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CONCENTRATION OF GAS ADMIXTURE FROM LINE SOURCE IN FLOW OVER TWO-DIMENSIONAL HILL

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ABSTRACT

Flow around the two-dimensional hill is of great interest in engineering application, namely in transport and dispersion of pollutants in atmosphere. A case of polynomial shaped 2D hill with the line source of tracer gas has been studied in detail. Geometry of the hill is the same as in [1]. Experimental study of both, the time-averaged velocity field and the binary-mixture concentration field has been done.

INTRODUCTION

Many problems of environmental aerodynamics and wind engineering are connected with turbulent air-flow in atmospheric boundary layer. Processes in this layer are complex and theoretical solution is not possible yet. Problems are studied by means of experiments in wind-tunnels and mathematical modelling. The turbulent diffusion of fluid particles is important problem. Experiments in wind-tunnels are crucial for improvement of computational methods and for their testing.

There was a two-dimensional polynomial shaped hill in the channel. Carbon dioxide was streamed into the main air-flow as a tracer. Experiments have been provided on the open type wind rig, which is powered by ventilator. All measurements were done at one value of mass flow of the main stream and one value of mass flow of the tracer stream. Behind the hill there were measured fields of: the static pressure, the total pressure, and the molar concentration of the tracer. First two allow us to determine the velocity field.

NOMENCLATURE

u	[m/s]	fluid velocity in main free-stream direction (x direction)
v	[m/s]	fluid velocity in y direction
C	[-]	molar concentration of CO_2 in the mixture with air
Q	[m^3/s]	fluid volume rate
x	[m]	Cartesian coordinate, in the undisturbed flow direction
y	[m]	Cartesian coordinate, opposite to the direction of gravity
h	[m]	height of the hill
H	[m]	height of the channel

EXPERIMENTAL SETUP

The existing blow-down test rig was modified for experiments with the hill in a channel. The tunnel has rectangular crosssection with filled corners (to suppress corner vortices), honeycomb and a system of damping screens followed by contraction with contraction ratio 16. The area of the test section is 0.25 m in height and 0.1 m in width. The time-mean velocity departures from homogeneity in planes perpendicular to the tunnel axis are of order tenth of percent with the exception of corners, where corner vortex starters could be detected. Reynolds number based on the height of the hill and volume velocity was about 1.3×10^4. The natural turbulence level was about 0.1% in the working section input.

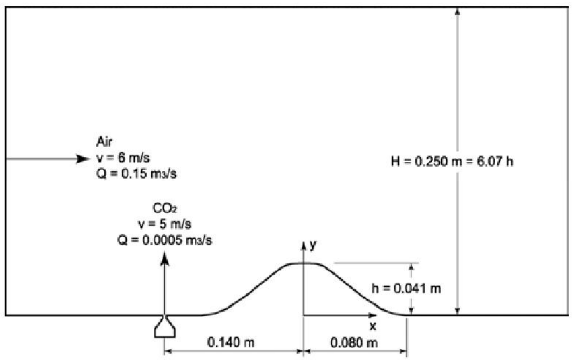

Figure 1 Experimental arrangement.

The channel downstream the hill was 0.4 m in length, and the ratio of the hill height h to the channel height H was 6.07 (H = 0.250 m, h = 0.041 m).

A sketch of the experimental arrangement with fundamentals dimensions is shown in Fig.1.

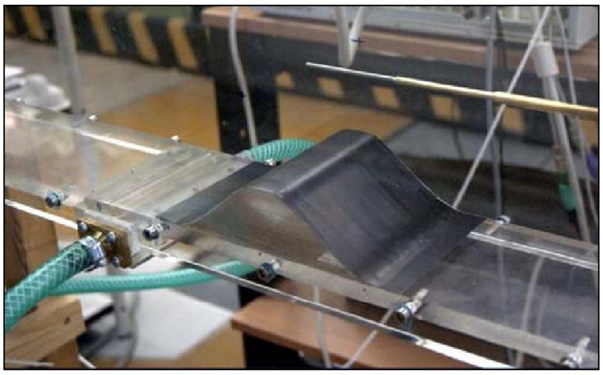

Figure 2 The slot upstream the hill and the total-pressure probe.

The channel has perspex walls (see Fig. 2). Upstream of the hill there is a slot for admixture input. The width of the slot is 0.001 m. The admixure was supplied from a gas bottle. Pressure of the gas flow is mantained by reduction valve on a constant value. A metering nozzle is placed ahead of the slot.

MEASUREMENTS

The operating flow parameters in the test rig were measured by means of a Pitot-static tube and a RTD thermometer Pt100 inserted upstream the hill. The inlet velocity upstream the hill was calculated from measured data. The mass flow through the slot was calculated from pressure differences measured on the metering nozzle and temperature measured upstream from the inlet of metering nozzle.

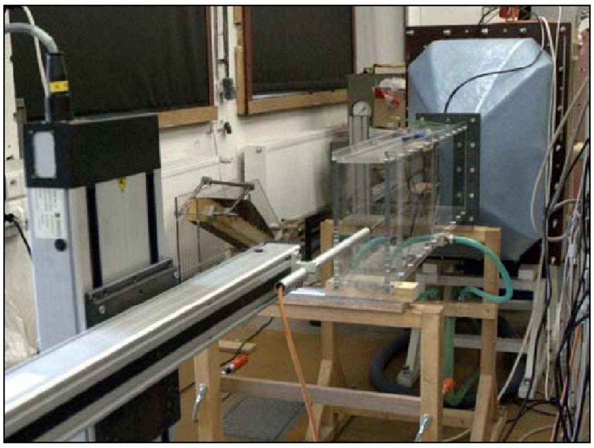

Figure 3 Blow-down test rig with channel and traversing system.

The distribution of static pressure was measured by means of Pitot-static tube (diameter of approx. 1.5 mm). The distribution of total pressure was measured by total pressure probe (dia of 2.6 mm). The same probe was used for the concentration sampling. The averaging time of the pressure measurements was set up to 10 second. Because of slow response of CO_2-analyzer there was placed a break of 35 second long before each measurement.

The following differential pressure transducers were used at the mentioned measurements: OMEGA PX653-05D5V 0.1, range 0.025 kPa, error < ±0.4% FS (OMEGA Technologies Ltd., England) and BHV 5355, range 10 kPa, error < ±0.1% FS and range 100 kPa, error < ±0.1% FS (BHV Sensors, Czech Republic). The distribution of molar concentration C was measured using Carbon Dioxide Monitor Guardian Plus (Edinburgh Instruments and Sensors). The output signals of transducers and analyser were digitalized using the A/D transducer (National Instruments data acquisition system, sampling frequency 25 kHz, 16 bit). Time-mean values of flow temperature, pressure etc. were stored in the controlling PC, using the LabVIEW software.

RESULTS

The velocity of the main flow was set at 6 m/s. Volume rate of CO_2-admixture was set at 5×10^{-4} m^3/s. It corresponds with velocity in the slot of 5 m/s. The results of the measurements are the time-averaged distribution of both, the velocity in main free-stream direction u and the concentration C. The x-profiles of the velocity show graphs in Fig. 5 and Fig. 6.

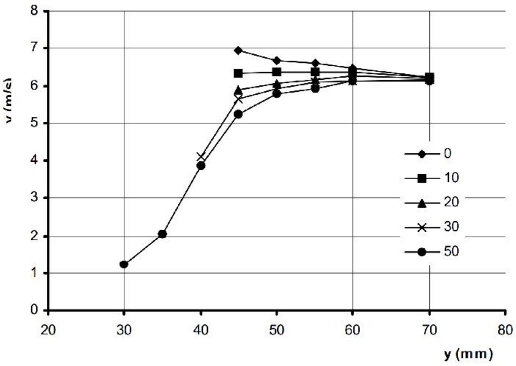

Figure 4 Velocity distribution u (m/s) along y coordinate at vertical planes x=(0;10;20;30;50) mm

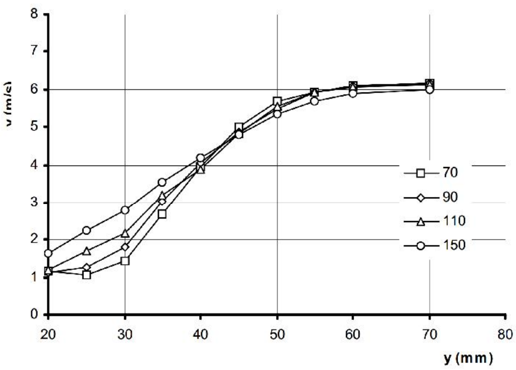

Figure 5 Velocity distribution u (m/s) along y coordinate at vertical planes x=(70;90;110;150) mm.

The x-profiles of the molar concentration show graphs in Fig. 6 and Fig. 7.

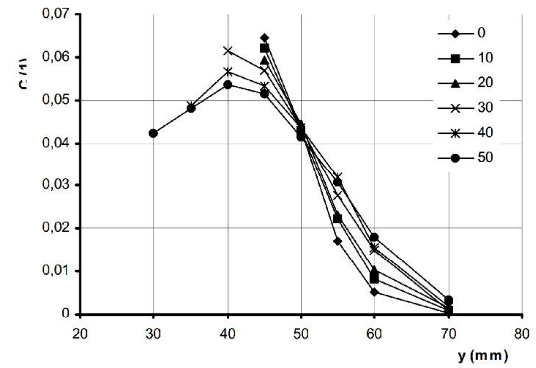

Figure 6 Concentration distribution C (-) along y coordinate at vertical planes x=(0;10;20;30;50) mm.

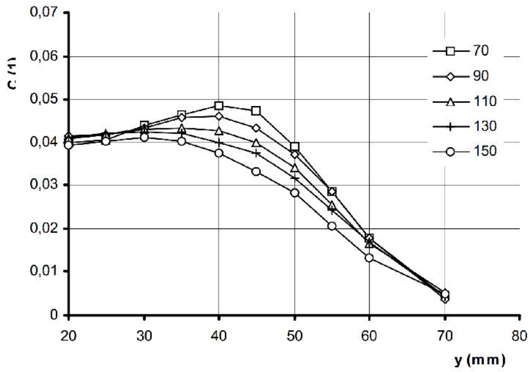

Figure 7 Concentration distribution C (-) along y coordinate at vertical planes x=(70;90;110;150) mm.

The scalar maps of the velocity and the molar concentration show graphs in Fig. 8 and Fig. 9.

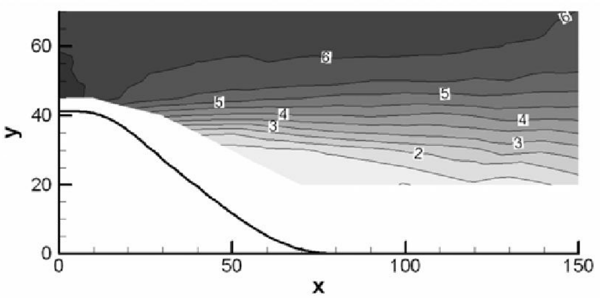

Figure 8 Velocity map over the hill u (m/s).

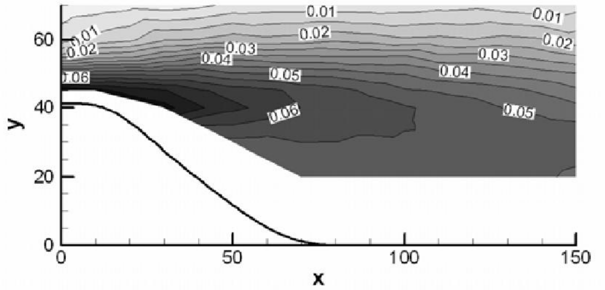

Figure 9 Concentration map over the hill C (-).

CONCLUSION

The paper presents time-averaged distributions of the velocity and concentration over a two dimensional polynomial-shaped hill at Reynolds number based on the height of the hill 1.3×10^4. The maximum value of the concentration at the top of the hill is smoothed out with the increasing x-coordinate due to diffusion. At the present time we continue with measurements on this case with means of hot-wire anemometry. From such measurements we will be able evaluate fluctuations of the velocity. Moreover, with a special designed multiple hot-wire probe there is also possible obtain fluctuations of the concentration.

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