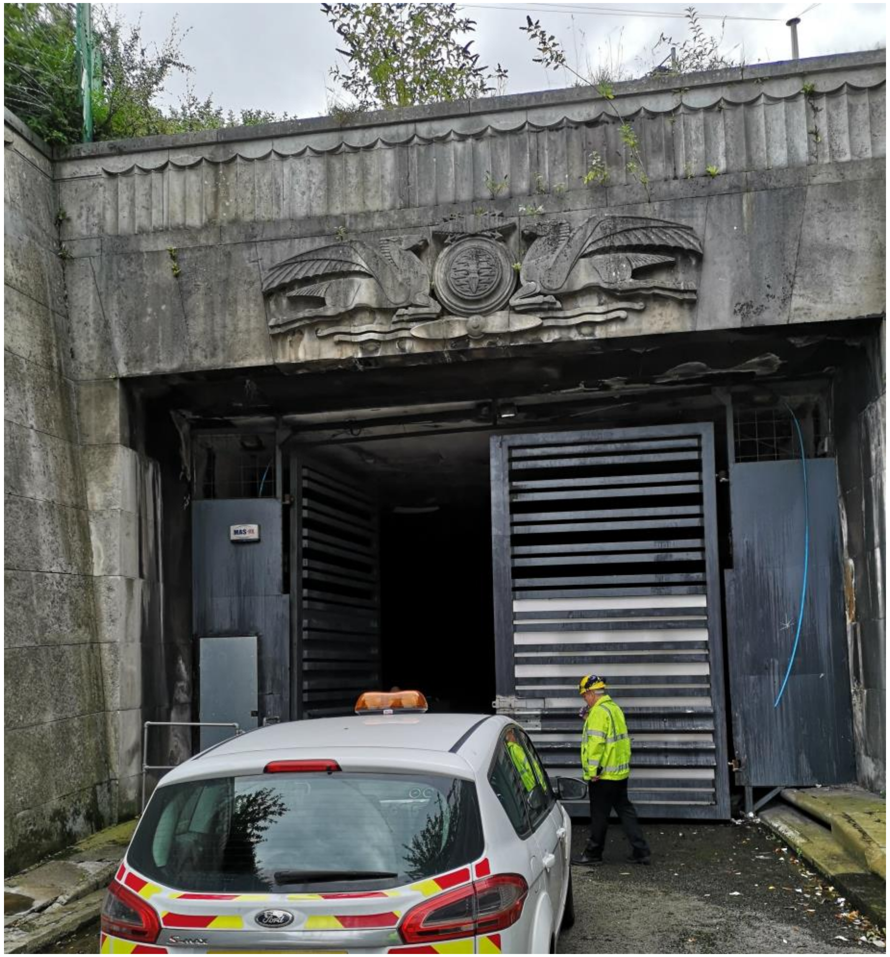
MoJet in Mersey Queensway Tunnel

Mosen Ltd

Motivation

- Can we deliver aerodynamic thrust in a tunnel
  - Significantly more than that delivered by a conventional jet fan
  - With less power consumption than a conventional jet fan
  - Within the same headroom as a conventional jetfan

Mersey Queensway Tunnel – Rendel Street Branch



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Rendel Street Branch Tunnel
(500 m long x 7 m wide approx.)

Jet Fan Bench thrust

CFD MODEL SETTINGS

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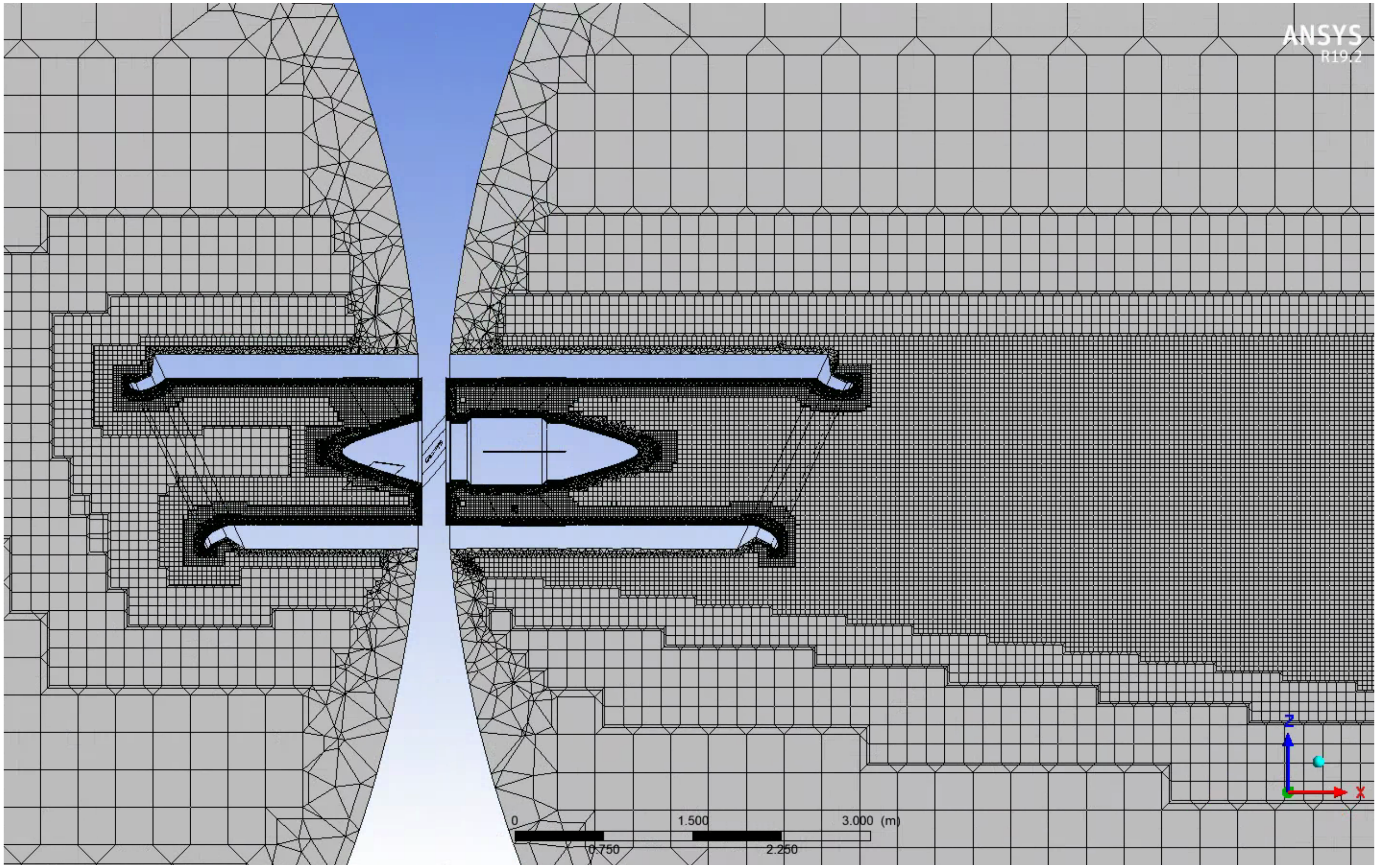
Settings

Case configuration

- The simulations were run in CFX (2019R2) with the following conditions:
  - Fan rotational speed of 1485 rpm, blade pitch angle 32°
  - Non-buoyant model
  - 1 atm Reference Pressure
  - Total Energy with Viscous Work Term
  - Turbulence Model: k-ω SST
- Mesh of approximately 55 million hex cells

Settings

Mesh example



Settings

Calculation of discharge angle

- The discharge flow has a highly 3D nature which makes 2D angle analysis subjective (i.e. dependent on the 2D plane used and user interpretation of boundaries).
- A script was produced to calculate the average (velocity weighted) XZ plane angle.
- This seemed to give representative numbers for the effectiveness of the discharge silencer + bellmouth in turning the flow.

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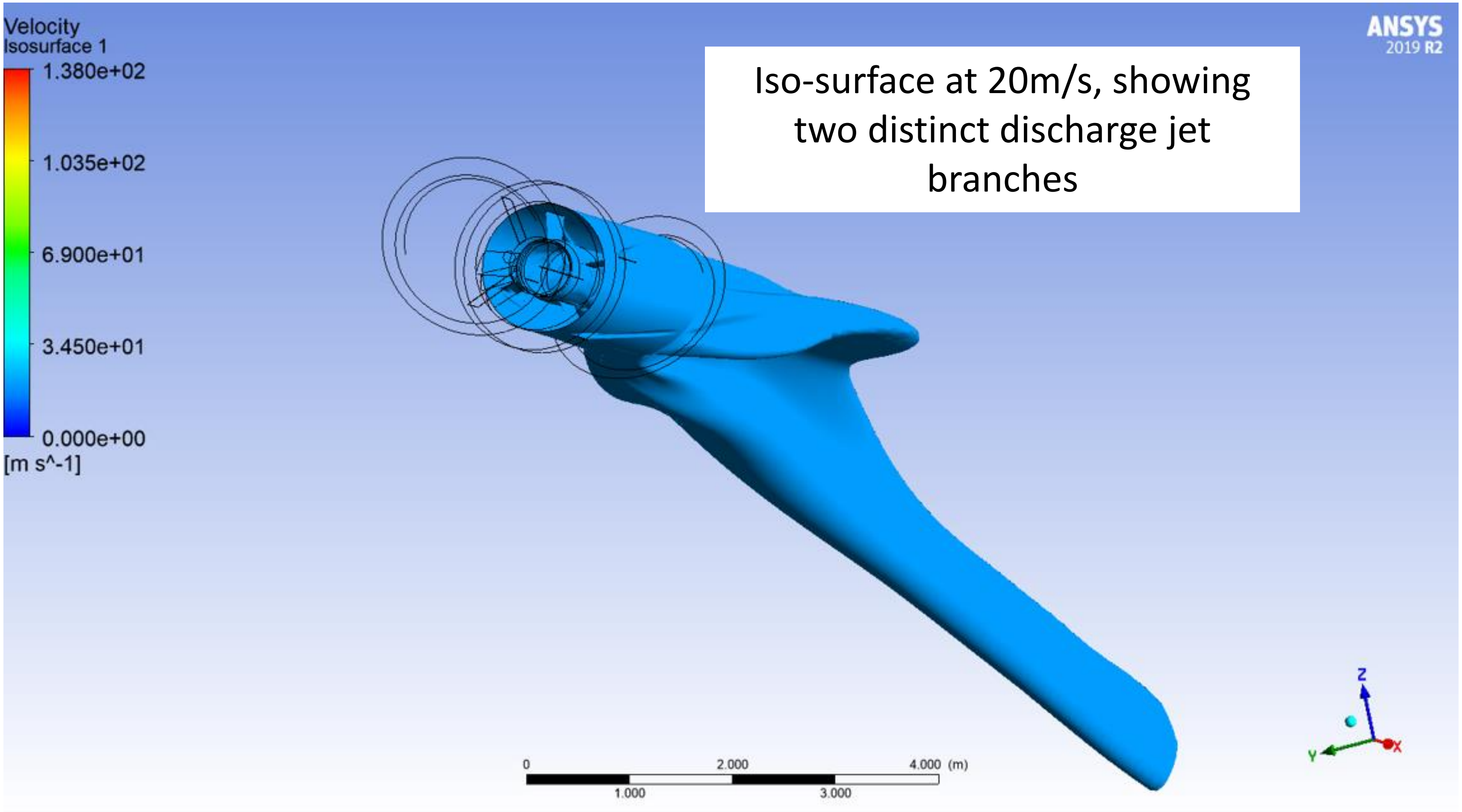
MoJet Model

Calculation of discharge angle



CFD bench thrust simulation results

1.25M MOJET

1.25m Ø MoJet

Bench thrust simulation

• Mass flow rate	46.0 kg/s
• Thrust	1599 N
• Discharge angle	6.1°

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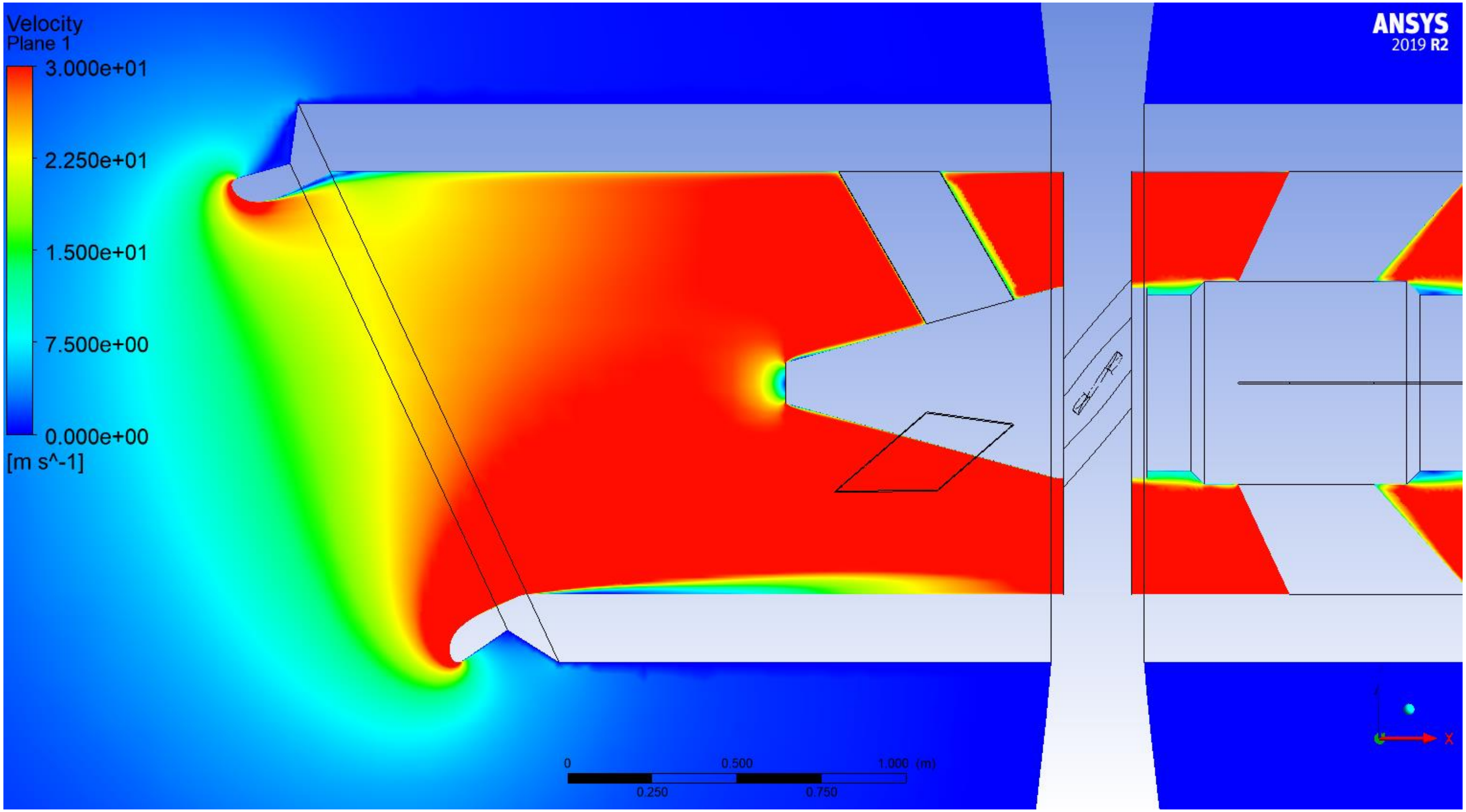
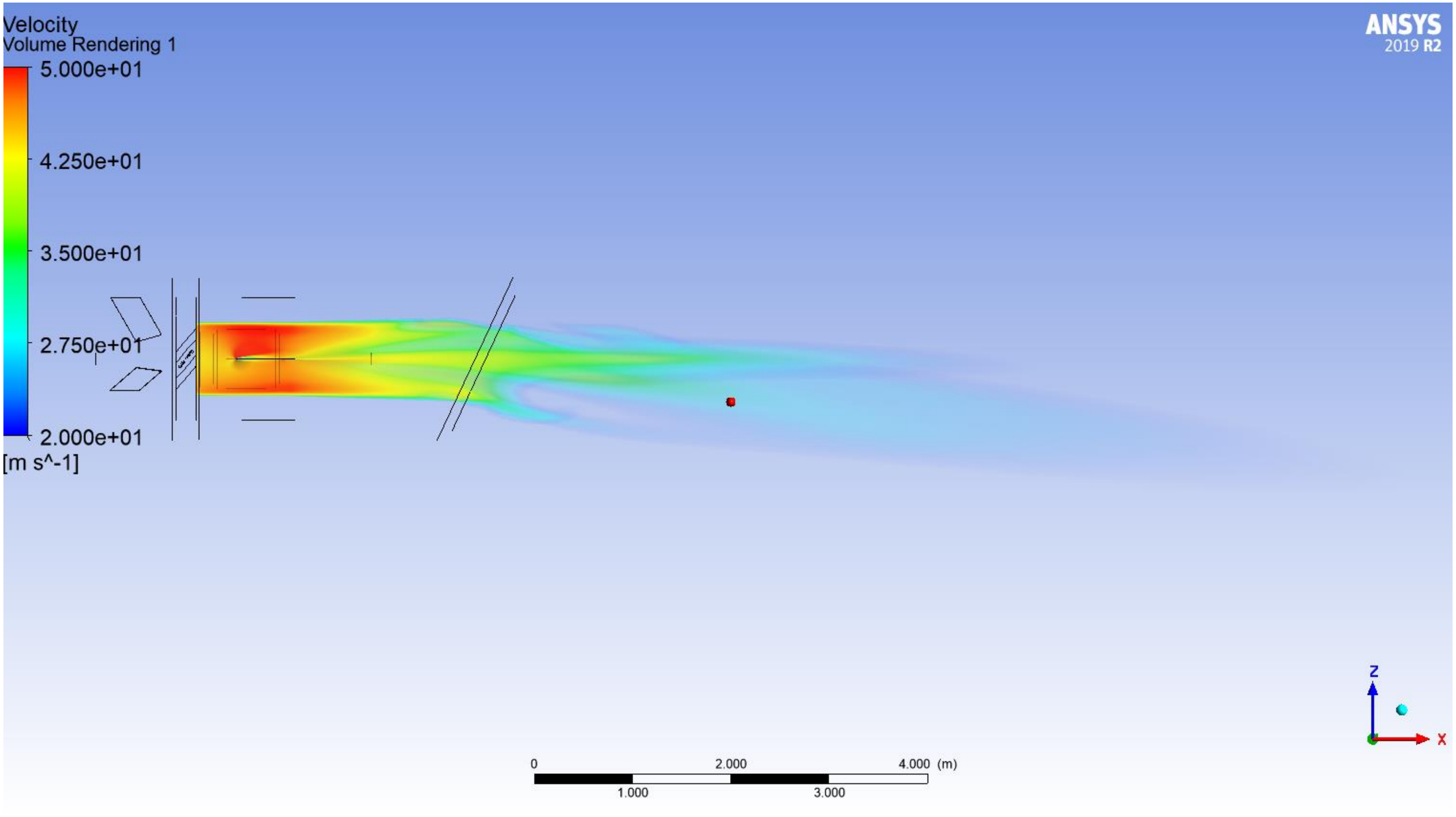
MoJet model

Inlet flow characteristics



MoJet model

Outlet flow characteristics



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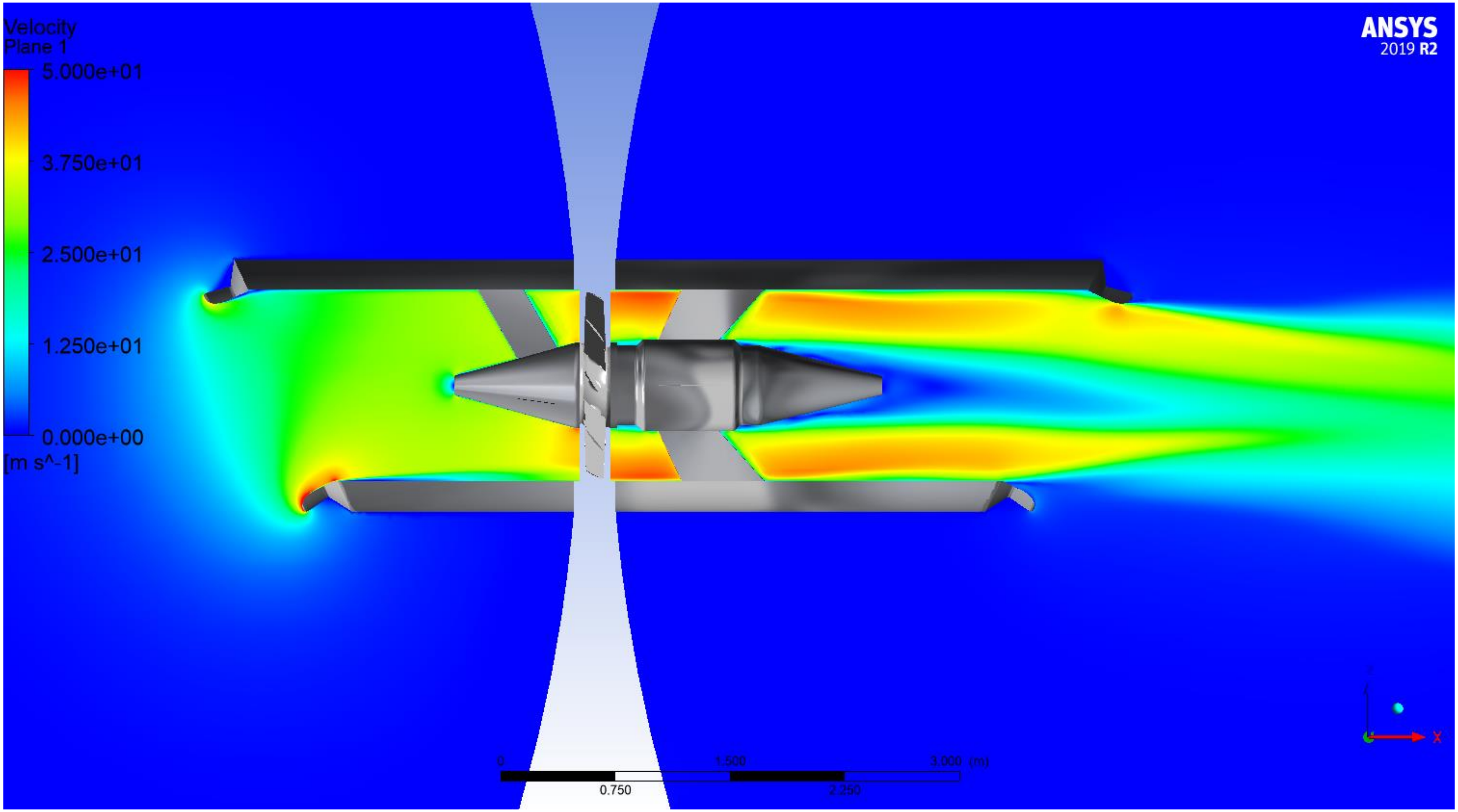
MoJet model

Results



CFD tunnel simulation

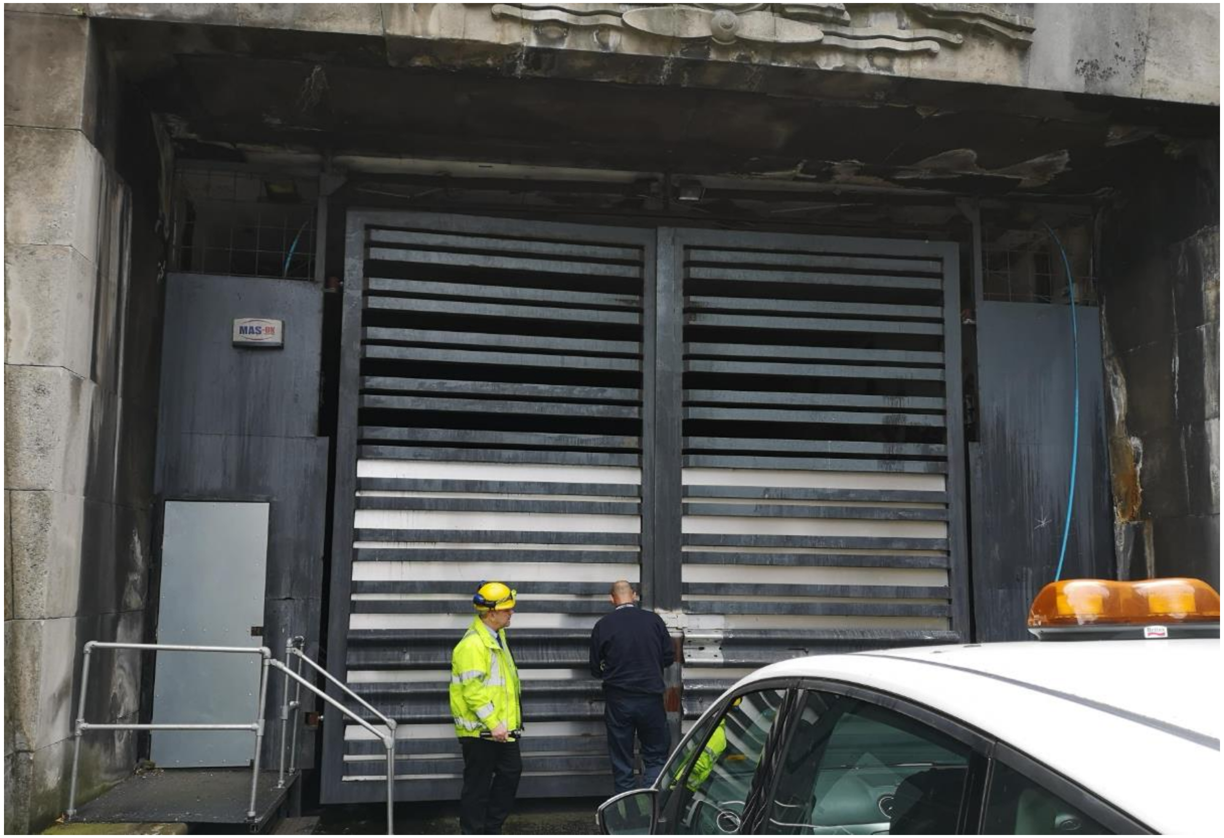
MOJET IN QUEENSWAY TUNNEL

Queensway MoJet model
Settings

- The 1.25m MoJet was simulated within the Rendel Street branch of the Mersey Queensway tunnel.
- A single fan was mounted 12m from the portal plane.
- An inlet loss coefficient of 5.6 was calculated using IDA RTV.
- An outlet loss coefficient of 4.0 was calculated as the open area ratio due to the portal doors.

Queensway MoJet model

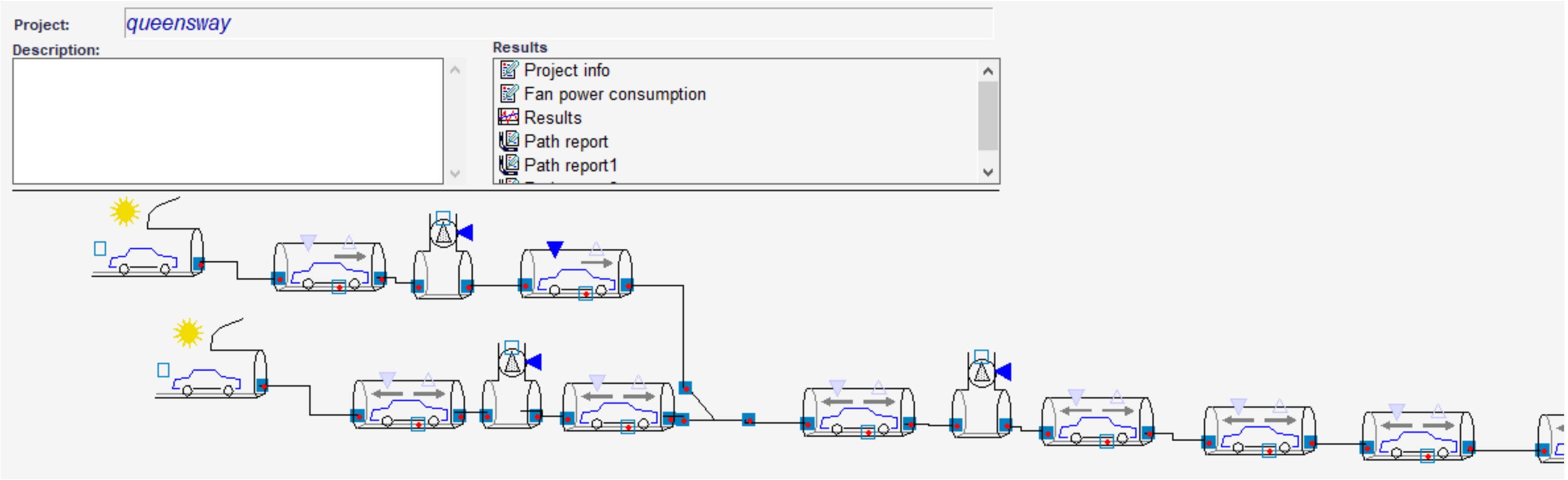
Settings



- Tunnel cross sectional area is 48.3m.
- Closed area of 22.9m.
- Area ratio is close to a half and hence a loss coefficient of 4 was used.

Queensway MoJet model

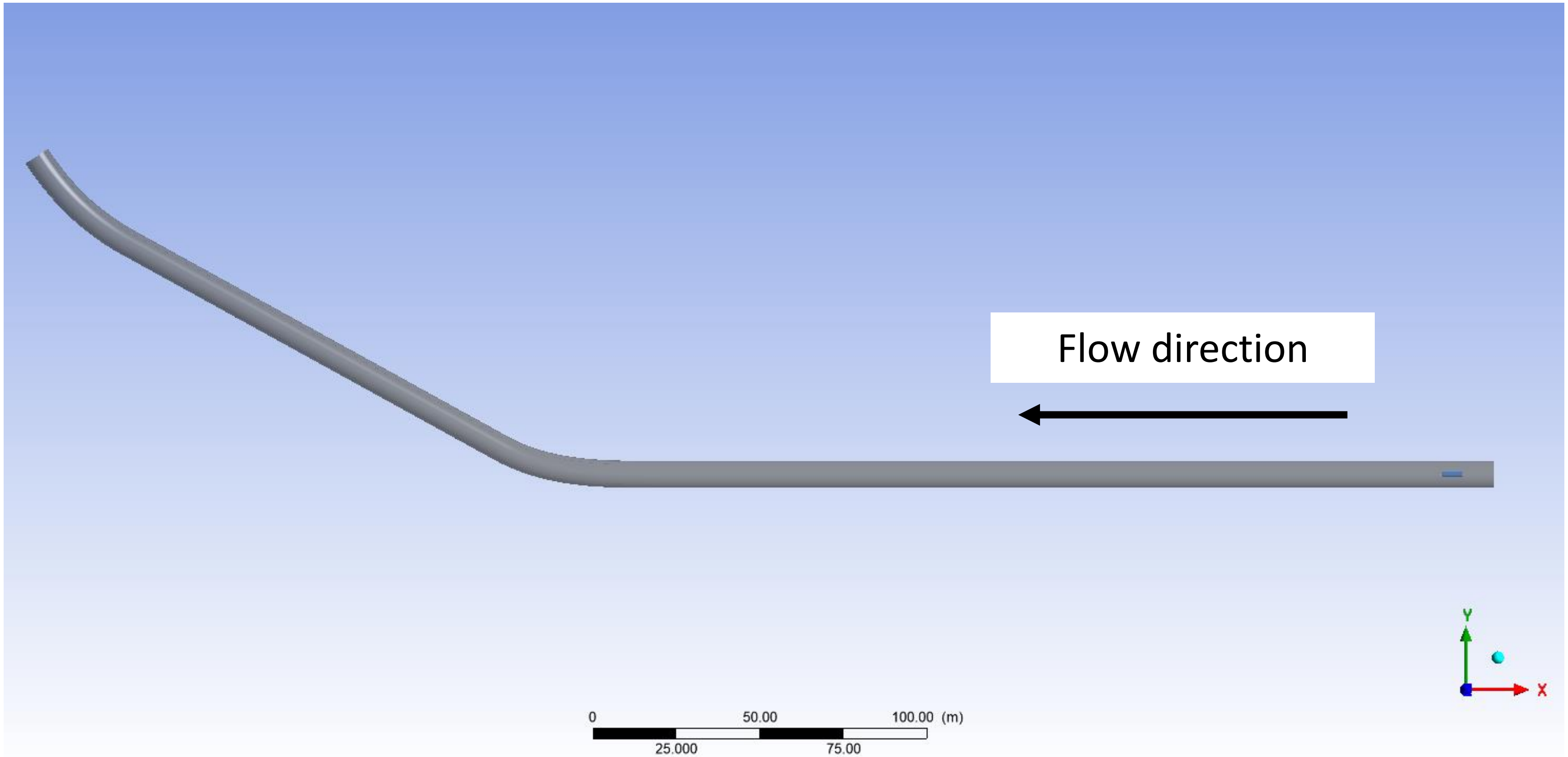
Settings



- IDA model of Queensway tunnel with Rendel Street branch.
- The main tunnel fans were switched off for the calculation to determine the inlet loss coefficient.

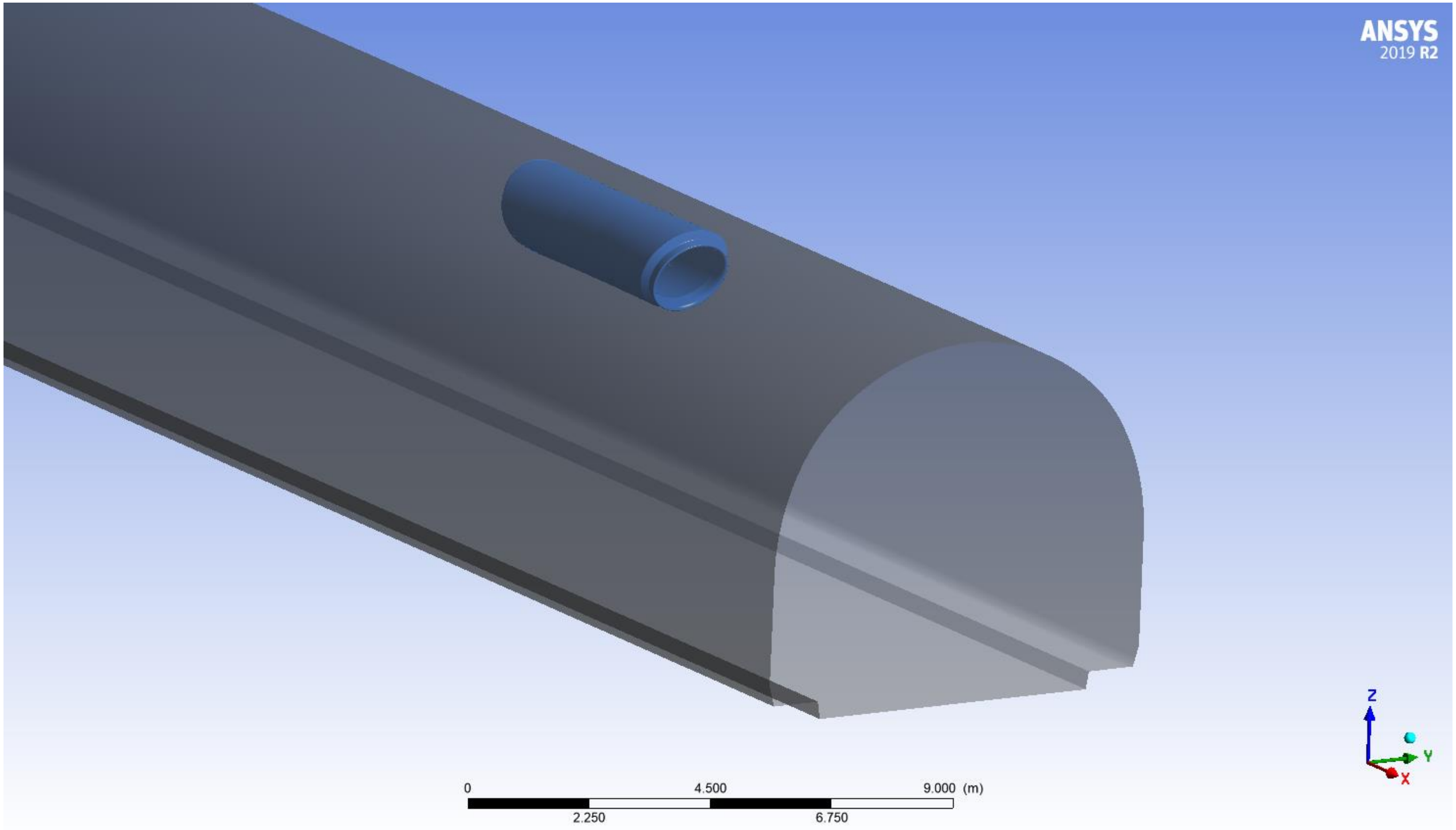
Queensway MoJet model

Settings



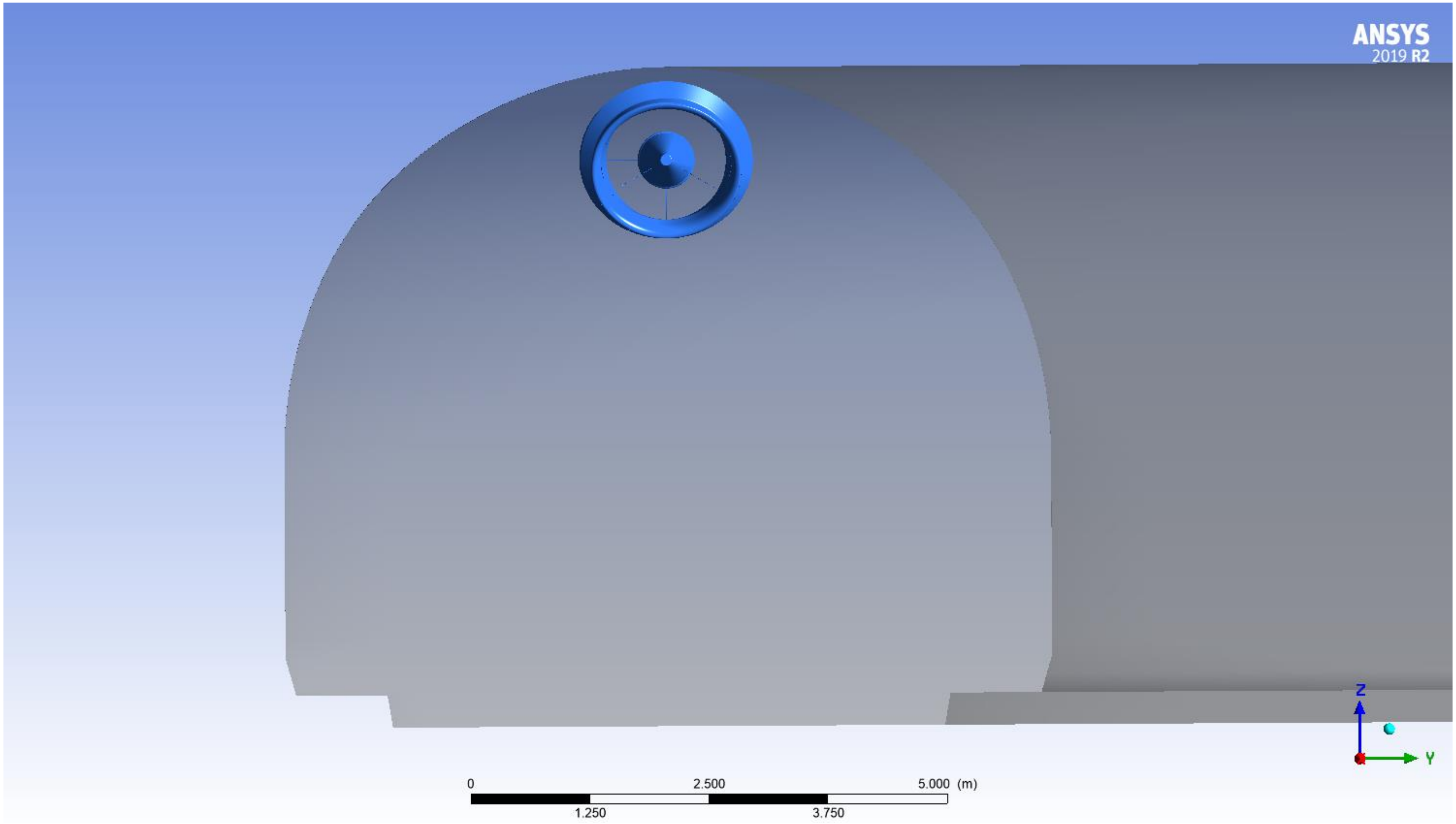
Queensway MoJet model

Settings

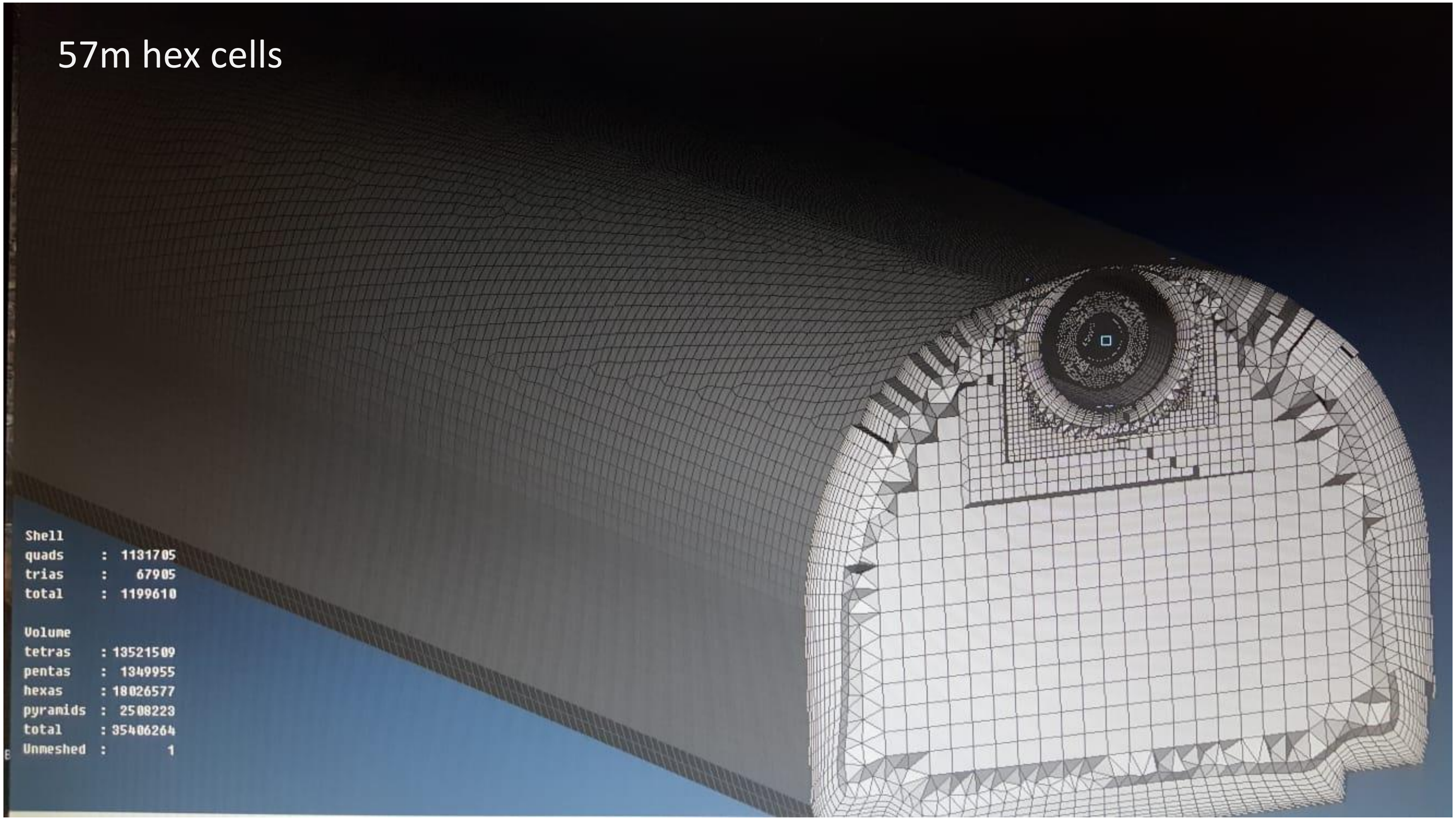


Queensway MoJet model

Settings



Cross-Section of Mesh Across MoJet



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Queensway Tunnel - MoJet model
Results

- Area flow average velocity at outlet was 1.97 m/s.
- The discharge from the MoJet tends to split with the majority of flow going to the centre of the tunnel whilst another much smaller branch tends to stick to the soffit.

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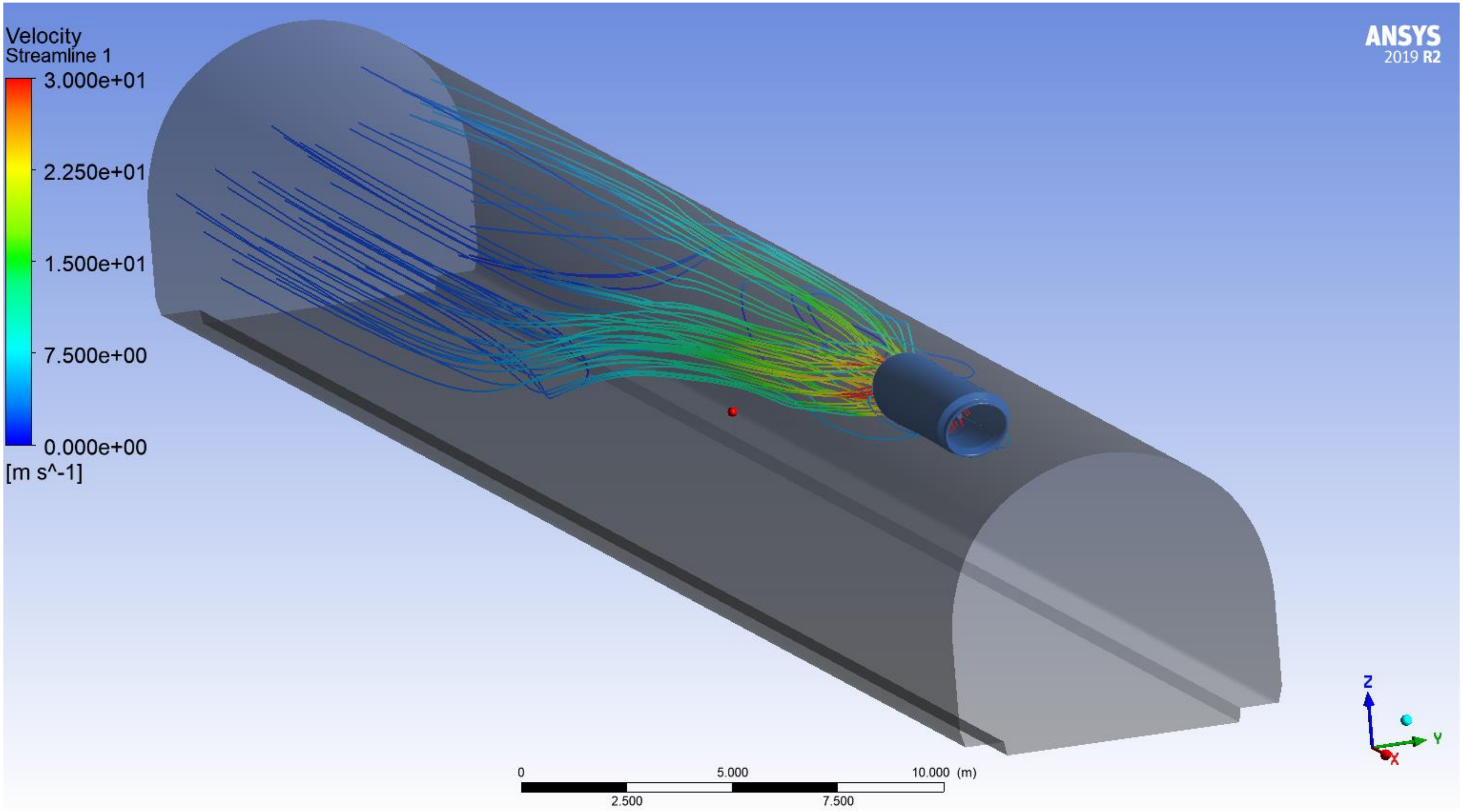
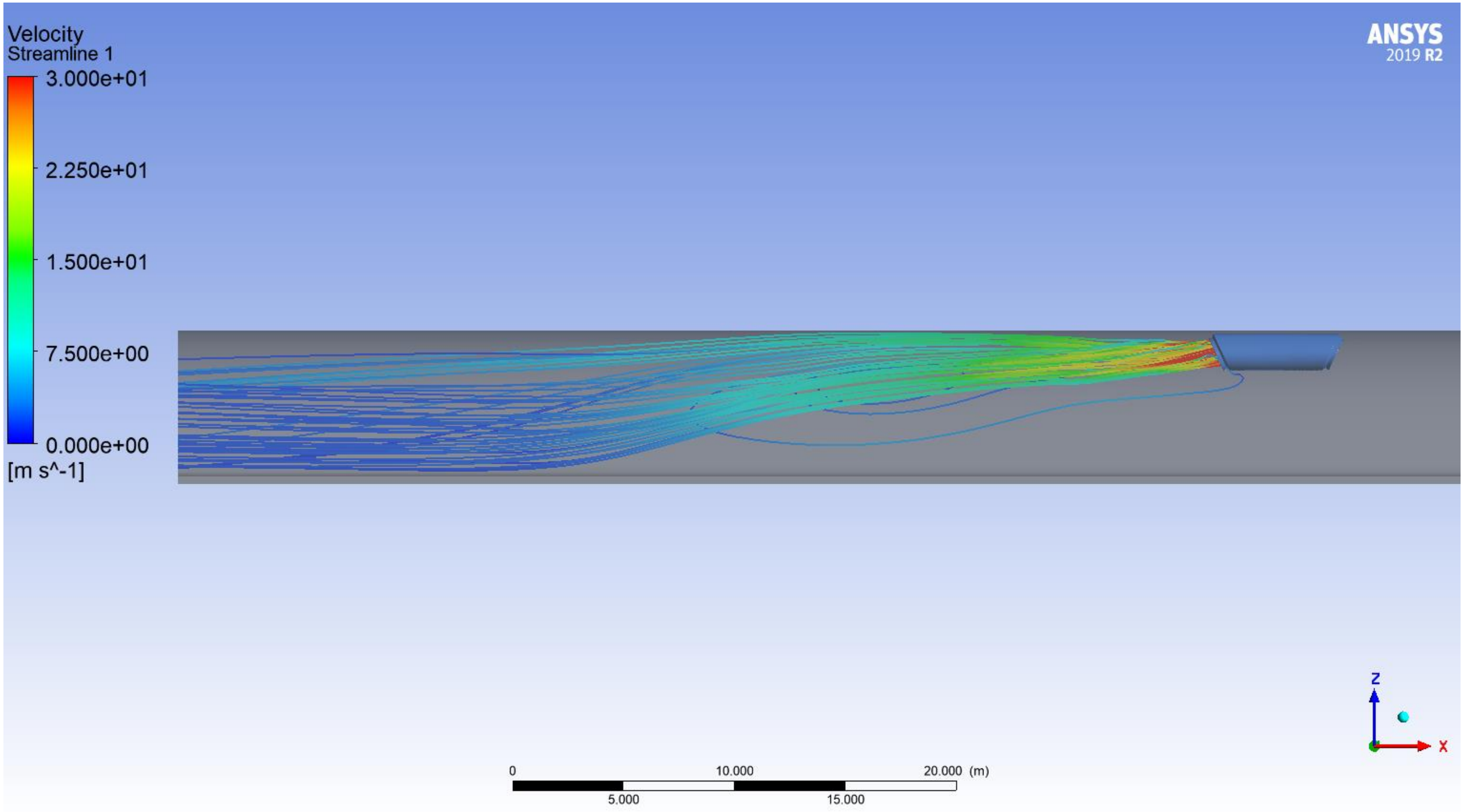
Queensway MoJet model

Results



Queensway MoJet model
Discharge Particle Tracks



CFD tunnel simulation

CONVENTIONAL JETFAN IN QUEENSWAY TUNNEL

Queensway - conventional jetfan
Settings

- A conventional 1.25m jet fan was simulated within the Rendel Street branch of the Mersey Queensway tunnel.
- The settings were the same as the equivalent MoJet case.
- 36M hex cells were used in the CFD model.

CFD tunnel simulation

MOJET/CONVENTIONAL JETFAN COMPARISON

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Queensway Tunnel
Conventional Jetfan vs MoJet

- Area flow average velocity at outlet was 1.79 m/s.
- The MoJet therefore increases the outlet velocity by 10%, and the in-tunnel thrust by 21%
- The mass flow rate of 47.1 kg/s through the MoJet was slightly higher (+0.5%) than the conventional jet fan (46.9 kg/s).

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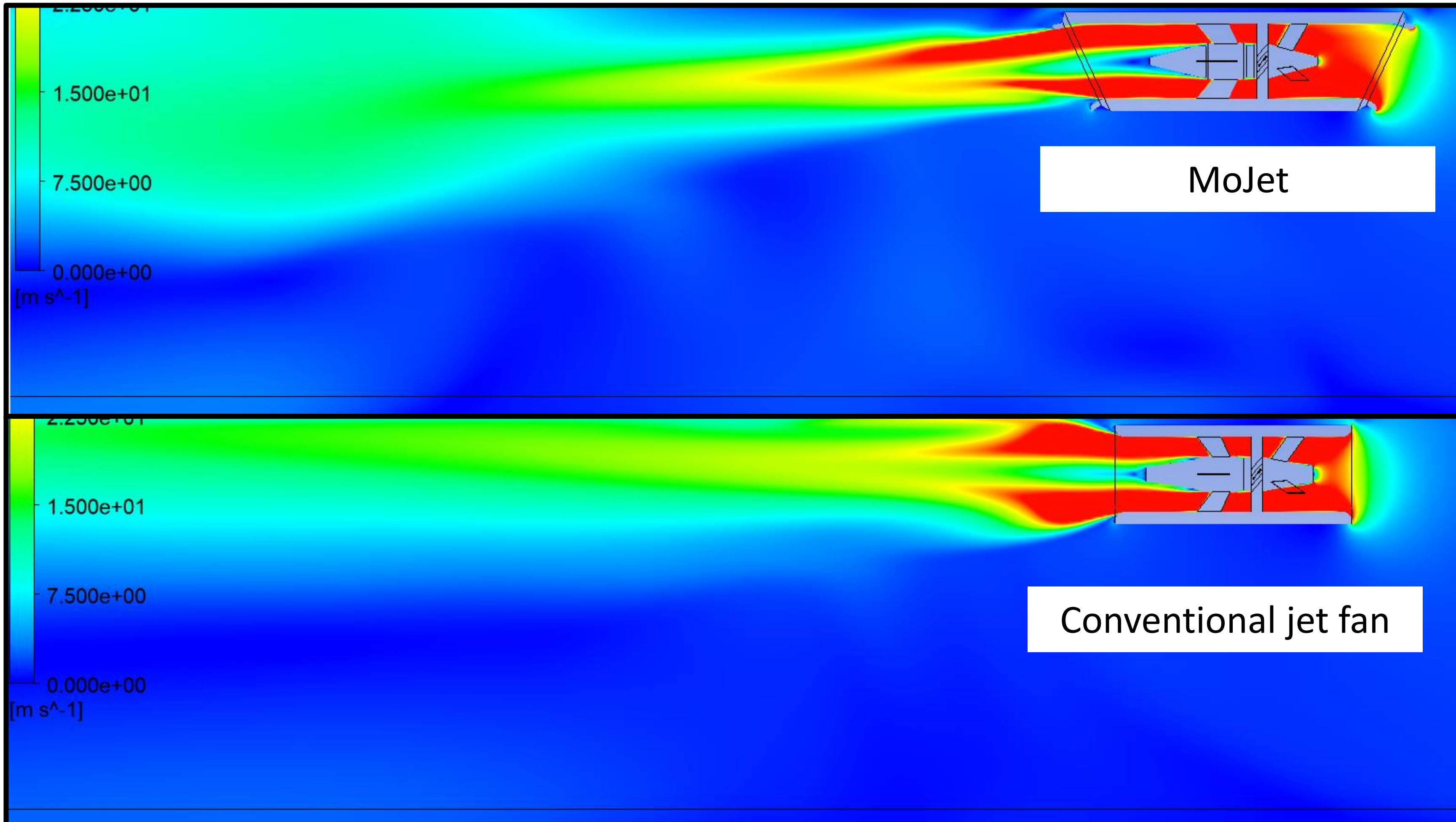
MoJet/Conventional jet fan comparison



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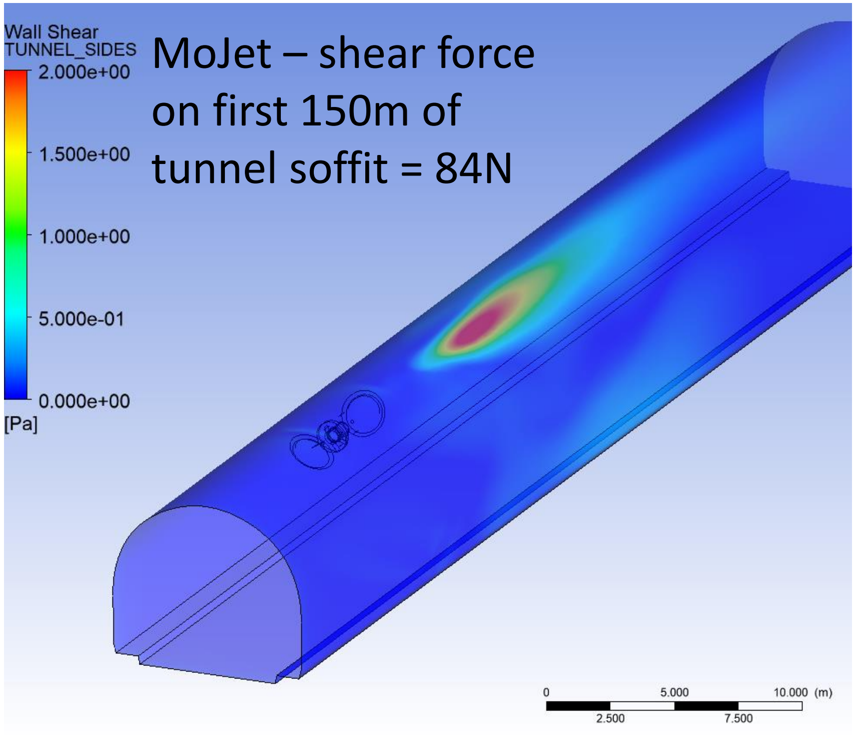
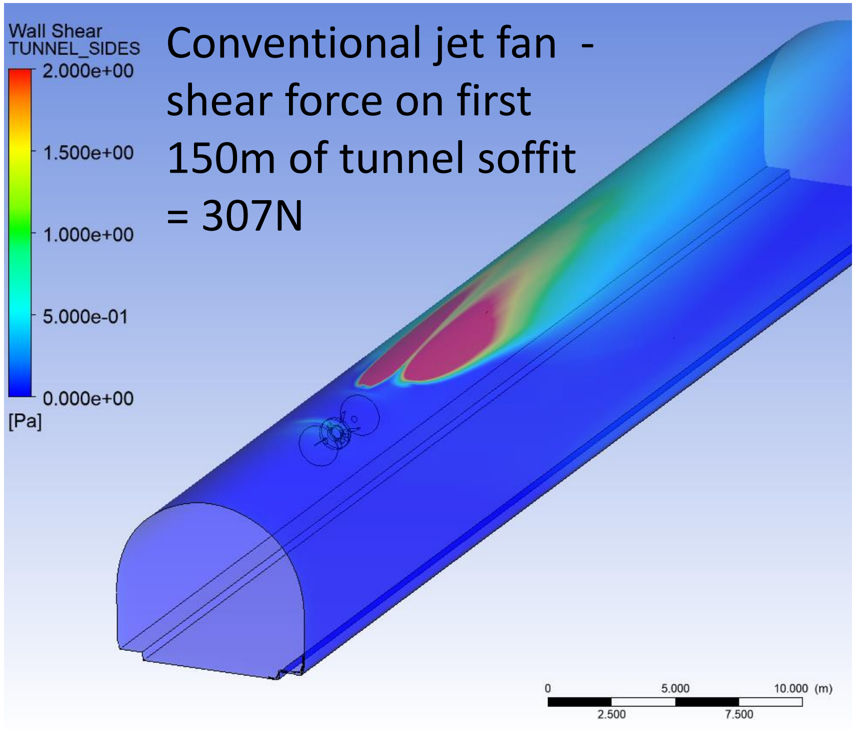
MoJet/Conventional jet fan comparison

Shear on tunnel soffit





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MoJet/Conventional jet fan comparison
Power absorption

- The power absorbed by each jetfan operating within the tunnel was calculated as:
  - Conventional jet fan 33.9 kW
  - MoJet 33.4 kW (-1.5%)

MoJet/Conventional jet fan comparison
Jetfan installation factors

- A baseline CFD model was simulated without a jet fan to calculate the jetfan installation factors.
- The shear force on the first 150m of the baseline model was 64N.
- On that basis, the jetfan installation factors were calculated as:
  - Conventional jet fan 0.82
  - MoJet 0.98 (+20%)

Conclusions

- The MoJet is predicted to deliver 21% more thrust, at 1.5% less power consumption, than an equivalent conventional jet fan (within the same headroom)
- Discharge swirl is retained with the MoJet, limiting the extent of the jet throw
- These predictions will be compared with the forthcoming experimental measurements