Numerical study of the dispersion of carbon nanoparticles in the near wake of a cylinder

N.S. Keita[1], A. Mehel[1], F. Murzyn[2], B. Diourte[3] and A. Tanière[4]

[1] Department of Composite Materials Mechanics and Environment, ESTACA, 78180, Montigny-le-Bretonneux, France
[2] Department of Composite Materials Mechanics and Environment, ESTACA, 53061, Laval, France
[3]Physics Department, Faculty of Science and Technology, USTTB, Bamako, Mali
[4]LEMTA – Lorraine-University–CNRS, ESSTIN, 2 rue Jean Lamour, 54500, Vandœuvre-lès-Nancy, France

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Presenting author email: namamoudou-sidiki.keita@estaca.fr

Predicting local-scale transport and dispersion of ultrafine particles emitted from traffic sources is a key-point for urban air quality and exposure risks assessments. These solid carbonaceous nanoparticles (most important in number rather in mass) are the worst and most harmful particles in terms of health effects. Indeed, they are able to reach the respiratory system in its deepest part (the alveolar region) where they can readily penetrate the blood stream leading to major cardiovascular diseases or cancer (Valberg, 2004; Silverman et al., 2012).

The description of the concentration patterns of these UFP downstream of a car are linked with an accurate representation of local features and turbulence structure developing on the wake of the vehicle. Indeed, it has been shown that their dispersion is enhanced by both the interaction between particles and the recirculation region and particles and lateral longitudinal vortices that develop in the vehicle wake (Mehel and Murzyn, 2015).

To improve our understanding of these interactions, a numerical study is undertaken to assess the unsteadiness of the flow. We investigate the dispersion of UFP in a classical wake flow which is well documented in the literature: the flow downstream of a circular cylinder (D=2,5cm). This approach allows us to correlate particle dispersion with the structure of the wake flow. This is a preliminary step before doing a numerical study downstream of a more complex geometry (Ahmed body).

$2{\cdot}10^6$ carbon nanoparticles (diameter of 10 nm) are injected continuously at a flow rate of 6.2510^{-8} kg/s from an injection point located at 3 mm under the bottom of the cylinder. These input parameters are defined according to the EURO 6 standard for particles (PM) limitation. The investigated air velocity is typical of urban areas, i.e., U_∞=20 km/h and the velocity of the exhaust air/particles at the tailpipe corresponds to an engine speed of 2000 rpm. The Reynolds number of the flow is Re=9259 (based on the D). The turbulence is first modeled with an isotropic and homogeneous standard k-ε model which is associated to the enhanced wall treatment model. Figure1 shows the particle locations (colored by their residence time) superposed to the mean velocity vectors. The behavior of the flow and the dispersion of carbon particles in the near wake flow of the cylinder are then highlighted. We demonstrate that these nanoparticles behave as a passive tracer showing the occurrence of two symmetrical vortices downstream of the cylinder that are alternatively released and known as the Karman vortex street. The particles with higher residence time are those which are situated in the core of the vortex street. This suggests that they are trapped by the moving vortices.

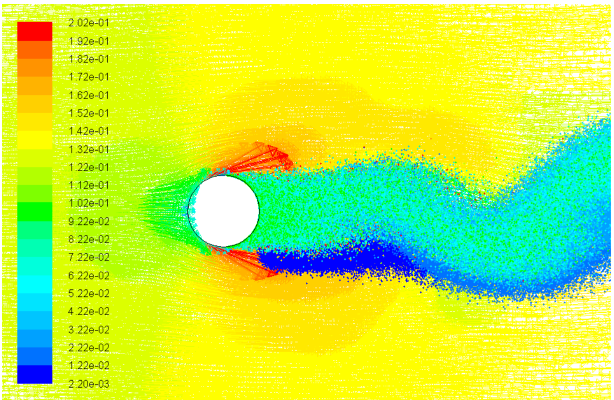

Figure1. Superposition of the mean Velocity vectors and particle residence time(U∞=20 km/h)

These preliminary results tend to confirm the strong interactions between particles and vortices developing in the wake of a cylinder. Future developments including a more detailed study of the local turbulence structure will be conducted to increase our understanding of the particle dispersion related to the presence of vortices.

References

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