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W. S. Blanchard, Jr.

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Wallops Flight Center
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W. S. Blancnard, Jr.

W. S. Blanchard, Jr.
1733 Beach Road
Hampton, Virginia 23664

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A FLIGHT INVESTIGATION OF THE ULTRA-DEEP-STALL DESCENT AND SPIN RECOVERY CHARACTERISTICS OF A 1/6-SCALE RADIO-CONTROLLED MODEL OF THE PIPER PA38 TOMAHAWK

W. S. Blanchard, Jr.

SUMMARY

This flight investigation, which included more than 50 ultra-deep-stall descents of a 1/6-scale radio-controlled model of the Piper PA38 Tomahawk airplane, has shown that the full scale PA38 is a suitable airplane for conducting ultra-deep-stall research. Descents in the ultra-deep-stall mode would be stable and controllable, with sea level sink rates at a gross weight of 685.8 kg (1,512 pounds) ranging from about 13.4 m/sec. (44 feet per second) power off to about 7.6 m/sec. (25 feet per second) at a thrust-to-weight ratio of 0.25. An increase in rudder area or an increase in available rudder deflection would be desirable to increase the control power of the rudder in the power off ultra-deep-stall mode. Spin recovery using the ultra-deep-stall mode would be satisfactory. However, since the PA38 has excellent spin recovery characteristics using normal recovery techniques (such as opposite rudder and forward control column pressure), recovery using ultra-deep-stall would be beneficial only if the pilot was suffering disorientation.

INTRODUCTION

In 1931, the National Advisory Committee for Aeronautics (NACA) published a paper on the behavior of conventional aircraft in situations thought to lead to most crashes (ref. 1). Four of the ten airplanes tested exhibited maximum vertical velocities of 4.0 m/sec. (13 feet per second) or less, at wing loadings between 42.6 kg/m^2 (8.9 pounds/ft.^{2}) and 51.8 kg/m^2 (10.6 pounds/ft.^{2}) with power off and the control stick full back. It is interesting to note that these wing loadings are comparable to many of today's general aviation machines, and 4.0 m/sec. (13 feet per second) is a surprisingly low sink rate.

In 1943, Carl Goldberg disclosed his invention which was called the "Goldberg Dethermalizer" (ref. 2). The purpose of this invention was to bring a model airplane down in level flight attitude at survivable sink rates. This was accomplished by rotating the horizontal tail to a very large trailing-edge up deflection, to force the model to trim at a very high (ultra-deep-stall) positive angle of attack. Since 1943, many thousands of free-flight model aircraft (some weighing many pounds) have been successfully recovered from high altitudes in this manner.

Two previous ultra-deep-stall investigations (NASA Wallops Contract Order #P70201 and NASA Langley Contract Order #L54153A) have shown promising results from generalized low-wing and high-wing aircraft configurations. The investigation reported herein is considered to be the next logical step in the progression, to wit: A scale model of a typical current general aviation machine. The airplane chosen was the Piper PA38 Tomahawk. The research vehicle was scaled 1:6 from Piper aircraft drawings and is believed to be accurate to within one percent. The aluminum skin of the full-scale aircraft was simulated by balsa and plywood covered with heat-shrunk Mylar. The research vehicle was powered by a single cylinder two-cycle internal combustion engine, turning a scale diameter propeller. The digital radio-control system provided proportional, simultaneous control of rudder, elevator, ailerons, flaps, and throttle. In addition, a sixth proportional control was used through a mechanical mixer to drive the horizontal tail to the very large trailing-edge up deflections required for stable ultra-deep-stall descents. As noted in the original proposal, the only deviation from scale was the use of an all-movable horizontal tail on the research vehicle to facilitate the ultra-deep-stall. The tail planform and airfoil section, however, are the same as for the full-scale aircraft. The wings (full-scale and research vehicle) utilized the NASA 6G(w)1 airfoil section, and the horizontal and vertical tails utilized NACA 0010 sections.

The primary physical characteristics of the full-scale aircraft and the 1/6-scale research vehicle are shown in the Appendix. Note that at maximum allowable take-off weight of 757.5 kg (1,670 pounds), the full-scale aircraft has a sea level relative density of 3.08, which is duplicated by the 1/6-scale research vehicle at a weight of 3.5 kg (7.73 pounds), and the empty full-scale aircraft would be duplicated at a research vehicle weight of 2.2 kg (4.93 pounds). All flight tests reported were performed at weights between 2.7 kg (6.0 pounds) and 3.5 kg (7.73 pounds), corresponding to full-scale sea level weights between 587.9 kg (1,296 pounds) and 757.5 kg (1,670 pounds), respectively.

No mass moments of inertia data were available for the full-scale aircraft, so no attempt could be made at duplicating the inertia. We were, therefore, forced to settle for duplicating the mass and the center of gravity envelope. However, since the engine and the radio control system of the research vehicle constitute about the same portions of the gross weight of the research vehicle as do the engine and payload of the full-scale aircraft at similar locations, the mass moments of inertia are probably closely approximated. The center of gravity envelope extends from 14 percent to 28 percent of the wing's mean aerodynamic chord.

RESULTS AND DISCUSSION

More than 50 ultra-deep-stall descents were made during the course of the investigation. While several descents were made at 3.5 kg (7.73 pounds) (simulating maximum take off gross weight), most descents were made at weights between 2.7 kg (6.0 pounds) and 3.2 kg (7.0 pounds), and at center of gravity locations covering the center of gravity envelope of the full-scale aircraft. The results of the tests are discussed below.

Stability and Controllability in the Ultra-Deep-Stall Mode

Throttle Position. - With the throttle closed (engine idling), the research vehicle consistently assured a level flight attitude in the ultra-deep-stall mode. At increasingly higher throttle settings, the machine assumed progressively nose-higher attitudes. At a thrust-to-weight ratio of about 0.5, the nose was consistently up about 45 degrees, and the sink rate was markedly reduced. Increasing throttle position, as would be expected, caused the rudder to be more effective as a turn pruducer. Over the full range of throttle position, entries to the ultra-deep-stall were made from various extreme attitudes, including vertical banked and inverted flight. In all cases, the vehicle rapidly assumed an up-right level flight attitude.

Rudder Deflection. - Left and right turns were attainable at all throttle settings tested, including power off. The pitch and roll attitudes were not noticeably affected by the turns. It is noted that power-off rudder control power was marginal, indicating a need for either a large rudder or large deflections.

Aileron Deflection. - There was no noticeable effect of aileron deflection on either stability or control.

Horizontal Tail Deflection. - At all horizontal tail deflections between 15 degrees and 60 degrees trailing-edge up, the vehicle would abruptly enter a spin, with or without rudder deflection. At all horizontal tail deflections between 60 degrees and 80 degrees trailing-edge up, the vehicle would rapidly assume a level flight attitude and could not be forced to spin with any combination of rudder and/or aileron deflections. There were no observable differences in stability or control over the 60-degree to 80-degree range of horizontal tail deflections.

Flap Deflection. - Over the range of flap deflections from 0-degree to 30-degrees trailing-edge down, the only observable effect was a moderate nose-down trend with increasing flap deflection. No difference in sink rate was apparent, but small differences could have been masked by data scatter.

Center of Gravity Location. - As noted previously, tests were performed over the extremes of the allowable center of gravity envelope. In the ultra-deep-stall mode, there was no apparent effect of center of gravity position. It should be noted, however, that in the normal flight regime, longitudinal stability was nearly marginal, and elevator effectiveness was excessive at the most rearward allowable center of gravity location.

Sink Rate in Ultra-Deep-Stall Mode

Horizontal Tail Position. - Over the range of horizontal tail positions that yielded stable ultra-deep-stall descent (60 degrees to 80 degrees trailing-edge up), there was no apparent change in sink rate.

Flap Deflection - Over the range of flap deflections tested (0-degree to 30-degrees trailing-edge down), there was no apparent change in sink rate.

Throttle Position. - Tests were performed at throttle positions from closed (engine idling) to positions yielding thrust-to-weight ratios as high as 0.5. At a vehicle weight of 3.2 kg (7.0 pounds) (corresponding to a full-scale airplane weight of 685.8 kg (1,512 pounds) at sea level) sink rates in the ultra-deep-stall mode varied from about 5.5 m/sec. (18 feet per second) throttle closed to about 1.2 m/sec. (4 feet per second) at a thrust to weight ratio of 0.5; for the full-scale 685.8 kg (1,512-pound) airplane at sea level, these numbers scale to 13.4 m/sec. (44 feet per second) throttle closed and 3.0 m/sec. (9.8 feet per second) at a thrust to weight ratio of 0.5. It is noted that the full-scale airplane is probably limited to a thrust-to-weight ratio of approximately 0.25. It is estimated that this would yield a sea level sink rate of about 7.6 m/sec. (25 feet per second) for the full-scale 685.8 kg (1,512-pound) airplane at full throttle.

Recovery from Ultra-Deep-Stall Mode

Power-on and power-off recovery from the ultra-deep-stall mode could always be affected promptly by simply returning the horizontal tail to normal flight position. This would immediately cause the vehicle to start a dive, from which recovery was readily accomplished by gentle back pressure on the stick.

Spin Recovery Using the Ultra-Deep-Stall Mode

Spin recovery was very rapid in all cases, power on and off, when the horizontal tail was moved to the ultra-deep-stall position. It is noted, however, that conventional spin recovery (opposite rudder and forward stick) was also very rapid for this particular airplane. Therefore, for the range of variables tested in this investigation, spin recovery via ultra-deep-stall has no advantage over conventional recovery. This would probably not be the case for configurations having spin modes that are difficult to recover from in the conventional manner, where the ultra-deep-stall could be used as a means of recovery.

CONCLUSIONS

Based on the results of this flight investigation of the ultra-deep-stall descent and spin recovery characteristics of a 1/6-scale radio-controlled model of the Piper PA38 Tomahawk airplane, the following conclusions are offered:

(1) Over the entire allowable PA38 center-of-gravity range, the machine is stable in the ultra-deep-stall mode with horizontal tail deflections between 60 degrees and 80 degrees trailing-edge up.

(2) At a gross weight of 685.8 kg (1,512 pounds), the full-scale PA38 at sea level would have ultra-deep-stall sink rates of about 13.4m/sec. (44 feet per second) power off and about 7.6 m/sec. (25 feet per second) at a thrust-to-weight ratio of 0.25.

(3) Ultra-deep-stall descents for the PA38 would be upright, level-flight attitude power off, even when entered from extreme flight attitudes such as steep banks and inverted flight. Power-on wings would be level, and the nose would be progressively higher with increasing throttle.

(4) Aileron and/or flap deflection would have no significant effect on stability or controllability in the ultra-deep-stall mode.

(5) Power-on and power-off turns could be made in the ultra-deep-stall mode using rudder deflection. However, control power with the existing PA38 rudder would be marginal with power off. This condition could be corrected by large rudder deflections or by an increase in rudder area.

(6) Exit from the ultra-deep-stall mode would be accomplished promptly, power on or power off, by returning the horizontal tail to the normal flight position then applying slight control-column back pressure to recover from the resulting dive.

(7) Spin recovery could be accomplished satisfactorily by entry to the ultra-deep-stall mode, followed by exit from the ultra-deep-stall mode. However, since the PA38 has excellent spin recovery characteristics using normal recovery technique (opposite rudder and forward control column), there would be no apparent benefit unless the pilot was suffering from disorientation.

APPENDIX

Primary Physical Characteristics of the Full-Scale Airplane and the Dynamically Similar Model

	Full Scale	1/6-Scale
Wing Span	34.0 ft.	5.67 ft.= 68.0"
Wing Area	125.0 ft. z	3.47 ft. z
Empty Weight	1064 lbs.	4.93 lbs.
Max. Take-off Weight	1670 lbs.	7.73 lbs.
Relative Density at Maximum Take-off Weight, Sea Level	5.08	5.08

REFERENCES

1. Weick, Fred E.: The Behavior of Conventional Airplanes in Situations Thought to Lead to Most Crashes. NACA TN #63, 1931.

2. Goldberg, Carl: "Bring Them Down Safely," Model Airplane News, September 1943.