Effect of Load Distribution

The effect of the position of the center of gravity on the load imposed on an airplane's wing in flight is not generally realized, although it may be very significant to climb and cruising performance. Contrary to the beliefs of some pilots, an airplane with forward loading is "heavier" and consequently, slower than the same airplane with the center of gravity further aft.

Fig. 17-51 illustrates the reason for this. With forward loading, "nose up" trim is required in most airplanes to maintain level cruising flight. Nose up trim involves setting the tail surfaces to produce a greater down load on the aft portion of the fuselage, which adds to the wing loading and the total lift required from the wing if altitude is to be maintained. This requires a higher angle of attack of the wing, which results in more drag and, in turn, produces a higher stalling speed.

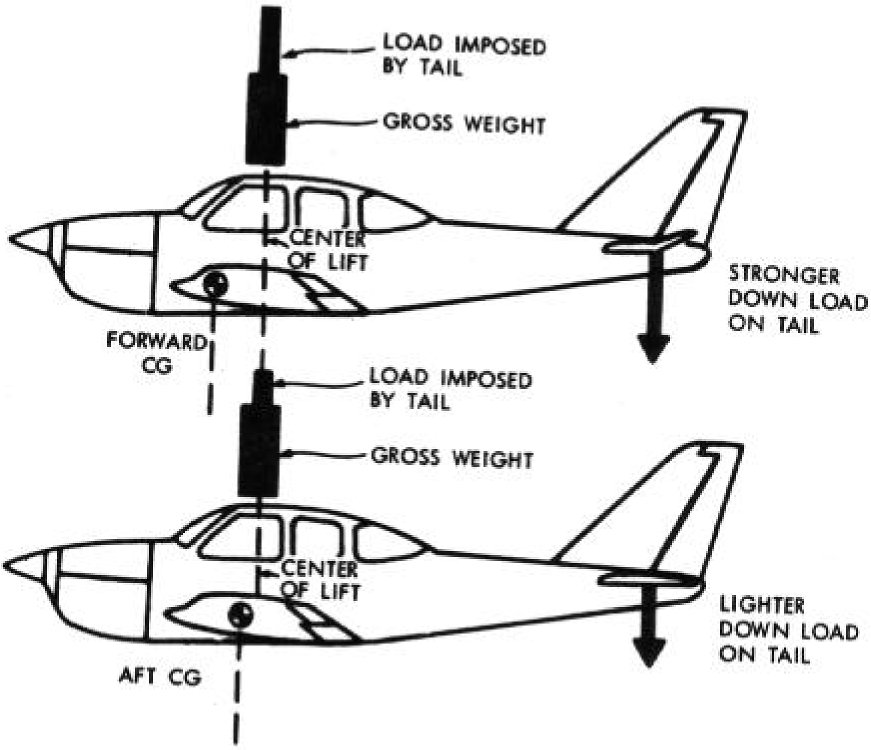

Figure 17–51 Load Distribution Affects Balance

With aft loading and "nose down" trim, the tail surfaces will exert less down load, relieving the wing of that much wing loading and lift required to maintain altitude. The required angle of attack of the wing is less, so the drag is less, allowing for a faster cruise speed. Theoretically, a neutral load on the tail surfaces in cruising flight would produce the most efficient overall performance and fastest cruising speed, but would also result in instability. Consequently, modern airplanes are designed to require a down load on the tail for stability and controllability.

Remember that a zero indication on the trim tab control is not necessarily the same as "neutral trim" because of the force exerted by downwash from the wings and the fuselage on the tail surfaces.

The effects of the distribution of the airplane's useful load have a significant influence on its flight characteristics, even when the load is within the center of gravity limits and the maximum permissible gross weight. Important among these effects are changes in controllability, stability, and the actual load imposed on the wing.

Generally speaking, an airplane becomes less controllable, especially at slow flight speeds, as the center of gravity is moved further aft. An airplane which cleanly recovers from a prolonged spin with the center of gravity at one position may fail completely to respond to normal recovery attempts when the center of gravity is moved aft by 1 or 2 inches.

It is common practice for airplane designers to establish an aft center of gravity limit that is within 1 inch of the maximum which will allow normal recovery from a one turn spin. When certificating an airplane in the utility category to permit intentional spins, the aft center of gravity limit is usually established at a point several inches forward of that which is permissible for certification in the normal category.

Another factor affecting controllability which is becoming more important in current designs of large airplanes is the effect of long moment arms to the positions of heavy equipment and cargo. The same airplane may be loaded to maximum gross weight within its center of gravity limits by concentrating fuel, passengers, and cargo near the design center of gravity; or by dispersing fuel and cargo loads in wingtip tanks and cargo bins forward and aft of the cabin.

With the same total weight and center of gravity, maneuvering the airplane or maintaining level flight in turbulent air will require the application of greater control forces when the load is dispersed. This is true because of the longer moment arms to the positions of the heavy fuel and cargo loads which must be overcome by the action of the control surfaces. An airplane with full outboard wing tanks or tip tanks tends to be sluggish in roll when control situations are marginal, while one with full nose and aft cargo bins tends to be less responsive to the elevator controls.

The rearward center of gravity limit of an airplane is determined largely by considerations of stability. The original airworthiness requirements for a type certificate specify that an airplane in flight at a certain speed will dampen out vertical displacement of the nose within a certain number of oscillations. An airplane loaded too far rearward may not do this; instead when the nose is momentarily pulled up, it may alternately climb and dive becoming steeper with each oscillation. This instability is not only uncomfortable to occupants but it could even become dangerous by making the airplane unmanageable under certain conditions.

The recovery from a stall in any airplane becomes progressively more difficult as its center of gravity moves aft. This is particularly important in spin recovery, as there is a point in rearward loading of any airplane at which a "flat" spin will develop. A flat spin is one in which centrifugal force, acting through a center of gravity located well to the rear, will pull the tail of the airplane out away from the axis of the spin, making it impossible to get the nose down and recover.

An airplane loaded to the rear limit of its permissible center of gravity range will handle differently in turns and stall maneuvers and have different landing characteristics than when it is loaded near the forward limit.

The forward center of gravity limit is determined by a number of considerations. As a safety measure, it is required that the trimming device, whether tab or adjustable stabilizer, be capable of holding the airplane in a normal glide with the power off. A conventional airplane must be capable of a full stall, power off landing in order to ensure minimum landing speed in emergencies. A tailwheel type airplane loaded excessively nose heavy will be difficult to taxi, particularly in high winds. It can be nosed over easily by use of the brakes, and it will be difficult to land without bouncing since it tends to pitch down on the wheels as it is slowed down and flared for landing. Steering difficulties on the ground may occur in nosewheel type airplanes, particularly during the landing roll and takeoff.

1. The CG position influences the lift and angle of attack of the wing, the amount and direction of force on the tail, and the degree of deflection of the stabilizer needed to supply the proper tail force for equilibrium. The latter is very important because of its relationship to elevator control force.

2. The airplane will stall at a higher speed with a forward CG location. This is because the stalling angle of attack is reached at a higher speed due to increased wing loading.

3. Higher elevator control forces normally exist with a forward CG location due to the increased stabilizer deflection required to balance the airplane.

4. The airplane will cruise faster with an aft CG location because of reduced drag. The drag is reduced because a smaller angle of attack and less downward deflection of the stabilizer are required to support the airplane and overcome the nose down pitching tendency.

5. The airplane becomes less and less stable as the CG is moved rearward. This is because when the angle of attack is increased it tends to result in additional increased angle of attack. Therefore, the wing contribution to the airplane's stability is now decreased, while the tail contribution is still stabilizing. When the point is reached that the wing and tail contributions balance, then neutral stability exists. Any CG movement further aft will result in an unstable airplane.

6. A forward CG location increases the need for greater back elevator pressure. The elevator may no longer be able to oppose any increase in nose down pitching. Adequate elevator control is needed to control the airplane throughout the airspeed range down to the stall.