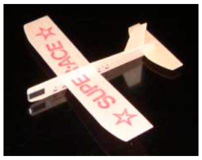

Transportation

Balsa Glider and 747s

Take-Home Experiment Write Up

Introduction

Small gliders made of paper or balsa wood are frequently used in physics classes to demonstrate the balance of forces and features of fluid mechanics such as Bernoulli's Theorem. One immediate observation is that all gliders - balsa or paper - have about the same glide slope, about 1 in 4 , which coincides neatly with the angle of the seating in a typical lecture theatre. This seemingly innocuous feature is however at odds with the behaviour of larger models and full-sized aircraft, the shape of whose wings critically affects the glide slope. The natural flying velocities of small gliders are also very much alike, a few m/s. Here we present the results of an experiment done with a small glider, a "Guillow Super-Ace" ($1.99) made of sheet balsa, of a sort which can be bought in any toy or model store (see specifications in Table I). The experiment can also be done with a well-made paper glider, WhiteWings^{TM} etc.

Flight is achieved by the interaction of a vehicle with the air surrounding it (Fig 1.). As an aircraft moves through the air the flying surfaces deflect air downwards creating a force which can be resolved into components perpendicular to its motion (lift, *L*), and parallel to its motion ("induced" drag).

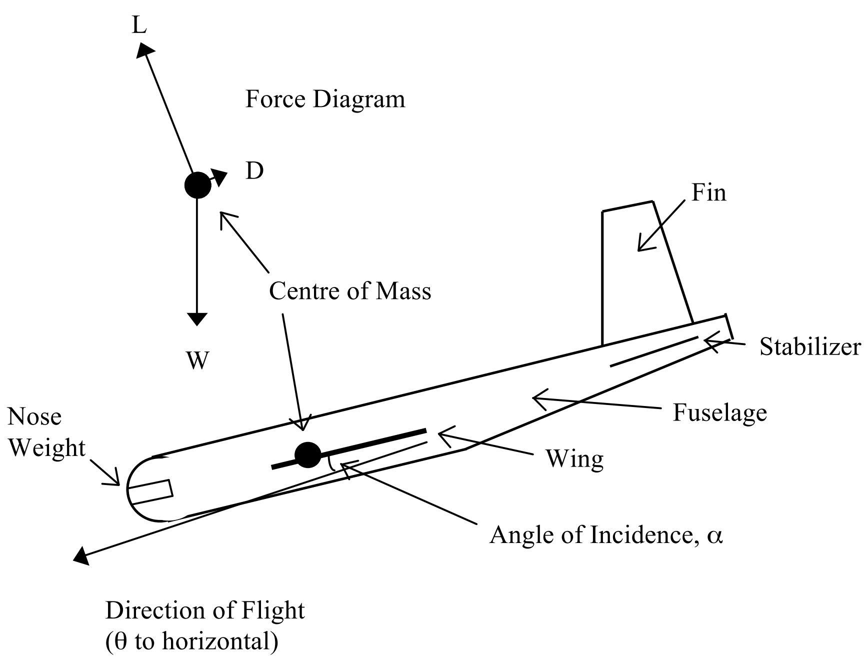

Figure 1: Force diagram for a balsa glider at constant velocity.

At the same time the flow of air past the wings and body of the craft is slowed by friction and changes in pressure caused by the shape; this causes more resistance called friction and pressure (or form) drag respectively. The sum of these drags is denoted by *D*. A well-trimmed glider flies in a straight line at a constant speed, necessarily in a slightly downward direction, by balancing the forces of lift and drag with that of its weight. The flight path is determined by the relative sizes of the two types of drag force. A little geometry on the force diagram will reveal that the tangent of the glide slope θ is just the ratio *D/L*.

The Experiment

The experiment was performed in a large, steep, empty lecture theatre. The glider was thrown many times and great effort was made to launch it at about the right angle and speed to give it a linear trajectory. The flight was timed and the impact point was noted so that *v* and θ could be obtained using a measuring tape and a homemade theodolite (a tool for measuring horizontal and vertical angles). The flight path was 25 m long. The position of the wing in the fuselage was varied to optimize the glide slope. The process was not easy and only a small fraction of the flights were straight enough to give good data.

Mass	3.51 g
Wing area	0.0070 m^2
Chord	36.5 mm
aspect ratio	5.25
Fuselage area	0.0026 m^2
Length	150 mm
Stabilizer area	0.0017 m^2
Chord	22 mm
angle of attack	-2.75° (at $\alpha = 0$)
Fin area	0.0006 m^2
Chord	20 mm
Total surface area / wing area	1.7

Table I: Glider Specifications

Results

The glide slope was measured to be 1:4.5. Therefore the angle to the horizontal was calculated to be:

$$\tan\theta = \frac{1}{4.5}$$
$$\theta = 12.5°$$

The component of lift force (L) is:

$$L\cos\theta = mg$$
$$L = \frac{mg}{\cos\theta}$$
$$= \frac{0.00351\,kg \cdot 9.8\,m/s^2}{\cos(12.5°)}$$
$$= 35.2\,mN$$

The glide ratio (L/D) was about 4.5, therefore the drag force is

$$\frac{L}{D} = 4.5$$
$$D = \frac{L}{4.5} = \frac{35.2\ mN}{4.5} = 7.8\ mN$$

The speed was 3.7 m/s (calculated by measuring total displacement and time). Therefore the power required to keep the glider in the air is

$$P = D \cdot v$$
$$= (7.8\,mN)(3.7\,m/s)$$
$$= 30\ mW$$

Summary

The glide ratio of a balsa glider was found to be ~4.5 and was used to calculate the amount of power required to keep the glider into the air.

References

Waltham, C. E., "The Flight of a Balsa Glider", Am. J. Phys. 67 (1999) 620-624.

Chris Waltham (2009-10-17)