Flight Lab: Calculation of C.G

Group D

April 3, 2018

1 Aim of the Experiment

To find the center of Gravity of the Airplane and find the C.G of the airplane as passengers are loaded.

2 Introduction

The Location of center of gravity has great influence on the stability and control of the airplane. An airplane must be designed in such a manner that there is minimum variation of C.G. In this Experiment We need to find out how C.G travels longitudinally when passengers move in and out of airplane.The C.G is further used in determination of neutral point and maneuvering point.

The center of gravity is calculated as follows.

$$x_{c.g} = \frac{x_1 N + x_2 L + x_3 R}{L + N + R}$$

Where:
x_1 is distance of Reference point from Nose wheel
x_2 is distance of Reference point from Rear wheel
L is weight measured in Nose wheel
N is weight measured in left wheel
R is weight measured in Right wheel

For **Piper Saragota Aircraft**: $x_1 = 14.2$ inches,$x_2 = 109.7$ inches.

3 Procedure

1. Find Out Reactions at Nose Wheel, and main Wheels when 5 passengers are sitting.
2. One by one ask each passenger to move out of aircraft and Note down the reactions.
3. Note Down reading in Tabulated Form

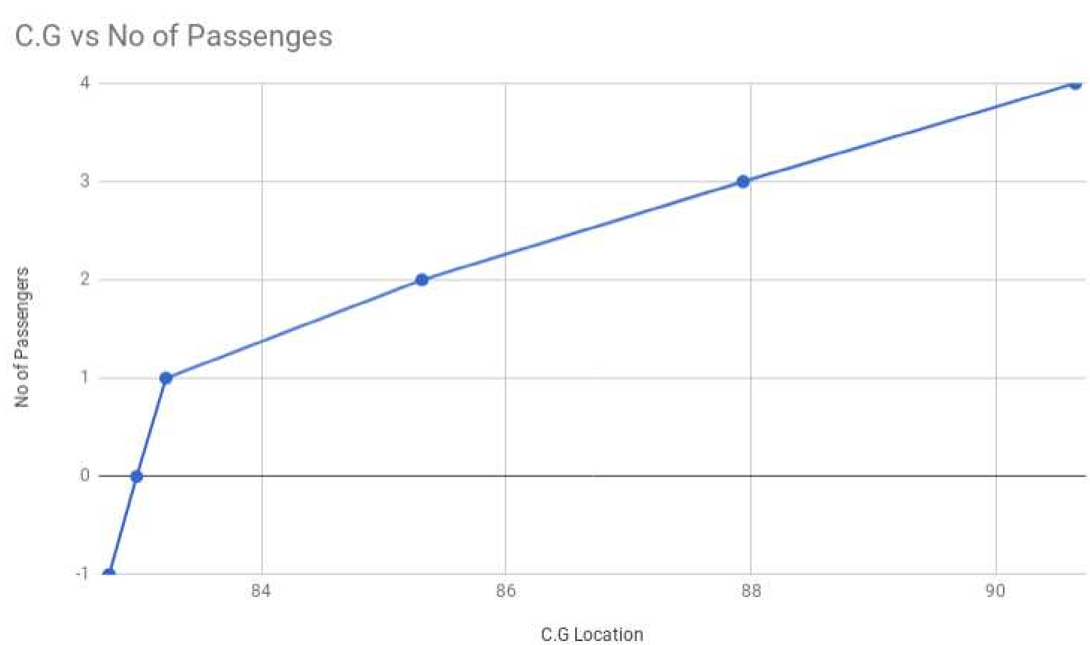
4. Plot a Graph Showing Variation of C.G and number of passengers

4 Record Chart : CG Location

No of Passengers	Left Wheel Reaction (L)	Nose Wheel Reaction (N)	Right Wheel Reaction (R)	Total Weight	$X_{C.G}$ (inches)
P4	603	308	633	1544	90.649481865285
P3	564	338	581	1483	87.9339851652057
P2	500	355	535	1390	85.3097122302158
P1	467	366	487	1320	83.2204545454546
P0	441	343	442	1226	82.9818107667211
Empty	406	325	421	1152	82.7577256944445

Table 1: Observation table

5 Plot



6 Discussions

1) Why this graph look like this?
A)The position of cg is closer to the pilot seat so addition of pilot, co-pilot weights doesn't effect the position much but as the number passengers gets increased and as they sit farther from the C.G the position of cg will shift away from the reference point.From the Graph we can confirm that addition of pilot and co pilots weight change the C.G position little compared to the addition of passengers which changed the C.G

2) What is Range of C.G position drastically.?
A) the position of cg moves away as the number of passengers gets increased with a range of 9 inches (82.98-90.64 inches).

3)Why pilot prefers for having a co-pilot with heavier mass?
A)Heavier mass co-pilot will shift the cg towards the pilot (or will not shift too much away from him) so that he can apply less amount of stick forces to control the aircraft.static Stability is more when the cg is nearer.

Physical Significance

- The position of the C.G is important since it affects the static margin.
- The C.G position is important in case of disturbance to flight angle the stability is affetced by position of C.G as the control to be applied depends on the posotion of Center of gravity.

7 Conclusions

- The Center of Gravity of the Piper Saratoga aircraft is 82.7 inches from the Reference point.
- variation of the C.G with addition of passengers is observed.

Flight Lab: calibration of control surfaces

Group D

April 5, 2018

1 Aim of the Experiment

To Calibrate the Control Surfaces like ailerons and Elevators on airplane to construct a Scale for measurement in flight

2 Introduction

Calibration is the process of configuring an instrument to provide a result for providing sample within an acceptable range. Eliminating the factors that cause inaccuracies is the fundamental aspect of instrumentation design.
In This experiment we will determine the relationship between the control surface deflection angle and the output voltage. Calibration will be performed on Hansa-3 aircraft using inclinometers and data acquisition system. Hansa-3 is manufactured by National Aerospace laboratories, Banglore.The Calibration data is used in the other experiments like estimation of neutral point and maneuvering point. since in these experiments we need to record elevator deflection and aileron deflection.

3 Procedure

1. Fix the inclinometer on the control surface where we have to measure the output voltage of the control surface such as alierons on the wing and elevators on the horizontal stabilizers for specific deflection angle.
2. Connect the Data Acquisition system.
3. Measure the Control surface Deflection using control stick.
4. Measure corresponding output Voltage.
5. Plot a Graph With voltage on X-axis and deflection on y-Axis.
6. Draw a straight line joining the points and measure deflection.

4 Observations Record

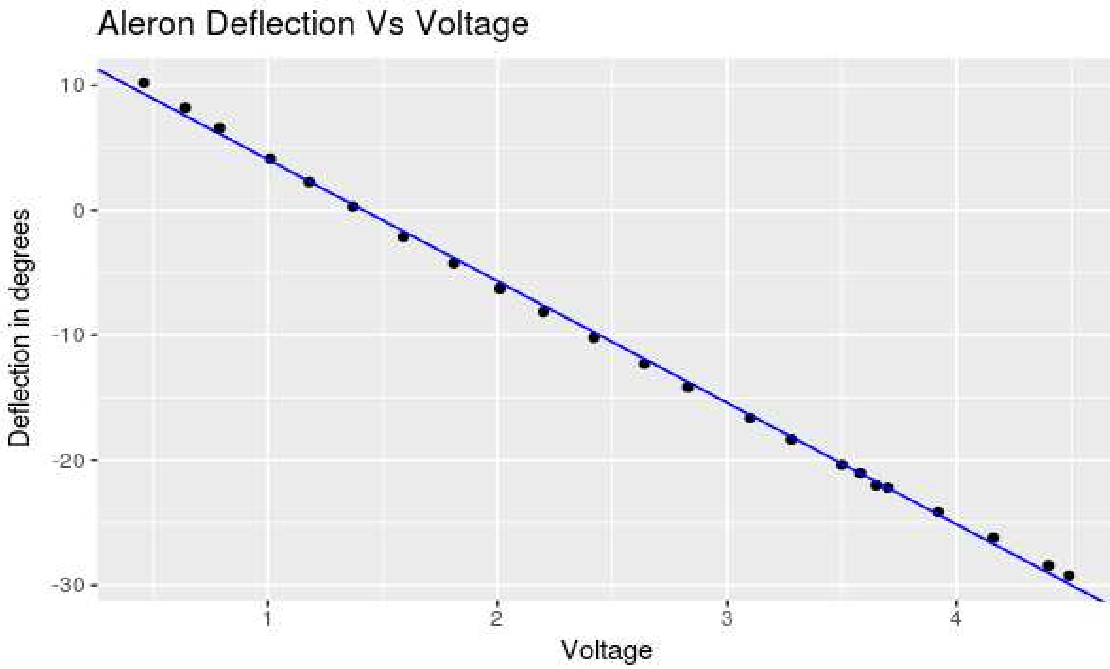
v	θ
0.46	10.21
0.64	8.19
0.79	6059
1.01	4.13
1.18	2.28
1.37	0.3
1.59	-2.12
1.81	-4.26
2.01	-6.27
2.2	-8.14
2.42	-10.19
2.64	-12.28
2.83	-14.17
3.1	-16.62
3.28	-18.35
3.5	-20.38
3.65	-22.02
3.58	-21.05
3.7	-22.2
3.92	-24.16
4.16	-26.24
4.4	-28.45
4.49	-29.26

Table 1: Elevator Calibration Data

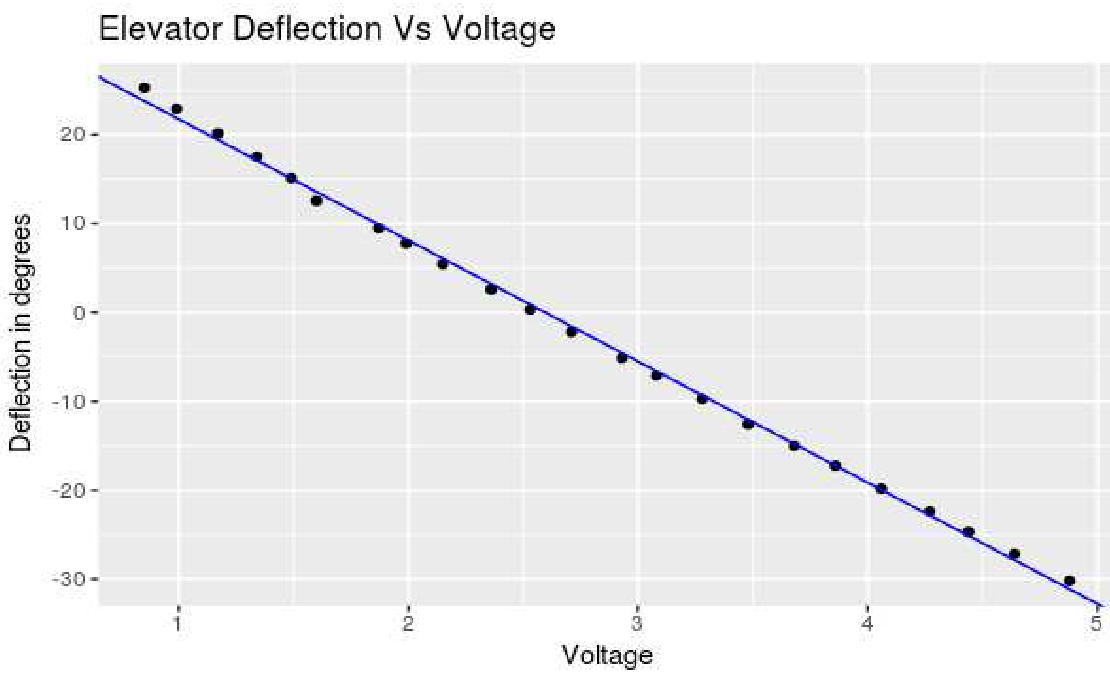
v	θ
0.85	25.26
0.99	22.89
1.17	20.15
1.34	17.5
1.49	15.12
1.6	12.56
1.87	9.49
1.99	7.76
2.15	5.46
2.36	2.57
2.53	0.31
2.71	-2.2
2.93	-5.11
3.08	-7.09
3.28	-9.72
3.48	-12.56
3.68	-14.98
3.86	-17.26
4.06	-19.83
4.27	-22.4
4.44	-24.66
4.64	-27.15
4.88	-30.17

Table 2: Alieron Calibration Data

5 Plot



Aleron Deflection Vs Voltage
Deflection in degrees
10
0
-10
-20
-30
1
2
3
4
Voltage



Elevator Deflection Vs Voltage
Deflection in degrees
20
10
0
-10
-20
-30
1
2
3
4
5
Voltage

6 Discussions

6.1 Importance of Calibration

- The calibration process generally involves using the instrument to test samples of one or more known values called calibrators. The results are used to establish a relationship between the measurement technique used by the instrument and the known values.

- Ideally a product would produce test results that exactly match the sample value, with no error at any point within the calibrated range. This line has been labeled Ideal Results. However, without calibration, an actual product may produce test results different from the sample value, with a potentially large error.

- Calibrating the product can improve this situation significantly. During calibration, the product is taught using the known values of Calibrators 1 and 2 what result it should provide. The process eliminates the errors at these two points, in effect moving the Before Calibration curve closer to the Ideal Results line shown by the After Calibration curve. The Error At Any Point has been reduced to zero at the calibration points, and the residual error at any other point within the operating range is within the manufacturers published linearity or accuracy specification.

6.2 Precautions

- Calibrators should be well maintained in order to reduce the external influences.

- Calibration should take place in secured environment to ensure minimal impact of external vibrations etc

- Random Errors produced can be reduced by producing large number of measurements and taking mean of the experiment.

7 Conclusions

- The Slope of Elevator Deflection vs Voltage plot is -13.6200. intercept is 35.3413

- The Slope of Aleron Deflection vs Voltage plot is -9.73849. intercept is 13.80354

Flight Lab: Drag Polar Estimation using Cessna-206H

Group D

April 10, 2018

1 Aim of the Experiment

To CalculateC_{D0} and k of the Cessna 206H using the Drag polar of the aircraft through Flight testing.

2 Introduction

The purpose of this experiment is to estimate drag polar relationship for Cessna 206H aircraft. The drag polar is the relationship between the lift on an aircraft and its drag, expressed in terms of dependence of the lift coefficient on the drag coefficient. Many performance parameters can be determined from the drag polar such as optimum rate of climb. The drag polar equation may be written as

$$C_D = C_{D0} + KC_L^2$$

where C_D is total coefficient. C_{D0} is the drag coefficient.C_L denotes coffieient of lift and $K = \frac{1}{\pi ARe}$ where AR is aspect ration of the wing and e is oswald efficiency factor. KC_L^2 is the induced drag coefficient of a wing. and unavoidable companion of the Lift of Wing. The other drag are parasite drag and wave drag are included in the C_{D0}.

3 Cruise mode

In this experiment we will take the readings at cruise mode. Cruise is the level portion of the aircraft travel where flight is most fuel efficient. It occurs between ascent and descent phases and is usually the majority of a journey, Technically. cruise consists of heading changes only at a constant airspeed and altitude.for most commercial passenger aircraft. the cruise phase consumes a lot of fuel consumes the majority of fuel, typical speed is 400-500 knots.Commercial aircraft is optimized for cruise phase.

3.1 Instruments for this Experiment

- Airspeed Indicator

- Engine RPM Indicator
- Manifold pressure gauge
- Outside air temperature
- Altimeter
- Stopwatch

3.2 Calculation

Brake horse power Equation

$$BHP = D \cdot V$$
$$D = \frac{\rho V^2 S C_D}{2}$$
$$C_D = C_{D0} + K C_L^2$$
$$BHP = \frac{\rho V^2 S}{2}(C_{D0} + K C_L^2)$$

Now using $L = \frac{\rho V^2 S C_L}{2}$ and also knowing $L = W$ during cruise, we get:

$$BHP = \frac{\rho S C_{D0}}{2} + \frac{2KW^2}{\rho S}$$

The Density correction is applied with the international standard ISA Table

Break Horse Power using Data

$$BHP = \frac{(rpm)(MP)(Ts)(rHP)}{(rrpm)(rMP)(OAT)}$$

3.3 Procedure

- Wait Until altitude is reached.
- Record airspeed indicator, Engine manifold pressure, outside air temperature, RPM of engine during the cruise.
- Obtain Break Horse Power using the Recorded Data.
- Repeat for all Altitudes.
- Power required for the Steady level flight is given by

$$P_{req} = \frac{1}{2}\rho V^3 S C_{D0} + \frac{\frac{W^2}{\frac{1}{2}\rho V S}}{\pi A R e \rho S}$$

- The Above equation is modified as

$$PV = (\frac{1}{2}\rho S C_{D0})V^4 + \frac{2W^4}{\pi A R e \rho S}$$

- The above equation is a straight line $Y = mX + c$ with

$$Y = PV$$
$$m = \frac{1}{2}\rho S C_{D0}$$
$$e = \frac{2}{\pi A R e \rho S}$$

We can calculate the slope and intercept from data We can calculate the required parameters using above equations

4 Climb Mode

Following Take off Airplane Has to climb to maintain safe and economic Flight. Climb may be achieved by increasing angle of attack on the wing, or by increasing the thrust of the engine to increasing speed in some cases both techniques are used.

As lift decreases with density a climb once initiated, ends when lift is equal to weight at that point steady flight.

4.1 Calculations

Consider Equilibrium of Forces.

$$T - D - W \sin\gamma = 0$$
$$L - W \cos\gamma = 0$$

Now By rearranging terms we get that

$$\frac{VT - VD}{W} = V \sin\gamma$$
$$RC = \frac{dh}{dt} = V \sin\gamma$$

This can be evaluated at various speeds and the values of v corresponding to maximum rate of climb can be obtained.

4.2 Rate of Climb

if the time to traverse the altitude band is also recorded then we can actually calculate tru rate of climb of the aircraft.
Let observed temperature is T_0 and the standard temperature at the altitude is T_s, Then Pressure recorded since the pressure change is always the true pressure difference for altitude change shown by the altimeter.

$$\delta p = -\rho_s g(\delta H)_p$$

s:Standard altitude
p:Pressure altitude
δH_T is true change in altitude, will have same temperature difference.

$$\delta p = -\rho T g(\delta H)_T$$
$$\frac{\delta H_T}{\delta H_p} = \frac{\rho_s}{\rho_T} = \frac{T_0}{T_s}$$

Therefore ,

$$RC_{true} = RC_{observed} * \frac{T_0}{T_s}$$

4.3 Procedure

- Record the Take off Weight(W_T).
- Note the initial and final altitudes (h_1 h_2) and time instants (t_1 t_2).
- Repeat for different climb speeds.
- Record the weight after the landing.and consider average weight for calculations.
- Find out the rate of climb for each velocity and corresponding angle of climb Γ using following equations.

$$RC \approx \frac{h_2 - h_1}{t_2 - t_1} \cdot RC_{true} = RC_{observed} \times \frac{T_0}{T_s}$$

- Plot rate of climb vs speed.
- Plot angle of climb vs speed
- From the plots find Maximum rate of climb and maximum angle of climb and the corresponding velocities.

5 Observations Record

Cessna 206H parameters

Parameter	Value
Rated RPM	2700
Manifold pressure	29.92 in Hg
Sea Level Tempeature	288.15K
Wing Area (S)	16.16 m2
Wing Span (b)	10.9728m
Rated Hp (rHP)	223.709 kW

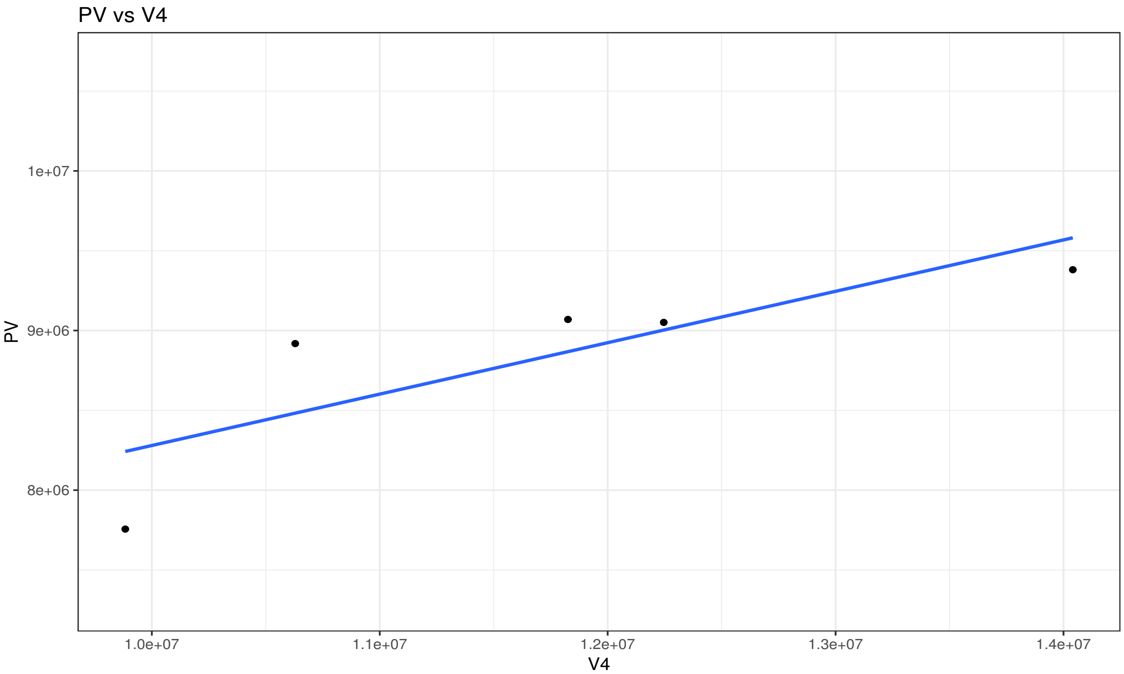
V	MP	RPM	OAT	Altitude
93	19.5	2270	32	500
99	21.1	2260	30	1000
95	20.9	2310	28	1600
93	22.9	2300	28	2020
90	22	2440	26	2400
94	21.2	2380	24	3040

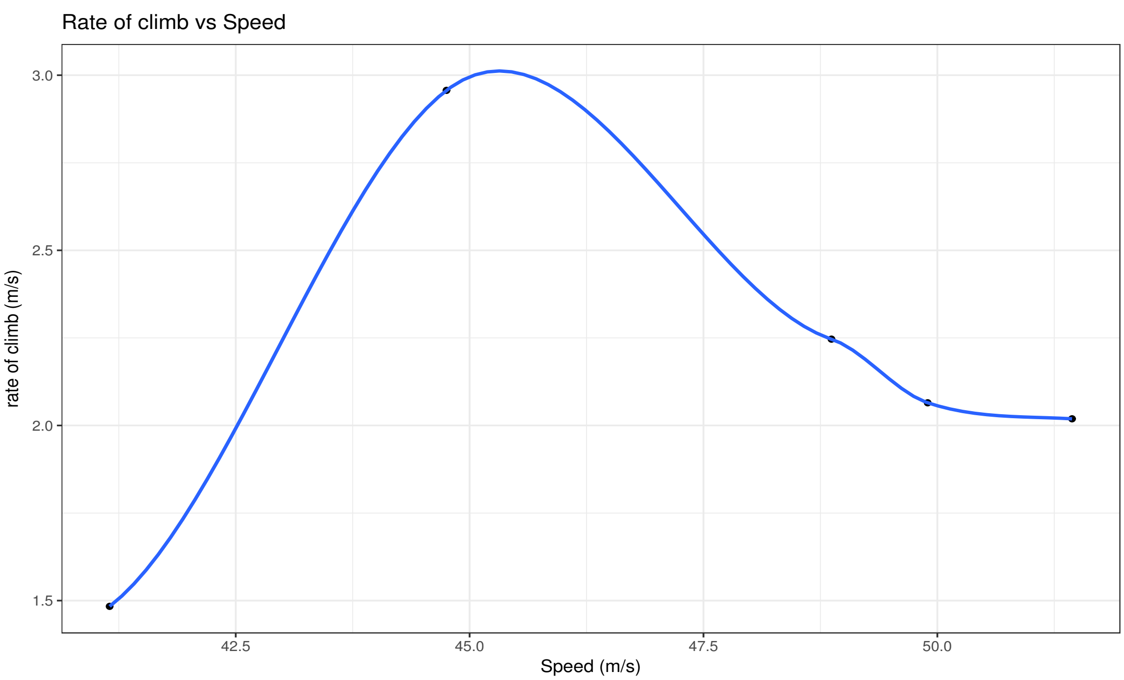
Table 1: Cruise Expreiment Data

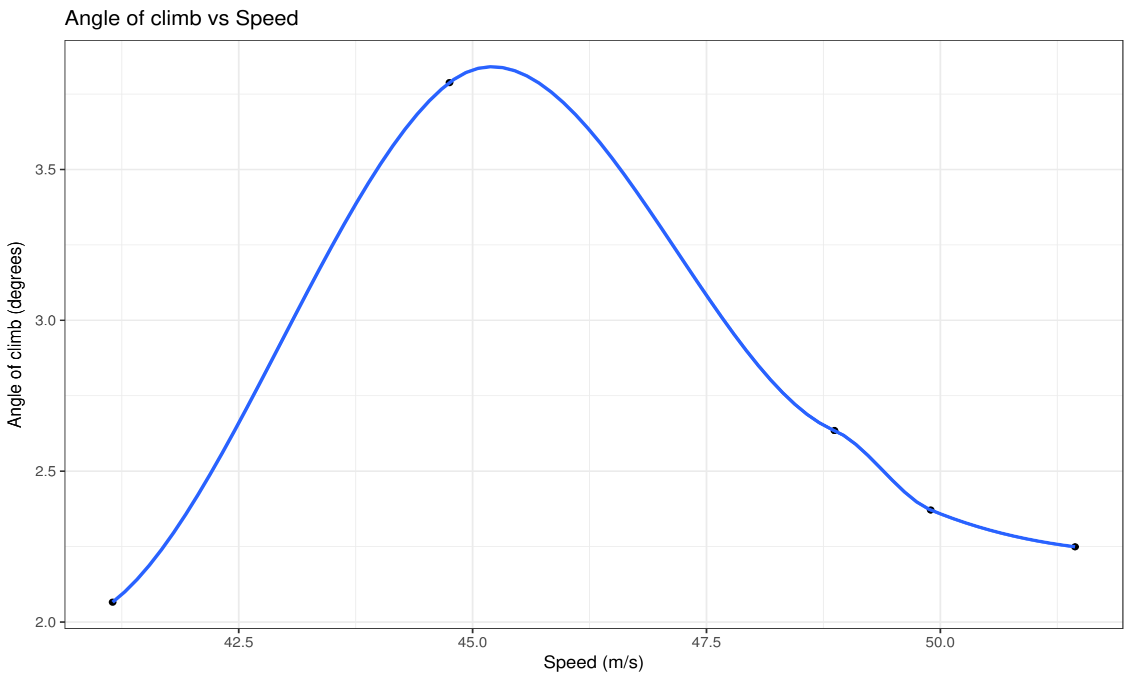
V	RPM	MP	OAT	h1	h2	Time
97	2530	25.2	31	500	1000	77.91
95	2370	25.3	30	1000	1500	71.37
80	2550	24.6	28	1500	2000	107.36
87	2550	24.4	27	2000	2500	53.69
100	2540	24	25	2500	3000	78.1

Table 2: Climb Experiment Data

6 Plot


PV vs V4
1e+07
9e+06
8e+06
PV
1.0e+07
1.1e+07
1.2e+07
1.3e+07
1.4e+07
V4


Rate of climb vs Speed
3.0
2.5
2.0
1.5
rate of climb (m/s)
42.5
45.0
47.5
50.0
Speed (m/s)



7 Calculation

- The value of Aspect ratio is calculated as 7.456
- The line Equation of the Cruise equation for the graph is given by $Y = .03220X + 5.059e + 06$
- From the Formulas above we can calculate the $C_{D0} = 0.0326$ and $e = 0.21565$
- the value of k is equal to 0.20

8 Discussions

- The Drag Polar is the relationship between the lift on an aircraft and its drag, expressed in terms of the dependence of the lift coefficient on the drag coefficient.
- Drag Polar helps to determine many performance parameter such as the power required at different altitudes and speed, the optimum speed and altitude for cruise. and optimum rate of climb.
- We can verify the rate of climb obtained from the altitude and time measurement with help of temperature readings at the corresponding altitude.Since we know the

standard atmosphere lapse rate, we can calculate the altitude from the difference between temperature readings. Since we know the time, we can get the rate of climb from the above mentioned. And hence verify the the rate of climb. Both the observed and the rate of temperature changes should have a similar profile.

- Oswald's efficiency factor is a generalized parameter connected with an aircraft's aerodynamic efficiency . Specifically, for a parabolic drag polar, there exists a dependency.The Oswald efficiency factor e reflects the airplane lifting properties deterioration caused by the distortion of an elliptical lift distribution and accounts for the non-ellipticity of the lift distribution, the increase of profile drag of the wing, fuselage, tail plane, nacelles and various interference effects with angle of attack
- There is a discrepancy between expected and actual value obtained because oswald efficiency factor depends upon the area of fuselage and the wing leading edge cross-sectional shape which can enforce the suction at the leading edge zone and decrease drag due to lift.
- All the measurements are taken from FPS system is a system of units. Here all our calculations are done in SI units the appropriate conversions are applied before calculation procedure.
- The script used for the Generation of plots can be found here.
- The average weight of aircraft is used in the formulas which is average of take off and landing weight.

9 Conclusions

- The coefficients C_{D0} and e are calculated.
- The Plots for the Angle of Climb and rate of climb with the variation of velocity are plotted.
- The maximum rate of climb is found around 45.2m/s.
- the maximum angle of climb is also found around 45m/s.

Flight Lab: Determination of Neutral Point and Maneuvering Point from Flight Tests

Group D

April 10, 2018

Aim of the Experiment

To find Neutral Point and Maneuvering Point of NAL Hansa-3 aircraft by performing flight experiments.

Introduction

In this experiment our aim is to determine the stick fixed (Elevator Fixed) neutral point from flight test. Neutral Point is the center of gravity position where the pitching moment is independent of the angle of attack. It is called airplane aerodynamic center, when the C.G. is at this point the airplane is neutrally stable.

Estimation of the Neutral point (Stick Fixed)

$$\delta_{etrim} = \delta_{e0} + \left(\frac{\partial \delta_e}{\partial C_{L_{trim}}} \right)$$

$$\frac{\partial \delta_e}{\partial C_{L_{trim}}} = \frac{-\partial C_m}{C_{m\delta_e}}$$

N.P. is the C.G. location where,

$$\frac{\partial \delta_e}{\partial C_{L_{trim}}} = 0$$

Instruments Used

1 Airspeed indicator

2 Elevator angle indicator

3 Altimeter

4 OAT gauge

5 Bank Angle Indicator

Procedure

1 Fly at different center of gravity configuration and execute cruise.

2 Estimate corresponding $C_{L_{trim}} = \frac{2W/s}{0.5\rho V^2}$ and record δ_e.

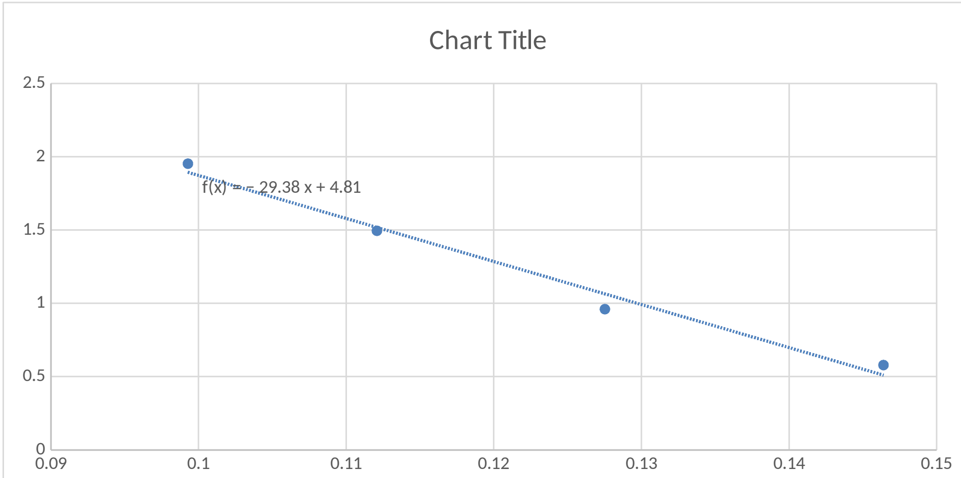
3 Plot $\delta_{e_{trim}}$ vs $C_{L_{trim}}$

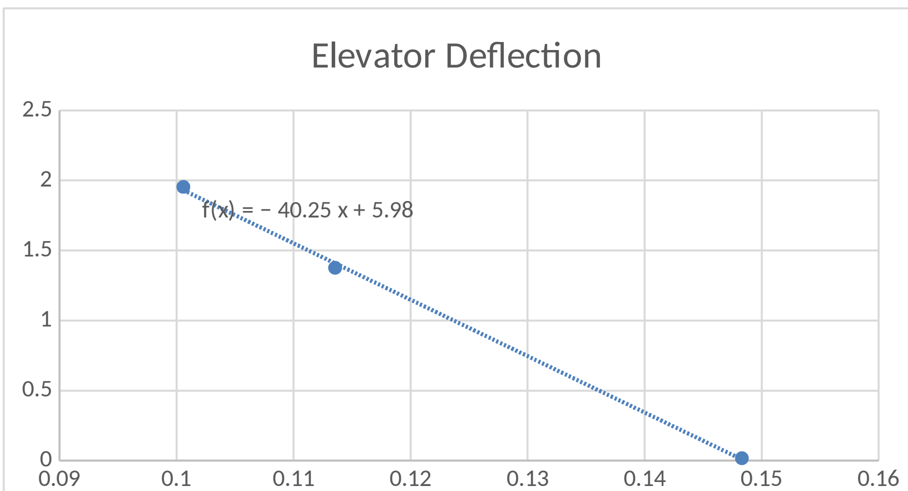
4 Cross plot $\left[\frac{\partial \delta_e}{\partial C_L} \right]_{trim}$ vs $\acute{x}_{cg}$ to get neutral point

Observations and Results

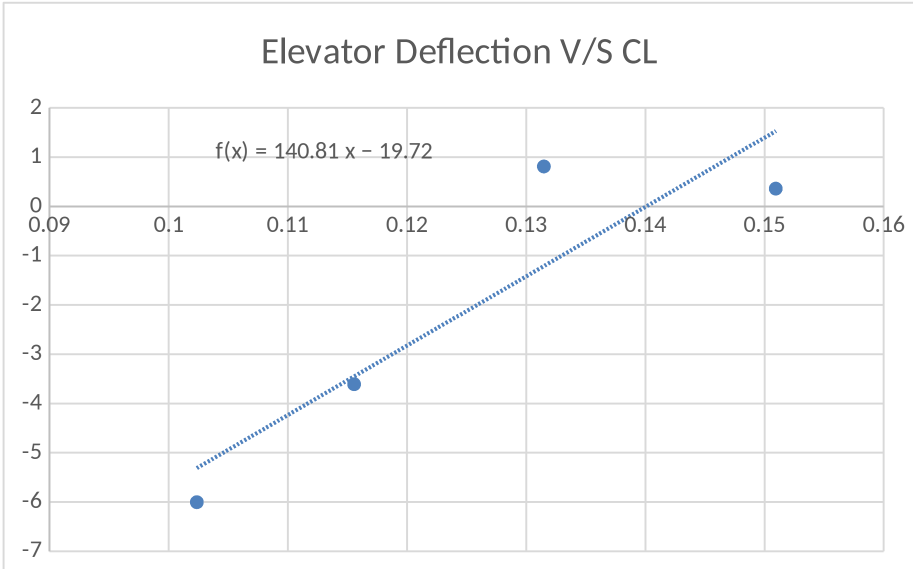
Take-off Total Weight (Kg)	727			
Landing Total Weight (Kg)	723			
Average Weight (Kg)	725			
Pilot Weight (Kg)	85			
Student Weight (Kg)	71			
Label	**Mass**	**Weight (Kg)**	**Moment Arms (mm)**	**Moment (N-mm)**
Plane Structure	550	5401	1027.52	5549635.52
Pilot+ Student	156	1531.92	1130	1731069.60
Fuel (Average)	19	186.58	1800	335844.00
	Total Weight	**7119.5**	**Total Moment**	**7616549.12**
			CG	**1069.82**

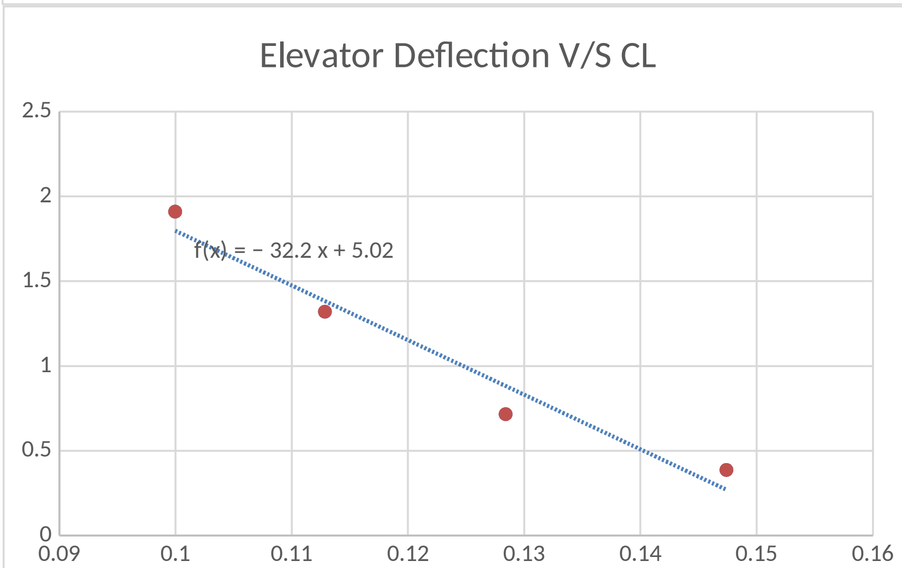
Velocity (Knots)	Velocity(m/s)	CL (Trim)	Elevator Deflection (degrees)
70	36.01108	0.146393961	0.5788
75	38.5833	0.127525406	0.96037
80	41.15552	0.112082877	1.495
85	43.72774	0.099284486	1.9529

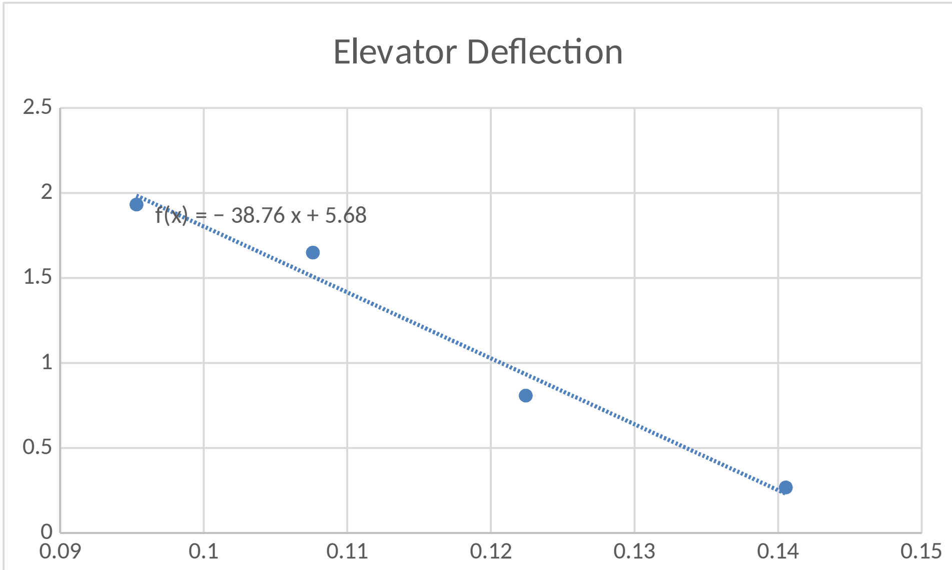


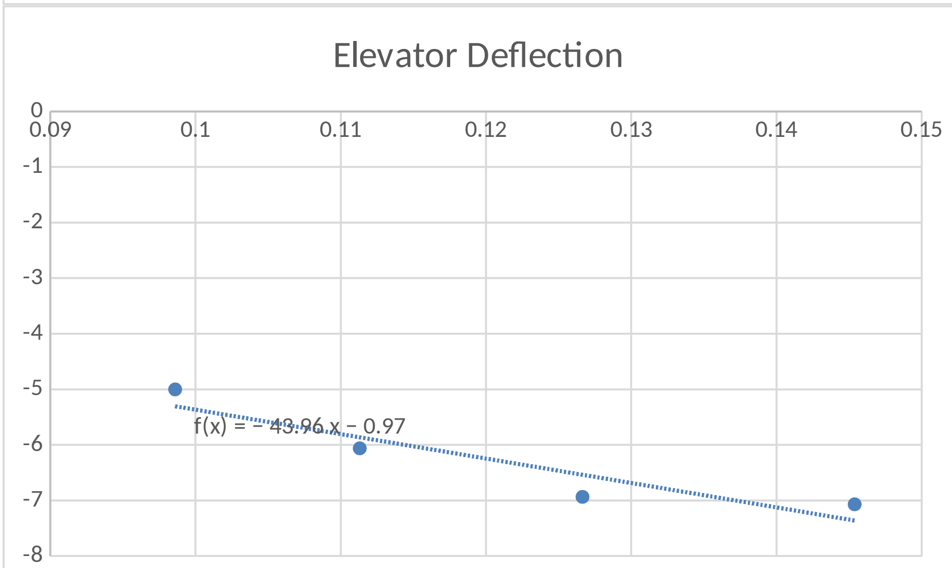


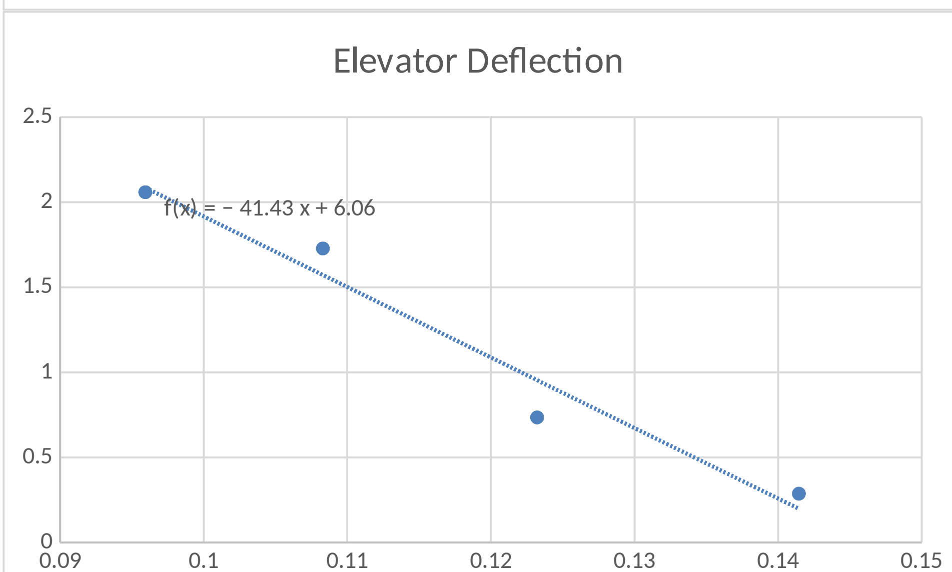
All Groups graphs:


Elevator Deflection V/S CL
f(x) = 140.81 x − 19.72
2
1
0
-1
-2
-3
-4
-5
-6
-7
0.09
0.1
0.11
0.12
0.13
0.14
0.15
0.16


Elevator Deflection V/S CL
f(x) = − 32.2 x + 5.02
2.5
2
1.5
1
0.5
0
0.09
0.1
0.11
0.12
0.13
0.14
0.15
0.16


Elevator Deflection
f(x) = − 38.76 x + 5.68
2.5
2
1.5
1
0.5
0
0.09
0.1
0.11
0.12
0.13
0.14
0.15


Elevator Deflection
f(x) = − 43.96 x − 0.97
0
-1
-2
-3
-4
-5
-6
-7
-8
0.09
0.1
0.11
0.12
0.13
0.14
0.15


Elevator Deflection
f(x) = − 41.43 x + 6.06
2.5
2
1.5
1
0.5
0
0.09
0.1
0.11
0.12
0.13
0.14
0.15

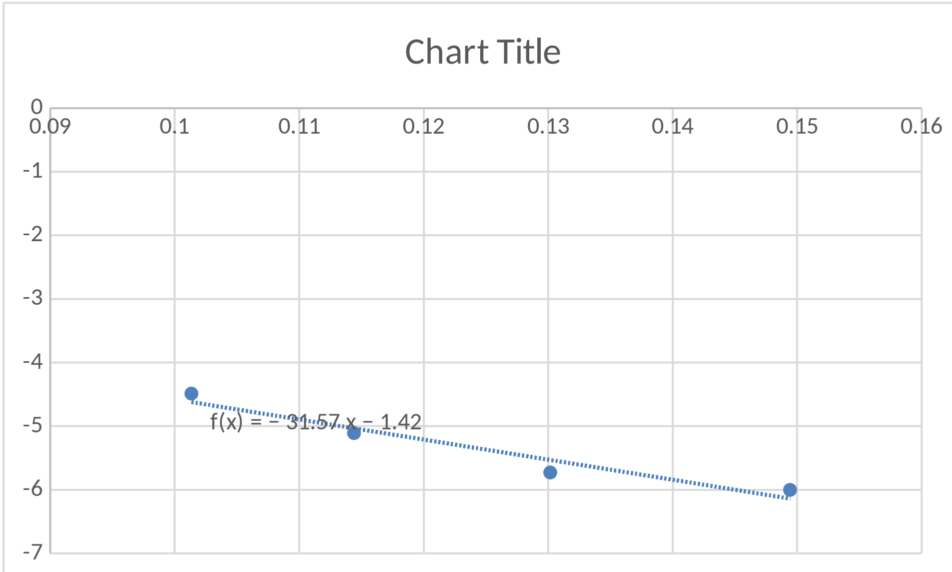


Fig 1: Graph – δe vs CL (at trim)

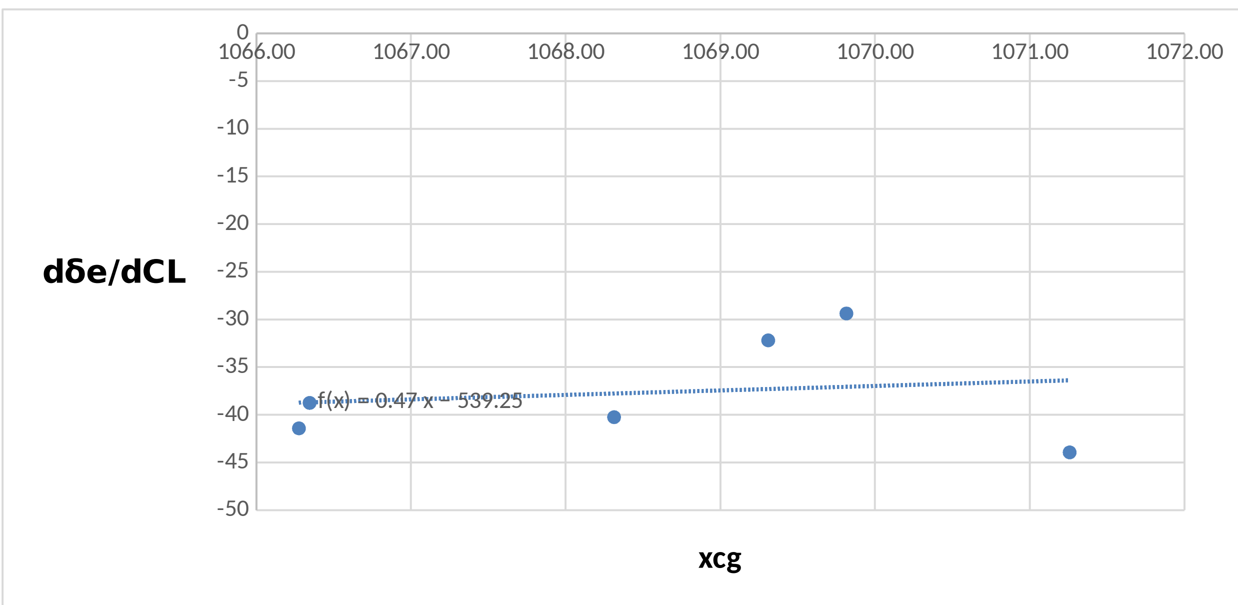


Fig 2: Graph – dδe/dCL vs different cg locations

Equation of the straight line $y=0.469x-539.25$

Neutral point is the x location when y=0, thus **Neutral point is at x=1148.8 mm**.

Discussions

1. Was there any incident related to this experiment ?

   The experiment was performed carefully in NAL Hansa and therefore there was no report of any accident.

2. Why is V' is used instead of V_∞ for relative wind at tail ?

   Tail aerodynamics is influenced by two inference points. Due to the finite wing, the airflow at the tail was deflected downwards by the downwash.
   Due to the retarding force of skin friction and pressure drag over the finite wing, the airflow reaching the tail got slowed.

3. What is the physical relevance of this experiment ?

   For static longitudinal stability, the neutral point and thus the static margin are very important factors. If an aircraft in flight suffers a disturbance in pitch that causes an increase (or decrease) in angle of attack, it is desirable that the aerodynamic forces on the aircraft cause a decrease (or increase) in angle of attack so that the disturbance does not cause a continuous increase (or decrease) in angle of attack. This is longitudinal static stability. Static margin is a concept used to characterize the static longitudinal stability and controllability of aircraft.

4. What is the significance of the experiment for commercial flying ?

   The knowledge of static margin and point of neutral stability is a must for any aircraft. For the stick fixed stability, elevator trim angle, Coefficient of Lift at trim etc are required.