Aerodynamic modeling of trees for small scale wind tunnel studies

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In the framework of environmental aerodynamic wind tunnel studies, natural vegetative structures like bushes or trees have to be modeled. From a fluid mechanical point of view, these structures differ essentially from man-made constructions (e.g. buildings, cars, planes) because of their structural flexibility and permeability. Whereas the knowledge concerning the small scale modeling of technical structures is wide, less experience on the adequate modeling of vegetative structures is available.

In this article, the aerodynamic characteristics of the flow field of inflexible model trees with permeable crowns are presented. In order to modify the permeability and the aerodynamic behavior, different crown materials and various porosities have been tested. All in all, twelve prototypes were manufactured, six of them with crowns made out of sisal, five with crowns made out of wood wool and one with porous foam crown.

Drag force measurements were performed in a homogeneous approaching flow. The flow field data of the trees subjected to a boundary layer flow were acquired by 2-component laser Doppler velocimetry (LDV). Additionally, pressure loss measurements were carried out for the foam material.

The force measurements resulted in values for the drag coefficient in the range of 0.8 and 1.2, which is in good accordance with observations at natural trees for low wind velocities (< 10 m/s). The velocity data were analyzed in regard to the mean velocity components u and w, as well as to the standard deviations. Furthermore, the friction velocity u_*, the turbulent kinetic energy (TKE) and the velocity spectra of the u component were evaluated. The measurement results show typical wake characteristics of permeable structures with recirculation zones being either extended or detached from the obstacle when compared to impermeable bodies. By means of spectral analysis, an energy shift from lower to higher frequencies, i.e. a break down of eddies, in the crown wake region was found.

Keywords: crown permeability, flow field measurement, drag coefficient, single tree, physical modeling