A DISCUSSION OF SPEED EFFECTS ON MODEL TRIM

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An article found in the effects of our late squadron leader, Paul Grabski. The original source is unknown

The aerodynamic forces and moments on a model characteristically vary with the square of the velocity. For example, flying a model at twice its glide speed will increase the lift of its wing two squared or four times what its gliding lift coefficient (CL) will give at glide speed. However, the lift of the horizontal tail will also increase by the same factor so the model stays in trim. That is, its lift coefficient doesn't normally change just because the speed does. The resulting lift due to the speed increase may be too large to allow a stable climb path and the model may loop, but its lift coefficient still maintains essentially the value it had in the glide, only being decreased a bit by the effects of the curved flight path it is flying (circular airflow.)

The lift coefficient that the model glides at is determined by the horizontal tail setting and the stability of the model. Typically, our models glide at a lift coefficient in the vicinity of 1.0 for this is about where we get the minimum rate of sink needed for maximum glide duration.

The further forward the model's center of gravity (measured from the wing leading edge in percent of mean aerodynamic chord), the more stable it is and the more the trailing edge of the stabilizer has to be raised to get the desired lift coefficient. Most of us have experienced this large angular difference between the wing and the tail — which we will define as geometric decalage -- required on a model with a forward C.G. We have also experienced the converse, where the C.G. is moved rearward, very little geometric decalage is required to get the desired glide lift coefficient.

From this it follows that the more stable a model is, the more we have to deflect the horizontal tail to get a given change in the lift coefficient. In fact if the model is twice as stable with the C.G. forward as it is with the C.G. back, it will take twice the tail deflection at the forward C.G. as it will at the aft C.G.to get the some change in the lift coefficient, say 0.1.

Thus the model is more sensitive to trim changes at the aft C. G. than it is at the forward C.G. Big news? Not really, but it is necessary to lay a little foundation before we start discussing the model characteristics that do affect the model trim, and do change the model's lift coefficient as the speed changes.

There are two factors acting on models flying in our speed regime that change the model's trim, and thus its lift coefficient. This change occurs in flight even though the model's geometric decalage is not changed from its glide value. These factors are down-thrust and Reynolds Number (Rn) effects. The discussion in this paper is based on references 1 and 2 (listed at the conclusion of this article) in which the effect of these factors on Wakefield models was analyzed. The factors, however, affect all models and the following discussion has general application.

- Down-thrust is defined as the distance that the thrust-line passes above or below the vertical position of the model's C.G. The angle that the thrust-line makes with the wing chord plane has some effect too, but it is not a very powerful one.

The Reynolds Number is a non-dimensional scale parameter. Big airplanes have big Rn (in the millions) and small airplanes (models) have small Rn (in the thousands). The characteristics of the aerodynamic forces on an airplane's flying surfaces change as the Rn changes.

For standard air conditions, the Rn may be determined from:

Rn = 532 x Chord (in inches) x Velocity (in ft. per sec)

Thus, the Rn changes directly with speed. If we double the speed of the model, we double the Rn.

Several of the model's aerodynamic characteristics change as the Rn changes. The particular aerodynamic characteristic which varies with Rn that concerns us is the angle of zero lift of the model's airfoil. The angle of zero lift on an airfoil is the angle that the wind would have to make with a line through the leading and trailing edges to result in no lift from the airfoil regardless of the model's speed (i.e. CL = *0)*. For cambered airfoils, this is usually a negative angle, for the wind must strike the airfoil from above the leading edge to get a zero lift coefficient. (See reference 3 for more information on angle of zero lift) How each of these factors affect model trim will now be discussed.

EFFECTS OF DOWN-THRUST

When the thrust-line passes above the vertical C. G. position, the thrust creates a nose-down moment on the model. The larger the thrust is and the greater the perpendicular distance from the thrust line to the C.G., the greater will be the nose-down moment. The same is true when the thrust-line passes below the C.G. except the moment is now nose-up.

The nose-down moment reduces the model's angle of attack and thus decreases its lift coefficient from the value it has in the glide. The nose-up moment of course does just the opposite, it increases the model's lift coefficient from the glide value. The degree to which the thrust moment changes the model's lift coefficient depends on how sensitive the model is. If the C. G. is aft and the model has low stability we can get large changes in lift coefficient with small down-thrust or up-thrust values. With the C.G. forward, the model is less sensitive and thus more down-thrust or up-thrust is required to achieve the same change. Incidentally, the same is true for side-thrust, the lower the model's directional stability (e.g. small vertical tail), the more sensitive it will be to side-thrust changes!

- Since the aerodynamic forces increase and the thrust of a model's propeller decreases as the model's speed increases, down, up or side-thrust is most effective when a model's speed is low and least effective when the model's speed is high.

Another aspect of the thrust-line effects is associated with the propellor slipstream and its interaction with the flying surfaces. If this effect is a very strong one (this author has done no calculations, nor has he seen any done for models) its effectiveness will be most pronounced at low-speeds and will increase as the model speed increases. On a Wakefield model, it may be of little consequence for the slipstream velocity at flying speed is little different from the model's speed. On a gas powered model, it could be of more significance, however.

REYNOLDS NUMBER EFFECTS

As mentioned earlier, the principle Rn effect that we are concerned with is the variation in airfoil angle of zero lift with Rn. In the low Rn range that our models fly (up to about 200,000) the angle of zero lift of on airfoil becomes a bigger negative number as the Rn is increased and vice versa. (Reference 4.) The reason that this is so is that at very high Rn, the airflow can follow the concave lower surface of a cambered airfoil even though the stagnation point is on the upper surface. Thus, to reach the angle of zero lift, the airfoil must be inlined to larger negative angles.

As the Rn is decreased, the boundary layer flow has less and less energy. It becomes less able to follow the concave lower surface and tends to separate near the bottom of the leading edge. Consequently, the same airfoil will not have to be tipped to as large a negative angle to reach the airfoil zero lift angle at low Rn as it will at high Rn. As a result, the angle of zero lift of the wing and stab airfoils actually changes in flight as the Rn varies in accordance with the model's speed changes!

In trimming a model for the glide, we establish two relationships between the wing and tail:

a. The geometric decalage, which is the angle between the wing and stab chord planes.

b. The aerodynamic decalage,which is the angle between the wing and stab angle of zero lift lines.

The geometric decalage stays fixed throughout the flight for a fixed tail model. The aerodynamic decalage, however, will vary with the model's speed since the airfoil angles of zero lift vary.

This is a very significant factor, for the lift coefficients of the wing and the stab are measured from their angle of zero lift, by definition. If the wing and stab angles of zero lift vary in flight, then the CL of the wing and stab must also vary.

The angle of zero lift of the wing and stab can change by as much as one to two degrees when going from glide speed to powered flight speed. This is exactly equivalent to changing the geometric decalage by the same amount, and definitely changes the trim of the model from what it was in the glide.

The strength of this change depends on several factors:

a. If the stab mean camber is greater than the wing mean camber, the stab lift coefficient will increase more than the wing lift coefficient as the speed increases and will cause a nose-down moment decreasing the model's lift coefficient.

b. If the wing mean camber is greater than the stab mean camber, the wing lift coefficient will increase more than the stab lift coefficient due to speed increases causing a nose-up moment which will increase the model's C/L.

c. The greater the stab tail-volume-coefficient, the stronger the effect of the Rn angle of zero lift change on the stab, regardless of it's mean camber. This means that a stab with a mean camber less than that of the wing, could still create a nose-down moment and decrease the model's lift coefficient with an increase in speed; provided its tail volume was big enough.

d.) The more sensitive a model is due to on aft placement of the C. G. position, the more effective the nose-up or nose-down Rn effects will be. If the model has a combined tail volume and mean camber arrangement that causes the model to nose-up as the speed increases, this effect will be accentuated by putting the C.G. back. If it has a nose-down tendency with speed increase and the C.G. is moved bock, the nose-down tendency will increase.

Thus, it can be seen that the Rn nose-down effect with on increase in model speed can be, and in fact is, used to decrease the model's lift coefficient from the value it has in the glide to a lower value under power to achieve climb stability.

That is exactly what we are doing when we move the C. G. back gradually on a power model until we get just the right amount of nose-down effect to control the climb. If the C.G. is placed too far back, the climb may be controlled but the model will never get a chance to slow down and change its aerodynamic decalage back to its glide value. The result is straight up – and straight down!

* A rubber model which has too small a tail volume coefficient and a mean camber of the stab which is smaller than that of the wing will try to increase its CL under power, rather than decrease it. The net result is that the model will just continue to power stall. Moving the C.G. back will make it worse. To cure this problem the stab's tail volume must be made bigger or its mean camber must be increased or both.

* *A!2* gliders and hand launch gliders which have their C.G. too far buck can get upset in a thermal, pick up speed, change their aerodynamic decalage enough so that the decrease in CL causes a further increase in speed, etc., until they are on their way down in a spiral dive.

* A contributing factor to this problem can be a large rudder deflection. The vertical tail is also a cambered surface when the rudder is deflected, and as the speed (Rn) increases, its side force can increase enough to put the wing down, which will increase the speed, increasing the side force, etc. Even with a forward C.G., too big a rudder deflection, which may work fine in undisturbed flight, can spiral dive an A/2 all by itself. A trick the author is currently using on A/2 is an all moving vertical tail which, because it is not cambered by rudder deflection, has no speed sensitivity.

* Another factor which helps on an A/2 but not on a hand launch glider is to make the wing mean camber greater than the stab mean comber intentionally. Thus, as the model's speed increases, the CL increases and vice versa helping the model's oscillations damp out quicker, This in fact is a form of speed stability, but it cannot be used on power models or hand launch gliders for they require a bit of speed instability (i .e. nose-down effect with increase in speed) to control the climb pattern.

* One possibility for hand launch gliders which to my knowledge has not been used to date is to:

1. Increase the mean camber of the stab so that it more closely approaches that of the wing;
2. Put the C.G.further forward (the exact position depends on the glider's tail volume and relative mean camber;
3. Increase the geometric decalage between the wing and the stab. Without the increase in the mean camber of the stab, the glider would have too much geometric decalage and could not be launched effectively.

The benefits to be gained are a decrease in the speed instability. The C.G. can be put forward for stable glide while still having enough nose-down effect to control the launch.

CONCLUDING REMARKS

Both the Reynolds Number effects and down-thrust can be used to help decrease a model's CL from its glide value to a value that is compatible with the requirements of climb stability. Both effects are more pronounced as the model is made more sensitive by rearward C. G. movement. Both effects can cause either on increase or a decrease in model CL when going from gliding flight to powered flight. The Reynolds Number angle-of-zero-lift change can also affect a model's lateral-directional characteristics when a model's rudder is deflected substantially to achieve a turning flight path. The affects of these two factors appear to explain many of the flight characteristics that are experienced when trimming models having fixed geometric: decalage.

REFERENCES,

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