AERODYNAMICAL PROPERTIES OF AN AIR LAYER AFFECTED BY VEGETATION*

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(received 17 December, 1982)

ABSTRACT

Over flexible vegetation, during windy conditions, a coupling of the airflow and the vegetation takes place. This builds up the waving form of the canopy surface in addition to producing streamlining and fluttering phenomena. Consequently, it may be estimated that the aerodynamic properties vary with the wind speed. This is one of the most striking phenomena of the airflow over a canopy.

In order to investigate the above problems, some measurements are carried out at the heat and water balances observation field in the Environmental Research Center of the University of Tsukuba, in 1978 to 1980. The main subjects of the measurements are the wind profile above and within a pasture canopy and the fluctuation of the vertical wind just over a canopy. Additionally, the author takes VTR films of the displacements of a plant showing simulteneous measurements of the wind velocity fluctuations. Further, for the purpose of verification of the theoretical relationships, a numerical solution of the wind profile is solved and compared with results of the field experiments.

At first, by the concept that the eddy diffusivity is uniquely decided by the leaf area density, the roughness length and the zero-plane displacement are defined as:

$$z_0 = h\,(\frac{k}{\beta\Gamma})^{\frac{1}{m-1}}\ \exp(\frac{k\Gamma}{m-1}),\quad d = h\ [\,1-(\frac{k}{\beta\Gamma})^{\frac{1}{m-1}}\ \exp(\frac{mk\Gamma}{m-1})\,].$$

After the theoretical consideration, the following topics are evaluated. (1) From the static treatment of z_0 and d, their normalized parameters ζ_0 and δ can be approximated by: $\zeta_0 = 0.07$, $\delta = 0.04$. (2) The effective roughness parameter, $\eta = \zeta_0/(1-\delta)$, increases with an increase of the surface friction. For a pasture canopy, the above parameter is smaller than those of other canopies. This suggests that the pasture canopy contributes less effectively to aerodynamical roughness than does other canopies. But for an actual, the values approximated above are vary with the wind conditions. (3) For an actual canopy, the following equations are estimated:

$$\zeta_0 = (0.72\,\Gamma)^{3.08}\ \exp(-1.23\,\Gamma),\quad \delta = 1-(0.72\,\Gamma)^{3.08}\ \exp(-0.83\,\Gamma).$$

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* Doctor of Science Thesis in the Institute of Geoscience, the University of Tsukuba.

These equations show that the normalized roughness length decreases and the normalized zero-plane displacement increases with the nondimensional rapidity respectively. (4) The peak value of the normalized spectrum is increasing with the wind speed and its frequency increases with an increase in the wind speed under the relation of $n_m = 0.71\ \bar{u}_h$. Further, the value of the dominant wavelength just over a canopy ($\lambda_m = 1.41$, for the present study) is in accordance with that of already researched. (5) The maximum reduced frequency is well represented by use of the variation of the wind speed. Namely, $f_m = \exp\ [0.50\ (3.02 - \Gamma)]$, This indicates that vegetations affect the airflow above a canopy and modity the above canopy turbulence. (6) Maximum frequency of the displacement of a leaf ($n_m = 1.2$ Hz) agrees well with that of the vertical wind fluctuation ($n_m = 1.4$ Hz). It is generally accepted that the former contributes to the latter just over a canopy. (7) From the integration of an ordinary differential equation, close agreement between the observed and the calculated wind profile is obtained. Consequently, a result which supports the validity of the theoretical relationships is verified.