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Experimental Aerodynamic Static Stability Analysis of Different Wing Planforms

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ABSTRACT

This paper presents a simple approach to experimenting an aerodynamic static stability analysis of different types of wing planforms. NACA 0016 chosen as airfoil of all the wings, which had the chord length of 0.100 m and span of 0.250 m. The reduced scale size of wings of different shapes like rectangular (B1), rectangular with tip curved (B2), Tapered (B3), Tapered with tip curved wing (B4) were chosen for this analysis. The wings manufactured by Teak wood. All the wings were tested using low speed subsonic wind Tunnel at different airspeeds and different angles of attack. The variation of coefficient of moment with respect to the angles of attack and the Airspeed was calculated. By performing this experiment it was clearly evident that the tapered wing with curved tip (B4) was found to be the most stable at different speeds and range of working angles of attack.

Keywords : Aerodynamics, Static stability, Wing planform, Airfoil, Coefficient of moments, Angle of attack.

1 INTRODUCTION

IN this paper an investigation is carried out for the different planforms of the wing of scaled sizes, with different shapes of the wing. The aerodynamic characteristics of each wing were evaluated by using low speed sub sonic wind tunnel of 300 mm X 300 mm cross section test area.

The primary aerodynamic characteristics like lift (L), drag (D), moment (M), and their coefficients were found out with different angles of attack (α) and different speeds. The symmetrical airfoil NACA 0016 was used for this work .The L/D Ratio, which is the principal aerodynamic feature for selection of the airfoil also found in this investigation. The static stability of all the wings tested by wind tunnel is calculated as per following criteria [Ref 2].

2 CRITERIA FOR STATIC STABILITY

Considering a rigid airplane with fixed controls, for example, the elevator in some fixed position. Assuming the airplane has been tested in wind tunnel for free flight and that its variation of pitching moment with respect to centre of gravity (M_{cg}) with angle of attack has been measured. The value of coefficient of moments with respect to the centre of gravity ($C_{M.cg}$) at zero lift (where $\alpha_0 = 0$) is denoted by $C_{M.0}$. The value of α_0 where $M_{cg} = 0$ is denoted by α_e ; this is the equilibrium or trim, angle of attack.

Assuming airfoil is in trim position, if some disturbance took place due to gust or by some other means, the angle of attack will change. There are two possibilities; an increase of angle of attack or a decrease in angle of attack. If airfoil is pitched upwards then $\alpha_a > \alpha_e$, in this condition the moment about the cg is negative, the negative moment is in counter clock wise, tending to pitch the nose downwards, hence the airfoil will tend to come back to its original condition.[Ref 2]

On the other hand, if the airfoil is pitched downward by the gust then $\alpha_a < \alpha_e$, The resulting moment about the centre of gravity will be positive (clockwise) and will tend to pitch the nose upward. Thus again we have the situation in which, the airfoil will initially tend to move back towards its equilibrium position (trimmed condition) after being disturbed.

Therefore, we conclude that an airfoil (airplane wing) that has a $C_{M.cg}$ versus - α_a variation positive to negative, is statically stable. The necessary criteria for longitudinal balance and static stability are

1. $C_{M.0}$ must be positive
2. $\delta C_{M.cg}/\delta \alpha_a$, must be negative

3 EXPERIMENTAL SET UP AND TESTING PROCEDURE

3.1 Manfacuring of a Wing

Wings of airfoil NACA 0016 [3] are manufactured taking Chord length of 100 mm, max thickness 16 mm at the 25% of the chord length (at quarter chord length), span of blades are taken 250 mm (see fig 1 for drawing prepared in Auto CADD 2010) due to suitability of this length to be tested in wind tunnel.

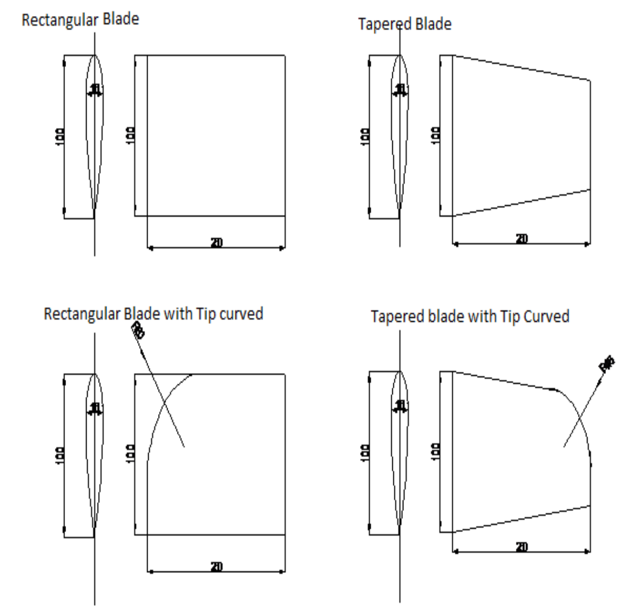

Fig. 1. Auto CAD Drawing of all types of wings

Fig. 2 Photographs of all types of wings.

Teak wood of 300mm x 120mm x 25mm size is used as raw material for the wings. Using carpentry tools and with the Auto CAD drawing of NACA 0016 (Fig. 1), prepared number of wing sets like rectangular wing (3 pieces) Fig.2, taper wing (3 pieces), Rectangular with tip curved (Fig. 2) and tapered wing with tip curved (3 each) Fig.2. One tapered wing along with 12 pressure tapings also prepared for measurements of pressure distribution over the tapered wing. These pressure tapings are attached with flexible plastic tubes to the manometer which is the part of wind tunnel.

3.2 Experimental Set Up

3.2.1 Low Speed Wind Tunnel

Low Speed wind Tunnels are those tunnels with test section speed less than 650 kmph (180 m/s). Depending upon test section speed they are referred to as small size or full scale size tunnels [1].

Fig. 3. Photograph of subsonic wind tunnel (courtesy CMR Technical Campus Hyderabad)

In low speed wind tunnels, the predominant factors influencing tunnel performance are inertia and viscosity. The effect of compressibility is negligible for these tunnels. Thus, if the Reynolds number of the experimental model and full scale prototype are equal, any difference in viscosity becomes unimportant. The general utility Low Speed wind Tunnel has four important components, namely, the effuser, the test section, the diffuser, and the driving unit.

3.2.2 Effuser

This is basically a contraction cone, as shown in Fig. 6. Its application is to bring down the level of turbulence and increase the velocity of flow. The contraction ratio n of an effuser is defined as n = Area at entry to convergent cone/Area at exit of convergent cone. The contraction ratio usually varies from 4 to 20 for conventional low speed tunnels.

3.2.3 Test Section

The portion of the tunnel with constant flow characteristics across its entire section is termed as test section or working section. Because a boundary layer is formed along the test section walls, the walls are given a suitable divergence so that the net cross sectional area of the uniform flow is constant along the length of the test section.

3.2.4 Diffuser

The purpose of the diffuser is to convert the kinetic energy of the flow coming out of the test section to pressure energy, before it leaves the diffuser, as efficiently as possible.

Generally, the smaller the diffuser divergence angle, the more efficient is the diffuser. Near the exit, its cross section should be circular to accommodate the fan (Fig.6).

3.2.4 Driving Unit

Generally the driving unit consists of a motor and a propeller or fan combination. The fan is used to increase the static pressure of the stream leaving the diffuser.

The wind tunnel fan, looking similar to the propeller of an airplane, operates under peculiar conditions that put it in a class by itself (see Fig. 6). Because of the thrust of the fan and the drag of the various tunnel components vary with the square of the fan rpm, it would appear that to maintain a uniform velocity distribution in the test section, speed adjustments should be made by varying the fan rpm rather than fan pitch.

Although this conclusion is justified in short tunnels of low contraction ratio, for large tunnels it is not true. Indeed, many large tunnels that are equipped with both rpm and pitch change mechanisms use only latter, being quick and simpler. In this tunnel the fan pitch is fixed and fan rpm can be varied. This variation in rpm is done by a control knob present in the control panel of wind tunnel.

3.3 Test Procedure

1. Check the wind tunnel for any FOD (Foreign Object Debris).
2. Check power connection for proper power supply.
3. Open the test section window
4. Remove the push-pull rod from the wind tunnel
5. Fit the test model in this rod
6. Insert the rod inside the wind tunnel test section
7. Lower end of the push-pull rod should be inside the 3 component balance and should be tightened by the lock screw.
8. Close the test section window of wind tunnel and lock by given fastener
9. Set the angle of attack of model as per required angle.
10. Switch on the AC motor.
11. Increase the motor r.p.m slowly and see the velocity indicator in control panel
12. At the required velocity see the forces by digital 3 component balance indicator in control panel
13. Note the reading of aerodynamic forces (lift, drag and moment).
14. Velocity (V) of test section is obtained by velocity indicator. By using formula $L=0.5*\varrho*V^2*S$, calculate the ideal lift force.
15. To find the coefficient of lift use the formula $C_l = L/0.5*\varrho*V^2*S$
16. Drag (D) is found directly from thee component balance and coefficient of drag (C_D) is calculated by using $C_D = D/0.5*\varrho*V^2*S$
17. Repeat the procedure for other angles of attack and other wind velocity.

4 Test Results and Analysis

The aerodynamic tests on the four types of wings are under taken and the results are mentioned in the given tables.

4.1 Result Analysis of all the Wings at 10 m/s Speed

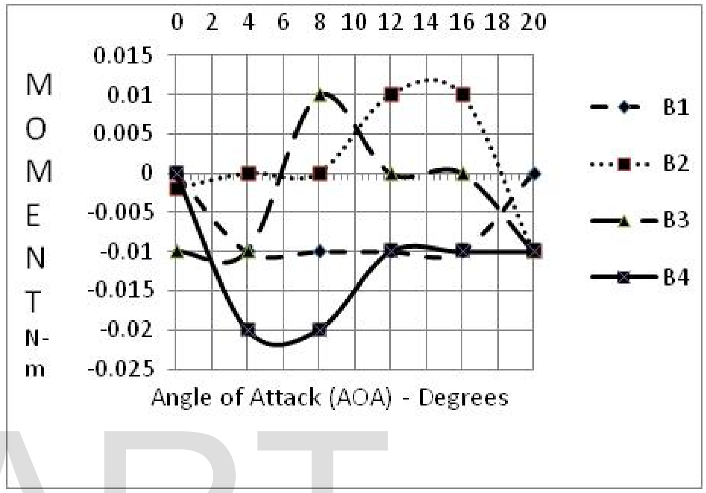

Fig. 4. Result Analysis of all the Wings at 10 m/s Speed

4.2 Result Analysis of all the Wings at 15 m/s Speed

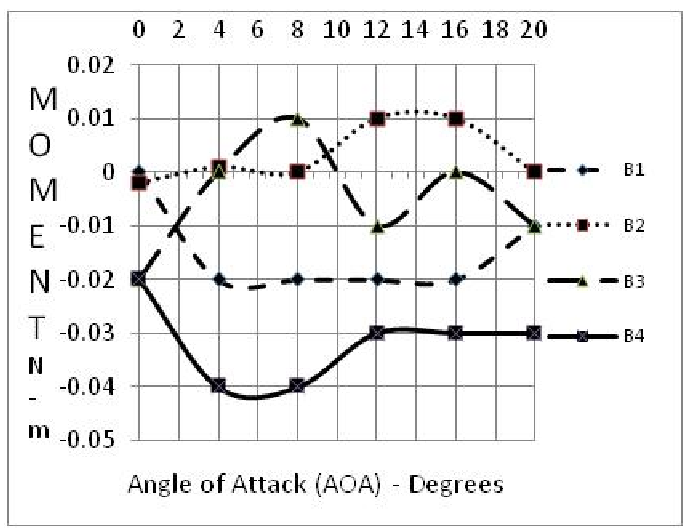

Fig. 5. Result Analysis of all the Wings at 15 m/s Speed

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4.3 Result Analysis of all the Wings at 20 m/s Speed

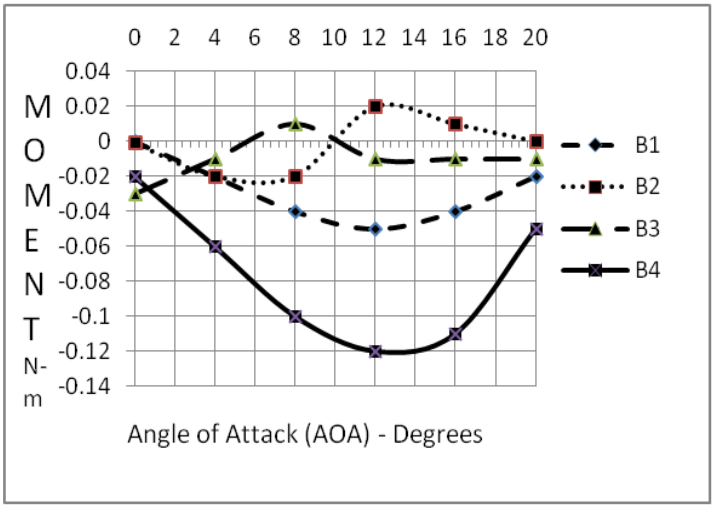

Fig. 6. Result Analysis of all the Wings at 20 m/s Speed

4 CONCLUSION

From the above tests and results the following conclusion is drawn

The tapered wing with curved tip (B4) is found to be the most suitable wing in all range of speeds and angle of attacks as for as static stability is concerned. This high negativity of the moment is the basic requirement for high speed military fighter planes; this increases the manoeuvring capacity of aircraft.

Next Suitable Wing is Rectangular Wing (B1), as this shape of wing is also giving negative moments as the angles of attack increases, however the rate of change of negativity is quite lesser than the tapered wing with tip curved(B4), So this wing is not suitable for high manoeuvring aircrafts

The rectangular wing with tip curved (B2) is not at all suitable as its gives positive moments at most of the angles of attack and at various speed conditions. This wing shape is most unstable.

The moments of tapered blade (B3) found to be near zero or positive, hence this wing is also not having appropriate static stability and hence not suitable for high stability and high manoeuvring aircrafts.

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