A 2-D tolerant wind tunnel for testing bodies with large blockage

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Abstract

The existing Boundary Layer Wind Tunnel at the University of Sydney will soon be modified into a 'Tolerant Tunnel' so that bodies with large blockages can be tested without correction. The solid ceiling of the tunnel will be replaced by a transversely slatted ceiling backed by a plenum chamber which should reduce any errors normally induced by blockage. This paper will discuss the concept of the tolerant tunnel and describe a numerical calibration used on the Sydney University BLWT.

INTRODUCTION

Wind tunnels provide an indispensable means for testing models to predict prototype characteristics. Tunnel wall boundaries impose constraints on flow around a model and as such deviate the measured values from the required free air values. One way of reducing the induced errors is to use smaller models. This solution is not always feasible especially when the prototype is several kilometres in dimension and requires accurate contouring.

The most widely used solution to wall interface problems is to apply an empirical correction factor to the raw data. Such correction factors are shape dependent and are often only valid in a particular facility. Slatted wall tolerant tunnels are gaining in popularity since they provide an automatic, passive method for minimising the effects of blockage induced by large models.

The envisaged slatted ceiling and plenum chamber to be installed in the University of Sydney BLWT is drawn in elevation in Figure 1. NACA0015 aerofoil sections of 100mm chord length inclined at zero angle of incidence will constitute the slatted ceiling.

TOLERANT WIND TUNNEL CONCEPT

The tolerant tunnel concept was first devised by Parkinson in 1984 and has since been tested in a number of applications. Parkinson, Williams and Malek [6] used a tunnel with a section of the side wall replaced by slats to test high lift aerofoils. Further work performed by Parkinson and Hameury [4] utilised two slatted side walls to test 2-D sectional bluff bodies. An axi-symmetric form of the tolerant tunnel was tested by Premnath [5] on bodies of revolution.

The concept of a slatted wall tolerant wind tunnel arises from the fact that an open jet section and a closed jet section produce blockage corrections of opposite sign. A slatted wall consisting of evenly spaced transversely placed aerofoil sections will act as an intermediate between the two jet configurations. A certain amount of flow is able to diverge into the plenum at the upstream end of the model and rejoin at the downstream end. Correct blockage tolerance is obtained when the resistance provided by the aerofoils matches the resistance that would be provided by an external unbounded flow. A free air boundary condition is then established. Control of the flow entering the plenum is governed by the Open Area Ratio (OAR). OAR is the percentage of a slatted wall which is open to the plenum. An optimal OAR of 56% [4,1] has previously been found to most effectively remove blockage errors for blockages of up to 30%.

Tolerant wind tunnels have been built and calibrated at the University of British Columbia [6,4,5], Canada, BRE in England [3] and Central Laborites in New Zealand [1]. The performance of the BRE tunnel was not as good as expected. It was found that a small L/H ratio (slatted wall length / tunnel height) of 1.12 did not sufficiently reduce blockage effects. A numerical investigation of the Sydney University BLWT was thus made to determine an appropriate slatted ceiling length.

NUMERICAL INVESTIGATION

Surface singularity method [2] was used for the numerical investigation. Initially a model was made of a half cylinder placed at the base of the tunnel (Figure 2). The distribution of Cp (coefficient of pressure) over the cylinder was determined with and without a solid ceiling in place. The blockage ratio produced by the cylinder with the tunnel ceiling in place was modelled at 30%. The results presented in Figure 3 show perfect agreement with the ideal analytical case (solid line) for the free air configuration. An error of 20% can be seen at 30% blockage demonstrating the need for pressure correction with a solid ceiling in place.

An indirect method for calculating the required slotted ceiling wall length (L/H ratio) is to alter the solid ceiling wall length above the half cylinder model and calculate the variation of Cp values at the apex of the cylinder. Figure 4 represents such a relationship for varying values of blockage ratio. The point at which the ceiling wall length is seen to have no further affect upon the Cp value represents an appropriate slotted ceiling wall length for a particular blockage ratio. An L/H value of 4 is seen to be suitable at 30% blockage. This is equivalent to an 8m slatted ceiling wall length in the Sydney University BLWT.

FURTHER WORK

Installation of a slatted ceiling to the tunnel has commenced. Once modifications are complete the tunnel will be calibrated. 2-D bluff bodies including steps, fences and half cylinders with blockage ratios 10% and 30% will be tested with a slotted and solid ceiling. Cuboid bodies will also be used. Provision will be made for the adjustment of the OAR so that experiments can be carried out to determine whether any change in OAR will give better results.

A 1:1000 scale model of the Mt Dandenong escarpment will eventually be tested in the tunnel producing 25% blockage. This work will coincide with full-scale measurements being taken on the mountain by the CSIRO Division of Building, Construction and Engineering, Melbourne.

CONCLUSION

Modification to the existing Sydney University BLWT to include a slatted ceiling is in progress. Similar tolerant tunnels which are able to accommodate models with large blockage ratios have yielded reliable results in other places. A numerical procedure adopted to calculate the length of the test section to be slotted is outlined.

REFERENCES

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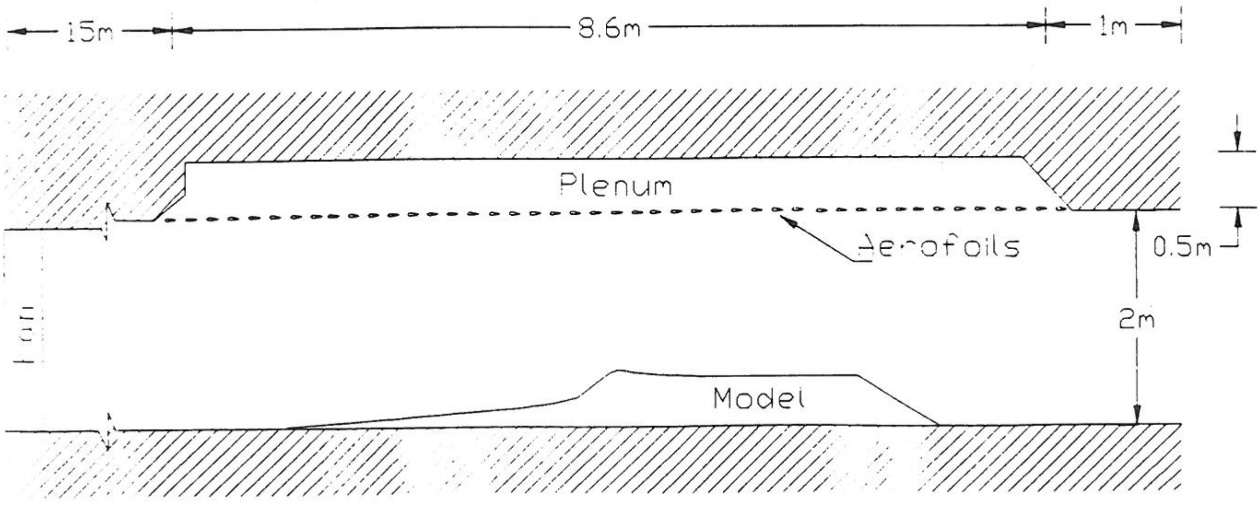

Figure 1: Elevation of the Sydney University tolerant tunnel.

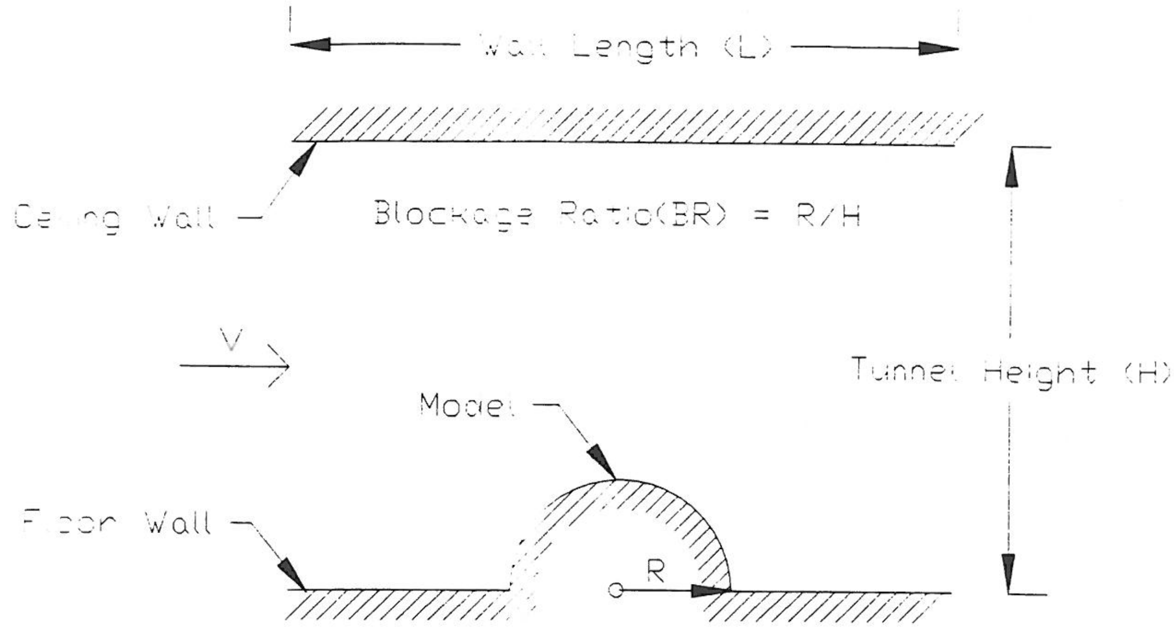

Figure 2: Numerical model tunnel configuration

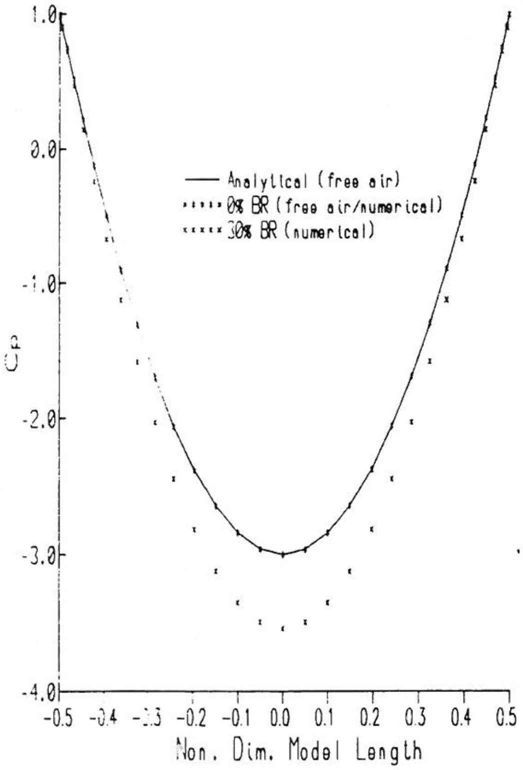

Figure 3: Pressure distribution over a half cylinder.

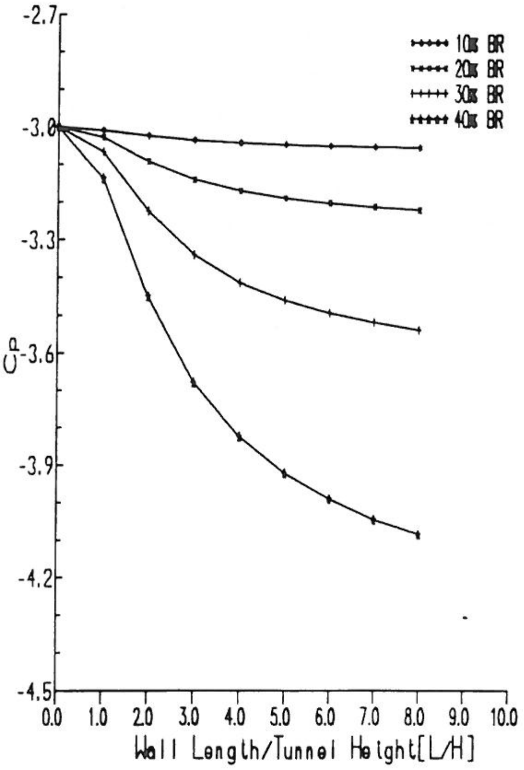

Figure 4: Variation of the numerical apex Cp value with tunnel ceiling wall length