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Report – Plane FW28

Background

The FW28 was my first powered prototype of a foam board RC airplane, built in June 2022. This plane mounts foam board wings built earlier in December 2021.

Description of plane

The plane is based around the 28” span 5” Armin wing design presented by the YouTube channel Experimental Airlines (2012). This is attached to a haphazardly constructed cardboard tube frame comprising of two telescoping tubes, the front mounting the wing and electronics and the back mounting the tail.

Components

- Battery: GensAce 2200mAh 25C LiPo 3S battery (11.1V, 171g)
- Motor: FliteTest Radial 2212-1050kV brushless outrunner DC motor (25A)
- Propellor: 9”x4.5” propellor
- ESC: FliteTest 35A ESC with 5V BEC
- Receiver: FS-iA10B (10-channel, packaged with FS-i6x transmitter)
- 5x micro servo 9g (SG90 and HXT900)

Characteristic	Value	Comments
Length	600 mm	
Wingspan	28” (711 mm)	
Chord	150 mm	Slightly modified 5” wing design: 4.5”+1.25”
Thickness	20 mm	Ratio 13.3%
Weight	545 g	Fully loaded, with GensAce 2200 mAh 25C battery

Results of flight tests 2022-06-07

The plane was test-flown three times on June 7, 2022. The results of the test flights are summarized below:

Flight 1

Plane was thrown forwards on half throttle. Power was increased to full throttle. Plane glided down the hill slope before shallow impact with the ground. Due to unpreparedness, no control inputs were made. 2 screws mounting the engine to the front cardboard plate popped out. The airframe was slightly w0arped, but with no serious damage.

Flight 2

Before this flight, the engine was re-mounted at a slightly different location with new screws, the maximum up elevator position was set to 120% from 100%, and the elevator was trimmed to 13% up (nose-up).

The plane was thrown forwards at approximately a 20° angle on half throttle. Power was increased to full throttle and full up elevator was held continuously. The plane rapidly continued to nose up, stalled, and rolled sharply left into a terminal dive before impacting the ground. The propellor broke and all 4 screws mounting the engine popped out, and the front fuselage tube was significantly warped.

Flight 3

Before the flight, some damage from Flight 2 was repaired using Scotch tape and spacers. The current wing was swapped out for a backup wing with no ailerons. The engine was re-mounted using Scotch tape and a new propellor was fitted. The elevator trim was set to neutral. The main objective was to return to the straight gliding path exhibited in Flight 1 by emulating the launch conditions as best as possible.

The plane was thrown straight forwards on half throttle, and power was increased to full throttle. Without any control inputs the plane nosed up and to the left, then rolled over into a terminal dive. On impact, the propellor broke, the engine tore from its mountings, and the front fuselage tube buckled.

The airframe was irreparably damaged and shall not be test-flown again.

Discussion

In all three flights, control inputs to resolve an undesirable position were either not made or were made around a second too late, when they additionally may have contributed to the ill-fated terminal maneuvers. Two causes may be drawn:

1) Inexperience with flying RC planes. I had no experience flying other RC planes beforehand, so I did not know what control inputs to make and my reaction time was extremely slow.
2) Design features of the FW28 plane leading to difficult handling characteristics, specifically:
    a. Small wing area and wingspan relative to weight and power, leading to a high stall speed and general flight speeds. Consistently fast reactions are required to maintain control of the airplane.
    b. Low length relative to wingspan, so that the tail contributes a smaller stabilizing moment, contributing to low dynamic stability

Additionally, construction imperfections likely negatively impacted the control authority and dynamic stability of the airplane:

3) Poor construction resulting in bad stabilizers. The vertical and horizontal stabilizers were angled from vertical/horizontal, leading to mixing of control surfaces (elevators and rudder have secondary effect in yaw/pitch axes respectively). The stabilizers were attached directly to the wall of the rear fuselage tube, which was not exactly rectangular in shape due to loose tolerances.
4) Shifting Center of Gravity (CoG) and Center of Lift (CoL): The battery was not mounted in a fixed position and may have slid within the front fuselage tube. The wing was not fixed at a consistent

position before flight and may not have been held down tightly enough by rubber bands to avoid shifting in flight, especially when thrown. The shifting CoG and CoL positions means the plane could become nose-heavy, tail-heavy, or otherwise dynamically unstable before a flight, or the airplane might abruptly go out of balance mid-flight.

Light crosswinds in the flight environment may also have made control more difficult. However, the high weight and low wingspan should have limited the susceptibility of the FW28 airplane to deflection by crosswinds.

Finally, the way in which the airplane is thrown on launch may contribute to the terminal flight paths after launch in Flights 2 and 3. From previous testing with gliders, the best throwing method to achieve a stable initial flight path is a light throw at a straight or slightly downwards (<10°) angle. Applying a near-constant force (and therefore resultant acceleration) and emulating a 'shotput throw' (almost pushing instead of pulling) were identified to help, and jogging into a throw may make throwing larger planes easier. Throwing upwards and/or very fast (which would likely lead to a misalignment of the flight path and the plane's resultant attitude) almost always resulted in a vertical climb into a stall or an immediate roll-over, which is consistent with what happened in Flights 2 and 3.

Conclusion and list of recommendations

Flight 1 demonstrated the ability of the airplane to generate lift and obtain a stable flight path. However, the immediate crashes in Flights 2 and 3 demonstrated the poor flight characteristics of the FW28 for novice flying. For future RC flying, I will first train with lighter, less powerful planes before building more powerful designs.

In summary, the main issues identified are:

1) Inexperience with flying RC aircraft
2) Design characteristics leading to poor handling characteristics (high stall speed and low dynamic stability)
3) Loose tolerances in construction, especially with the tail section
4) Shifting center of lift and center of gravity due to loosely secured wing and internal components sliding around
5) Improper throwing technique for launching the plane leading to stall

Specific recommendations to address these issues include but are not limited to the following:

1) Practice RC flying on a free trainer
2) For my next project, use a design template known to be novice friendly. My current preference is the FliteTest FT Tiny Trainer glider/pusher (FliteTest, 2015). (Many FT planes have a free build plan and video build guide on the FliteTest YouTube channel.) Practice gliding, then powered flight with this plane before moving onto trickier designs. Also practice balancing the plane and throwing.
3) For following projects, build planes with easier handling characteristics, with the following design choices in mind:
    a. Longer wingspan to reduce wing loading (wing area to mass ratio) and increase aspect ratio, resulting in lower stall speed and better gliding characteristics

   b. Longer fuselage/tail distance from center of gravity: length should be at least 1x wingspan for smaller planes (<= 30” wingspan)
   c. Lighter battery (1000/1300 mAh, < 100g) for planes with lower power-draw motors
   d. Larger control surfaces
   e. Dihedral, possibly with elimination of ailerons for simpler planes. Learn how to use a bent connecter and/or spacers to hold the wings in place.
4) Improve construction tolerances on tube parts to ensure rectangular shape. Additionally, use foam board instead of cardboard where possible, as foam board is much harder to crease or buckle.
5) Learn the ‘power pod’ design (FliteTest, 2014) or your own engine housing design. Use a hard, solid material (such as plywood sheets) to mount the engine onto and glue the ‘mounting plate’ to the airframe. Use at least 1/8” (3mm) craft plywood for both screws and nuts and bolts.
6) Add stoppers into the fuselage tubes to hold batteries and wings in position; add an access door if needed. Internal stoppers can be added before folding the tube.
7) Conduct thorough scientific tests on future planes to measure thrust, (engine) adverse yaw, and engine torque, and location of the center of gravity to get an idea of what trimming is required to counter these effects.
8) Conduct thorough scientific tests on the Armin wing airfoil (e.g. wind tunnel) and graph coefficient of lift with respect to angle of attack. This data can be used to find the stall speed.
9) Set up the ESC brake to reduce prop-breaking incidents.
10) Install landing gear on all pusher prop planes that are fast and heavy to allow for takeoffs, which will be more reliable than throwing launches, and normal landings, which will eliminate prop-breaking and airframe damage.

References

Experimental Airlines. (2012, April 22). *ARMIN WING CONSTRUCTION: start-to-finish process with links to detail videos* [video]. YouTube. https://youtu.be/karr67ZYho4

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