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Design, Construction and Flight Performance on T-Tail Airplane

Khin Zaw Linn[a], Zar Zar Aye[a]

[a]Department of Propulsion and Flight Vehicles, Myanmar Aerospace Engineering University
Myanmar

Abstract

This paper covers the design, construction and flight performance on T-tail airplane (SK^{2}Y WAY). First of all, design sizing have been calculated. And then, static stability and flight performance to determine the airplane's qualities have been considered. From the result of AEROPACK, the construction is processed. After construction process, ground tests and flights. Flight performances are done for two times.

Keywords: T-tail plane; UAV; Flight performance; RC plane

1. Introduction

An unmanned aerial vehicle (UAV), commonly known as a drone and also referred to as a remotely piloted aircraft (RPA) by the International Civil Aviation Organization (ICAO), is an aircraft without a human pilot aboard. Its Flight is controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. Moreover, our aircraft need to fly the remote control of a pilot on the ground.

2. Design Considerations

SK^2Y WAY is aimed for Environmental monitoring, and so, its mission design endurance is obtained as 30 min and the operational altitude is designated as 500 ft for a large surveillance area.

SK^2Y WAY is high wing, T-shaped tail, one tail-boom and motor type. The effect of T-tail and how it is influenced by wing effect is the interesting point and the construction of T-shape tail made us confuse. SK^2Y WAY is expected to fly for environmental surveying and so considered to be thrust to weight ratio (1:1) because it doesn't need to perform aerobatics. As SK^2Y WAY's motor consumes the maximum current of 50 A, an ESC which can supply 60 A and contains 5.5 V BEC built-in, is selected.

2.1. Wing Design

The wing area and profile section have to generate a lift capable of lifting 5.5 lb weight. Thus, NACA 4412 is selected for SK^2Y WAY because its camber design provides higher coefficients of lift at lower angle of attack. Moreover, a flat bottom airfoil has tendency to have a soft stall. This type of flight characteristic is beneficial to an RC aircraft flying at low altitude.

2.2. Fuselage Design

After the general configuration of fuselage is obtained, the fuselage length and the diameter are considered. Fuselage length is assumed as 70% of wing span and it is the common value for reference design and fitness ratio (d/l) is chosen as 13 0.1145. The common stiffness ratio stands between 0.08 and 0.125.

2.3. Tail Design

The selected tail design, the T-tail which has many benefits and bad points. For home-built aircraft, horizontal tail coefficient is 0.5 and vertical tail coefficient is 0.04. The advantages of T-tail design is that it is kept well out of disturbed airflow behind the wing and fuselage, less interference drag, better pitch control, good for low speed aircraft and it is also allow high performance aerodynamics and excellent glide ratio.

2.4. Landing Gear Design

Tri-cycle type landing gear is chosen. Two main wheel must be the 50% - 55% of the root chord and so its centerline must be at 3 in from the wing leading edge. To avoid the ground roll, the angle of two landing gears should not be less than 30 deg. In this project, the angle of 70 deg is chosen for the safety of wing and its height is designed as 6 in.

2.5. Control Surface Design

Aileron chord length should be between 15 % and 25 % of the main wing chord length. Span of the aileron can be extended from 25 % to 90 % of the wing span. Span of aileron should be 25 % of wing span because it is enough for small aircraft rolling. Chord of aileron is considered 25 % of main wing chord. Therefore, aileron length is 20.52 in and the chord is 2 in.

Table 1. Design summary of SK^2Y way

Configuration	**Value**	**Unit**
gross weight	5.5	lb
stall velocity	30	ft/sec
wing loading	1.44	ft/sec
wing span	5.7	ft
aspect ratio	8.5	-
taper ratio	0.6	-
root chord	10	in
tip chord 6 in	6	in
wing airfoil	NACA 4412	-
fuselage length	4	ft
fuselage diameter	4.5	in
vertical tail length	9	in
root vertical tail length	7	in
tip vertical tail length	5.6	in
horizontal tail length	1.286	ft
horizontal tail chord	5.6	in
tail airfoil	Flat Plate	-
aileron chord	2.05 ~ 2	in
aileron span	1.71	in
rudder chord	1.35	in
rudder height	8	in
elevator chord	1.4	in
elevator length	1.286	ft

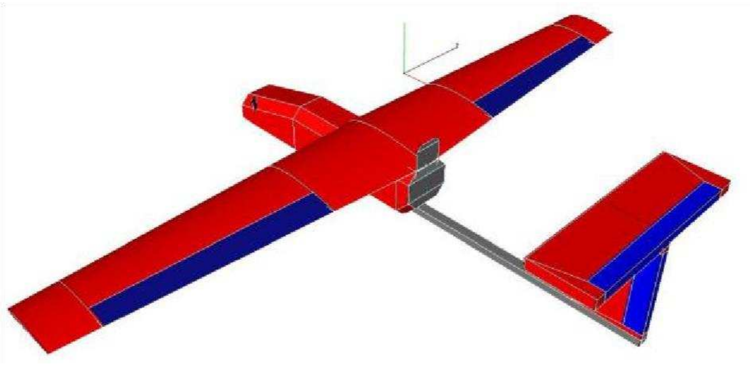

Fig. 1. 3-d view of SK^2Y WAY

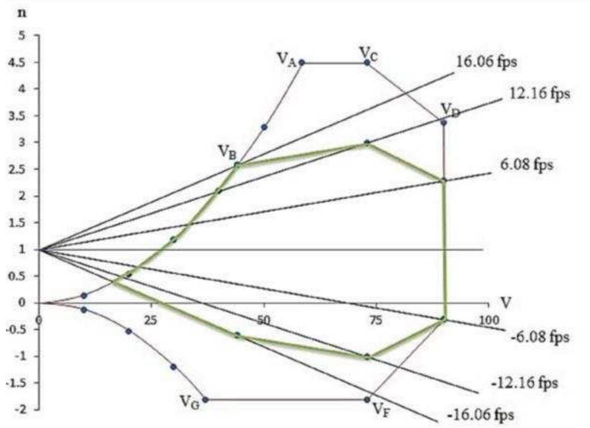

Fig. 2. V-n diagram for SK²Y WAY

From this V-n diagram figure, SK2Y WAY can fly a safe flight below 500 ft with predetermined velocities in encountering standard gust speed because the gust case is inside manoeuver case. Therefore it will not face any stall condition and structure damage due to over-speeding throughout the flight phase, and airplane is safe in flying and maneuvering under certain amount of velocity.

3. Stability and Control

The requirements for static stability, we have considered only the total airplane pitching moment curve. However, it is of interest to know the contribution of the wing, fuselage, tail, propulsion system, and the like, to the pitching moment about the center of gravity of the airplane. In the following sections, each of the components will be considered separately.

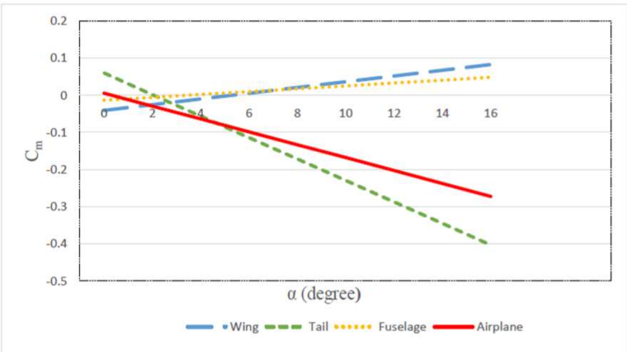

Fig. 3. Pitching moment versus angle of attack curve

From the above graph, it can be said that wing and fuselage instability is compensated by horizontal tail contribution. In considering power effect, since motor mount is located above fuselage center line, power contribution has negative pitching moment on the airplane. Thus SK²Y WAY is statically stable in longitudinal contribution. Since static Margin is positive, the airplane is stable as long as CG moves inside the range.

As $C_n\beta > 0$, the aircraft design is stabilizing in directional stability. SK^2Y WAY doesn't need to be trimmed to keep the level flight because its original pitching moment is balanced at zero angle of attack.

4. Performance

The performance of SK^2Y WAY is following.

Table 2. Performance of SK^2Y WAY

Performance	Value	Unit
max range	45.37	miles
takeoff distance	95.58	ft
landing distance	78	ft
ROC	74.84	ft/s
endurance	6.68	sec

5. Conclusions

When testing the flight test, some difficulties had been encountered in SK^2Y WAY. At first flight test, the left wing of the aircraft was lower than the right wing in take-off condition, which is a common high risk of T-tail airplane. While performing flight test, the wind is heavy and it encountered rough wind (10 - 12 knots). In comparing theoretical and practical results, the theoretical take-off distance was found to be the same in the flight test. The theoretical take-off distance is 96 ft and in the flight test, take-off distance was found to be the distance nearly 100 ft in both flight tests. At first in weighing SK^2Y WAY, its weight is found to be 5 lb. After counter weight and the CG location were rearranged and balanced, the weight becomes 5 lb, 7 oz. Therefore the actual SK^2Y WAY's weight is found to be the same as weight which is estimated in design development (5.5 lb). The structure of SK2Y WAY is even not deformed when meeting the airspeed at 20.20 knots that is beyond the specified value (16.16 knots) and the gust case was out of manoeuver case. When calculating static stability of SK^2Y WAY, it was found to be perfect and satisfactory in longitudinal, lateral and directional stability. Therefore SK^2Y WAY is stable in static longitudinal stability. The CG location is the same in static CG calculation.

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