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Static Stability of Micro-Air Vehicles

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Objective

The purpose of this research was to find the optimal combination of three static stability-enhancing features: dihedral angle, vertical position of center of gravity, and tail volume ratio.

Procedure

Five test aircraft were built using a computer aided foam-cutting machine. We varied tail-volume ratio and dihedral at high, low, and center positions. All planes were built such that vertical position of center of gravity could also be varied. One previously selected airfoil was used in all of the test planes to eliminate the airfoil as a factor in the experiment. All of the aircraft were built identical to each other, except for controlled variation of the test parameters.

A sophisticated launch mechanism was designed and built. The launch mechanism was designed such that the correct angle of attack, glide angle, and glide speed for the test aircraft could be achieved consistently without varying between test flights.

A three variable factorial experiment was performed where all three parameters were tested at high low and center levels. The glide tests were run in a large enclosed space to provide a controlled area for consistent glide test conditions. The nine settings were each run twice in random order. The landing position of each glide test was recorded in a Cartesian coordinate system, where the y-axis represented the distance along a straight trajectory and the x-axis represented the deviation from a straight trajectory.

The collected data was then analyzed to see which variables were significant, and if any of the variable interactions were significant. We then were able to see how each variable affected the glide distance as well as the deviation from a straight trajectory.

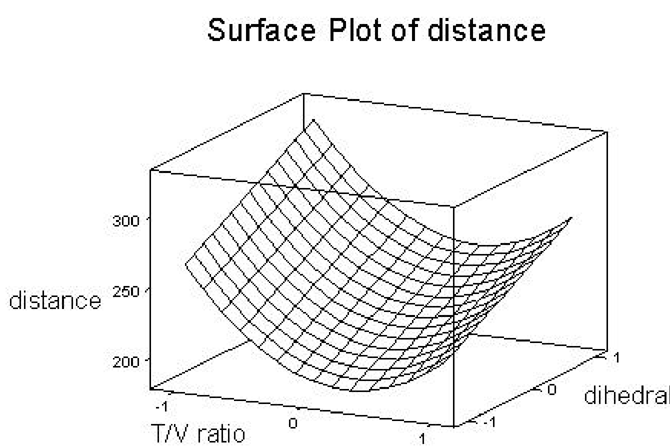

Figure 1. Effects of tail-volume ratio and dihedral on distance.

Results

A statistical analysis was performed on the collected data. Separate analyses were performed on the effects of all the variables on distance and deviation. Before making any conclusions about our statistical model, we checked to make sure the plot of the residuals were normal. The normality of the residuals is necessary to assure that our statistical model is valid. Contrary to our predictions, the only significant variables to affect distance were tail-volume ratio and dihedral. A surface plot of these significant variables and their effect on the distance can be seen in Figure 1. This figure shows that a low tail-volume ratio and high dihedral result in the greatest distance of our micro-air vehicle. The significance on distance of all of the factors can be seen in Table 1. Factors whose significance values are less than 0.05 have an affect on the distance. Since the significance of dihedral is considerably less than 0.05, we can conclude that it is the most significant factor.

The effects of the variables on flight deviation were also analyzed. All of the one-way and two-way interactions seemed to be insignificant, but the three-way interaction showed some significance. To find which three-way interaction gave us the smallest deviation, all of the 8 different three-way interactions were looked at. The three-way interaction that resulted in the smallest deviation was low tail-volume ratio, low center of gravity, and high dihedral. The significance of the factors on the deviation can be seen in Table 2.

Table 1.

Factor Effects on Flight Distance		
Factor	**Significance**	**Significant**
Tail Volume Ratio (TVR)	0.044	YES
Center of Gravity (CG)	0.340	NO
Dihedral	0.018	YES
TVR-CG interaction	0.553	NO
TVR-dihedral interaction	0.165	NO
Cof G-dihedral interaction	0.438	NO
TVR-CG-dihedral interaction	0.625	NO

Table 2.

Factor Effects on Straight Flight		
Factor	**Significance**	**Significant**
Tail Volume Ratio (TVR)	0.296	NO
Center of Gravity (CG)	0.218	NO
Dihedral	0.749	NO
TVR-CG interaction	0.975	NO
TVR-dihedral interaction	0.951	NO
Cof G-dihedral interaction	0.343	NO
TVR-CG-dihedral interaction	0.032	YES

Conclusion

The test performed in this study show that dihedral angle had a greatest positive effect on the stability of micro-air vehicles. Therefore, in the design of MAVs, effort should be made to optimize dihedral angle to improve airplane flight characteristics. It also should be noted that the three way combination of high dihedral, low tail-volume ratio and low vertical position of center of gravity was important in reducing deviation from straight flight. More work should be done to find the dihedral angle, tail-volume ratio, and vertical position of center of gravity that provides the optimal combination of the three.