Dynamics of separation zone behind the 2D hill in oscillating incident wind.

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The experimental and numerical simulation of the unsteady wind phenomena around the two-dimensional hill has been performed for different parameters of inflow periodicity.
The study of the turbulent flow over curved surfaces or hills is an excellent way to exploring fundamental aspects of air flow over complex terrain for environmental and meteorological problems such as turbulent transfer and diffusion, which play a critical role in determining the transfer of momentum, heat and moisture in the atmospheric surface layer. An analysis undertaken here were motivated to a considerable extent by potential wind energy applications as well as the guidelines to refine wind estimates in complex terrain especially useful for soil erosion and pollutant dispersion problems.
The dynamics of flow over hills has been an object of great interest of many recent studies [1,2,3] assuming the steady inflow expressed as typical mean velocity profile (exponential or logarithmic) over the terrain of different aerodynamic roughness. These studies provide useful tests for both theoretical analysis and numerical calculations of practically important quantities like the maximum acceleration over the hill summit, surface drag, separation and recirculation position. Far less has been done to take into account the effects of velocity fluctuations in upstream shear boundary layer which can strongly affect the base flow structure downstream the ground object. Especially the unsteady conditions related with periodical gust phenomena or large scale vortices generated in wind environment of the object are the factors of great importance for the overall flow picture around the hill.
In the present paper the formation of wake in the lee of the sinusoidally shaped hill has been simulated by the use both wind tunnel technique and numerical methods. The modelled hill has been immersed in the boundary layer flow formed over the terrain of moderate roughness. To study the effect of periodical disturbances of the approaching wind the oscillating component superimposed on the mean velocity profile has been introduced. (see Fig.1).

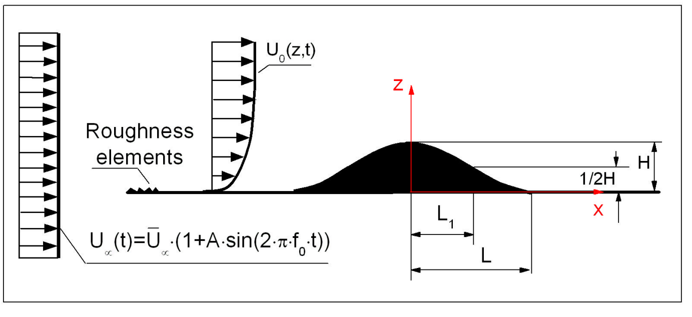

Fig.1. Scheme of the flow over an isolated hill in oscillating wind.

The main parameters of the simulations are specified by the hill slope $s=H/2L_1=0.6$, Reynolds number $Re_\delta=2.6\cdot10^4$, inflow oscillations frequency $f_0=0\div16$Hz, and amplitude $A_\infty=0.2$. Experimental test has been done in wind tunnel equipped with devices generating unsteady wind boundary layer. The fast-scanning acquisition system of X array hot-wire signal was been applied. The numerical simulations, guiding the experimental tests programme, have been performed by the use of phase averaged form of RNG version of k-ε turbulence model. The major findings of the simulations have been illustrated in Figs 2÷5. They reveal the strong dependence between the characteristics of inflow periodicity and vorticity structure of separation region behind the hill (Fig.2).

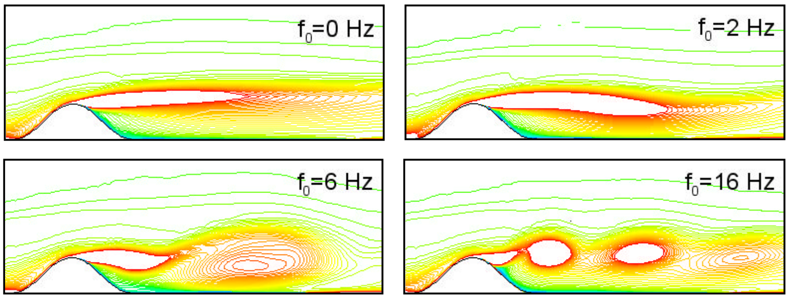

Fig.2. Instantaneous vorticity fields behind the hill for different frequency of incident oscillation (t/T_0=0.25).

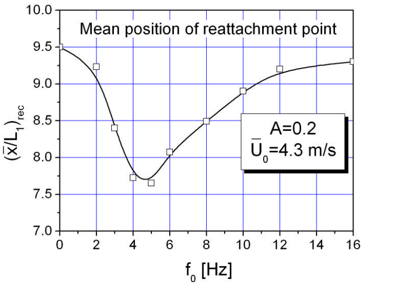

Fig.3. The influence of inflow oscillations on the mean position of downstream attachment

a) b)

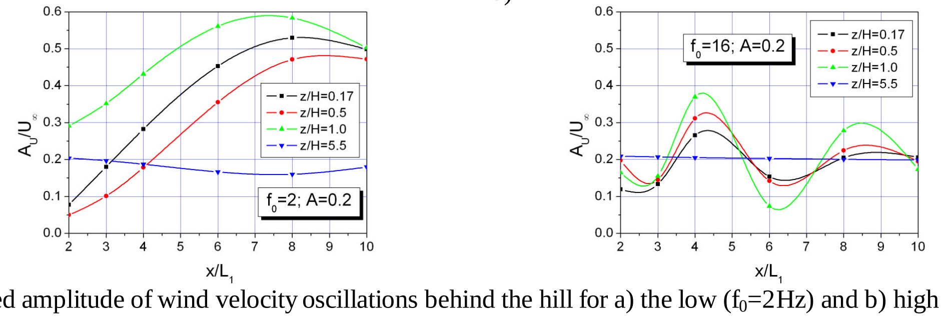

Fig.4. Normalized amplitude of wind velocity oscillations behind the hill for a) the low (f_0=2Hz) and b) high (f_0=16Hz) gust frequency.

a) b)

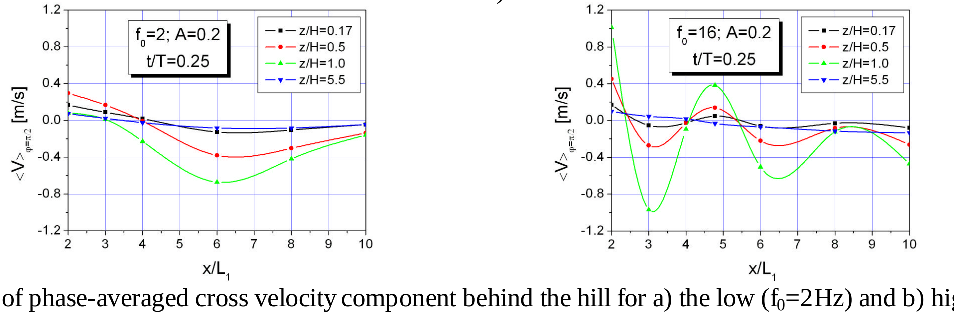

Fig.5. Evolution of phase-averaged cross velocity component behind the hill for a) the low (f_0=2Hz) and b) high (f_0=16Hz) gust frequency.

The mean position of reattachment point is also clearly affected by incident gust frequency (Fig.3). The changes in the wake formation under different inflow periodic conditions are particularly visible in distributions of oscillating velocity amplitude behind the hill (Fig.4.). The phase-averaged traces of cross velocity component shown in Fig.5 reveal the zones of intensive vertical gusts accompanying the process of vorticity decay behind the hill.

References

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