“Multi Swept Wing”– Elite Execution Over Wing's History

Ramesh Kumar, Sabarikumar M, Vignesh S, Boopathi D, Ranga Raj R

Abstract - Profundity of wing structure that needs change has no closure. A wing is a type of fin with surface that produce aerodynamic force for aircraft through the atmosphere, In that way, a high performance aircrafts capable of subsonic, transonic and supersonic speed employ a forward swept wing platform. Due to aero elasticity effect, the aerodynamic force on wing tip tends to bend it in forward swept wing. But in the wing design that we propose, has smaller elasticity effect. The air flows towards the wing root and hence the dangerous tip stall becomes safer in our wing. Also due to sweep at the tip of the wing, it increases the aileron performance and further it increases the yaw directional stability. Since the wings are generally larger at the root and due to multi swept, this improves the lift performance. As a result, maneuverability is improved especially at both lower and higher angle of attacks. Thus the stability of a forward swept wing aircraft is disclosed that corrects a dynamic instability phenomenon which occurs when the whole vehicle (rigid body) motion couples with the wing structural motion. Our technology will be elite in wing’s ability today.

Keywords - Aerodynamics, Improved lift and drag, Maneuverability, Multi swept, Stability

I. INTRODUCTION

It is very easy to design a wing if we have data’s about already existing aircrafts of similar type. It provides more satisfaction and avoids confusion while choosing some design parameters for our wing. In this detailed survey some many important design drivers like aspect ratio, wing loading and overall dimensions are determined for our reference. It assists in proposing a new design and modification in our design which will improve the performance of the proposed aircraft. This assures the performance of the aircraft as per the design calculations and easy way of designing a wing within particular period of time. So in this literature survey we have collected some specifications and design development to introduce our new high performance multi-swept wing.

A forward-swept wing is an aircraft wing configuration in which the quarter-chord line of the wing has a forward sweep.

Typically, the leading edge also sweeps forward. With the air flowing inwards, wingtip vortices and the accompanying drags are reduced, instead the fuselage acts as a very large wing fence and, since wings are generally larger at the root, this improves lift allowing a smaller wing. As a result maneuverability is improved, especially at higher angle of attack. At transonic speeds, shockwaves build up first at the root rather than the tip, again helping to ensure effective aileron control. One problem with the forward-swept design is that when a swept wing yaws sideways, one wing moves rearwards. The other problem is a structural one. Due to aero elasticity, the lift force on any wing tends to bend it upwards at the tip. On a forward-swept design, this increases the angle of incidence at the tip, increasing lift and causing further bending which causes further lift and so on. Any swept wing tends to be unstable in the stall, since the rearward end stalls first causing a pitch-up force worsening the stall and making recovery difficult. This effect is more significant with forward sweep because the rearward end is the root and carries greater lift. In order to overcome the disadvantages in forward-swept wing, we modified that wing to some extent and design a new multi-swept wing which carries both forward and backward swept platform in it.

II. WING DESIGN

A. AIRFOIL SELECTION

The airfoil in many aspects is the heart of the wing. The airfoil affects the cruise speed, take-off and landing distance, stall speed, handling qualities (especially near the stall), overall efficiency during all phases of flight. The front of the air foil is defined by a leading edge radius which is tangent to the upper and lower surface. The back of the airfoil is defined by a trailing edge.

An airfoil designed to operate in subsonic flow will have a curvedly or nearly-sharp leading edge to prevent a drag producing. An air foil in (2-D) flow does not experience any drag due to the creation of lift. The pressure forces produced in the generation of lift are at right angles to the oncoming air. All two-dimensional air foil drag is produced by skin friction and pressure effects resulting from flow separation and shocks. It is only in three-dimensional flow that drag to lift is produced.

In our wing design, it is only applicable to fly the aircraft at subsonic speed and hence we selected a NACA 6-series airfoil (64-012).

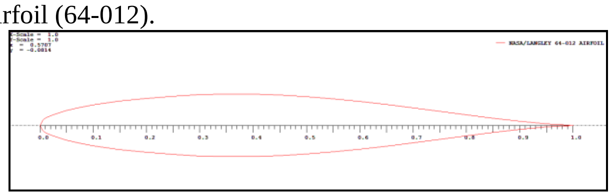

Fig. NACA 6-series airfoil (64-012)

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B. DESIGN CALCULATION

In order to design multi-swept wing, the following values are taken as reference value from the bomber aircraft **"Boeing-52H stratofortress"**

S.No	Parameters	Values
1.	Cruising speed	0.8 Mach
2.	Wing area	378 m^2
3.	Maximum take-off weight	222000 kg
4.	Empty weight	83250 kg
5.	Aspect ratio	8.56
6.	Cruising altitude	14000 m
7.	T/W	0.3
8.	W/S	587.3 kg/m^2

Aspect ratio decides the max angle of attack, increasing the AR, lesser the stall Angle Of Attack .So care must be taken while assuming AR based on flight operation

$$\text{Aspect ratio (AR)} = \frac{(Wing\ span)^2}{wing\ area}$$

.

Therefore, wing span (b) = 56.4 m

Root chord,

$$C_{root} = \left(\frac{2S}{b\times(1+\lambda)}\right)$$

$$C_{root} = \frac{2\times 378}{56.4\times(1+0.3)}$$

$$C_{root} = 10.32 \text{ m}$$

Tip chord, $C_{tip} = (\lambda \times C_{root})$

$$C_{tip} = 0.3\times 10.32$$

$$C_{tip} = 3.1 \text{ m}$$

Forward sweep angle = 32.5°

(75% of wing span from wing root)

Backward sweep angle= 20°(25% of wing span from wing tip)

Chord length at x position:

$$C(x) = \frac{2s}{(1+\lambda)b}\left(1 - \frac{2(1-\lambda)}{b}\times y\right)$$

At 75%, Chord length= 4.9805 m

At 50%, Chord length= 6.7070 m

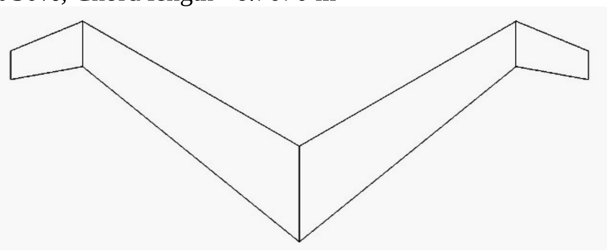

Fig. Top View of Multi- Swept Wing

III. ESTIMATION OF WING

A. WING LOADING

The wing loading is the weight of the aircraft divided by the area of the reference wing. It affects stall speed, climb rate, take-off and landing distance and turning performance. Also it determines the design lift coefficient and impact drags through its effect upon wetted area and wing span.

1. At cruise,

The wing loading should be selected to provide a high L/D at the cruise conditions.

Maximum propeller range,

$$W/S = q\times(\pi\times e\times A\times C_{d,o})^{1/2}$$

$$W/S = 6836.314 \text{ N/m}^2$$

Maximum jet range,

$$W/S = q\times(\pi\times e\times A\times C_{d,o}/3)^{1/2}$$

$$W/S = 3946.95 \text{ N/m}^2$$

2. At Instantaneous turn,

If the aircraft turns at quicker rate, the drag becomes greater than the available thrust, so the aircraft begins to slow down or lose altitude .the "instantaneous" turn rate is the highest turn rate possible, ignoring the aircraft that the aircraft will slow down or lose altitude.

$$W/S = q\, C_{L\,max}/n$$

$$= 3627.03 \text{N/m}^2$$

3. At Sustained turn,

The sustained turn rate is also important for success in combat. If two aircraft pass each other in opposite directions, it will take them about 10 seconds to complete 180 degree turns back towards the other. The aircraft will probably not be able to maintain speed while turning at the maximum instantaneous rate. If one of the aircraft slows down below corner speed during this time it will be at a turn rate disadvantage to the each other, which could prove fatal. It is usually expressed in terms of the maximum load factor at some flight condition that the aircraft can sustain without slowing or losing altitude.

$$W/S = q/n\,(\pi AR\, e\, C_{d,o})^{1/2}$$

$$= 1953.23 \text{N/m}^2$$

4. At maximum ceiling,

$$W/S = q\times C_L$$

$$W/S = 4704.76 \text{ N/m}^2$$

5. At minimum power,

For a high- altitude aircraft such as an atmospheric research or reconnaissance plane, the low dynamic pressure available may determine the minimum possible wing loading.

$$W/S = q\,(\pi AR\, e\, C_{d,o})^{1/2} = 6836.3 \text{ N/m}^2$$

6. At maximum power,

$$W/S = q\times((C_{L\,max})_{t.o}/1.31) = 8393.14 \text{ N/m}^2$$

B. WEIGHT OF WING

$$W_{wing} = C_1C_2C_3\,(W_{dg})\,C_4\,(n)\,C_5\,(S_W)\,C_6\,(AR)\,C_7\,(t/c)\,C_8\,(C_9+\lambda)\,C_{10}\,(\cos\alpha)C_{11}\,(S_f)\,C_{12}\,(q)\,C_{13}\,(W_{fw})\,C_{14}$$

$$W_{wing} = 16389.65 \text{ N}$$

IV. EXPERIMENTAL TEST

An experiment is an orderly procedure carried out with the goal of verifying, refuting, or establishing the validity of a hypothesis. The following experiments are undertaken to analyze the prototype using wind tunnel.

1. Coefficient of lift vs. Alpha
2. Coefficient of drag vs. Alpha
3. Flow visualization

A. WIND TUNNEL

The aim of wind tunnel tests is the simulation of the flow around bodies or their scaled models. In aeronautical applications, the measurement of aerodynamic loads in a wind tunnel, forces and momentums, is a very difficult task due to the required accuracy. The wind tunnel balances, comprised by several hardware and software components, provides directly the pursued measurements, with high accuracy and reliability. There are various types of wind tunnels are available. As per our requirements, we carried our experimental test in suction wind tunnel.

Suction type wind tunnels are open type tunnels and also used for subsonic testing of aerodynamic models. Air is sucked into the tunnel through a contraction (nozzle) by an exhaust fan. The air jet in the entire tunnel is slightly below atmospheric pressure. Therefore for a given velocity in the test section the power required to drive the fan is comparatively less.

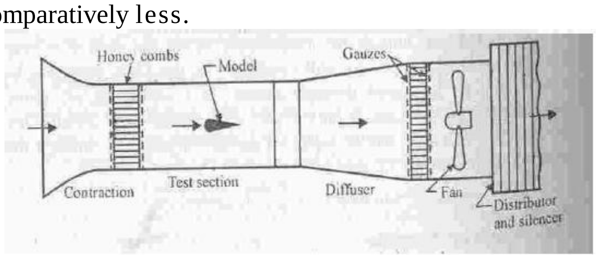

Fig. suction type wind tunnel

B. Three Component Balance:

These balances are designed specifically for use in small to medium sized wind tunnels having cross sections of about 500 to 1200mm. Of high accuracy, they are ideally suited to both undergraduate teaching and post graduate research work. The load sensing elements are high precision, strain gauged load cells with excellent repeatability and linearity characteristics and are temperature compensated for a temperature range of 0 to 60^{C}. The geometrical construction of the load sensing systems allows the complete separation and independent measurement of the components of Lift, Pitch and Drag with negligible interactions of one component into another.

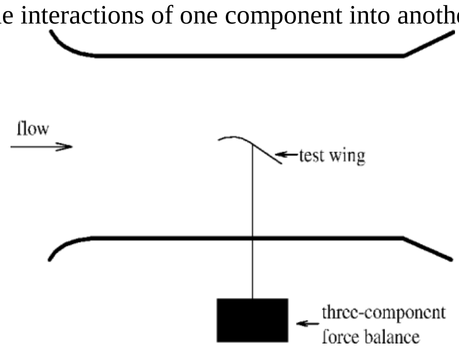

Fig. Layout diagram of Experimental test

In order to find the value of the velocity, we find the ΔH value and then we equate hydrostatic law and dynamic pressure to find velocity. (i.e.)

$$P_1 + (p/2)\, V^2 = T_p$$

$$P_T - P_\infty = ½(pV^2)$$

$$pg\Delta h = ½(pV^2)$$

$$V = \sqrt{\frac{2*9.81*1000*5}{1.1794}} = 9.12 \text{ m/s}$$

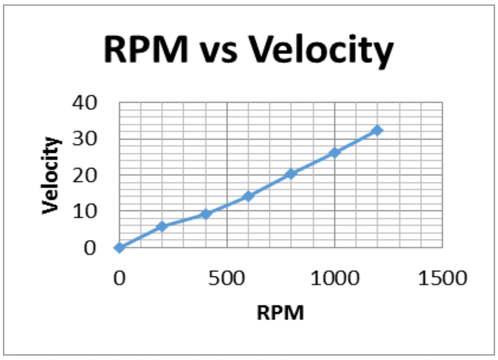

Fig. RPM vs. Velocity

S.No	Velocity (m/s)	rpm	ΔH (mm)
1	0	0	0
2	5.77	200	2
3	9.12	400	5
4	14.13	600	12
5	20.39	800	25
6	26.12	1000	41
7	32.37	1200	63

At Velocity= 20 m/s

Angle of Attack (Degree)	Lift (N)	Drag (N)	CL	CD
-3°	-4.46	1.52	-0.5002	0.1705
0°	1.76	0.16	0.1974	0.0179
3°	2.50	0.67	0.2800	0.0750
6°	4.54	0.69	0.5092	0.0774
9°	5.91	0.99	0.6628	0.1110
12°	5.57	0.97	0.6247	0.1088
15°	5.34	1.58	0.5989	0.1772

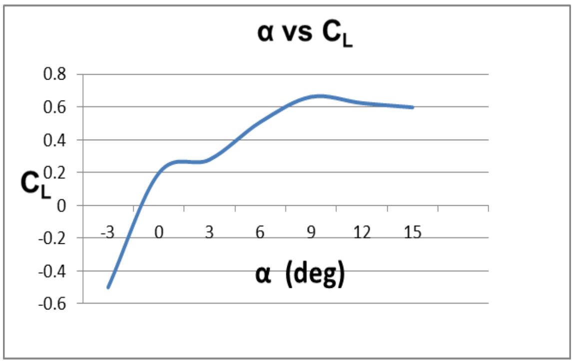

Fig. Coefficient of lift vs. Alpha

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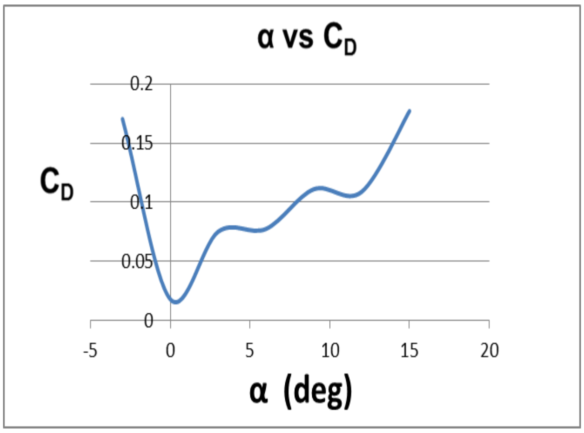


Fig. Coefficient of drag vs. Alpha

At Velocity= 25 m/s

Angle of Attack (Degree)	Lift (N)	Drag (N)	CL	CD
-3°	-6.69	2.23	-0.4802	0.1601
0°	2.85	0.75	0.2046	0.0538
3°	4.33	1.16	0.3110	0.0833
6°	7.52	0.95	0.5398	0.0682
9°	8.67	0.38	0.6223	0.0273
12°	8.78	1.22	0.6302	0.0876
15°	8.59	1.84	0.6166	0.1321

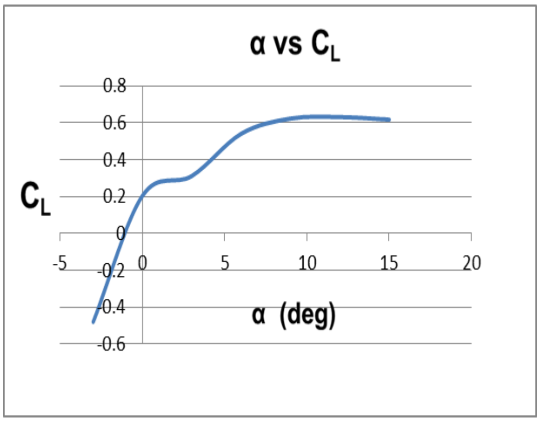


Fig. Coefficient of lift vs. Alpha

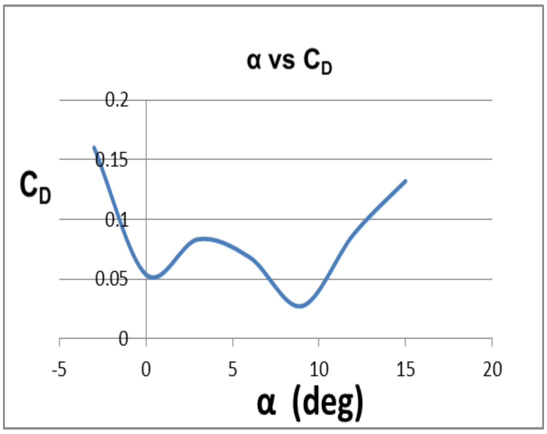
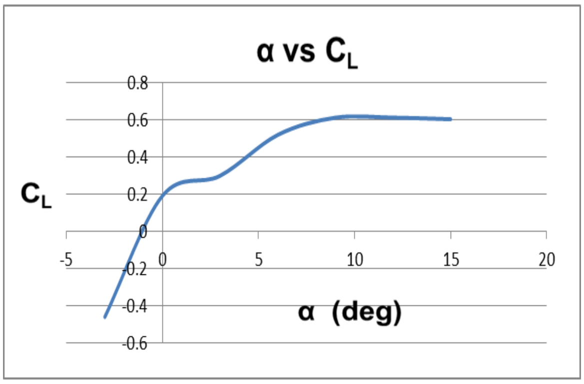


Fig. Coefficient of drag vs. Alpha

At Velocity= 30 m/s

Angle of Attack (Degree)	Lift (N)	Drag (N)	CL	CD
-3°	-9.21	2.95	-0.4591	0.1470
0°	3.85	0.82	0.1919	0.0409
3°	6.01	1.22	0.2996	0.0608
6°	10.42	0.81	0.5194	0.0404
9°	12.28	0.51	0.6121	0.0254
12°	12.28	1.48	0.6121	0.0738
15°	12.11	1.96	0.6036	0.0977



sFig. Coefficient of lift vs. Alpha

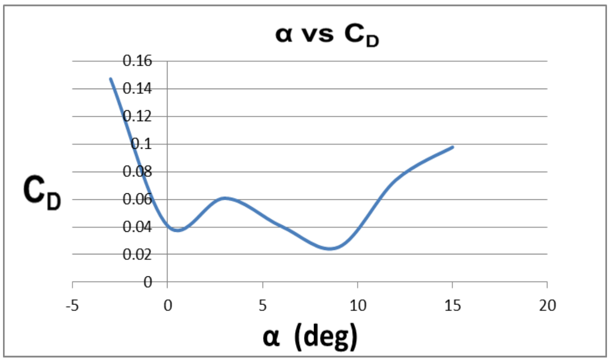


Fig. Coefficient of drag vs. Alpha

C. FLOW VISUALIZATION

Experimental flow visualization techniques are applied for several reasons:

1. To get a picture of fluid flow around a scaled model of a real object, without any calculations;
2. To develop or verify new and better theories of fluid flow or models.

If the flow could be made visible by some kind of flow visualization technique, it would be possible to observe flow phenomena which are essentially in viscid (e.g., vortex flows, flows distant from surfaces) as well as those phenomena which are dominated by the effects of viscosity (e.g., boundary layer flows, separation). Flow visualization may be divided into surface flow visualization and off-the-surface visualization. Surface flow visualization involves tufts, fluorescent dye, oil or special clay mixtures, which are applied to the surface of a model.

Visual inspection of such tufts and coatings as a function of time or after some time, will give valuable information on such things as the state of the boundary layer (laminar or turbulent), transition, regions of separated flow and the like. Tuft technique that is used in both flight test and wind tunnel testing. Tufts are small lengths of string that are frayed on the ends. Popular materials for tufts include monofilament nylon, and polyester or cotton sewing threads. Tufts may be coated with fluorescent dyes to increase visibility for photography. The tufts are attached to the surface of the model using some adhesive such as tape or glue, and as the air flows over the model, the tufts are blown and point downstream. If the entire model is tufted, as shown on the photo, then regions of strong cross-flow, reverse flow, or flow separation are indicated by the direction of the tufts. Tufts can also indicate regions of unsteady flow when recorded by film or video.

Fig. Laminar flow over the wing (0 to 11 degree)

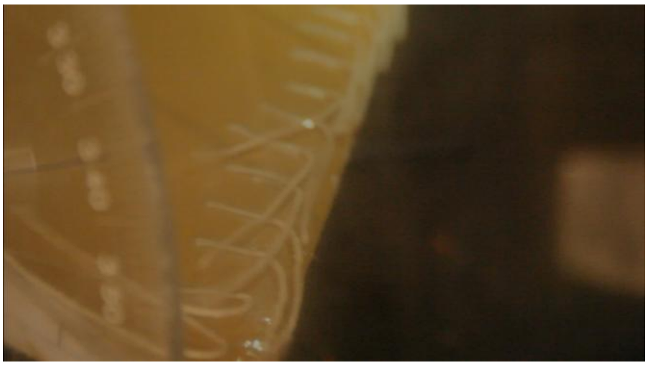


Fig. Turbulent flow over the wing (12 and above degree)

V. RESULTS

Comparison between multi-swept, forward swept and backward swept wings:

The following table and graph describes the comparison between Multi-swept, forward swept and backward swept at different angle of attacks.

AOA	Multi Swept Wing		Forward Wing		Backward Wing	
A	C_L	C_D	C_L	C_D	C_L	C_D
-3°	-0.218	0.0019	-0.2173	0.0019	-0.2272	0.0019
0°	0	0	0	0	0	0
3°	0.2985	0.0019	0.2173	0.0019	0.2272	0.0019
6°	0.4351	0.0076	0.4328	0.0075	0.4526	0.0077
9°	0.6482	0.0170	0.6447	0.0167	0.6744	0.0572
12°	0.8560	0.0298	0.8515	0.0243	0.8908	0.0301
15°	1.0569	0.0455	1.0515	0.0448	1.1002	0.0460

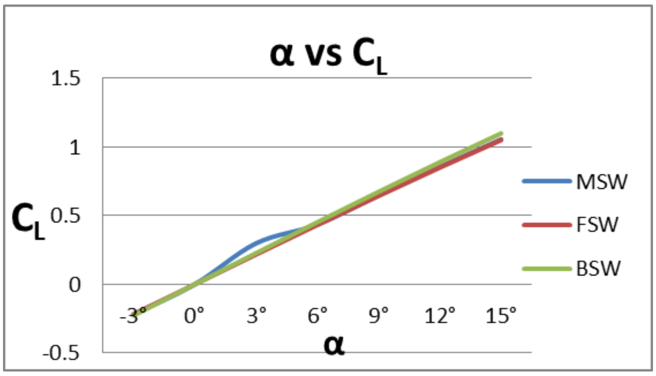


Fig. Coefficient of lift vs. Alpha

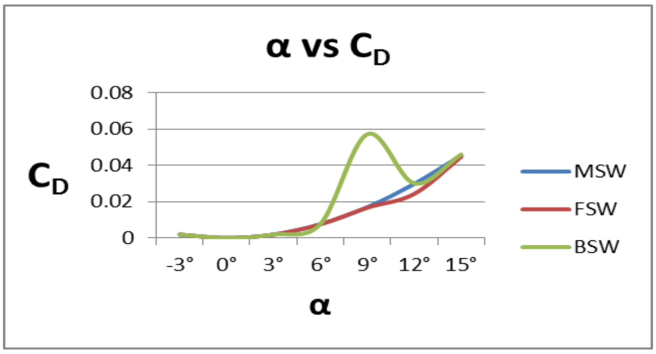


Fig. Coefficient of drag vs. Alpha

From the above result, it can be seen that

1. The amount of CL produced in multi-swept wing is higher than the forward and backward swept wing.
2. It produces less amount of drag compared to the backward wing, because of the absence of tip effect.
3. It gives better performance result compared to both.
4. Aero elasticity effect is reduced at the tip of wing compared to the forward swept wing.
5. Stall angle occurs at 11 to 12 degree.

VI. CONCLUSION

The wing has gone through many design modifications since its early conceptual designs expected; among these was a growth in technology. The design of this multi-swept wing performs at subsonic speed and overcomes the disadvantages of other swept wings. In forward swept wing, due to aero elasticity effect, the aerodynamic force on wing tip tends to bend it and it is unstable at yaw moment. Similarly in backward swept wing, it causes a severe induced drag on it. But in our wing, the dangerous tip stall becomes safe because it reduced the aero elasticity effect and induced drag acting on it. Also it gives better maneuverability at high angle of attacks. It will be elite in subsonic speed aircrafts and hence it can be used in an aircraft's such as bomber, civilian and cargo. A design never gets completed in a flutter sense but it is one step further towards ideal system.

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