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THE STUDY ON ANTI-ICING AREAS OF LEADING-EDGE SLATS IN MODERN CIVIL AIRCRAFT

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Abstract

It is very dangerous for the airplane to fly under icing conditions. As flying accidents caused by in-flight icing have still be occurred recently, expanded attentions are paid on anti-icing design of civil aircraft. It is crucial for civil aircraft to determine anti-icing areas of high lift leading-edge devices. The high lift leading-edge slats are divided several blocks through the span-wise wing. The larger the leading edge radius of the airfoil is, the more icing the wing collects, if no appropriate anti-icing methods are taken. The choice for anti-icing areas of the slats are analyzed through regional, trunk and wide-body airliners. The slats icing influence on longitudinal lift and moment coefficient are researched for two typical civil aircraft by wind tunnel test.

Keywords: anti-icing,slats,civil aircraft, lift coefficient

1. General Introduction

The choice for anti-icing areas of the slats is determined from aerodynamics, longitudinal stability, layout, weight and energy. Many pipelines are placed on leading edge of the wing, and the space of leading edge is very narrowness, so the layout around the leading edge is very difficulty. The components of anti-icing system will add the weight of systems and structure. The anti-icing system absorbs hot gas from the engines resulting the energy loss of the engines which will decrease the thrust of the engines. So the less the area of leading edge anti-icing is, the better it is because of the layout, weight and energy.

2. The effects of flaps

Figure 1 shows the lift coefficient distribution along the wing span.The lift coefficient around at 70% span-wise location is largest. The suction peak of the slat leading edge will be increased when the flaps afterwards drop down because of the increment of airfoil camber and the up-wash towards the slat due to the flap. So the suction peak the slat leading edge around at 70% span-wise location will augment badly resulting in wing stall easily when the slats accumulate some ice.So the flap improves the stall trend of the slat on the conditions of icing, this area is the anti-icing sticking point.

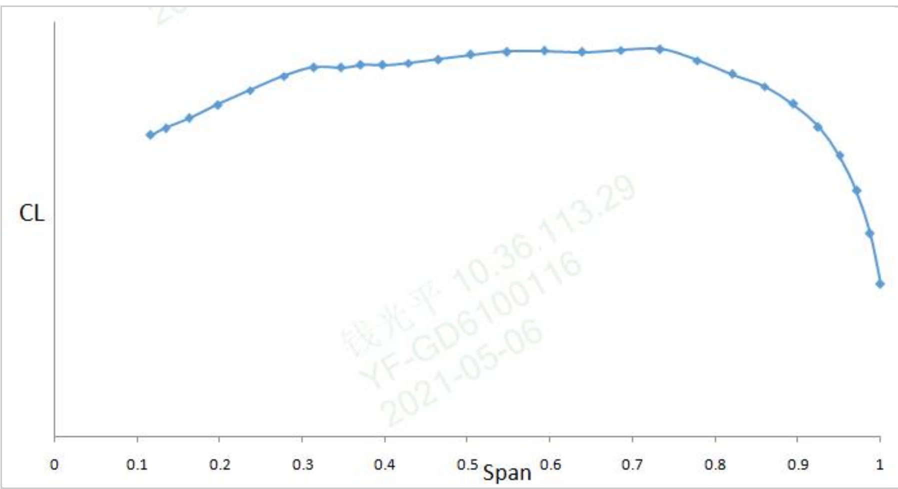

Figure 1 – The lift coefficient distribution along the wing span

3. The effects of slats leading edge radius

The larger the icing intensity is,the smaller the slats leading edge radius is. The inner slats leading edge radius is larger leading to the less icing intensity,meanwhile the inner slats are closed to the fuselage. The roll moment due to icing on the inner slats is litter resulting in less influence on aerodynamics,stabilization and flight quality.Consequently the whole slats have anti-icing methods for the regional airplanes due to the smaller slats leading edge radius,meanwhile the trunk and wide-body airplanes have few anti-icing areas for slats because of the larger slats leading edge radius.

4. The effects of aeroelastics

The wing has sweep-back angle for civil airplanes commonly. The attack angle for the wing airfoil will decrease because of the wing aeroelastic deformation. The outer wing has larger deformation than the inner wing resulting in less lift coefficient. So the outermost wing slats usually have no anti-icing methods.

5. The results of wind tunnel test for some trunk airplane

Figure 2 shows the effects on maximum lift coefficient and stall angle from slat icing through the wind tunnel tests for some trunk airplane. The slat 1(innermost slat) icing has more significant effect on maximum lift coefficient and stall angle than other slats.

The deflect degree of the slats have significant influence on the aerodynamic suction peak and its development resulting in significant effect on maximum lift coefficient and stall angle. So the deflect degrees should be optimized under both no icing and icing conditions.

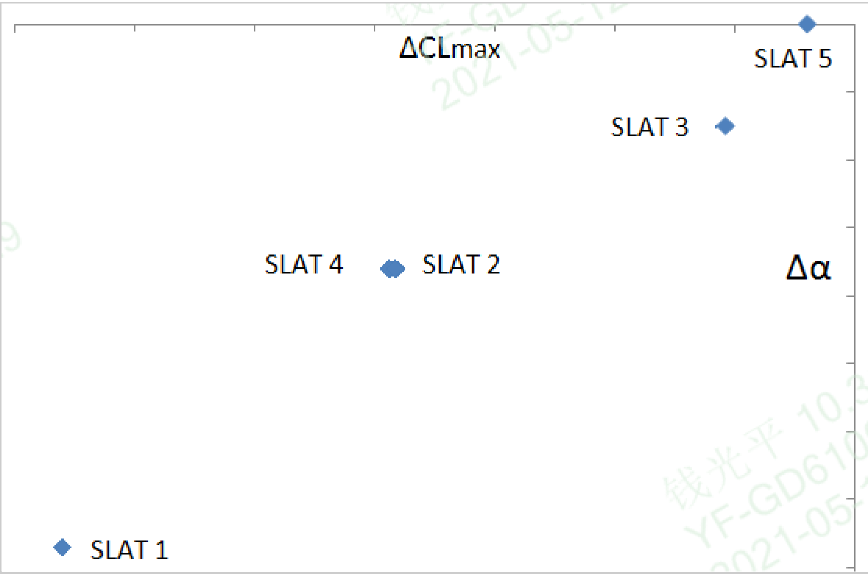

Figure 2 – The effects on maximum lift coefficient and stall angle from slat icing

6. The results of wind tunnel test for some wide body airplane

Through the wind tunnel tests for some wide body airplane, the third slat(illustrated fig.3 and 4) with icing has the largest influence on the maximum lift coefficient and stall angle. The first and second slats with icing have little influence on maximum lift coefficient and stall angle. The seventh slat with icing has little influence on maximum lift coefficient, but significant influence on longitudinal moment coefficient. So the third and seventh slats should have anti-ice methods for the wide body.airplane.

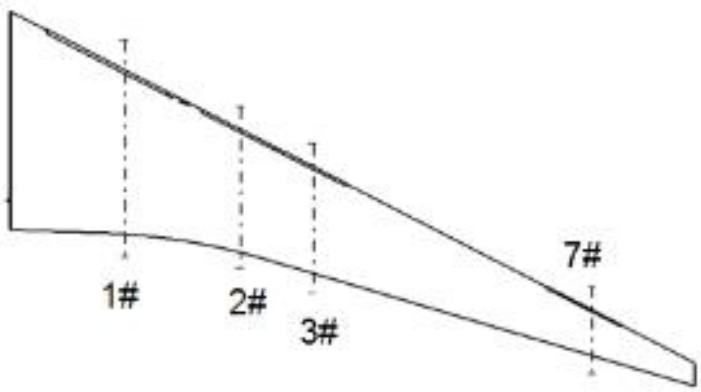

Figure 3 – The slats distribution for some wide body airplane

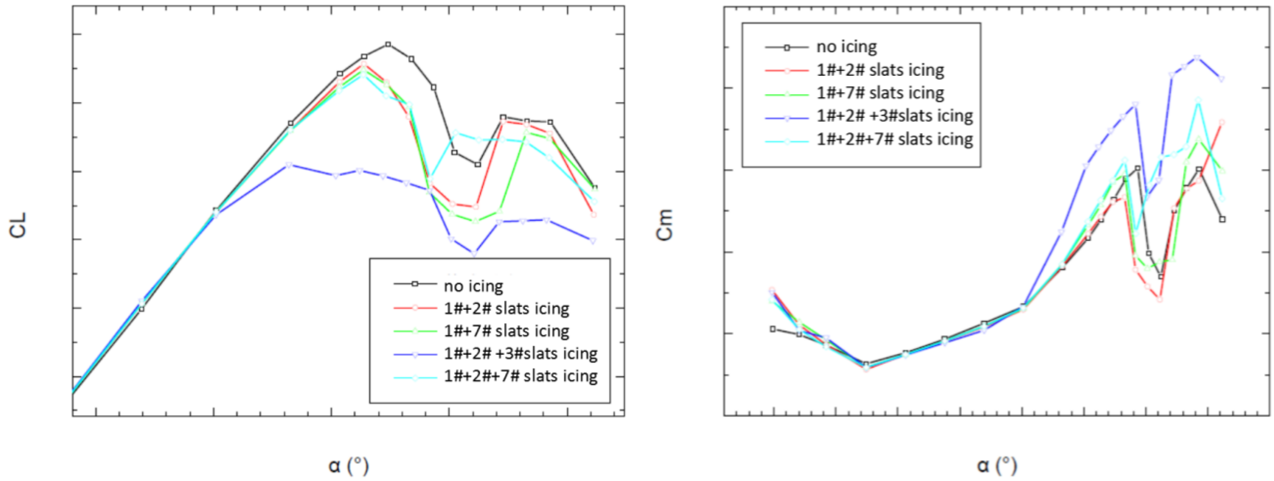

Figure 4 – The slats icing influence on lift and moment coefficient for some wide body airplane

7. Conclusions

In this work, we presented some effects on the choices of slat anti-icing area. The following conclusions are drawn.

(1) The lift coefficient around at 70% span-wise location is largest, meanwhile the flaps have significant influence on the suction peak of the slats. The suction peak will increase when the flaps deflect down. It is more easy to stall under icing conditions. Consequently, the slats located in front of the flaps are key anti-icing areas.

(2) The whole slats have anti-icing methods for the regional airplanes because of the smaller span and leading edge radius of the airfoil. The trunk and wide-body airplanes have few anti-icing areas for slats. The fewer anti-icing areas the larger the airplanes are.

(3) The lift coefficient for the outermost wing will decrease seriously due to the influence of sweep-back wing aeroelastics, so the outermost slats usually have no anti-icing methods.

(4) The deflect degrees of the innermost slats have significant influence on the lift coefficient under icing conditions through the research on some trunk airplane. The deflect degrees should be optimized under both no icing and icing conditions.

(5) Through the research on some wide body airplane, the middle slat and outermost slat should have anti-ice methods.

(6) Based on the analysis and wind tunnel test about study on slat anti-icing areas, the regional, trunk and wide-body airliners have different anti-icing characteristic for the choice of slat anti-icing area. Meanwhile it should consider the influence from wing aeroelastics and flaps. The final choice of slat anti-icing area is based on the wind tunnel test and flight test.

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