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# Steep 2D Hill effect on Vertical Wind Speed Distribution

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**Abstract**

Complex terrain sites are associated with hard flow conditions. Wind tunnel tests were carried out to investigate the effect of a 2D hill on the vertical wind speed distribution. Experiments were performed in the boundary layer wind tunnel to measure the average vertical wind speed distribution at a number of locations over the 2D hill. Current studies showed the great effect of the 2D hill on wind flow.

## 1. Introduction

Onshore wind farms number has increased over the last years [1]. Wind farms are being built over or close to complex terrains, because possible sites with flat terrain are already developed. Complex terrain sites can generate large amounts of turbulence and high loads on wind turbine blades [2]. Therefore, wind farm terrain shape must be considered along with wind turbine wake effects during the wind farm layout optimization process.

This work investigates the effect of a 2D hill on the vertical wind speed distribution. Wind tunnel tests were performed in the boundary layer wind tunnel where the average vertical wind speed distribution was measured along the hill without the wind turbine.

## 2. Method

Experiments were performed in the boundary layer wind tunnel of Kyushu University. The Boundary Layer Wind Tunnel is a closed circuit type and can be switched to open circuit if required. The test section of the wind tunnel is 3.6 m wide, 2 m high, and 15 m long. A uniform air flow with turbulence intensity less than 0.5% can be achieved in this wind tunnel, and the maximum wind speed is 30 m/s [3]. The 2D hill is represented by equation (1) and shown in Figure 1. Where h is the height of the 2D hill and equals to the diameter of the wind turbine rotor, L equals to h/2S, S is the slope of the hill and equals to 0.45, Z-axis is the vertical direction, and X-axis is the streamwise direction.

$$Z = h\ e^{\left[-0.5\left(\frac{X}{\frac{L}{1.1774}}\right)^2\right]} \qquad (1)$$

Various measurements were done at the top of the hill in order to make sure that the flow over the hill is two dimensional. The hill model was positioned at a distance from the wind tunnel floor in order to get a uniform flow condition.

The objective of the wind tunnel test was to examine the flow over the 2D hill without wind turbines, as shown in figure 2. The inlet wind velocity was constant, and the average wind speed distribution was measured using a hot wire anemometer at six locations over the hill along the streamwise direction and vertically along the Z-axis.

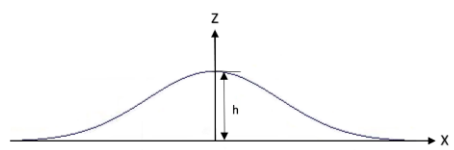


Figure 1. Schematic diagram of the 2D hill model.

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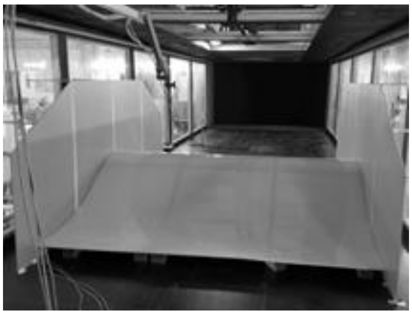

Figure 2. Wind speed measurements over the hill.

### 3. Results and discussion

Figure 3 shows the average vertical wind speed distribution over 2D hill at six locations starting at X = -1560 mm to X = 390 mm with an increment of 390 mm. In figure 3, the vertical axis represents the height of the wind tunnel test which is equal to 2m, and the horizontal axis is the wind velocity in (m/s). Wind velocity is almost constant at X = -1560 mm along the Z-direction, afterwards, wind velocity starts to increase at X = -780 mm until it reaches the maximum wind speed at the top of the hill (at X = 0), then starts to decrease at the downstream of the hill at X = 390 mm. Figure 3 shows the great effect of the 2D hill on the average vertical wind speed distribution.

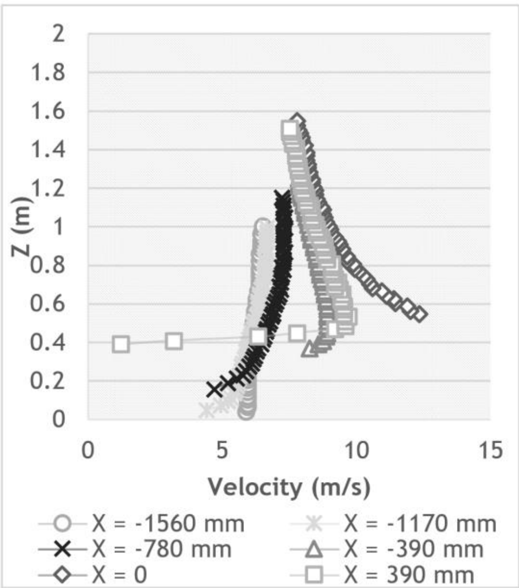


Figure 3. Average vertical wind speed distribution over 2D hill at six locations.

### 4. Conclusions

This work investigated the effect of a 2D hill on the average vertical wind speed distribution. Experiments were performed in the boundary layer wind tunnel where the average vertical wind speed distribution was measured using a hot wire anemometer along the hill without the wind turbine at six locations starting at X = -1560 mm to X = 390 mm with an increment of 390 mm. The results showed the great effect of the steep hill on the average vertical wind speed distribution

### Reference

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