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MAE462 Design Problem

Stable Balsa Glider

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I. PROBLEM DESCRIPTION

A balsa wood glider is to be constructed from the supplied materials and designed with specific stability properties. The supplied materials as are follow, one balsa sheet of dimensions 1/16”x2”x18” with a density of .10 oz/in^3, one balsa stick of dimensions 1/4”x1/4”x18” with a density of .16 oz/in^3. The glider will be constructed with provided adhesives, knives, cutting pads, sand paper, and masking tape. The glider should be constructed with specific design requirements in mind. A static margin between 15 and 30 percent is desired. The glider should also be directionally stable with an effective dihedral angle between 5 and 10 degrees.

II. ASSUMPTIONS

During the design processes many assumptions are required to make calculations easer, however it should be kept in mind that actual properties may differ and that future adjustments may be required. It will be assumed that the given material densities are correct and consistent throughout the materials. The weight of the glue in bonded segments will also be assumed to be zero, this will contribute the most error in calculations out of all assumptions and it will be countered by ensuring that glue distribution is equal and whenever possible, small in quantity. I will be assuming a symmetric airfoil exists and that there is no inherent camber or warp of the balsa wood prior to construction.

III. PRELIMINARY STABILITY ANALYSIS

In order to achieve the desired static margin and stability requirements some basic calculations are required. The static margin which is required to fall in the range of values between 15 and 30 percent is described by Kn in the equations below.

$$K_n = (h_n - h)$$

In addition h is the relative distance of the center of gravity to the length of the mean aerodynamic chord, or xcg/mac, and hn is the relative distance of the neutral point to mac, or xn/mac. Both of these values are dependent on the position of the wing along the fuselage. In the analysis of center of gravity considering my assumptions the volume distribution of the wing, tail, and fuselage can be used to estimate the center of gravity with respect to the datum line which will be placed at the tip of the fuselage. This equation can be described in summation for as,

$$x_{CG} = \frac{\sum x_i \rho_i V_i}{\sum \rho_i V_i}$$

With this information h is easily calculated with respect to change in position. The neutral point position is described by,

$$h_n = h_{n_{wb}} + \frac{a_t}{a}\overline{V_h}\left(1 - \frac{\partial \epsilon}{\partial \alpha}\right) - \frac{1}{a}\frac{\partial C_{m_p}}{\partial \alpha}$$

The variables now of concern are hnwb, a, at, Vh, de/da, and Cmp. As a symmetric airfoil was assumed, a value of .25 may be assumed for the neutral point of the wing body, and a simplified equation for the lift curve slope of the airplane and tail may be used.. In addition because there will be no onboard propulsion system the change in pitching moment due to propulsion effects will go to zero. In the interest of design an alternative equation can now be used which incorporates the individual effect of each aerodynamic surface. The equation for the neutral point now takes the form of,

$$h_n = (\frac{1}{2}\rho V_{trim}^2)\frac{h_{acwb}a_{wb}S_{wb} + h_{act}a_tS_t}{a_{wb}S_{wb} + a_tS_t}$$

where Vtrim is the speed of the glider toss, which will be estimated later. The lift curve slopes , a, of the wing and tail can be calculated as follows:

$$a_{(wb\ or\ t)} = \frac{2\pi}{1 + \frac{2\pi}{\pi e AR_{(wb\ or\ t)}}}$$

While the aspect ratio of the wing and tail will differ, the Oswald efficiency factor e for both the wing and tail can be estimated as .80.

To confirm the aircraft design is statically stable the static margin may be used in addition to the lift curve slope for the following relation,

$$\frac{dC_{M_{cg}}}{d\alpha_a} = \frac{hn - h}{-a}$$

Where a is the total life curve slope described by,

$$a = \frac{a_{wb}S_{wb} + a_tS_t}{S_{wb} + S_t}$$

As both the main wing and horizontal tail will be tapered the equation for the mean aerodynamic center of each wing will be described as,

$$h_{ac\ for\ taper} = \frac{x_{LE} + \frac{b}{6}\left(\frac{1 + 2\lambda}{1 + \lambda}\right)\tan(\Lambda) + c}{c}$$

The variables listed include Λ sweep angle, λ taper ratio, and the distance from the nose to the leading edge of the wing x, and the chord length c.

The sweep angle is calculated with the formula below.

$$\Lambda = tan^{-1}\left(\frac{\frac{C_r - C_t}{2}}{b/2}\right)$$

IV. DESIGN PROCEDURE

In the interest to simplify the calculations necessary to achieve the design requirements, a specific approach will be taken. First the wing, tail, and vertical stabilizer areas will be decided as limited by the least amount of cuts required and the dimensions of the materials provided. Once the shapes of the lift surfaces have been determined the tail will be set at the rear of the balsa wood stick. To achieve the desired static margin the wing will be moved either up or down on the stick. The exact distance from the datum line required to achieve the design requirements will be calculated with excel. To achieve the desired dihedral angle a high wing placement with cut wingtips, as well as a slight sanding of the glue surface to achieve a small angle change will be used together for a final dihedral angle of 5 degrees.

When the final wing placement configuration has been calculated the aerodynamic and stability properties of the balsa wood glider will be recalculated for additional confidence in the values. Once the plane has been constructed physical measurements of the center of gravity will be made in order to confirm our calculations before flight.

V. PRELIMINARY CAD MODELING

The basic shape and layout of the balsa wood glider is shown here. Smaller details such as wing tapering and the dihedral angle of 2-3 degrees are not shown. Only 12 of the 18 possible inches of the balsa wood stick are used in this rendering though additional length will be added if it is required to meet the stability requirements.

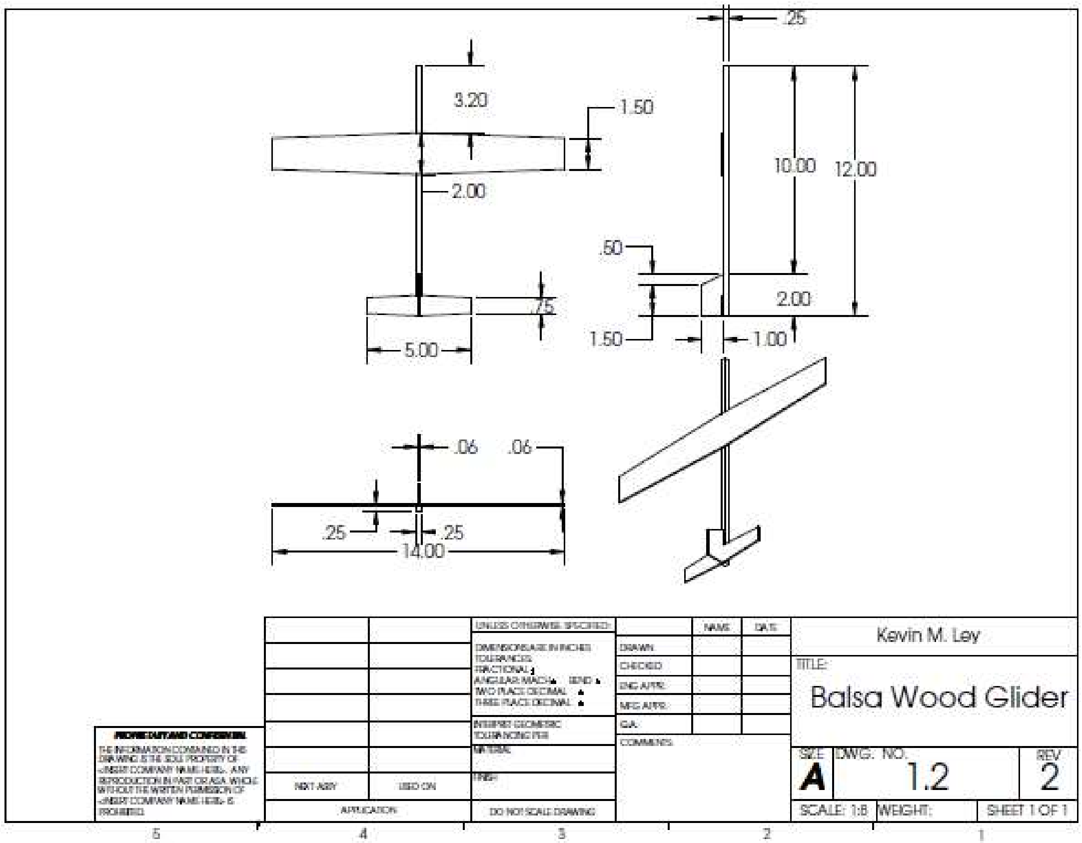

Figure 1: CAD Drawing Balsa Wood Glider Revision 1.2

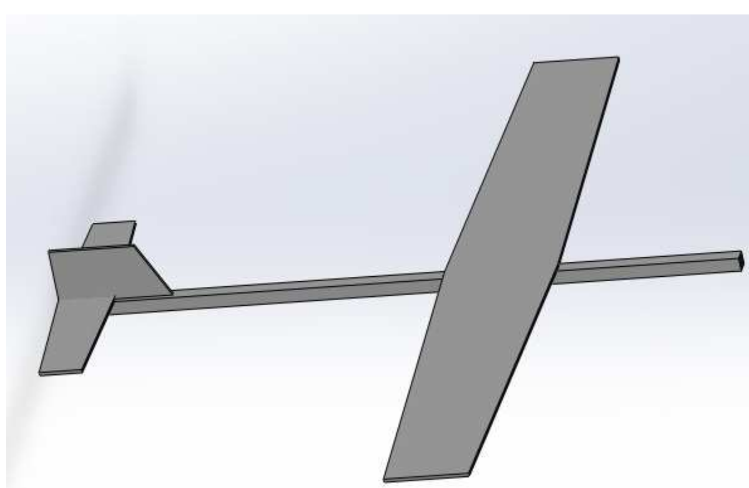

Figure 2: CAD Rendering Balsa Wood Glider Revision 1.2

VI. AERODYNAMIC AND STABILITY COMPUTATION

Using the formulas presented in section 3 a Excel computation sheet was formed to compute all necessary values to determine static margin and directional stability. While the coefficent of yawing moment with respect to beta was not directly calculated It can be determined by the size and placement of the vertical stabalizer that this value will be positive. Future calculations may be used to determine if an addition of weight at the nose is necessary to increase stability. Basic goals were also set when designing the lifting surfaces. It was desired that the tail surface area was atleast half that of the horizontal stabalizer and that the horizontal stabalizer aspect ratio be roughly half that of the main wing.

In regards to the diheral angle two methods will be used to increase the effective dihedral angle. The first method aplyed is placeing the wing high on the fuselage. If it is found that due to the minimilistic size of the fusalage the effective dihedral is less than the additional 2.2 degrees predicted, the wing will be raised using a tab formed from the extra balsa wood stick material. The second method planed to be applied is tapering the wing tips in such a way that a predicted 1 percent increase in effective dihedral angle will occur. In addition to meet the required 5 to 10 degree effective dihedral angle listed an angle of 1.8 degrees or larger will be designed into the main wing.

The most important values calculated using the Excel computation sheet are shown below in table 1.

Table 1: Important Aerodynamic and Static Values

Geometry				
	Wing	hTail	vTail	Fuselage
Cr (in)	2.0000	1.0000	2.0000	NA
Ct (in)	1.5000	0.7500	1.5000	NA
Taper	0.7500	0.7500	0.7500	NA
Cbar (in)	1.7619	0.8810	1.7619	NA
b (in)	14.0000	5.0000	1.0000	NA
S (in^2)	24.5000	4.3750	2.6250	NA
AR	8.0000	5.7143	0.3810	NA
Sweep (rad)	0.0357	0.0500	0.4636	NA
hn	2.1338	12.8041	NA	NA
h	2.3838	13.0541	6.8108	NA
xcg (in)	4.2000	11.5000	11.0000	6.0000
xn (in)	3.7595	11.2798	NA	NA
Weight (lb)	0.0096	0.0900	0.0017	0.0010
Moment (lb*in)	0.0402	0.5400	0.0196	0.0122

Positioning	
Stick Length	12
X Wing	3.2
X Tail	11
X Vtail	10
Static Stability	
Xcg plane	5.9714
h plane	3.3892
hn plane	3.6296
dcm/dα	-0.0432
Kn	0.2404
Density (oz/in^3)	
Lifting Surfaces	0.1000
Fuselage	0.1600

As shown in table 1 a static margin of .24 was achived which is comfortably within the design rnge of .15 to .3, or 15 to 30%. In addition the change in pitching moment with respect to a change in angle of attack is negative. The center of gravity sits just behind the wing and the spacing between the wing and tail is 7.8 inches, additional weight may be added to the nose in the future to increase stability.

VII. PLANNED ADDITIONS

Several features are planned to be added to the aircraft and to this report. The CAD model will correctly show the dihedral deflection as well as the tapered wing tips. A full appendix with all equations listed will be attached. A more complete description of the applecation of said equations will develop. In addition I plan to experiment with increasing stability and efficency by using the extra balsa wood stick material to place the center of gravity more desirably. And finaly a full reference will be provided to support the assumptions made in this report.