MEASUREMENT OF SETTLING VELOCITY OF HEAVY PARTICLES IN OPEN CHANNEL FLOWS USING AN ACOUSTIC DOPPLER VELOCIMETER

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The mean settling velocity is an important parameter in transport modeling of particulate material. In the previous studies, it has been demonstrated that the mean settling velocity in isotropic turbulence considerably deviates from that in a quiescent fluid through a variety of mechanisms. It turns out that the settling velocity is suppressed or enhanced depending on relative turbulent intensity. However, the experimental data for settling velocity are sparse. Moreover, most previous studies have been confined to isotropic turbulence that has no mean flow.

Murray (1970) showed that the average settling velocity in turbulent water can be considerably reduced below its terminal settling velocity in still water though there were the apparent increases in the settling velocity for a quasi-neutral particle. Nielsen (1993) monitored the settling velocities of a heavy particle in a turbulence tank with oscillating grid plates. He found that the reduction and increase of settling velocity were due to the ratio of the turbulent intensity, σ, and terminal settling velocity, w_0.

In the present study, the settling velocities of heavy particles are monitored in open channel flows. The particle velocity are directly measured by using an acoustic Doppler velocimeter (ADV). This is a novel application of the ADV. Our results in terms of relative settling velocity, $\overline{w}_p / w_0$, vs. relative turbulence intensity, σ_f / w_0, are shown in Fig. 1. The turbulence intensity σ_f is estimated as the standard deviation of the vertical velocity of the seeding material, which is spherical particle (density is 1.1 g/cm^3 and mean diameter 10 □m) composed of borosilicate glass. The solid curve, which mimics the trend for all experimental particles, is given by

$$\frac{\overline{w_p}}{w_0} = \frac{1 + \dfrac{1}{2.5}\left(\dfrac{\sigma_f}{w_0}\right)^2}{1 + \dfrac{\sigma_f}{w_0}} \qquad (4)$$

So, the trend reverses around $\sigma_f / w_0 = 2.5$.

Fig. 1 indicates that the mean settling velocity can be increased considerably in strong turbulence as shown in previous work. The mean settling velocity is increased by a factor of 6 in the present experiment. At low turbulence intensity, the heavy particles settle at rate equal to the settle rate in a still water. At intermediate turbulence intensity, it seems that the data bifurcate, i.e., the heavy particles with the large Stokes number St tend to be slowed, while settling velocity of the particles with small St are increased. Moreover, the quadrant analysis suggest that more particles tend to be on the enhanced side of vortices than the suppressed side. Thus, it seems that trajectory biasing causes the enhanced settling.

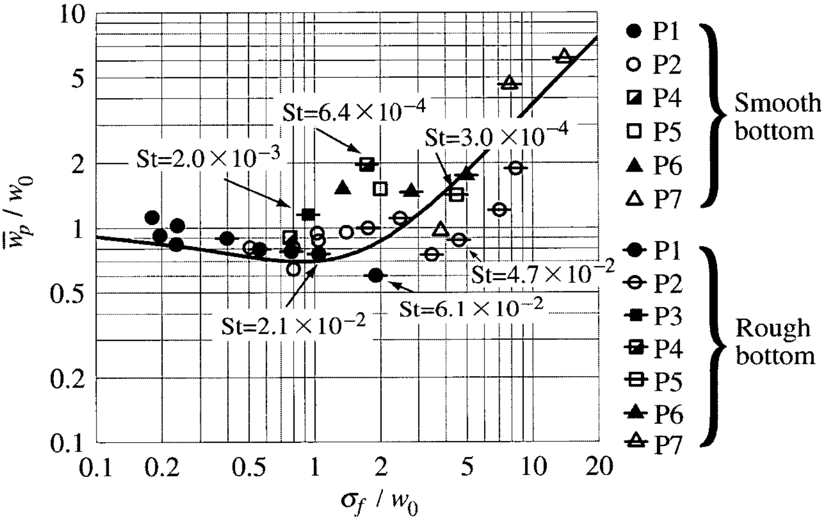

Fig. 1 Relative settling velocity vs. relative turbulence intensity.

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