FLIGHT CONTROLS LABORATORY

LAB MANUAL

Course Code	**:**	**AAE102**
Regulation	**:**	**R16**
Semester	**:**	**V**
Branch	**:**	**AE**

PREPARED BY

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INSTITUTE OF AERONAUTICAL ENGINEERING
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DEPARTMENT OF AERONAUTICAL ENGINEERING

VISION AND MISSION OF THE DEPARTMENT

VISION

To build a strong community of dedicated graduates with expertise in the field of aeronautical science and engineering suitable for industrial needs having a sense of responsibility, ethics and ready to participate in aerospace activities of national and global interest.

MISSION

To actively participate in the technological, economic and social development of the nation through academic and professional contributions to aerospace and aviation areas, fostering academic excellence and scholarly learning among students of aeronautical engineering.

INSTITUTE OF AERONAUTICAL ENGINEERING

(AUTONOMOUS)

Dundigal, Hyderabad - 500 043

Certificate

This is to certify that it is a bonafied record of practical work done by Sri/Kum.__________________________ bearing the Roll No._______________of______class _________________ branch in the Engineering Physics laboratory during the academic year ____________ under our supervision.

Head of the Department **Lecture In-Charge**

External Examiner **Internal Examiner**

INSTITUTE OF AERONAUTICAL ENGINEERING

(AUTONOMOUS)

Dundigal, Hyderabad-500043

DEPARTMENT OF AERONAUTICAL ENGINEERING

PROGRAM OUTCOMES	
PO1	**Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The Engineer and Society** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice **.**
PO7	**Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES	
PSO1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products
PSO2	**Problem solving skills:** Imparted through simulation language skills and general purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles.
PSO3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies.
PSO4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats.

FLIGHT CONTROLS LABORATORY

SYLLABUS

FLIGHT CONTROLS LABORATORY

OBJECTIVE:

The objective of this lab is to teach students and give knowledge about the simulation of aircraft performance in the flight simulator and access the parameters that are affecting the performance of the flight with different boundary conditions. This lab also enables the students to write the MATLAB scripts for the analysis of problems like evaluating equations of motion with one DOF, two DOF and three DOF and also the dynamics of the aircraft. This laboratory also enhances experimental skills to the students to assess the performance and static stability of an aircraft.

OUTCOMES:

The course should enable the students to:

I. Learn the basic MATLAB simulation of un-accelerated flight for takeoff, cruise and landing conditions by solving equations of motions.

II. Understand the concept behind the conventional and unconventional airfoil performance and stability conditions.

III. Identify the functions of the basic controls like ailerons, elevators and rudders used in typical airplanes.

IV. Understand the dynamics of the aircraft flight simulator and it’s functioning in different flight conditions like takeoff, landing and cruise condition.

ATTAINMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Experiment No	Program Outcomes Attained	Program Specific Outcomes Attained
1	PO1,PO2,PO5	PSO1,PSO2
2	PO1,PO2,PO5	PSO1,PSO2
3	PO1,PO2,PO5	PSO1,PSO2
4	PO1,PO2, PO5	PSO1,PSO2
5	PO1,PO2,PO5	PSO1,PSO2
6	PO1,PO2,PO5	PSO1,PSO2
7	PO1,PO2,PO4	PSO1,PSO2
8	PO1,PO2,PO4	PSO1,PSO2
9	PO1,PO2,PO4	PSO1,PSO3
10	PO1,PO2,PO4	PSO1,PSO3
11	PO1,PO2,PO4	PSO1, PSO3
12	PO1,PO2,PO4	PSO1, PSO3

EXPERIMENT 1

INTRODUCTION TO FLIGHT WITH MAT LAB

Aim:
To solve basic mathematical equations related to pressure and density used in aircraft performance with basic loops.

Software used:
MAT LAB

Formulae:

$$\frac{P}{P_1} = e^{-[g_o/(RT)](h-h_1)}$$

$$\frac{\rho}{\rho_1} = e^{-[g_o/(RT)](h-h_1)}$$

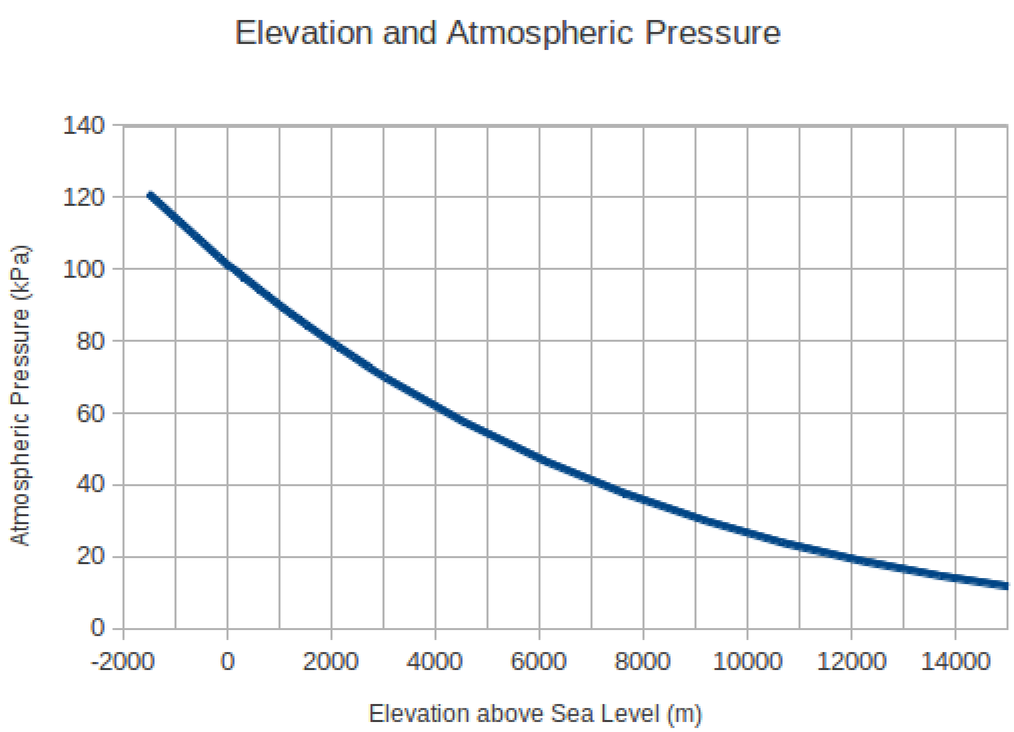

Fig 1.1. Plot of atmosphere pressure and Elevation

Program code:

```
% pressure and density variation with altitude
g=9.81;
t=288.15;
h1=0;
h=0:1000:10000;
R=287;
P1=101325;
D1=1.225;
P=P1*exp((-g/(R*t))(h-h1));
D=D1*exp((-g/(R*t))(h-h1));
plot(P,h);
plot(D,h);
```

Observations:

A variation of pressure and density with altitude is observed to be an exponential decay.

Result:

Variation of pressure and density with altitude is observed and plotted using basic mathematical tools in MATLAB.

Viva questions:

1. What is MATLAB?
2. What is linspace?
3. Write ratio command?
4. Give formula for pressure variation with altitude?
5. Give formula for density variation with altitude?
6. Give formula for gravity variation with altitude?

EXPERIMENT 2

ISA PROFILE FOR FLIGHT

Aim:
To extract data of atmospheric conditions at different altitudes for aircraft equation of motion.

Software used:
MAT LAB

Formulae:

$$\frac{T - T_1}{h - h_1} = \frac{dT}{dh} \equiv \alpha$$

Variables	Gradient layer	Isothermal layer
Pressure	$\frac{P}{P_1} = \left(\frac{T}{T_1}\right)^{-\frac{g_0}{\alpha R}}$	$\frac{P}{P_1} = e^{-[g_o/(RT)](h-h_1)}$
Density	$\frac{\rho}{\rho_1} = \left(\frac{T}{T_1}\right)^{-\left(\frac{g_0}{\alpha R}+1\right)}$	$\frac{\rho}{\rho_1} = e^{-[g_o/(RT)](h-h_1)}$

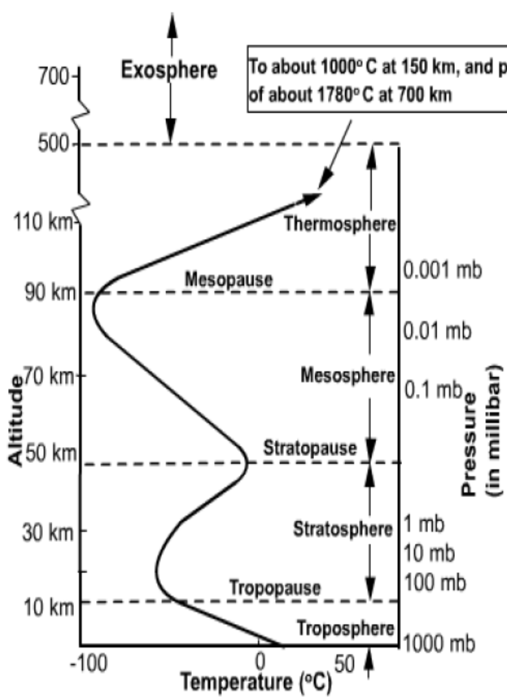

Fig.2.1 Plot of Altitude versus temperature and pressure

Lapse rate for 0 m to 11000 m= -0.0065
Lapse rate for 11000 m to 20000 m= 0
Lapse rate for 20000 m to 32000 m= 0.001

Program code:

```
% ISA PROFILE
% t(1)=288.15;
% x(1)=0;
%  i=1;
%  for h=1000:1000:11000
%  x(i+1)=h;
%  lp=-0.0065;
%  alt(i)=x(i+1)-x(i);
%  t(i+1)=t(i)+lp*alt(i);
%  i=i+1;
%  end
clc;
clear all;
t(1)=288.15;
x(1)=0;
i=1;
for h=1000:1000:32000
x(i+1)=h;
 if x(i)>=0 && x(i)<=11000
lp=-0.0065;
alt(i)=x(i+1)-x(i);
t(i+1)=t(i)+lp*alt(i);
elseif x(i)>=11000 && x(i)<=20000
 t2(i)=t(end);
lp=0;
alt(i)=x(i+1)-x(i);
t(i+1)=t2(i)+lp*alt(i);
else
 %disp('a')
t3(i)=t(end);
lp=0.001;
alt(i)=x(i+1)-x(i);
 t(i+1)=t3(i)+lp*alt(i);
end
i=i+1;
end
plot(t,x)
xlabel('temperature')
ylabel('altitute')
```

Observations:

Variation of pressure and density with altitude is observed to be an exponential decay in isothermal region. It is observed that aircraft can move from sea level conditions to stratosphere because of decrease in density and pressure.

Result:

Data of atmospheric conditions at different altitudes for aircraft equation of motion is extracted and plotted.

Viva questions:

1. What is MATLAB?
2. What is linspace?
3. Write ratio command?
4. Write the syntax for loop?
5. Write the syntax for if, elseif loop?
6. Give formula for pressure variation with altitude?
7. Give formula for density variation with altitude?
8. Give formula for gravity variation with altitude?

EXPERIMENT 3

EQUATION OF MOTION WITH ONE DOF

Aim:
To solve the equation of motion governed by one DOF using MATLAB tools.

Software used:
MATLAB

Formulae:

$$v_x(0) = v_{x_0}$$
$$v_z(0) = v_{z_0}$$
$$x(0) = x_0$$
$$z(0) = z_0$$

Differential equation

$$\dot{v}_x(t) = 0$$
$$\dot{v}_z(t) = -g \quad (z \text{ positive } \mathbf{up})$$
$$\dot{x}(t) = v_x(t)$$
$$\dot{z}(t) = v_z(t)$$

Integral

$$v_x(T) = v_{x_0}$$
$$v_z(T) = v_{z_0} - \int_0^T g\,dt = v_{z_0} - gT$$
$$x(T) = x_0 + v_{x_0}T$$
$$z(T) = z_0 + v_{z_0}T - \int_0^T gt\,dt = z_0 + v_{z_0}T - gT^2/2$$

Program code:

```
%one D.O.F Equation of motion
g = 9.8;
 t = 0:0.1:40;
 vx0 = 10;
 vz0 = 100;
 x0 = 0;
 z0 = 0;
 vx1 = vx0;
 vz1 = vz0 – g*t;
 x1 = x0 + vx0*t;
 z1 = z0 + vz0*t - 0.5*g*t.* t;
 function xdot = FlatEarth(t,x)
% x(1) = vx
% x(2) = vz
% x(3) = x
% x(4) = z
 g = 9.8;
 xdot(1) = 0;
 xdot(2) = -g;
 xdot(3) = x(1);
 xdot(4) = x(2);
 xdot=xdot'
 end
 tspan = 40;
xo = [10;100;0;0];
[t1,x1] = ode45('FlatEarth',tspan,xo);
```

Observations:

There is no variation of axial velocity and the path is parabolic.

Result:

Using ODE45 the equations of motion with one D.O.F is solved and it is seen that path is parabolic.

EXPERIMENT 4

EQUATION OF MOTION WITH TWO DOF

Aim:
To solve the equation of motion governed by two DOF using MATLAB tools.

Software used:
MATLAB

Formulae:

$$-D\sin\gamma + L\cos\gamma + T\sin(\gamma+\theta_T) - mg = \left(\frac{dv}{dt}\sin\gamma + v\cos\gamma\frac{d\gamma}{dt} - v\cos\gamma\frac{d\phi}{dt}\right)m..$$

$$-D\cos\gamma - L\sin\gamma + T\cos(\gamma+\theta_T) = \left(\frac{dv}{dt}\cos\gamma - v\sin\gamma\frac{d\gamma}{dt} + v\sin\gamma\frac{d\phi}{dt}\right)m.$$

From kinematic equations we have,

$$\frac{d\phi}{dt} = -\frac{v}{r}\cos\gamma................$$

$$-v\sin\gamma = \frac{dh}{dt}, \sin\gamma \approx \gamma \text{ if } \gamma << 1$$

$$\frac{dr}{dt} = \frac{dh}{dt} = -v\sin\gamma...................$$

Program code:

Observations:
Flight path angle plays an important role to predict the trajectory of an aircraft.

Result:
Using Euler integration the equations of motion with two D.O.F is solved and it is seen that flight path angle plays a major role.

EXPERIMENT 5

AERODYNAMIC PERFORMANCE STUDY OF A SYMMETRICAL AIRFOIL

Aim:

Carryout aerodynamic performance study of a symmetrical airfoil and draw a plot for Cl/Cd verses angles of attack.

Materials and Equipments used:

1. Low speed wind tunnel
2. Six component balance
3. Wing model of the symmetrical airfoil
4. Tools like spanner, screw driver
5. Spirit level to measure angle of attack of the tested wing

Methodology

A) Formulae:

Glide Performance: Range (R)= Altitude (h) * L/D or h* C_L/C_D --------------------------------(1)

Landing Performance:

$$S_{G_{landing}} = \frac{W}{g\rho S(C_D - \mu_r C_L)} \ln\left[1 + \frac{(C_D - \mu_r C_L)\rho S V_{TD}^2}{2(-T + \mu_r W)}\right]$$

--(2)

Descend Performance:

$$= \frac{C_D}{C_L^{3/2}} \sqrt{\frac{2W}{\rho S}}$$

--(3)

Range Performance:

$$R = \sqrt{\frac{2W}{\rho_\infty S}} \frac{1}{TSFC} \frac{C_L^{1/2}}{C_D} \ln\frac{W_0}{W_1}$$

------------------------------(4)

Endurance Performance:

$$:\frac{1}{TSFC}\left(\frac{C_L}{C_D}\right)\ell n\,\frac{W_0}{W_1}$$ ---(5)

Thrust Required

$T_{req} = W/(C_L/ C_D)$ ---(6)

B) Model Description and Drawing:

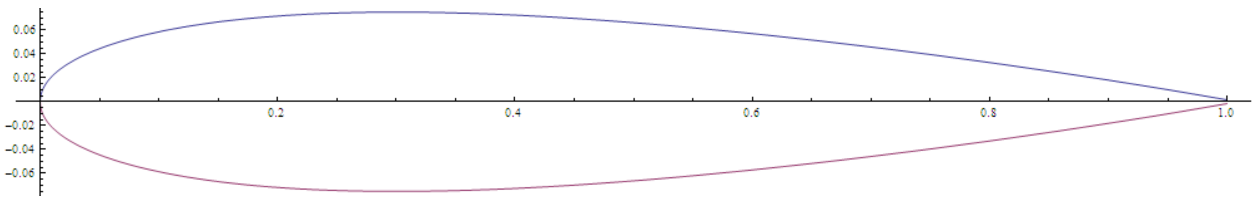

Fig.1.1. Symmetrical Airfoil NACA 0012

C) Procedure:

1. Fix the model inside the test section and make sure the angle of attack (AOA) is as per requirement.
2. Fix the Six component balance as per given condition and connect with power plugs.
3. Make it zero setting.
4 See and ensure safety of Wind Tunnel and make sure that no foreign object debris (FOD) are present.
5. Note the initial value of inclined tube manometer (hi).
6. Start the Wind Tunnel slowly and run for few minutes in that slow speed.
7. Now increase the Wind Tunnel RPM as per required speed in steps and should stabilize in that speed.
8. Observed the reading in Six Component display and note it down the Lift and Drag values.
9. Find the Coefficient of Lift and Drag by dividing $\frac{1}{2} \rho V^2 S$.
10. Prepare the table and fill all the column.
11. Plot a graph the Cl/Cd verses angle of attack.
12. Find the maximum Cl/Cd by drawing tangent from the vertical axis and get the corresponding value of AOA.
13. This AOA is the required AOA for best performance cruise condition.

Table:

S.N	Velocity m/s	AOA (Deg)	Lift (N)	Drag (N)	C_L	C_D	CL/CD	$CD/CL^{3/2}$	$CL^{1/2}/CD$

D) Result and discussion:

Write the physics behind the result. Write and discuss the importance of the result. Give significant point of interest and your logic behind the result.

Conclusions:

In this write the result main point obtained. How it can be applied for real scenario?

Safety Precautions:

1. Use apron and shoes during lab.
2. Follow the instruction of the faculty.
3. Do not leave any FOD inside the wind tunnel.
4. Do not operate or start the wind tunnel by your own.
5. Make sure that all electrical plugs and equipments and fixed before starting the wind tunnel.
6. Do not change the position or AOA during running of the wind tunnel.

Viva questions:

1. What is aerodynamic performance?
2. What is glide?
3. What is reference area?
4. What is density?
5. What is free stream velocity?
6. What is the importance of maximum C_L/C_D?
7. What is the AOA?
8. What angle of attack is the best for cruise flight?
9. What is Symmetrical Airfoil?
10. What is the meaning of NACA0012?
11. How it differs from NACA 2312?
12. Where is the maximum thickness to chord ratio in Symmetrical Airfoil?
13. What is the importance of location of the maximum t/c?
14. What is climb of an aircraft?
15. What is the landing and takeoff of an aircraft?

EXPERIMENT 6

AERODYNAMIC PERFORMANCE STUDY OF A CORRUGATED AIRFOIL

Aim:
Carryout aerodynamic performance study of a symmetrical corrugated airfoil and draw a plot for Cl/Cd verses angles of attack.

Materials and Equipments used:
1. Low speed wind tunnel
2. Six component balance
3. Wing model of the symmetrical airfoil
4. Tools like spanner, screw driver
5. Spirit level to measure angle of attack of the tested wing

Methodology

A) Formulae:

Glide Performance: Range (R)= Altitude (h) * L/D or h* Cl/Cd --------------------------------(1)

Landing Performance:

$$S_{G_{landing}} = \frac{W}{g\rho S(C_D - \mu_r C_L)} \ln\left[1 + \frac{(C_D - \mu_r C_L)\rho S V_{TD}^2}{2(-T + \mu_r W)}\right]$$ ---(2)

Descend Performance:

$$= \frac{C_D}{C_L^{3/2}}\sqrt{\frac{2W}{\rho S}}$$ ---(3)

Range Performance:

$$R = \sqrt{\frac{2W}{\rho_\infty S}}\frac{1}{TSFC}\frac{C_L^{1/2}}{C_D}\ln\frac{W_0}{W_1};$$ ------------------------------(4)

Endurance Performance:

$$: \frac{1}{TSFC}\left(\frac{C_L}{C_D}\right)\ln\frac{W_0}{W_1} \quad \text{---(5)}$$

Thrust Required

$$T_{req} = W/(C_L/ C_D) \quad \text{---(6)}$$

B) Model Description and Drawing:

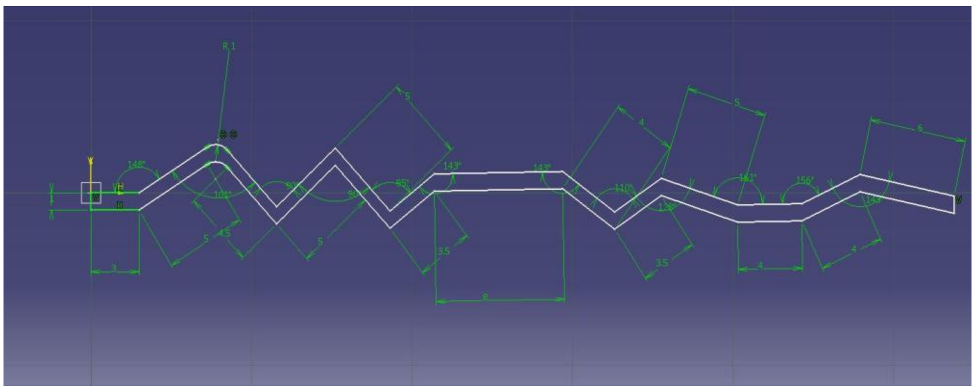

Fig.2.1. Corrugated Airfoil with dimensions CAD Model

C) Procedure:

1. Fix the model inside the test section and make sure the angle of attack (AOA) is as per requirement.
2. Fix the Six component balance as per given condition and connect with power plugs.
3. Make it zero setting.
4 See and ensure safety of Wind Tunnel and make sure that no foreign object debris (FOD) are present.
5. Note the initial value of inclined tube manometer (hi).
6. Start the Wind Tunnel slowly and run for few minutes in that slow speed.
7. Now increase the Wind Tunnel RPM as per required speed in steps and should stabilize in that speed.
8. Observed the reading in Six Component display and note it down the Lift and Drag values.
9. Find the Coefficient of Lift and Drag by dividing ½ ρ V^2 S.
10. Prepare the table and fill all the column.
11. Plot a graph the Cl/Cd verses angle of attack.
12. Find the maximum Cl/Cd by drawing tangent from the vertical axis and get the corresponding value of AOA.
13. This AOA is the required AOA for best performance cruise condition.

Table:

S.N	Velocity m/s	AOA (Deg)	Lift (N)	Drag (N)	C_L	C_D	CL/CD	$CD/CL^{3/2}$	$CL^{1/2}/CD$

Result and discussion:

Write the physics behind the result. Write and discuss the importance of the result. Give significant point of interest and your logic behind the result.

Conclusions:

In this write the result main point obtained. How it can be applied for real scenario?

Safety Precautions:

1. Use apron and shoes during lab.
2. Follow the instruction of the faculty.
3. Do not leave any FOD inside the wind tunnel.
4. Do not operate or start the wind tunnel by your own.
5. Make sure that all electrical plugs and equipments and fixed before starting the wind tunnel.
6. Do not change the position or AOA during running of the wind tunnel.

Viva questions:

1. What is aerodynamic performance?
2. What is glide?
3. What is reference area?
4. What is density?
5. What is free stream velocity?
6. What is the importance of maximum C_L/C_D?
7. What is the AOA?
8. What angle of attack is the best for cruise flight?
9. What is Symmetrical Airfoil?
10. What is the meaning of NACA0012?
11. How it differs from NACA 2312?
12. Where is the maximum thickness to chord ratio in Symmetrical Airfoil?
13. What is the importance of location of the maximum t/c?
14. What is climb of an aircraft?
15. What is the landing and takeoff of an aircraft?

EXPERIMENT 7

AERODYNAMIC PERFORMANCE STUDY OF A DELTA WING AIRCRAFT

Aim:

Carryout aerodynamic performance study of a Delta Wing aircraft model and draw a plot for C_L/C_D verses angles of attack.

Materials and Equipments used:

1. Low speed wind tunnel
2. Six component balance
3. Wing model of the symmetrical airfoil
4. Tools like spanner, screw driver
5. Spirit level to measure angle of attack of the tested wing

Methodology

A) Formulae:

Glide Performance: Range (R)= Altitude (h) * L/D or h* (C_L/C_D) --------------------------------(1)

Landing Performance:

$$S_{G_{landing}} = \frac{W}{g\rho S(C_D - \mu_r C_L)} \ln\left[1 + \frac{(C_D - \mu_r C_L)\rho S V_{TD}^2}{2(-T + \mu_r W)}\right]$$ ---(2)

Descend Performance:

$$= \frac{C_D}{C_L^{3/2}} \sqrt{\frac{2W}{\rho S}}$$ --(3)

Range Performance:

$$R = \sqrt{\frac{2W}{\rho_\infty S}} \frac{1}{TSFC} \frac{C_L^{1/2}}{C_D} \ln \frac{W_0}{W_1}$$ ------------------------------(4)

Endurance Performance:

$$= \frac{1}{TSFC}\left(\frac{C_L}{C_D}\right)\ln\frac{W_0}{W_1} \qquad \text{---(5)}$$

Thrust Required

$$T_{req} = W/(C_L/ C_D) \qquad \text{---(6)}$$

B) Model Description and Drawing:

Fig.7.1. Delta Wing Aircraft Model

C) Procedure:

1. Fix the model inside the test section and make sure the angle of attack (AOA) is as per requirement.
2. Fix the Six component balance as per given condition and connect with power plugs.
3. Make it zero setting.
4 See and ensure safety of Wind Tunnel and make sure that no foreign object debris (FOD) are present.
5. Note the initial value of inclined tube manometer (hi).
6. Start the Wind Tunnel slowly and run for few minutes in that slow speed.
7. Now increase the Wind Tunnel RPM as per required speed in steps and should stabilize in that speed.
8. Observed the reading in Six Component display and note it down the Lift and Drag values.
9. Find the Coefficient of Lift and Drag by dividing ½ ρ V^2 S.
10. Prepare the table and fill all the column.
11. Plot a graph the C_L/C_D verses angle of attack.

12. Find the maximum C_L/C_D by drawing tangent from the vertical axis and get the corresponding value of AOA.
13. This AOA is the required AOA for best performance cruise condition.

Table:

S.N	Velocity m/s	AOA (Deg)	Lift (N)	Drag (N)	C_L	C_D	CL/CD	$CD/CL^{3/2}$	$CL^{1/2}/CD$

Result and discussion:
Write the physics behind the result. Write and discuss the importance of the result. Give significant point of interest and your logic behind the result.

Conclusions:
In this write the result main point obtained. How it can be applied for real scenario?

Safety Precautions:

7. Use apron and shoes during lab.
8. Follow the instruction of the faculty.
9. Do not leave any FOD inside the wind tunnel.
10. Do not operate or start the wind tunnel by your own.
11. Make sure that all electrical plugs and equipments and fixed before starting the wind tunnel.
12. Do not change the position or AOA during running of the wind tunnel.

Viva questions:

1. What is aerodynamic performance?
2. What is glide?
3. What is reference area?
4. What is density?
5. What is free stream velocity?
6. What is the importance of maximum C_L/C_D?
7. What is the AOA?
8. What angle of attack is the best for cruise flight?
9. What is Symmetrical Airfoil?
10. What is the meaning of NACA0012?
11. How it differs from NACA 2312?
12. Differentiate between static and dynamic pressure.
13. Where the velocity is maximum in cambered airfoil?
14. Where is the maximum thickness to chord ratio in Symmetrical Airfoil?
15. What is the importance of location of the maximum t/c?
16. What is climb of an aircraft?
17. What is the landing and takeoff of an aircraft?

EXPERIMENT 8

AERODYNAMIC STATIC STABILITY STUDY OF A SYMMETRICAL AIRFOIL

Aim:

Carryout aerodynamic static stability study of a symmetrical airfoil and draw a plot for Cm verses angles of attack.

Materials and Equipments used:

1. Low speed wind tunnel
2. Six component balance
3. Wing model of the symmetrical airfoil
4. Tools like spanner, screw driver
5. Spirit level to measure angle of attack of the tested wing

Methodology

A) Formulae:

The longitudinal stability of an aircraft refers to the aircraft's stability in the pitching plane - the plane which describes the position of the aircraft's nose in relation to its tail and the horizon.

$$Cm_0 > 0 \quad \text{----------------------------------} \quad (1)$$

$$dCm/d\alpha < 0 \quad \text{----------------------------------} \quad (2)$$

B) Model Description and Drawing:

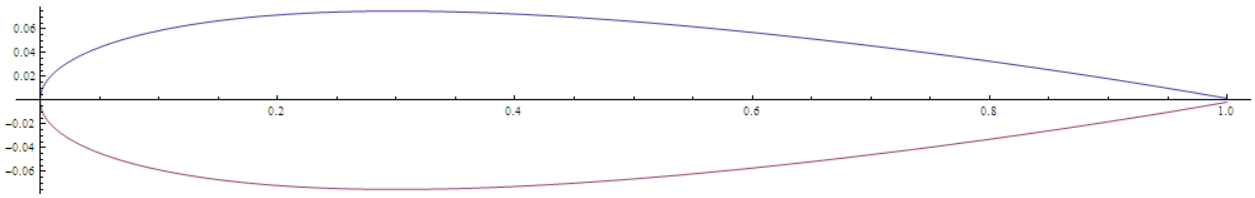

Fig.8.1. Symmetrical Airfoil NACA 0012

2. Aircraft stability ($dC_m/dC_N < 0$ which is the same as $dC_m/d\alpha < 0$). If this value is negative, the airplane is stable.

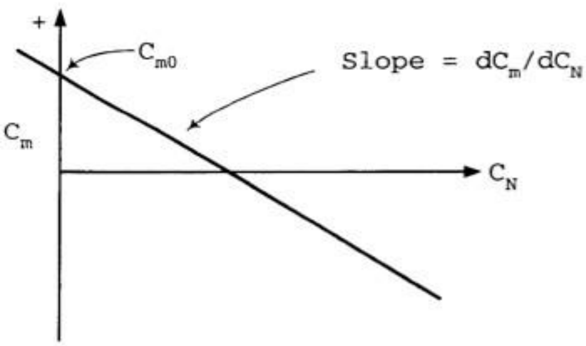

Figure 13-2. C_m versus C_N.

Note: The notation $C_{m,} C_N$ is equivalent to dC_m/dC_N.

If a disturbance causes a lower C_N (lower α) then it also causes a positive C_m which increases C_N (and α) and vice versa.

Fig.8.2. Aircraft Stability Criteria

C) Procedure:

1. Fix the model inside the test section and make sure the angle of attack (AOA) is as per requirement.
2. Fix the Six component balance as per given condition and connect with power plugs.
3. Make it zero setting.
4 See and ensure safety of Wind Tunnel and make sure that no foreign object debris (FOD) are present.
5. Note the initial value of inclined tube manometer (hi).
6. Start the Wind Tunnel slowly and run for few minutes in that slow speed.
7. Now increase the Wind Tunnel RPM as per required speed in steps and should stabilize in that speed.
8. Observed the reading in Six Component display and note it down the Cm values.

9. Find the moment and dividing ½ ρ V^2 S c. This will give Cm that is coefficient of moment.
10. Prepare the table and fill the entire column.
11. Plot a graph the Cm verses angle of attack.
12. Find the maximum Cm by drawing tangent from the vertical axis and get the corresponding value of AOA where it cuts the x axis called trim.
13. This AOA is the required AOA for trimmed condition.

Result and discussion:
Write the physics behind the result. Write and discuss the importance of the result. Give significant point of interest and your logic behind the result.

Conclusions:
In this write the result main point obtained. How it can be applied for real scenario?

Safety Precautions:
1. Use apron and shoes during lab.
2. Follow the instruction of the faculty.
3. Do not leave any FOD inside the wind tunnel.
4. Do not operate or start the wind tunnel by your own.
5. Make sure that all electrical plugs and equipments and fixed before starting the wind tunnel.
6. Do not change the position or AOA during running of the wind tunnel.

Viva questions:

1. What is aerodynamic performance?
2. What is glide?
3. What is reference area?
4. What is density?
5. What is free stream velocity?
6. What is the importance of maximum Cl/Cd?
7. What is the AOA?
8. What angle of attack is the best for cruise flight?
9. What is Symmetrical Airfoil?
10. What is the meaning of NACA0012?
11. How it differs from NACA 2312?
12. Where is the maximum thickness to chord ratio in Symmetrical Airfoil?
13. What is the importance of location of the maximum t/c?
14. What is climb of an aircraft?
15. What is the landing and takeoff of an aircraft?

EXPERIMENT 9

AERODYNAMIC STATIC STABILITY STUDY OF A CORRUGATED AIRFOIL

Aim:

Carryout aerodynamic static stability analysis of a corrugated airfoil and draw a plot for Cm verses angles of attack and ascertain its stability at given Speed and Reynolds number.

Materials and Equipments used:

1. Low speed wind tunnel
2. Six component balance
3. Wing model of the symmetrical airfoil
4. Tools like spanner, screw driver
5. Spirit level to measure angle of attack of the tested wing

Methodology

A) Formulae:

The longitudinal stability of an aircraft refers to the aircraft's stability in the pitching plane - the plane which describes the position of the aircraft's nose in relation to its tail and the horizon.

$$Cm_0 > 0 \quad \text{----------------------------------} \quad (1)$$
$$dCm/d\alpha < 0 \quad \text{---------------------------------} \quad (2)$$

B) Model Description and Drawing:

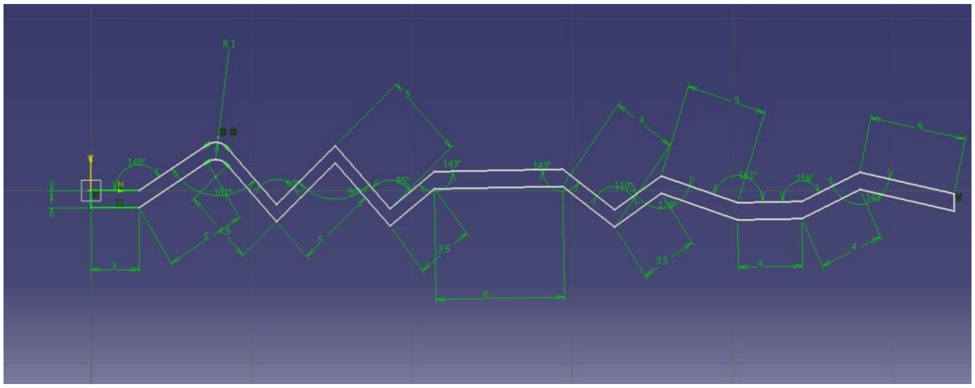

Fig.9.1. Corrugated Airfoil with dimensions CAD Model

C) Procedure:

1. Fix the model inside the test section and make sure the angle of attack (AOA) is as per requirement.
2. Fix the Six component balance as per given condition and connect with power plugs.
3. Make it zero setting.
4 See and ensure safety of Wind Tunnel and make sure that no foreign object debris (FOD) are present.
5. Note the initial value of inclined tube manometer (hi).
6. Start the Wind Tunnel slowly and run for few minutes in that slow speed.
7. Now increase the Wind Tunnel RPM as per required speed in steps and should stabilize in that speed.
8. Observed the reading in Six Component display and note it down the Cm values.
9. Find the moment and dividing $\frac{1}{2} \rho V^2 S c$. This will give Cm that is coefficient of moment.
10. Prepare the table and fill the entire column.
11. Plot a graph the Cm verses angle of attack.
12. Find the maximum Cm by drawing tangent from the vertical axis and get the corresponding value of AOA where it cuts the x axis called trim.
13. This AOA is the required AOA for trimmed condition.

Result and discussion:

Write the physics behind the result. Write and discuss the importance of the result. Give significant point of interest and your logic behind the result.

Conclusions:

In this write the result main point obtained. How it can be applied for real scenario?

Safety Precautions:

1. Use apron and shoes during lab.
2. Follow the instruction of the faculty.
3. Do not leave any FOD inside the wind tunnel.
4. Do not operate or start the wind tunnel by your own.
5. Make sure that all electrical plugs and equipments and fixed before starting the wind tunnel.
6. Do not change the position or AOA during running of the wind tunnel.

Viva questions:

1. What is aerodynamic performance?
2. What is glide?
3. What is reference area?
4. What is density?
5. What is free stream velocity?
6. What is the importance of maximum Cl/Cd?
7. What is the AOA?
8. What angle of attack is the best for cruise flight?
9. What is Symmetrical Airfoil?
10. What is the meaning of NACA0012?
11. How it differs from NACA 2312?
12. Where is the maximum thickness to chord ratio in Symmetrical Airfoil?
13. What is the importance of location of the maximum t/c?
14. What is climb of an aircraft?
15. What is the landing and takeoff of an aircraft?

EXPERIMENT 10

AERODYNAMIC STATIC STABILITY STUDY OF A DELTA WING AIRCRAFT

Aim:

Carryout aerodynamic longitudinal static stability study of a delta wing aircraft and draw a plot for Coefficient of Moment verses angles of attack.

Materials and Equipments used:

1. Low speed wind tunnel
2. Six component balance
3. Wing model of the symmetrical airfoil
4. Tools like spanner, screw driver
5. Spirit level to measure angle of attack of the tested wing

Methodology

A) Formulae:

The longitudinal stability of an aircraft refers to the aircraft's stability in the pitching plane - the plane which describes the position of the aircraft's nose in relation to its tail and the horizon.

$Cm_0 > 0$ ---------------------------------- (1)

$dCm/d\alpha < 0$---------------------------------(2)

B) Model Description and Drawing:

Fig.10.1. Delta Wing Aircraft Model

C) Procedure:

1. Fix the model inside the test section and make sure the angle of attack (AOA) is as per requirement.
2. Fix the Six component balance as per given condition and connect with power plugs.
3. Make it zero setting.

4 See and ensure safety of Wind Tunnel and make sure that no foreign object debris (FOD) are present.

5. Note the initial value of inclined tube manometer (hi).
6. Start the Wind Tunnel slowly and run for few minutes in that slow speed.
7. Now increase the Wind Tunnel RPM as per required speed in steps and should stabilize in that speed.
8. Observed the reading in Six Component display and note it down the Cm values.
9. Find the moment and dividing $\frac{1}{2} \rho V^2 S c$. This will give Cm that is coefficient of moment.
10. Prepare the table and fill the entire column.
11. Plot a graph the Cm verses angle of attack.
12. Find the maximum Cm by drawing tangent from the vertical axis and get the corresponding value of AOA where it cuts the x axis called trim.
13. This AOA is the required AOA for trimmed condition.

Result and discussion:

Write the physics behind the result. Write and discuss the importance of the result. Give significant point of interest and your logic behind the result.

Conclusions:

In this write the result main point obtained. How it can be applied for real scenario?

Safety Precautions:

7. Use apron and shoes during lab.
8. Follow the instruction of the faculty.
9. Do not leave any FOD inside the wind tunnel.
10. Do not operate or start the wind tunnel by your own.
11. Make sure that all electrical plugs and equipments and fixed before starting the wind tunnel.
12. Do not change the position or AOA during running of the wind tunnel.

Viva questions:

1. What is aerodynamic performance?
2. What is glide?
3. What is reference area?
4. What is density?
5. What is free stream velocity?
6. What is the importance of maximum Cl/Cd?
7. What is the AOA?
8. What angle of attack is the best for cruise flight?
9. What is Symmetrical Airfoil?
10. What is the meaning of NACA0012?
11. How it differs from NACA 2312?
12. Where is the maximum thickness to chord ratio in Symmetrical Airfoil?
13. What is the importance of location of the maximum t/c?
14. What is climb of an aircraft?
15. What is the landing and takeoff of an aircraft?

EXPERIMENT 11

SIMULATION OF TAKEOFF AND LANDING PERFORMANCE

Aim:
To perform take off, cruise, co-ordinate turn and landing with aircraft in the flight simulator in the normal weather conditions, the flight is from ‘Begumpet airport’ to ‘Hakimpet airport’.

Apparatus:

1. FSTF’ (flight simulation test facility).
2. Booklet of performance specifications of that particular aircraft.
3. Booklet of checklist for that particular aircraft.
4. Software to feed the conditions of flight.

Description:

1. ‘Flight simulator is a test facility’ which provides the feel, how an airplane flies and performs the maneuvers.
2. Analyse the effects of aerodynamic derivatives.
3. FSTF is used to understand the dynamics and demonstrate the control of flight vehicles.
4. ‘Flight Simulation Test Facility is provided with basic cockpit requirements like PFD, MFD, ‘yoke’ used for rolling and pitching, ‘pedals near legs’ are used for yawing and also different functional elements and switches are placed.

Procedure:

1. Firstly turn on the flight simulator and sit in the pilot seat and adjust the seat for comfortable look over the cockpit switches and outside.
2. Take the cabin check checklist and compare all the switches according to the list and confirm everything is right.
3. Always put the parking break when the aircraft is on the ground and turn on the ‘PFD’ (primary flight display) and ‘MFD’ (multi-functional display).
4. Now increase the fuel air mixture to 70 present and start the engine by starting the ignition also put the throttle 50 present.
5. Increase the throttle to certain level such that required RPM is obtained.
6. Put the flaps down to 20 degrees and remove the parking brakes and now the planes starts to move forward on the runway.
7. Generate the yaw moment using the rudder on the runway as the propeller generates the unnecessary right moment on the plane.
8. When the plane reaches to 70 miles per hour slight give the pitch up moment in the plane by pulling the yoke towards us and climbs till the 3000 ft. and stabilize the plane and pull the flaps up.
9. Now watch the multi-functional display and plan the flight and move according to the c-ordinates given in the navigation display.
10. Remember not to exceed the pitch angle, roll angle, altitude and speed of aircraft.

11. After travelling in the given co-ordinates for a distance take the checklist and check the cockpit before landing check and get ready to perform landing.
12. Put the flaps down and reduce the altitude gradually as we reaching the runway as well as maintain the speed.
13. Keep the plane towards the direction of the runway landing line wait for the signals and watch for PAPI lights (precision approach and path indicator lights) for safety.
14. Aim for the two light glowing PAPI light which is a sign of the good approach towards the runway.
15. Slowly land the plane using rudder, when the plane touches the runway reduces the throttle to zero and flaps in upper position.
16. Now apply the airbrakes by pushing the both the legs, when the plane stops keep the fuel air mixture zero and turn on the parking breaks.

Result:

Hence safe take-off, cruise, co-ordinate turns and landing was performed between Begumpet airports to Hakimpet airport.

EXPERIMENT 12

SIMULATION OF TAKEOFF AND LANDING PERFORMANCE WITH WIND CONDITIONS

Aim:

To perform take off, cruise, co-ordinate turn and landing with aircraft in the flight simulator in the gusty weather conditions, the flight is from ‘Begumpet airport’ to ‘Hakimpet airport’.

Apparatus:

1. ‘FSTF’ (flight simulation test facility).
2. Booklet of performance specifications of that particular aircraft.
3. Booklet of checklist for that particular aircraft.
4. Software to feed the conditions of flight.

Description:

1. ‘Flight simulator is a test facility’ which provides the feel, how an airplane flies and performs the maneuvers.
2. Analyse the effects of aerodynamic derivatives.
3. FSTF is used to understand the dynamics and demonstrate the control of flight vehicles.
4. ‘Flight Simulation Test Facility is provided with basic cockpit requirements like PFD, MFD, ‘yoke’ used for rolling and pitching, ‘pedals near legs’ are used for yawing and also different functional elements and switches are placed.
5. In this aspect of simulation heavy winds are added to the weather which makes the pilot to control the aircraft difficult.
6. In this process the use of control surfaces is more to maintain the steady flight conditions so the pilot must be more alert than in the normal weather conditions.

Procedure:

1. Firstly turn on the flight simulator and sit in the pilot seat and adjust the seat for comfortable look over the cockpit switches and outside.
2. Take the cabin check checklist and compare all the switches according to the list and confirm everything is right.
3. Always put the parking break when the aircraft is on the ground and turn on the ‘PFD’ (primary flight display) and ‘MFD’ (multi-functional display).
4. Now increase the fuel air mixture to 70 present and start the engine by starting the ignition also put the throttle 50 present.
5. Increase the throttle to certain level such that required RPM is obtained.
6. Put the flaps down to 20 degrees and remove the parking brakes and now the planes starts to move forward on the runway.
7. Generate the yaw moment using the rudder on the runway as the propeller generates the unnecessary right moment on the plane.
8. When the plane reaches to 70 miles per hour slight give the pitch up moment in the plane by pulling the yoke towards us and climbs till the 3000 ft. and stabilize the plane and pull the flaps up.

9. Now watch the multi-functional display and plan the flight and move according to the c-ordinates given in the navigation display.
10. Remember not to exceed the pitch angle, roll angle, altitude and speed of aircraft.
11. After travelling in the given co-ordinates for a distance take the checklist and check the cockpit before landing check and get ready to perform landing.
12. Put the flaps down and reduce the altitude gradually as we reaching the runway as well as maintain the speed.
13. Keep the plane towards the direction of the runway landing line wait for the signals and watch for PAPI lights (precision approach and path indicator lights) for safety.
14. Aim for the two light glowing PAPI light which is a sign of the good approach towards the runway.
15. Slowly land the plane using rudder, when the plane touches the runway reduces the throttle to zero and flaps in upper position.
16. Now apply the airbrakes by pushing the both the legs, when the plane stops keep the fuel air mixture zero and turn on the parking breaks.

Result:
Hence safe take-off, cruise, co-ordinate turns and landing was performed between Begumpet airports to Hakimpet airport.