United States
Department of
Agriculture

Forest Service

**Technology &
Development
Center**

5700—Aviation Mgmt.
April 1991
9157 1206

Improving Safety of Observation Aircraft

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TE01P12
Technical Services, Aviation

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INTRODUCTION

Fixed-wing light aircraft, such as the Super Cub, are used extensively for aerial observation. This class of aircraft continues to be over-represented in accident statistics. This study presents an analysis of the problem, and suggests some measures which could reduce the crashes. Helicopters are not considered.

PROBLEM ANALYSIS

Fixed-wing light aircraft observation flights are typically conducted at low altitude, slow flying speed, and often in a turn. The situation that causes most crashes occurs when the pilot exceeds the flight envelope of the aircraft; this results in a "departure" from controlled flight. In this condition, the outboard section of one wing stalls. This leads to a loss in effectiveness of the corresponding aileron and roll control authority; frequently with a significant yawing moment (*1*). The plane then crashes before the pilot can fully recover, since observation flights take place so close to the ground. The steep flight path after the departure from controlled flight, and the often precipitous crash impact angle, can result in severe injury or death to occupants and major damage to the aircraft.

The worst case occurs at a high angle of attack (*alpha*) with one wing stalling, frequently accompanied by a side slip. (*Beta* is the term for side slip angle.) This asymmetric condition results from a cross-controlled aircraft and is not limited to aircraft performing observations. The same scenario develops when a pilot overshoots the base to final turn in the landing pattern and tries to force the plane to the correct ground track (*1*). The resulting stall/spin accident often has fatal results.

The problem is not the specific stall speed of the aircraft, but rather the way or manner in which it stalls. Stall speed, V_S, is the airspeed at which an increase in angle of attack no longer results in an increase in lift. This occurs when the airflow over the surface of the wing has sufficiently separated. To enhance controllability, the difference or margin between the alpha at which the inboard panel of the wing stalls, and at which the outboard panel stalls, needs to be large. If this difference is large enough, controllability is maintained in the stalled configuration, even with a significant beta (*2, 4*). There are two basic ways to achieve this large difference on existing aircraft—increase the speed at which the inboard wing stalls, or decrease the speed at which the outboard wing stalls.

In addition to consideration of the cross-controlled condition, another important parameter that needs to be taken into account when looking at stall entry and recovery is the center of gravity of the aircraft. If the center of gravity is too far aft, there exists reduced, or even no, tendency for the aircraft to recover from the stall. If the aircraft with an aft center of gravity enters a spin, the same condition of poor recovery also exists, along with an increased chance of the aircraft entering a flat spin. It is also possible in the case of an aircraft with an extremely far aft center of gravity, to have the aircraft pitch up when even a slight downward pitch moment is applied. This is obviously a very undesirable condition. When the center of gravity is too far forward, the aircraft is very stable and has a natural tendency to recover from a stall. Although not as undesirable a situation as an aft center of gravity condition, there are cruise speed penalties resulting from the need to trim the aircraft with a downward load on the tail. The stall speed of the aircraft is also increased slightly when the center of gravity is too far forward.

Note that the actual stall speed itself is not the main issue; rather it is the controllability of the aircraft after the stall condition is entered.

RECOMMENDED IMMEDIATE CORRECTIVE ACTIONS

The most effective measure that can be taken to reduce the possibility of an accident in existing aircraft due to the problem described, is to increase pilot awareness of approaching stall conditions. However, it must be emphasized that this action is intended to help the pilot avoid getting into such a situation, and will ***not*** eliminate the problem of stall/spin recovery. Some pilots involved in this type of accident, even though they are "high time" and experienced, make the classic mistakes that are emphasized early in all pilot training. The aerial observation flying task is highly demanding, with numerous pilot duties outside the cockpit. This can result in a diversion of attention from the flying of the aircraft. Although stall-warning horns are installed on some of these aircraft, pilots may be turning them off (or mentally "tuning them out") while performing the observation task.

One low-cost, specific action that can be undertaken is to place alpha sensors, which indicate the approach of a critical angle of attack, on the outboard region of each wing. The indication these sensors provide might be binary (on/off), multiple position (close, closer, closest), or variable. The signal from the sensors ought to drive a very loud and obnoxious horn close to the pilot—one that cannot be ignored. This horn should ***not*** have an override or on/off switch. In fact, it should ***not*** be on a circuit breaker that can be pulled to disengage and, thus, disable the horn. In addition to the aural warning, an alpha indicator should be installed in the pilot's field of view while flying. Even though this might not aid in preventing the initial stall, it might contribute to a successful recovery without entry into a secondary stall.

Many authorities believe that a stick shaker is the best stall-warning cue for pilots *(2)*. This system is commonly installed on large and military aircraft, and has had considerable success in reducing the type of accident under discussion. The difficulty and cost of installing a stick shaker system in light observation aircraft should be investigated. The stall-warning light currently onboard most of these aircraft is of very limited value; the other methods just presented would be much more effective.

AIRCRAFT ALTERATION/MODIFICATION PROGRAMS

With good slow-flight, visibility, and short-field operational characteristics; the Super Cub, Maule, and Robertson STOL-modified Cessna 180 are as good as any aircraft available today for observation missions. The low-speed flying qualities of these aircraft can be enhanced through various modifications. However, before any modification is accepted, a thorough and complete test and documentation program must be undertaken. Anything less than complete baseline flight tests with accurate instrumentation to collect data in all flight regimes could expose the person or organization initiating the modification to severe criticism and potential liabilities should there be any accident involving a modified aircraft. A test program consisting of the following procedures is recommended for implementation before any flight characteristic alterations are attempted on a plane such as the Super Cub:

1. Define the problems and parameters of the existing aircraft and establish procedures to identify accurately what the problem really is. Accident reports should be analyzed to ascertain the maneuvers involved, aircraft employed, and piloting techniques utilized.

2. Direct specific attention to the aircraft's flying qualities, the effect of the center of gravity, and cross controlling. Literature on the plane's flying problems, accidents, and modifications or improvements already attempted should be reviewed to determine previous investigative work. Present data indicate that aft center of gravity and/or cross controlling at low airspeed and high alpha are primary concerns. The center of gravity may be within the manufacturer's limits; however, the published aft center of gravity limit may not be conservative enough for the observation mission. This mission profile needs to be compared against normal operations, such as takeoff and landing. It would be unacceptable to improve the observation mode performance if the capabilities of the aircraft, such as the controllability in the landing mode, were degraded.

3. Evaluate aircraft baseline data to set the control conditions against which any alterations can be compared. This flight test should thoroughly investigate all flight conditions—not just the low-speed regime, and be a thoroughly instrumented flight certification type of review. It is doubtful that these data have been compiled because, when these planes were originally certified, sophisticated data-gathering means did not exist. The instrumentation should record such parameters as the alpha of each wing, beta, control positions, power settings, and airspeed. The data should be recorded on a data-bus memory chip for post-flight data processing and analysis. Also, flow visualization by using yarn tufting should be recorded by a video camera mounted on the tail. This instrumentation system, without consideration of flight test expenses, would be a major cost. The instrumentation system being proposed is similar to that used by NASA and the Air Force for their new aircraft. This method of data gathering is a reliable and well-accepted aircraft industry practice.

4. Install the most promising modifications, and conduct a basic flight test. If there seems to be an improvement in the low-speed regime, a complete flight test program should be implemented to verify the improvement and make sure no adverse effects occur in other flight areas.

5. Conduct a limited field test to prove the modification in actual use environment. This should be done under an experimental certificate for one aircraft.

6. Perform a complete certification of the modified aircraft. This phase might be fairly easy to accomplish because of the extensive data gathered and flight tests performed in other parts of this plan.

A spin chute is absolutely mandatory before any flight of an aircraft modified in any manner whatsoever. This safety precaution is needed for the survival of both the pilot and plane.

POSSIBLE MODIFICATIONS TO ELIMINATE PROBLEM

Aircraft modifications that appear to be worthy of additional evaluation to reduce the stall/spin accidents of observation aircraft are listed in this section. The list is arranged in order of the most promising improvement first, followed by next most promising, down to the least likely. Note that modification costs differ greatly, and that some of the modifications could be tried with little capital expenditure. The single largest cost for any aircraft modification will probably be the required instrumentation and flight tests.

1. As previously discussed, install dual stall-warning systems, one on each wing, with an audio signal that cannot be defeated by the pilot. In addition, an alpha indicator should be installed in the pilot's field of view while flying; i.e., a "heads up" type of arrangement *(3)*. The best and least expensive way to mount this might be in the top of the cowling. Further, a stick shaker should be installed. This might seem like overkill, but something drastic is required to change the way pilots do things.

2. Install fixed drooped leading edges on the outboard wing panels to provide a large margin between the stalling of the inboard and outboard wing sections *(4, 5, 6)*. This should maintain aileron effectiveness and control after the wing has entered the stalled flight regime. The drooped leading edge, in some cases, has more than doubled the stall alpha of the basic airfoil section, and all but eliminated possible entry into spins. For example, deliberate spin entries were attempted in a Piper PA-28 with and without this modification. The unmodified aircraft was successful in entering the spin 83 percent of the time, while the modified aircraft only entered the spin 5 percent of the time *(6)*. Spin recovery should also be enhanced by this modification. The cost of fabricating the parts and installing them on aircraft would be very low. Only a minor (if any) cruise speed penalty should be incurred with the implementation of the system. Investigation into this modification may show that it degrades directional stability, and might require a larger vertical fin.

3. Install slats and/or slots in the forward portion of the outboard wing panels. Details of the design need to be investigated—including the type, location, and span distance utilized *(1, 3)*. This modification is likely to provide an acceptable solution to the problem. The slats could be fixed or variable. Fixed slats would be less expensive, but would add a slight drag penalty, and corresponding reduction in cruise speed *(3)*. This reduction in speed (5 kt or less) does not significantly impact the overall mission profile of the aircraft. The cost of this modification would be considerably higher than the leading edge cuff discussed in item 2. As in item 2, a larger vertical fin might be required.

4. Install a center of gravity limiter by placing a stop on the longitudinal trim to make the aircraft untrimmable for an aft center of gravity range. Since the plane could not be trimmed, there would be a corresponding increase in elevator control pressure. The limiter would be very simple to install, and the cost would be minimal. The only adverse affect that can be foreseen is possible interference with other normal flight profiles.

5. Install an adjustable leading edge droop on the outboard wing section. Performance benefits similar to leading edges with fixed drooped could be obtained without any loss in performance at cruise. This approach should be explored only if the full drooped leading edge is effective at low speed *and* adds an unacceptable cruise speed reduction. It would cost considerably more to install than the fixed device, and more engineering would be required to establish a mechanism to deploy the device. Moving parts would be required and additional failure modes introduced.

6. Increase the elevator forces in the high alpha region with a complex system that may employ one or more of the following as inputs. These include throttle, elevator, rudder, ailerons, center of gravity, and differential lift. The object here is that as the critical attitude is approached, increasing back pressure would be required on the elevator control. This would require a major engineering effort, would be a complex system, and probably be quite expensive.

7. Limit control power or authority through physical stops on the control stick. Some interconnection between the rudder and elevator might be required *(2)*. The Ercoupe is an example of an aircraft with this arrangement, and was designed to be "spin proof".

This study did not consider such devices as canards or floating tip ailerons *(7)*, since these would probably require a substantial re-engineering of the entire aircraft at prohibitive cost.

SUMMARY

The serious stall/spin problem of aircraft during observation operations does not lend itself to an easy or "quick fix" solution. It has plagued aircraft designers and operators since the beginning of flight. Some improvement can be made by improving the stall-warning systems of these aircraft and paying strict attention to center of gravity loadings. Beyond these simple approaches, improvements can only be made through a large commitment of time and money, with the largest expense being the instrumentation system and documentation required to accurately record the physical phenomenon occurring. Without such a system, modifications to existing aircraft could be extremely dangerous, producing disastrous results.

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