Evaluation of the Collector for Bluff Body Testing in an Open Test Section Wind Tunnel

Kevin P. Garry[1], Jennifer Holt[2] and Michel Chauvet[3]
Applied Aerodynamics Group, Cranfield University
Bedford, MK43 OAL UK

1. Head, Applied Aerodynamics Group, corresponding author, k.p.garry@cranfield.ac.uk 2. Research Officer 3. MSc Student

Abstract.

An existing wind tunnel is to be modified to incorporate a new open test section within the existing circuit that will be used primarily for bluff body flow investigations. A new collector will be designed to minimise the distortion of the axial pressure gradient and facilitate tests at area blockage ratios of 15% with acceptable corrections. The design will also ensure that low frequency 'pulsation' of the working section flow is avoided.

A combined experimental and CFD investigation is reported in which a reduced scale model of the proposed contraction nozzle and collector is used to optimise the working section flowfield. CFD simulations are used both to design the experimental test matrix and to extrapolate the reduced Reynolds number data to full scale.

The optimum orientation of a simple collector profile is established together with size of a breather gap that will be used to control the flow at high blockage ratios. Low frequency pulsations are assessed on the basis of acoustic signatures and found to be acceptable. Correlation between the CFD predictions and measurements in the model scale nozzle are good, particularly in the vicinity of the collector and diffuser inlet. An optimised collector configuration for the full scale facility is proposed which incorporates an adjustable breather slot and fixed collector orientation.

Introduction & Background

The 2.4m x 1.2 Atmospheric Boundary Layer Wind Tunnel (ABLWT) operated by the Applied Aerodynamics Group is currently being refurbished. The new flow development section will incorporate a removable element to create an open working section downstream of the contraction that is specifically intended for 'bluff body aerodynamics' investigations. A preliminary series of experiments has been carried out to investigate and optimise the flow characteristics of the proposed new working section using a subscale model of the wind tunnel. These measurements have been supplemented by CFD simulations of the flow field. The aim is to ensure a collector design that will accommodate bluff body models at relatively high working section blockage ratios without suffering from low frequency pulsation.

An element of the initial working section design was carried out on the basis of previously published data. However, practical constraints limited the configuration of the collector itself and this necessitated the investigation outlined in this paper.

The existing 8x4 ABLWT is blower configuration in which an axial fan, driven by a DC electric motor, is mounted upstream of a settling chamber and 4:1 contraction nozzle. The flow development section is 12 metres long upstream of a closed working section with overhead three component probe traverse system and 360 deg rotating turntable. The proposal is to create an optional open working section immediately downstream of the contraction.

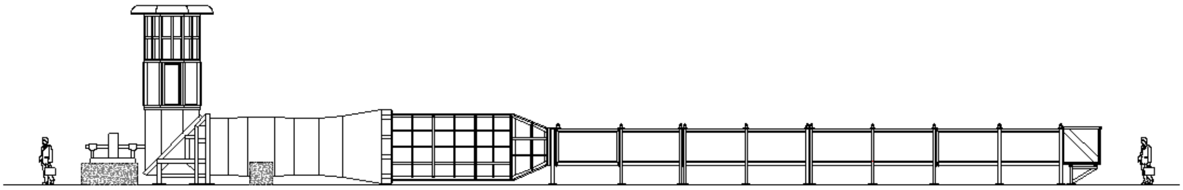

Figure 1. Layout of 8x4 ABLWT

An initial assessment of the proposed open working section flow was carried out by Guerin[1] using a modified blower wind tunnel fitted with a 15% sub scale model of the 8x4 ABLWT contraction, see Figure 2. These measurements were made at a nozzle centre line flow velocity of 30 metres/sec which corresponds to nominally 30% of the operating Reynolds number in the full scale facility. This experimental data was used to validate a CFD model of the nozzle flow using FLUENT® 6.3

Figure 2. View of 15% sub scale model of contraction with total pressure rake.

Following a grid dependency study the computational model was used to design the experimental test matrix. This focussed on the optimisation of (i) collector flap length, (ii) collector flap angle and (iii) breather slot size (between flap and downstream diffuser lip). The geometry of the collector flap itself was chosen to be a simple flat plate with hemispherical leading and trailing edges, see the geometric layout in Figure 3.

Data assessment was based on the predicted axial pressure gradient in the open working section and the effectiveness of the collector in preserving the nozzle mass flow rate at the diffuser inlet.

The collector breather slot is seen to be important in terms of ensuring both acceptable variations in axial pressure (for the empty test section) and low levels of pulsing flow at typical test section blockage levels (simulated using rectangular flat plates mounted normal to the free stream on the test section centre line).

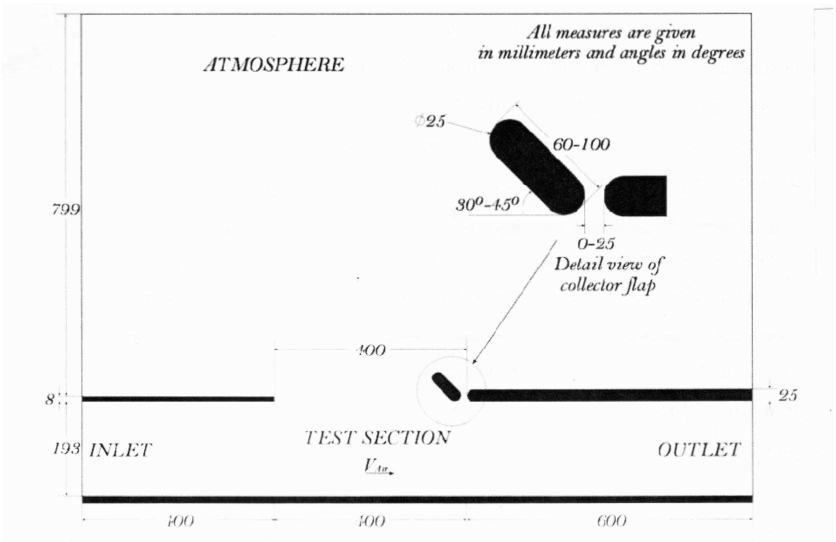

Figure 3. Arrangement of test section geometry used in the 2D CFD simulation

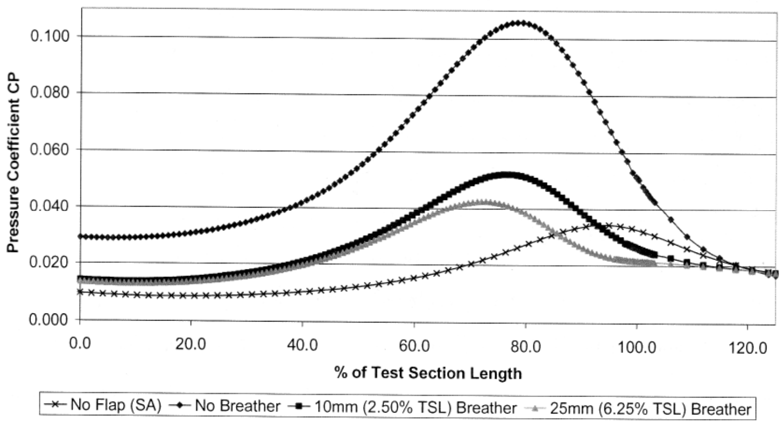

Figure 4. Effect of collector breather gap size on the predicted working section axial pressure distribution.

Conclusions

The preliminary 2D CFD simulation proved effective in capturing the sensitivity of the axial pressure gradient to collector flap angle and flap length. As a result it was possible to reduce the subsequent experimental test matrix.

An optimum collector flap angle of 45 degrees was identified with a breather gap corresponding to 2.5% of the test section length (TSL). An adjustable breather gap is seen to be effective in reducing the severity of axial pressure gradients induced at higher working section blockage ratios (<15% based on projected frontal area)

Measurements of sound pressure level (SPL) at the proposed model location suggest relatively weak peak values at model scale frequencies of 67Hz and 147Hz.

Peak values in the axial pressure gradient were very slightly under estimated by the CFD simulation with the position of the peaks predicted to within 5% of that measured experimentally. The magnitude of the pressure variation upstream of the proposed model location was not predicted accurately by the CFD simulation. This is believed to be due to the relatively simplistic realisation of the wind tunnel settling chamber and contraction nozzle in the computational model.

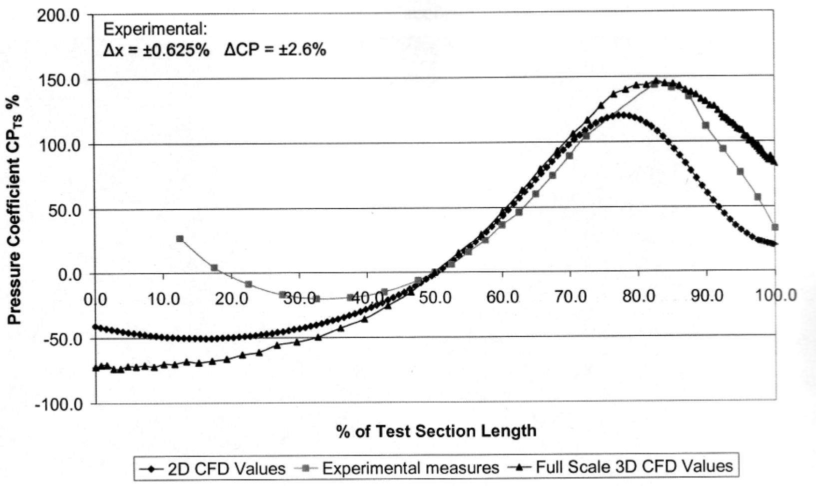

Figure 5. Comparison of measured and CFD predictions of the working section axial pressure distribution.

References.

[1] Guerin, E. *Preliminary aerodynamic design of an aeroacoustic working section for the Cranfield University 8x4 atmospheric boundary layer wind tunnel*. Cranfield University MSc Thesis. (2006)

[2] Chauvet, M. *Design and evaluation of the collector for an aeracoustic test section in the Cranfield University 8'x4' atmospheric boundary wind tunnel (ABLWT).* Cranfield University MSc Thesis (2007).

[3] Rennie, M. Kim, M-S. Lee, J-H. Kee, J-D. *Suppression of open-jet pressure fluctuations in the Hyundai aeroacoustic wind tunnel*. SAE Paper 2004-01-0803 (2004).

[4] Wickern, G. von Heesen, W. Wallmann, S. *Wind tunnel pulsations and their active suppression.* SAE Paper 2000-01-0869 (2000).

[5] Owen, P.R. *The interference of a collector duct on the flow in a wind tunnel.* RAE TN1637 (1945).

[6] Holutsen, H. Kooi, J.W. *Model and full scale investigations of the low frequency vibration phenomena of the DNW open jet wind tunnel*. AGARD CP-585 (1996).

[7] Manuel, G.S. Malloy, J.K. Barna, S.P. *Effect of collector configuration on test section turnulence levels in an open jet wind tunnel*. NASA TM4333 (1992).