FLOW DOCUMENTATION

The measurements were made in the Boundary Layer Wind Tunnel of the Aerospace and Ocean Engineering Department at Virginia Tech. The tunnel has a 24 ft. long test section with a rectangular cross section that is 3 ft. wide with variable height to adjust the streamwise free-stream velocity. The nominal free-stream air speed was 27.5 m/s for the two lower Re_θ flows and 32.0 m/s for the two higher Re_θ flows. All measurements were made at ambient pressure and a temperature of 25°C ± 1°C.

The pressure-driven three-dimensional turbulent boundary layer was produced by a wing-body junction geometry. The wing used has a 3:2 elliptical nose, NACA 0020 tailed wing profile. It has a maximum thickness of 7.17 cm, chord length of 30.5 cm, and a height of 23.2 cm. The wing was mounted at zero angle of attack with the leading edge 302 cm downstream of the test section entrance in the $Re_\theta = 5940$ flow and 707 cm downstream of the test section entrance in the $Re_\theta = 23200$ flow. A 3.7 mm gap was left between the ceiling of the test section and the top of the wing model in order to prevent the formation of a second horseshoe vortex. Measurements of p were made at 10 stations that traverse one side of the wing (figure 1) and are away from the wing-body junction horseshoe vortex. These measurement stations were chosen based on the existence of previously reported mean velocity, Reynolds stress, triple products, and skin friction measurements[1-6]. Some relevant flow parameters are given in tables 1 and 2. The two-dimensional zero-pressure-gradient flows were produced by removing the wing. In the $Re_\theta = 7300$ flow, measurements were carried out 303 cm downstream of the test section entrance. In the $Re_\theta = 23400$ flow, measurements were carried out 696 cm downstream of the test section entrance. Streamwise traverses showed a closely constant free-stream velocity (±2%) when the wing was removed[4].

The pressure transducer was an Endevco model 8507-C2 which has a flat frequency response from 0 to 70 kHz. The transducer signal was amplified by a Measurements Group model 2310 strain gage conditioning amplifier and stored to 12-bit precision by an IBM type PC. The surface pressure fluctuations were sampled at 67 kHz. At each location, 512 records of 32768 contiguous samples per record were acquired. The total sampling period at each measurement location was 16 minutes in order to insure that all relevant time scales were measured[†].

References

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[†] A time interval was allowed to elapse in between the acquisition of each contiguous record of data in order to lengthen the total sample period. These time intervals were not necessarily equal to one another.

Table 1. Some boundary layer parameters. Lower Re_θ flow data (Re_θ = 7300 (2-D), 5940 (3-D)) of Ölçmen and Simpson[3]. Higher Re_θ flow data (Re_θ = 23400 (2-D), 23200 (3-D)) of Ölçmen *et al.*[4]

Station	U_e m/s	δ mm	δ^* mm	Q_e Pa	u_τ m/s	ν, m²/s (×10⁵)	τ_w, Pa	d^+
Re_θ = 7300 (2-D), 5940 (3-D)								
2D	27.1	39.1	6.20	399	0.98	1.69	1.04	29.5
0	26.4	N/A	N/A	379	1.15	1.69	1.44	34.6
1	24.9	39.2	6.90	340	0.86	1.68	0.818	26.2
2	24.8	40.2	7.54	337	0.87	1.68	0.821	26.2
3	25.3	39.3	6.86	351	0.96	1.68	1.00	29.0
4	27.3	39.0	5.53	409	1.11	1.67	1.35	33.7
5	29.5	39.6	5.37	477	1.15	1.67	1.45	34.9
6	30.5	39.2	5.24	511	1.16	1.67	1.48	35.3
7	31.0	38.8	5.20	528	1.20	1.67	1.58	36.5
8	30.9	38.4	5.08	524	1.02	1.67	1.15	31.1
9	30.5	40.7	5.68	511	1.01	1.67	1.12	30.7
Re_θ = 23400 (2-D), 23200 (3-D)								
2D	31.3	134.2	15.8	543	1.03	1.66	1.17	31.5
0	31.0	N/A	N/A	532	N/A	1.66	N/A	30.6
1	29.3	136.4	22.8	470	0.91	1.68	0.906	27.5
2	28.7	135.1	18.4	451	0.92	1.68	0.918	27.7
3	29.0	136.8	16.8	462	1.09	1.68	1.31	33.2
4	31.1	131.9	17.3	530	1.24	1.68	1.68	37.5
5	33.0	123.3	13.7	598	1.21	1.67	1.60	36.7
6	34.7	128.6	17.2	660	1.21	1.67	1.60	36.7
7	35.5	129.0	12.9	694	1.30	1.67	1.88	39.8
8	35.2	133.5	13.0	682	1.13	1.67	1.40	34.4
9	34.3	134.6	13.5	650	1.10	1.66	1.35	33.8

Table 2. Additional parameters used to non-dimensionalize the pressure spectra. Lower Re_θ flow data (Re_θ = 7300 (2-D), 5940 (3-D)) of Ölçmen and Simpson[3]. Higher Re_θ flow data (Re_θ = 23400 (2-D), 23200 (3-D)) of Ölçmen *et al*.[4]

Station	Δ	Conditions at τ_{MAX}			Conditions at W_{MAX}			
	cm	y mm	$(U^2+W^2)^{1/2}$ m/s	τ_{MAX} Pa	y mm	$(U^2+W^2)^{1/2}$ m/s	W_{MAX} m/s	$\frac{1}{2}\rho W_{MAX}$ Pa
Re_θ = 7300 (2-D), 5940 (3-D)								
2D	17.1	0.726	13.9	0.832	—	—	—	—
0	16.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1	19.9	0.855	11.4	0.955	0.855	11.4	-1.73	1.64
2	21.6	1.79	12.6	0.947	0.865	11.2	-3.58	7.04
3	18.1	5.91	16.6	1.14	0.650	12.3	-6.41	22.6
4	13.6	0.473	14.6	0.745	1.05	16.5	-8.14	36.3
5	13.8	0.511	17.8	0.884	1.13	19.6	-8.19	36.8
6	13.8	0.472	17.3	1.24	1.73	21.4	-6.53	23.5
7	13.4	0.434	16.7	1.73	2.30	22.5	-4.35	10.4
8	15.3	0.567	16.7	1.72	0.164	9.46	0.327	0.059
9	17.1	0.534	15.1	1.46	0.333	13.1	1.03	0.581
Re_θ = 23400 (2-D), 23200 (3-D)								
2D	48.0	0.562	14.4	1.12	—	—	—	—
0	71.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1	73.4	6.47	18.1	1.21	0.589	11.9	-1.79	1.75
2	57.6	6.49	17.8	1.25	0.610	11.7	-3.40	6.31
3	44.7	6.44	18.8	1.22	0.568	13.5	-6.21	21.2
4	43.4	0.923	17.7	0.930	1.00	18.3	-7.80	33.3
5	37.5	0.455	17.3	1.09	1.50	21.2	-7.72	32.7
6	49.3	0.349	17.4	1.40	1.50	23.0	-6.61	24.0
7	35.0	0.601	20.1	1.91	2.47	24.3	-4.64	11.9
8	40.5	0.568	18.6	2.13	0.215	13.1	0.469	0.121
9	42.0	0.341	16.3	1.90	0.191	11.7	1.33	0.984

Table 3. Variation of $\overline{p^2}$ and p' for the lower Re_θ flows, Re_θ = 7300 (2-D), 5940 (3-D) and the low and the high frequency contributions to the $\overline{p^2}$ integral. The values of $\overline{p^2}$ presented here were calculated by integrating the p spectra.

		Contribution to $\overline{p^2}$ integral, Pa²					
Station	$\overline{p^2}$, Pa²	< 1 kHz		> 1 kHz		p'/τ_W	p'/Q_e
		Re_θ = 7300 (2-D), 5940 (3-D)					
2D	12.9	5.4	42%	7.5	58%	3.44	0.0090
0	13.7	7.3	53%	6.4	47%	2.57	0.0098
1	14.8	8.3	56%	6.5	44%	4.71	0.0114
2	17.5	10.8	62%	6.7	38%	5.10	0.0124
3	21.4	14.7	69%	6.7	31%	4.61	0.0132
4	27.7	13.1	47%	14.6	53%	3.90	0.0129
5	17.6	10.1	57%	7.5	43%	2.89	0.0088
6	20.7	8.2	40%	12.5	60%	3.08	0.0089
7	28.7	8.1	28%	20.6	72%	3.39	0.0102
8	30.6	7.9	26%	22.7	74%	4.80	0.0106
9	33.0	9.5	29%	23.5	71%	5.12	0.0113
		Re_θ = 23400 (2-D), 23200 (3-D)					
2D	25.8	11.4	44%	14.4	56%	4.32	0.0094
0	26.8	15.4	57%	11.4	43%	4.67	0.0097
1	27.8	17.3	62%	10.5	38%	5.81	0.0112
2	33.8	23.6	70%	10.2	30%	6.34	0.0129
3	40.1	30.2	75%	9.9	25%	4.82	0.0137
4	34.2	24.6	72%	9.6	28%	3.48	0.0110
5	29.5	18.7	63%	10.8	37%	3.39	0.0091
6	30.2	15.2	50%	15.0	50%	3.43	0.0083
7	36.1	13.6	38%	22.5	62%	3.20	0.0087
8	38.8	12.6	32%	26.2	68%	4.44	0.0091
9	41.3	13.2	32%	28.1	68%	4.77	0.0099

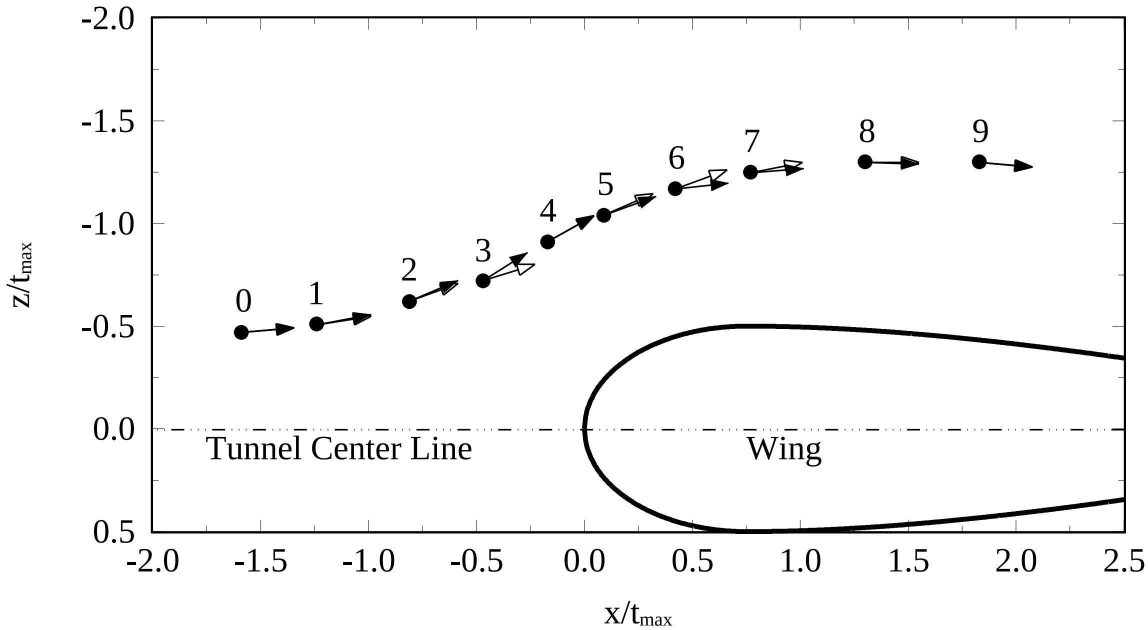

Figure 1. Wing shape and measurement stations. Full arrows are the wall-shear-stress direction in the $Re_\theta = 5940$ flow. Empty arrows are the free-stream direction in the $Re_\theta = 5940$ flow. The *y* coordinate is normal to the paper forming a right-handed coordinate system.

Station	*x*, cm	*z*, cm
2D	—	—
0	-11.40	-3.35
1	-8.89	-3.68
2	-5.82	-4.45
3	-3.38	-5.18
4	-1.19	-6.55
5	0.66	-7.47
6	3.02	-8.38
7	5.51	-8.97
8	9.30	-9.35
9	13.11	-9.30