viscous effects can be ignored (Currie 2003). From the above, the wind field over the gorge terrain can also be approximately divided into two layers, i.e., the gorge inner layer and the gorge outer layer. In the gorge inner layer, the wind field is very complex due to the influences mainly caused by the two side slopes of the gorge and also caused by the oncoming wind. For the present study, the gorge inner layer is about below the range of 0.205 ~ 0.231m, where the mean wind speeds accelerate, but the acceleration is not stable. Also, the variations of the turbulence intensity fluctuate remarkable. While in the gorge outer layer which is about above the range of 0.205 ~ 0.231m, the variations of the mean wind speed and turbulence intensity are stable and simple, the reason is that the influences of the two side slopes of the gorge on the wind field in the gorge outer layer are small, and the wind field in the gorge outer layer mainly depends on the oncoming wind filed. Therefore, the mean wind speeds and turbulence intensities in the gorge outer layer are very consistent with those of the oncoming wind.

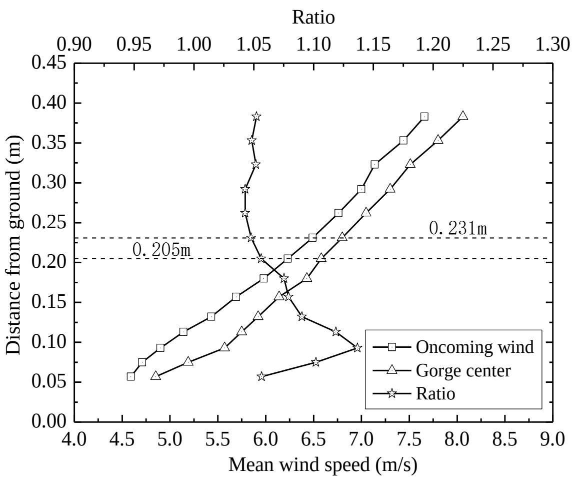

Fig. 7 Mean wind speed profiles at the oncoming wind and the gorge center

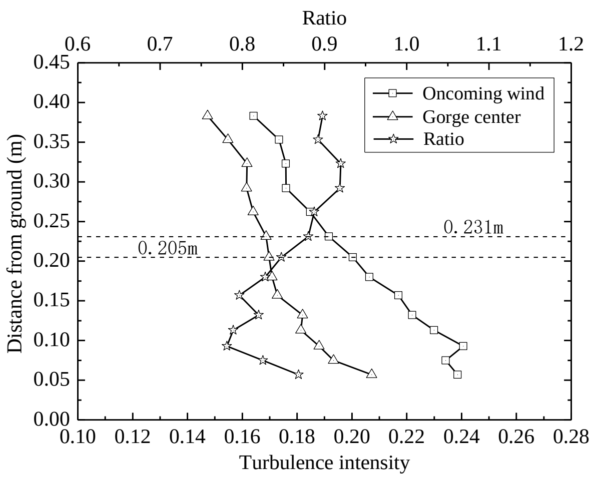

Fig. 8 Turbulence intensity profiles at the oncoming wind and the gorge center

3.2 Integral length scale

Integral length scales are measures of the average size of the turbulent eddies of the flow, and it is very important to the wind loads on the structures. When the oncoming wind flows into the gorge, the turbulent eddies and the integral length scale will change. According to the Taylor’s hypothesis (Taylor 1938), the longitudinal integral length scale can be computed by the following Eq. (1). However, it should be noted that the Eq. (1), which is valid for the homogeneous and stationary turbulence (Mizuno 1975), is not hold in the complex terrain. Therefore, the integral length scales in the gorge terrain computed by Eq. (1) may not be accurate. From the view point of engineering application, the integral length scale results computed by Eq. (1) can still be represent the average sizes of the turbulent eddies of the flow in the gorge terrain, at least they can be taken as the basis for comparing the different average sizes of the turbulent eddies in the gorge terrain. Therefore, based on the Eq. (1), the longitudinal integral length scales at the gorge center and the oncoming wind are shown in Fig. 9. It can be seen that the longitudinal integral length scales generally become large with the measurement positions move away from the ground. More importantly, the longitudinal integral length scales at the gorge center are remarkable smaller than those of the oncoming wind. The reason is that when the oncoming wind flows into the gorge, the turbulent eddies break into the smaller eddies due to the disturbances mainly caused by the two side slopes of the gorge. Therefore, the integral length scales at the gorge are smaller compared with those of the oncoming wind.

$$L_u^x = \frac{U}{\sigma_u^2}\int_0^\infty R_u(\tau)\mathrm{d}\tau \qquad (1)$$

where $R_u(\tau)$ is the auto-correlation function of the longitudinal fluctuating wind u; σ_u is the root mean square of u. It is generally believe that when the value of $R_u(\tau)$ is very small, the errors caused by the Taylor's hypothesis will increase. To improve the precision of Eq. (1), the upper limit of integral in Eq. (1) is suggested to equal to $0.05\sigma^2_u$ (Flay 1984).

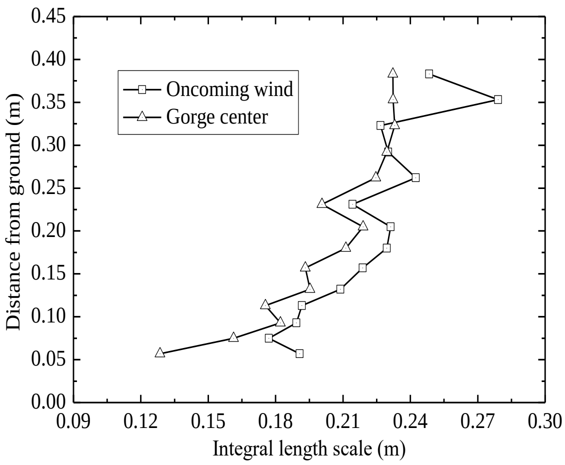

Fig. 9 Integral length scales at the oncoming wind and the gorge center

4. Analysis of effect factors on the wind characteristics over a simplified gorge

To further investigate the wind characteristics over a simplified gorge, the effect factors such as the oncoming wind field and the oncoming wind direction on the mean wind speed and turbulence intensity over a simplified gorge are analyzed.

4.1 Effects of the oncoming wind field

To investigate the effects of different oncoming wind field on the wind characteristics over a simplified gorge, the tests with the uniform flow served as the oncoming wind were carried out. In the present study, the wind speed of the uniform flow was 10.6m/s, and the turbulence intensity was about 1%. To enhance the comparability of mean wind speeds in the gorge center between the different oncoming wind field, i.e. the simulated type IV atmospheric boundary layer (IV ABL for short) and the uniform flow filed (UFL for short), the ratio of the mean wind speeds at the gorge center to those of the oncoming wind with these two oncoming wind field are calculated and shown in Fig. 10. In the range of the gorge inner layer, the mean wind speed ratios associated with the IV ABL are much larger than those associated with the UFL. However, the mean wind speed ratios are almost the same for these two oncoming wind field in the range of the gorge outer layer. Considering that the wind characteristics of the oncoming wind field can be generally divided into two parts, that is the mean wind characteristics and the turbulence wind characteristics. To investigate the effects of the mean wind characteristics of the UFL such as the mean wind speed, the tests of UFL with the mean wind speed of 6.8 m/s were conducted, and the corresponding mean wind speed ratios are also shown in Fig. 10. It can be seen that the UFL with different mean wind speeds are very close to each other in the mean wind speed ratios, which indicates that the effects of the mean wind speed of the oncoming wind on the mean wind speed ratios at the gorge center are very small, and then the turbulence wind characteristics of the oncoming wind field probably have a remarkable effects on them.

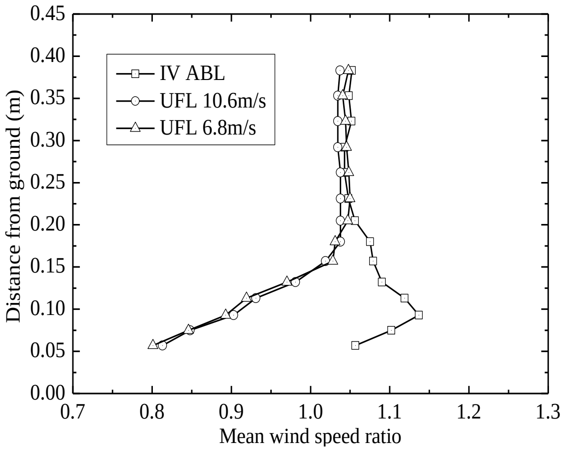

Fig. 10 Mean wind speed ratios at the gorge center with three different oncoming wind field

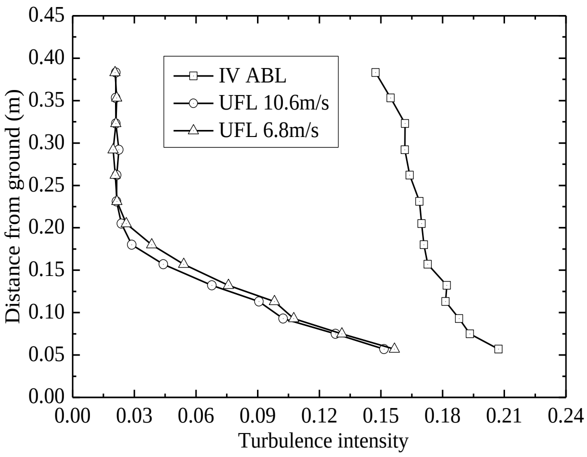

Fig. 11 Turbulence intensity profiles at the gorge center with three different oncoming wind field

The turbulence intensity is the simplest parameter to describe the turbulence wind characteristics, and it is also the important parameter to distinguish the oncoming wind field of IV ABL and UFL. Fig. 11 shows the turbulence intensities at the gorge center with these two oncoming wind field, where turbulence intensities at the gorge center associated with the IV ABL are much larger than those associated with the UFL. However, the turbulence intensities at the gorge center associated with the UFL with different mean wind speeds are almost the same. From Fig. 10 and Fig. 11, the variation of mean wind speed ratios associated with the IV ABL and UFL can be explained below. In the range of the gorge inner layer, especially near the ground, the mean wind speeds are very small due to the presence of the small roughness elements on the two side slopes of gorge. However, when the oncoming wind of IV ABL with high turbulence intensity flows into the gorge, the wind near the ground will get more kinetic energy supplies due to the effects of the turbulent mixing. As a result, the speeds of the wind near the ground increase. While the oncoming wind of UFL with the low turbulence intensity flows into the gorge, the effects of the turbulent mixing become very small, and then the speeds of the wind near the ground cannot increase. Therefore, the mean wind speed ratios caused by the IV ABL with high turbulence intensity are much larger than those caused by the UFL with low turbulence intensity. On the other hand, in the range of the gorge outer layer, as the measurement positions are far away from the ground and the two side slopes of the gorge, which makes the effects of the turbulent mixing become small for different oncoming wind field. Therefore, the mean wind speed ratios caused by the IV ABL are almost the same with those caused by the UFL in such circumstances. Actually, the mean wind speeds in the gorge outer layer mainly depends on the mean wind speeds of the oncoming wind as discussed earlier.

4.2 Effects of the oncoming wind direction

The different oncoming wind directions have remarkable effects on the wind field over the gorge (Li 2011). Therefore, the tests with the angles between the oncoming wind and the axis of the gorge equaling to 10° and 20° were carried out. Certainly, the angles were completed by rotating the circular terrain, as shown in Fig. 1. Fig. 12 shows the mean wind speed profiles at the gorge center with different oncoming wind directions. The mean wind speeds associated with the wind direction of 10° are very close to those associated with the wind direction of 0° (refer to the oncoming wind flowing along the axis of the gorge). Especially for the measurement positions near the ground, such as in the range of the gorge inner layer, the mean wind speeds associated with these two wind directions are almost the same. However, the mean wind speeds associated with the wind direction of 20° are obviously smaller than those associated with the wind direction of 0° and 10°. If compare the mean wind speeds of oncoming wind with those induced by the three oncoming wind directions, it is founded that the wind speedup associated with the wind direction of 0° and 10° are more significant than those associated with the wind direction of 20°, and the mean wind speeds at the gorge center associated with the wind direction of 20° even decrease at the higher measurement positions.

Fig. 13 shows the turbulence intensities at the gorge center with different oncoming wind directions. It can be seen that the turbulence intensities associated with the wind direction of 0° and 10° are close to each other, and they are both smaller than those associated with the oncoming wind. However, the turbulence intensities associated with the wind direction of 20° are very large, and they are generally larger than those associated with the oncoming wind. The main reason is probably that the flow separation occurs in the gorge when the oncoming wind flows into the gorge with large wind directions, such as the oncoming wind direction of 20°, which result in a very large turbulence intensities in the gorge.

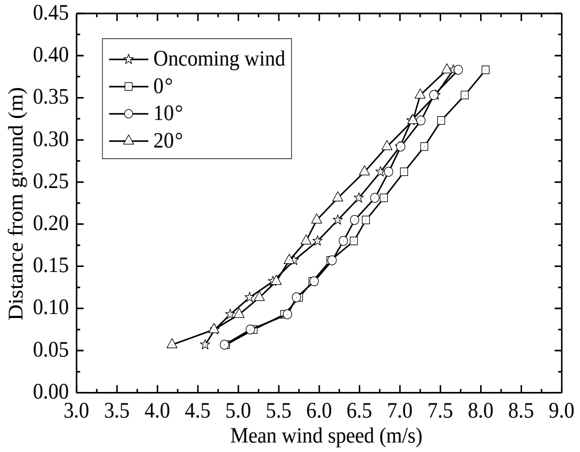

Fig. 12 Mean wind speed profiles at the gorge center with different oncoming wind directions

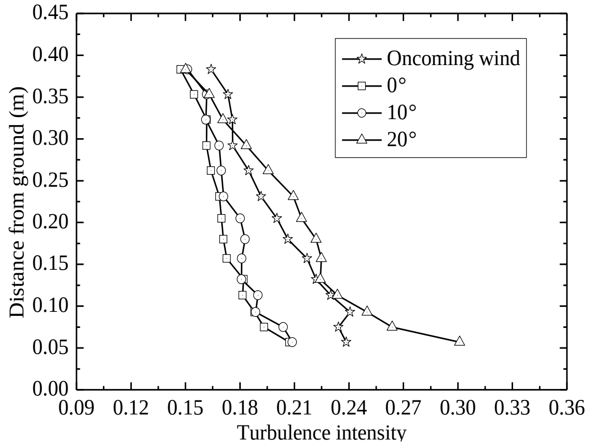

Fig. 13 Turbulence intensity profiles at the gorge center with different oncoming wind directions

From the above, it can be concluded that when the angle between the oncoming wind and the axis of the gorge is in certain range, such as smaller than 10°, then the wind field including the mean wind speed and turbulence intensity in this case are very close to those associated with the wind direction of 0°. However, when the angle between the oncoming wind and the axis of the gorge is in other certain range, such as larger than 20°, then the wind field in the gorge will significant change. To be specific, the mean wind speed will decrease, the turbulence intensity will increase. Furthermore, the closer the measurement positions move away from the ground, the greater the wind filed changes.

5. Conclusions

From the above, the main conclusions are summarized as follows:

(1) Compared with the oncoming wind, the wind speeds at the gorge center become larger, but the turbulence intensities at the gorge center become smaller. With the measurement positions move away from the ground, the mean wind speed ratios first increase and then decrease but gradually become stable at last, while the turbulence intensity ratios first decrease and then increase but gradually also become stable at last.

(2) The longitudinal integral length scales at the gorge center are remarkable smaller than those of the oncoming wind due to the disturbances mainly caused by the two side slopes of the gorge.

(3) The wind field over the gorge terrain can be approximately divided into two layers, i.e., the gorge inner layer and the gorge outer layer. In the gorge inner layer, the wind field is very complex due to the influences mainly caused by the two side slopes of the gorge and also caused by the oncoming wind. While in the gorge outer layer, the wind field is relatively stable and simple due to the influences caused by the two side slopes of the gorge are small, and the wind field in this case mainly depends on the oncoming wind filed.

(4) Because the oncoming wind of IV ABL has a relatively high turbulence intensity,

which result in the mean wind speed ratios in the range of the gorge inner layer are much larger than those associated with the UFL. However, the mean wind speed ratios are almost the same for these two oncoming wind field in the range of the gorge outer layer.

(5) When the angle between the oncoming wind and the axis of the gorge is in certain range, such as smaller than 10°, then the wind field in this case are very close to those associated with the wind direction of 0°. However, when the angle between the oncoming wind and the axis of the gorge is in other certain range, such as larger than 20°, then the wind field in the gorge will significantly change. Furthermore, the closer the measurement positions move away from the ground, the greater the wind filed change.

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