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Investigation of Airframe Stability Derivatives due to Manufacturing Deviations

Suhail Ahmed Khan K A
UG Student, Aeronautical Engineering, MVJ College of Engineering,
Shoib Akthar Sipai
UG Student, Aeronautical Engineering MVJ College of Engineering
Syed Kashifulla. A
UG Student,Aeronautical Engineering MVJ College of Engineering
Sachin MM
UG Student, Aeronautical Engineering MVJ College of Engineering
Vishnu Raj
Assistant Professor, Aeronautical Engineering, MVJ College of Engineering, Bangalore-67

ABSTRACT

Stability derivatives which is also called control derivatives are measures of how particular forces and moments on an aircraft change as other parameters related to stability change. The parameters may be airspeed, altitude, angle of attack etc. The estimation of stability derivative is very important during preliminary design phase of aircraft design. However due to manufacturing deviations of an aircraft the expected stability derivatives is not achieved. This research paper focuses on study of stability derivatives due to manufacturing deviations and it's after effects. This research emphasis on analysis of longitudinal stability derivatives of flying wing.

KEYWORDS

Stability Derivatives, Flying wing, Manufacturing deviations

1. INTRODUCTION

In order to perform its intended mission an aircraft must have adequate stability and control. The quantity of each of these items will depend on the mission or purpose of the aircraft. For instance, a transport aircraft is interested in a high stability level in order to give the passengers a smooth ride through turbulence, while at the other end of the spectrum, the fighter aircraft needs a high level of controllability for air combat maneuvering, So like aircraft performance, the stability and control is a function of the aircraft mission. As a result, the applicable regulations that govern the levels of stability are somewhat different depending on the aircraft's mission. In order to quantify stability and control parameters and have a common reference system, several systems of axes have been established. Fig. 1.1 illustrates one of the axis systems in common use known as the body axis system. Other axes systems referenced to the Earth's surface or inertial space are also useful in evaluating stability and control but are not used in this paper. For the body axis system the X axis, or longitudinal axis, runs fore and aft in the aircraft and is located on a plane of symmetry. The positive direction for this axis is in the direction of light. Motion about the longitudinal axis is called roll and is positive when it is to the right as viewed from the cockpit. The notation for a rolling moment about the longitudinal axis is the capital letter L.The Z or vertical axis is also in the plane of symmetry and the positive direction is down. This convention was established for the aero-dynamic theorist by the NACA; however, in the real world of flight test we generally consider up as the positive direction. This is because down is where the ground is and no one wants a collision with the ground; therefore how could down be positive? A moment about the vertical axis is called a yawing moment. Its notation is the capital letter N and is also positive to the right when viewed from the cockpit. The Y or lateral axis is perpendicular to the plane of symmetry and is positive to the right side of the aircraft. A moment about this axis is a pitching moment and is positive in the nose up direction. It is noted by the capital letter M.

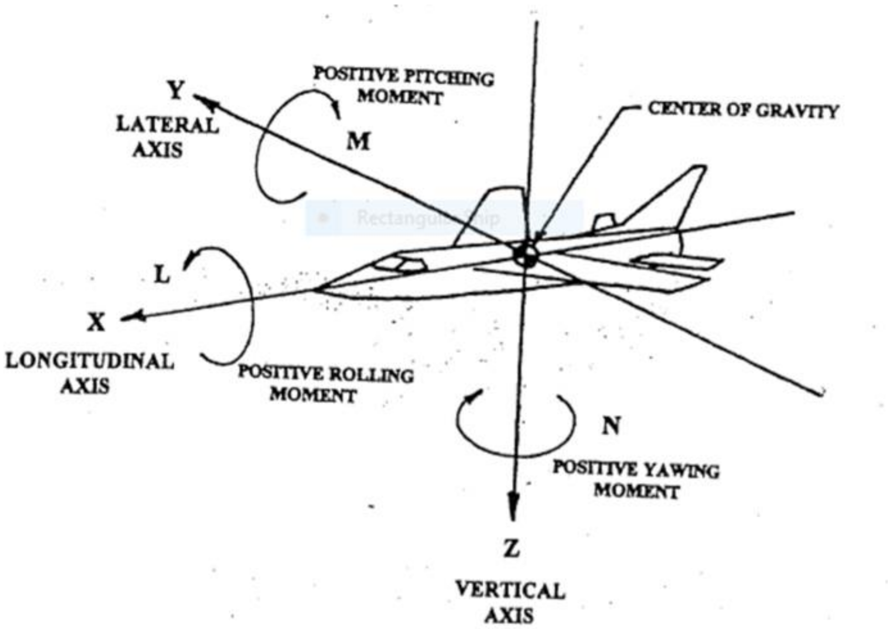


Figure 1: Axis System of an Aircraft

The stability of the aircraft is classified into **static** and **dynamic stability**, this project focuses mainly on **static stability**.When we speak of longitudinal motion we are speaking about motion in the plane of symmetry of the aircraft, or motion about the lateral Y axis. For small disturbances, longitudinal motion does not generally couple with motion about other axes and can therefore be handled as two-dimensional motion which greatly simplifies its analysis. In this research a flying wing is investigated since it does not have a vertical tail and which makes it difficult to have a longitudinal stability. A standard flying wing model is selected and stability analysis is done and compared with deviated model.

2. STABILITY ANALYSIS OF STANDARD FLYING WING MODEL

The standard model has been modelled in VSP Aero software. The details of the model is given in the table below

PARAMETERS	VALUE
WING SPAN, b	18.00137 ft
ASPECT RATIO, A.R	7.19890 ft
SWEEP ANGLE	23 Degree
DIHEDRAL ANGLE	1 Degree
AREA	45.00 ft^2
CHORD	2.4598 ft
TWIST	4 Degree

Table 1: SPECIFICATIONS OF STANDARD FLYING WING

The flying wing is designed in such a way that Airfoil used at the root is NACA 65019 and at the tip is NACA 63018. Control surfaces such as rudder and elevator has been removed to avoid complexity to find stability derivatives

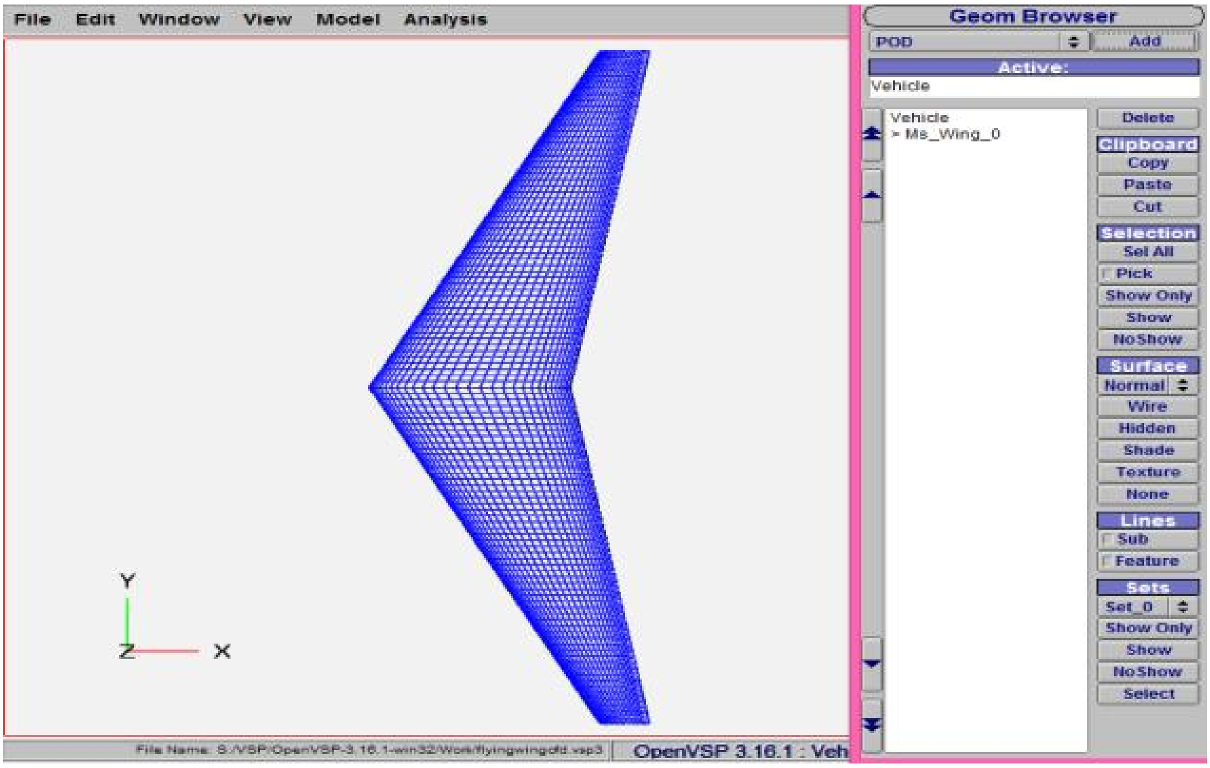
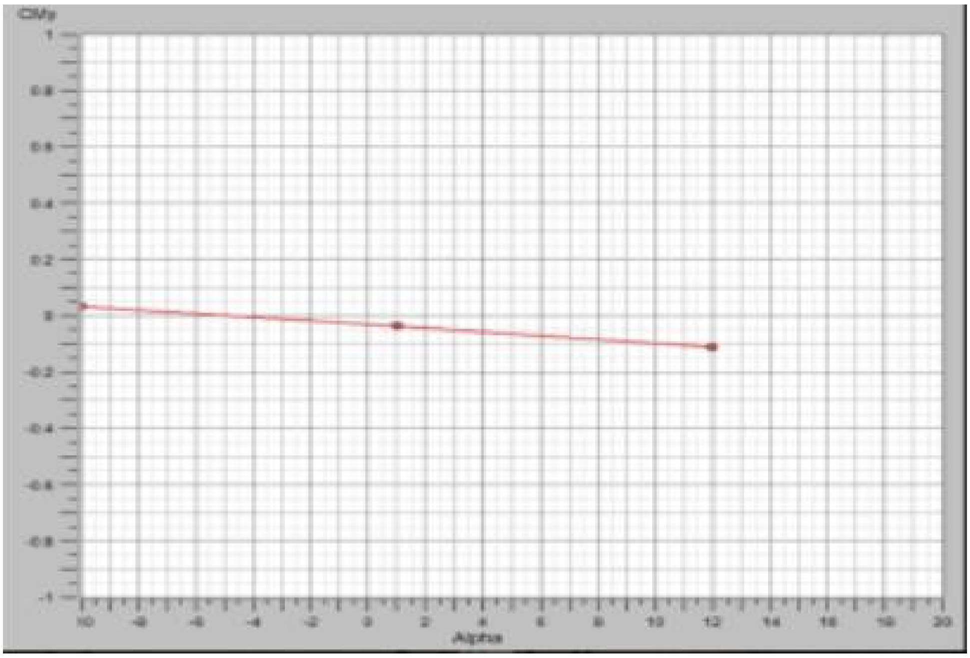


Figure 2: Modelling of Standard model in VSP Aero

Analysis of flying wing is done in between Mach number 0 to 0.65 at an angle of attack, α ranges from -10 to 12. The results of the standard model is as follows



Graph 1: Coefficient of Moment C_m vs. Angle of Attack α

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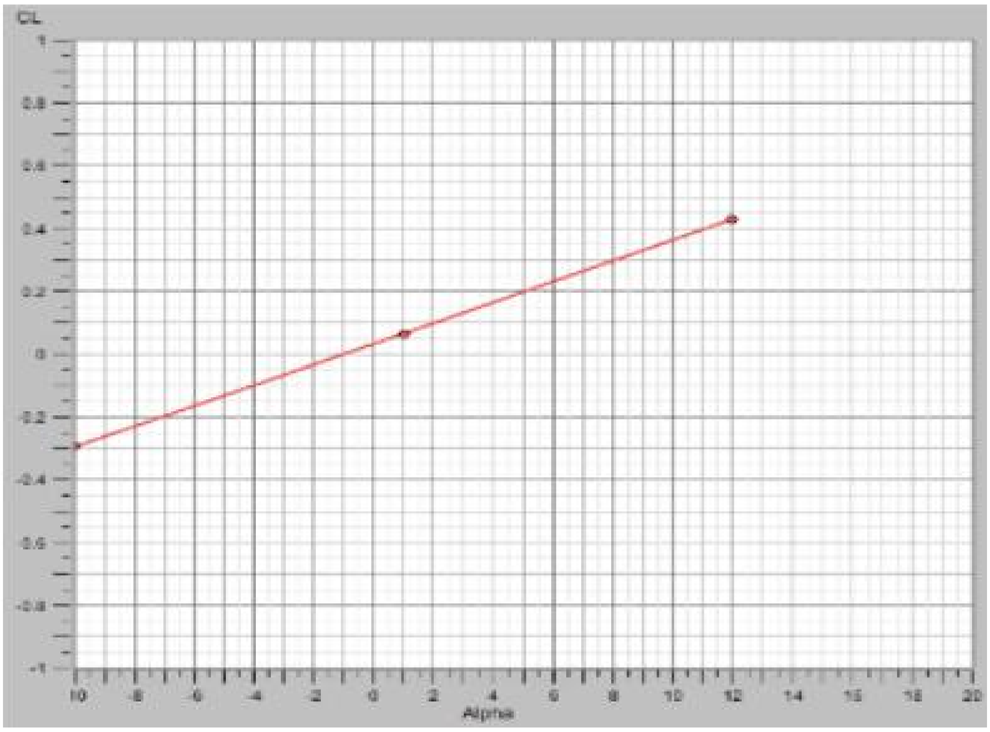
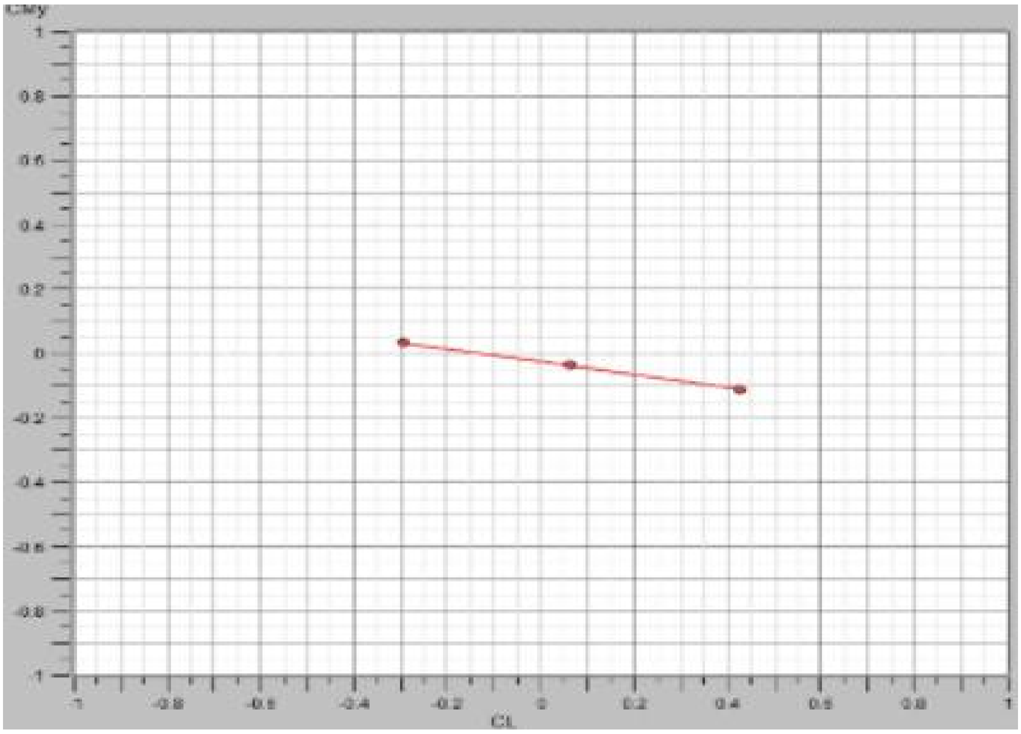


Graph 2: Coefficient of Lift C_L vs Angle of Attack α



Graph 3: Coefficient of Moment C_m vs. Coefficient of Lift C_L

From Graph 1 we have found out that the value of $\mathbf{C_{m\alpha}}$is **-0.006818.**From Graph 2 we have found out that Cl_{α} is **0.03252** and from Graph 3 the value obtained for Cm/Cl is **-0.2.** The analysis has been done at a Mach number of 0.33.

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3. STABILITY ANALYSIS OF DEVIATED FLYING WING MODEL

The parameters which has been changed is given in the table below:

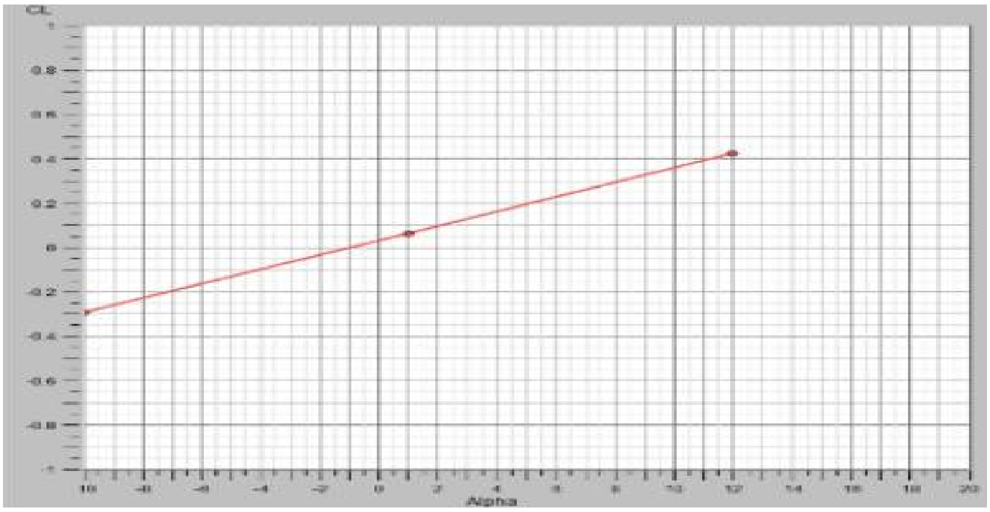
PARAMETER	DEVIATIONS
Sweep Angle	+ 1 Degree or -1 Degree
Twist Angle	+2 Degree or -2 Degree
Leading edge and trailing edge sweep	+2 Degree or -2 Degree

Table 2: Deviations

The mentioned parameters are changed and keeping remaining specification of Flying model same.

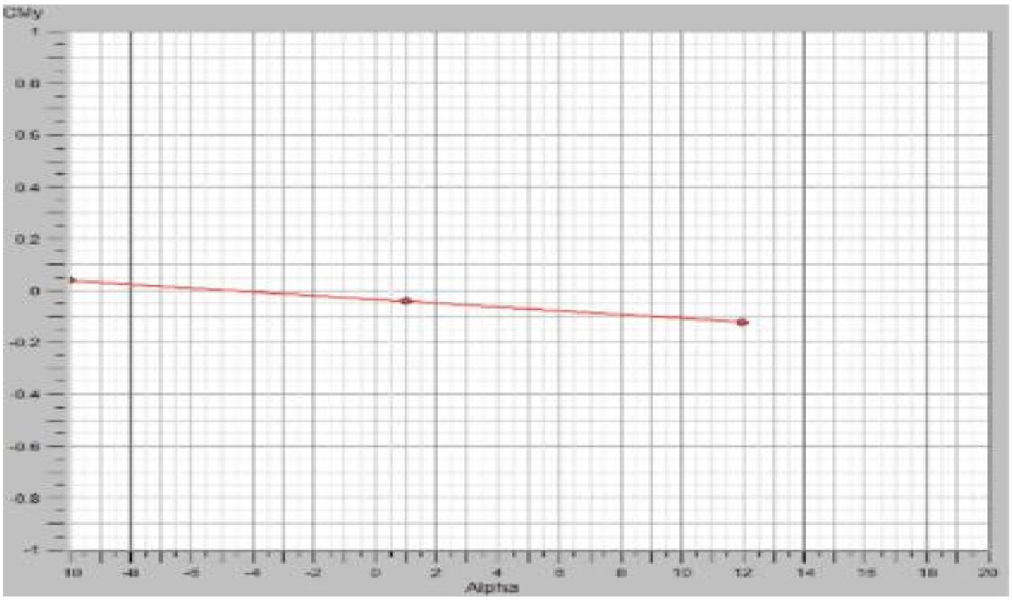
3.1 Analysis of deviated model with Sweep Angle Change at Mach number 0.33

The standard sweep angle is 23.12 degree. Results of stability derivatives when sweep angle is 24.12 degree.



Graph-4: C_L vs α at Mach Number, M= 0.33

From the above graph the value of $C_{L\alpha}$ is **0.03222**



Graph-5: Cm vs α at Mach number, M= 0.33

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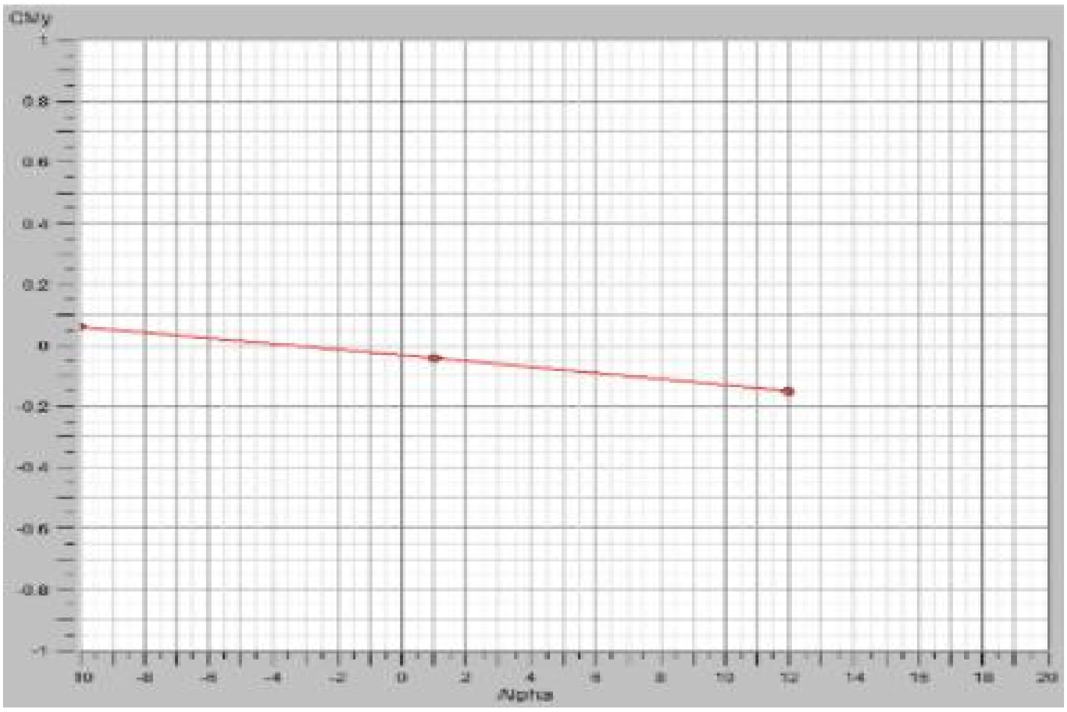
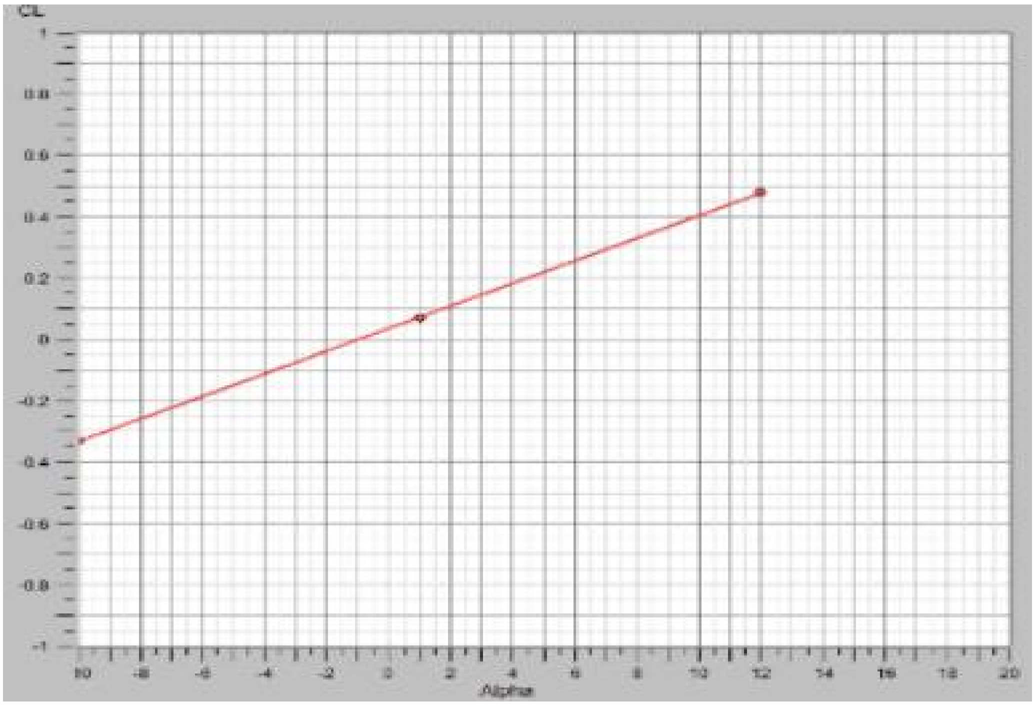
From the graph the value of Cmα is **-0.007954**

3.2 Analysis of deviated model with Increasing Leading Edge and Trailing edge sweep by 2° at Mach number 0.33



Graph-6: Cm vs α at Mach number, M= 0.33

From the graph the value of Cmα is **-0.01**



Graph-7: C_L vs α at Mach Number, M= 0.33

From the above graph the value of Clα is **0.0377**

The summary of results are interpreted in the tables given below

Mach	Sweep Angle	Cmα	Clα
0.33	22.12°	-0.00568	0.03318
0.33	23.12°	-0.00682	0.03252
0.33	24.12°	-0.00795	0.03222

Table 3: Stability Derivative Deviations due to Sweep Angle Changes

Mach	Leading Edge Sweep	Trailing Edge Sweep	Cmα	Clα
0.33	24.9°	7.9°	-0.00136	0.027
0.33	26.9°	9.9°	-0.00682	0.03252
0.33	28.9°	11.9°	-0.01	0.0377

Table 4: Stability Derivative Deviations due to Leading Edge and Trailing edge Sweep Changes

4. CONCLUSION

Increasing sweep angle or Leading edge and trailing edge sweep increases Cmα which means aircraft is becoming more stable. So more elevator power is required for maneuverability. These deviations affects the maneuverability of fighter aircraft. By changing the twist angle the curve shifts downward which means C_L envelope and Speed envelope is decreasing. Decreasing the sweep angle reduces the stability of aircraft such deviations are not suitable for commercial aircraft. Good efficiency can be obtained if deviations are controlled.

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