INVESTIGATION ON FLOW SEPARATION EFFECTS ON AIRCRAFT LONGITUDINAL MOMENT CHARACTERISTIC FOR FUSELAGE-MOUNTED AIRCRAFT

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Abstract

The paper used the high lift configuration of the modern civil fuselage-mounted aircraft as its research object, and researched the effects of flow separation on the wing on aircraft longitudinal moment. The numerical simulation was chose for study. Based on three-dimensional time-dependent compressible Reynolds-averaged Navier-Stokes equations, the elects of the two kinds of flow separation on the wing: the inboard separation and the outboard separation were simulated, and their effects to longitudinal moment as well as flow analysis were given. The paper also analyzed the reason why the longitudinal moment characteristic changes when separation start from the different area of the wing.

1 Foreword

The lowspeed longitudinal moment characteristic of civil aircraft can directly affect its security and takeoff and landing performance. If the lowspeed longitudinal moment characteristic is bad, when the angle of attack(AOA) reaches the stall angle, the longitudinal moment presents "rise" form; that means the aircraft will quickly rise after pulling up the AOA to stall angle, thus it is likely to cause a flight accidents. Therefore, for the safety of aircraft, poor lowspeed longitudinal moment characteristic planes often use pusher or other devices which also have the function of the AOA limits, to limit the maximum AOA the aircraft can be used, making it smaller than the stall angle. Furthermore, in order to ensure safety, aircraft still need to improve the probability of failure of such devices, making it "impossible" failure. Since the maximum AOA that the aircraft can be used is limited, the maximum lift coefficient can be used is less than the maximum lift coefficient. This will make the takeoff and approach speed an obvious increase, so that the takeoff and landing distance will increase significantly. The aircraft approach category might reduce.

Therefore, the aerodynamic design of modern civil aircraft requires a good lowspeed longitudinal moment characteristic. In order to design an aircraft with good lowspeed longitudinal moment characteristic, we must find flow form corresponding to longitudinal moment characteristic and the flow mechanism such flow form affects the longitudinal moment characteristic.

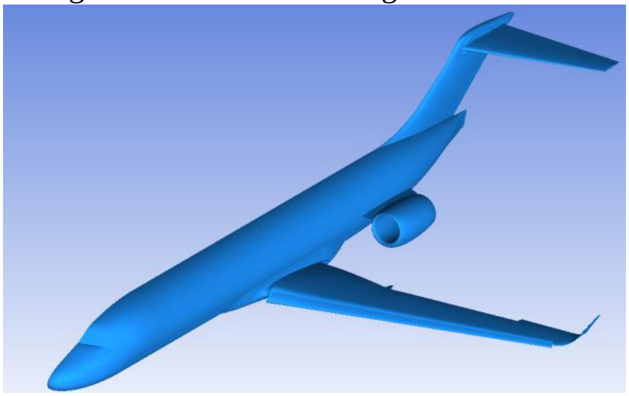
Two ways, the wind tunnel test and the numerical simulation can be used for research. However, because of the vice on flow visualization, the wind tunnel test can't get a good solution on the problem closely related to flow form. The numerical simulation now already has a considerable accuracy, and it is fully capable of being used to study lowspeed problem. Furthermore, the numerical simulation can directly show the flow. So, the paper chooses the numerical simulation to study.

The paper used two wings of a civil fuselage-mounted aircraft's high lift configuration to study: the all slat configuration and the inner slat shorter configuration. The main job of the paper is to research the differences of the two wings and the flow mechanism they affect the longitudinal moment characteristic.

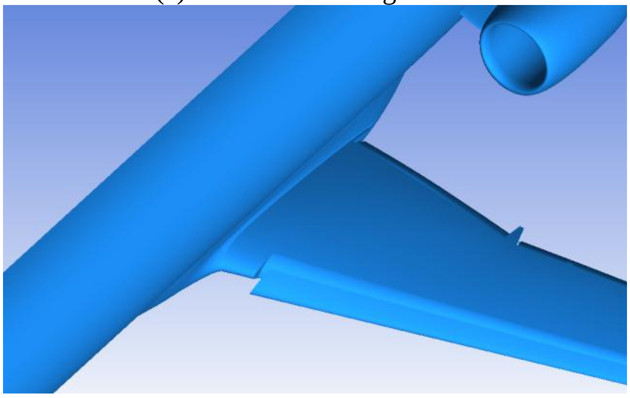
2 The Geometric Model and Grid

2.1 The Geometric Model

The geometric models the paper used: the all slat configuration and the inner slat shorter configuration are shown in Figure 1.



(a) The all slat configuration



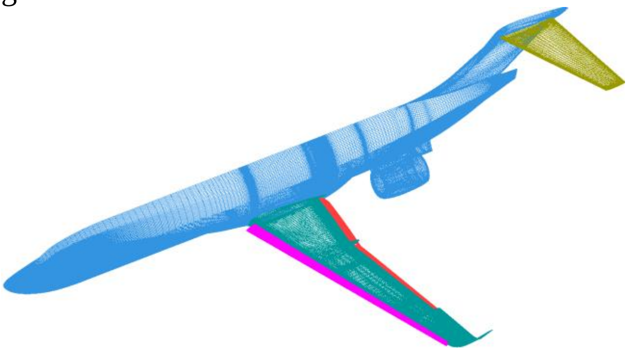
(b) The inner slat shorter configuration

Figure 1. The geometric models the paper used

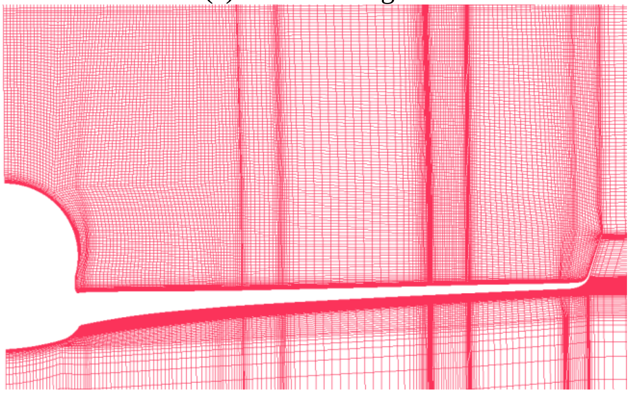
2.2 The Grid

To the complicated geometric shape, it is difficult to generate the body-fitted grid in single domain. Even though the grid is generated constrainedly, the quality may be bad. And the results of the numerical simulation will be affected directly. So, it is quite common in present day to use zone division grid generation technique. Based on the characteristic of the shape, the total flow field is divided to several subdomains. The topology of the grid of each subdomain must be simple. Then generates grid in every subdomain. Zone division grid generation technique makes the structure grid have engineering practicability. Based on the differences of the connection type between block to block, the zone division grid can be divided as three types: 1-1 blocking, patching and overlapping. The paper used the point-to-point patched multi-block technology to generate high quality grid.

Figure 2 shows some grids the paper generated.



(a) The surface grid



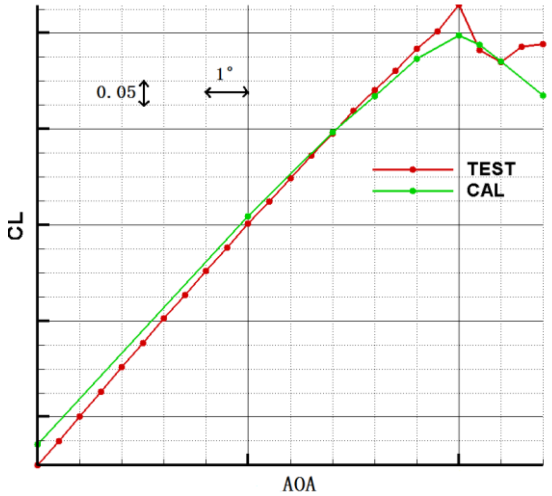
(b) The space section grid

Figure 2. Some grids of the paper generated

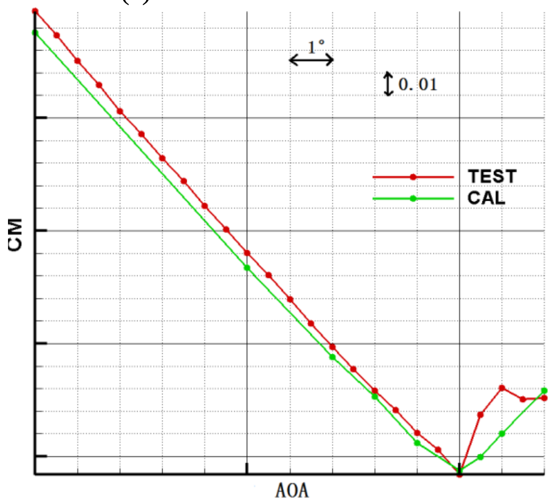
3 The Calculation Method

The paper solved three-dimensional time-dependent compressible Reynolds-averaged Navier-Stokes equations with third-order upwind-biased flux-difference splitting method and approximate factorization method. The multi-grid technique was employed to accelerate the convergence.

Figure 3 shows us the comparison between calculation and wind tunnel test of the all slat configuration when Mach number is 0.2 and Reynolds number is 6.6e6. We can see that the lift coefficient curve and the longitudinal moment coefficient curve of the calculation agree well with the experimental values. So, the numerical simulation method the paper used is believable.

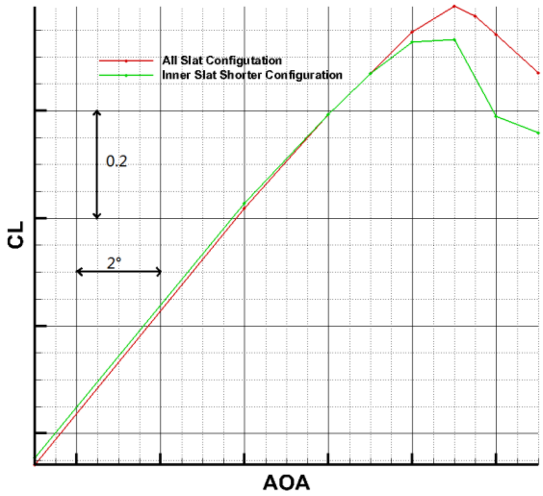


(a) The lift coefficient curve

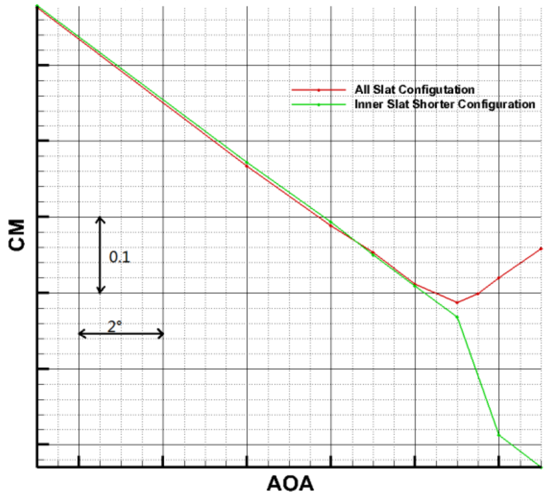


(b) The longitudinal moment coefficient curve

Figure 3. The comparison between calculation and the Wind Tunnel Test



(a) The lift coefficient curve



(b) The longitudinal moment coefficient curve

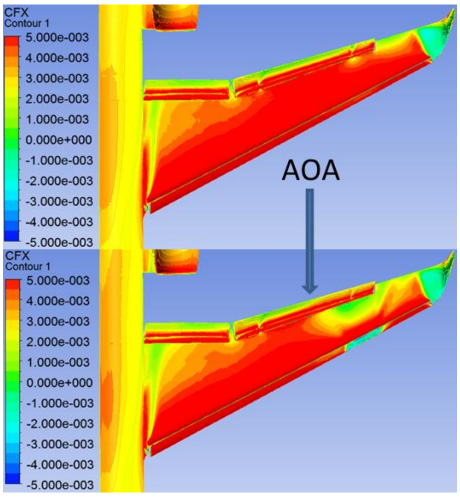
Figure 4. The comparison between the two wings

4 The Calculation Results and Analysis

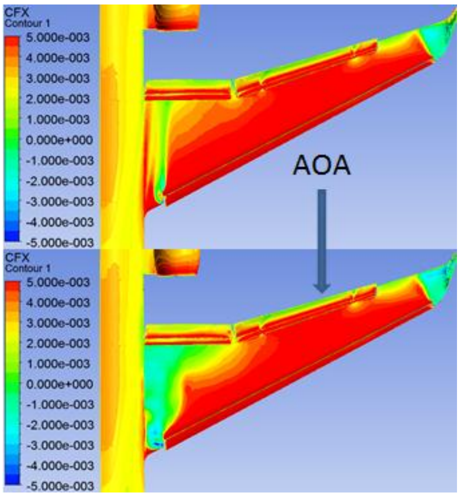
4.1 The Numerical Simulation of Two Wings

The calculation of the two wings: the all slat configuration and the inner slat shorter configuration are shown in Figure 4. The maximum lift coefficient of the inner slat shorter configuration is 0.06 lower than the all slat configuration. However, the inner slat shorter configuration's longitudinal moment curve presents "downward" after stall angle. This form can make aircraft without use of the AOA limit device. Therefore, the maximum lift coefficient can be used.

Figure 5 shows the surface friction coefficient distribution of the two wings when AOA increases.



(a) The all slat configuration



(b) The inner slat shorter configuration

Figure 5. The surface friction coefficient distribution

As the Figure shows, the separation of the all slat configuration starts from the outboard wing, and the separation of the inner slat shorter configuration starts from the inboard wing. That is the reason why the longitudinal moment characteristics of the two wings are different.

4.2 The Analysis of the Two Configurations without Horizontal Tail

Figure 6 shows the longitudinal moment curve of the two configurations without horizontal tail.

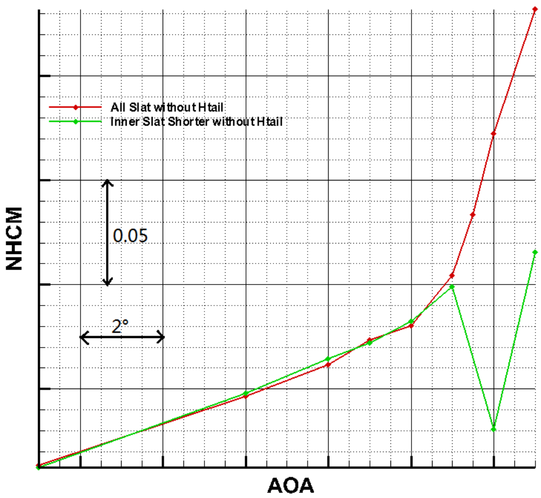
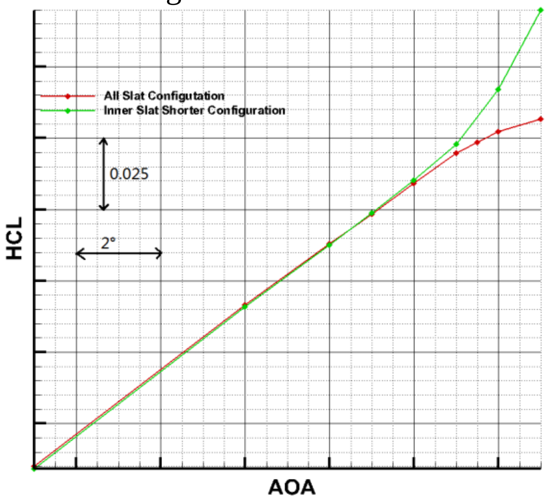


Figure 6. The comparison of the configurations without horizontal tail

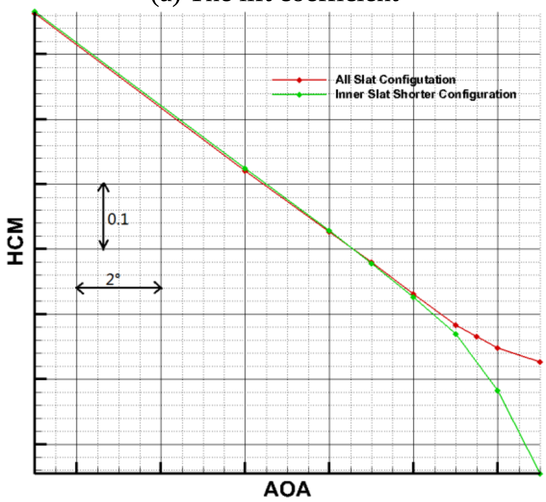
As the figure shows, the slat shorter without horizontal tail configuration has a larger bow moment when at high attack of angle. That because the lift the inboard wing generates affords "rise" longitudinal moment. The separation starts from the inboard wing makes the lift decrease, so that the inner slat shorter without horizontal tail configuration has a larger bow longitudinal moment.

4.3 The Analysis of the Two Configurations' Horizontal Tails

Figure 7 shows the lift coefficient curve and the longitudinal moment coefficient curve of the two configurations' horizontal tails.



(a) The lift coefficient

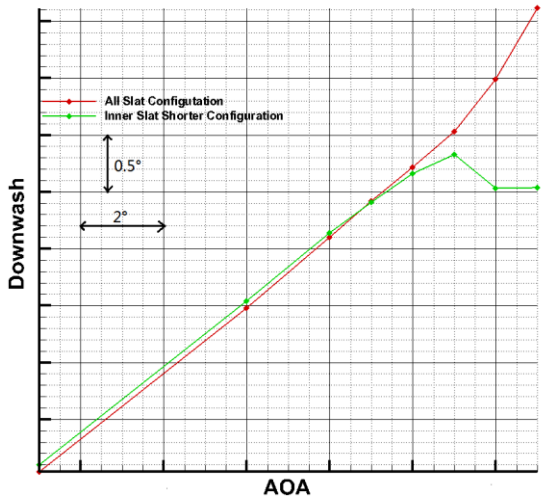


(b) The longitudinal moment coefficient

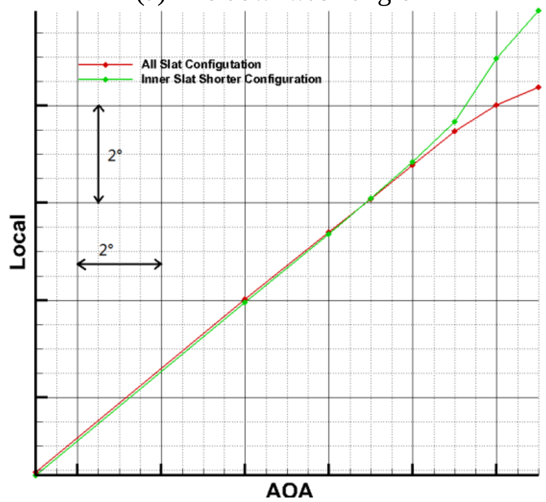
Figure 7. The comparison of the two configurations' horizontal tails

The horizontal tail of the inner slat short configuration has a larger lift coefficient, and it can also afford a relatively larger bow longitudinal moment.

Figure 8 shows the downwash angle and the local AOA of the two configurations' horizontal tails. When at the high angle of attack, the downwash angle of the inner slat shorter configuration is greatly reduced, and the local AOA is much increased. This is the reason the lift and the bow longitudinal moment of the inner slat shorter configuration's horizontal tail increased.



(a) The downwash angle



(b) The local AOA

Figure 8. The downwash angle and local AOA of the two configurations' horizontal tails

Figure 9 shows the comparison of the two configurations and the two configurations without horizontal tails.

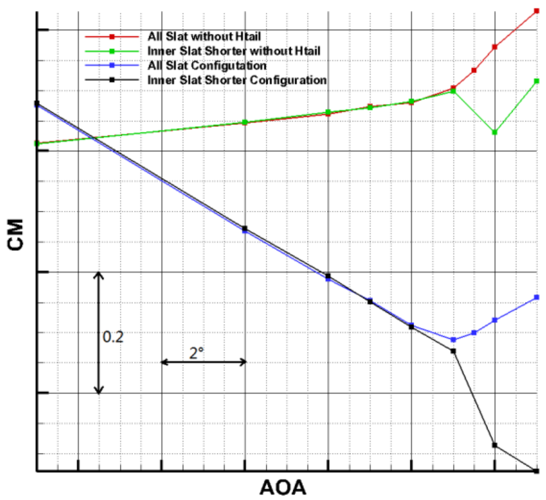


Figure 9. The comparison of the two configurations' with or without horizontal tails

As the figure depicts, the longitudinal moment of the inner slat shorter without horizontal tail configuration appears upward, however, the longitudinal moment of the inner slat shorter configuration is downward. So, the aerodynamic change of the horizontal tail is the key reason why the longitudinal moment of the inner slat shorter configuration improves.

5 Conclusions

Based on the high lift configuration of the civil fuselage-mounted aircraft, the two wings which lead to different separation were investigated, and got several conclusions:

a) Separation starts from the inboard wing can improve the longitudinal moment characteristic;

b) The separation on the inboard wing makes an increase of the bow longitudinal moment of the wing itself;

c) The separation from the inboard wing reduces the downwash angle of the horizontal tail, and makes the local AOA a larger increased. So, the bow longitudinal moment the horizontal tail affords is greatly increased;

d) The increase of the bow longitudinal moment the horizontal tail affords is the key reason why the whole aircraft's longitudinal moment improves.

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