Landing Gears: Toe In Or Toe Out?

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SEVERAL TIMES when landing gears for small, amateur-built aircraft were being welded up, fellows who gathered to watch the fun have come out with this question:

"In welding up the landing gear for a conventional aircraft, should the wheels be given toe-in or toe-out? Automobiles have toe-in, so why not airplanes?"

Every time I heard it, I felt chills run up and down my spine—it was that hard to imagine a cute little airplane with toe-in deliberately built into its undercarriage! But, odd questions have a way of leading to interesting and profitable avenues of thought. If you will bear with me, and try to follow my reasoning, I will herewith attempt to show that while toe-in definitely should not be used, there is, in fact, a case for the use of toe-out.

It is assumed that everyone understands what toe-in and toe-out means, but, to be sure we're all speaking the same language, toe-in means that the center points of the wheels — or more properly, of the tire treads — are closer together in the front than at the rear when we look down upon a pair of wheels. If unrestrained by axles, the wheels would move closer together as they moved forward. Toe-out, of course, is the exact opposite.

My first experience with toe-out was while tinkering with model airplanes. After a nice flight, it was disillusioning to see my rubber-powered models complete their landings with ground loops. I built a small scale model for the purpose of experimenting with landing roll control and from it I found that, when the wheels were given about five degrees of toe-out, the landings were straight and happily realistic.

Later models provided yet another lesson. A friend was entered in a flying model event called "Clipper Cargo," in which the model is given the greatest possible load and is allowed to take off with the timer set for a 15-second motor run. The object was to try to make the model remain aloft for 40 seconds. Under the rules, the take-off run could last as much as six or eight seconds. In that amount of time we found a model could wander off into a take-off ground loop. Seeking to help my friend overcome this problem, I told him about my experience with toe-out. He tried it — and came back from the next contest carrying the trophy for First Place.

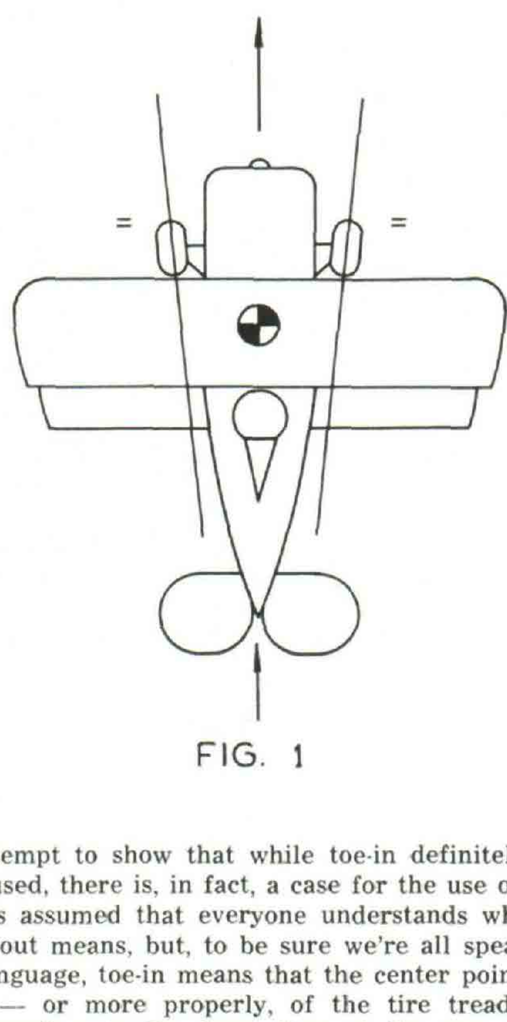


FIG. 1

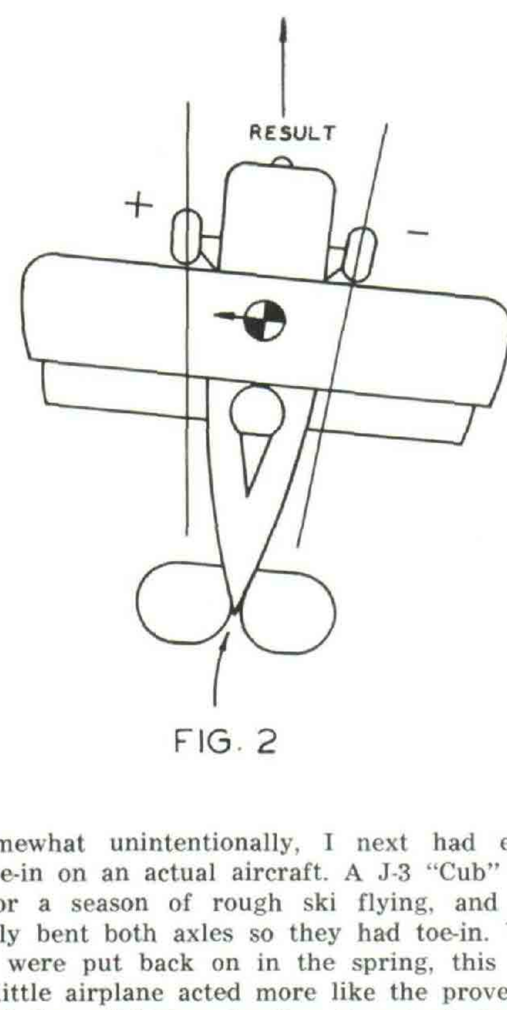


FIG. 2

Somewhat unintentionally, I next had experience with toe-in on an actual aircraft. A J-3 "Cub" had been used for a season of rough ski flying, and that had evidently bent both axles so they had toe-in. When the wheels were put back on in the spring, this reputedly docile little airplane acted more like the proverbial "cat on a hot tin roof." Upon landing, it sort of skipped from one wheel to the other on its way down the runway. If the same axle bending had happened on a bigger and faster plane, the resultant ground looping tendency would have been terrific, and I don't know if anyone could have made corrections fast enough to avoid rolling the wings up.

In short, these experiences taught me that toe-in can cause marked instability, and that toe-out can, when wisely used, add to stability. I can explain it best with diagrams. In Figs. 1, 2 and 3 are shown typical small biplanes of the kind known to be a little hot to handle on landings. I would point out, first of all, that when an airplane turns or swerves on its landing run, the tire and shock absorber on the outside of the turn compress and the plane leans to that side. This is because, in the actual airplane, the center of gravity is an appreciable distance above the point of contact between wheels and runway. This, of course, puts a greater percentage of the plane's weight onto the outside wheel. In Fig. 1 the plane is rolling straight and there is equal weight and therefore equal friction on each tire.

But as soon as there is a swerve, however slight it may be, the plane's momentum is great enough to work on the high CG and create a leaning force as indicated by the arrows on the CG marks in Figs. 2 and 3. Also note the plus and minus signs, denoting increase and decrease of tire-to-runway pressure. The wheel with the most weight on it must obviously have the most effect upon the direction in which the plane will go.

With toe-out, Fig. 2, the airplane is caused to move in such a direction that the tendency is to minimize the centrifugal force applied to the CG by a swerve, and the reason is that the left hand wheel has the greater load and pulls away from the incipient swerve to the right. The tendency for this layout is to pull the plane back to a straight, stable course.

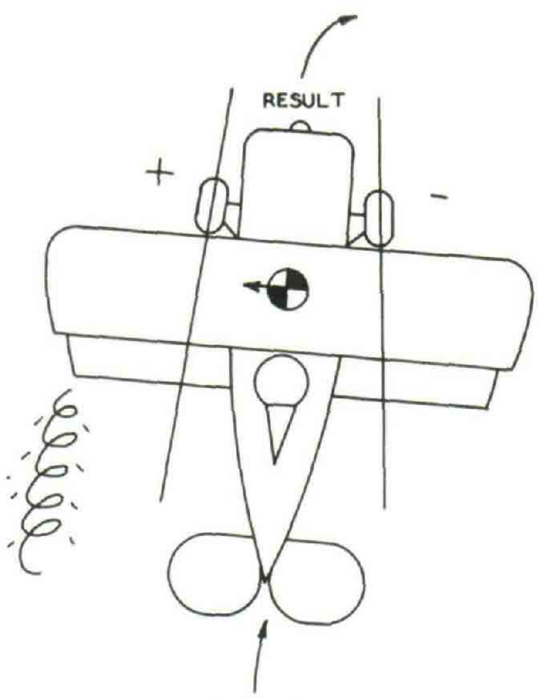


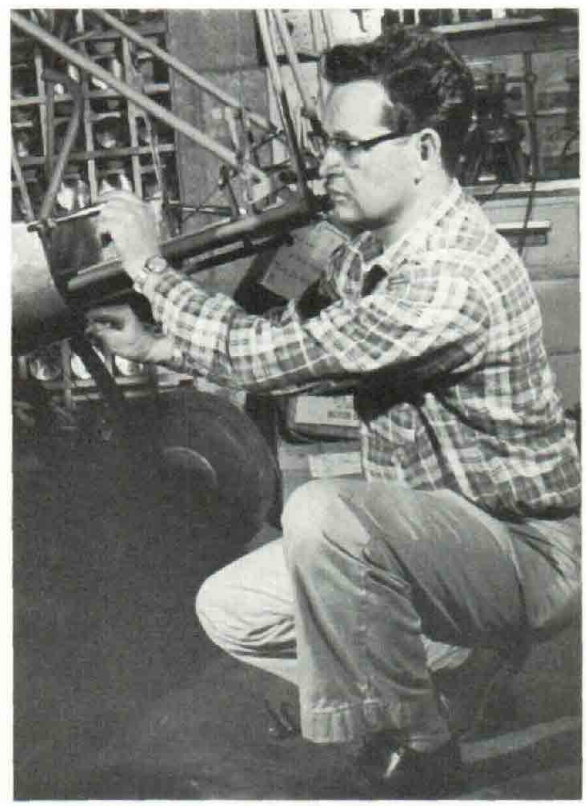
FIG. 3

But when there is toe-in, Fig. 3, the effect of greater weight on the outboard wheel is to make the swerve become tighter. Even when there is no swerve, it is possible to touch down on one wheel first, rather than on both at the same instant. If the plane in Fig. 3 touched down on its left wheel first, that wheel would immediately impart a force tending to drift the ship to the right. The high CG would then go right to work to make the ship lean to the left, further increasing pressure on the left wheel. The forces triggered by landing on one wheel can amplify so quickly that it would be a lucky and highly skilled pilot that was able to stop it quickly enough to prevent a bad ground loop.

With toe-out, corrective force for small tendencies to swerve are automatically fed into the force system as soon as they appear, and the corrective effort tends to amplify itself such as to give the pilot time to make appropriate control movements. In swift, jumpy little airplanes, even a fraction of a second leeway can make the difference between an uneventful landing and a severe ground loop.

In the accompanying sketches, the amount of toe-out has been exaggerated for clarity. My suggestion for practical application of the toe-in, toe-out lessons imparted by this article is to check and double-check the completed, installed landing gear on your airplane to make sure there is no treacherous toe-in. It would do no harm to put in a little toe-out. About one or two degrees ought to represent a good compromise, for too much toe-out would, in spite of affording a very stable landing roll, introduce the disadvantages of excess tire wear and slight drag on the take-off run.

If this piece saves just one amateur-built plane from grinding a wing upon landing, I will feel my effort has been justified! ●



In Memoriam

In the west, where aerial maps are solid brown, a story was closed upon EAA member Melvin G. Morrill (EAA 7649), a member of the Salt Lake City, Utah Chapter 23, who gave his life while searching a desolate area of Utah for a California pilot reported down.

Melvin was flying a CAP search plane, along with a companion from Bountiful, Utah, when they, too, became lost. They were unreported and not found until a year later, last August, and everyone's belated fears were confirmed. They were flying in a most defying country, with its many crevasses and towering canyon walls. It requires considerable courage to fly into this kind of country.

The members of Chapter 23 will long remember his generosity, and the fine association which they had with Melvin Morrill. Some months before his death, Melvin had donated to Chapter 23 his Taylorcraft L-2 which was in need of repair, and the aircraft was used as a Chapter project.

Not only was Melvin's death a loss to Chapter 23, but to the entire EAA movement as well.