WIND TUNNEL MODELLING – WHY MOVE A WIND TUNNEL?

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1. INTRODUCTION

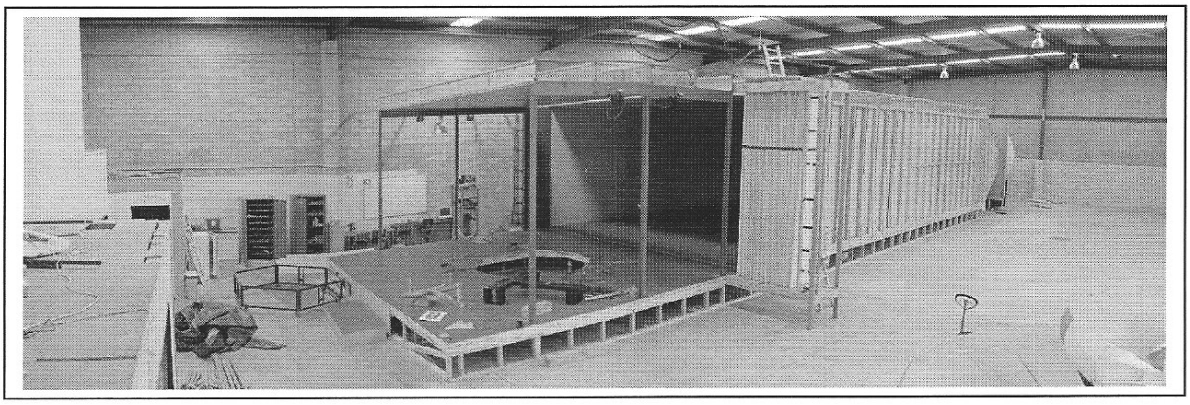

Figure 1. The Twisted Flow Wind Tunnel (TFWT) while being prepared for moving

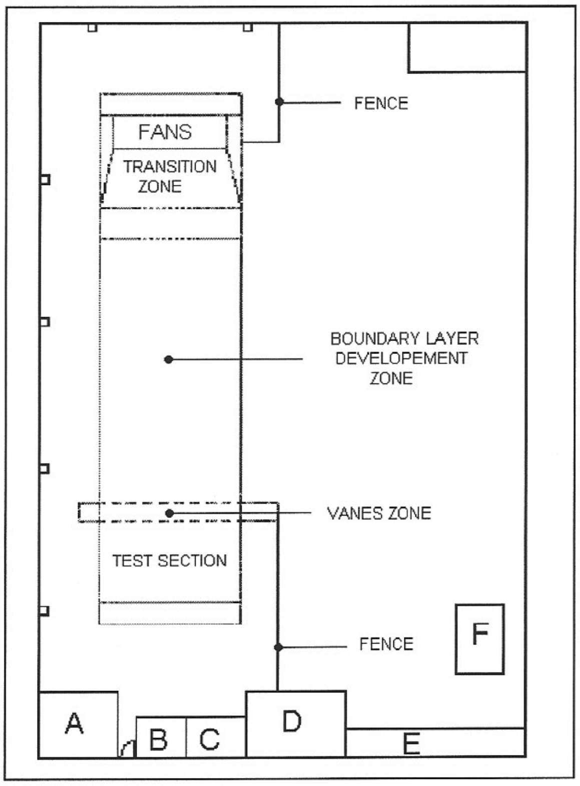

Figure 2. Plan of the tunnel and building

The University of Auckland Twisted Flow Wind Tunnel (TFWT) was designed and constructed in 1994[1] and was extensively used by Team New Zealand in winning the America's Cup in 1995. Since that campaign the wind tunnel facilities have gained a strong reputation and are used by many high profile yacht design syndicates, including six of the eight syndicates in the last Volvo round-the-world yacht race. In one recent article the wind tunnel facilities were referred to as "The Ubiquitous Twisted Flow Wind Tunnel".

In 2000 it became necessary to move the tunnel to a different building. During this move the tunnel was widened slightly and several new features added. Since the new building was to be shared with another research group, the tunnel occupied one half of the building, as illustrated in Figure 2. While the remodelled tunnel had better turning vanes and was easier to change from the full 7m x 3.5m section to the contracted 3.5m x 3.5m, the flow quality was not as uniform or steady as desired. This paper is not about modelling in a wind tunnel, but is rather about modelling the wind tunnel and building in the search for solutions to the flow problems.

2. FLOW QUALITY

After the recommissioning of the Twisted Flow Wind Tunnel, it was observed that there were a number of flow quality problems. These included:

- The flow velocity tended to decrease through the working section.
- The forces measured on model yachts showed significant fluctuations with periods of about 10s. This meant that a long averaging period was required in order to obtain repeatable results.
- There were some changes in flow direction in the working section.
- There was a suspicion that the pressure gradient in the working section may be affecting the forces being measured.

In order to evaluate some of these effects, hot-wire anemometer measurements were made at a variety of positions. Figure 3 shows the mean velocities and turbulence intensities measured at a height of 1.5m. These data show that the mean velocity decreases by about 10% between the end of the closed section (where the turning vanes are located, but with these vanes folded away to the side) and a position just downstream of the turntable. Over the same distance the turbulence intensity more than doubles.

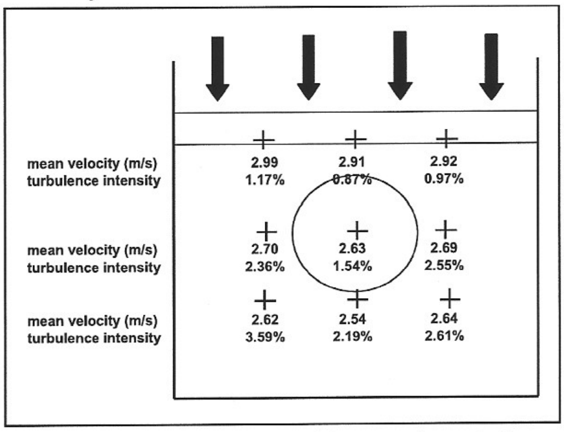

Figure 3. Mean velocities and turbulence intensities in the real TFWT, located in its old position, at a height of 1.5m.

While the decrease in mean velocity is a nuisance, it is the increase in turbulence that was of greater concern. Figure 4 further illustrates this by showing the changes in the character of the time histories and the associated spectra for points along the tunnel centreline. Figure 4a illustrates both the change in mean velocity and the increase in turbulent fluctuations. The spectral analysis in Figure 4b shows that while there is some increase across a broad frequency range, it is particularly fluctuations at frequencies around 0.1 Hz, periods of the order of 10s, which are developing in the working section.

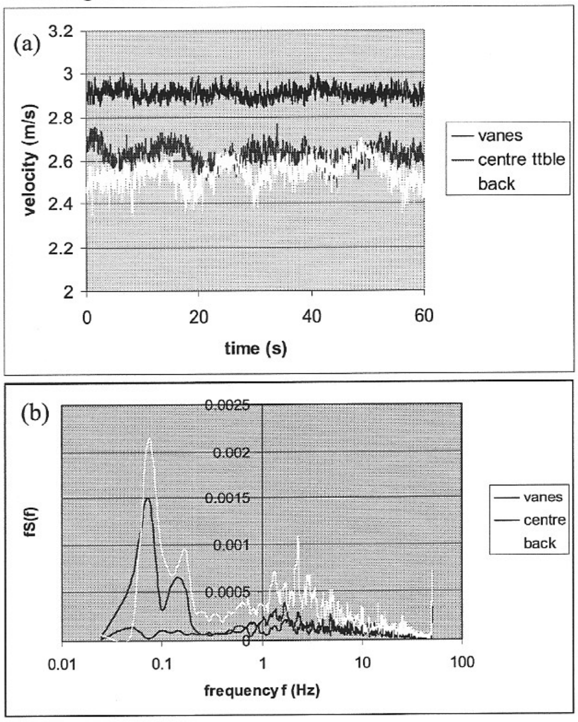

Figure 4. (a) Time histories and (b) spectra for positions along the tunnel centreline at a height of 1.5m in the real TFWT, in its old position.

3. CFD MODEL

Although it was unable to model the unsteady flow, a RANS finite volume model was used to investigate the effects that various modifications might have on the flow uniformity. The software package used in this study was PHOENICS. Figure 5 shows a general view of the simple block model of the tunnel and building. This model was used to investigate various options such as shortening the tunnel, moving the tunnel to various positions within the building, etc. It may be noted that when the TFWT was originally installed in this building it had been restricted to using only one side, however the other half of the building had never been occupied and so moving the tunnel to a more central location was now a possibility. However since this was likely to be an expensive exercise we wanted to be certain that any move would solve our flow problems before going ahead.

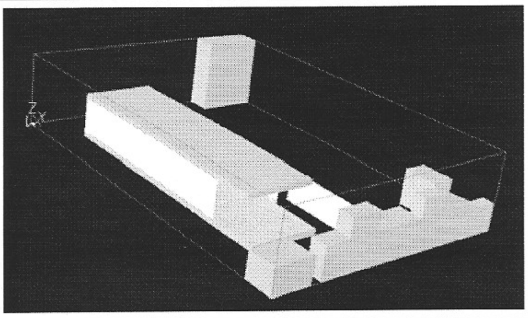

Figure 5. CFD model of the tunnel and building

Results, such as those shown in Figure 6, suggested that shortening the wind tunnel by about 2.4m and possibly moving it to a more central location would improve the flow uniformity through the working section and straighten the flow. However these results could not indicate whether such modifications would also reduce the turbulent fluctuations.

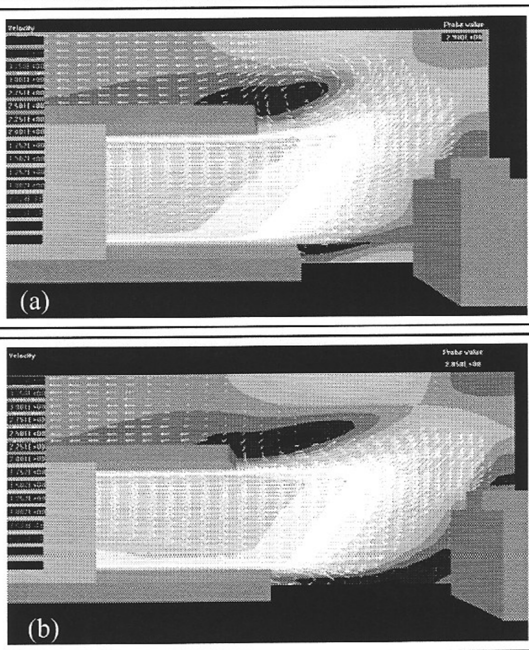

Figure 6. Velocity vectors and contours on the central plane of (a) the original tunnel model and (b) with the tunnel shortened by 2.4 m.

4. SCALE MODEL

In order to investigate the unsteady nature of the flow a scale model of the TFWT and building was constructed. It was decided that a small-scale model would be unlikely to correctly reproduce the fluctuating flow and so a relatively large scale of 7.9:1 was used. The exact scale was determined by the availability of 380mm fans that could model the real 3m diameter fans. The total model, see Figure 7, was 4.75m long, 3.14m wide and up to 950mm high.

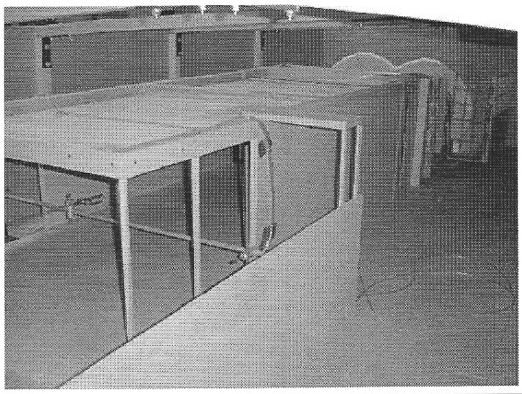

Figure 7. The 7.9:1 sale model of the TFWT

Initial experiment with the model tunnel showed that the turbulence level at the end of the closed section was too high. However after some modifications to the fans and the installation of an additional gauze screen, the results shown in Figure 8 were obtained. These show that the model is reproducing the increase in turbulence through the working section and particularly the increase at the low frequency end which at model scale is around 0.8Hz, one cycle in 1.25s.

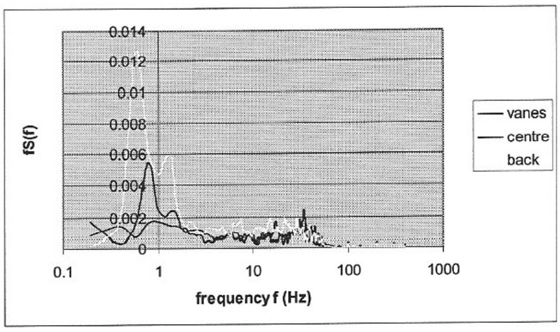

Figure 8. Turbulence spectra along the centreline of the model TFWT, in the original position, at a height of 1.5m (full-scale equivalent).

Further experiments investigated various modifications. The most promising of these was shortening the tunnel by 2.4m and moving it 5.5m across the building to a central position. The model then predicted the spectra shown in Figure 9, which shows very little change through the working section.

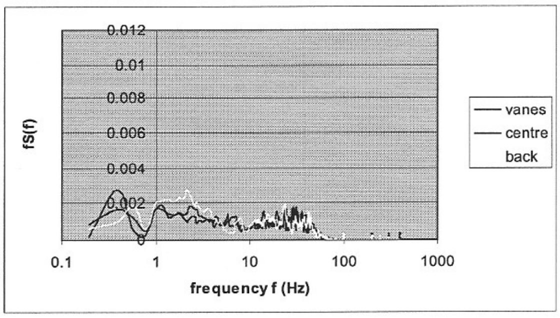

Figure 9. Turbulence spectra along the centreline of the shortened model TFWT, in the centre of the building, at a height of 1.5m (full-scale equivalent).

5. RELOCATION

Since the modelling had shown that moving and shortening the tunnel would solve all flow problems, it was decided to go ahead. This involved moving the fans with a forklift truck (Figure 10a), lifting the tunnel and supporting it on roller and then pulling it across the room with a house moving truck (Figure 10b), removing a 2.4m section (Figure 10c) and then closing the gap.

Once the alterations were completed, new velocity measurements yielded the results summarised in Table 1. These show that the mean wind velocities are generally more uniform, but more importantly the turbulence intensity hardly increases across the working section. Spectral analysis shows that there is little sign of the annoying low frequency fluctuations.

Table 1. Mean wind speed ratios and turbulence intensities in the relocated tunnel in comparison with the TFWT in its original position.

		Height 1.5 m		
		left	middle	right
		Mean velocity relative to centre		
vanes	TFWT old position	1.14	1.11	1.11
	TFWT new position	1.01	1	0.97
centre	TFWT old position	1.03	1	1.02
	TFWT new position	0.99	1	0.96
back	TFWT old position	1	0.97	1
	TFWT new position	0.99	0.99	0.95
		Turbulence Intensity (%)		
vanes	TFWT old position	1.17	0.87	0.97
	TFWT new position	1	0.89	0.97
centre	TFWT old position	2.36	1.54	2.55
	TFWT new position	1.02	0.99	0.94
back	TFWT old position	3.59	2.19	2.61
	TFWT new position	1.08	0.96	1.06

6. CONCLUSION

Both a CFD and a scale model of the Twisted Flow Wind Tunnel and surrounding building have been used to investigate what modifications might improve flow quality. Both models suggested that shortening the tunnel by 2.4m and moving it 5.5m to the centre of the building should have beneficial effects. Implementation of these modifications resulted in more uniform flow and significantly reduced turbulence.

REFERENCE

1. FLAY R.G.J. "A twisted flow wind tunnel for testing yacht sails", *Journal of Wind Engineering and Industrial Aerodynamics, 63, 171 – 182,* 1996.

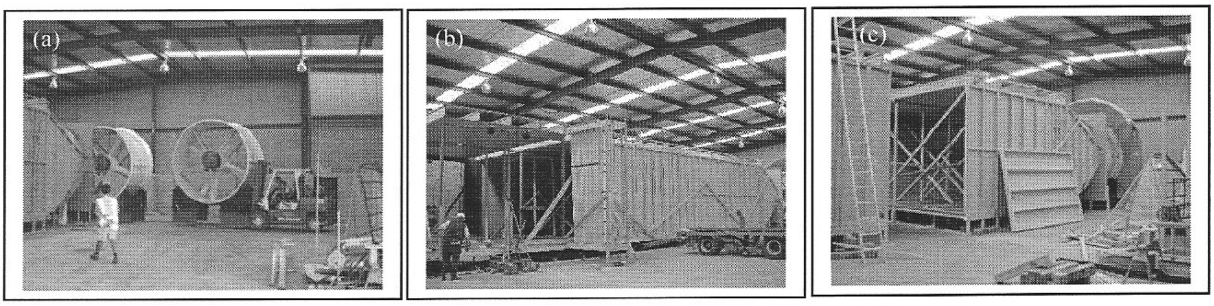

Figure 10. (a) Moving the fans, (b) moving the tunnel and (c) removing the middle section.