A comparison of approaches for simulating DPM over one hour in underground mines

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Outline

- Introduction
- Literature review
- Research objectives
- Overall methodology
- Experiment overview
- A comparison of DPM simulation using CFD and a ventilation network solver
- Results
- Conclusion

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Introduction

- DPM: diesel particulate matter
  - carcinogenic
- DPM source:
  - Light-duty diesel equipment (like tractor)
  - Heavy-duty diesel equipment (like truck, LHD)
- Components:
  - Organic carbon (OC)
  - Elemental carbon (EC)
  - Total carbon (TC) = OC + EC
- DPM control strategies:
  - Environmental cabs
  - Diesel particulate filters
  - Personal particulate filters
  - Diesel engine
  - Ventilation

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Literature review

- Steady-state simulation of DPM using computational fluid dynamics (CFD) by Zheng and others (2011)
- Transient simulation (about 200 seconds) of DPM using CFD by Zheng and others (2015)
- Steady-state simulation of hazardous gas released by diesel equipment using CFD by Kurnia and others (2014)

Conclusion:

- No long-term (more than an hour) DPM simulation using CFD
- CFD simulation is computationally expensive
- No literature on DPM simulation using ventilation network solver

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Research Objectives

- Comparison of long-term DPM simulation in CFD and ventilation network solver
- Propose a methodology of integrating CFD with a ventilation network solver for long-term DPM simulation

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Overall Methodology

- Comparison of a long-term DPM simulation in CFD and ventilation network solver
- Establish a hybrid methodology (quick and accurate)
- Use a CFD approach to find the DPM concentration and velocity magnitude inputs for the DPM source
- CFD model calibration – Predict DPM concentration over time
  - Time-weighted average (TWA) DPM data for different structured cycle times of the diesel equipment
- Define a workflow to use CFD results correct the ventilation solver results

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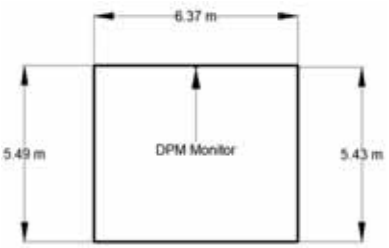
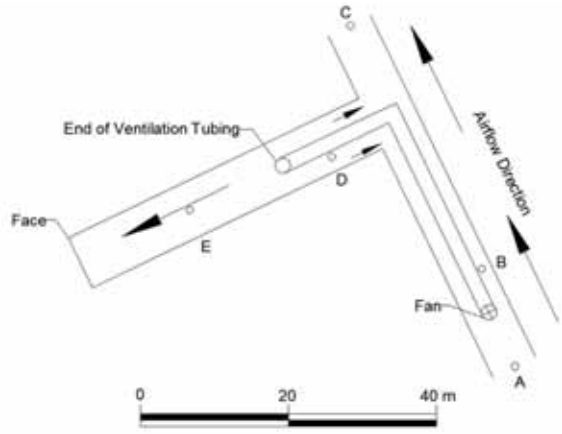
Experiment overview

- Ventilation survey at A, B, C, D, and E
  - Dimensions of the experiment area
  - Velocities
- DPM monitors at A, C, D, and E
  - Collect DPM data every minute





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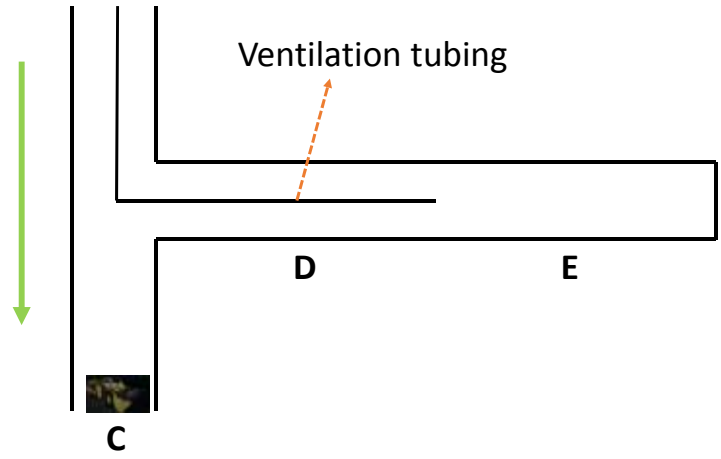
LHD path



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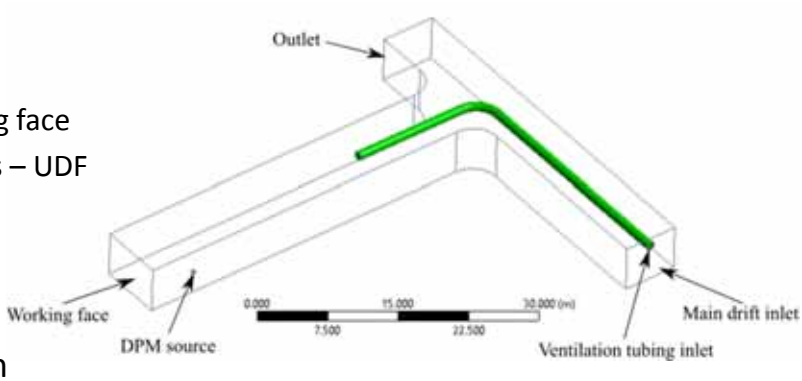
DPM simulation using CFD

- Single DPM source:
  - 0.3 x 0.3 x 0.3 m^3
  - 7.5 m away from the working face
  - mimic the exhaust emissions – UDF
  - UDF: user-defined function
- DPM: octane (C_8H_{18})
- Species transport model
- This CFD approach has been calibrated by using experimental data.



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DPM simulation using CFD

- Boundary conditions

	Area (m^2)	Velocity (m/s)	DPM mass fraction	Temperature (K)
Ventilation tubing inlet	0.89	35.97	0	300.00
Main drift inlet	34.08	1.61	0	300.00
Outlet	Outflow boundary condition			
DPM source inlet	DPM and velocity profiles (using UDFs)			594.00

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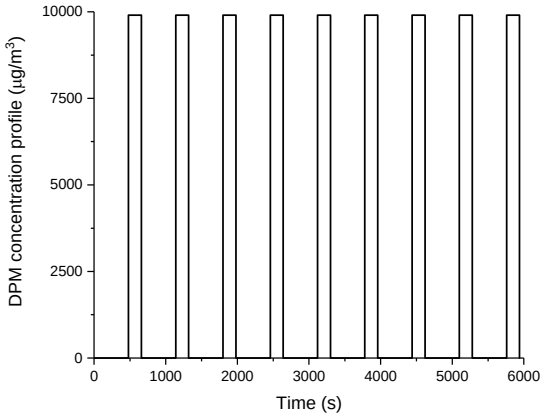
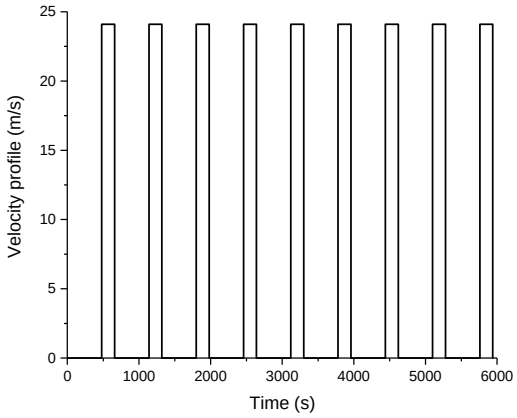
DPM simulation using CFD

- DPM and velocity profiles
- LHD cycle time: 3 mins inside the heading and 8 mins outside of the heading





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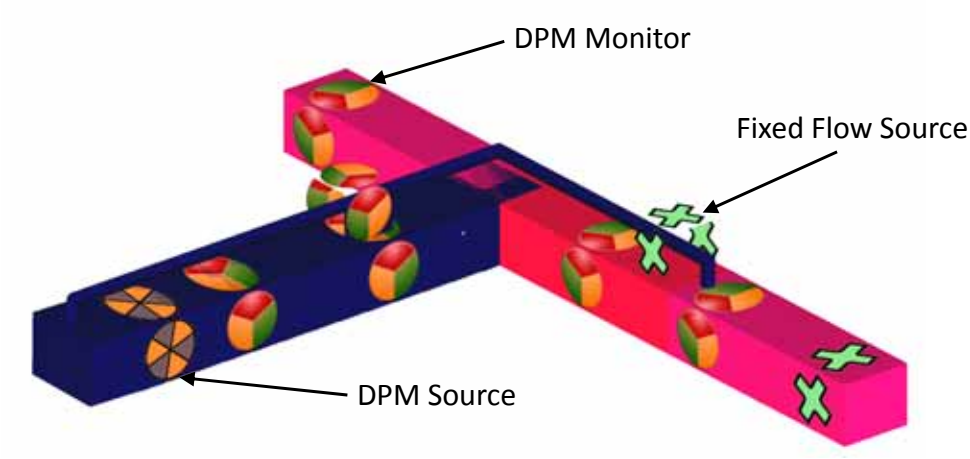
DPM simulation using a ventilation network solver



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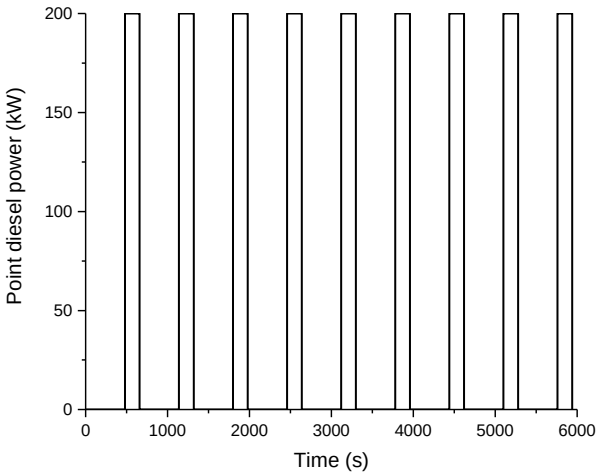
DPM simulation using a ventilation network solver

- Diesel power profile over time



- Multi-simulation of airflow and diesel
- Diesel emission rate: 0.1 g/(kW·h)
- Point diesel power: 200 kW and 1117kW

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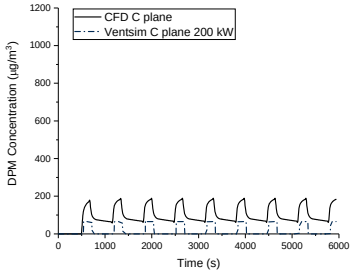
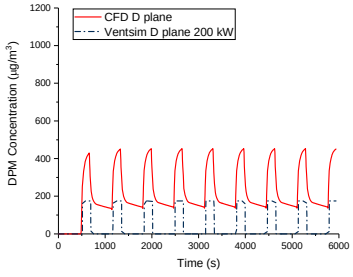
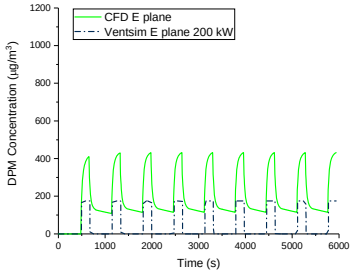
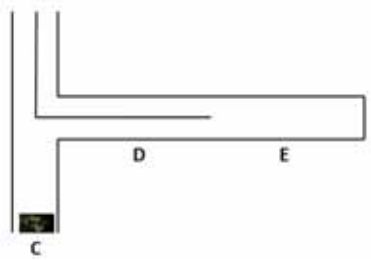
Results (200 kW diesel power in the network solver)







CFD Solution time < **3 hours**
Ventsim Solution time < **5 seconds**



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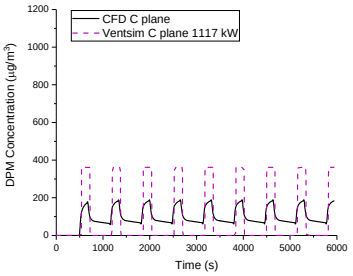
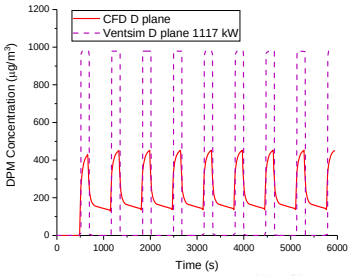
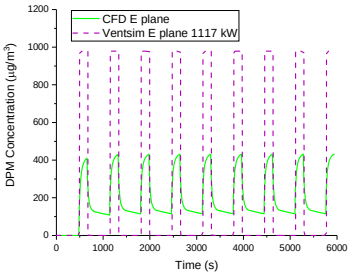
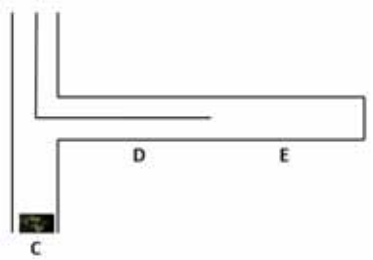
Results (1117 kW diesel power in the network solver)







CFD Solution time < **3 hours**
Ventsim Solution time < **5 seconds**



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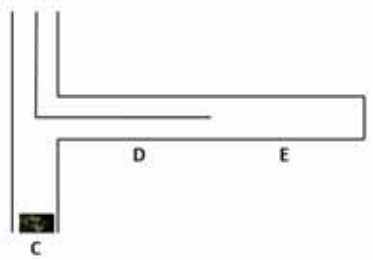
Results

Comparison of TWA DPM concentration ($\mu g/m^3$) in CFD and ventilation network solver

Location	CFD (plane)	Ventsim (1117 kW)	Ventsim (200 kW)
C	95.06	95.18	17.09
D	218.18	262.28	46.88
E	194.03	265.18	47.40

CFD Solution time < **3 hours**
Ventsim Solution time < **5 seconds**



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Conclusion

- A 99-minute DPM simulation was individually conducted in CFD and a ventilation network solver. This is the first time.
- The CFD model is accurate but slow.
- The ventilation network solver is quick but not accurate with reasonable diesel power input.
- The results at the outlet in the ventilation network solver need to be corrected by those from the CFD model.
- The combination of CFD and a ventilation network solver is essential and promising for long-term DPM simulation.

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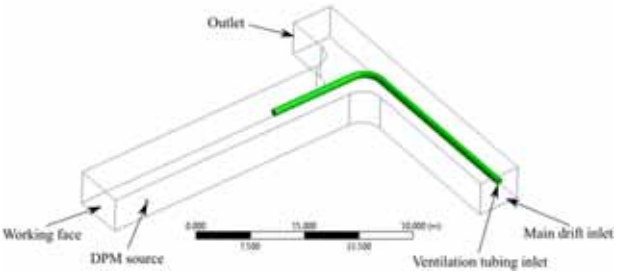
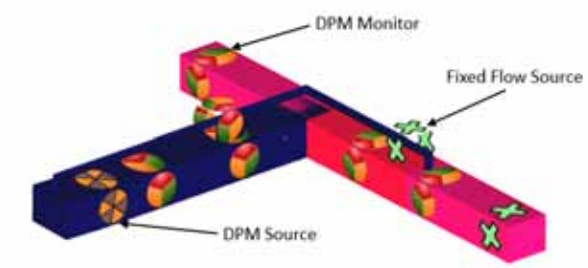
Thank you





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