OBSERVATIONS OF THE WIND TUNNEL BLOCKAGE EFFECTS ON THE MEAN PRESSURE DISTRIBUTIONS AROUND RECTANGULAR PRISMS IN SMOOTH AND GRID TURBULENT FLOWS

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1 INTRODUCTION

This paper deals with the modification of the pressure distributions due to the constraining effects of the walls when a stationary prism is tested in a channel. These constraining effects are often defined as solid and wake blockages.

Solid blockage is due to the reduction of the flow area in the channel test section by the presence of the prism: the resulting increase of the flow velocity is observed to be much less severe (about one-fourth according to Ref [1]) than the one predicted by the direct application of continuity.

The wake downstream a rectangular prism has a lower mean velocity than that of the oncoming freestream: the shear layers from the separation points of the prism as well as the vorticity shed in the wake are related to the velocity shear between the flows outside and in the wake. The modification of this velocity shear caused by the increase of the flow velocity outside the wake is associated with wake blockage.

Although these blockage effects modify the values of the force and moment coefficients of the stationary prisms, their impacts also extend to the determination of onset conditions of instabilities such as galloping.

Previous contributions have dealt with the effects of blockage on the drag force or the pressure distribution on the frontal and base surfaces of rectangular prisms but few considered the effect of blockage on the side wall pressure distribution or the force transverse to the flow. Moreover, the combined effects of blockage and turbulence level contained in the oncoming flow are not well known. In this paper, attention is then paid to the side wall pressure distributions (partly the source of transverse vibrations since the wake vorticity is organized over the side wall) in the case of two-dimensional rectangular prisms exposed to smooth and grid turbulent flows. Conditions are examined for which similitude is lost and correction techniques

are not expected to perform well. An experimental set-up is developed to preserve the additional similitude criteria of grid turbulent flows.

2 EXPERIMENTAL APPROACH

In the case of rectangular prisms (geometrically defined by H, d, L, respectively the side, the frontal and the long axis dimensions) mounted in a square test section channel (with area dimension C) and exposed to uniform flows (fluid defined by ρ, the density, and μ, the dynamic viscosity) with and without superimposed grid turbulence defined by the variables U, u', v', w', Lx, Ly, Lz (respectively the mean flow velocity, the three velocity fluctuations components and the three turbulent length scales), the independent similitude criteria are:

H/d, L/d, Ld/C (or S/C), Reynolds, u'/U, v'/U, w'/U, Lx/d, Ly/d and Lz/d.

In low turbulence uniform flows, called smooth flows, only the four first independent criteria prevail: the effect of blockage or the ratio S/C can be evaluated by changing the model size d and adjusting the flow velocity to maintain the Reynolds number. This approach is mostly adopted in previous works and remains valid as long as the ratio L/d is sufficiently large to reduce the importance of the effect of the channel walls boundary layers interacting with the ends of the model.

In turbulent flows, the effect of modifying d in order to evaluate the effect of blockage modifies the values of the three turbulent length scale ratios. The only alternative consists in keeping the flow characteristics constant and by moving two of the channel walls in order to modify C instead of d. This is an originality of the present research project: two false walls are mounted inside the channel test section to generate a smaller channel around the model within the test section. This approach allows keeping constant all the independent similitude criteria while varying the blockage ratio. Since the local mean pressure (p) distributions were of interest, the similitude criteria is the usual pressure coefficient ($Cp= (p-p_\infty)/(0.5\rho U^2)$). Force coefficients can obviously be deduced from the pressure distributions.

Six families of rectangular prisms (with H/d= 0.5, 0.6, 0.8, 1.0, 2.0 and 3.0) were tested under five different solid blockage ratios (S/C= 6.6%, 9%, 12%, 15% and 20%) and three types of flows (smooth flow, grid turbulent flow with 5% and 10% intensities). The Reynolds number was set to exceed 5×10^4. The value of H/d was the result of different sizes of the side walls: the frontal and base walls' dimension was kept constant (d=12cm). Pressure taps were machined on all the models' surfaces: a higher concentration of taps (18 to 24 taps according to the length H) was selected in the case of the side walls in order to examine the influence of blockage on the force transverse to the flow. The models were mounted inside the wind tunnel test section and two false walls were displaced within the test section to generate the constraining effects.
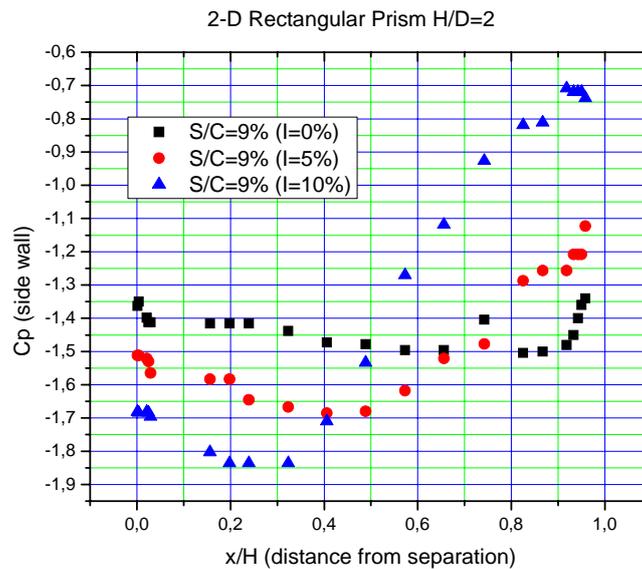
3 RESULTS

The first set of figures shows the case of a rectangular prism with a short afterbody, that is H/D=0.6 in smooth flow. The complete pressure distribution (figure at the left) measured under five blockage configuration is observed to remain similar from the point of stagnation to the point of separation ($0\leq$ z/D ≤ 0.5) and to progressively loose its similitude on the side wall ($0.5\leq$ z/D ≤ 1.1) and the base area ($1.1\leq$ z/D ≤ 1.6) especially for S/C>10%. The detailed pressure distribution on the side wall ($0 \leq$ x/H ≤ 1.0) shows that the location of the minimum

pressure shifts towards the separation point: a pressure recovery follows. The comparison between the S/C=6.56% and 15% or 20% indicates that similitude is lost on the side wall pressure distribution even in the case of short afterbody prisms in smooth flow.
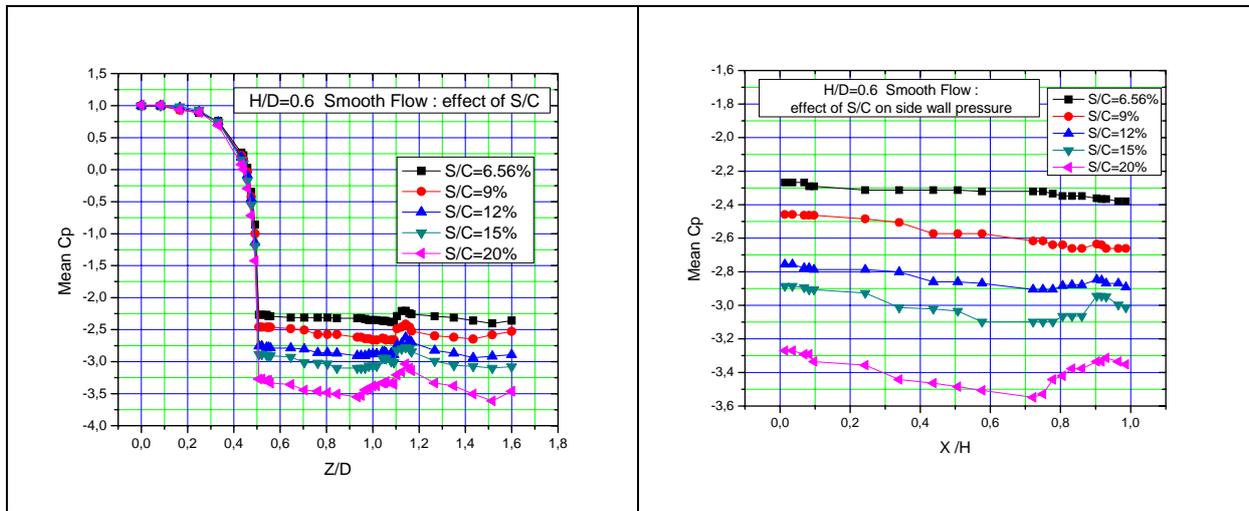
The next figure shows the effect of a grid turbulence superimposed to an otherwise smooth flow. Three levels of turbulence are applied in this case and a longer afterbody prism (H/D=2) is subjected to a constant blockage value (S/C=9%).

The slight pressure recovery observed in smooth flow conditions becomes much more important as the level of turbulence is increased.

4   CONCLUSIONS

The main results are:

• The effects of blockage for a given grid turbulent flow, are not limited to a simple increase of the mean flow velocity: reattachment of the shear layer may occur.

• For a given blockage condition, the effects of superimposed turbulence on the oncoming flow may also cause an earlier reattachment of the shear layer on the side wall (especially again in the case of prisms with H/d>1.

• The dimensionless pressure distribution over the surface of the model facing the flow is weakly influenced by the independent variables, H/d, S/C and the turbulence levels; the distribution resembles that of a flat plate normal to the flow. Similitude is preserved in this region and the effect of increasing blockage is to lower the static pressure at the separation point.

• In the case of prisms with H/d >1, similitude is lost for the pressure distributions on the side wall since blockage induces an earlier reattachment of the shear layer over this region. This conclusion can be extended to the base area.

ACKNOWLEDGEMENTS

REFERENCES

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