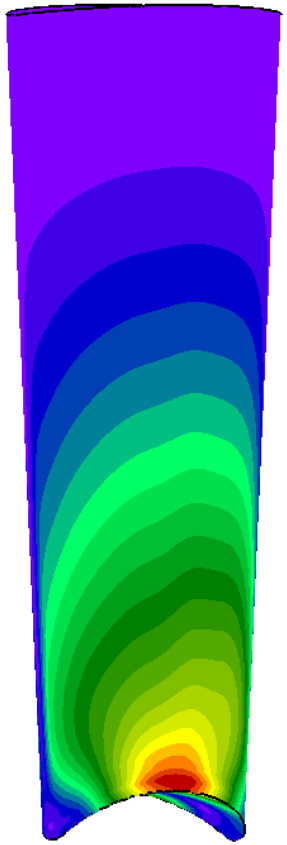
CALCULIX*
(CSM system)



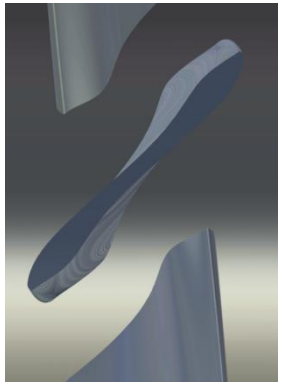
Original Geometry

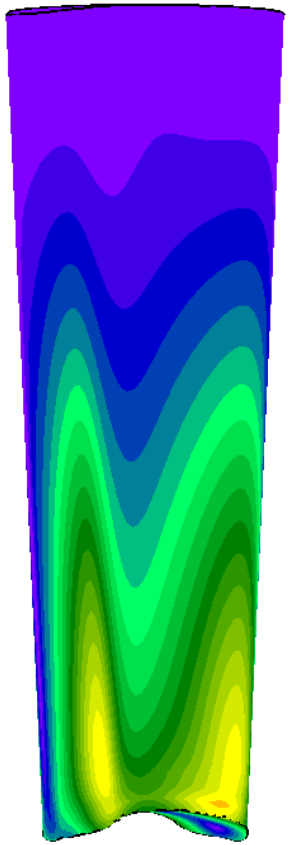




Max. Stress = 306 MPa

OPT02 – Design 42





Max. Stress = 248 MPa

MDO Optimisation: Reversible Axial Flow Fan
Results: Aerodynamic Efficiency

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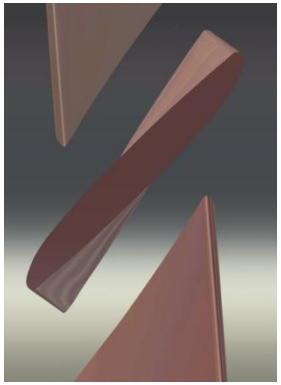
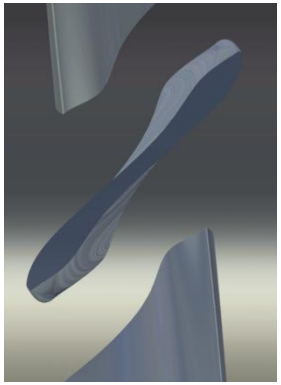
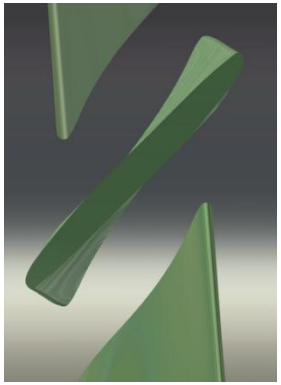
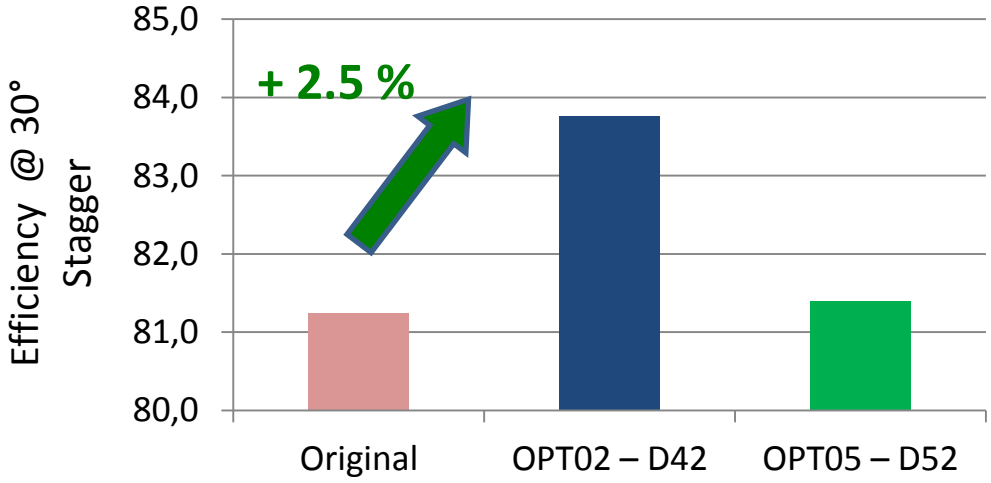




Volume	Original geometry	OPT02 – Design 42	OPT05 – Design 52
[%]	81.25	83,76	81,40



Ø 1000mm

MDO Optimisation: Reversible Axial Flow Fan
Results: Aerodynamic Efficiency

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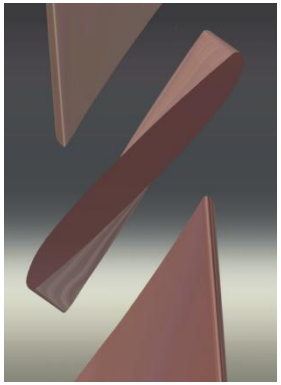
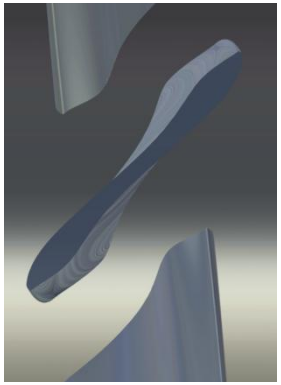
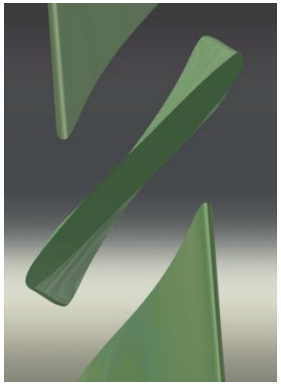
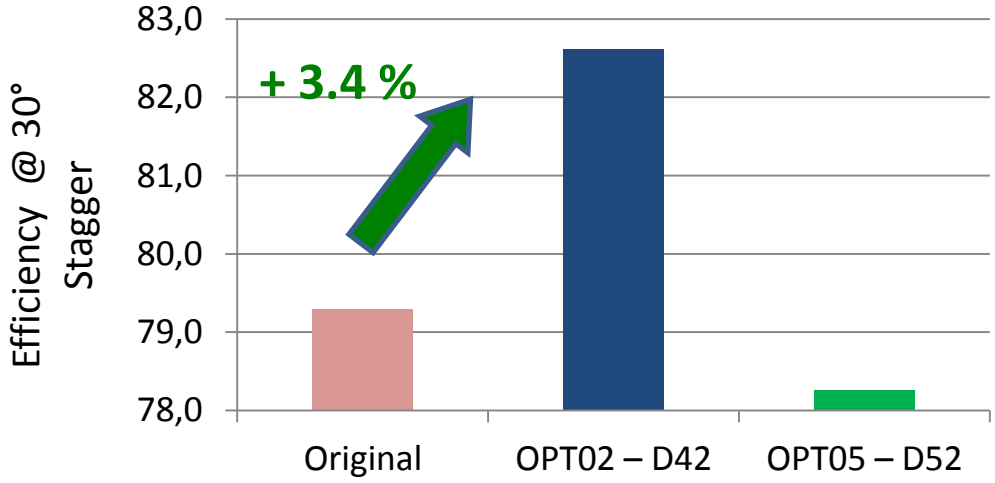
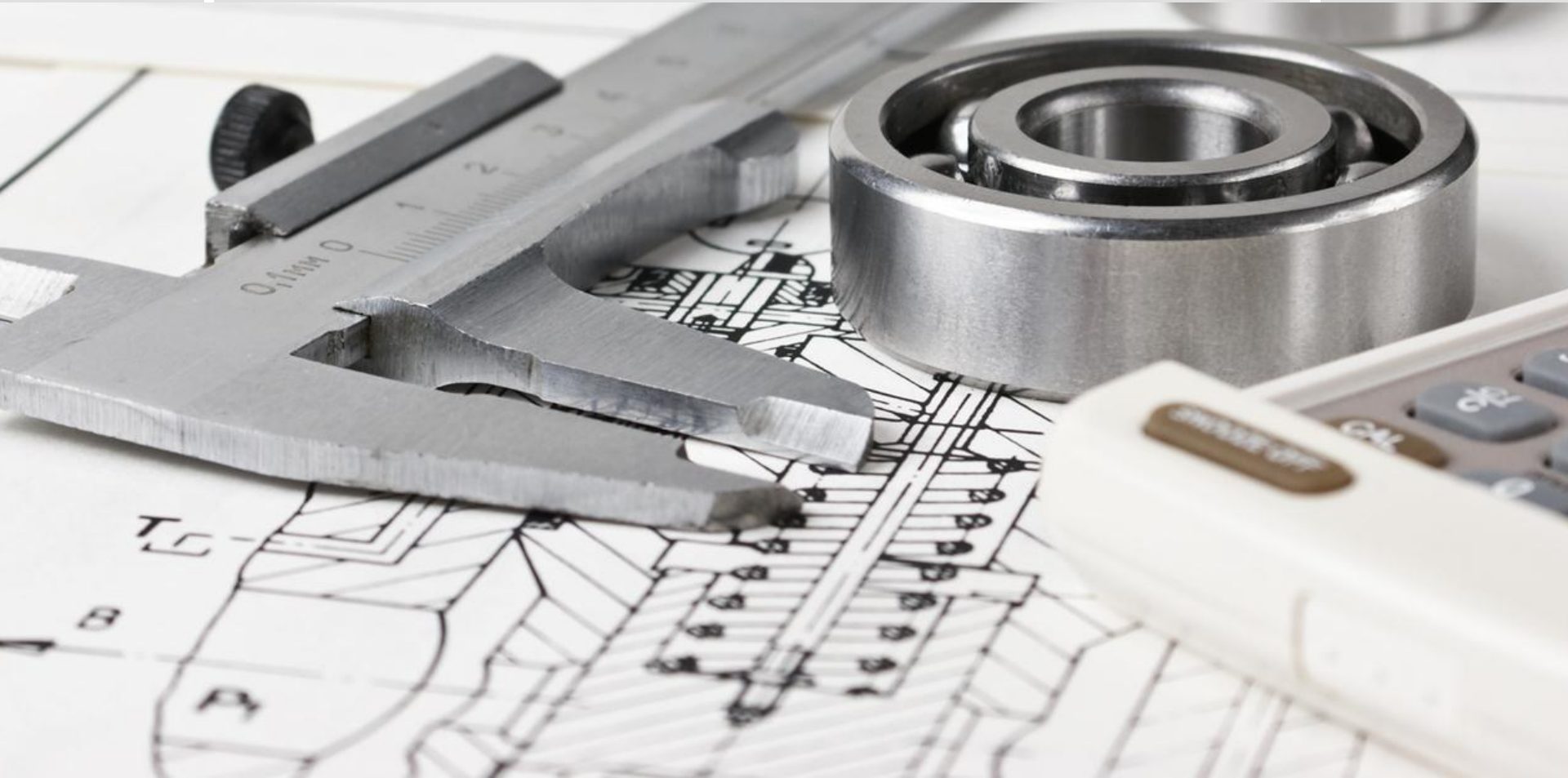




Volume	Original geometry	OPT02 – Design 42	OPT05 – Design 52
[%]	79.29	82.61	78.26



Ø 800mm

03 Conclusion



CFD Optimisation:
Aerodynamic efficiency increased by 2,0…3,5%.
Equal to ~8000 kWh annual saving per fan.

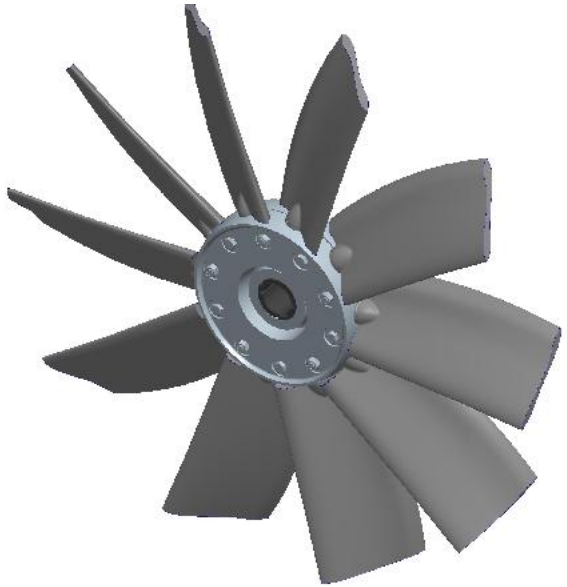
Practical Example:
“Bannewitz-Tunnel”: > 60 Fans
~480 MWh annual saving, equal to 140.000 l fuel oil

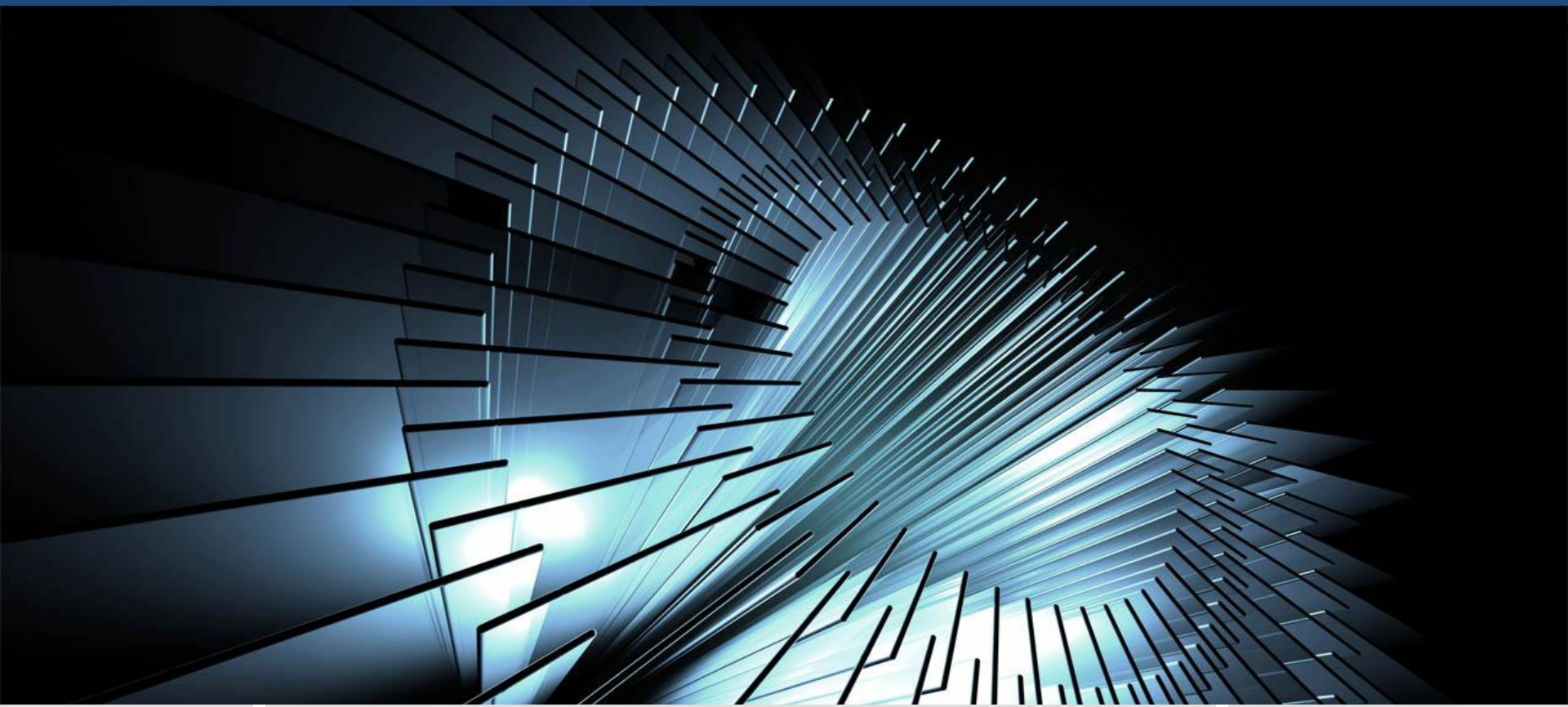
CSM Optimisation:

Consumption of expensive blade material can redu

Successful Multi-Disciplinary Optimisation

Optimised fan now in serial production.





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Thank You!

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