AF103

NACA2412 Aerofoil with Variable Flap

User Guide

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Introduction

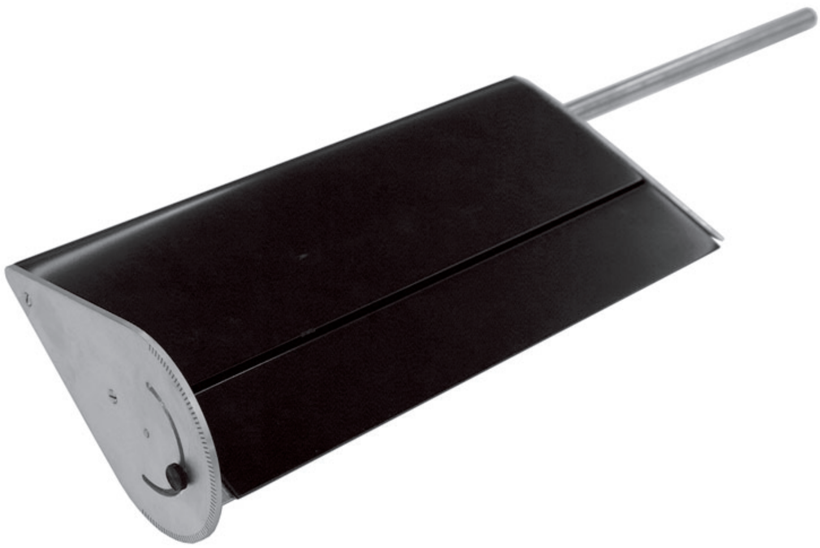


Figure 1 The AF103 NACA 2412 Aerofoil with Variable Flap

The AF103

The AF103 NACA 2412 Aerofoil with Variable Flap Model is designed for use with the AF100 Subsonic Wind Tunnel. When used with other TecQuipment wind tunnel instruments It illustrates the effect of control surface deflection on lift, drag and pitching moment.

The Aerofoil Model is just one of a range of models that TecQuipment manufacture to accompany our range of wind tunnels. Each model allows a wide variety of experiments and demonstrations to be conducted.

The Aerofoil Model is a 150 mm chord, 300 mm span aerofoil with an unsymmetrical NACA2412 profile. The trailing edge flap can be adjusted through 90 degrees up or down. A tear drop shaped end plate is engraved with 2.5 degree increments to help set the flap angle accurately.

When fitted inside the working section of a wind tunnel, the angle of incidence of the aerofoil and the flap angle can be adjusted. If a suitable three component balance is fitted, the resulting lift, drag and pitching moment can be measured. TecQuipment recommend the AFA3 Three Component Balance for use with this model for full tests, or the AFA2 Single Component balance for lift and drag measurements only.

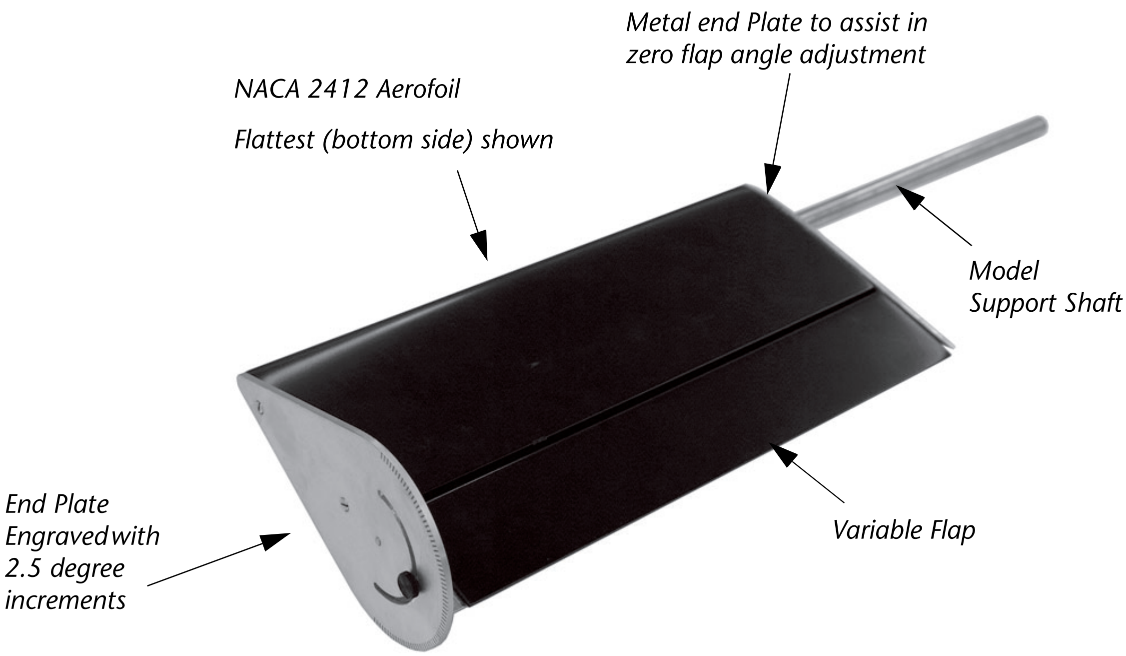


Figure 2 The Main Parts of the Aerofoil Model

Installation

The terms **left**, **right, front** and **rear** of the apparatus refer to the operators’ position, facing the unit.

NOTE Follow any regulations that affect the installation, operation and maintenance of this apparatus in the country where it is to be used.

Assembly

Nett Weight: 2 kg

Procedure - Refer to Test Procedures.

Test Procedure

Force Measurement with the AFA3 Three Component Balance

1. Make sure the electrical supply to the wind tunnel is disconnected.
2. Create a blank table of results similar to Table 1. Record the ambient temperature and pressure.
3. Fit the AFA3 Three Component Balance to the Working Section of the wind tunnel (refer to the AFA3 User Guide for details). Remove the clear panel from the opposite side of the wind tunnel.
4. Make sure that any pitot tubes in the working section are out of the way.
5. Fit the aerofoil model into the collet of the AFA3 so that the flattest side is to the top.

NOTE *The aerofoil is flying upside down, so that the load cells and connecting wires on the AFA3 are in tension. Pitch is positive, with the leading edge towards the floor.*

6. Adjust the variable flap so that it is in line with the main part of the aerofoil and the metal plate at the support shaft end of the aerofoil. The flap angle is now zero.
7. Set the scale on the AFA3 to zero and lock it in position. Rotate the aerofoil so that the trailing edge is 2.6 mm higher than the centre line of the support shaft. Lock the support shaft in position on the AFA3. The 2.6 mm offset allows for the camber of the aerofoil. The aerofoil angle is now set to zero.
8. Refit the clear panel that you removed in step 2.
9. Set the wind tunnel speed to a wind velocity of 33 $m.s^{-1}$. Note that the pressure difference (RPD) used to calculate the wind velocity varies due to ambient conditions.
10. In steps of 1°, take readings of Fore and Aft drag forces at aerofoil angles (incidence angles) from -5° to the stall angle. You may need to adjust the wind tunnel fan speed to maintain a constant wind velocity as the incidence angle changes.

NOTE *The stall angle changes with flap setting. The wing is at stall when the lift starts to decrease as the incidence angle increases. Lift = Fore + Aft forces.*

11. Stop the wind tunnel, remove the clear panel opposite the AFA3 and adjust the flap angle to 22.5 degrees and repeat the experiment.
12. Repeat the experiment with a flap angle of 45 degrees.
13. Refer to **Results and Analysis** on page 11 to complete the last five columns of your results table.

Flap Angle							
RPD mm H_2O			**Air density**		kg/m^3		
Ambient Temperature °C	**Aerofoil Area**	0.045 m^2	**Wind Velocity**		m.s^{-1}		
Ambient Pressure mbar	**Chord**	0.15 m	**1/2 $\rho V^2 S$**		N		
Incidence Angle (°)	**Lift (N)**	**Drag (N)**	**Pitching Moment (Nm)**	C_L	C_D	C_M	C_L/C_D

Table 1 Blank Results Table for Force Measurement Test

Results and Analysis

Note: Any results are for guidance only, actual results may differ slightly.

The lift and pitching moment are automatically calculated by the AFA3 from the equation:

Lift = Fore load cell Force + Aft load cell Force

Pitching Moment = Moment Arm Length x (Fore load cell Force - Aft load cell Force)

The lift/drag ratio is calculated from:

Lift/Drag Ratio = C_L/C_D

It is convenient to refer to the non-dimensional coefficients of lift, drag and pitching moment as follows:

Coefficient of Lift: $C_L = \dfrac{L}{1/2\rho V^2 S}$

Coefficient of Drag: $C_D = \dfrac{D}{1/2\rho V^2 S}$

Coefficient of Pitching Moment: $C_m = \dfrac{M}{1/2\rho V^2 Sc}$

Where:

L = Lift
D = Drag
M= Moment Arm Length (0.0645 m)
S = Area of aerofoil
c = Chord of aerofoil

Calculate the coefficients of lift, drag and pitching moment on each of your results tables. Also calculate the lift to drag ratio. Plot your results as a graph of lift/drag ratio against incidence angle for each flap angle.

a) Comment on how the lift, drag and pitching moment vary.
b) What effect does the stall have on the lift and the drag?
c) If you were choosing this aerofoil to use on an aircraft, what incidence angle would give the best performance and why?
d) Why does the pitching moment change with angle of incidence?
e) From your graphs, how can you tell that the aerofoil has an unsymmetrical section?

Plot the coefficents of lift and drag on the same vertical axis of a graph against a horizontal axis of incidence angle.

a) What effect does the flap angle have on the lift at a particular angle of incidence?
b) What effect does the flap angle have on the maximum lift ($C_{L\ max}$) of the aerofoil?
c) Why does the incidence angle at which maximum lift is produced change with flap angle?

NOTE *The flap adjustment mechanism may cause drag results that are slightly higher than theoretical results. The flap may cause slightly higher drag results than for a standard aerofoil.*

Flap Angle 0°							
RPD 60 mm H_2O			**Air density**		1.227 kg/m^3		
Ambient Temperature 21°C	**Aerofoil Area**	0.045 m^2	**Wind Velocity**		30.98 m.s^{-1}		
Ambient Pressure 1035 mbar	**Chord**	0.15 m	**1/2 $\rho V^2 S$**		26.49 N		
Incidence Angle (°)	**Lift (N)**	**Drag (N)**	**Pitching Moment (Nm)**	C_L	C_D	C_M	C_L/C_D
-4	-4.40	0.91	-0.21	-0.166	0.034	-0.053	-4.835
-3	-1.60	0.83	-0.23	-0.060	0.031	-0.058	-1.928
-2	0.20	0.80	-0.23	0.008	0.030	-0.058	0.250
-1	2.90	0.77	-0.24	0.109	0.029	-0.060	3.766
0	6.20	0.80	-0.24	0.234	0.030	-0.060	7.750
1	9.60	0.82	-0.23	0.362	0.031	-0.058	11.707
2	12.30	0.86	-0.23	0.464	0.032	-0.058	14.302
3	15.10	0.90	-0.23	0.570	0.034	-0.058	16.778
4	18.10	1.05	-0.22	0.683	0.040	-0.055	17.238
5	20.40	1.20	-0.21	0.770	0.045	-0.053	17.000
6	24.40	1.40	-0.22	0.921	0.053	-0.055	17.429
7	26.60	1.75	-0.22	1.004	0.066	-0.055	15.200
8	29.10	1.90	-0.21	1.099	0.072	-0.053	15.316
9	31.00	2.20	-0.26	1.170	0.083	-0.065	14.091
10	32.90	2.25	-0.19	1.242	0.085	-0.048	14.622
11	35.00	2.70	-0.19	1.321	0.102	-0.048	12.963
12	35.10	4.10	-0.27	1.325	0.155	-0.068	8.561
13	35.00	4.60	-0.40	1.321	0.174	-0.101	7.609
14	30.50	7.40	-0.55	1.152	0.279	-0.138	4.122

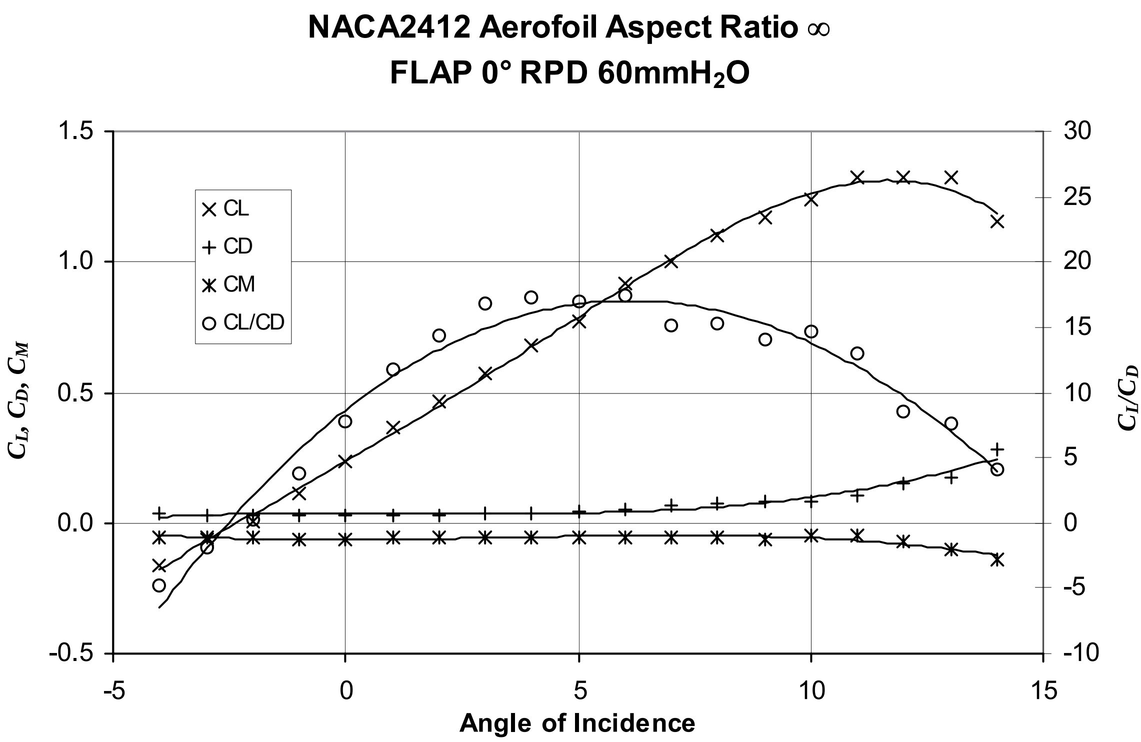
Table 2 Results for Force Measurement Test with Flap at 0°.

Flap Angle 22.5°							
RPD 60 mm H_2O			**Air density**		1.227 kg/m^3		
Ambient Temperature 21°C	**Aerofoil Area**	0.045 m^2	**Wind Velocity**		30.98 m.s^{-1}		
Ambient Pressure 1035 mbar	**Chord**	0.15 m	**1/2 $\rho V^2 S$**		26.49 N		
Incidence Angle (°)	**Lift (N)**	**Drag (N)**	**Pitching Moment (Nm)**	C_L	C_D	C_M	C_L/C_D
-4	18.60	2.85	-0.84	0.702	0.108	-0.211	6.526
-3	20.60	2.90	-0.83	0.778	0.109	-0.209	7.103
-2	24.40	3.00	-0.83	0.921	0.113	-0.209	8.133
-1	27.30	3.05	-0.83	1.031	0.115	-0.209	8.951
0	29.30	3.10	-0.83	1.106	0.117	-0.209	9.452
1	32.30	3.20	-0.80	1.219	0.121	-0.201	10.094
2	35.00	3.20	-0.78	1.321	0.121	-0.196	10.938
3	37.80	3.52	-0.76	1.427	0.133	-0.191	10.739
4	41.00	3.76	-0.75	1.548	0.142	-0.189	10.904
5	43.40	4.00	-0.73	1.639	0.151	-0.184	10.850
6	45.30	4.30	-0.73	1.710	0.162	-0.184	10.535
7	47.60	4.89	-0.73	1.797	0.185	-0.184	9.734
8	50.10	5.21	-0.71	1.891	0.197	-0.179	9.616
9	54.10	6.10	-0.80	2.043	0.230	-0.201	8.869
10	51.00	7.40	-0.84	1.925	0.279	-0.211	6.892
11	44.00	11.30	-1.03	1.661	0.427	-0.259	3.894

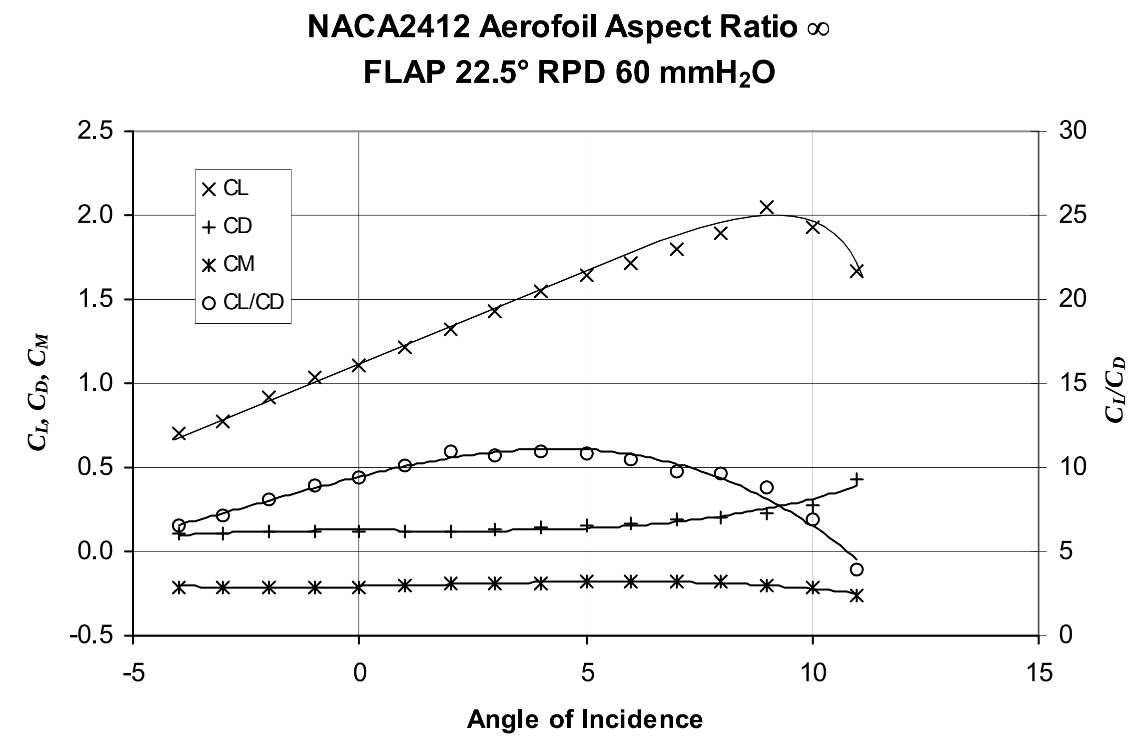
Table 3 Results for Force Measurement Test with Flap at 22.5°.

Flap Angle 45°							
RPD 60 mm H_2O			**Air density**		1.217 kg/m^3		
Ambient Temperature 21°C	**Aerofoil Area**	0.045 m^2	**Wind Velocity**		31.10 m.s^{-1}		
Ambient Pressure 1027 mbar	**Chord**	0.15 m	**1/2 $\rho V^2 S$**		26.49 N		
Incidence Angle (°)	**Lift (N)**	**Drag (N)**	**Pitching Moment (Nm)**	C_L	C_D	C_M	C_L/C_D
-5	27.6	6.25	-1.02	1.042	0.236	-0.257	4.416
-4	31	6.60	-1.08	1.170	0.249	-0.272	4.697
-3	33.6	6.75	-1.03	1.269	0.255	-0.259	4.978
-2	35.1	6.80	-0.98	1.325	0.257	-0.242	5.162
-1	38.2	7.05	-0.96	1.442	0.266	-0.242	5.418
0	39.80	7.10	-0.96	1.503	0.268	-0.242	5.606
1	43.30	7.50	-0.96	1.635	0.283	-0.247	5.773
2	45.50	7.70	-0.98	1.718	0.291	-0.252	5.909
3	50.10	8.30	-1.00	1.891	0.313	-0.247	6.036
4	52.60	8.30	-0.98	1.986	0.313	-0.247	6.337
5	56.30	8.45	-0.95	2.126	0.319	-0.239	6.663
6	57.90	8.60	-0.91	2.186	0.325	-0.229	6.733
7	59.00	9.50	-0.95	2.228	0.359	-0.239	6.211
8	54.00	14.00	-1.05	2.039	0.529	-0.264	3.857

Table 4 Results for Force Measurement Test with Flap at 45°.



Graph 1 Results for Aerofoil with Flap at 0 Degrees



Graph 2 Results for Aerofoil with Flap at 22.5 Degrees

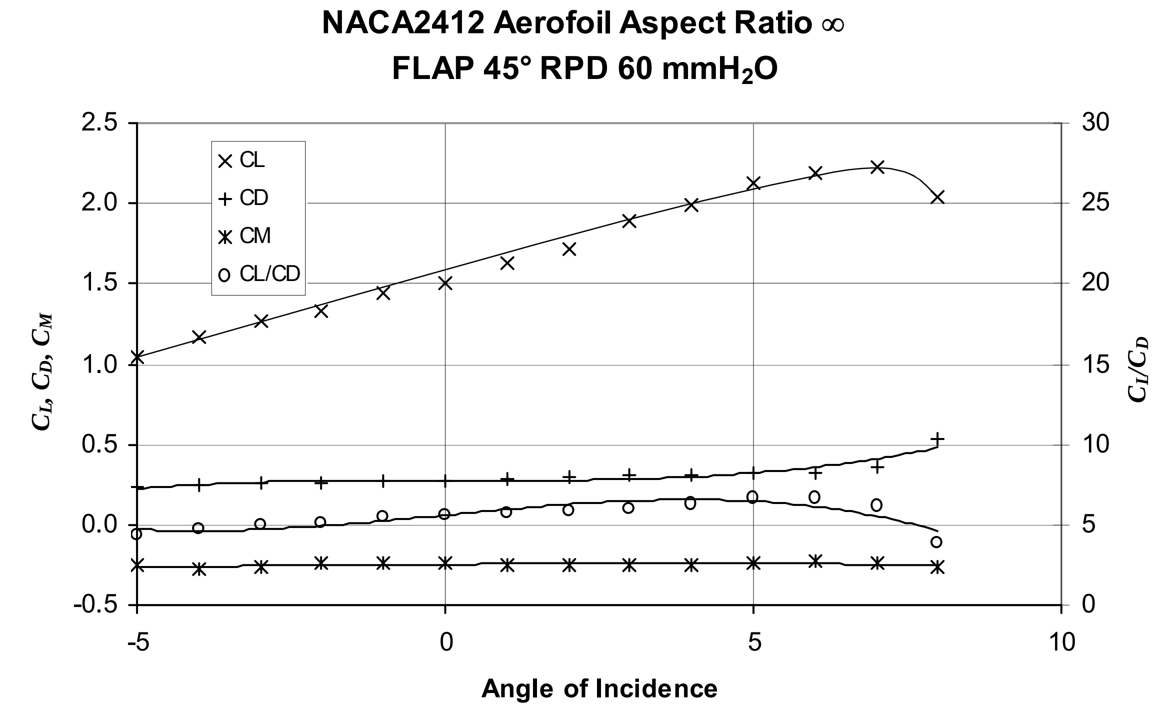
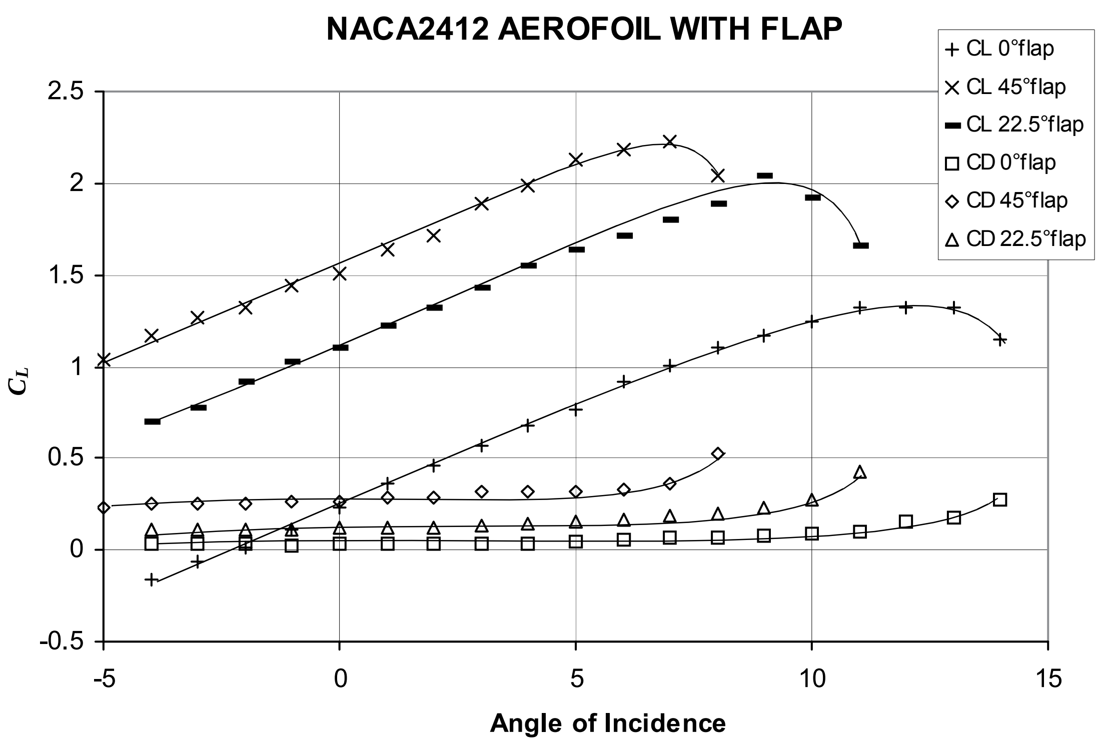


Figure 3 Results for Aerofoil with Flap at 45 Degrees



Graph 3 Results for All Three Flap Angles

References

Aerodynamics

by LJ Clancy

Published in 1991 by Longman Scientific &Technical

ISBN 0582 988802

Maintenance

To clean the apparatus, wipe clean with a damp cloth - do not use abrasive cleaners.

Store the model in a dry and dust free area, suitably covered.

Spare Parts

Refer to the Packing Contents List for any spare parts supplied with the apparatus.

If you require technical assistance or spares, please contact your local TecQuipment agent, or contact TecQuipment direct.

To assist us in processing your request quickly and efficiently, when requesting spares please include the following:

- Your name
- The full name and address of your college, company or institution
- Your email address
- The TecQuipment product name and product reference
- The TecQuipment part number (if known)
- The serial number
- The year of purchase (if known)

Please provide us with as much detail as possible about the parts you require and check the details carefully before contacting us.

If the product is no longer under warranty, TecQuipment will send you a price quotation for your confirmation.

Customer Care

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