# THE STUDY ON THE AIRCRAFT INTEGRATED CHARACTERSWITH DIFFERENT HEIGHT WINGLETS

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**[Key word] winglet; height;drag reduction;weight;flutter**

## Abstract

This paper has calculated the wingbody shape with two different types of winglets(the blended winglet and shark winglet) by discreted Renault average Navier-Stokes equation and aero-structure coupled equation.The results showed that the weight increase of aircraft structure is lower than the weight increase of available loads and that the flutter velocity decrease is adjustable whin the safety range.so the selction of winglet height should give priority to the lift-drag ratio character.

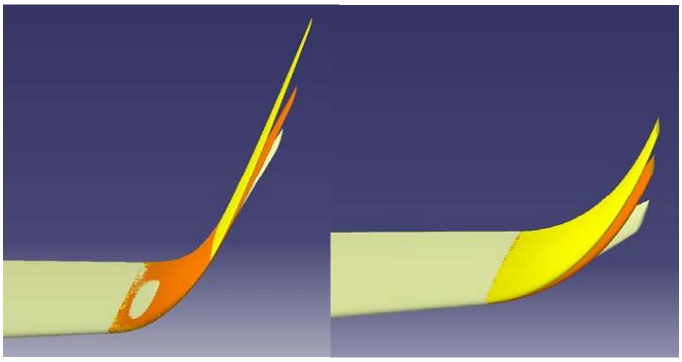
## 1 General Introduction

The sharklet winglet project used on A320 had been publicized at the Dubai Airshow on November, 2009.It was reported that the first A320 with sharklet winglet would start servce at New Zealand Aviation in 2012, then all series of A320 would fix sharklet winglet.According to the traditional experience,the height of winglet generally shouldn't longer than the chord of wingtip.however,the winglet height of A320 is 2.4m vs the chord of wingtip 1.5m, the height of winglet of B737-800 is 2.6m vs the chord of wingtip 1.6m,the winglet height of the two most populular airplane is more longer than the wingtip chord. The designer have to compromise among the aerodynamic,the weight and the flutter character because of the additional weight by the wingroot moment and the decreased critical flutter velocity as a result of winglet[1,2,3]. Therefore,there is a puzzling problem:the additional weight and the flutter velocity limit generally has been overrated according to the traditional experience,so the potential aerodynamic efficiency doesn't received. The reseach based on KC-135 reported that the height of winglet would produce more benefit on aerodynamic character comparing to the taper ratio and area[1].

This paper has studied quantitatively on the effect of aerodynamic,weight and flutter with two types of different height winglets, it would offer some suggestions on the selection of winglet height.

## 2 Winglet Geometry

Fig1 display the geometry of two types of winglets with different height. Fig1 (a) display the traditonal winglet, Fig1 (b) display the sharklet winglet.Fig2 display the statistics of the winglet height vs the wing span of the classic aircrafts all around the world.



(a) traditonal winglet (b)sharklet winglet
fig1. winglets geometry of different height

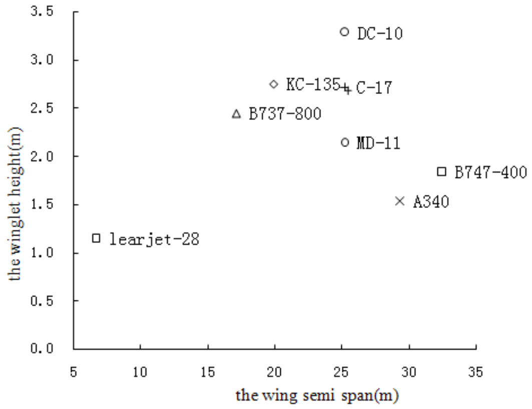



Fig2. the winglet height vs the wing semi span

## 3 The Method of Computation

This paper has calculated the longitual and the flutter character.The longitual computation base on the Renault-Average Navier-Stokes equation by the multi_level grid generation,the flutter computation base on the Aero-Structure coupled equation by unstucture dynamic mesh.Fig3-Fig4 display the aerodynamic structure grid topology.Fig5 display the flutter surface unstructured mesh.

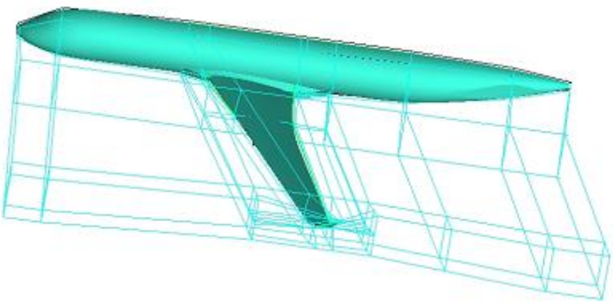


Fig 3. the wingbody structure grid topology

Fig 4. the wingbody body-fitted grid

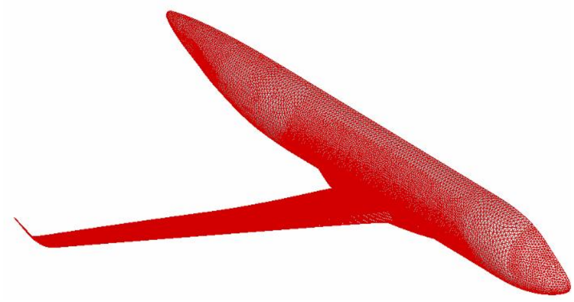


Fig 5. the wingbody unstructured mesh

## 4 Examples

This paper has calculated the lift and drag character of DLR-F6 wingbody at ma=0.75(Fig6 display the wall grid) and the flutter critical velocity of a wing with winglet(Fig7 display the wall mesh).It is obvious that the difference between the calculate and experience accord with well from Fig8.It is also agreeable with the experience on the flutter critical velocity from Fig9.

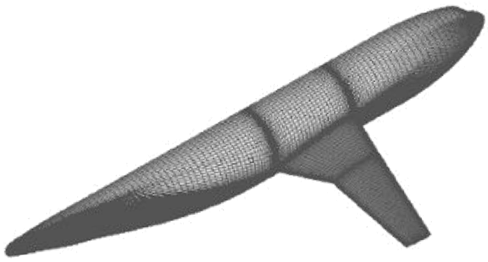


Fig6. The wall grid of DLR-F6

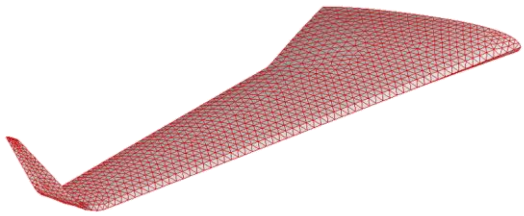


Fig7. The wall mesh of a wing

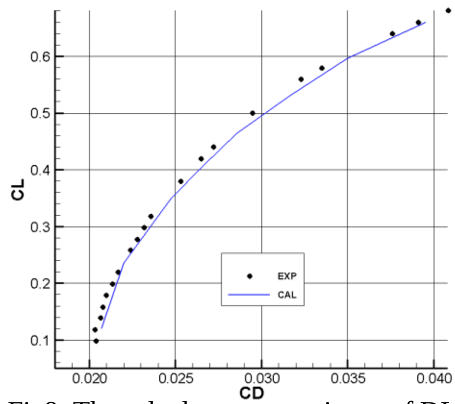



Fig8. The calculate vs experience of DLR-F6

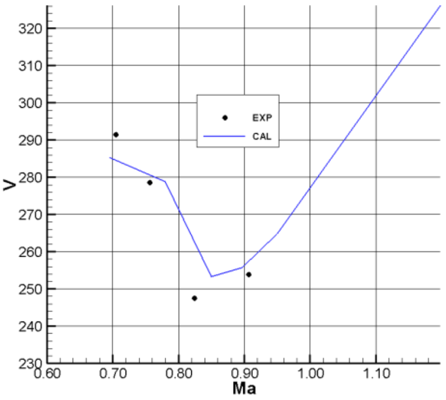



Fig9. The calculate vs experience of the flutter critical velocity

## 5 The Results and Analyse

### *5.1 Longitual*

The basic physical effect of winglets is the diffusion of the vortex flow just downstream of the wing. The induced drag is reduced is a decrease in downwash of the flow approaching the wing due to the winglet.The winglet influences the flow over the wing[2].With the height increasing,the effect is more obvious,then the drag is smaller.Fig10-Fig11 shows that the winglet is higher,the lift-drag ratio is bigger when the coeffient of lift CL above 0.4 both the traditional and the sharklet winglet,which is accord with the aerodynamic theory.Fig12 display the lift-drag ratio vs the winglet height curve when the coeffient of lift CL=0.55,it also shows that the winglet could explode the wingtip vortex as long as the winglet height above a critical height.However there is also another critical height when the winglet is longer than it,the lift-drag ratio wouldn't get gains.The sharklet winglet is shorter than the traditional winglet when at the same lift-drag ratio,perhaps it is one of the advantage of sharklet winglet.

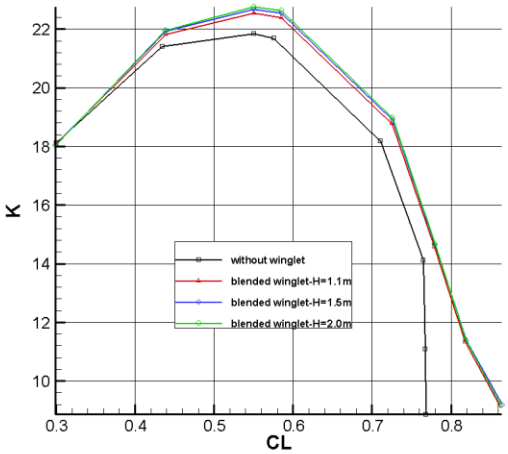



Fig10. The lift-drag ratio vs coeffient of lift Of traditional winglet

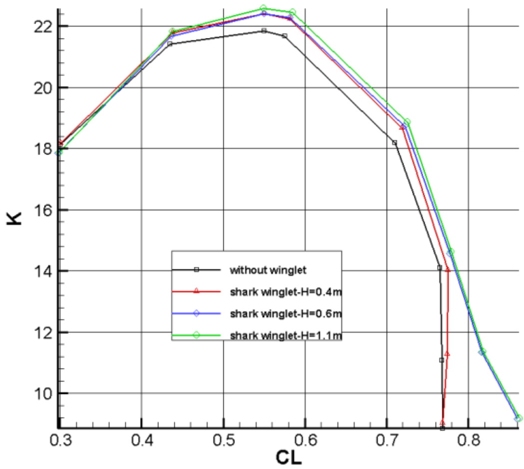



Fig11. The lift-drag ratio vs coeffient of lift Of sharklet winglet

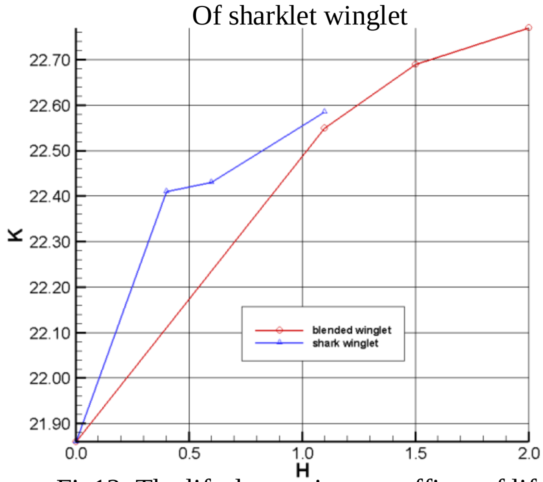



Fig12. The lift-drag ratio vs coeffient of lift Of the two types of winglet at CL=0.55.

### *5.2 The Pressure Center of Wing*

When the winglet is fixed, The center of wing pressure move towards the wingtip ,then the moment of wing root increase. With the height increasing,the center of wing pressure is more outer.There is a critical height which the center of wing pressure wouldn't move.

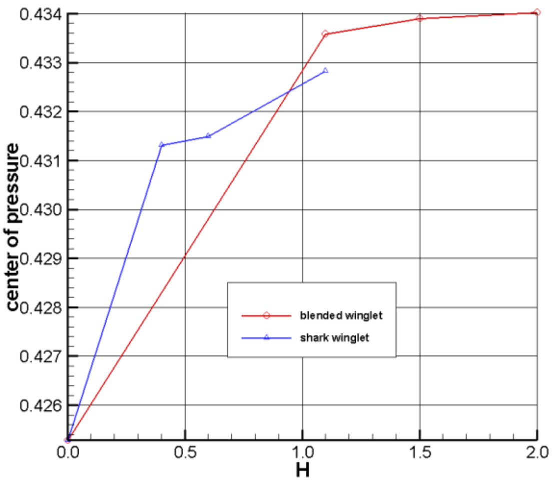



Fig13. the position of pressure center vs the winglet height Of the two types of winglets at CL=0.55

## *5.3 The Weight Analyse*

The structure additional weight when winglet is fixed include the self winglet weight and the wingroot reinforce weight.Furthermore,the load increase with the lift-drag ratio increase as a result of winglet at the same oil weight.

The self winglet weight M0 is supposed equal 100kg。

The wingroot reinforce weight is in direct proportion to the movement of the center of wing.

$$\Delta M1=M*(Z1/Z0-1) \quad (1)$$

M —the wing weight； Z1 — the spanwise position of the center of wing with winglet. Z0 —the spanwise position of the center of wing without winglet.

Breguet equation:

$$R=\frac{L}{D}\cdot\frac{V}{SFC}\cdot Ln(\frac{W_L+W_F}{W_L}) \quad (2)$$

When the oil weight $W_F$ keeps a certain,the basic weight：

$$W_L=W_F\Big/(e^{\frac{R\cdot SFC}{K\cdot V}}-1) \quad (3)$$

ΔM2 — the additional basic weight as a result of lift-drag ratio increasing.

The total weight profit:

$$\Delta M=\Delta M2-\Delta M1-M0 \quad (4)$$

Fig14-Fig15 shows that the additional basic weight as a result of lift-drag ratio increasing is more than the self winglet weight and the wingroot reinforce weight both the traditional and sharklet winglet.With the height increasing,the total weight profit increase.

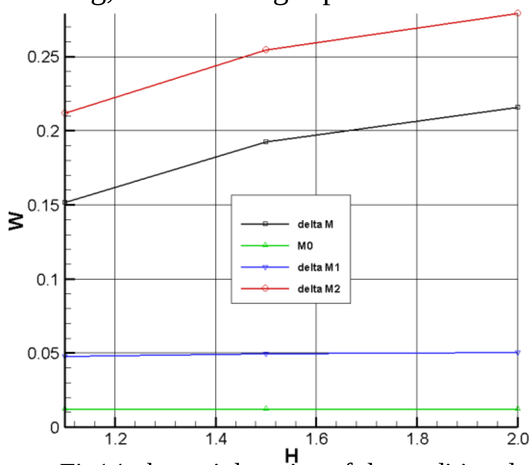



Fig14. the weight gains of the traditional winglet(W=ΔM/Mwing)

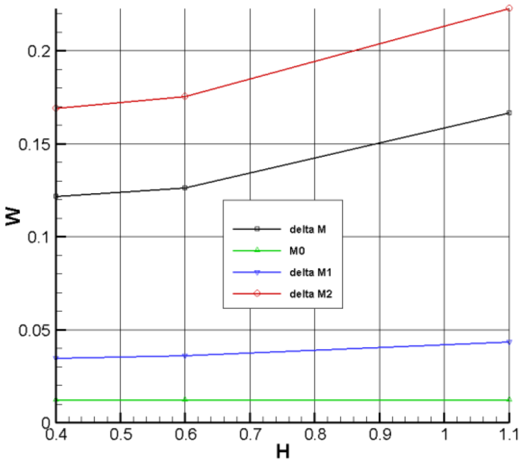



Fig15. the weight gains of the sharklet winglet(W=ΔM/Mwing)

## *5.4 The Flutter Analyse*

Fig16 display the least flutter critical velocity vs the winglet height at the sea level.It shows that the least flutter critical velocity decrease with the winglet height increase both the traditional and shraklet winglet,this is accord with the previous research[4,5,6].The least flutter critical velocity of wingbody with different winglet height decreased by at most 6% than wingbody without winglet.However the flutter boundary is 15% more than the safty requirement,so the decrease of least flutter critical velocity wouldn't cause serious result.Now the winglet is more and more made of composite matiarial,the decrease of least flutter critical velocity is smaller.

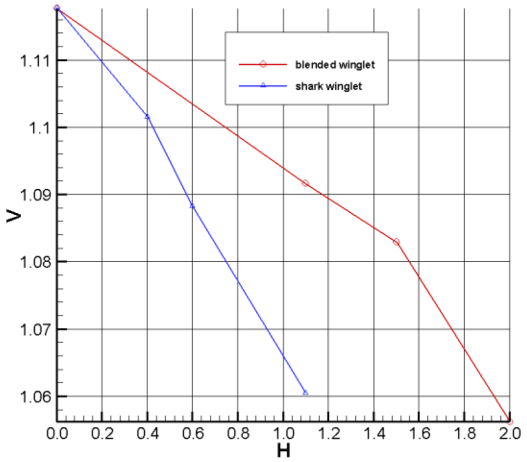



Fig16. The critical flutter velocity vs the winglet height Of the two types of winglets (v=Vmin/Vcruise)

## 6 Conclusion

It is well known all around the world that the winglet could increase lift and reduce drag.tThe study on the winglet dimension reveal that the more winglet height is,the drag is smaller to a extend,at the meanwhile,the aircraft would pay for the additional weight and flutter price.However,the additional weight is far less than the increased efficiency load,the decreased critical flutter velocity is adjustable within the safty range.So,the author advise that the selction of winglet height should give priority to the lift-drag ratio character.

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