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EVALUATION OF THE INFLUENCE OF POWER SETTING ON AIRCRAFT PERFORMANCE IN A SPIN

JELENA ŠOBOT
Technical Test Centre, Belgrade, jsobot@outlook.com

ĐORĐE JANKULOSKI
Technical Test Centre, Belgrade, jankuloskidj@gmail.com

MIŠA ŽIVKOVIĆ
Technical Test Centre, Belgrade, misazivkovic89@gmail.com

JASMINKA JELISAVAC
Technical Test Centre, Belgrade, jjelisavac@gmail.com

IVAN VESIĆ
Technical Test Centre, Belgrade, ivesic01@gmail.com

Abstract: *Aircraft spin is a critical flight regime that is strictly prohibited for the majority of airplanes. However, due to its critical nature, it is mandatory in military aerospace to carefully test and analyze different spin scenarios and observe all spin characteristics. This paper presents an analysis of the influence of varying power and thrust on aircraft performance during spin and spin recovery. The behavior of the aircraft was observed and analyzed during flight tests of a light airplane in a clear configuration with two different c.g. positions. Due to the gyroscopic effects of the propeller, the influence of power differs between left and right spins, necessitating tests for both spin directions in each configuration. The results reveal significant differences in spin dynamics based on power settings, highlighting the role of propeller-induced forces. Spins entered with full throttle exhibited more pronounced entry characteristics and pre-spin roll compared to spins entered at idle. Left spins were found to be less oscillatory and had a lower pitch angle, while right spins were more oscillatory and steeper. The data obtained provides valuable insights into spin dynamics, contributing to improved pilot training, flight safety protocols and aircraft design considerations related to spin performance. The findings from these tests are crucial for enhancing spin awareness and serve as a guide for both engineers and pilots.*

Keywords: *aircraft, flight test, power, spin recovery.*

1. INTRODUCTION

Aircraft spin is a critical flight regime that is strictly prohibited for the majority of airplanes. After stalled aircraft begins autorotating in a helical path around its vertical axis we say it has entered spin. The spinning rotation can include variations in pitch, roll and yaw. The spin reaches its fully developed state when its path becomes vertical and its characteristics consistently repeat from one rotation to the next. [1] Some airplanes can continue autorotation for multiple turns, repeating their movement at regular intervals without stabilization. However, most airplanes do not achieve a fully developed spin within just one turn. Spin flight testing in some general aviation, aerobatic airplanes, trainers and highly maneuverable fighter aircraft is crucial for several reasons. Firstly, understanding and examining the spin characteristics of an aircraft is vital for improving aircraft safety by helping developing effective recovery procedures and training pilots for minimizing the risk of accidents. Secondly, all regulatory authorities require spin testing as part of certification process. Thirdly, spin testing results provide valuable input in improving aircraft design and performance as well as increasing safety and knowledge. Comprehending the impact of various factors, such as weight distribution, control inputs and power setting on spin behavior provide guidance for both engineers and pilots.

1.1. Spin Awareness

Even though for majority of aircraft spin is forbidden procedure, for some aircraft flight testing in spin is mandated by regulations and certification processes. The FAA (Federal Aviation Administration) recognizes airman certification process (ACS) [2] which goal is to ensure the applicant possesses the knowledge and ability to manage risk and demonstrate the skills consistent with the privileges of a Commercial Pilot Certificate and any associated ratings being exercised, in order to act as pilot-in-command (PIC). One part of testing is to test various airplane configurations, including relationship between

Corresponding author: J.Šobot;
E-mail: jsobot@outlook.com
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AOA, airspeed, load factor, power setting, airplane weight and center of gravity (c.g.) etc.

2. FLIGHT TEST

2.1. Flight test aircraft

Aircraft used for flight testing is light military trainer airplane UTVA LASTA 95 Prototype 1 (Figure 1). Lasta 95 is a low-wing, metal constructed airplane with two seats powered by single piston engine propeller group. This aircraft's aerobatic capabilities renders it suitable for conducting various spin tests. The aircraft Lasta has been analyzed in many scientific papers such as: Flight testing methodology and procedure of spin characteristic on basic training aircraft [3], Analysis of the impact of aileron deflection on aircraft spin [4], Power optimization of a single propeller Airplane take-off run on the basis of lateral maneuver limitations, stability characteristics of the single-engine tractor propeller airplane in climb, etc.

For this specific flight test, due to the sensitivity of spin test procedure, aviation regulations and potentially hazardous activities airplane was equipped with antispin parachute as external spin recovery device (Figure 2). [5]

Figure 1. Airplane Lasta 95, Prototype 1

Antispin parachute and parachute deployment system has been tested on ground in order to safely determine its reliability and susceptibility to unintentional or undesired deployment.

Figure 2. Antispin parachute system on airplane Lasta 95

2.2. Flight test equipment

To guarantee the successful execution of flight spin tests, a credible configuration management system is crucial. This system must ensure accurate time synchronization and data recording, enabling easy searches for specific events and ability to replay sections of the recordings when needed. For data acquisition the next equipment is used: acquisition system, recorder and multiple transducers. Acquisition system used is Airborne acquisition and transmission system ACRA KAM-500 9U (Figure 3) and recorder NET-500 (Figure 4). [4] [6]

ACRA acquisition system and its transducers possess ability to record numerous flight parameters based of measuring sensors installed in airplane, from which essential parameters for this evaluation are, beside velocity and altitude, deflections of all three primary controls (δl, δm, δn), angular rates of yaw, roll and pitch (r, p, q) and yaw, roll and pitch angles (ψ, φ, θ). These parameters were later used to determine airplane behavior in spin and calculate spin recovery delay.

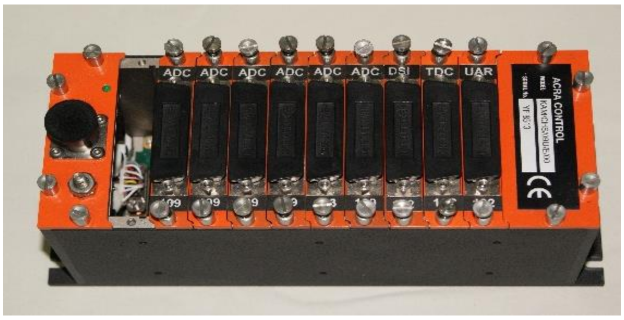

Figure 3. ACRA acquisition system KAM-500 9U

Figure 4. ACRA recorder NET-500

2.3. Flight test procedure

In order to achieve flight test conditions of evaluation of influence of power setting change on aircraft behavior during spin, two variants of c.g. positions have been tested:

- Single-seat with c.g. position of around 27%MAC (variant A).
- Twin-seat with c.g. position of around 31%MAC, with 50 kg weight used as balance in second pilot seat (variant B).

Flight test conditions were defined in two configurations for two variants of c.g., for both spin was entered from the altitude of 3000 m with different power setting:

- Spin entry with power reduced to idle and normal spin entry procedure. After two turns of the commanded spin, power was set to the maximum RPM.
- Spin entry with full engine power and normal spin entry procedure.

For both variants, after 4 spin turns power was reduced to idle, stopping of rotation and spin recovery were commanded via standard procedure, or stopping of rotation and spin recovery were commanded via standard procedure with full power setting. Due to the gyroscopic effects of the propeller, the influence of power differs between left and right spins, necessitating tests for both spin directions in each configuration.

3. RESULTS AND EVALUATION

Results obtained from flight test data during a spin show highly oscillatory motion in terms of angular velocity “p” (angular velocity around x-axis, roll), “q” (angular velocity around y-axis, pitch) and pitch angle “θ”.

It can be noted that angular velocity “p” (Figure 5) in right spin varies in interval between approximately 230º/s and approximately -50º/s in direction opposite to the commanded spin direction. In left spin (Figure 6), “p” varies in interval between approximately -140º/s and approximately -20º/s in direction opposite to the commanded spin direction.

During fully developed spin phase maximum value of angular velocity (piques on diagram) is increased up to the fourth turn after which it changes slightly.

Angular velocity “q” in right spin varies in interval between approximately -50º/s and approximately 110º/s, and in left spin it varies between approximately -40º/s and approximately 80º/s. The maximum values of this speed occur after the second turn.

The change of pitch angle (θ) is oscillatory in accordance with the variation of angular pitch velocity. Value of pitch angle in right spin (Figure 7) varies from -20º to -80º, while in left spin (Figure 8) pitch angle varies from -25º to -50º. In both side of spins value changes synchronously with the angular velocity alteration around the "y" axis.

Left spins with full engine power display reduced oscillatory tendencies and show a lower pitch angle by absolute value (while angle of attack is higher).

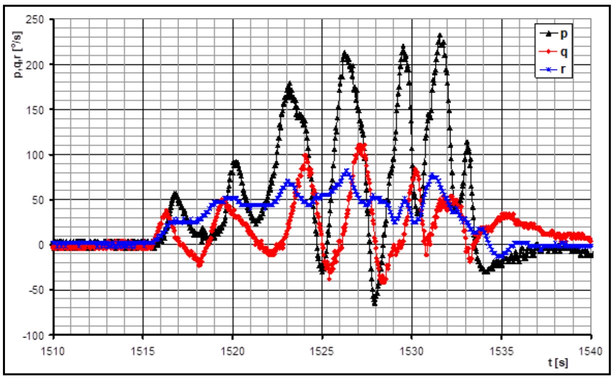

Figure 5. Angular velocities in right spin, full power

In order to effectively recover from the spin, the aircraft requires standard control inputs, which are full rudder deflection in the opposite direction and elevator deflection towards the approximately neutral position. If the elevator is controlled more aggressively, the aircraft exits the spin with a backward tumble.

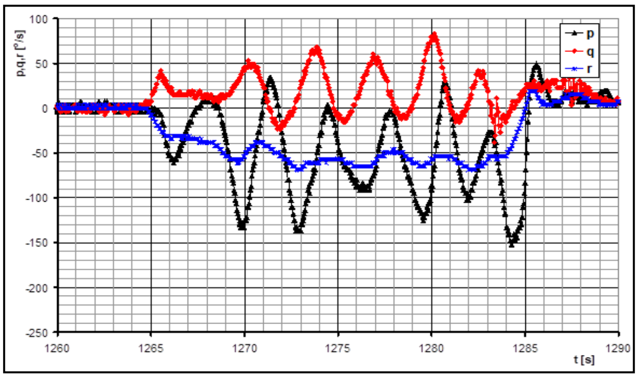

Figure 6. Angular velocities in left spin, full power

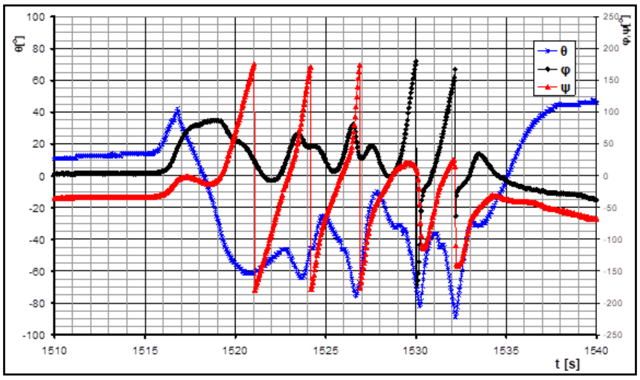

Figure 7. Angles of rotation in right spin, full power

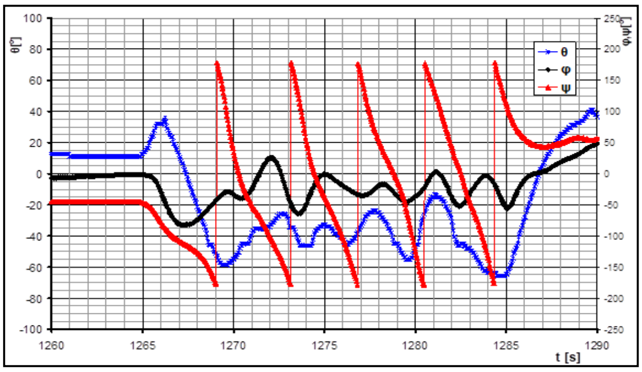

Figure 8. Angles of rotation in left spin, full power

In table 1. spin delay in both right and left spins for both c.g. variants and power setting is presented. As expected, B variant shows higher delay in turns. Rear c.g. position increases aircraft longitudinal stability, which with increased inertia reduces speed of control input change which is critical for spin recovery.

It is worth noting that the recovery delay is significantly shorter than the specifications outlined in the MIL-F-8785C aerospace technical regulations [7] (less than 1.5 turns).

Due to the higher angle of attack in left spins, the spin recovery delay is approximately ¼ of a turn longer compared to right turns, but still less than allowable limit of 1.5 turns.

Table 1. Spin recovery delay

Power setting	c.g. variant	R/L spin	φ [turns]	Δφ [turns]	ΔH [m]	nz
Power at idle	A	L	4	0.66	140	3.4
Power at idle	B	L	4.6	0.7	150	4.6
Full power	A	L	4	0.43	140	3.5
Full power	B	L	4.4	0.6	170	4
Power at idle	A	R	4.4	0.45	160	3.5
Power at idle	B	R	4.6	0.35	135	3.6
Full power	A	R	4.2	0.3	180	3.5
Full power	B	R	3.9	0.3	100	4.2

4. CONCLUSION

An experimental flight test was conducted in order to evaluate the influence of power setting on aircraft performance in spin. The results obtained from flight test data during a spin show that the airplane exhibits very similar behavior in all phases of the spin for both test variants. The only notable difference is that, in both left and right spins, when airplane enters spin with full engine power from a climb, airplane performs a pre-spin roll which is significantly slower than the pre-spin roll entered with power at idle.

Two different c.g. positions were tested and presented. Rearward position of c.g. resulted in a longer spin recovery delay because of reduced longitudinal stability, reduced efficacy of controls, higher inertia and less effective aerodynamic forces needed for spin recovery maneuvers compared to forward c.g. position.

The main characteristic of airplane performance in spin with the influence of power setting lies in discrepancy between left and right spins. Left spin is significantly less oscillatory and has shallower descent angle compared to the right spin.

In left spins, the power setting (as a result trust) slightly increases airplane’s angle of attack and decreases oscillatory behavior in spin. In right spins, the trust does not significantly affect the airplane’s behavior.

Regardless of variant of power setting the airplane can be effectively recovered from the spin using standard control inputs, with delays in spin recovery well within the allowable limit of 1.5 turns. This study emphasizes the impact of power setting on airplane behavior in spin, highlighting distinctions between left and right spins, forward and rearward c.g. influence while confirming airplane’s capability of effective spin recovery in tested cases.

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