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2D Particle Transport in a Full Dilution Tunnel of Diesel Vehicle Emissions

L. Isella, B. Giechaskiel, P. Dilara and Y. Drossinos

European Commission, Joint Research Centre, I-21020 Ispra (Va), Italy

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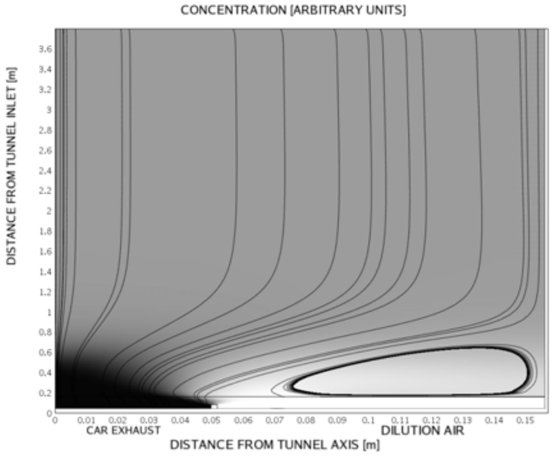
Current EU legislation establishes particulate-mass emission limits for diesel vehicles, but limits on particle number emissions are also under consideration due to concerns about the adverse health effect of fine particles.

We study the turbulent transport of light-duty diesel engine exhaust particles in a standard emission facility. We investigate particle transport from the tailpipe to the sampling point both by experimental measurements and two-dimensional modeling. The experiments were performed at the VELA-2 laboratories at JRC, Italy. The experimental setup consists of a long flexible cylindrical tube (anaconda) connected to the car exhaust pipe that conducts the exhaust fumes into a wider cylindrical duct [dilution tunnel (DT)]. As a first step, only tests at steady vehicle velocity were conducted. While the dilution air and exhaust flow rates were approximately constant, temperature transients were often observed in the core region. The walls of the anaconda were kept at a constant temperature of 70°C, whereas constant room temperature was assumed for those of the DT. For simplicity, the experimental manifold is modeled as axisymmetric (the anaconda has a bend with a large curvature radius before reaching the DT). The modeling of the experiments differs from previous works [e.g. Vouitsis *et al.* (2005)] as it relies on a 2D calculation for the fluid flow, the temperature and concentration.

The flow field in the bulk region is calculated by a standard k-ϵ implementation in the finite-element PDE solver Comsol Multiphysics (Comsol Multiphysics, 2006). The wall boundary layer is not resolved at this stage, but we determine the velocity and temperature fields close to the wall by using law-of-the-wall functions to match the CFD solution (Housiadas & Drossinos, 2005). The use of turbulent conductivity and mass diffusivity in the bulk accounts for the effect of turbulence on heat and mass transport. An accurate treatment of the boundary layer is also fundamental for the modelling. Indeed the high resistance of the near-wall region to heat and mass transfer has a dramatic effect on the concentration and temperature profiles.

From experiments performed at VELA-2, we investigate the concentration and temperature profiles along the experimental manifold. The measured particle size distribution shows only the accumulation mode: the fitted mean mobility diameter of the distribution at the DT inlet ranged from 60 to 80 nm with a geometric standard deviation of a few nm, depending on car speed and dilution ratio. The relaxation time τ_p of such soot particles is of the order of 10^{-8} s. The fluid characteristic time τ_f is fixed by turbulence. Analytical estimates (valid for a circular pipe) and numerical simulations determine the fluid turbulent time scale to be in the range 10^{-3} to 10^{-4} s. Consequently, the Stokes number is St=$\tau_p / \tau_f \simeq 10^{-5}$-$10^{-4}$ s, and the soot particles can be treated as inertialess particles following the fluid.



In the figure we plot the particle concentration inside the DT (the dark shades stand for high concentration) along with the particle streamlines. In the simulated case the car speed is 120Km/h, and the nominal Venturi flow rate is 6.2 m^3/min with an exhaust dilution ratio around three. One notices the area of low concentration past the diaphragm corresponding to a region of dilution air flow recirculation. At the sampling point, the concentration radial profile becomes relatively flat (a similar conclusion holds for the temperature profile), thus ensuring the robustness and repeatability of measurements of particle concentration. Mass losses along the anaconda (neglecting thermophoresis), estimated both from numerical simulations and the 1D correlation used by Vouitsis *et al.* (2005), amount at most to 1%.

Housiadas C. & Drossinos Y. (2005), *Aerosol Science and Technology*, 39, 304-318.

Vouitsis E., Ntziachristos L. & Samaras Z. (2005), *Atmospheric Environment*, 39, 1335-1345.

Comsol Multiphysics (2006), *Chemical Engineering Module User's Guide*, September 2005.