

The Effects of Dihedral and Anhedral Angles on the Flight Performance of UAVs

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Abstract: The field of unmanned aerial vehicle research is made possible by developments in GPS navigation and wireless controlling systems. As a consequence, the pilot does not need to ride within the aircraft. Eliminating the human payload allows the size of UAVs to be much smaller than traditional aircraft, and reduces the number of design constraints, allowing a larger number of shapes to be considered. In this study, a small UAV with triangular wings was tested in a wind tunnel at 18 m/s. Various anhedral and dihedral wing angles were tested and evaluated for lift-to-drag ratio. The peak lift-to-drag ratios were obtained for angles of ± 20 degrees, i.e., for both the dihedral and anhedral angles. The anhedral angle exhibited the better peak lift-to-drag ratio, 1.97.

Keywords-engineering; aeronautics; unmanned aerial vehicles

INTRODUCTION

The field of unmanned aerial vehicle research is made possible by developments in GPS navigation and wireless controlling systems [1,2]. Eliminating the human payload allows the size of unmanned aerial vehicles (UAV) to be much smaller than traditional aircraft, and reduces the number of design constraints, allowing a larger number of shapes to be considered [3-9]. One of the critical components of the creation and design of airplanes and UAVs is the angles of the wings. The deviations from the horizontal plane are called dihedral (upward) and anhedral (downward) angles. In this project, one triangular wing shape at several certain angles was evaluated for maximum and minimum lift-to-drag ratios.

METHODS

A pair of wings was carved from extruded polystyrene foam and sanded smooth. A mount for the wings was made from a soft metal alloy strip through which a hole was drilled to accept an M5 screw to attach to the aeroSTREAM wind tunnel [10] force transducer (model ST180, L. J. Technical Systems, Norwich England UK). The resulting “flying wing” UAV had a wingspan of approximately 18 cm. By bending the wing support, the wing angles were varied from 0 to ± 45 degrees, as measured with a protractor.

Lift and drag on the model UAV (at a wind speed of 18 m/s) were measured with the voltmeter of the force transducer. The voltmeter was calibrated with a spring scale so that measurements could be presented in force units. Three measurements were averaged for each angle.

RESULTS

Figure 1 presents the calibration of the force transducer. At each sensitivity setting, the force used to deflect the force transducer is linearly related to the lift and drag meter readings in volts, with coefficients of fit exceeding 0.98. Figure 2 presents the lift-to-drag ratios vs. the wing angles. Twenty degree dihedral and anhedral angles produced the peak lift-to-drag ratios, 1.97 and 1.59 respectively. Zero degree angle (i.e., the wings horizontal) produced the minimum lift-to-drag ratio, 0.84.

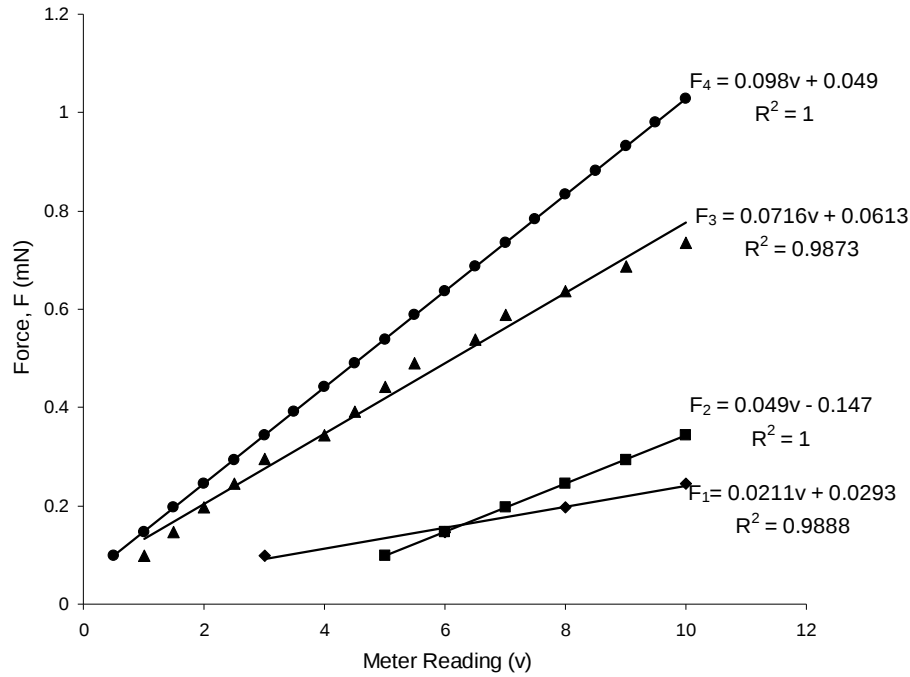


Figure 1. Calibration of the force transducer used for lift and drag measurements in the aeroSTREAM wind tunnel. Subscripts on the force variable indicate meter sensitivity level. The horizontal axis displays the meter readings in native units of volts; the vertical axis displays the measured force in millinewtons. Within uncertainties, identical values were obtained for lift and drag.

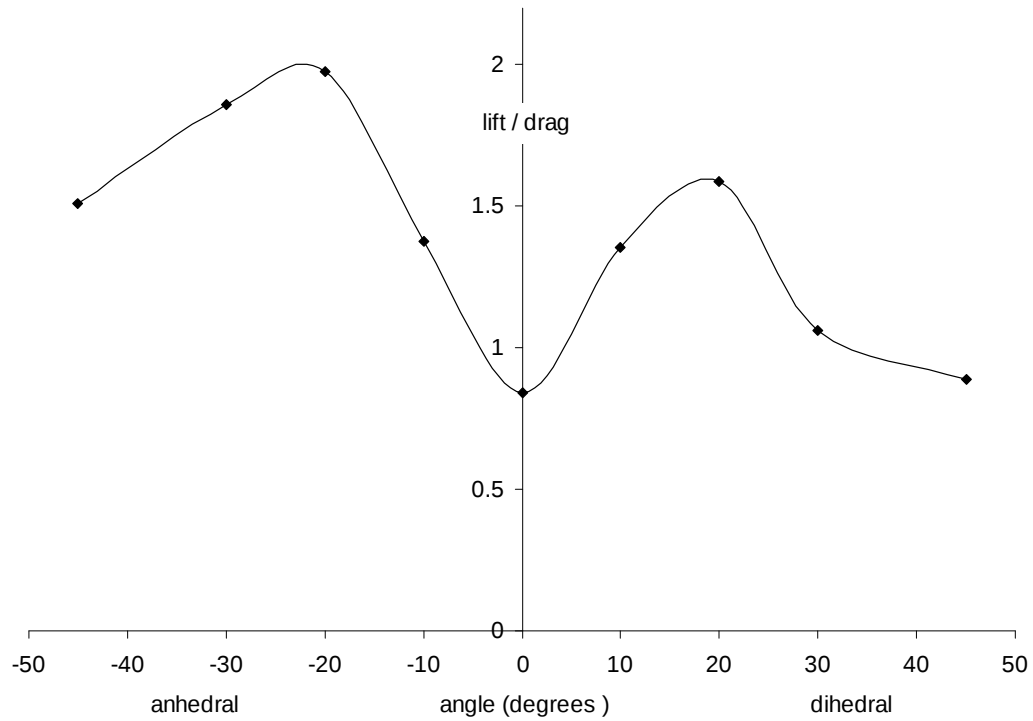


Figure 2. The horizontal axis displays the anhedral (negative) and the dihedral angle (positive) angles between the UAV wings; the vertical axis displays the lift to drag ratio at fixed air speed, as measured with the force sensor (which calibration is shown in Figure 1). A “smoothed” cubic-spline line connects the data points.

DISCUSSION

The wind tunnel used in testing in was small. The chamber could only hold a wingspan of about 20.5 cm, and reach a maximum airspeed of about 18 meters per second.

The ideal shape of UAVs is not necessarily the conventional shape of miniature piloted airplanes portrayed in today's toy industries, but likely to be a much more aggressive flying wing.

Turbulence and controllability were not evaluated, and the optimum angle for these considerations might be different from the optimum lift-to-drag ratio angle.

CONCLUSION

For a UAV with triangular wings in an airflow of 18 m/s, 20 degree dihedral and anhedral angles produced the peak lift-to-drag ratios. The anhedral wing set exhibited a peak lift-to-drag ratio of 1.97, 24% better than the dihedral wing set. The minimum lift-to-drag ratio, 0.84, occurred at 0 degrees.

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