Simulations of trapping of diesel particulate matter in a metallic substrate with protrusions

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Simulations of trapping of diesel particulate matter in a metallic substrate with protrusions

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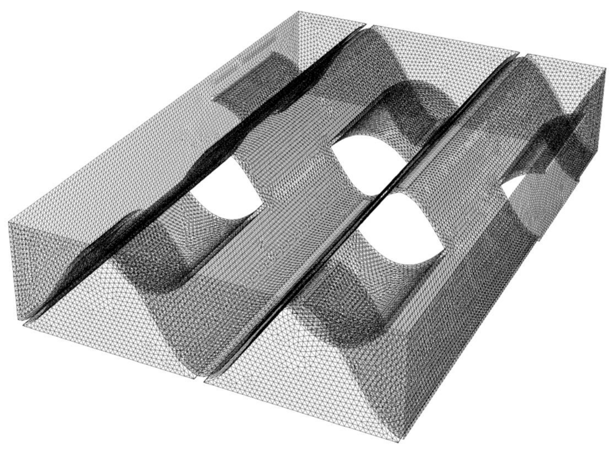
Overview

Flow-through filters may be a plausible solution for PM reduction on gasoline vehicles and for pre-filter PM capture on heavy-duty diesel vehicles in order to optimize wall-flow filter efficiency and reliability. In this study, the PM trapping characteristics of a metallic flow-through substrate with protrusions were investigated.

Modeling

The forces acting on the particles taken into consideration were the drag force, the gravitational force, the lift force, the van der Waals interaction between the particles and the walls, and the Brownian motion of the particles. The gas flow was solved for using Large Eddy Simulation. Particles are released evenly on the inlet and are assumed to always stick at walls.

Substrate property	Measurement
Channel height	1 mm
Wall thickness	50 μm
Mesh dimensions	4 (W) x 1.05 (H) x 6 (L) mm
Substrate length	72 mm



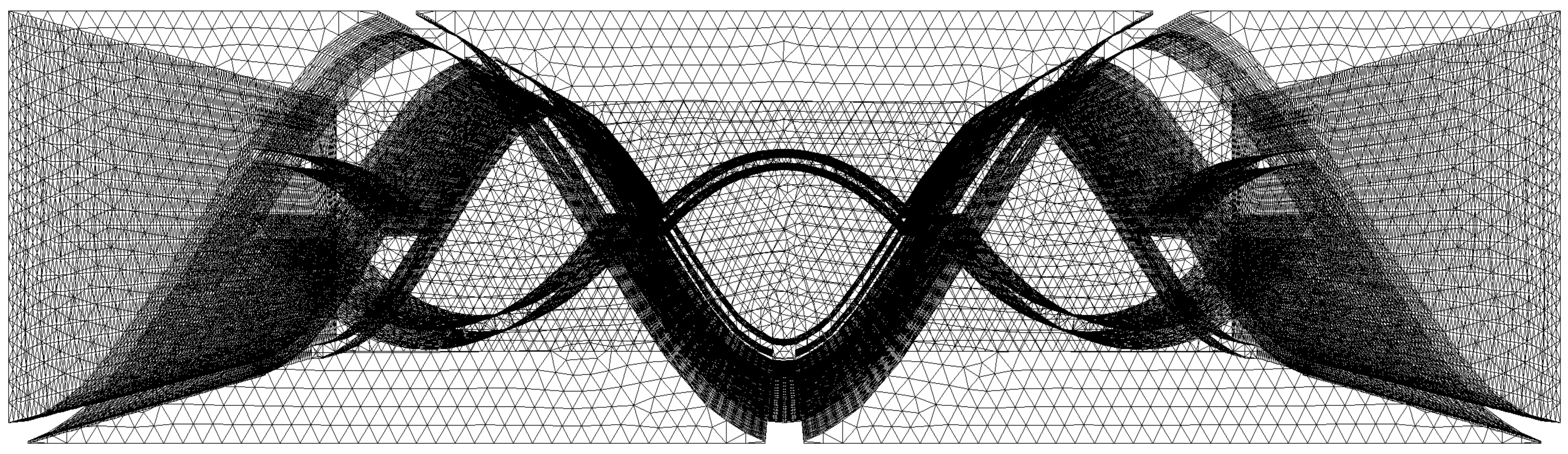
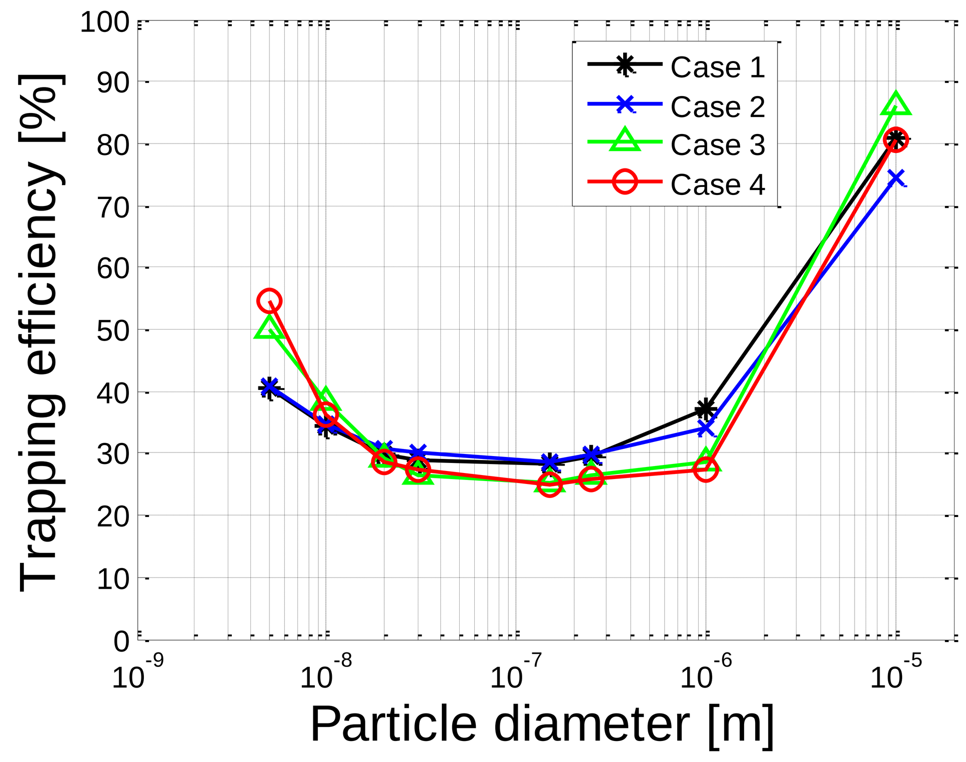


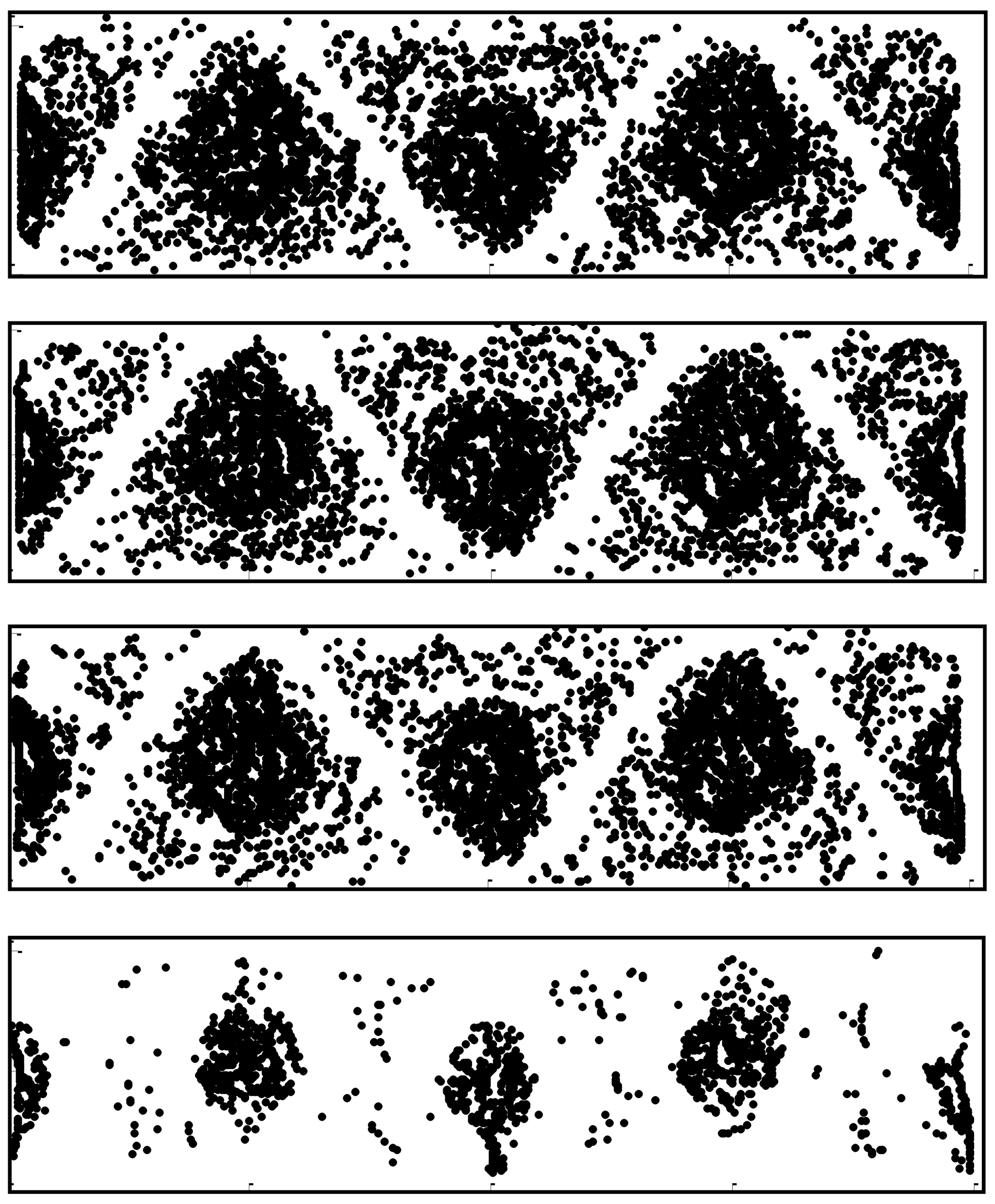
Figure 1 Computational mesh and substrate properties

Results



Case	V_{mean} [m/s]	Re	T [°C]
1	24	380	400
2	17	480	200
3	12	190	400
4	8	240	200

Figure 2 Particle trapping efficiency



d_p = 20 nm
ρ = 1000 kg/m^3

d_p = 250 nm
ρ = 640 kg/m^3

d_p = 1 μm
ρ = 200 kg/m^3

d_p = 10 μm
ρ = 200 kg/m^3

Figure 3 Particle patterns on substrate outlet for four different particle types

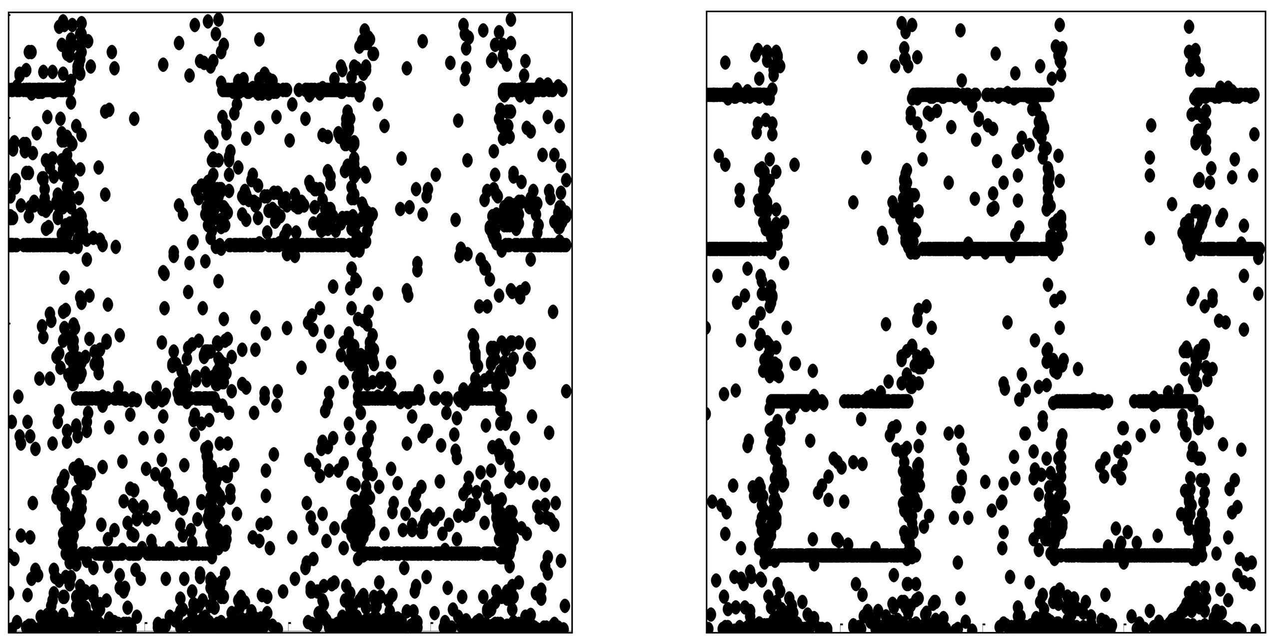


Figure 4 Patterns of particle trapping for small (20 nm; to the left) and large (1 μm; to the right) particles. The gas flows from bottom to top and modules are shown from above. The domain is 12 modules in total and the results are layered on top of each other. 23% more particles are trapped in the right picture.

Conclusions

- There is a minimum trapping efficiency for medium-sized particles (around 150 nm in diameter) in this substrate (see Figure 2)
- This is due to the interaction between the two dominant trapping mechanisms (Brownian motion and inertial impaction)
- Small and large particles are trapped in different regions of the substrate (see Figure 4)
- Redistribution of particles at the edges of the protrusions are important for the dispersion of larger particles
- This model can be used to study the particle trapping efficiency of arbitrary flow-through devices in an aftertreatment system and will be further developed to also allow particle tracking inside porous structures

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