MODELLING AEROSOL TRANSPORT AND DEPOSITION IN A VENTILATED ROOM

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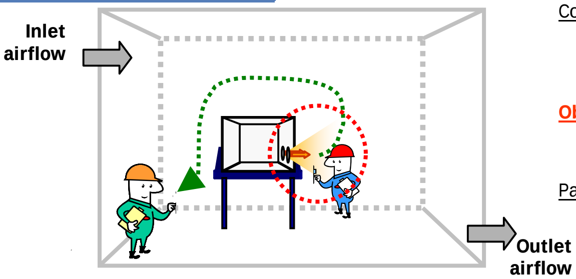
Problem approach



Context: To ensure protection of operators working in a ventilated room and to optimize supervision of workspaces, it is necessary to have access to aerosol concentration in every point of this room. The transfer of this contamination is independent of its radioactive properties.

Objective: **This study aims at developing a model of aerosol transport and deposition, giving the space-time evolution of the particulate contamination concentration C(x, y, z, t)**

Parameters:
- aerosol mass median aerodynamic diameter
- aerosol concentration and velocity at emission
- configuration of ventilation
- airflow velocity

Aerosol transport modelling

Simplification of the problem:

- **very dilute two-phase flow**

  → no particle collision or coalescence

- **high density of particles** ($\rho_p / \rho_f \geq 1000$)

  → Stokes' law can be applied, particle relation time follows the relation:

$$\tau_p = \frac{d_p^2 \rho_p}{18 \mu_f} Cu$$

→ phenomena such as pressure gradient force, virtual mass force or lift force can be neglected.

Formulation of the transport model:

Airflow is simulated with **RANS method** with k-ε turbulence model or R_{ij}-ε turbulence model.

Particles (dispersed phase) are simulated with a simplified Eulerian model, called **"Diffusion-Inertia Model"** (Zaichik et al., 2004). It contains a single transport equation of particle concentration:

sedimentation — particle deviation from streamlines

$$\frac{\partial C}{\partial t} + \frac{\partial}{\partial x_i}\left\{\left[U_{f,i} + \tau_p g_i - \tau_p\left(\frac{\partial U_{f,i}}{\partial t} + U_{f,k}\frac{\partial U_{f,i}}{\partial x_k}\right)\right]C\right\}$$

$$= \frac{\partial}{\partial x_i}\left[\left(D_B \delta_{ik} + D^t_{p,ik}\right)\frac{\partial C}{\partial x_k} + C\frac{\partial}{\partial x_k}\left(D_B \delta_{ik} + \frac{\Omega}{1+\Omega} D^t_{p,ik}\right)\right]$$

Brownian and turbulent dispersion — migration due to thermophoresis and turbophoresis

The model accounts for Brownian diffusion. But in most of cases, Brownian effects are negligible comparing to turbulent effects.

Aerosol deposition modelling

Deposition models

In this study, deposition laws in **diffusion and gravitational regime** have to be considered (0.1 µm < d_p < 50 µm).

- **two categories of models**

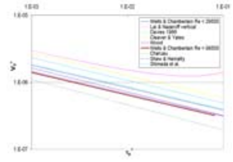
  → semi-empirical laws: $v_d^+ = k_1 Sc^{k_2} + \delta v_s^+$

  → theoretical laws:

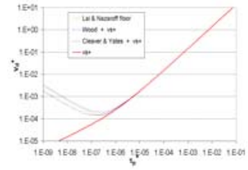
$$v_d^+ = \frac{1}{I_f} \qquad v_d^+ = \frac{v_s^+}{1-\exp(-v_s^+ I_f)} \qquad v_d^+ = \frac{v_s^+}{\exp(v_s^+ I_f) - 1} \qquad I_f = \int_{d_p^+/2}^{30}\left(\frac{\nu_f}{\nu_t + D_B}\right)dy^+$$

vertical surfaces — upward surfaces — downward surfaces

- **comparison of deposition laws**



Horizontal surface



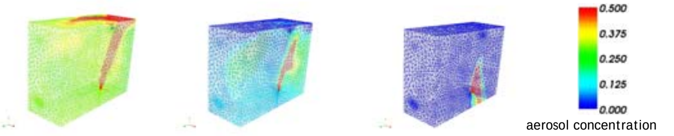
Upward surface

Simulations

The Diffusion-Inertia model and deposition laws have been implemented in *Code_Saturne*, an open-source free software CFD code, developed by EDF R&D.

First simulations of aerosol dispersion in a ventilated room (36 m³):

d_p = 2 µm: d_p = 20 µm: d_p = 50 µm:

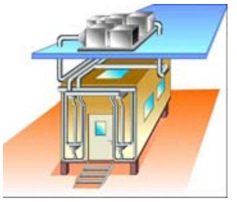


Validations on simple geometries are currently carried out (sedimentation channel, cylindrical ducts, bent tubes) in parallel.

Conclusion

- Preliminary bibliographical researches allowed to identify transport and deposition models, and to test them with first calculations using *Code_Saturne*. Tracing experiments carried out in a 36 m³ room are intended to validate these models in ventilated room, with different configurations of ventilation.

- In order to improve the precision in aerosol deposition results, and also to obtain deposition results independent of meshes used, a method establishing the aerosol concentration profile in the near-wall region is currently developed.



Experimental facility CEPIA (36m³)