Shape Optimization of the Vegetation Barriers Close to the Highway

Luděk Beneš, Viktor Šíp
CTU in Prague, Fac. of Mechanical Engineering, Dept. of Technical Mathematics
ludek.benes@fs.cvut.cz, viktor.sip@fs,cvut.cz

Abstract

The contribution deals with the numerical simulation of the influence of near-road vegetation barriers on the dustiness along the highway. Various type of the Vegetation barrier close to the road has been proposed to reduce the amount of PM10 and PM2.5.

The flow in the Atmospheric Boundary Layer (ABL) is described by the of RANS equations for viscous incompressible flow with variable density. The two equations turbulence model is used for the closure of this set of equations. The pollutant density is computed using additional transport equation. Influence of the vegetation barrier is modeled by the Leaf area density with original profiles different for the deciduous and evergreen trees. Three effects of the vegetation should be considered: effect on the air flow, ie. slowdown or deflection of the flow, influence on the turbulence levels inside and near the vegetation, and filtering of the particles present in the flow. Deposition velocity reflects four main processes by which particles depose on the leaves: Brownian diffusion, interception, impaction and gravitational settling.

The finite volume numerical scheme with artificial compressibility method is used. For the convective terms are approximated by the AUSM+up scheme is used. Second order accuracy is achieved by the linear reconstruction, where gradients are calculated using least squares approach. To prevent artificial overshooting, Venkatakrishan limiter is utilized. For the viscous fluxes diamond type scheme is used. Resulting set of ODE equations is integrated by the BDF2 method.

Concentration of PM2.5 and PM10 behind the block is studied in dependence on various parameters e.q. size and position of the block, wind speed, tree species, meteorological conditions. Gradient based optimization is used, where the gradient of the target function with respect to the optimized parameters is calculated via tangent linear method. The relative importance of some parameters involved to the our model is studied. The sensitivity analyses is carried out for inlet velocity, terrain roughness, particle diameter and density, vegetation porosity, deposition velocity and temperature lapse rate.

References

1. V. Šíp and L. Beneš. Modelling the effects of a vegetation barrier on road dust dispersion.. Appl. Mech. Mater. (in press).
2. L. Beneš. and J. Fürst and Ph. Fraunié. Comparison of two numerical methods for the stratified flow.. J. Computers & Fluids, Vol 46(1) 2011, p 148-154. .