

Aerodynamics of a Circular Planform Aircraft

Bryan Recktenwald¹
Auburn University, Alabama, 36832

A circular planform non-spinning body with an airfoil section offer advantages over a conventional wing aircraft. One such configuration developed and produced by Geobat Flying Saucer Aviation Inc. was tested in the Auburn University wind tunnel facility. For comparison purposes a Cessna 172 model was also tested. Results indicate that the lift curve slope of the Geobat was less than that of the Cessna 172 but displayed better stall characteristics. The Geobat was found to be neutrally stable at lower angles of attack but became more stable at higher angles in comparison to a statically stable Cessna 172. Results of aerodynamic forces and moments are presented and discussed.

Nomenclature

a	=	Lift curve slope
b	=	Span, ft
c	=	Chord, ft
C_D	=	Drag coefficient
C_{D0}	=	Minimum drag coefficient
C_L	=	Lift coefficient
$C_{L, \max}$	=	Maximum lift coefficient
C_M	=	Pitching moment coefficient
L/D_{\max}	=	Maximum lift to drag ratio
S	=	Wing area, ft ²
α	=	Angle of attack, deg
$\alpha_{L=0}$	=	Zero lift angle of attack, deg
δ_e	=	Elevator deflection, deg
δ_F	=	Flap deflection, deg

I. Introduction

Unconventional aircraft configurations have been studied for several decades particular by those of a disk shape with low aspect ratio planforms. An aircraft with this planform can offer distinct advantages over a conventional long, narrow wing planform including structural integrity, maneuverability, decrease in parasitic drag and greater internal volume storage. At very low aspect ratios, the ability of the air to escape around the wing tips tends to prevent stalling even at very high angles of attack while the shorter distance of the control surfaces from the aircrafts centerline allows for higher roll rates.¹ A planform with an elliptical shape, such as disks, yields the minimum induced drag over a rectangular or tapered wing configuration.² However, disadvantages of a circular planform aircraft include a reduced lift-curve slope and longitudinal instability.¹

Jack Jones³, a RC model airplane enthusiast, designed, built and flew a circular wing airplane named Geobat and claimed it to be a “flying saucer.” Flight tests showed excellent low speed handling qualities, nearly stall free landing and high alpha characteristics. A detailed analysis of flight videos showed that the Geobat possessed good overall performance envelope combining outstanding Short Take Off and Landing (STOL) performance and

¹ Graduate Research Assistant, Aerospace Engineering Department, 211 Davis Hall, Auburn, AL 36849, Student Member

reasonably high cruise speeds with superb aerobatic capabilities. Later the Geobat Flying Saucer Aviation Inc. approached Auburn University to investigate and document the aerodynamic characteristics of the Geobat airplane.

The objective of this investigation was to compare aerodynamic characteristics of the Geobat and Cessna 172 model. Both aircrafts possess similar characteristics including passenger capacity and gross weight.

II. Experimental Setup

Model Geometry Comparison

The Geobat model had a disc-shaped body of 22 inch outer diameter with a central opening. The model can be best described as a back-swept front wing, a forward-swept rear wing and connecting wing tips, thus creating a 360 degree circular planform (Figure 1). The control surfaces included front ailerons, rear ailerons, a large elevator and two rudders. The Cessna 172 model is presented in Figure 2. Characteristics of both models can be found in Table 1.

Both models were set up to allow for the same flap and elevator deflections. Flaps deflected at $\delta_F = 0, 10$ and 20 degrees and the elevator deflected at $\delta_e = -20, -10, 0, 10$ and 20 degrees. All cases are presented in this report. A transition strip was installed on both models to produce turbulent flow over the wing section of the models.

Table 1. Geometric Parameters

	Geobat model	Cessna 172 model
Airfoil Section	NACA 23012	Clark Y
Span, b (ft)	1.830	2.500
Chord, c (ft)	0.820	0.375
Wing area, S (ft ²)	1.320	0.940
C.G. loc. From nose (ft)	0.645	0.585



Figure 1. The Geobat model

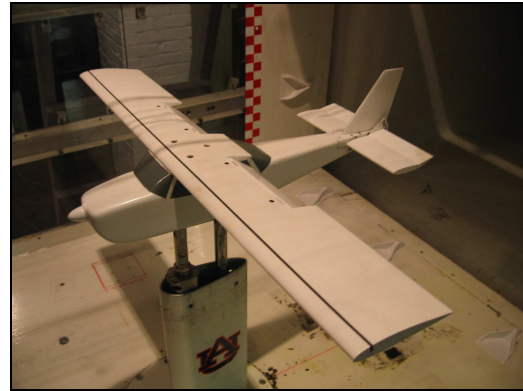


Figure 2. The Cessna 172 model

Test Facility and Experimental Setup

Experiments were conducted at the Auburn University 3 ft x 4ft low subsonic closed circuit wind tunnel with speeds capable of 180 ft/s. Force and moment data was acquired from a 6 component pyramidal balance with the help of National Instruments A/D board and Labview data acquisition software. Data was acquired at a sampling rate of 500 hertz. The raw data consisted of 1,000 samples per degree which was later processed through Labview and stored in coefficient form.

All tests results presented were performed at 100 ft/s with angle of attack ranging from -5 to 20 degrees in 1 degree increments. The Geobat model has a larger Reynolds number due to the larger chord length, c. The unit Reynolds number for the tests was 550,000. The mounting of the model was located at the center of gravity and was secured using the same mount and screws. Prior to each test the pyramidal balance was re-calibrated and check for

reliability. The uncertainty error was 4% for the entire test setup. The models were mounted to the external pyramidal balance. The mounting system was covered with an airfoil shaped shroud to minimize flow interference on the mount (Figure 3).

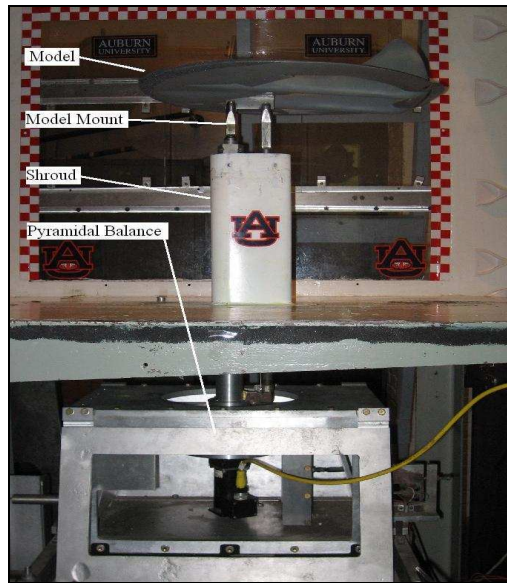


Figure 3. Experimental setup with model

III. Results and Discussion

The lift and drag trends that are presented in Figures 4 through 7 are typical of a finite aspect ratio wing⁴. Figure 4 and 5 shows a comparison of the lift curve of the two models. It is noticed that the lift slope for the Cessna 172 is larger than that of the Geobat but the stall angle is 14 degrees vs. 19 degrees of the Geobat. The flap deflection for the Geobat model does not vary as much as the Cessna 172.

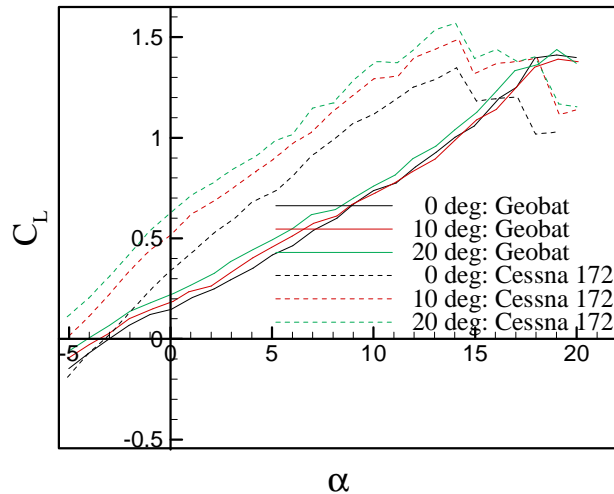


Figure 4. Lift curve: $\delta_c = 0$ deg, $\delta_F = 0, 10, 20$ deg

Comparing the two models with a $\delta_F = 0$ deg and a varying δ_e , as shown in Figure 5, a noticeable difference can be seen in the stall region of the Geobat as well as the $C_{L,max}$ and $\alpha_{L=0}$. Again, the lift curve slope is larger for the Cessna 172 model, but stall characteristics are better for the Geobat model.

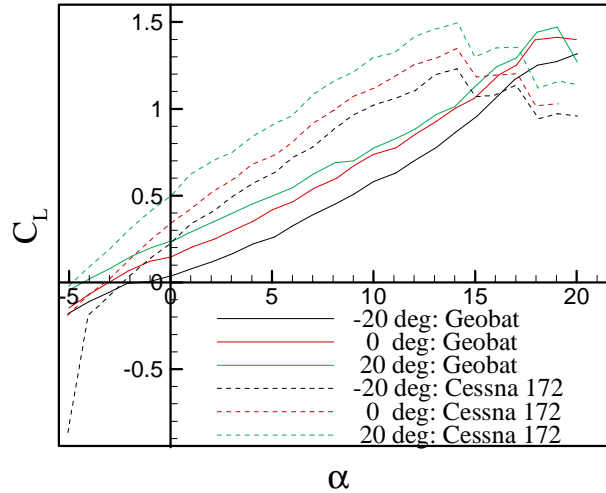


Figure 5. Lift curve: $\delta_e = -20, 0, 20$ deg, $\delta_F = 0$ deg

Figure 6 and 7 show the comparison of drag for both models. It was noticed that the Geobat possesses better drag characteristics than the Cessna 172 model as shown in Figure 6. Both the drag for $C_{D,min}$ and the stall region are better. Changing the elevator and keeping the flap settings the same, drag trends for both models are relatively equal with higher drag for the Cessna after stall. This is shown in Figure 7.

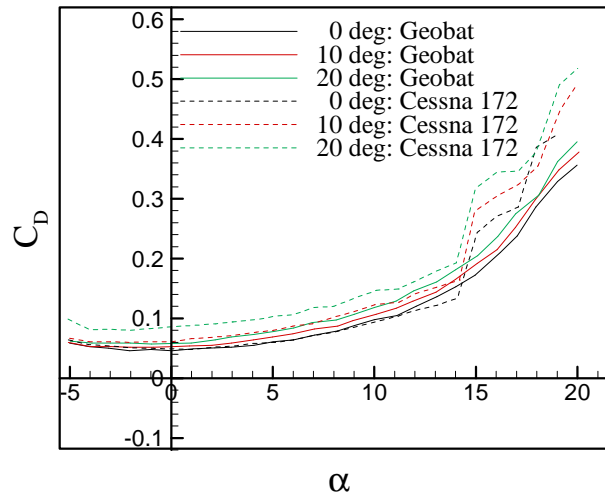


Figure 6. Drag curve: $\delta_e = 0$ deg, $\delta_F = 0, 10, 20$ deg

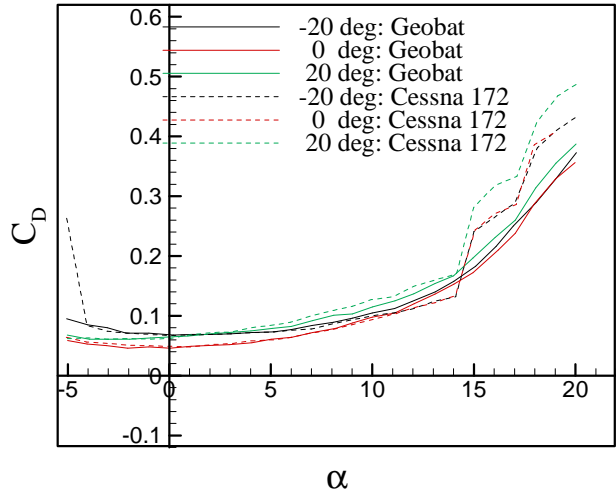


Figure 7. Drag curve: $\delta_e = -20, 0, 20$ deg, $\delta_f = 0$ deg

Plotting C_L vs. C_D , for both cases of flap and elevator deflection shows a higher maximum lift to drag ratio for the Cessna 172, $L/D_{max} = 11$, in comparison to the Geobat, $L/D_{max} = 7.5$. It is also noticed that as the lift coefficient increases for the Geobat the drag coefficient increases also, much more than the Cessna 172, although the stall region of the Geobat is much better.

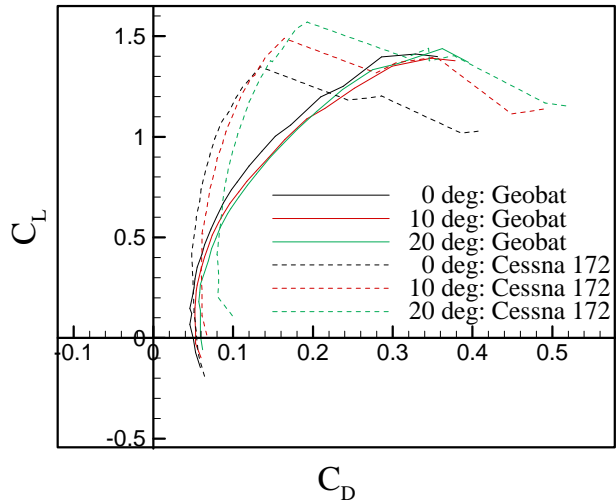


Figure 8. Drag polar: $\delta_e = 0$ deg, $\delta_f = 0, 10, 20$ deg

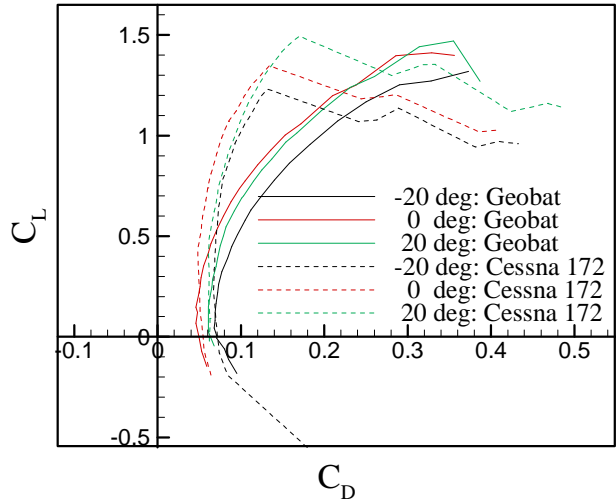


Figure 9. Drag polar: $\delta_e = -20, 0, 20$ deg, $\delta_F = 0$ deg

There is a large difference in the pitching moment coefficient plots, presented in Figures 10 and 11. Figure 10 shows a much larger negative pitching moment slope throughout the α range for the Cessna 172. The Geobat shows a relatively neutral to stable⁵ trend for the range of angles of attacks tested. The pitching moment coefficient for the Geobat model remain neutrally stable up to 9 degrees AoA and followed by a linear decrease in slope between 9 degrees and 20 degrees AoA, resulting in a more statically stable condition. This pattern is similar to the pitching moment characteristics of a NACA 23012 series airfoil⁴.

The stability of both aircraft in Figure 11 are more closely related. With elevator deflection both models have a larger change in C_M in comparison to just a flap deflection change. Again, the Geobat remain neutrally stable with a slight increase in stability at higher α . The Cessna 172 model has a smaller change in slope in comparison to the slope in Figure 10.

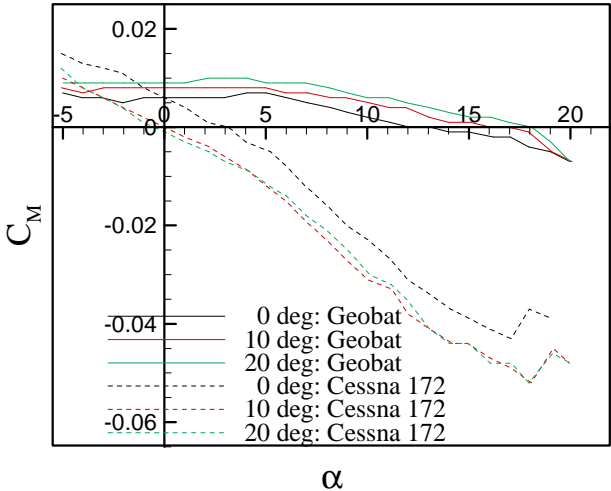


Figure 10. Pitching moment curve: $\delta_e = 0$ deg, $\delta_F = 0, 10, 20$ deg

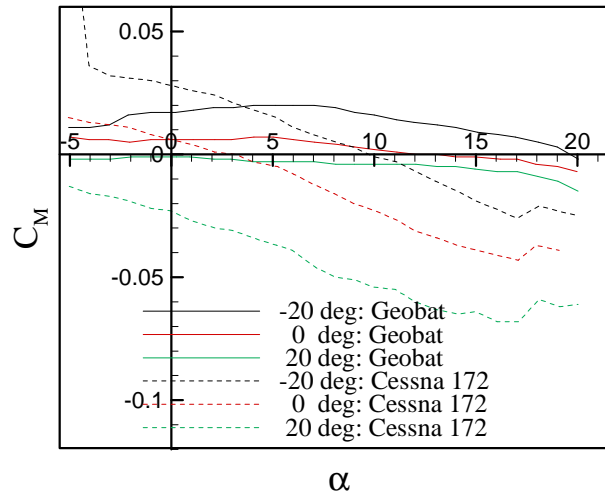


Figure 11. Pitching moment curve: $\delta_e = -20, 0, 20$ deg, $\delta_F = 0$ deg

IV. Conclusions

Wind tunnel tests confirmed acceptable aerodynamic characteristics of the Geobat airplane. The lift curve shows a higher stall angle for the Geobat with relatively the same $C_{L,max}$ as the Cessna 172. The lift curve slope of Geobat however was lower than that of Cessna 172 model. Drag data revealed a lower minimum drag for the Geobat model and better stall characteristics but with lower L/D_{max} when compared to Cessna 172.

The pitching moment for the Geobat indicated neutral stability in the lower α range and higher stability with increasing angle of attack while the Cessna 172 has good stability characteristics through for the entire range of angles of attack.

V. Acknowledgements

The Geobat testing was funded through a grant from Geobat Flying Saucer Aviation Inc., with Randy Pollard as the grant monitor. Appreciation and acknowledgement is extended to the Geobat designer, Jack Jones.

VI. References

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