

The Fifth Experiment

Estimating the horizontal wind speed at the chimney nozzles

The Objective of the experiment:

1. Demonstration of the uses of the Wind Tunnel.
2. Calculation of wind speed at different altitudes.
3. Calculating the rate of the exponential law of wind forces
4. Using the law to calculate the wind speed at a chimney mouth using the value of the wind speed at a low altitude

The Theoretical Part:

Knowing the average wind speed in the surface layer (10% of the height of the specific layer) is of particular importance in air pollution, wind energy and other applications, as when applying the Causs equation to calculate pollutant concentrations at different distances from the chimney, you need to know the wind speed at the chimney nozzle level. Winds at high altitudes have higher speeds than those at the low level near the surface of the earth for a specific time and place, meaning that in general the wind speed increases with the increase in height above the surface of the earth. The reduction in wind speed at low levels is due to the intensity of turbulence caused by surface roughness elements such as trees, buildings, and others.

One of the equations used in engineering applications is the exponential force law of the wind used to estimate the wind speed for high altitudes less than 200 m, its formula below [10]:

$$\frac{U_2}{U_1} = \left(\frac{Z_2}{Z_1}\right)^\alpha \quad (1-3)$$

Where U_1 and U_2 are the wind speed at altitudes Z_1 and Z_2 respectively, α : an empirical constant that depends on the surface roughness and atmospheric stability. It can be calculated from the above equation if wind speed data are available at two heights by rearranging them and assuming that $\frac{U_2}{U_1} = U$, $\frac{Z_2}{Z_1} = Z$

$$\alpha = \frac{d \ln U}{d \ln Z} = \frac{Z}{U} \frac{dU}{dZ} \approx \frac{Z \Delta U}{U \Delta Z} \quad (2-3)$$

In order to obtain the average value of α through a complete vertical section, we divide the section into several layers, then calculate α for each layer and thus take the average that represents its value for the complete section. After determining the average value of α , we can predict the wind speed at any height we need using equation (1-3), as we will explain in this experiment. Here it is necessary to refer to field studies and scientific research which indicated that the value of the exponent α changes according to the roughness and atmospheric stability, as we mentioned earlier [10]. This can be illustrated by Table (1-3) which shows the changes of α values depending on the surface roughness and the type of inductance.

Table (1-3): the values of the exponent α for the exponent of the force law for winds [4].

F	E	D	C	B	A	location
0.30	0.30	0.25	0.20	0.15	0.15	urban
0.55	0.35	0.15	0.10	0.07	0.07	rural

This experiment can be carried out in the laboratory using a wind tunnel or channel used to generate a specific layer with a small gradient (note Figure 2-3 below). Wind ducts shall consist of an inlet orifice having a straight stream flow through a long rectangular section length and cross section in which the tests are carried out. And finally, from an electric fan (pull) with different speeds controlled by a motor.

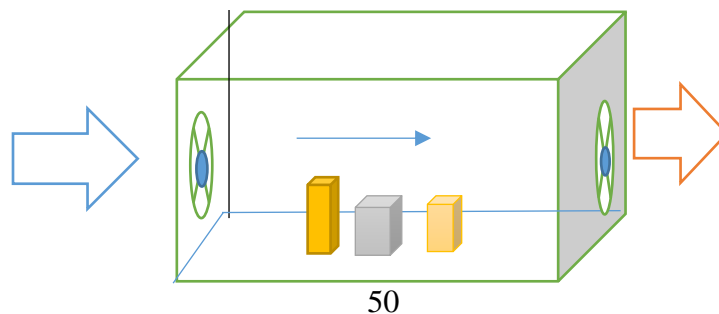


Figure (2-3): The wind channel diagram used to calculate the α in equation (1-3).

The Materials and Tools used

1. A wind channel for the specific stratum strait.
2. Models of chimneys of different lengths.
3. Synthetic roughness elements to generate turbulent vortices.
4. Sensor measuring flow speed.

The Method of Work

1. Turn on the wind channel..
2. Measure the vertical flow velocity and make sure the laminar flow is equal velocity:
3. Fix the roughness elements in an irregular arrangement around a particular chimney in the test segment.
4. Start by measuring the flow velocity for several altitudes listed in the following table:

50	30	20	12	8	5	3	(cm) height
							U (m/s)
							Z_2/Z_1
							$U_2/U_1 = U$
							$\Delta U/\Delta Z$
							α

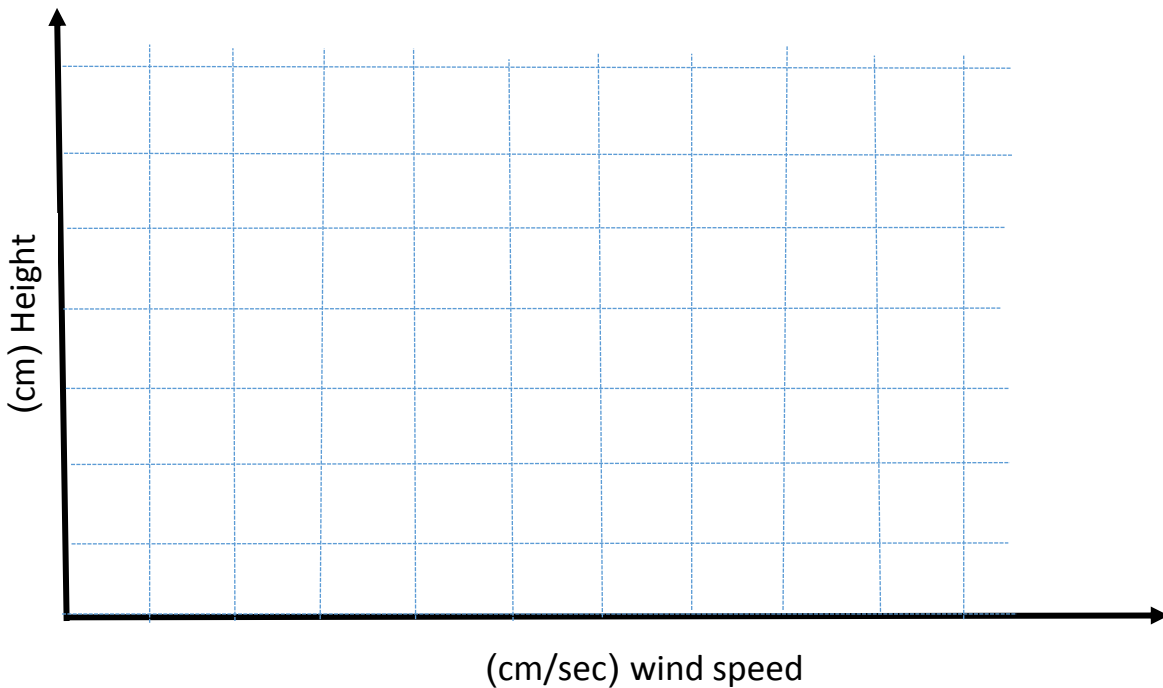
5. Find the ratio of $\frac{U_2}{U_1}$ and $\frac{Z_2}{Z_1}$ between each of the two successive levels and record your results in the table above.
6. Calculate the value of α for each two successive levels using Equation (2.3).

7. Calculate the average value of α to represent the vertical cross-section of the air layer between 3 cm and 50 cm.
8. Measure the height of the top of the chimney, let it be z_2 .
9. Measure the velocity of flow at a height of 5 cm = z_1 .
10. Calculate the value of the flow velocity at the chimney nozzle using Equation (1.3).

Discussion

Q1: Plot the relationship between $\log z$ values and $\log U$ values Find the slope value? And what does it represent?

Q2: Draw the relationship between the values of altitude and wind speed and discuss the graph?



Q3: What does the vertical section of the wind look like over an urban area and a rural area?

Q4: In your opinion, it is possible to rely on the results of the wind channel and generalize them to the real atmosphere?

Q5: Compare the average value of α with its reality value in Table (1-3)? Find the error rate?

Good Luck

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