

LANDING GEAR DESIGN

OSHKOSH '77

FORUM

By Ladislao Pazmany
Condensed By Lu Sunderland

Second in a series of Oshkosh '77 Technical Forums condensed by Lu Sunderland from tapes made by Dave Yeoman. Ladislao Pazmany has approved this summary of his forum and has generously provided drawings from his excellent design manuals. Paz will have a book out soon on landing gear design.

A HISTORICAL SURVEY of early aircraft designs reveals that some features commonly believed to be fairly recent developments actually were employed on the very first airplanes. Landing gear design is a prime example. For instance, the first oleo shock absorber was designed in England by Duncan in 1915. His basic design is still used today in hydraulic shock absorbers. Duncan, an engineer, worked on guns and experimented with ways to absorb recoil. He applied this knowledge to aircraft as well.

The first retractable gear was patented by Martin in 1911 on the K3 Scout which was a small squarish biplane. The gear half-retracted into the wing straight aft. Another type of retractable gear was used on the Dayton-Wright Gordon Bennett single place racer of 1920. The gear, which retracted into the fuselage, was similar to many used today. In 1922 another designer, Fred Verville, had a retractable gear on his racer which retracted, with a screw jack, between the wing and the fuselage. A major innovation was the location of a wheel on the nose and it was used on the June Bug in 1908.

There are three general types of landing gear; namely, tailwheel, tricycle and tandem gear. Let us first consider how the designer would go about designing a tailwheel type gear.

TAILWHEEL CONFIGURATION

To set up the geometry of the tailwheel type landing gear, first it is necessary to locate the most forward center of gravity on a side view drawing. Then calculate the angle of attack for maximum lift coefficient during landing. This is normally 12° to 15°. When the main and tail gear are deflected 1 g, the wing angle of attack should fall in this range. The main gear should contact the ground at least 15° ahead of the most forward center of gravity with the aircraft in level attitude as shown in Figure 1. Next you must determine the length of the gear.

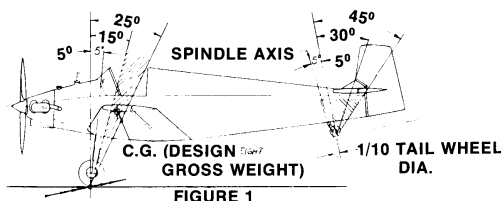


FIGURE 1

The C.G. should be located as shown in the front view (Figure 2).

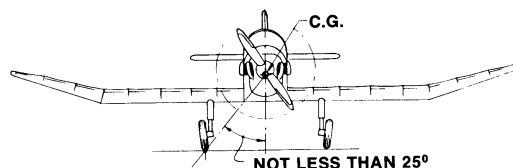


FIGURE 2

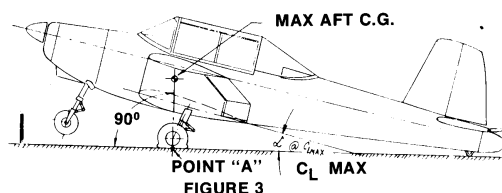


FIGURE 3

FAR Part 23 states that with the airplane in level attitude and the gear deflected for 1 g loading at gross weight, the propeller should have 9 inches clearance. Also, with one flat tire and the gear deflected, there must be some positive clearance between the propeller and ground.

Another way to locate the gear on a tail sitter is to use equations given in FAR Part 23 concerning reactions on the gear.

Vertical load $V_r = (n - L)W$

n = load factor which gear should take — normally about 3

L = lift coefficient of wing which should be taken as .66

Vertical load = $(3 - .66)W = 2.33W$

Drag reaction D is found as follows:

$D = knW$

k = friction coefficient — normally .25

n = load factor

W = weight

$D = .25 \times 3 \times W = .75W$

The resultant of these two forces, V_r and D , is usually at 15° to 18°.

$$\tan \theta = \frac{D_r}{V_r} = \frac{.75W}{2.33W} = .322$$

$$\theta = 18^\circ$$

Thus the gear should be located about 18° from the cg. If the resultant goes behind the cg, the aircraft could pitch over.

The tailwheel should be located as far aft as possible for best ground handling and to minimize loads in it.

On a front view, the angle between vertical and a line from cg to point of wheel contact with ground should be not less than 25°. See Figure 2. Too narrow a gear will make the aircraft tip over. For example in the Japanese motor glider, Nippy, the gear is narrow. It doesn't have outriggers so these angles are very small and requires a skilled pilot.

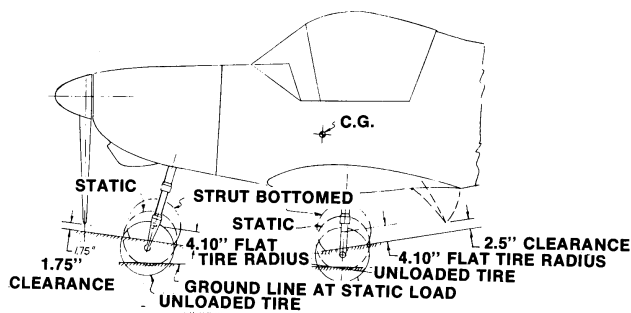


FIGURE 4
LANDING GEAR CLEARANCES — PL-1 LAMINAR

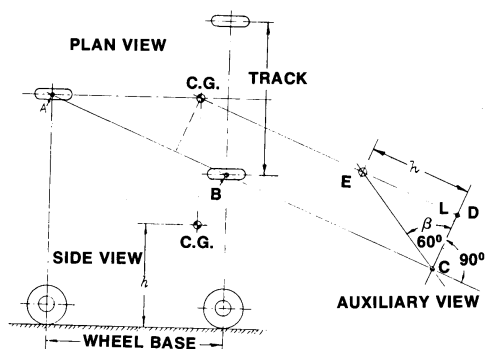


FIGURE 5
TURNOVER ANGLE

NOSE WHEEL CONFIGURATION

First locate the wheels on a side view in a landing attitude at maximum angle of attack, flaps up as shown in Figure 3. To locate main gear, draw a line perpendicular to the ground through the max aft cg. This line is the forward limit for the axle. Preferably, it should be moved one or two inches aft of this line. Make the gear legs long enough to clear the tail skid by one or two inches and make sure the flaps in full down position have a few inches clearance.

To locate the nose wheel, draw the aircraft sitting on the ground as in Figure 4. It is desirable to have the distance between nose wheel and main wheel as large as possible. If this distance is too small, the aircraft will porpoise. With the nose gear fully compressed, the nose wheel tire flat and main gear fully extended barely touching the ground, there must be some positive clearance between the prop and the ground.

The track and wheel base should be determined next. The relationship between the track and wheel base is dictated by the Turnover Angle which is determined as follows: (See Figure 5.)

1. Draw a top view showing the desired nose wheel and tail wheel positions. Also show the C.G. location.
2. Draw a side view showing the C.G. position and the landing gear with shock absorbers and tires statically deflected.
3. Establish line A-B. Extend the line to a point "C".
4. Through point "C" draw a perpendicular to line A-C.

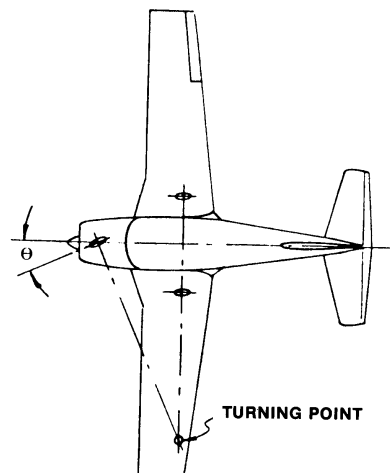


FIGURE 6
TURNING POINT

5. Through the C.G. (in the plan view) draw a line parallel to A-B and obtain point "D".
6. From point "D" measure the height of the C.G. (h) obtained from the side view and obtain point "E".
7. Draw line E-C and measure angle "B". This is the turnover angle and should be less than 60°. If the turnover angle is more than 60°, increase the track or the wheel base and try again. For a tail wheel type airplane, the turnover angle should be checked using the same procedure. The angle β should not exceed 60°.

The steerable nose wheel should have an angular movement θ such that the turning point falls inside the wing tip as shown in Figure 6. To check the position of the turning point, simply project the main wheel axis and the nose wheel axis at the maximum steer angle until they intersect.

TANDEM GEAR

In order to minimize drag and weight of landing gear, especially in sailplanes and motor gliders, it is common to use a single main wheel and a tailwheel. The two wheels are located on the center line of the aircraft, so this configuration is called a tandem gear.

Since sailplanes are not landed in the same fashion as airplanes — that is, you don't make full stall landings — the angle of attack at touchdown is quite small, between 5 and 8 degrees. To maintain a wings level attitude for taxiing and to eliminate the need for a ground crew, it is common to use some type of outrigger. Unless these are retracted, their drag will approach that of another wheel and thus lose some of the advantage over a conventional tail sitter design. That is one reason the RG-100 Cloudster powered sailplane has conventional gear.

COMPARISON OF GEAR TYPES

In comparison to the tricycle gear the tailwheel type is lighter, cheaper, and has considerably less drag. It also favors use on rough fields. Since the propeller is much further from the ground during taxiing and the beginning of take-off ground roll, propeller damage due to debris is far less.

The biggest disadvantage of the tailwheel type gear of course is that with the cg behind the fixed wheels, it is basically unstable. A side force on the main wheels causes the airplane to tend to turn around with the tail first. It takes conscious pilot action to prevent a ground loop. Not so with the nose wheel type.

The nose wheel or tricycle type gear is unquestionably safest for ground handling and makes landings a less challenging adventure. With the cg ahead of the fixed wheels, the aircraft is basically stable and will not normally ground loop as long as the nose wheel is free to swivel. It is of course heavier and, unless retracted, has considerably higher drag. On a clean airplane, a nose wheel will reduce the cruise speed by as much as 15%. Since the nose wheel is in the high velocity propeller slipstream, it is particularly important to put a fairing on both the wheel and strut. The airplane is less likely to nose over and cause propeller damage during braking, but braking at high speed is ineffective if the nose wheel is carrying much of the load.

On the tandem gear, ground looping is very severe since the cg is aft of the fixed wheel and there is little or no force on the tailwheel. The critical stage on the motor glider is at intermediate speeds during take-off or landing, between 15 and 25 mph.

SHOCK ABSORBER DESIGN

Shock absorber design for either oleo or spring steel gear is very complicated and beyond the scope of this paper but a few observations will be related here. (For

more information, see **Light Airplane Design** by Ladislao Pazmany or his new book **Landing Gear Design For Light Airplanes** soon to be published.)

A spring steel gear must be designed to absorb a certain amount of energy without yielding and still provide adequate clearance when deflected. The process usually requires some trial and error and changes after testing, however. For instance, three engineers stress analyzed the PL-4 spring steel gear legs and determined that $\frac{1}{2}$ inch steel plate would be adequate. But when we tested the first gear, we found we could push down on a wing tip until it touched the ground without raising the opposite wheel off the ground. This gear was obviously too soft so we increased the steel leg to $\frac{3}{4}$ inch, a 25% thickness increase giving a 100% strength and stiffness increase. This proved to be just right.

The design of oleo shock absorbers also usually requires some experimenting to calibrate the orifice size. Part 23 of FAA Regulations gives the requirements for shock absorber drop testing.

Wheels should have zero camber with oleo shock absorbers. Sufficient camber should be put into a spring steel gear to give the wheel zero camber when loaded. Wheels should have zero toe in or toe out.

ABOUT THE AUTHOR

Ladislao Pazmany, aircraft designer, was born in Hungary. He migrated to Argentina where he lived for 30 years. He was educated there in aeronautical engineering. He has been in the U.S. since 1956 where he has worked for Convair, Ryan, Rohr, San Diego Aircraft, and presently Ryson Aircraft Company. His own company is the Pazmany Aircraft Corporation. He is responsible for the design of the PL 1, PL 2, PL 4, and the Ryson ST 100 Cloudster.