TITLE: Low Speed Straked Delta Wing

18E. LOW SPEED STRAKED DELTA WING

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INTRODUCTION

Straked wings have become common features of advanced fighter-type aircraft. The strakes are designed to generate vortices from their highly swept leading edges, which stabilise the flow over the wing and provide additional lift up to high angles of attack. In this way the strakes contribute much to a high manoeuvrability. The vortex lift capability of straked wings has been extensively explored and experimental data concerning aerodynamic loading are available for various planforms and Mach numbers. The knowledge of unsteady loading on straked wings is less developed, both in the cases where the loading is due to wing oscillations - as required for aircraft stability and flutter analysis - and in cases where fluctuations in the flow are induced by vortex burst (or vortex breakdown) - as required for stall and buffet predictions.

Some physical aspects of the unsteady vortex flow are described briefly below.

Vortices are shed from the leading edges of the strake and the wing. The sharp leading edges generate vortex sheets, even at low incidence, which roll up spirally into the strake vortices and flow downstream over the wing. The vortices induce strong lateral velocities at the strake and wing upper surface, giving rise to suction peaks at the position of the vortex cores. When the lateral velocities are large enough, secondary flow separations occur, leading to secondary vortices spiralling opposite to the primary vortices. At moderate incidences vortex sheets start to develop from the wing leading edges, starting at the kinks. At higher incidences vortex burst or vortex breakdown occurs, initially for the wing vortices, followed by the strake vortices. An important consequence of vortex burst is that the corresponding suction peaks become weaker and that the vortices lose their ability to produce additional lift. A normal behaviour of vortex burst is that it will move upstream when the incidence increases. At still higher incidences large-scale boundary layer or stall separation occurs, starting often at the trailing edge.

The explanation of the above vortex flow becomes increasingly complicated in case of interactions of strake and wing vortices, their influence on vortex burst and flow separation and, at high enough speeds their interactions with shock waves.

When the straked delta wing is oscillating, the strength and the position of the wing and strake vortices will oscillate. As the vortices are being fed through the vortex sheets emanating from the leading edges, it is to be expected that the oscillations of vortex strength and position will lag the wing oscillation.

Some phenomena can be distinguished in the results of the steady measurements, shown in figure 1, at some characteristic incidence ranges:

- up to 9° attached ("linear") flow
- 9° to 19° fully developed vortex flow
- 19° to 38° vortex burst extending from trailing edge
- beyond 38° vortex burst penetrating the strake, almost fully stalled flow

For the data selection special interest was placed on incidences which mark transition of flow characteristics, or were typical for the flow characteristics in some incidence range. These incidences were 9°, 19°, 22°, 36° and 42°.

- alpha = 9° attached flow
- alpha = 19° onset to vortex burst
- alpha = 22° burst vortex flow
- alpha = 36° maximum CN, change of 180° in phase angle of unsteady pitching
- alpha = 42° fully separated flow

The above values are the correct geometric incidences as are included in the database files; in the data point overview adjusted values are indicated. For the above characteristic values of incidence a large number of test conditions was explored. Though there is a full-span model, and conditions for plus and minus 5 degrees side-slip are expected to give the same results, both cases are included, because pressure transducers were situated only in the right half-wing. Both conditions are necessary to understand side-slip effects. This all leads to a selection of test cases as indicated in table 1.

LIST OF SYMBOLS AND DEFINITIONS

Definitions

Figure 2a is included as an example of the CATIA based geometry file, included in the database, with the CATIA body-fixed axis system. The CATIA file provides half of the model geometry. The wind tunnel model was a full model, but because of its symmetry only half of the model had to be designed in CATIA.

x-axis: chord-wise co-ordinate in wing reference plane; at apex x = 0

y-axis: span-wise co-ordinate in wing reference plane; y'-axis = rotation axis or pitching axis at x/cr = 73.27 %

z-axis: co-ordinate in plane of symmetry normal to wing reference plane

Figure 2b shows the definitions and sign conventions used for non-dimensionalisation.

Non-dimensionalisation

Mean	**Unsteady**
steady component	First harmonic component (sometimes also second) the unsteady component is indicated by the suffix i, each unsteady component has been decomposed into a real (in-phase) and an imaginary (out-of-phase) part; e.g.(C#)i = Re (C#) + i * Im (C#)

Pressures

(Cp)m	= (p – ps) / q	(Cp)i	= $(p)_i$ / (Q * dα)

Balance loads

(Cl)m	= l / (Q * S * bw)	(Cl)i	= l_i / (Q * S * bw * dα)
(Cm)m	= m / (Q * S * cr)	(Cm)i	= m_i/ (Q * S * cr * dα)
(CN)m	= N / (Q * S)	(CN)i	= N_i / (Q * S * dα)
(Cn)m	= n / (Q * S * bw)	(Cn)i	= n_i / (Q * S * bw * dα)
(CT)m	= T / (Q * S)	(CN)i	= T_i / (Q * S * dα)
(CY)m	= Y / (Q * S)	(CY)i	= Y_i / (Q * S * dα)

Note: Each harmonic component has been non-dimensionalized by the first harmonic of dα (in radians).

Symbols and abbreviations

ALPHA, alpha, α	(°)	wing incidence
b	(m)	local wing span
bw	(m)	wing span; reference span bw = 0.8000 m
BETA, beta, β	(°)	sideslip angle
c	(m)	local chord
CD	(-)	wing drag force coefficient
CL	(-)	wing lift force coefficient
Cl	(-)	wing rolling moment coefficient
Cm	(-)	wing pitching moment coefficient; reference axis = rotation axis x/cr = 73.27 %
CN	(-)	wing normal force coefficient
Cn	(-)	wing yawing moment coefficient
Cp	(-)	pressure coefficient
cr	(m)	root chord; reference chord cr = 0.7855 m
CT	(-)	wing tangential force coefficient
CY	(-)	wing side force coefficient
D	(N)	wing drag force
DALPHA, dalpha, dα	(°, rad)	harmonic oscillations: amplitude of unsteady wing incidence (1-cosine) inputs: magnitude of wing incidence variation
(d)i	(mm/rad)	unsteady displacement of accelerometer relative to angular displacement of wing
DPN		Data point number
FREQ, freq, f	(Hz)	frequency, frequency of model oscillation
HARM, harm, h		harmonic component; harm = 0: mean, harm = 1: first harmonic
i		$\sqrt{-1}$
L	(N)	wing lift force

l	(Nm)	wing rolling moment
LVDT		Linear Variable Displacement Transducer
m	(Nm)	wing pitching moment; rotation axis x/cr = 73.27 %
MACH	(-)	freestream Mach number
N	(N)	wing normal force
n	(Nm)	wing yawing moment
NO		number of pressure transducers
p	(Pa)	pressure at model surface
ps	(Pa)	freestream static pressure
pt	(Pa)	total pressure
PHI, φ	(°)	phase angle
Q	(Pa)	dynamic pressure
REDFR	(-)	reduced frequency, REDFR = π * f * cr / V
RUN		run number, data point
S	(m^2)	wing area; wing reference area S = 0.2640 m^2
T	(°C)	stagnation temperature in settling chamber
T	(N)	wing tangential force
T	(s)	harmonic oscillation: period of oscillation
		(1-cosine) inputs: duration of a (1-cos) input
t	(s)	time
V	(m/s)	freestream velocity
WRP		Wing Reference Plane
x	(m)	chordwise ordinate (see Definitions)
Y	(N)	wing side force
y	(m)	spanwise ordinate (see Definitions)
z	(m)	ordinate (see Definitions)

Subscripts

a, _a	adjusted
g	geometric
m	mean
i	unsteady
ref	reference value

FORMULARY

1 General Description of model

1.1	Designation	Low Speed Straked Delta Wing
1.2	Type	Full-span model, supported by struts
1.3	Derivation	Research fighter-type wing
1.4	Additional remarks	-
1.5	References	Ref. 1, Ref. 2, Ref. 6

2 Model Geometry

2.1	Planform	Trapezoidal main wing with simple strake
2.2	Aspect ratio	2.422

2.3	Leading edge sweep	Wing: 40°, strake: 76°
2.4	Trailing edge sweep	No
2.5	Taper ratio	-
2.6	Twist	No
2.7	Root chord	0.7855 m
2.8	Span of model	0.800 m
2.9	Area of planform	0.264 m^2
2.10	Leading-edge flap	Not present
2.11	Trailing-edge flap	Not present
2.12	Location of reference sections and definition of profiles	Measured upper and lower co-ordinates at 4 chordwise sections (3 on port and starboard side and one at line of symmetry) and at 5 spanwise sections
2.13	Form of wing-body or wing-root junction	No fuselage and empennage, middle of main wing thickened to accommodate balance
2.14	Form of wing tip	Fairing: geometry included in CATIA file in database
2.15	Additional remarks	Outboard wing: NACA 64A005 airfoil, Strake: diamond shaped with sharp LE Geometry data included as CATIA file in database
2.16	References	Ref. 2, Ref. 6 Part I, Appendix A

3 Wind Tunnel

3.1	Designation	NLR Low Speed Wind Tunnel LST
3.2	Type of tunnel	Atmospheric, closed-circuit, interchangeable test sections
3.3	Test section dimensions	Width 3 m, height 2.25 m, length 8.75 m (5.75 m forward part for aeronautical testing, aft part for non-aerodynamical (industrial) testing
3.4	Type of roof and floor	Solid
3.5	Type of side walls	Solid
3.6	Ventilation geometry	-
3.7	Displacement thickness of side wall boundary layer	Aeronautical testing (forward part): 10 to 11 mm, nonaeronautical testing (aft part): 15 to 20 mm
3.8	Displacement thickness of boundary layers at roof and floor	About the same as in 3.7
3.9	Method of measuring Mach number in the contraction and a calibration correction	Combination of 4 total pressures in settling chamber, 4 static pressures
3.10	Flow angularity	Well within 0.1%
3.11	Variation in flow velocity across the test section	Less than 0.2%
3.12	Variation in static pressure along length of test section	Less than 0.5% of established dynamic pressure
3.13	Sources and levels of noise or turbulence in empty tunnel	0.02% - 0.03%
3.14	Tunnel resonance	-
3.15	Additional remarks	-
3.16	References on tunnel	-

4 Model motion

4.1	General description	Harmonic sinusoidal pitching motion, (1-cos) pitch manoeuvres
4.2	Reference co-ordinate and definition of motion	LVDT between model and support gave correct geometric incidence, which included deformation of balance
4.3	Range of amplitude	1° to 18°
4.4	Range of frequency	1 to 16 Hz

4.5	Method of applying motion	Electro-hydraulic shaker system (Ref. 8)
4.6	Timewise purity of motion	Adequate purity
4.7	Natural frequencies and normal modes of model and support system	Natural frequencies: 31.97 Hz (yaw), 38.66 Hz (roll), 45.36 Hz (roll + pitch), 53.03 Hz (pitch), also higher frequencies; see Ref. 3
4.8	Actual mode of applied motion including any elastic deformation	Measured with 9 accelerometers; elastic deformation negligible Position and output included in database files.
4.9	Additional remarks	-

5 Test Conditions

5.1	Model planform area/tunnel area	0.0391
5.2	Model span/tunnel height	0.2667
5.3	Blockage	Solid blockage negligible, corrected for wake blockage according standard procedure
5.4	Position of model in tunnel	Supported by struts, Wing reference plane in centre of tunnel
5.5	Range of velocities	80, 55 and 30 m/s (Mach numbers: 0.225, 0.155, 0.085)
5.6	Range of tunnel total pressure	Atmospheric
5.7	Range of tunnel total temperature	Actual total temperature value included in database files
5.8	Range of model steady or mean incidence and sideslip angles	Adjusted incidences: -10° to 55° Sideslip angles: -5°, 0°, +5°
5.9	Definition of model incidence	Relative to WRP
5.10	Position of transition, if free	-
5.11	Position and type of trip, if transition fixed	-
5.12	Flow instabilities during tests	-
5.13	Changes to mean shape of model due to steady aerodynamic load	Not measured
5.14	Additional remarks	Correct geometric incidences and amplitudes in data files
5.15	References describing tests	Refs. 5, 6 and 9

6 Measurements and Observations

6.1	Steady pressures for the mean conditions		Yes
6.2	Steady pressures for small changes from the mean conditions		No
6.3	Quasi-steady pressures		No
6.4	Unsteady pressures	Measured directly	
		- harmonic components	Yes
		- time histories	Yes
6.5	Steady loads for the mean conditions	Measured directly	Yes
6.6	Steady loads for small changes from the mean conditions		No
6.7	Quasi-steady loads		No
6.8	Unsteady loads	Measured directly	
		- harmonic components	Yes
		- time histories	Yes
		- Power Spectral Densities	Yes
		- manoeuvres	Yes
6.9	Measurement of actual motion at points on model		Yes
6.10	Observation or measurement of boundary		No

	layer properties	
6.11	Visualisation of flow	Yes
6.12	Visualisation of shock wave movements	No
6.13	Additional remarks	-

7 Instrumentation

7.1	Steady pressure	
	7.1.1 Position of orifices spanwise and chordwise	See Figure 3: positions included in database files of pressures
	7.1.2 Type of measuring system	42 in situ miniature pressure transducers
7.2	Unsteady pressure	
	7.2.1 Position of orifices spanwise and chordwise	See Figure 3: positions included in database files of pressures
	7.2.2 Diameter of orifices	0.8 mm
	7.2.3 Type of measuring system	Processor for measuring harmonic components; see Ref.7
	7.2.4 Type of transducers	Endevco 8507-5, Kulite CQL-080-5D, Kulite XCS-093-5D
	7.2.5 Principle of calibration	Data acquisition system was calibrated daily, pressure transducers before the wind tunnel test
	7.2.6 Accuracy of calibration	~1%
7.3	Model motion	
	7.3.1 Method of measuring motion	LVDT: type Sangamo AFG 5.0 S
	7.3.2 Method of determining spatial mode of motion	9 accelerometers: 5 Endevco 2220 C, 4 Kulite GY-155
	7.3.3 Accuracy of measured motion	LVDT: better than 0.015 mm
7.4	Processing of unsteady measurements	
	7.4.1 Method of acquiring and processing measurements	Processor for measuring harmonic components
	7.4.2 Type of analysis	Fundamental harmonics: pressures, balance loads time histories: pressures, balance loads PSD plots: balance loads vortex core positions: visualisation
	7.4.3 Unsteady pressure quantities obtained and accuracy's achieved	Fundamental harmonics and time histories, for accuracy see 9.1.6
7.5	Additional remarks	-
7.6	References on techniques	-

8 Data presentation

8.1	Test cases for which data could be made available	see Tables 2 to 5
8.2	Test cases for which data are included in this document	Summarised and motivated in Introduction
8.3	Steady pressures	Mean values; see Low Speed Straked Delta Wing Database
8.4	Quasi-steady or steady perturbation pressures	
8.5	Unsteady pressures	Mean values and first harmonics; see Low Speed Straked Delta Wing Database
8.6	Steady loads	Mean values; see Low Speed Straked Delta Wing Database
8.7	Quasi-steady or unsteady perturbation forces	
8.8	Unsteady loads	Mean values and first harmonic; see Low Speed Straked Delta Wing Database
8.9	Other forms in which data could be made	-

	available	
8.10	Reference giving other representations of data	References 9 to 15

9 Comments on data

9.1	Accuracy	
	9.1.1 Mach number	+/- 0.001
	9.1.2 Steady incidence	+/- 0.01 at LVDT position
	9.1.3 Reduced frequency	+/- 0.0005
	9.1.4 Steady pressure coefficients	+/- 0.5 percent
	9.1.5 Steady pressure derivatives	-
	9.1.6 Unsteady pressure coefficients	+/- 0.5 percent
9.2	Spanwise variations	Dynamic pressure distribution around model in relation to dynamic pressure, measured by tunnel reference system, measured for zero-lift condition
9.3	Non-linearity's	-
9.4	Influence of tunnel total pressure	-
9.5	Effects on data of uncertainty, or variation, in mode of model motion	-
9.6	Wall interference corrections	Not measured
9.7	Other relevant tests on same model	Ref. 5
9.8	Relevant tests on other models of nominally the same shapes	Ref. 4
9.9	Any remarks relevant to comparison between experiment and theory	-
9.10	Additional remarks	An example of a database file and its explanation is included in table 6. Structure of file set-up is included in README file in database
9.11	References on discussion of data	References 9 to 15

10 Personal contact for further information

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11 List of references

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2 Horsten, J.J., "Design of the GD/NLR straked wing model and support system", NLR Memorandum AE-85-005 U, 1985.

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4 Persoon, A.J., Retel, A.P., "Some experiments with flow visualization of vortices over a vibrating straked wing", NLR Memorandum AE-86-001 L, 1986.

5 de Vries, O., "Force measurements in a low-speed wind tunnel on a model of a straked wing, suspended in wires", NLR TR 86047 C, 1986.

6 Cunningham, Jr., A.M., den Boer, R.G., et.al., "Unsteady low speed wind tunnel test of a straked delta wing, oscillating in pitch",

Part I General description and discussion of results

Part II Plots of steady and zeroth and first order harmonic unsteady pressure distributions

Part III Plots of zeroth and first order harmonic unsteady pressure distributions (concluded) and plots of steady and zeroth and first order harmonic overall loads

Part IV Plots of time histories of pressures and overall loads

Part V Plots of the overall loads spectra and the response of overall loads to single step (1-cos) inputs

Part VI Presentation of the visualization program

NLR TR 87146 L Parts I through VI, (also "published" in April 1988 as AFWAL-TR-8-3098, Parts I-VI).

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15 Cunningham Jr., A.M., den Boer, R.G., "Analysis of Unsteady Force, Pressure and Flow-Visualization Data for a Pitching Straked Wing Model at High Angles of Attack", AGARD FDP Conference Proceedings 497 Paper 8: Maneuvering Aerodynamics, Toulouse, France, 1-2 May 1991

Incidence [°] (adjusted)	8	22	22	22	22	22	38
Amplitude [°]	4	4	8	8	8	8	8
Frequency [Hz]	5	6	6	8	8	8	6
Side-slip [°]	0	0	0	0	+5	-5	0
Velocity [m/s]	80	80	80	80	80	80	80
Steady Pressures (Cp_s)	13	20	20	20			54
Unsteady Pressures (Cp0,Cp1)	1036	524	526	532, 976	919	929	593
Time histories of pressures	1036			976			
Time histories of balance loads				532	919	929	
Manoeuvres				3017			

Table 1: Selected test cases for Low Speed Straked Delta Wing (Values in shaded area indicate data point numbers)

α_a	$\beta = 0.0°$, V ~ 80 m/s
-10° (2°) 54°, 55°	without wire suspension blocks
4° (4°) 40°	with wire suspension blocks

Table 2: Steady test program

Oscillating amplitudes at alpha/frequency combinations								
$\beta = 0.0°$, V ~ 80m/s								
f	2	3	4	5	8	10	12	16
α_a								
-4		2,4		2,4	2,4		2	2
0		2,4,8		2,4,8	2,4,8		2	2
4		2,4,8,12		2,4,8,12	2,4,8		2	2
8		2,4,8,12,16		2,4,8,12,16	2,4,8		2	2
12	4,8	2,4,8,12		2,4,8,12	2,4,8		2	2
16	2,4,6,8,10,12	2,4,6,8,10,12	2,4,6,8,10,12	2,4,6,8,10,12	2,4,6,8		2	2
18	2,4,6,8,10,12,14	2,4,6,8,10,12,14	2,4,6,8,10,12,14	2,4,6,8,10,12,14	2,4,6,8		2	2
20	2,4,6,8,10,12,14,16	2,4,6,8,10,12,14,16	2,4,6,8,10,12,14,16	2,4,6,8,10,12,14,16	2,4,6,8		2	2
22	2,4,6,8,10,12,14,16,18	2,4,6,8,10,12,14,16,18	2,4,6,8,10,12,14,16,18	2,4,6,8,10,12,14,16,18 (6Hz) 2,4,6,8,10,12	2,4,6,8	2,4	2	2
24		2,4,6,8,10,12,14,16		2,4,6,8,10,12,14,16	2,4,6,8		2	2
26		2,4,6,8,10,12,14		2,4,6,8,10,12,14	2,4,6,8		2	2
28		2,4,6,8,10,12		2,4,6,8,10,12	2,4,6,8		2	2
30		2,4,6,8,10		2,4,6,8,10	2,4,6,8		2	2
32		2,4,6,8,10,12		2,4,6,8,10,12	2,4,6,8		2	2
34		2,4,6,8,10,12,14		2,4,6,8,10,12,14	2,4,6,8		2	2
36		2,4,6,8,10,12,14,16		2,4,6,8,10,12,14,16	2,4,6,8		2	2
38	2,4,6,8,10,12,14,16	2,4,6,8,10,12,14,16	2,4,6,8,10,12,14,16	2,4,6,8,10,12,14,16 (6Hz) 2,4,6,8,10	2,4,6,8	2,4	2	2
40		2,4,6,8,10,12,14		2,4,6,8,10,12,14	2,4,6,8		2	2
42		2,4,6,8,10,12		2,4,6,8,10,12	2,4,6,8		2	2
44		2,4,6,8,10		2,4,6,8,10	2,4,6,8		2	2
46		2,4,6,8 (also.1,1,3)		2,4,6,8	2,4,6,8		2	2
48		2,4,8		2,4,8	2,4,8		2	2
50		2,4		2,4	2,4		2	2
52		2		2	2		2	2
54		1		1	1		1	1

Table 3a: Unsteady test program (FUNDAMENTAL HARMONICS, BASIC PROGRAM)

Oscillating amplitudes at alpha/frequency combinations									
$\beta = +5°$, V ~ 80 m/s					$\beta = -5°$, V ~ 80 m/s				
frequency	3	5	8	16	frequency	3	5	8	16
α_a					α_a				
8	4,8,16	4,8,16	2,4,8	2	8	4,8,16	4,8,16	2,4,8	2
18	4,8,14	4,8,14	2,4,8	2	18	4,8,14	4,8,14	2,4,8	2
22	4,8,16	4,8,16	2,4,8	2	22	4,8,16	4,8,16	2,4,8	2
38	4,8,16	4,8,16	2,4,8	2	38	4,8,16	4,8,16	2,4,8	2
46	4,8	4,8	2,4,8	2	46	4,8	4,8	2,4,8	2

Table 3b: Unsteady test program (FUNDAMENTAL HARMONICS, SIDESLIP INFLUENCE)

Oscillating amplitudes at alpha/frequency combinations										
$\beta = 0.0°$, V ~ 55 m/s					$\beta = 0.0°$, V ~ 30 m/s					
frequency	2.06	3.44	5.50	11.0	frequency	1.13	1.88	3.0	6.0	12.0
α_a					α_a					
8	4,8,16	4,8,16	4,8	2	8	4,8,16	4,8,16	4,8,16	2,4,8	2
16	4,8,12	4,8,12	4,8	2						
18	4,8,14	4,8,14	4,8	2	18	4,8,14	4,8,14	4,8,14	2,4,8	2
20	4,8,16	4,8,16	2,4,8	2						
22	4,8,16	4,8,16	4,8	2	22	4,8,16	4,8,16	4,8,16	2,4,8	2
24	4,8,16	4,8,16	4,8	2						
36	4,8,16	4,8,16	4,8	2						
38	4,8,16	4,8,16	4,8	2	38	4,8,16	4,8,16	4,8,16	2,4,8	2
42	4,8,16	4,8,12	4,8	2						
44	4,8,10	4,8,10	4,8	2						
46	4,8	4,8	4,8	4	46	4,8	4,8	4,8,16	2,4,8	4

Table 3c: Unsteady test program (FUNDAMENTAL HARMONICS, VELOCITY INFLUENCE)

Oscillating amplitudes at alpha/frequency combinations						
$\beta = +0°$, V ~ 80 m/s						
frequency	2	3	4	5	8	16
α_a						
8		4,8,16		4,8,16	4,8	2
18	8,14	8,14	4,8	4,8,14	4,8	2
20	4,8,14		4,8,14		4,8	2
22	4,8,14	4,8,14	4,8,14	4,8,14	4,8	2
38		4,8,14		4,8,14	4,8	2
46		4,8		4,8	4,8	2

Table 4a: Unsteady test program (TIME HISTORIES of PRESSURES)

Oscillating amplitudes at alpha/frequency combinations									
	$\beta = +0°$, V ~ 80 m/s			$\beta = +5°$, V ~ 80 m/s			$\beta = -5°$, V ~ 80 m/s		
frequency	3	5	8	3	5	8	3	5	8
α_a									
0	8	8	8						
4	8,12	8,12	8						
8	8,12,16	8,12,16	8	8,16	8,16	8	8,16	8,16	8
12	8,12	8,12	8						
16	8,12	8,12							
18	8,12	8,12	8	8	8	8	8	8	8
20	8,12,16	8,12,16	8						
22	8,12,16,18	8,12,16,18	8	8,16	8,16	8	8,16	8,16	8
24	8,12,16	8,12,16	8						
26	8,12	8,12	8						
28	8,12	8,12	8						
30	8	8	8						
32	8,12	8,12	8						
34	12	8,12	8						
36	8,12	8,12	8						
38	8,12,16	8,12,16	8	8,16	8,16	8	8,16	8,16	8
40	8,12	8,12	8						
42	8,12	8,12	8						
44	8	8	8						
46	8	8	8	8	8	8	8	8	8

Table 4b: Unsteady test program (TIME HISTORIES of OVERALL LOADS, PSD'S)

Oscillating amplitudes at alpha/T combinations						
$\beta = +0°$, V ~ 80 m/s						
T	0.500	0.330	0.250	0.200	0.125	0.083
α_a						
8	8,16,24,32	8,16,24,32	8,16,24,32	8,16,24,32	8,16	8
16	24	24	24	24		
22	8,16,24,32	8,16,24,32	8,16,24,32	8,16,24,32	8,16	8
24	16	16	16	16	16	
30	24	24	24	24		
32	8	8	8	8	8	8
38	16	16	16	16	16	
46	8	8	8	8	8	8

Table 5: Unsteady test program: (1 - COSINE) INPUTS

```
File organization of "sel_st" and "sel_uns" (STeadu and UNSteady)
=================================================================
Selection of zeroth and first order harmonic (un)steady pressures
```

Description	FORMAT
DPN,HARM,ALPHA,Re(DALPHA),Im(DALPHA),FREQ,MACH	2i5,5f10.5
VELOCITY,REDFR,Q,ps,T,BETA,S	2f10.5,f10.2,4f10.5
NO,xref,x/xref,yref,y/yref,(Cp)m,Re(Cp),Im(Cp)	44*(i2,7f10.5,/)
(CN)m,Re(CN),Im(CN),(Cn)m,Re(Cn),Im(Cn)	6f10.5
(CY)m,Re(CY),Im(CY),(Cm)m,Re(Cm),Im(Cm)	6f10.5
(CT)m,Re(CT),Im(CT),(Cl)m,Re(Cl),Im(Cl)	6f10.5
NO,xref,x/xref,yref,y/yref,Re(d),Im(d)	9*(i2,6f10.5,/)

NB. Improper values represented as: 9999.99

Table 6a: Example of explanation of file organisation of pressure data files

```
1036    1   9.97900    .05941   -.02431   5.00000     .22346
  77.60194     .15900    3613.07102086.920 303.00000   0.00000    .26400
 1 785.50000     .40420   79.16000      .068109999990.009999990.009999990.00
 2 785.50000     .40420   79.16000      .204309999990.009999990.009999990.00
 3 785.50000     .40420   79.16000      .340609999990.009999990.009999990.00
 4 785.50000     .40420   79.16000      .476809999990.009999990.009999990.00
 5 785.50000     .40420   79.16000      .54480    -.45169   -5.93639     .79971
 6 785.50000     .40420   79.16000      .612909999990.00    -7.10090     .92673
 7 785.50000     .40420   79.16000      .68100    -.77757   -5.86580     .45257
 8 785.50000     .40420   79.16000      .749209999990.009999990.009999990.00
 9 785.50000     .40420   79.16000      .81730    -.62521   -2.84359    -.26235
10 785.50000     .40420   79.16000      .88540    -.69598   -2.79452    -.21200
11 785.50000     .65880  225.00000      .13110    -.24250    -.64196    -.29332
12 785.50000     .65880  225.00000      .26000    -.28479   -1.37241    -.14200
13 785.50000     .65880  225.00000      .32440    -.29590   -3.22860     .26914
14 785.50000     .65880  225.00000      .38890    -.57053   -4.92005     .50296
15 785.50000     .65880  225.00000      .42930    -.87438   -5.33319     .37613
16 785.50000     .65880  225.00000      .46930    -.85384   -3.98634    -.47575
17 785.50000     .65880  225.00000      .50980    -.52407   -3.34236    -.14527
18 785.50000     .65880  225.00000      .55020    -.44519   -2.48929     .05060
19 785.50000     .65880  225.00000      .59020    -.42339   -2.77352    -.11098
20 785.50000     .65880  225.00000      .63070    -.35628   -1.92341    -.17372
21 785.50000     .65880  225.00000      .67070    -.31453   -1.31876    -.18386
22 785.50000     .65880  225.00000      .71110    -.28706   -1.64119    -.15489
23 785.50000     .65880  225.00000      .75560    -.67130   -5.41212    -.85584
24 785.50000     .65880  225.00000      .80000   -2.21298  -18.60173     .19867
25 785.50000     .65880  225.00000      .84440   -1.79432   -5.78206    -.32753
26 785.50000     .65880  225.00000      .88890   -1.48771   -3.35132    -.54125
27 785.50000     .65880  225.00000      .933309999990.00    -2.65331    -.55818
28 785.50000     .65880  225.00000      .97780   -1.27615   -2.93168    -.64424
29 785.50000     .96820  400.00000      .20000    -.018249999990.009999990.00
30 785.50000     .96820  400.00000      .30000    -.10672    -.47488     .08081
31 785.50000     .96820  400.00000      .40000    -.02891    -.90136     .01624
32 785.50000     .96820  400.00000      .50000    -.00183    -.37925    -.12307
33 785.50000     .96820  400.00000      .60000    -.07435   -1.18126    -.05478
34 785.50000     .96820  400.00000      .70000    -.24055   -3.67764     .32366
35 785.50000     .96820  400.00000      .80000    -.37085   -2.92309    -.07185
36 785.50000     .96820  400.00000      .90000    -.33002   -1.53550    -.41388
37 321.38000     .05720  400.00000      .40000   -2.870869999990.009999990.00
22 321.38000     .16610  400.00000      .40000    -.28706   -1.64119    -.15489
38 321.38000     .29210  400.00000      .40000    -.27462   -1.47719     .04282
39 321.38000     .41820  400.00000      .40000    -.38444   -2.34909     .06812
40 321.38000     .54420  400.00000      .40000    -.25250   -1.12146    -.06194
41 321.38000     .67020  400.00000      .40000    -.19045    -.68371    -.15309
42 321.38000     .79620  400.00000      .400009999990.00     -.54453    -.11307
31 321.38000     .92220  400.00000      .40000    -.02891    -.90136     .01624
     .50894    3.00332     .31524    .00007    -.00037     .00039
     .00163     .01840     .00893    .03635     .21730    -.02732
    -.00451     .00380    -.01719    .00126     .00285    -.00096
 1 785.50000     .82750  400.00000      .86250 -70.42357    1.72442
 2 785.50000     .92940  400.00000      .86250-128.70087     .16808
 3 785.50000     .82750  400.00000     -.86250-140.47656 -43.30425
 4 785.50000     .92940  400.00000     -.86250-1265.5269-1767.7434
 5 785.50000     .92940  400.00000     -.37500   0.00000    0.00000
 6 785.50000     .93700  400.00000     0.00000    .66343     .49160
 7 785.50000     .46720  400.00000     0.00000 221.16983   72.80017
 8 785.50000     .21260  400.00000     0.00000 470.46179  148.68518
 9 785.50000     .62380  400.00000     -.37500 118.99069   61.73772
```

Table 6a: Example of an unsteady pressure measurement database file

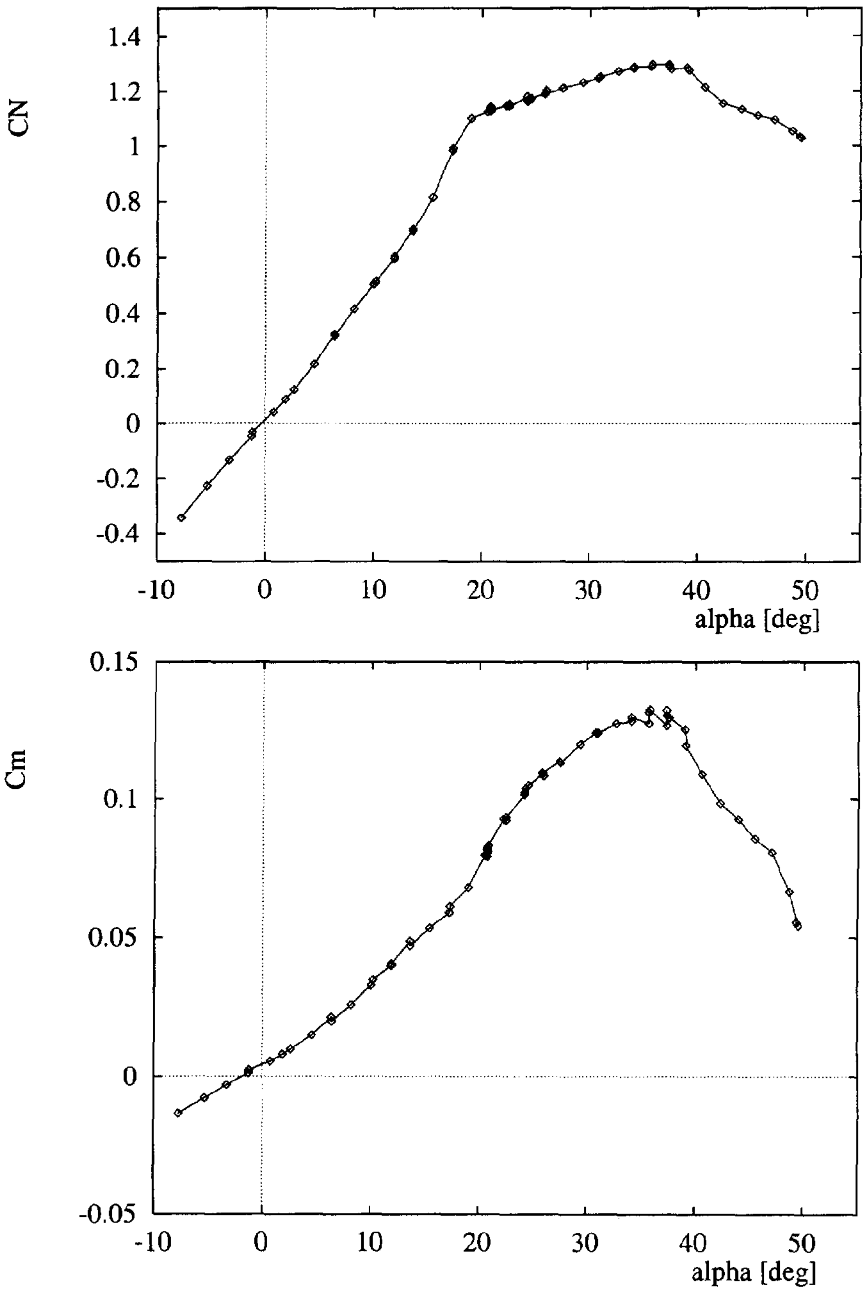

Figure 1: Low Speed Straked Delta Wing: Steady Normal Force and Pitching Moment vs. alpha.

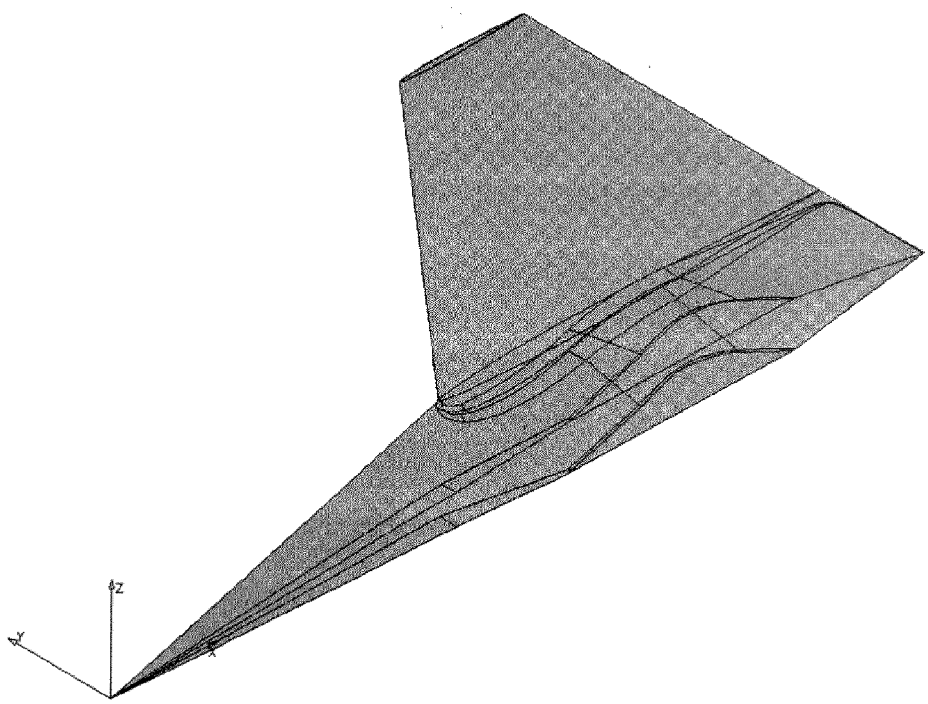

Figure 2a: CATIA example of NLR Low Speed Straked Delta Wing.

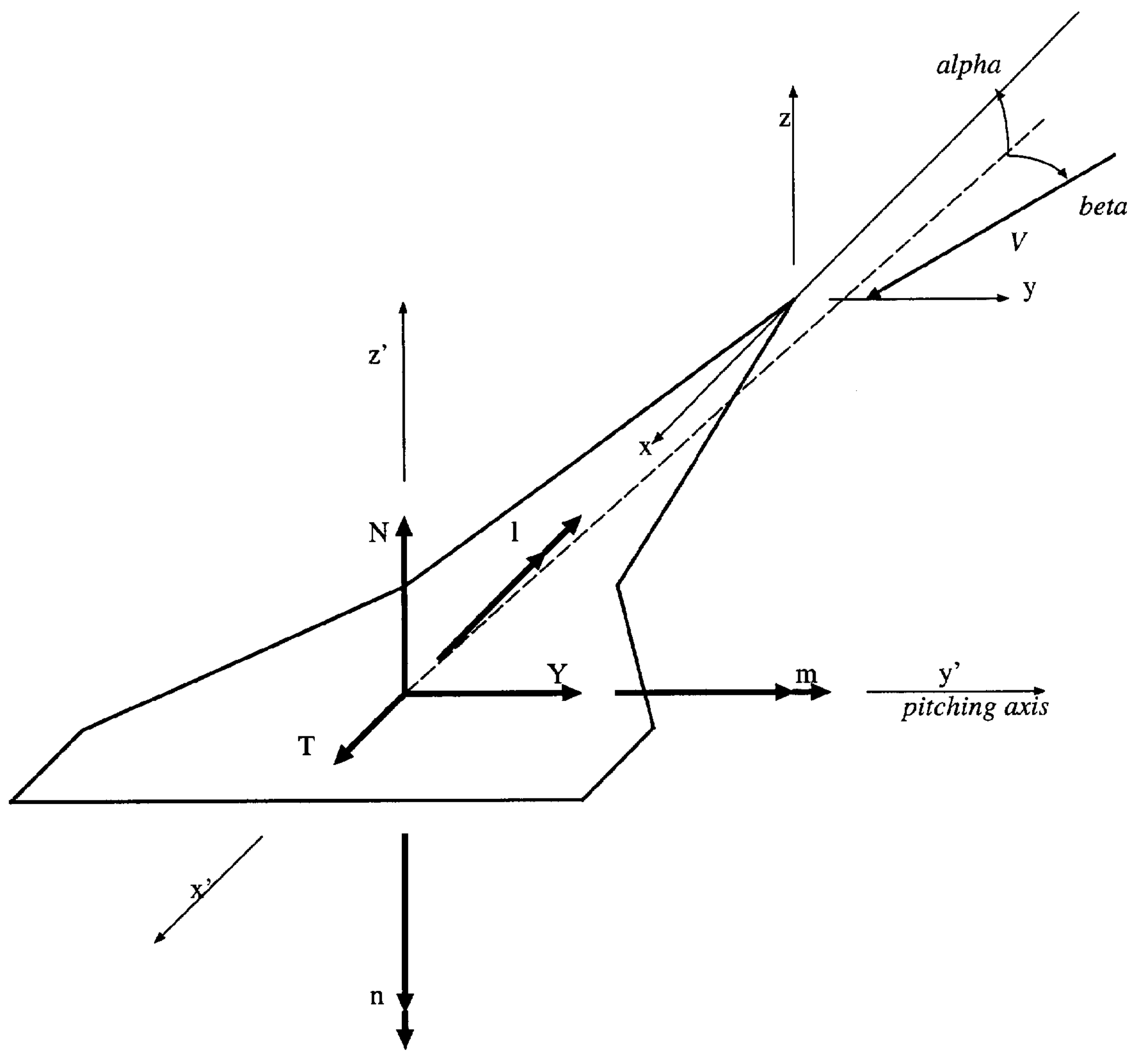

Figure 2b: Definitions and sign conventions

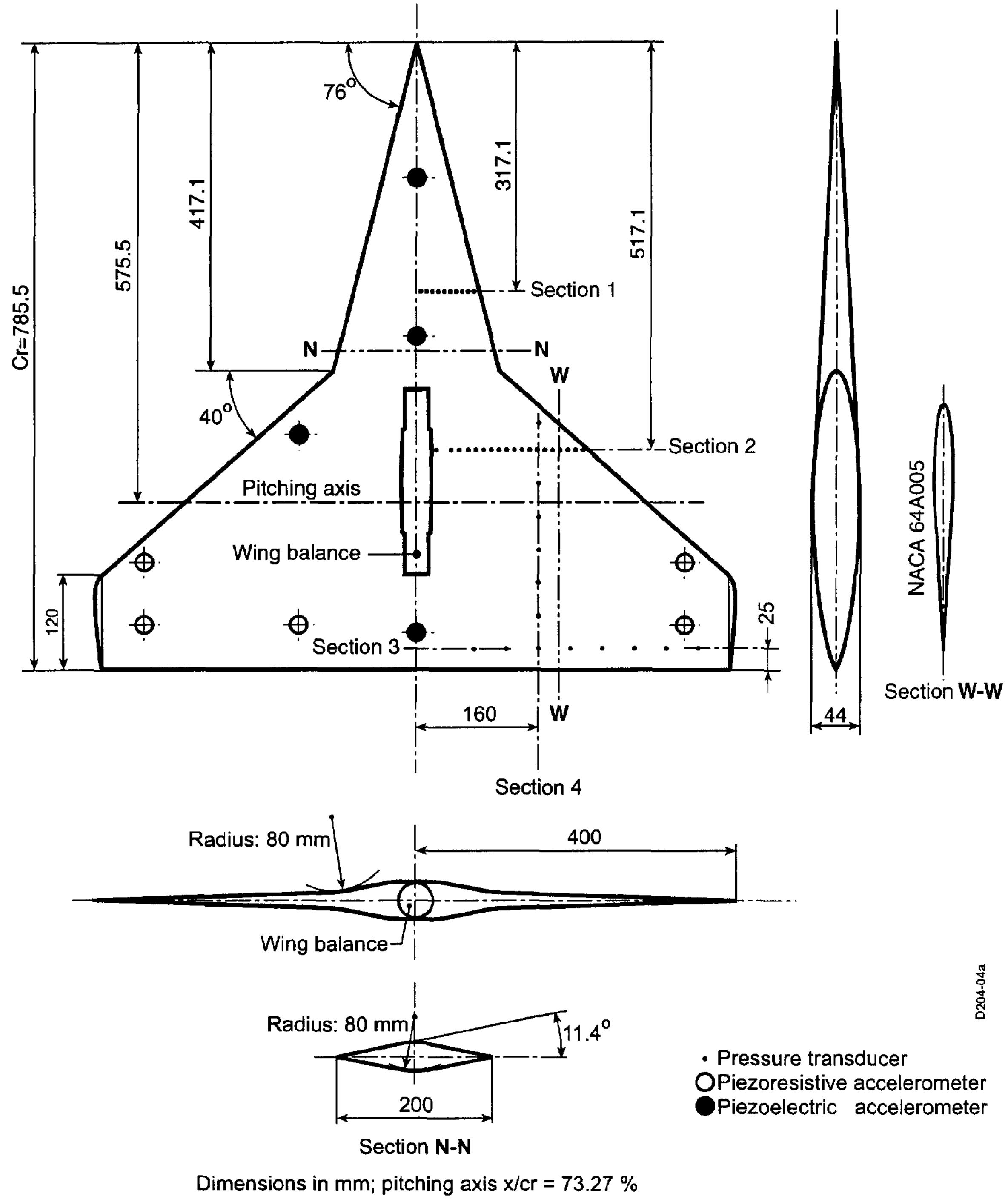

Figure 3: NLR Low Speed Straked Delta Wing, planform and model instrumentation