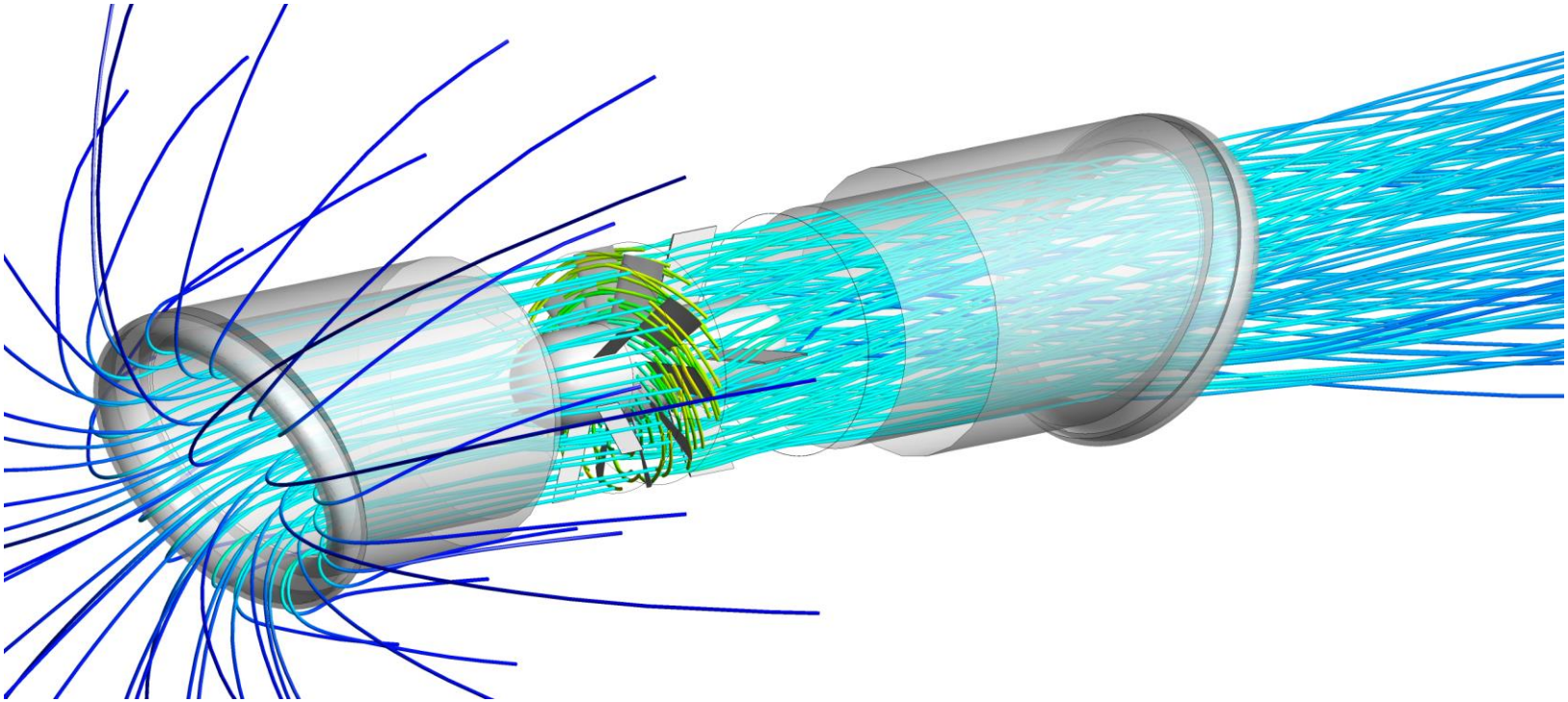
Comparison of Alternative Jetfan Technologies



mosen

Contents

- Methodology
- Conventional Jetfan
- Slanted Silencers (“Banana Jet®”)
- Deflectors
- MoJet®

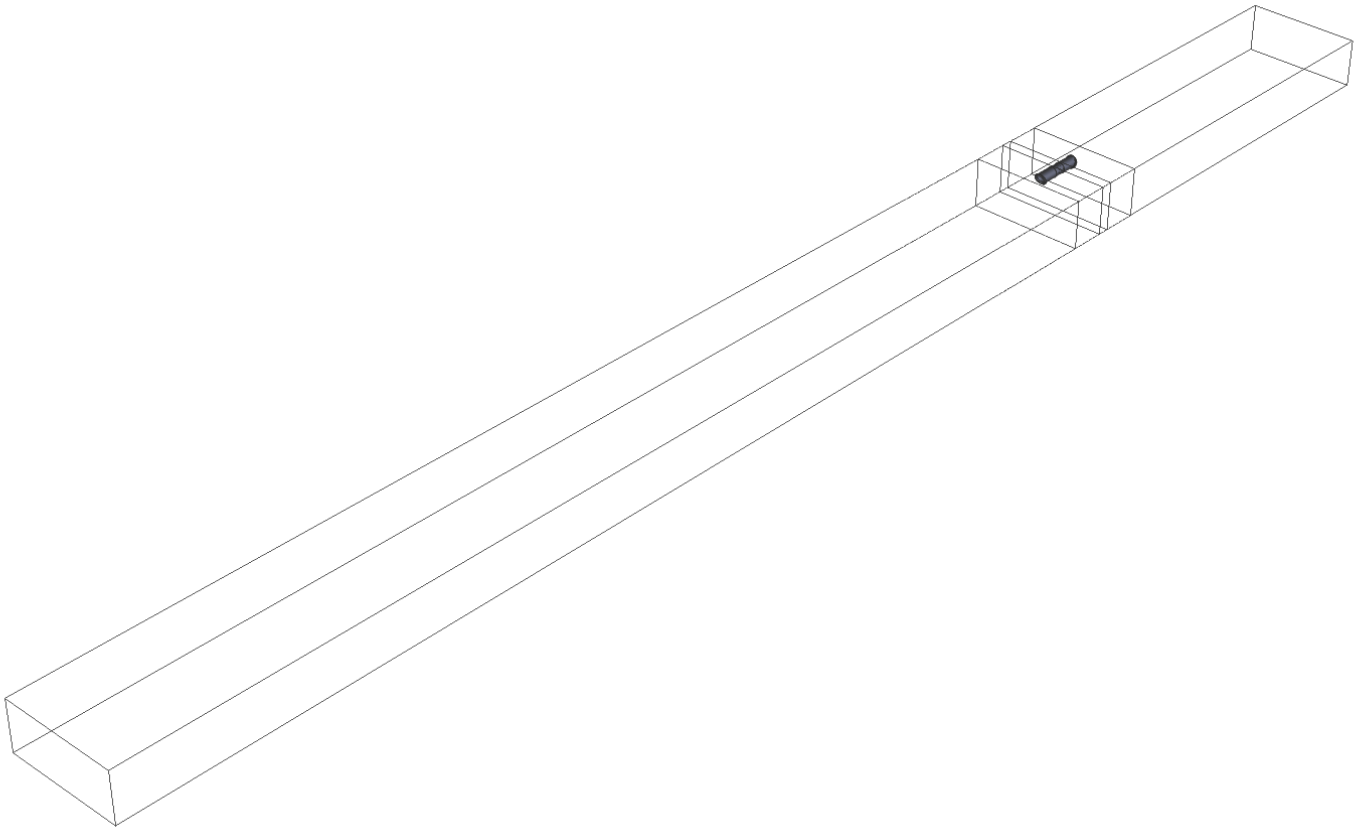
mosen

Basis of CFD Calculations

- 1500 revolutions per minute (4-pole motor)
- 10 blades on rotor
- Multiple frame of reference for modelling rotating blades (with circumferential averaging at interface planes)
- Tunnel length = 211.6 m
- Tunnel height = 6.75 m
- Tunnel width = 16 m
- Distance of jetfan casing below tunnel soffit = 150mm
- Maximum installation height below soffit = 1.7 m
- k-ω SST model of turbulence

mosen

CFD Domain – Tunnel & Jetfan

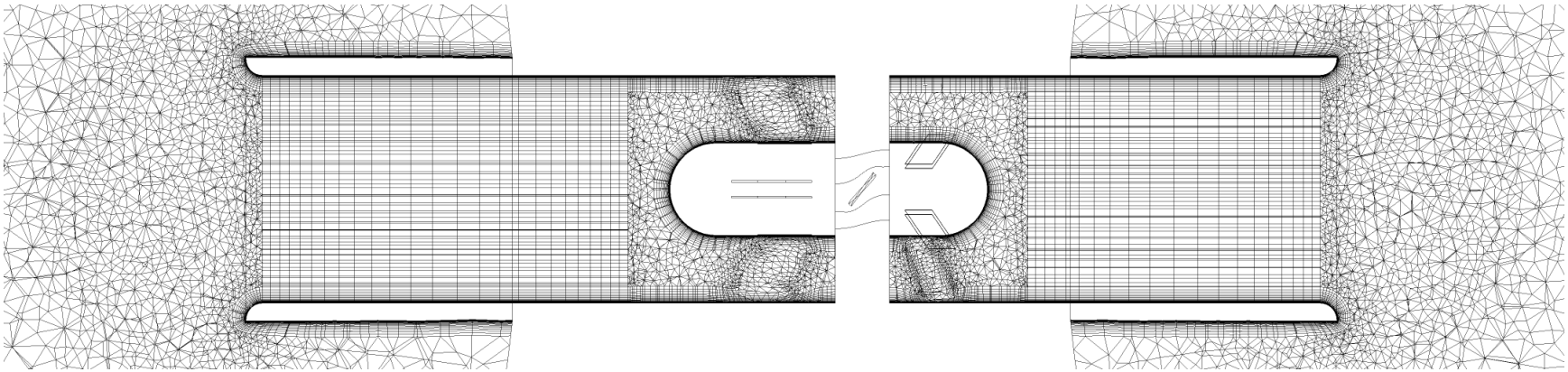


Jetfan Geometry

- Jetfan geometries defined by major tunnel ventilation manufacturer
- All aerodynamically relevant features (rotating blades, silencers, motor, struts, nose cones) were modelled

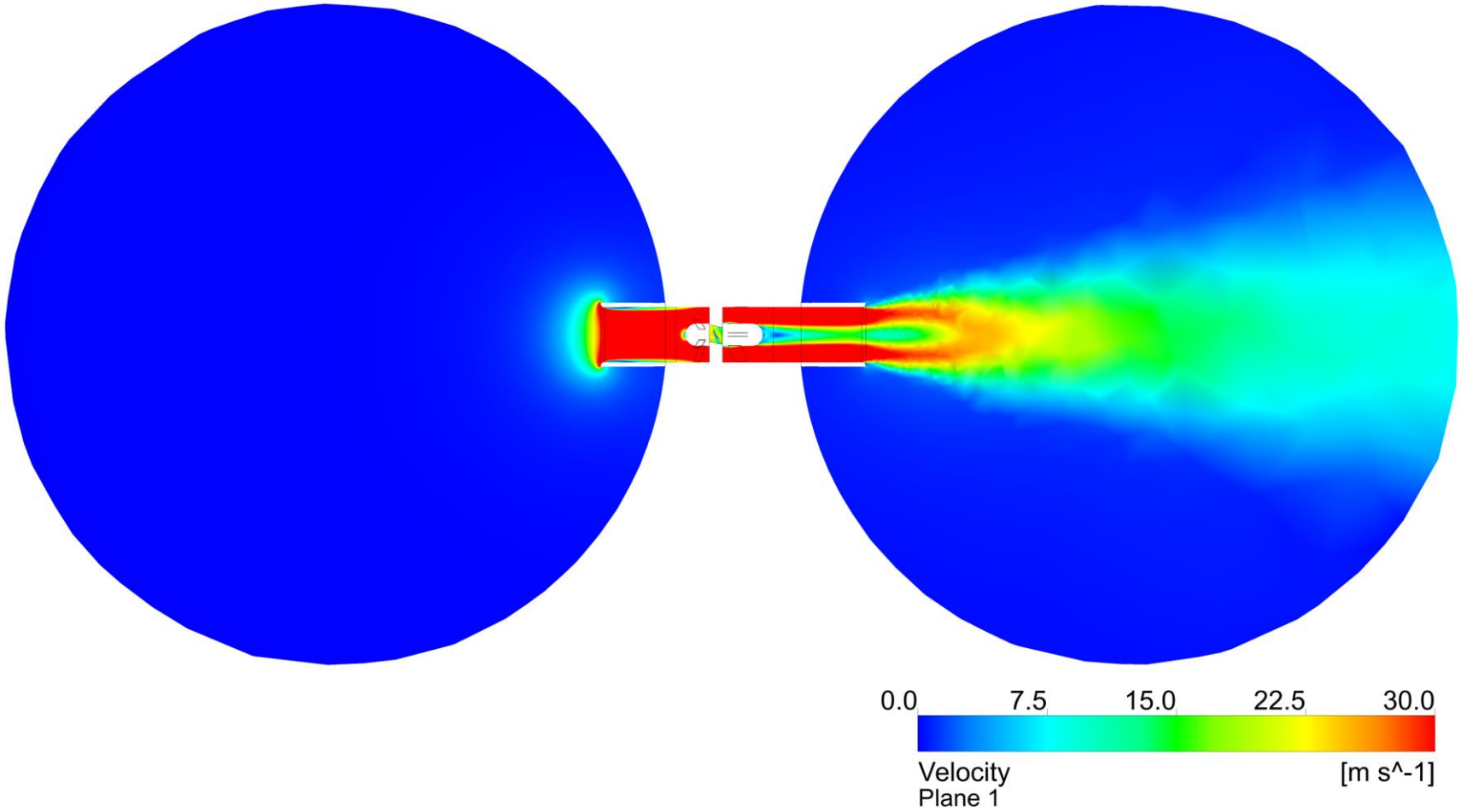
mosen

Conventional Jetfan - Geometry



- 1250 mm jetfan diameter
- Fan with 10 blades
- Nose cones at both ends of the centre-body
- Struts supporting the centre-body / motor on both sides of the fan

Conventional Jetfan Bench Thrust Test – Velocity Contours

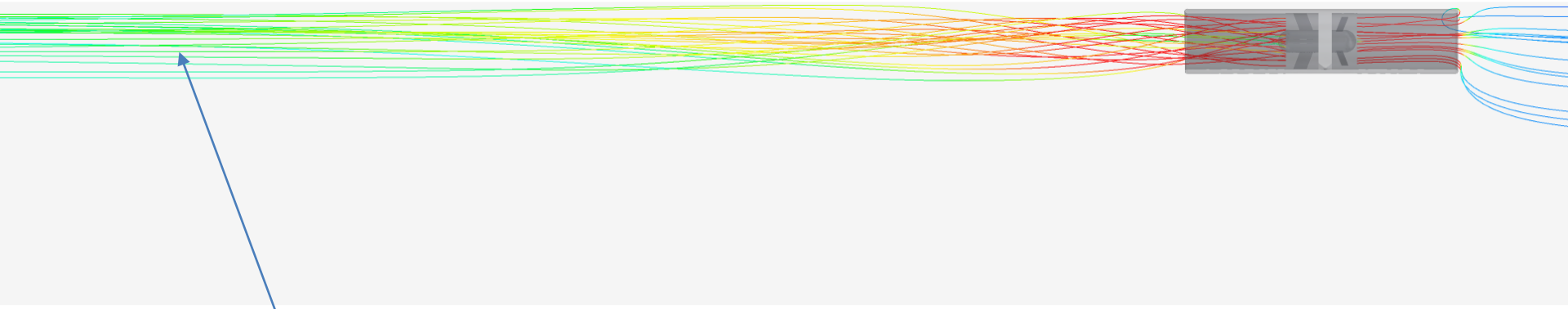


Conventional Jetfan Bench Thrust Test – Results

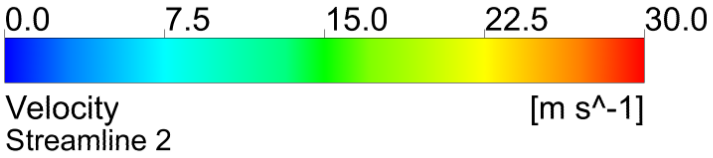
	Conventional Jetfan
Blade pitch angle	33.4°
Blade torque (Nm)	285.6
Fan shaft power (kW)	44.9
Fan mass flow (kg/s)	50.57
Thrust (N)	1759

mosen

Conventional Jetfan in Tunnel – Particle Tracks

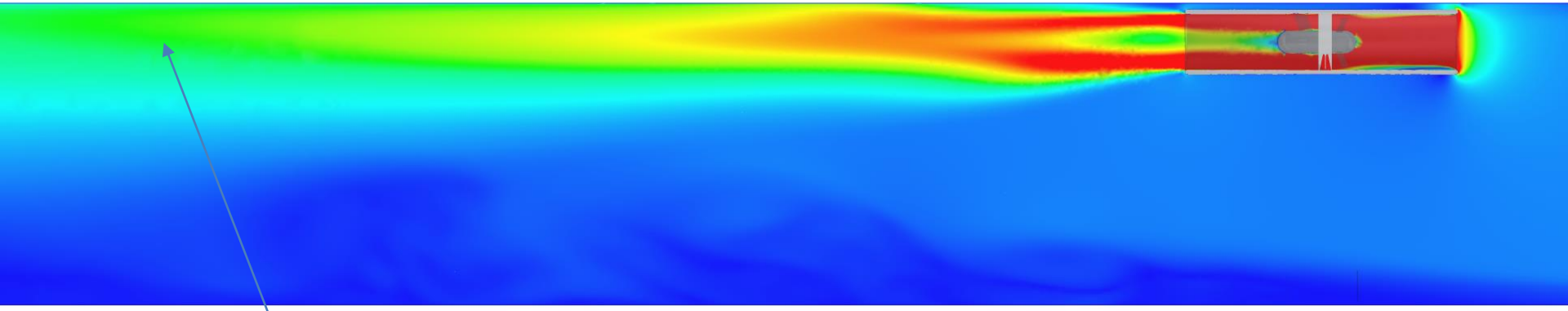


Discharged flow adheres to soffit due to Coanda effect

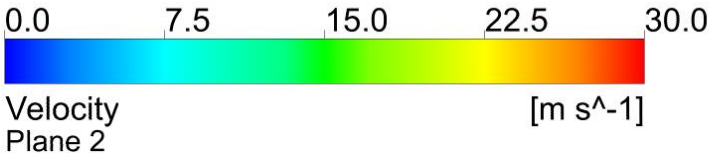


mosen

Conventional Jetfan in Tunnel – Velocity Contours



Discharged flow adheres to soffit due to Coanda effect



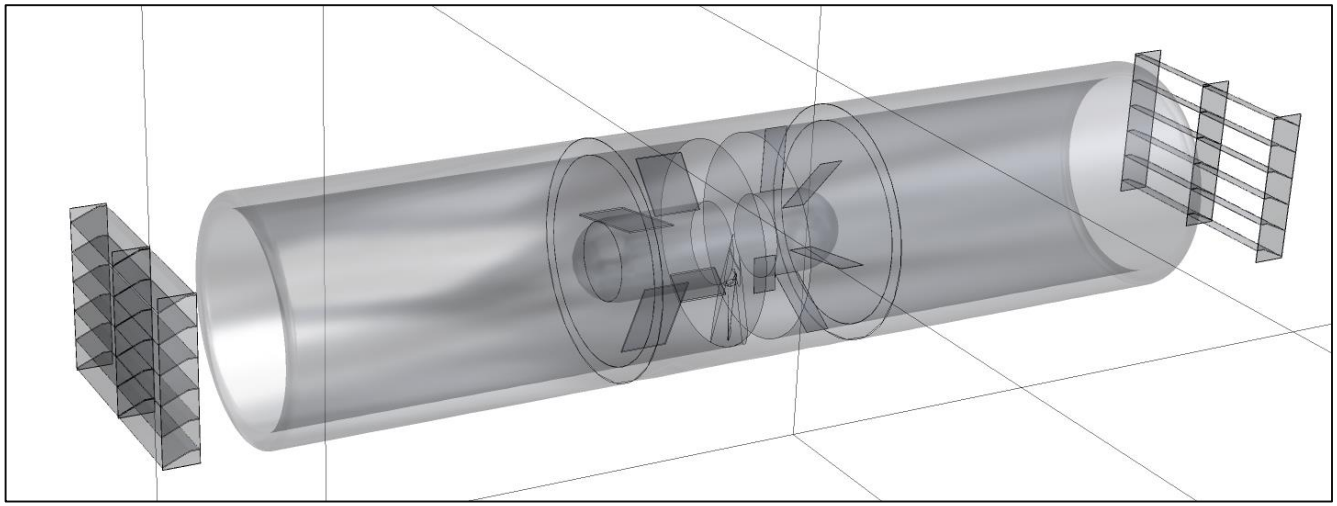
mosen

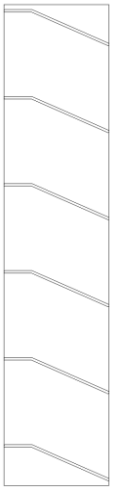
Conventional Jetfan in Tunnel - Results

	3D CFD Model
Number of CFD cells	25.1 million
Blade pitch angle	33.4°
Tunnel air velocity (m/s)	2.66
Installation factor	0.84
Fan shaft power (kW)	**56.7**
Fan mass flow (kg/s)	49.0
In-tunnel thrust (N)	**1277**

mosen

Deflection Vanes - Geometry

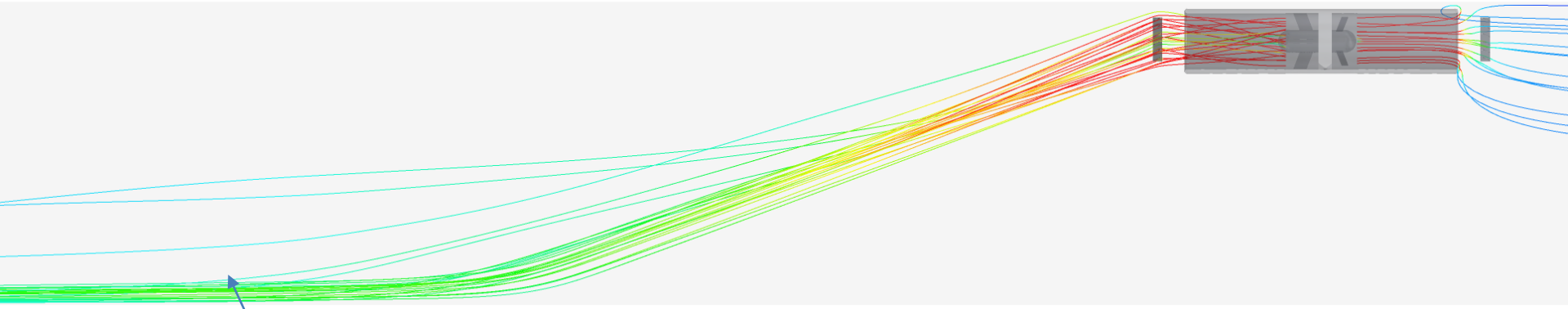




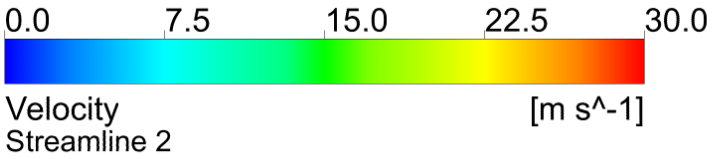
- 1250 mm jetfan diameter
- 25° deflection angle
- Positioned 0.504 m from silencer ends

mosen

Deflection Vanes – Particle Tracks

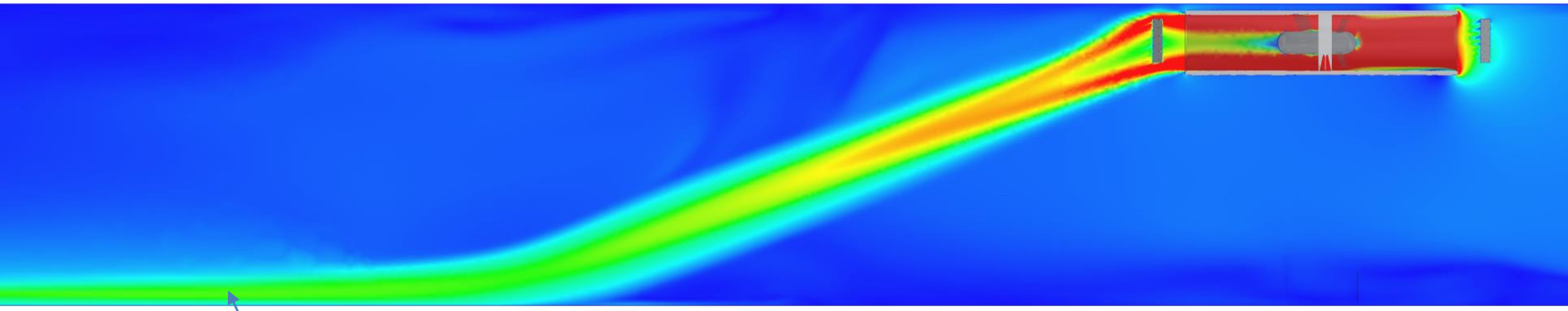


Discharged flow adheres to floor due to Coanda effect

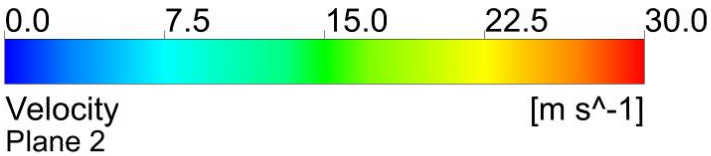


mosen

Deflection Vanes – Velocity Contours



Discharged flow adheres to floor due to Coanda effect



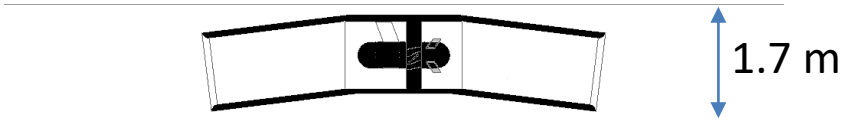
mosen

Deflection Vanes - Results

	3D CFD Model
Number of CFD cells	72.3 million
Blade pitch angle	33.4°
Tunnel air velocity (m/s)	2.26
Installation factor	0.60
Fan shaft power (kW)	**56.43**
Fan mass flow (kg/s)	49.39
In-tunnel thrust	946
% of conventional jetfan thrust	**74%**

mosen

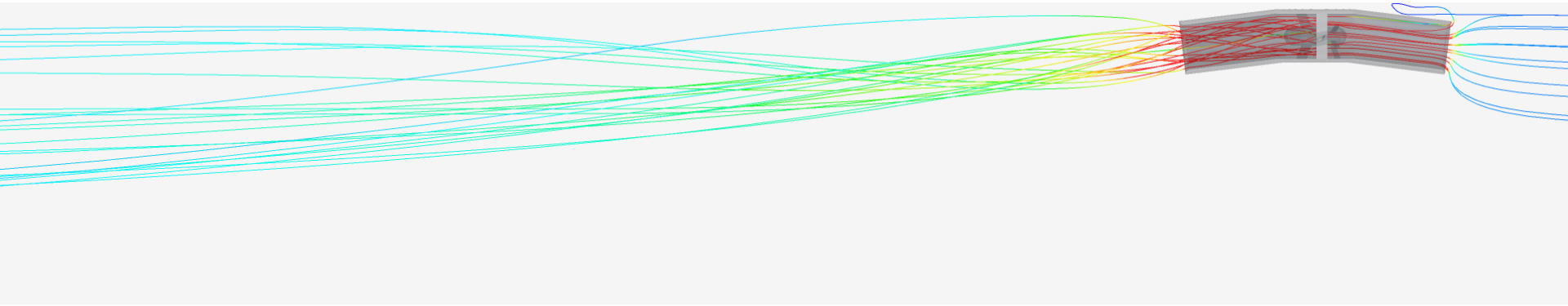
Slanted Silencers - Geometry

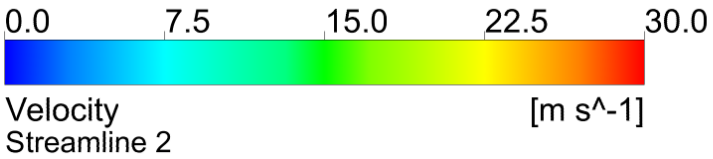


- 7° slanted silencers, each 2 m long
- Jetfan diameter had to be reduced to 1 m to fit into 1.7 m headroom
- 10 blades
- 43° blade pitch angle (maximum allowable without stalling)
- With supporting struts, centre-body and nose cones

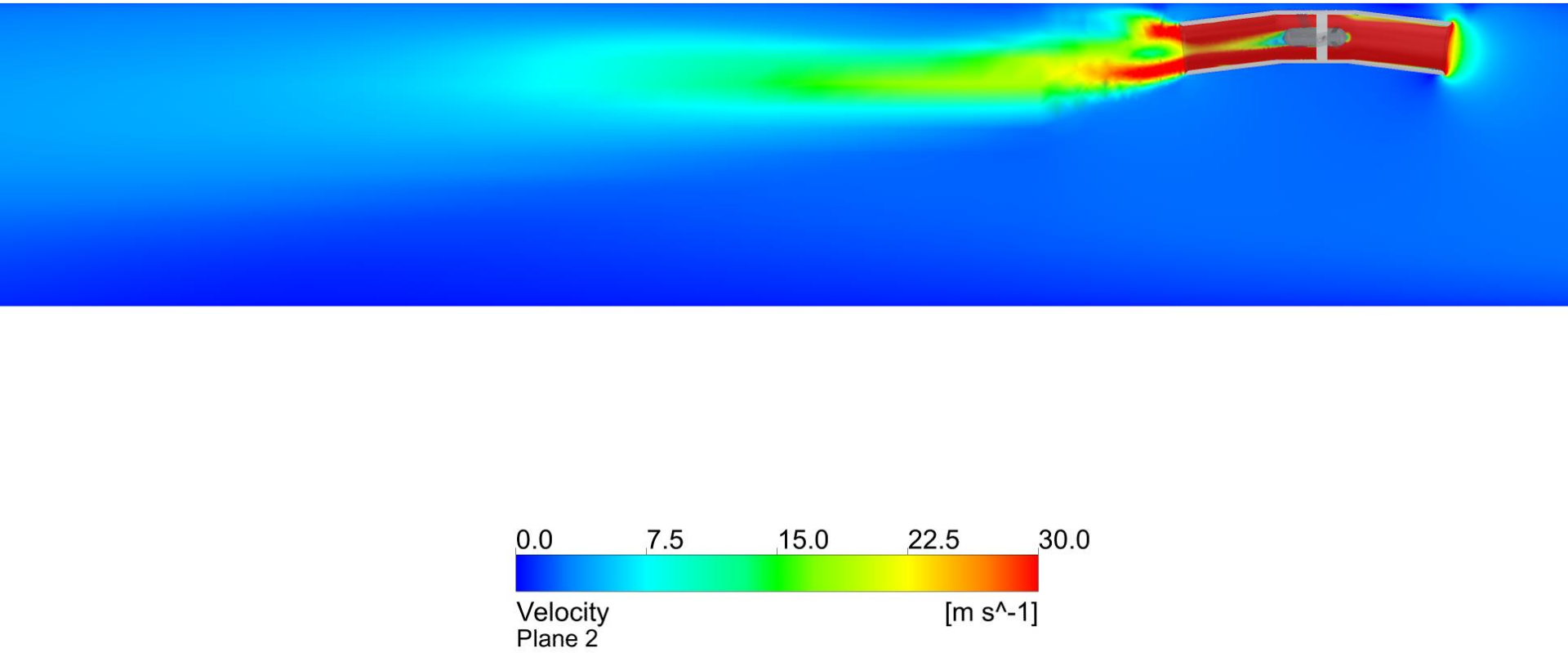
mosen

Slanted Silencers – Particle Tracks





Slanted Silencers – Velocity Contours

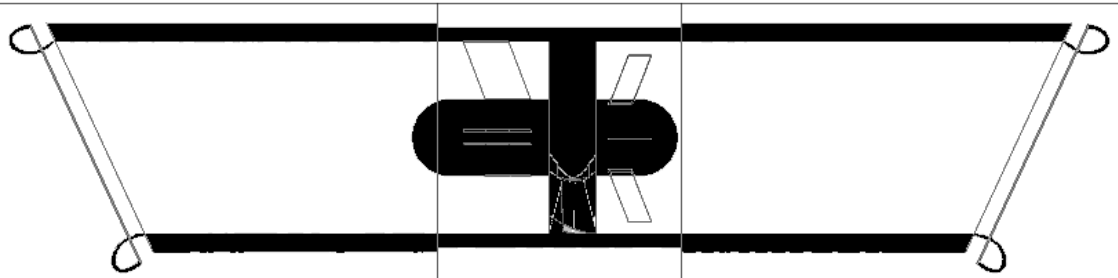


Slanted Silencers - Results

	3D CFD Model
Number of CFD cells	3.38 million
Blade pitch angle	43°
Tunnel air velocity (m/s)	2.39
Installation factor	0.89
Fan shaft power (kW)	**22.9**
Fan mass flow (kg/s)	34.01
In-tunnel thrust	1034
% of conventional jetfan thrust	**81%**

mosen

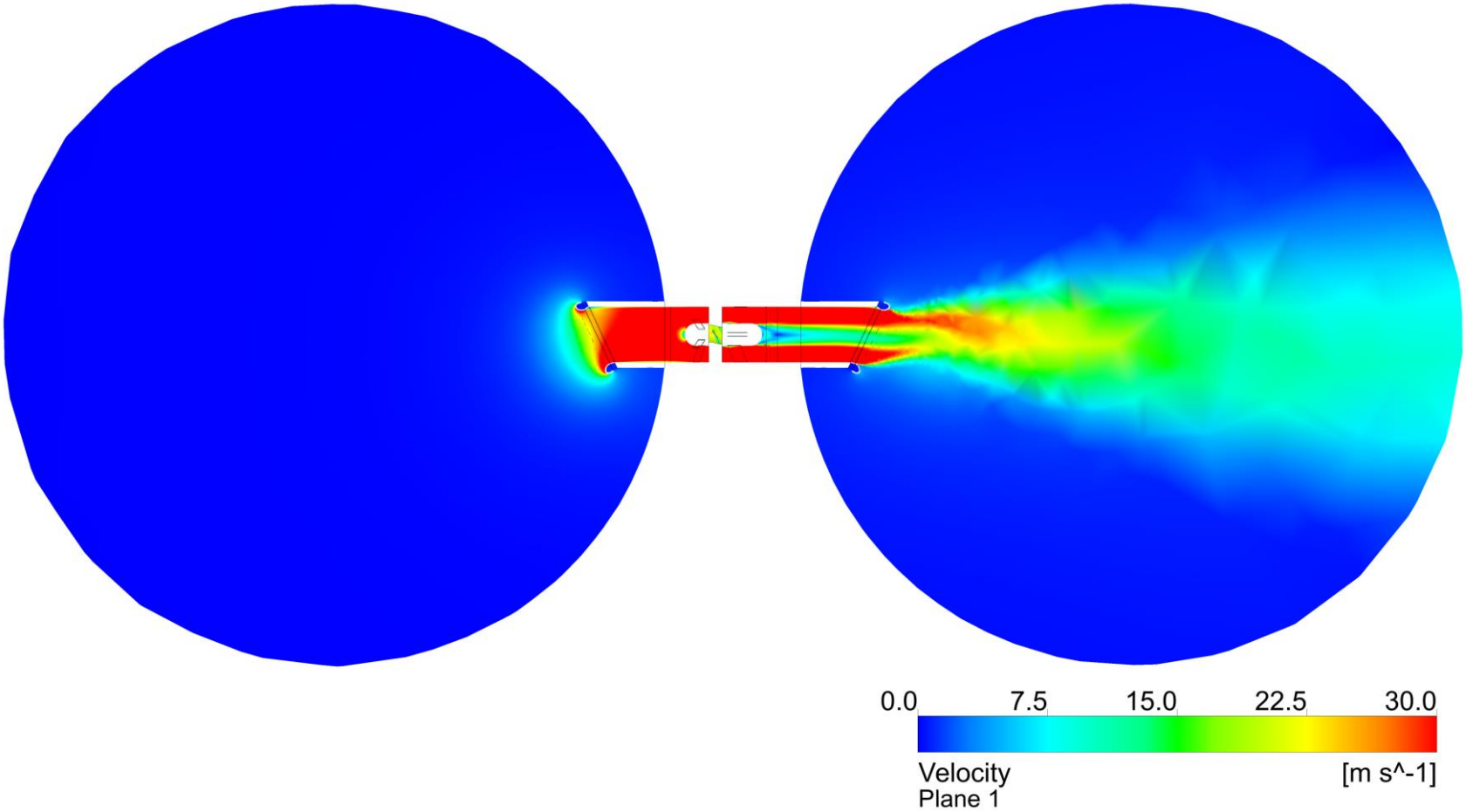
MoJet - Geometry



- 1250 mm jetfan diameter
- Fan with 10 blades
- Nose cones at both ends of the centre-body
- Struts supporting the centre-body / motor on both sides of the fan
- 25° inclination of silencer trailing edge

mosen

MoJet – Bench Thrust Test - 33.4° Blade Pitch Angle – Velocity Contours

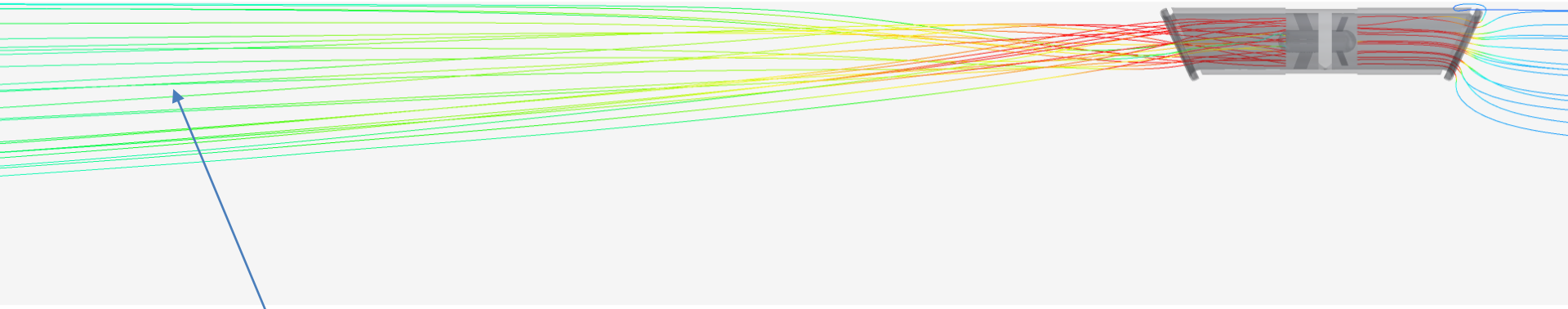


MoJet – Bench Thrust Test - 33.4° Blade Pitch Angle – Results

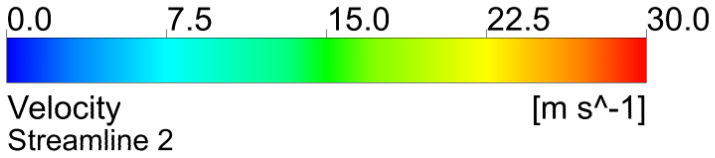
	MoJet
Blade pitch angle	33.4°
Blade torque (Nm)	275.3
Fan shaft power (kW)	43.2
Fan mass flow (kg/s)	51.38
Thrust (N)	1815

mosen

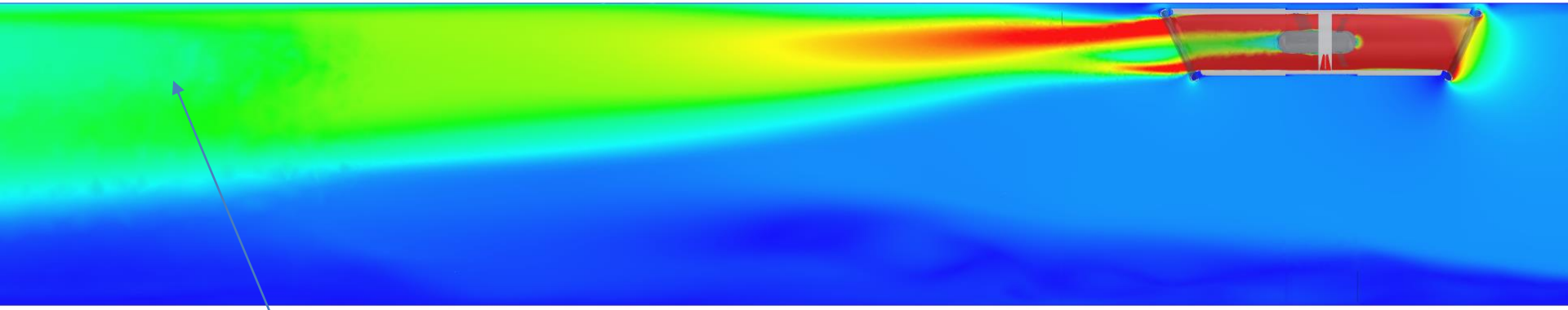
MoJet – 33.4° Blade Pitch Angle – Particle Tracks



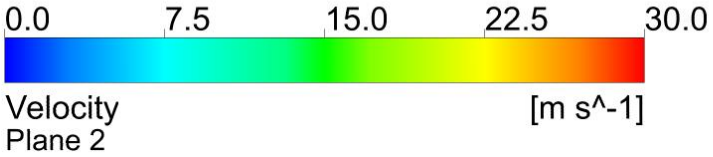
Coanda effect is overcome



MoJet – 33.4° Blade Pitch Angle – Velocity Profile



Coanda effect is overcome



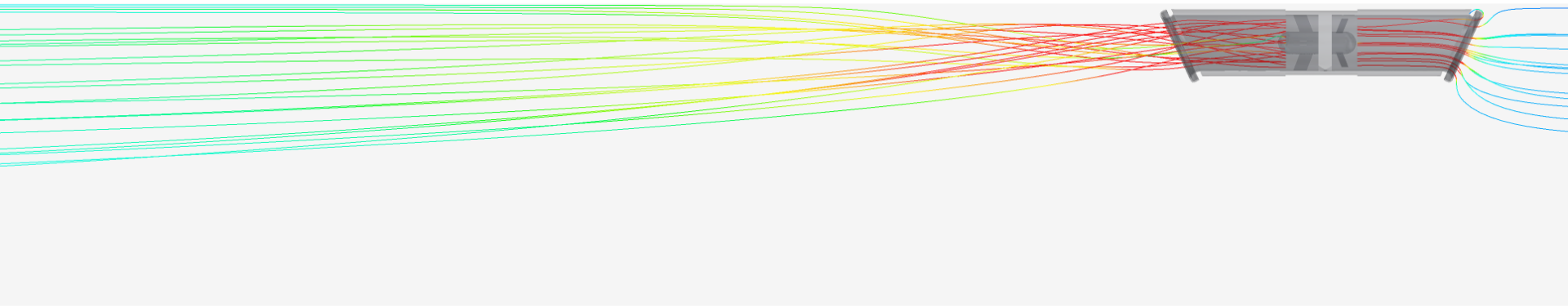
mosen

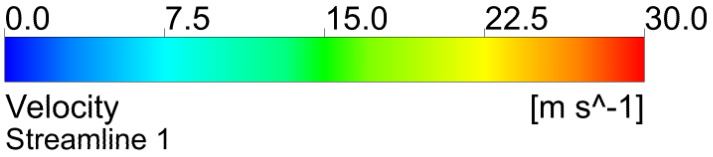
MoJet – 33.4° Blade Pitch Angle – Results

	3D CFD Model
Number of CFD cells	27.1 million
Blade pitch angle	33.4°
Tunnel air velocity (m/s)	3.04
Installation factor	0.92
Fan shaft power (kW)	**48.2**
Fan mass flow (kg/s)	52.24
In-tunnel thrust	1580
% of conventional jetfan thrust	**124%**

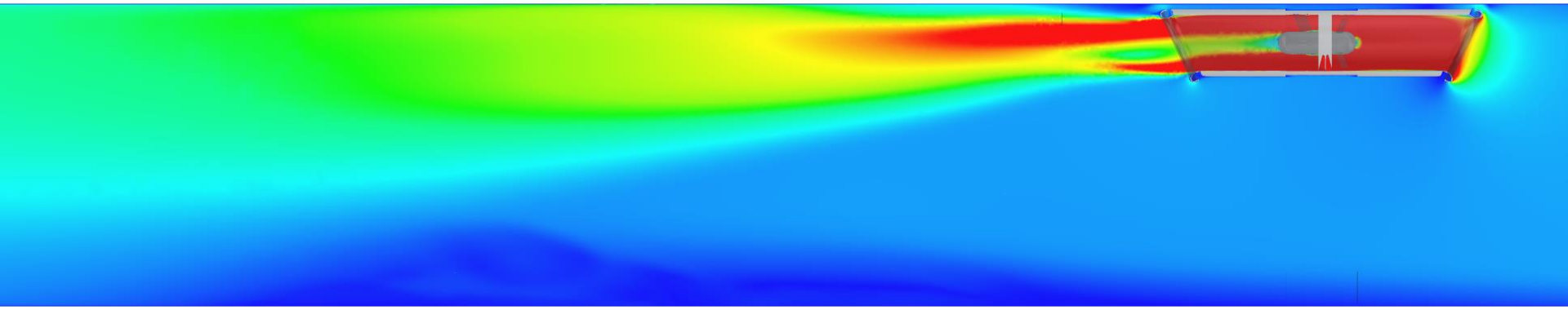
mosen

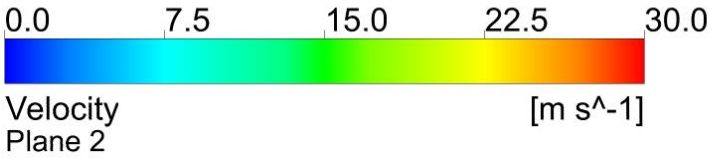
MoJet – 39° Blade Pitch Angle – Particle Tracks





MoJet – 39° Blade Pitch Angle – Velocity Profile





MoJet 39° Blade Pitch Angle – Results

	3D CFD Model
Number of CFD cells	27.1 million
Blade pitch angle	39°
Tunnel air velocity (m/s)	3.62
Installation factor	1.00
Fan shaft power (kW)	**56.3**
Fan mass flow (kg/s)	57.4
In-tunnel thrust	2061
% of conventional jetfan thrust	**161%**

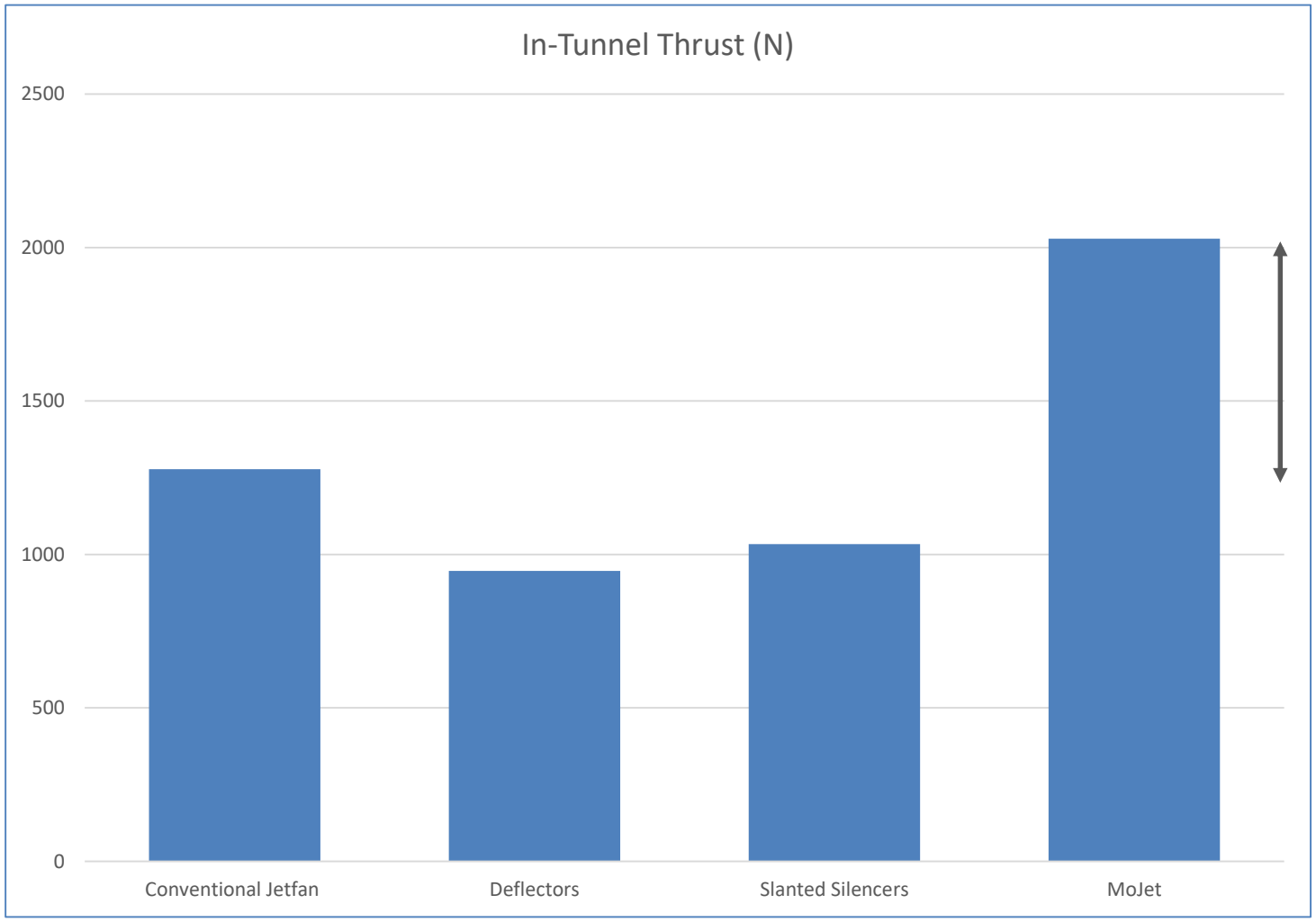
mosen

MoJet – Reasons for Additional In-Tunnel Thrust

1. Reduction in Coanda effect (i.e. the flow is turned away from the tunnel soffit)
2. Static pressure recovery downstream of the fan (due to increase in silencer cross-sectional area)
3. Increased mass flowrate through the fan (due to reduced inlet and outlet pressure drops)
4. Reduced discharge velocity, leading to lower shear stress at the tunnel soffit

mosen

In-Tunnel Thrust Comparison



61% more in-tunnel thrust than conventional jetfan, with less power consumption

mosen

Further Research

- Institute of Aerodynamics at RWTH Aachen University is manufacturing 1:18 scale models of tunnels incorporating jetfans with different silencer geometries including slanted silencers and MoJets, to measure their installation factors
- Full-scale tunnel testing of the MoJet is also planned

mosen