Down Thrust

The following is a discussion by Charles Hampson Grant in his 1941 book "Model Airplane Design and Theory of Flight." This is an exact copy of his discussion.

At almost any contest, when a model does not perform properly, "down thrust" is freely advised. If the model does not climb. "down thrust" is recommended; if it stalls - "Use down thrust."

This seeming cureall requires definition, and the nearest that be established is as follows: "down thrust" is the negative angle between thrust line and an arbitrary base or reference line established when building the airplane. It appears quite simple, but the measure of down thrust according to this definition depends entirely upon the position of the base line relative to other aerodynamic factors of the airplane. Builders, therefore, arc actually determining the degree thrust relative to a line whose position is not definite

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This contention may raise objection that this line has been drawn in a definite position after calculating the other factors (as angle of incidence and tail angle) in relation to this thrust line; but the objector will have failed to see that the position of such a line is purely arbitrary. In one model it may run from the top of the fuselage nose to the lower rear corner; or, it may start at the lower front and run to the upper rear corner.

This base line is an elusive aerodynamic factor and is hardly the proper basis for designing a mechanically accurate model. It is the result of specious thinking, visualizing models as concrete structures of balsa wood, paper, wire, etc.,instead of considering them as combinations of dynamic forces — the only way a designer should visualize a plane to understand what takes place during flight.

Down thrust should be determined and measured relative to the aerodynamic force setup, or to a structural factor which is related to the force arrangement, and not as a function of the top longeron or any other irrelevant structural unit.

To illustrate: in Fig. 96 a base line is drawn from nose to tail of the fuselage. The wing is set at 2° angle of incidence to this base line; stabilizer is set at zero, or parallel to the base line. To prevent the ship from stalling the builder usually decides to give it 4º down thrust; so he draws in the thrust line 4° negative to the base line as shown in the figure. Feeling he has followed all the rules of design, he then proceeds to determine plane speed, and the blade area, pitch or other propeller characteristics on a basis of 2º wing angle of incidence.

This designer could not have made a greater mistake. For suppose the base line is changed to the position shown in Fig. 97, all other features of the plane remaining in their same relative positions. This second base line is 2º more negative than in Fig. 96. Now we have the same airplane with a 4º wing angle of attack, and a stabilizer set at 2º positive. The negative thrust is 2º.

Which setup is right? Which should form the basis for calculating level flight speed and propeller characteristics?

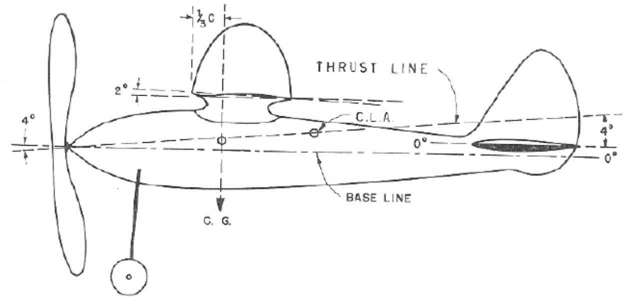

Fig. 96

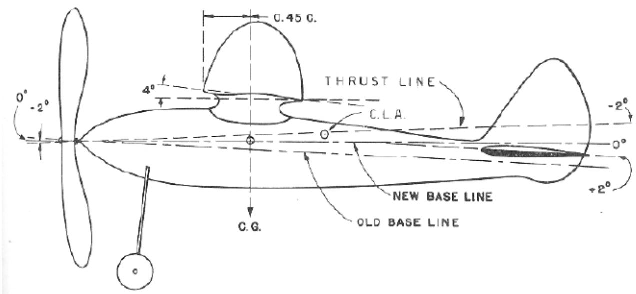

Fig. 97

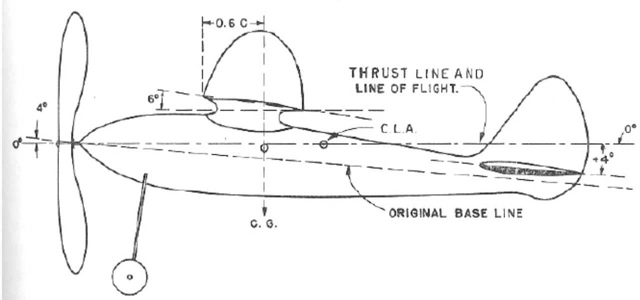

Fig. 98

Both models will perform alike, for none of their characteristics has been altered to affect aerodynamic force setup; but the down thrust in each model is different. It is apparent, therefore, that down thrust, when established relative to an arbitrary base line, cannot be a measure of aerodynamic effect.

The inference should not be taken that there is no such thing as downthrust; but the contention is that it is a misnomer. To give further credence to this, turn the plane clockwise about c.g. so the thrust line is horizontal, Fig. 98. The plane is the same in all respects in as the one in Figs. 96 and 97. The true aspect of the situation now begins to appear, and with a little thought one must come to the unavoidable conclusion that the flight path is parallel to the thrust line when the plane flies at minimum level flight speed. In this position there is no down thrust relative to line of flight. This proves that actually *in relation to aerodynamic factors* there is no such thing as down thrust; and to calculate it relative to some arbitrary construction line is misleading and complicates a simple problem.

Examine the aerodynamic setup in Fig-. 98. Thrust line being zero, the wing angle of incidence is +6º; stabilizer angle +4°. With this system, characteristics of the essential factors of the plane can be determined by merely considering three of these factors. It is not necessary to create a fourth — the arbitrary base line.

The fuselage is not horizontal; but this is unimportant because; it only affects flight through parasite resistance. On the basis of down thrust, as taken in the first example, some visualize the fuselage as passing through the air in a horizontal position. This is incorrect, for, as shown in Fig, 98 the fuselage at minimum speed in level flight travels "tail low." So, although the design is based on a misconception, aerodynamic forces are in the correct relative position and practical results are those desired — even though acquired indirectly.

Every model should be designed to give lowest resistance during climb; apply, then, the system just explained, assuming that thrust line is horizontal and that there is no down thrust. Then assign the proper wing angle of incidence and stabilizer angle; the value of each is an accurate measure of the effect each will have upon performance. An excellent setup for efficient climb is 5° wing angle of incidence measured from thrust line, and a stabilizer angle of +2 1/2°. This arrangement allows climb at the assumed angle of incidence, the angle with greatest lift-drag ratio. Lift-drag ratio is the measure of flight efficiency; the greater it is, the higher the climb.

In this setup there is the added advantage of a positive stabilizer and it actually carries part of the load, supplementing wing lift.

So, instead of calling this arrangement "down thrust:' a more correct name would be "positive stabilizer."

Still another benefit derived is its effect when gliding. Normally. with horizontal stabilizer parallel to the thrust line, the c.g. should be located 1/3 of the chord back of the leading edge for proper flight balance. When the stabilizer is given a positive angle relative to thrust line it generates lift; but to prevent nose-over and to insure correct flight poise, the c.g, must he shifted farther back. With 1º stabilizer angle of incidence, the c.g. must be 50% to 55% of the chord length to the rear. Often the c.g. is at the trailing edge. where the stabilizer angle should he 2 1/2º to 3° positive, relative to thrust line. This of course is based on the assumption that wing angle of incidence is 1º or 2° greater than the stabilizer angle. The total weight, acting at c.g., is carried in part by the wing and stabilizer.

Whereas the stabilizer acts at a positive angle under power, it is at zero angle without lift when gliding; c.g. being back of the wing c.l. After visualizing or drawing a sketch of this, one cannot fail to see that the ship will have a tendency to nose up due to the pull of c.g. to the rear of c.l.; this prevents dive-in and fast glide. It creates floating tendency that enables the plane to take advantage of the slightest thermal.

The numerous advantages of positive stabilizer may be more fully realized from the following: in Fig. 97, by dipping the thrust line — or in Fig. 98 lowering the rear of the fuselage so thrust line is horizontal — the thrust line is above c.g. If thrust line were coincident with base line it would be below c.g. Fig. 96 shows the center of lateral area, c.l.a., considerably above c.g. — a bad condition when thrust line is not negative to base line because it causes spiral diving under speed in horizontal flight. In Fig. 98, by placing the thrust line in position shown (miscalled "negative thrust") the c.l.a. will be on a horizontal line with c.g.

Here stability is assured by down thrust. Briefly, if thrust line is above c.g. there is less tendency to stall. With a c.l.a. on a horizontal line with c.g., or slightly above it, spiral stability results. It is evident, therefore, that if a model has these unfavorable characteristics they may be corrected by merely dipping the thrust line; this is one of the reasons it appears a "cureall" for difficulties resulting from primary design deficiencies.