Wind Tunnel Experiments on Fog Collectors

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Abstract: Artificial fog collectors are used for getting water out of advection fog in desert areas of Peru and Chile. The problem of wake geometry characterization downstream of such a vertical permeable surface is investigated in a wind tunnel physically modeling the collector at 1:100 scale. Preliminary results are discussed to spatially characterize the wake region downstream of the permeable obstacle varying the only free parameter, the mesh porosity. Results from anemometer velocity measurements and flow visualization techniques are analyzed to characterize the general direction of the flow. The greatest degree of wind abatement occurs within five times the height of the collector. Furthermore, the flow field downstream of two collectors, tested under different positions, is studied to characterize the influence of their positioning on the resulted wake. Results show the importance of such an approach in order to improve the understanding of the flow motion downstream of permeable surfaces. The spatial characterization of the wake region has a practical utilization whenever the knowledge of the disturbed flow field downstream of the obstacle is required.

1. INTRODUCTION

The Spanish word *atrapaniebla* is referred to artificial devices to collect water from the advection fog in some areas of the world such as the Pacific coast of South America as described by Schemenauer and Cereceda [1992]. The incoming fog is forced to hit on the capturing surface by horizontal winds and water particles, after being intercepted, flow down and can be collected. The capturing surface is represented by a polypropylene mesh vertically mounted and supported by two posts. It is 12 m long and 4 m high mounted at a height from the ground depending on the topography of the site. The mesh used for the EU fog collection project (TS3-CT94-0324, DG12 HSMU), in Peru (*Lomas de Mejia*) was Raschel type and mounted in a double layer.

The presence of such an obstacle induces a modification in the undisturbed velocity field, originating vortical structures downstream of the obstacle whose form, dimension and persistence is a function of the porosity of the obstacle itself. In recent years, new codes have been used to model the turbulent wake downstream regular shape obstacles as shown by O'Neil and Meneveau [1997]. But less is known about porous obstacle, where some of the hitherto horizontal air stream is deflected over the top, and the remainder, in a much weakened form, passes through the porous barrier resuming its normal pattern until some distance down-wind.

At this purpose, wind tunnel trials are conducted in order to spatially characterize the downstream region. Different meshes are tested in order to verify the influence of the porosity in the formation of different vortical structures and the modification induced by the presence of two collectors.

2. MATERIALS AND METHODS

The experiment is carried out physically modeling the permeable obstacle in the wind tunnel described by Bresci [1998]. The barrier is a rectangular shape panel mounted perpendicular to the bottom of the tunnel and whose horizontal dimension is three times the vertical one (h) and mounted at a distance from the ground equal to $3/8\ h$. The length reduction factor of the model is chosen equal to 100. It is placed perpendicularly to the bottom with a wind incidence angle equal to 90°.

Trials are made on different porous meshes available in Italy and used for different applications such as shading, hail defense, etc., as well as on meshes used for fog capturing experiments. Here only the results coming from tests on two different meshes used for fog capturing in Peru and in the Canary Islands are discussed. The meshes are made up with polypropylene ribbons mounted in a double layer. The difference between the two meshes consists in the width of the ribbon giving rise to different shade coefficients. The problem then is the relation of the shade coefficient with the porosity of the mesh, defined as the ratio of the void area and the total area. At this purpose, the porosity values for both meshes are calculated through the ARCView 3.2 sofware digitizing the voids; they are 22% and 17%.

In order to investigate the distance over which the wind velocity is slackened in speed as a function of the mesh porosity, velocity intensity measurements are collected through a vane anemometer. The wind run is measured during 5 seconds and each measure repeated five times in the same point of the grid of sampling and the mean value used for profiles plotting.

Measurements along a vertical line passing through the barycentre of the collector are made to map the variations of the vertical profile moving downstream of the obstacle for increasing distances *d* from it. Another set of velocity measurements, on a line along the wind direction passing through the barycentre of the panel at a dimensionless distance from the ground equal to *y/h=0.95*, are taken in order to map the longitudinal velocity profile in the downstream region at increasing *d* values.

The analysis of the flow pattern in the downstream region is carried out through visualization methods. The method used is given by the positioning of tracing colored particles on the bottom of the wind tunnel and observing the final disposition of the particle traces under the wind effect. The colored traces are produced by a suspension of titanium dioxide in a solution of mineral oil brushed on the surface. The traces left by the colored particles located on the ground are then able to picture the motion at the ground level and the presence and the form of vortical structures. Pictures with a digital camera were taken when the particles appeared to be firm on the surface.

3. RESULTS

The results, as coming from the anemometer measurement,s are presented through dimensionless units: velocities are made dimensionless dividing by the undisturbed velocity value (*Vinf*) and the distances by the height (*h*) of the obstacle.

Figure 1 shows the vertical profiles for increasing distances from the obstacle, respectively *d/h* equal to 2.5 5 and 10 as measured in the downstream region originated by the Peruvian mesh (dashed) and the Canary Islands one (solid). The two horizontal dashed lines represent the obstruction of the section due to the presence of the permeable barrier. The profiles show a good overlapping for all the three distances from the obstacle, a very weak shifting can be seen for the profile corresponding to *d/h* equal to 2.5 where in the area above the obstacle a greater reduction in velocity can be seen for the Spanish mesh. The two meshes having only 5% difference of porosity do not produce different patterns of wind reduction, because the amount of wind they let through is similar. The distance at which the vertical profile is completely re-established is greater than 10 times the height of the barrier. The greatest degree of wind abatement for *y/h* less than 1.45 does not occur close to the barrier but between two and five times its height down-wind. From this point of minimum wind, there is a gradual acceleration until the wind regains its former speed.

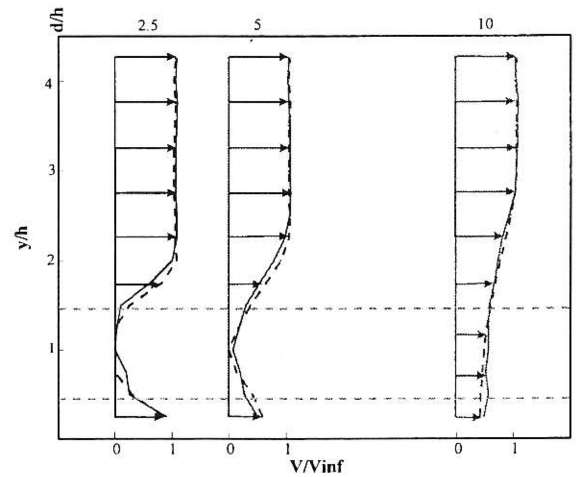

Figure 1. Velocity vertical profiles in the downstream region for increasing distance value from the obstacle (dashed: Peru, solid: Canary Isl.).

As regards *y/h* values greater than 1.45, the opposite trend verifies: values close to one verify close to the obstacle and reduce going far from it. The separation zone between disturbed and undisturbed value has a convex shape.

Figure 2 shows the longitudinal profiles as measured upstream and downstream of the two meshes. The profiles show a good overlapping with the exception of very weak differences far from the obstacle where the Spanish mesh velocity values are closer to one than the others. Even if the difference is almost imperceptible, it confirms the theory that a dense mesh determines the re-establishment of the velocity profile closer to the obstacle than a more permeable one. In both cases, the effect of the barrier is strongly felt up to thirty times its height. As regards the upstream region, velocity values do not fall very much since at *d/h* equal to 5 the ratio is still close to one.

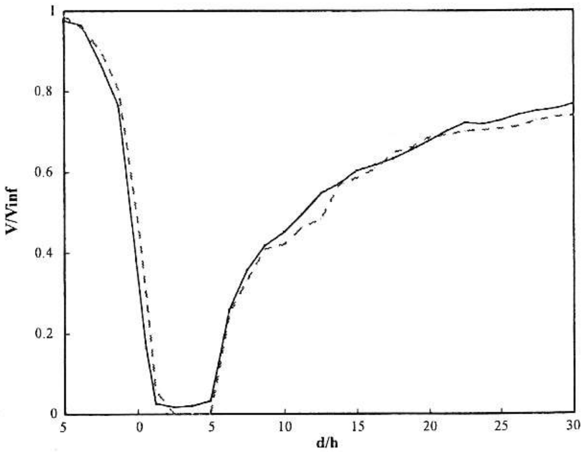

Figure 2. Velocity longitudinal profiles upstream and downstream of the obstacle (dashed: Peru, solid: Canary Isl.).

A wind incidence angle equal to 45° is tested only for the Peruvian mesh and the longitudinal profiles for angles equal to 90° and 45° are shown in figure 3, respectively as solid and dashed lines.

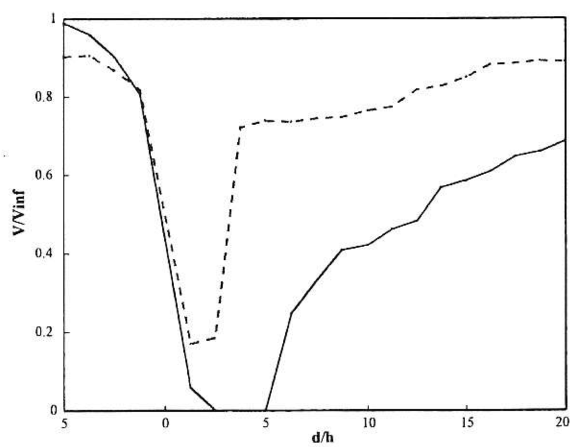

Figure 3. Velocity longitudinal profiles upstream and downstream of the Peruvian mesh (dashed: 45°, solid: 90°).

The two curves appear different both upstream and downstream of the barrier, but the main discrepancies are downstream. The 45° profile shows the greatest degree of wind abatement between two and three times the height of the mesh, starting from *d/h* equal to four the wind achieves the 70% of the undisturbed value. At *d/h* equal to 20 the wind velocity value nearly resumes its normal pattern, with a ratio of 0.90. On the contrary, for the 90° profile the area characterized by minimum velocity values extends up to a distance of five times and, moreover, the profile is not able to re-establish showing a maximum value of wind velocity ratio equal to 0.68. This different behavior may be justified observing that for the 45° angle the impact area for the incoming flow and the porosity value are reduced.

The effects of the presence of an additional collector in the downstream region are investigated through anemometer measurements. The second collector is located at a distance of respectively one (solid), two (dashed) and three (dashdot) times the height of the collector (fig. 4). The overlapping area between the two collectors is equal to the half of the total area. The longitudinal profiles corresponding to the region downstream of the two panels mounted with the Peruvian mesh are reported for the three different positions. The reciprocal distance between the two collectors seems to do not influence the upstream region, in fact the three profiles are overlapping.

The greatest reduction in wind velocity is given in the downstream region included between two and ten times their height. In the area between ten and twenty times the height of the mesh, the velocity gradient is reduced and the profiles start to re-establish as a function of the distance. For *d/h* equal to one, the profile is not able to re-establish showing a maximum velocity ratio value equal to 0.6, for *d/h* equal to two and three the maximum is roughly 0.7 like in the case of a single panel. The pattern of velocity longitudinal profile is then little different from that downstream of a single one. It seems that each panel acts independently of the others if their distance is more that two times the height.

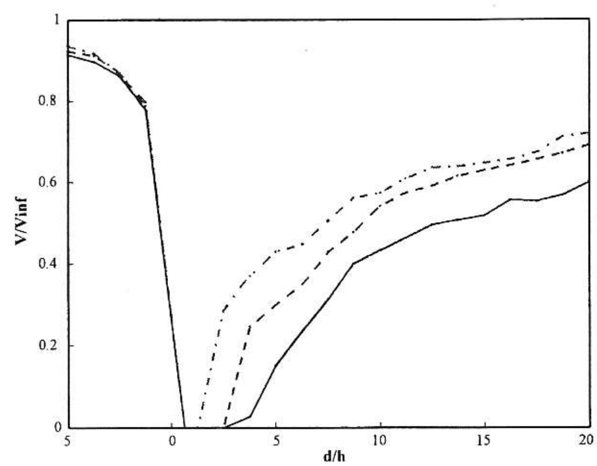

Figure 4. Velocity longitudinal profiles upstream and downstream of two Peruvian meshes located at increasing *d/h* values (solid: *d/h*=1; dashed: *d/h*=2; dashdot: *d/h*=3).

As regards visualization techniques here are discussed only the results coming from the Peruvian mesh.

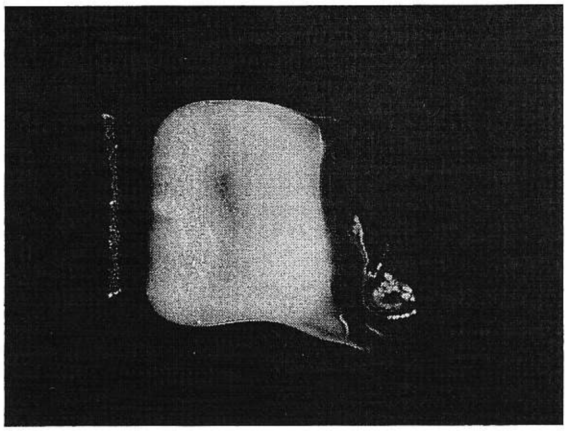

Figure 5. Colored particles visualization: Peruvian mesh.

Figure 5 shows the top view of the traces in the downstream region of a single Peruvian mesh. A vortical structure appears perfectly defined at one side, the absence on the other side can be justified with the non-uniformity overlapping between the two layers of the mesh which originates some parts more porous than others. Figure 6 shows the traces left on the downstream region of two collectors mounted with the Peruvian mesh situated at a distance of two times their height. The overlapping area is 50%.

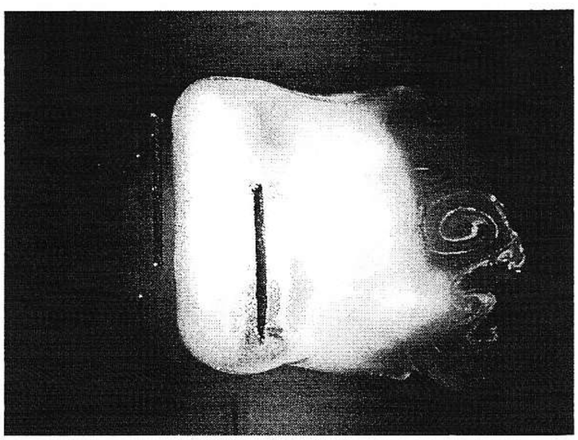

Figure 6. Colored particles visualization: two Peruvian meshes (*d/h*=2).

The oily mixture initially amid the two collectors is dragged up to a distance of more twice their height. A clear vortical structure originates exactly in the middle of the total capturing surface, some other minor structures form on the left side looking from downstream. The superimposition of the two disturbance effects originates two distinct zones: on the left side an area characterized by strong vortical effects and on the right a more regular flow field.

4. CONCLUSIONS

Wind tunnel experiments on fog collectors allowed to characterize the flow field in the downstream area. Longitudinal and vertical velocity profiles are reconstructed through anemometer measurements and analyzed to check the distance at which the profiles resumed their normal pattern. This distance is a function of the porosity of the mesh. Tests on two different meshes commonly used for fog capturing 22% and 17% porosity, gave very weakly differences in the velocity profiles due to their similar porosity. On the contrary, longitudinal profiles, coming from a variation in the incidence angle with the Peruvian mesh, showed that the wind direction is able to give rise to a very different profile in the downstream region, in particular, the disturbance effect peters more rapidly than in the other case. The utilization of colored particle traces showed the presence of vortical structure in the downstream region of the 22% mesh both in the case of a single mesh or two meshes. These first results seem to give a positive answer to the spatial characterization of the disturbed region downstream of permeable surfaces.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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