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EFFECT OF ANHEDRAL AND DIHEDRAL ON THE LATERAL-DIRECTIONAL STATIC STABILITY OF THE AIRCRAFT

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Abstract:

In aircraft industry, there has been a rapid development on static stability of the aircraft. Lateral-directional static stability is one of the most important factors in the aircraft staticand anhedral types of aircraft using the parameters-- side-slip angle and coefficient of rolling and yawing moments. This analysis had taken place in XFLR5 software. XFLR5 is an open-source software which is used to analyse three-dimensional models of aircrafts' wings, tails, and other structural parts. This work proposed a Dihedral and Anhedral wing simulation in XFLR5 software to increase the stability and manoeuvrability of an aircraft. XFLR5 analysis was then carried out for Dihedral and anhedral angles of 5deg, 10deg, with side slip angles ranging from -10 degrees to 10 degrees with a sequence of 0.5- degree increment. The NACA 4412 aerofoil is used in the wing and NACA0009 aerofoil is used in the tail of the aircraft. The simulation is done in a free stream velocity of 60m/s and in viscid flow. The graphs obtained by this analysis are plotted between 'coefficient of rolling moment and side-slip angle' and coefficient of yawing moment and side-slip angle'. This data obtained from this analysis can be used to observe the behaviour of the aircraft in the given constraints mentioned above.

KEY WORDS:

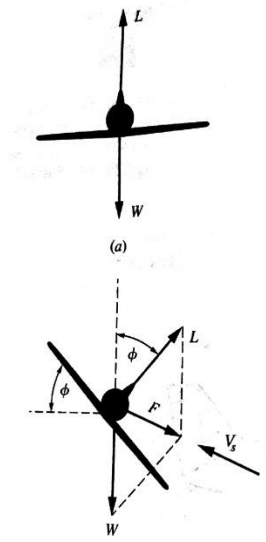
Anhedral, Dihedral, Lateral – directional static stability, Angle of attack, β=Side Slip Angle/ Bank Angle, cl=co-efficient of rolling moment, cn=co-efficient of yawing moment, CL/CD=lift to drag ratio.

INTRODUCTION:

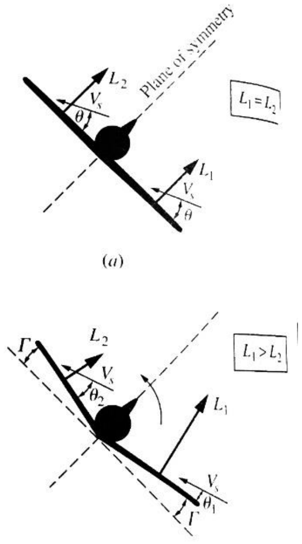
Unlike for birds; Wings are a critical part of airplane which provides the ability to fly, creating lift.The wings play's very crucial role for producing the lift of an aircraft. An aircraft must have the stability during its airborne. Stability is the ability of an airplane to correct the conditions which are acting up on the aircraft like turbulence etc.

Lateral Static Stability:

The stability associated with the angular motion about the X axis or rolling moment axis is called lateral static stability. Stability in roll is called lateral stability. When we consider an airplane in steadylevel flight; the lift equals the weight. They act equal and opposite to each other; there is no net side force.The airplane is suddenly perturbed by a gust that causes the right wing to dip; that is roll to the right, as shown in the figure. Here, the slide slip velocity makes an angle with respect to the right wing and a larger angel with respect to the left wing. As a result, the lift on the left wing L_2 is smaller than the lift on the right wing, and this creates a restoring rolling moment that tends to return the airplane to its equilibrium position, as shown in the figure. Hence, *dihedral is thedesign feature of the airplane that provides lateral stability.*Also, there is always a coupling between yawing and rolling motion, so that one does not occur without the other.



Generation of Side Slip



Effect of Dihedral

Directional Static Stability:

The longitudinal stability and control are concerned with angular motion about the Y axis – pitching moment. The stability associated with the angular motion about the Z axis – yawing moment. Stability in yaw is called directional stability. The vertical stabilizer (vertical fin or vertical tail) is the conventional mechanism for directional stability. Its function is shown in the figure (1). When we consider an airplane in equilibrium flight with no yaw, as shown in the figure 1(a). The vertical tail which is designed with a symmetric airfoil section is at zero angle of attack to the free stream, it experiences no net aerodynamic force perpendicular to V_∞. Now assuming the airplane is suddenly yawed to the right by a disturbance then the vertical tail will be at angle of attack and experiences an aero dynamic force F_{vt} (due to vertical tail) perpendicular to V_∞. This force creates a restoring yawing moment about the center of gravity that tense to rotate the airplane back towards its equilibrium position. The same situation prevails when the airplane is yawed towards left as shown in the sketch. (Introduction to flight, J.D. Anderson Jr, Fifth Edition).

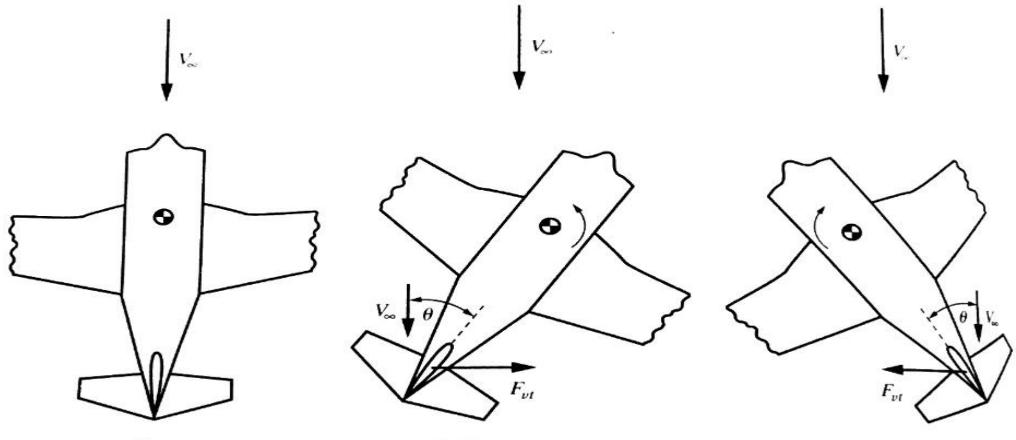


Figure: Effect of vertical stabilizer on directional stability

Considering the Lateral Stability (Rolling) and Directional Stability (Yawing).Both of them are coupled to each other.An aircraft having the straight-level wings has less Lateral and Directional stability. Dihedral wing is the upward angle of the wing from horizontal plane of a fixed-wing aircraft. Anhedral wing is the downward angle of the wing from horizontal plane of a fixed-wing aircraft, it is also known as negative dihedral. Replacing the straight-level wing with the Anhedral and Dihedral leads to changes in Lateral and Directional stability of an aircraft. Dihedral wing—due to its higher placement of wing from the horizontal plane, tends to attain its lateral-directional stability with ease. Whereas anhedral wing is placed under the horizontal plane which destabilizes the aircraft and reduces lateral-directional stability of the aircraft, but it also increases maneuverability of the aircraft. Usually, fighter aircrafts have anhedral wings and commercial or passenger aircrafts have dihedral wings because safety is the priority of passenger aircrafts. Most of the fighter aircrafts are computerized and has advanced technology like fly by wire, so it can operate with a destabilizing wing conveniently.

To get a deep understanding on this phenomenon, a simulation has been done on a basic aircraft in a simulation software called XFLR5. XFLR5 is an open-source software which was developed by Mr. Andre Deperrois, which is used to analyze aircrafts at low-reynolds numbers and different speeds, angle of attacks etc.

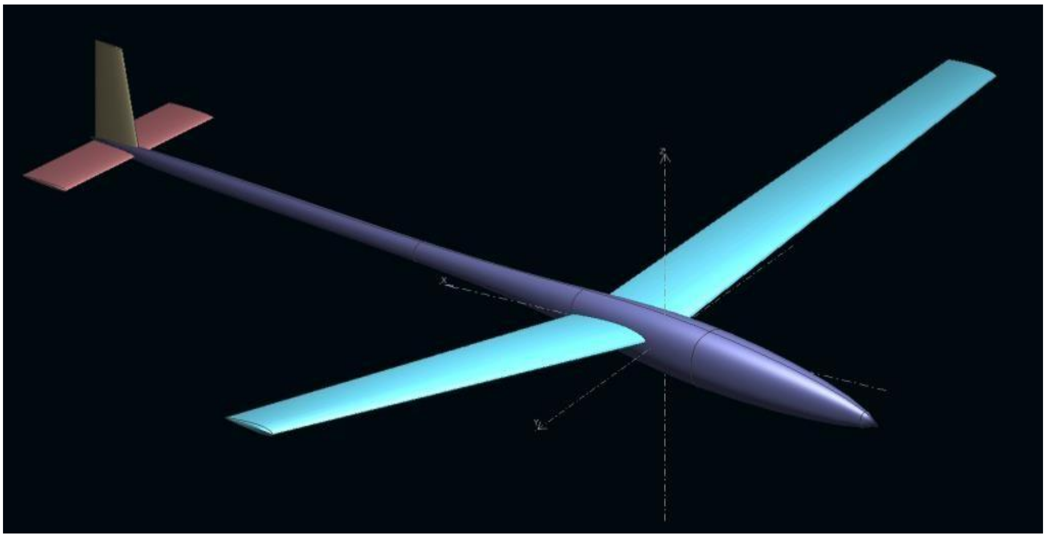
Simulation and Analysis:

In this simulation, to analyze the lateral-directional stability of the aircraft the following parameters are considered. This analysis is taken place with respect to the side-slip angles which are ranging from -10 degrees to 10 degrees with an increment of 0.5 degrees. The plane is defined with having the masses of wing, horizontal and vertical srabilizers. The NACA 4 digit airfoils are taken in to consideration. Considering NACA 4412 airfoil for wing and NACA 0009 airfoil for both horizontal and vertical stabilizers. Defining the elevator with an offset of 0.020m and wing span of 0.34m and aspect ratio of 3.79. Defining the fin with chord length of 0.060m and wing span of 0.24m and aspect ratio of 3. Defining the wing with span of 2m and aspect ratio about 13.79 and wing load as 21.289 kg/m2. The wing with dihedral of angle 5-degree and 10-degree and the wings with anhedral of -5-degree and -10-degree areanalyzed using XFLR5 software. The ground effect is not included in this analysis. Flow is considered as inviscid.

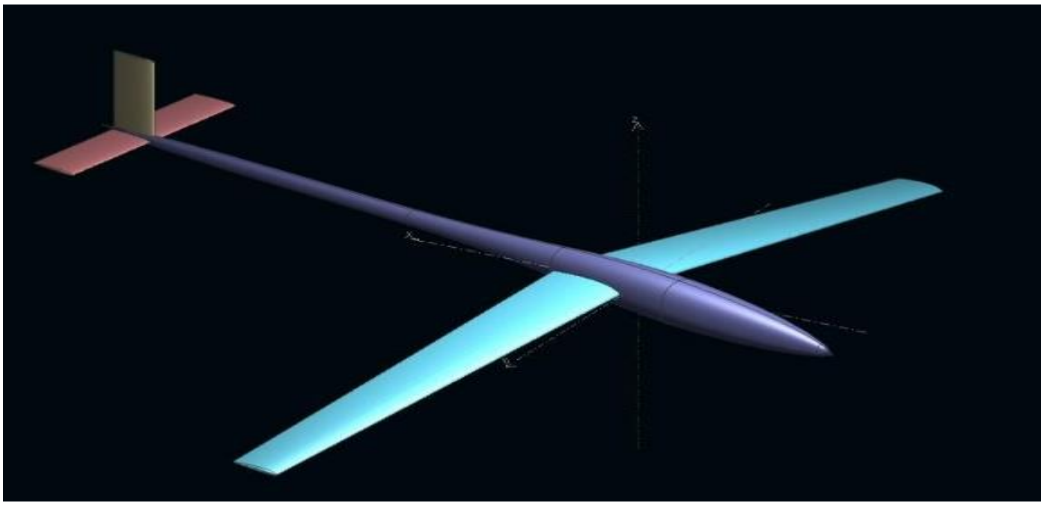
The stability analysis is defined with free stream velocity of 60m/s. While doing analysis VLM2/ mix 3D plane analysis method is selected. The refered dimension is not changed that is wing planeform which is projected on XY plane. The stability analysis has been excecuted. Theresultsin thexflr5 simulation are plotted on the graph ascoefficient of rolling moment(cl) vs beta and coefficient of yawing moment (cn) vs beta graphs for all the aircrafts considered.

The cL/cD and others graphs are obtained but, for the lateral-directional stability cl vs beta and cn vs beta graphs are considered. The plots shows that when the beta varies how the coeffecient of rolling moment and coeffecient of yawing moment varies and which way the both effects the lateral-directional stability for different diherdral angles of the aircraft

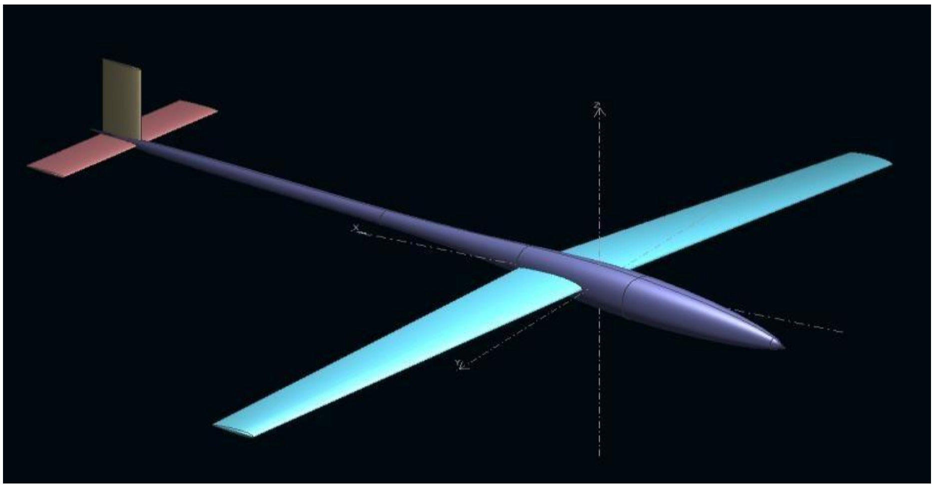
Dihedral of 10 degree



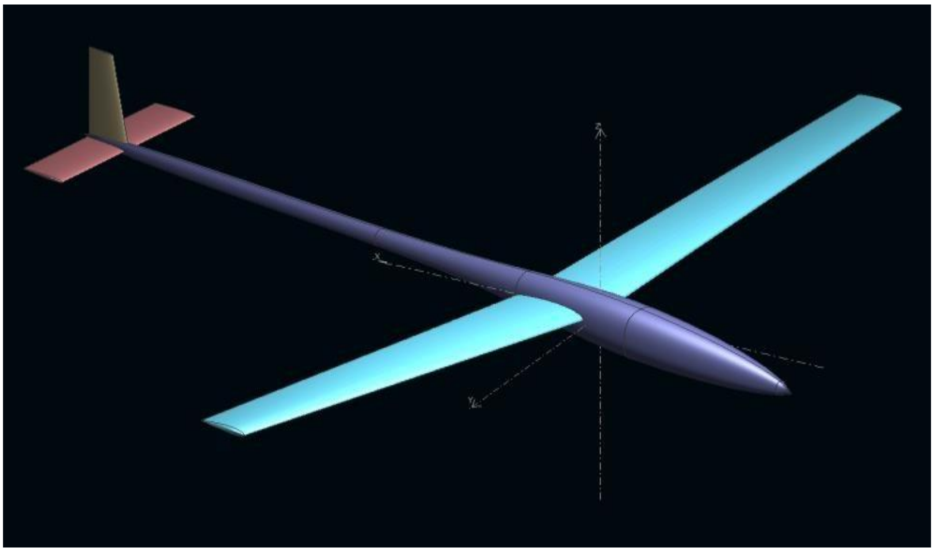
Anhedral 10 degree



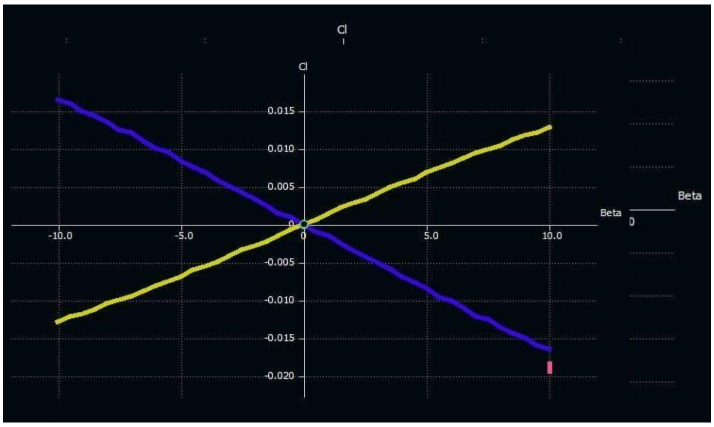
Dihedral of 5 degree



Anhedral of 5 degree

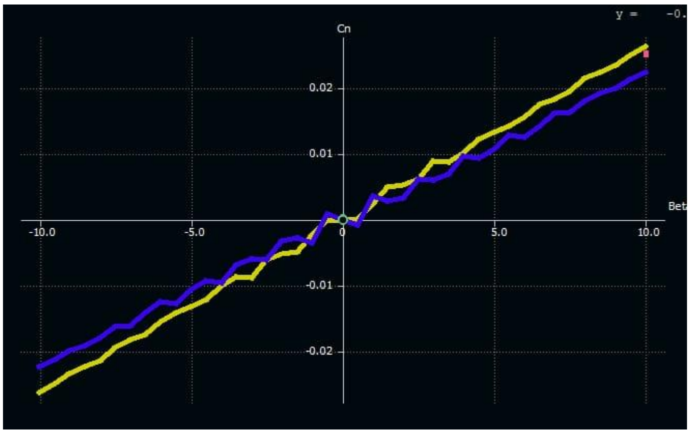


RESULTS:



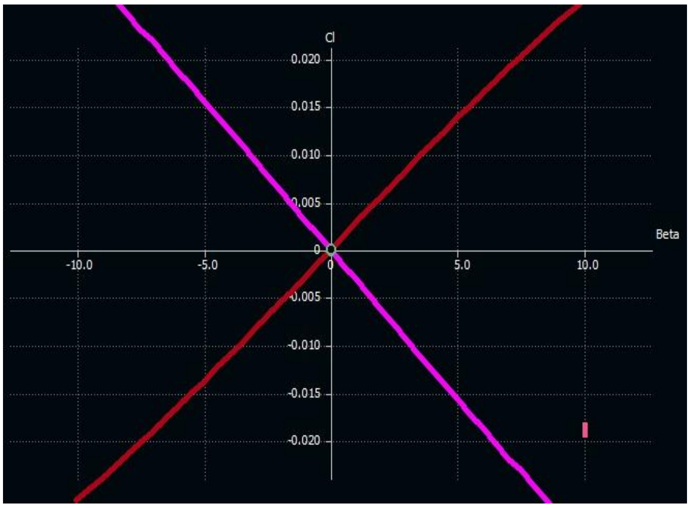
This is the graph between the cl and beta of 5 – degree of both anhedral and dihedral angles of aircraft. The blue curve is for dihedral. The yellow curve is for anhedral

Graph between cl vs beta(5-deg)



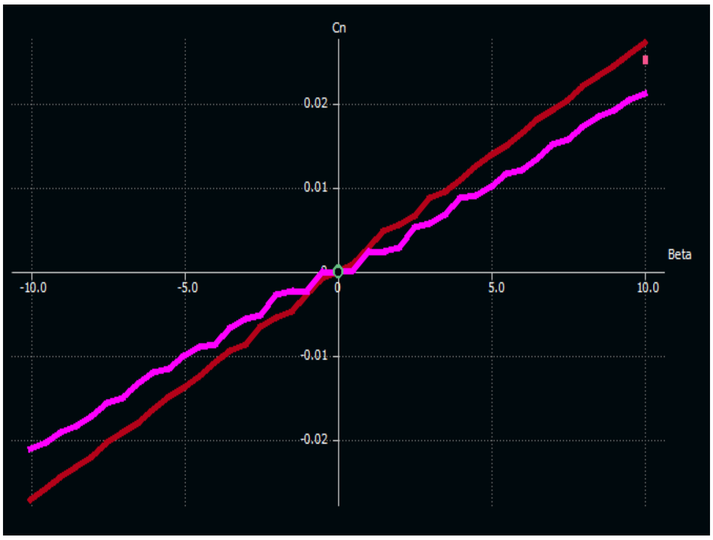
There is slight difference between the curves of Anhedral and Dihedral in cn vs beta graph, there would be a small difference while yawing the aircraft in cruise

Graph between cn vs beta(5-deg



This is plot of cl vs beta for both Anhedral and Dihedral of 10 – degree of angle. The purple curve indicates Dihedral. The red curve indicates Anhedral

Graph between cl Vs beta (10 -deg)



There is a difference between the anhedral and dihedral of yawing coefficient that is they both are increasing as the beta increases.

Graph between cn vs beta(10-deg)

CONCLUSION:

Lateral-directional static stability is one of the most important factors in the aircraft staticand anhedral types of aircraft using the parameters-- side-slip angle and coefficient of rolling and yawing moments. This analysis had taken place in XFLR5 software. XFLR5 is an open-source software which is used to analyse three-dimensional models of aircrafts' wings, tails, and other structural parts. This work proposed a Dihedral and Anhedral wing simulation in XFLR5 software to increase the stability and manoeuvrability of an aircraft. XFLR5 analysis was then carried out for Dihedral and anhedral angles of 5deg, 10deg, with side slip angles ranging from -10 degrees to 10 degrees with a sequence of 0.5- degree increment. The NACA 4412 aerofoil is used in the wing and NACA0009 aerofoil is used in the tail of the aircraft. The simulation is done in a free streamvelocity of60m/sandinviscidflow. The graphs obtained by this analysis are plotted between 'coefficient of rolling moment and side-slip angle' and coefficient of yawing moment and side-slip angle'. By obtaining the graphs, conclusion is that the dihedral is more stable compared to anhedral, due to this reason civil airplanes mostly have the dihedral and fighter planes use anhedral because it needs more manoeuvre.

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