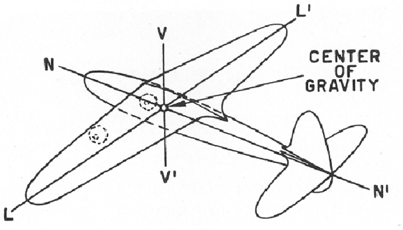
GRANT ON DIRECTIONAL STABILITY

This is the second in a series of articles abstracting information concerning Stability from the 1941 book "Model Airplane Design and Theory of Flight," written by the famous Charles Hampson Grant. Let the reader understand that I'm going to be liberally using Grant's exact words and illustrations, condensing them, and for ease of reading the constant use of quotation marks is omitted.

by George White

The first article in this series on stability dealt with Grant's defining the types of stability and talked about the factors influencing and methods of achieving lateral stability.



As a point of reference, Grant defines stability as the capacity of an airplane to overcome any tendency to displace or turn from normal flight — or to return to normal flight after displacement.

As can be seen from the diagram above, there are three kinds of stability to deal with, i.e. **Longitudinal stability** which refers to the maintenance of normal flight about axis, L-L^1. **Directional stability** which refers to the maintenance of normal flight about the vertical axis, V-V^1. **Lateral stability** which refers to the maintenance of normal flight about the axis running through the center of gravity on axis N-N^1.

As discussed in the previous article, critical to achieving stability in a model is the establishment of the center of gravity (c.g.) both vertically and laterally. Having done that, this article will discuss **Directional Stability** and the related **Spiral Stability**, which is a combination of lateral stability and directional stability which prevents the airplane from executing a spiral dive.

Grant defines the factors influencing directional stability as: **Area of the vertical tail surface, distance of fin from c.g.(Fin moment arm), wing span and distribution of weights along a horizontal plane relative to the c.g.**

Area of Vertical Tail Surface. The fin is the primary factor in obtaining directional stability. Some good rules of thumb are provided as follows:

On an "average model with regular proportions," make the fin area 12% of the wing area, but never less than 10% in a rubber powered model. In a gas model of "average" design is should be 7 1/2% of wing area, although some may require only 5%, the minimum. Grant then classifies rubber models as fuselage models and stick models with and without landing gear. The fin area on either scale or fuselage models should not be less than 12% of wing area. On stick models with landing gear, it should be 13% or more. On stick models without landing gear, the fin area should be 18% or more. Stick types usually require more fin area because the nose is long in front of the wing. On biplanes, the fin area should be about 20% less than on monoplanes. All this applies only to tractor types.

In shaping a fin, Grant states that the height of the fin should be not less than 80% of the width. Within reasonable limits, the greater height will be more efficient because the lower fin will be blanketed by the wings and stabilizer when the model is in a stall, losing effectiveness. He also praises the practice of placing part of the fin below the fuselage as a means of preventing spiral instability.

Fin Moment Arm is the distance from the airplane's c.g. (usually 1/3 of the chord back from the leading edge to the center of the fin area. Fin effectiveness may be increased by enlarging the area, so the farther the fin is from the c.g. the smaller it may be and yet give the same stabilizing effect. The shorter the moment arm, the larger the fin — or the longer the moment arm the smaller the fin should be. In rubber models, Grant recommends that the fin moment arm should be from 40% to 50% of the wing span, but never less than 40%. The fin area for the "average" rubber model should equal at least 12% of the wing area when the fin moment arm is equal to half the span. He states that when making the moment arm longer or shorter, the product of moment arm times fin area should be the same after either is changed. The stabilizing effect is proportional to moment arm times fin area.

The fin can be both a disturbing factor and a correcting factor. When a gust forces the fin sideways, the direction of the model is disturbed, but the air reaction to the other side allows the fin to also be a correcting factor.

Wing Span can act as a disturbing factor. For example, turbulence striking one wing will twist the model around the vertical axis, swinging the fin out of line. The fin is resistant and dampens the motion. Fin area must be enlarged proportionately with wing span so that the displacement due to wing action will not be so great as to prevent positive and quick recovery. The larger the fin, the less effect uneven drag on the wings will have. Grant's recommendation is to make the fin moment arm as long as possible, within limits of not making the tail too heavy.

Weight Distribution. The distribution of weight relative to the c.g. has a critical effect on the ability of a model to correct any directional displacement. For quick recovery from upsets, weights should be as close to the c.g as possible. This is much easier to do with a gas model than a rubber model carrying a large, heavy rubber band running the length of the fuselage. That weight requires a larger fin to offset any tendency to spin or crab. This is often overlooked in designing scale rubber models, when failure to recognize the weight of the rubber aft of the c.g. results in building too small a tail surface.

Spiral Stability is defined as the capacity to resist simultaneous displacement about all three axes or to recover from such displacement. When a spirally unstable plane is adjusted to fly horizontally or at a slight angle of climb, it noses down when banking. Increase in speed results, followed by a steeper bank, and so-on in increasing cycles until it crashes. A plane with spiral stability banks only slightly in a turn and holds this bank steadily without dropping the nose, and when upset, recovers immediately. This is actually a combination of lateral and directional stability. Grant uses the following illustration.

A scale model takes off for its initial flight. It climbs at a normal angle at first, but soon banks to one side; although the ship's hoped-for reaction is a sideways slip to immediately right the plane, it continues to bank and a turn results. The the nose drops and the turn becomes tighter and the bank steeper into a tight spiral and a crash. What's wrong with the plane? It's spirally unstable!

This can be corrected very simply. If it is a light, slow flying model, give the wings more dihedral (usually 6º to 10º on each side is sufficient); cut away part of the fin above and add area below the fuselage.

Spiral instability is usually prevalent in flying scale models because their design follows closely that of full scale ships which themselves are spirally unstable. It is often exaggerated in the model because the designer has increased the tail surfaces, including the fin. This fin enlargement, plus the customary lack of dihedral in scale models, ruins a model that otherwise would be an excellent flier.

Grant devotes several pages of his book to examining the complex theory behind achieving spiral stability. Rather than consuming an entire newsletter with the subject, I'll reproduce here how he summarizes the entire discussion with prescribed remedies in the following four points.

1. In a rubber powered model, make the fin not less than 10% nor more than 13% of the total wing area, and the tail moment arm equal to 1/2 the wing span. For gas models, make the fin 6% to 8% of the wing area. (Ed. Note. The longer the nose, the larger the fin needs to be.)

2. Dihedral the wing on each side not less than 6º above the **thrust line** and not more than 11º, (or 1.25in/ft to 2.3in/ft) (Ed Note: For a high thrust line low wing model, that can be a "sporty" amount of dihedral.)

3. Do not place the fin area too far above the thrust line.

4. Keep the c.g. 2/3 of the fuselage depth above the lowest contour of the fuselage.