NOVEMBER 1959

The AOPA **Pilot**

. . . voice of general aviation

Flying L Ranch
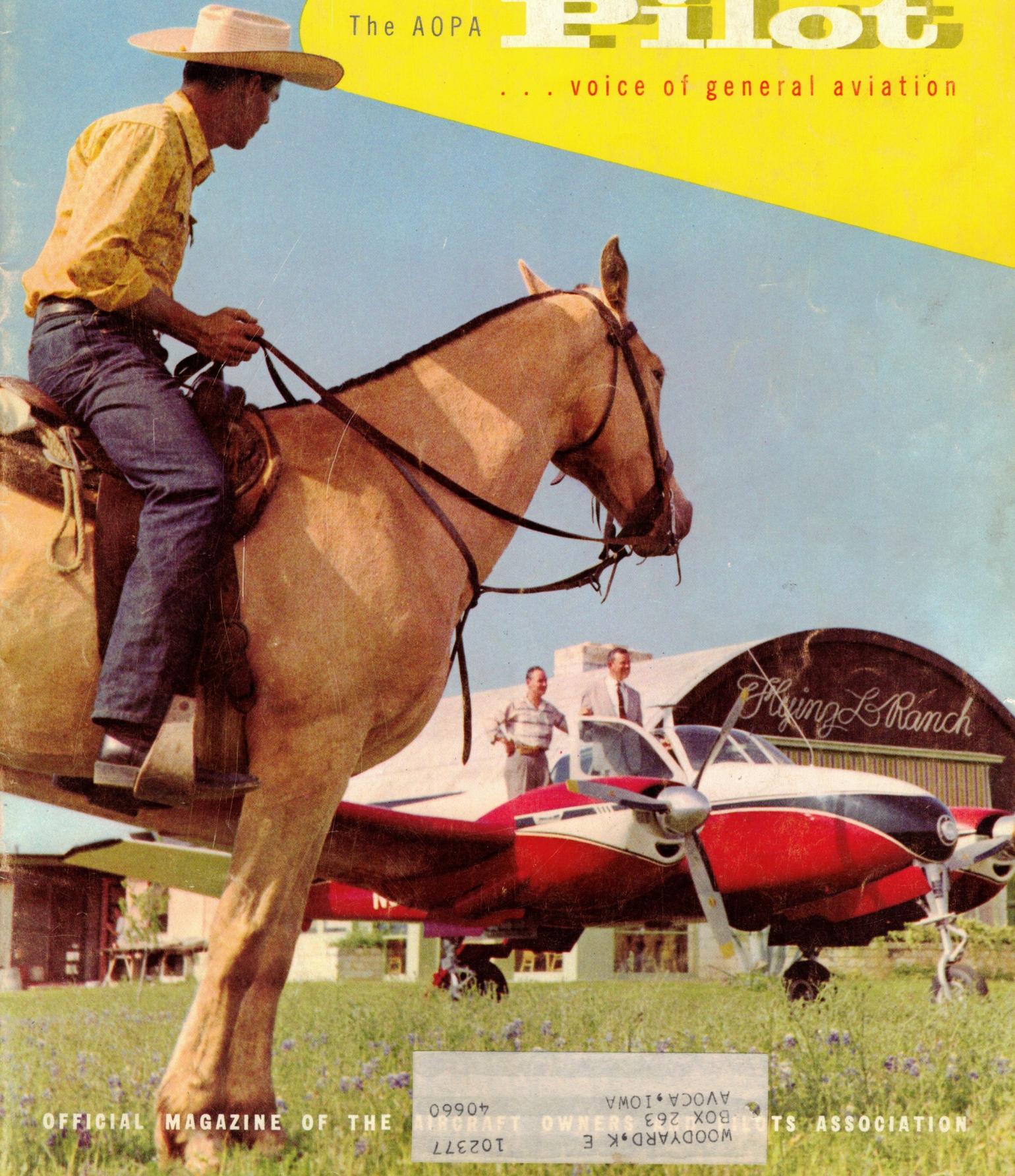
OFFICIAL MAGAZINE OF THE AIRCRAFT OWNERS AND PILOTS ASSOCIATION

Side Load Can THROW You!

An expert on the crosswind gear explains the physical forces at work in the groundloop and tricycle roll-over—still among general aviation's most prevalent accidents

by JOHN H. GEISSE

AOPA 60752

Close to one out of every four general aviation accidents is tagged in the FAA Statistical Analysis of General Aviation Accidents for 1958 as a roll-over or a groundloop. What's more, these accidents have increased in numbers over the past three years from 753 in 1956 to 894 in 1957, to 1,001 in 1958. This last sum can be visualized as nearly three a day.

There are no figures on the average cost of repairs, but damage ranges from a few hundred dollars to total replacement price of the airplane. An estimate of a $2,000,000 loss for last year would probably not be far wrong. Since these accidents are all due directly or indirectly to one factor, a little light thrown on their causes and avoidance would appear to be in order.

First, let's clear up a popular misconception of the cause of groundloops with tail wheel gears. This misconception is illustrated in Figure 1 in which the forces on the tires are shown as equal and parallel to the path of the airplane. The groundloop is charged to the difference in the moment arms of these two forces around the airplane's center of gravity. Arm "A" of the upwind wheel being greater than arm "B" of the downwind wheel, the turning moment of the upwind wheel would be greater than that of the downwind wheel; a groundloop would result. This explanation would be all right if the forces were indeed equal and parallel to the path but they are neither.

The fact that a groundloop continues even after the upwind wheel has left the ground should have discredited this theory long ago.

The correct analysis is illustrated in Figure 2 in which the forces on the tires are broken down into two components, one in the plane of the wheel and the other at 90° thereto. It will be immediately apparent that the moment arms of the former are both equal to one-half the distance between the wheels. The upwind wheel component would have to be greater than that of the downwind wheel to provide a groundlooping moment. Actually it is less as the weight of the airplane shifts to the downwind wheel in the turn. Hence this component can be ignored as a cause of groundloops.

The moment arms of the 90° components, the tire side loads, are both equal to the distance of the wheels ahead of the center of gravity. Groundlooping is caused solely by these tire side loads and the ground-looping moment is the product of their sum and the distance of the wheels ahead of the center of gravity.

Now let's get rid of the idea that centrifugal force creates tire side loads. It doesn't. Centrifugal force is actually the resistance of a body to movement in a curved path. To curve the path an outside force must be applied perpendicular thereto. In your automobile and in your airplane this force must come from the tires. But a tire which is aligned with its path produces no side load. To have a side load there must be some divergence of the heading of the wheel from its path. In your automobile you create this divergence of the front wheels with the steering wheel. The automobile then rotates about its vertical axis just enough to create the required divergence of the rear wheels.

The tires do not have to skid to create this side load. They do it by distortion. The relationship between the angle of divergence, called the

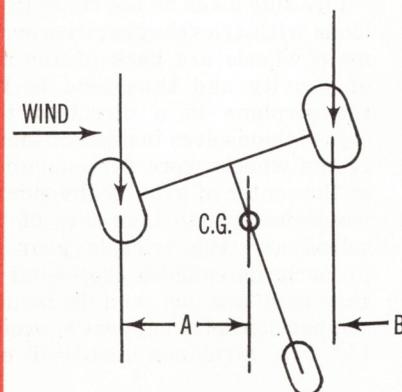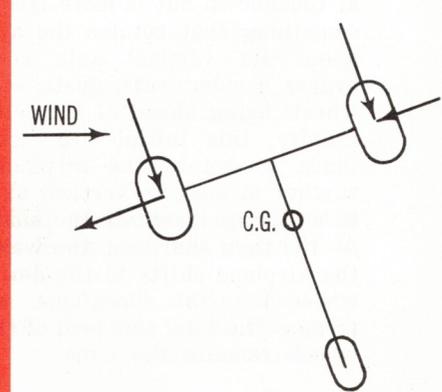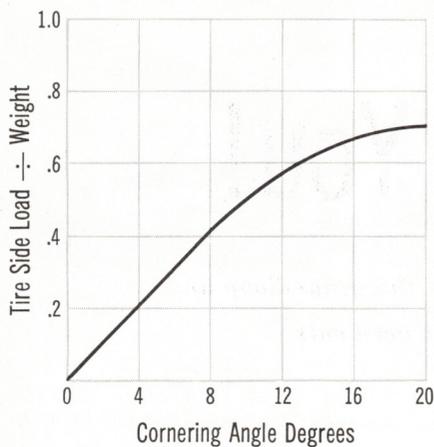If forces on tires paralleled plane's path (they don't), unequal moment arms (A,B) would cause groundloop
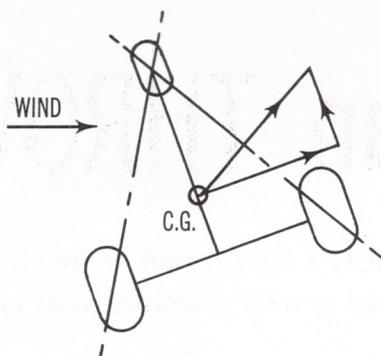
Forces on tires are actually in plane of wheel and 90° thereto; tire side loads cause groundloop or roll-over

FIGURE 3.

This chart shows the tire side load in terms of weight supported, plotted against the cornering angle

FIGURE 4.

Lines linking nose and main wheels are roll-over axes; roll-over force vectors from C. G. perpendicular to axis

"cornering angle," and the side load is well known. Although it differs with different tires and air pressures, the general character of the relationship is common to all. One common characteristic is that the side load is completely independent of speed. Another is that through a considerable range, it is directly proportional to the product of the cornering angle and the weight supported by the tire.

A typical graph is shown in Figure 3. This shows the tire side load in terms of the weight supported, plotted against the cornering angle. The maximum is determined by the coefficient of friction between the tire and the ground because at this point the tire skids. It should be noted that as little as 10° of cornering angle will create a tire side load equal to one half the weight supported and that the side load is no greater at higher angles than it is at 20°.

Now we can analyze the groundloop more completely. It starts with anything that sets up an initial cornering angle. This may be a drift at touchdown but is more frequently something that rotates the airplane about its vertical axis such as brakes, rudder, ruts, gusts, etc. The wheels being ahead of the center of gravity, this initial tire side load tends to rotate the airplane still further around its vertical axis and in so doing increases the side load. As the turn sharpens, the weight of the airplane shifts to the downwind wheel but this does not change things. The total side load of the two wheels remains the same.

Earlier your attention was called to the fact that a cornering angle of 10° will produce a tire side load equal to one half the weight of the airplane as this appears to be a significant figure. In a test conducted in England on a representative group of tail wheel airplanes with pilots of varying skills it was found that the most expert pilot, fully alert, could not prevent a groundloop following a touchdown with 10° of drift. An average pilot was found to be able to cope with drifts only up to 5° at touchdown.

Now let's evaluate these figures. The 10° cornering angle corresponds to the drift of an airplane traveling at 60 m.p.h. with a direct crosswind of just over 10 m.p.h. A direct crosswind of a little over five miles per hour will produce a 5° drift at the same airspeed. A cornering angle of 10° would be required at a taxi speed of just under 20 m.p.h. to make a turn of 50-foot radius, about the maximum possible in a turn from a 50-foot runway. Just under 14 m.p.h. taxi speed would require a 5° cornering angle.

Tire side loads do not cause groundloops with tricycle gears because the main wheels are back of the center of gravity and thus tend to rotate the airplane in a direction to decrease themselves instead of increase. If the wheels were far enough back of the center of gravity the side loads would be able to take care of themselves and the tricycle gear could properly be called a crosswind gear. But they are not and it is not. A comparison of one year's accidents for two airplanes identical except

for the undercarriage made this evident. The ratio of roll-overs to total accidents for the tricycle model was about the same as the ratio of groundloops to total accidents for the tail wheel model.

So let's take a look at tire side loads as they affect roll-overs. They are directly responsible for roll-overs with tricycle gears and indirectly responsible with tail wheel gears.

In Figure 2 it will be apparent that tire side loads can not be the direct cause of roll-overs with tail wheel gears as they are parallel to the roll-over axis. But the roll-over hazard is indirectly proportional to the distance of the wheels ahead of the center of gravity. And tire side loads prohibit moving the wheels farther forward to reduce the roll-over hazard because this would increase the groundloop hazard.

Figure 4 shows a typical tricycle gear configuration. The roll-over axes are the lines connecting the nose wheel to the two main wheels. These axes are typically at about 30° to the longitudinal axis of the airplane. The force required for roll-over is shown as a vector extending from the center of gravity and perpendicular to a roll-over axis. It is also broken down into two components, one fore and aft which would be created by braking or other resistance to wheel rotation. The other, perpendicular thereto, can only come from tire side loads. If you are thinking at this point that it could come from a crosswind, dismiss it from your mind. The crosswind could be responsible for the tire side load but if the latter were absent the crosswind would simply move the airplane sidewise—not roll it over.

The amount of force required for roll-over is proportional to the distance of the roll-over axes from the center of gravity and the height of the latter. A typical figure for a high wing airplane would be somewhat under 42% of the airplane weight. A tire side load of 50% could cause the roll-over and it is interesting to note that this is also the tire side load at which a groundloop is inevitable with a tail wheel gear.

To cause the roll-over with brakes alone would require a braking force equal to 84% of the airplane weight which is beyond the capacity of the brakes. However, the combination of a side load of 36% and a brake load of 21% can do the trick and frequently does.

Referring now to the chart of side loads versus cornering angle it will be seen that a side load of 36% would result from a cornering angle of only 7°. This is the drift of an

Side Load

airplane at 60 m.p.h. airspeed with a direct crosswind of 7.3 m.p.h. And a 16.4 m.p.h. taxiing speed would require a 7° cornering angle for a 50-foot radius turn.

In all of the foregoing I have deliberately omitted consideration of the effect of the wind force except as it affected drift angle because I wished to stress the little understood importance of tire side loads as the source of accidents. A crosswind does tend to increase the groundlooping tendency of a tail wheel airplane because of its weather-vaning effect but it has a much greater effect with high-wing tricycle geared airplanes. It increases the roll-over hazard in two ways. As mentioned previously it can increase the tire side loads which are a direct measure of the roll-over couple in one plane. In addition a quartering wind can provide a rolling moment all its own by increasing the lift on one wing and decreasing it on the other.

WARNINGS

TAIL WHEEL GEAR. For each tail wheel geared airplane there is a cornering angle beyond which the most expert pilot, fully alert, can not stop a groundloop. At lower angles avoidance is dependent upon how quickly and how forcibly corrective action is taken. If too little or too late the groundlooping moment will increase faster than the anti-groundlooping moment the pilot is applying.

TRICYCLE GEAR. For each high wing tricycle geared airplane there is a cornering angle at which roll-over is inevitable. At lesser angles the roll-over may be avoided by use of ailerons, rudder or steerable nose wheel *but not brakes.*   END
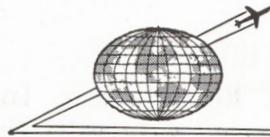
• • • • • • • • • • • • •

THE AUTHOR

John H. Geisse, president of Geiss-Gears, Inc., has for many years felt the aviation industry could combat the far too prevalent groundloop and nose-over with proper attention to the crosswind gear. As early as 1945, with the backing of Civil Aeronautics Administrator T. P. Wright, Geisse inaugurated a program within CAA to develop gears capable of handling crosswind conditions. Eventually, after leaving CAA, he designed the Geisse Safety Gear now available in both tricycle and conventional form. Unlike certain other crosswind gear designs, wheels of this model are not free-wheeling. Only the downwind wheel casters outward, absorbing dangerous side load. It then turns back and permits the aircraft to taxi with the wheels in normal position. For more information about the Geisse gear (now FAA certificated for most series of the Cessna models 120, 140, 170, 172, 175 and 180) see the AOPA Product Report, PILOT, June, 1959.