FLOW DOCUMENTATION

The measurements were made in the Virginia Polytechnic Institute and State University Stability Wind Tunnel. This tunnel is a continuous, closed return, subsonic wind tunnel with a 7 m long and 1.8 m square test section. The regulated fan d.c. power source, a 9:1 area contraction , and seven wire-mesh screens provide low free-stream turbulence levels - of the order of 0.03%.

The 6:1 prolate spheroid used for these measurements is 1.37 m long and is constructed of a machined fiberglass skin bonded to an aluminum frame. A circumferential trip, consisting of posts 1.2 mm in diameter, 0.7 mm high and spaced 2.5 mm apart, was placed around the model at $x/L = 0.2$. This fixed the location of transition. Windows of size 30 × 150 × 0.75 mm were placed in the skin for optical (Laser Doppler Velocimeter: LDV) access to the flow[1, 5, 6]. The windows were molded to the curvature of the model and mounted flush with the model surface in order to minimize flow disturbances. Wax was used to fill any small gaps in the model surface. The model was supported with a rear-mounted, 0.75 m long sting aligned along the model axis and connected to a vertical post extended through the wind tunnel floor. All measurements were conducted at a constant Reynolds number, $Re_L = 4.20\times10^6$, and ambient temperature.

Near-wall velocity measurements were carried out using a three-component, fiber-optic, LDV probe specifically designed for these experiments. This probe is able to measure the complete velocity vector and full Reynolds stress tensor. Three orthogonal velocity components are measured coincidentally in space and time in a probe volume that is nearly spherical with a diameter of approximately 55 µm. A full description of the LDV system is given in references 1, 5, and 6.

Outer-layer velocity measurements were carried out using a miniature, 4-sensor, hot-wire probe that consists of two orthogonal X-wire arrays. The probe has 5 µm tungsten sensors that are 0.8 mm in length and a measurement volume of 0.5 mm^3. A detailed description of the hot-wire measurement system and related calibration and reduction procedures is given by Devenport *et al*.[8] and Wittmer *et al*.[9]

The velocity components are presented in these files as U, V, W in the Body-Surface coordinate system. This is different than the Body-Axis coordinate system which uses x, r, ϕ to define position. The difference is shown in Figure 1. In the Body-Axis coordinate system, x is the distance from the nose of the model as measured along the model axis. The radial distance, r, from the surface of the model is measured perpendicular to the model axis. The azimuthal position, ϕ, is measured from the windward side of the model. In the Body-Surface coordinate system, U is tangent to the model surface and points toward the tail of the model; V is normal to the model surface, positive outward; and W is tangent to the model surface and forms a right-handed coordinate system. the transformation from the Body-Axis coordinate system to the Body-Surface coordinate system is a rotation about the ϕ-axis. The rotations required are 1.948° and 6.167° at $x/L = 0.600$ and $x/L = 0.772$, respectively.

Uncertainty Estimates

The uncertainty in mean velocity hot-wire measurements is within $0.015 \cdot U_{\infty}$. The circumferential position was measured with a sting-mounted, vernier-type scale and is certain to within 0.1°. A detailed discussion of the uncertainty of the LDV measurements is given by Chesnakas and Simpson[5]. Uncertainties associated with the four-sensor, hot-wire measurement system are given by Devenport *et al*.[8] and Wittmer *et al*.[9] Small alignment corrections were applied to the hot-wire data.

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Table 1. Some boundary layer parameters of the flow at $\alpha = 10°$, $x/L = 0.600$.

ϕ deg	ρ kg/m^3	$\nu\,(\times 10^5)$ m²/s	u_τ † m/s	U_e ‡ m/s	U_∞ m/s	δ^* ‡ mm	Re_θ ‡
90	1.05	1.79	2.45	54.8	54.7	1.16	2483
95	1.05	1.80	2.42	55.3	55.2	1.25	2673
100	1.05	1.80	2.36	55.3	55.2	1.35	2863
105	1.05	1.80	2.31	55.3	55.2	1.45	3073
110	1.06	1.78	2.23	54.8	54.6	1.56	3283
115	1.06	1.78	2.17	54.7	54.4	1.79	3739
120	1.06	1.76	2.10	54.2	53.9	2.01	4195
125	1.10	1.67	1.91	51.3	51.1	2.34	4797
130	1.10	1.66	1.82	51.1	50.9	2.66	5399
135	1.10	1.66	1.76	50.9	50.7	3.03	6084
140	1.10	1.66	1.70	50.9	50.7	3.40	6770
145	1.10	1.66	1.70	50.9	50.7	3.58	7182
150	1.10	1.65	1.70	50.8	50.6	3.76	7594
155	1.10	1.66	1.74	51.0	50.8	3.65	7501
160	1.10	1.66	1.77	51.0	50.8	3.55	7407
165	1.10	1.66	1.82	51.2	50.8	3.30	7031
170	1.10	1.66	1.88	51.6	51.0	3.05	6654
175	1.10	1.66	1.90	51.6	51.0	2.86	6254
180	1.10	1.66	1.92	51.5	51.0	2.67	5855

† Calculated using the C_f measurements of Chesnakas and Simpson[6]

‡ Calculated using the δ^*, θ, and U_e/U_∞ measurements of Goody *et al.*[7]

Table 2. Some boundary layer parameters of the flow at $\alpha = 10°$, $x/L = 0.772$.

ϕ deg	ρ kg/m^3	$\nu\,(\times 10^5)$ m²/s	u_τ † m/s	U_e ‡ m/s	U_∞ m/s	δ^* ‡ mm	Re_θ ‡
90	1.06	1.79	2.25	58.0	54.7	1.47	3145
95	1.05	1.80	2.23	58.0	55.0	1.59	3368
100	1.05	1.79	2.19	57.3	54.8	1.70	3592
105	1.06	1.79	2.07	56.8	54.7	1.99	4122
110	1.06	1.77	1.94	55.9	54.1	2.28	4651
115	1.07	1.76	1.82	55.3	53.8	2.79	5555
120	1.07	1.75	1.70	54.9	53.6	3.31	6458
125	1.07	1.74	1.65	54.6	53.4	4.06	7716
130	1.07	1.74	1.50	56.2	53.2	5.62	10417
135	1.07	1.73	1.47	55.6	53.1	6.39	11636
140	1.07	1.74	1.50	55.2	53.2	7.33	13394
145	1.07	1.74	1.61	54.4	53.2	7.24	14016
150	1.07	1.73	1.71	53.5	53.1	7.16	14637
155	1.08	1.73	1.84	52.5	52.9	5.81	12549
160	1.08	1.72	1.95	51.3	52.6	4.47	10640
165	1.09	1.70	2.01	51.2	52.0	3.57	8430
170	1.09	1.69	2.08	51.4	51.7	2.67	6400
175	1.09	1.68	2.06	51.3	51.5	2.25	5307
180	1.10	1.67	2.02	50.9	51.0	1.83	4213

† Calculated using the C_f measurements of Chesnakas and Simpson[6]

‡ Calculated using the δ^*, θ, and U_e/U_∞ measurements of Goody *et al.*[7]

Table 3. Some boundary layer parameters of the flow at $\alpha = 20°$, $x/L = 0.600$.

ϕ deg	ρ kg/m^3	$\nu\,(\times 10^5)$ m²/s	u_τ † m/s	U_e ‡ m/s	U_∞ m/s	δ^* ‡ mm	Re_θ ‡
90	1.10	1.66	2.55	51.0	50.9	0.67	1406
95	1.10	1.66	2.47	51.0	50.9	0.76	1586
100	1.10	1.66	2.38	50.9	50.9	0.85	1767
105	1.10	1.66	2.24	50.9	50.9	1.01	2056
110	1.10	1.66	2.10	50.9	50.9	1.18	2346
115	1.10	1.66	1.88	50.8	50.9	1.80	3358
120	1.10	1.66	1.62	50.8	50.9	2.42	4370
125	1.10	1.66	1.41	50.6	50.9	3.5	5790
130	1.10	1.66	1.29	50.4	50.9	4.98	10827
135	1.10	1.66	1.70	50.2	50.9	5.94	10546
140	1.10	1.66	1.91	50.0	50.9	6.24	12940
145	1.10	1.66	1.88	56.1	50.9	5.47	12242
150	1.10	1.66	2.44	54.8	50.9	4.57	10889
155	1.10	1.66	2.88	51.8	50.9	4.34	10405
160	1.10	1.66	3.04	49.5	50.9	4.00	9493
165	1.10	1.66	2.93	49.9	50.9	2.14	5045
170	1.10	1.66	2.80	50.4	50.9	0.28	597
175	1.10	1.66	2.71	50.7	50.9	0.37	781
180	1.10	1.66	2.61	51.0	50.9	0.45	965

† Calculated using the C_f measurements of Chesnakas and Simpson[6]

‡ Calculated using the δ^*, θ, and U_e/U_∞ measurements of Goody *et al.*[7]

Table 4. Some boundary layer parameters of the flow at $\alpha = 20°$, $x/L = 0.772$.

ϕ deg	ρ kg/m^3	$\nu\,(\times 10^5)$ m²/s	u_τ † m/s	U_e ‡ m/s	U_∞ m/s	δ^* ‡ mm	Re_θ ‡
90	1.07	1.74	2.36	59.4	53.3	0.82	1647
95	1.06	1.77	2.21	64.7	54.3	1.05	2055
100	1.06	1.77	2.00	68.8	54.3	1.28	2462
105	1.06	1.77	1.82	57.6	54.2	1.75	3249
110	1.05	1.79	1.56	57.5	54.9	2.60	4458
115	1.05	1.79	1.35	56.8	54.9	3.80	5910
120	1.06	1.78	1.53	55.7	54.5	5.19	8136
125	1.05	1.80	1.96	57.1	55.3	6.23	11434
130	1.05	1.80	2.29	57.7	55.1	7.28	14732
135	1.05	1.79	2.45	53.7	54.9	6.08	13550
140	1.05	1.80	2.62	50.2	55.3	4.88	12368
145	1.05	1.80	1.83	56.4	55.3	6.40	14625
150	1.05	1.80	2.21	57.3	55.1	5.29	13406
155	1.05	1.80	3.08	56.2	55.3	3.52	8935
160	1.05	1.79	3.29	55.5	54.9	2.60	6348
165	1.06	1.78	3.20	56.8	54.5	1.44	3474
170	1.05	1.80	3.15	58.9	55.0	0.28	600
175	1.05	1.79	2.99	58.0	54.8	0.34	727
180	1.05	1.79	2.83	57.2	54.8	0.39	854

† Calculated using the C_f measurements of Chesnakas and Simpson[6]

‡ Calculated using the δ^*, θ, and U_e/U_∞ measurements of Goody *et al.*[7]

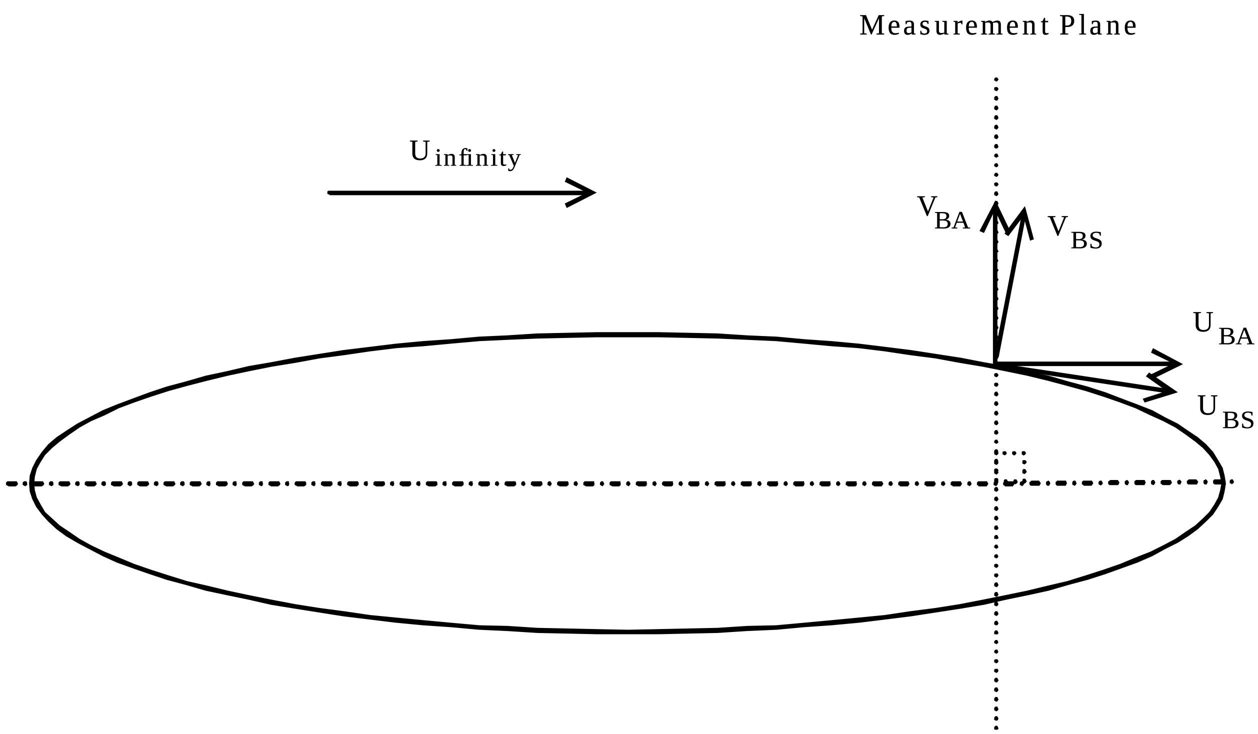

Figure 1. . Relationship between Body Axis (BA) coordinate system and Body Surface (BS) coordinate system.