THE COMPREHENSIVE STUDY ON ADVANCED WINGTIP DEVICES IN LARGE CIVIL AIRCRAFT

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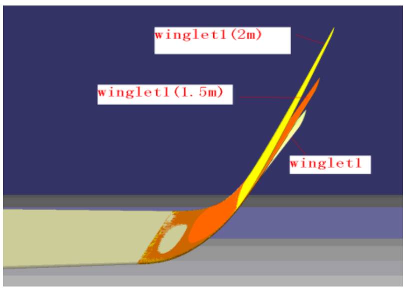
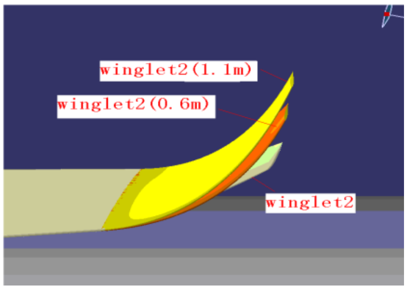
Abstract

Adding wingtip device to wings of aircraft can reduce the induced drag, improve lift-drag ratio, and also dissipate the strong wake vortex in aerodynamics etc. However, the flutter characterization of the aircraft is changed simultaneously, and so is the structural weight. There are many researches on the drag reduction of wingtip devices all over the world ,however ,the flutter characterization of three kinds of advanced wingtip devices(blended, sharklet, ladder) is not studied fully,especially the overall performance from aerodynamics,flutter and weight. So three kinds of advanced wingtip devices(blended, sharklet, ladder) are researched by using the numerical simulation method from aerodynamics,flutter and weight in this paper. Mean-while, the effects of wingtip device's height on aircraft's flutter is also investigated.

1 MODEL

On the clean wing, we add three kinds of advanced wingtip devices: blended (winglet1), sharklet (winglet2), ladder (winglet3) .We also do the research on the blended and sharklet wingtip devices at three different heights.(Fig1)





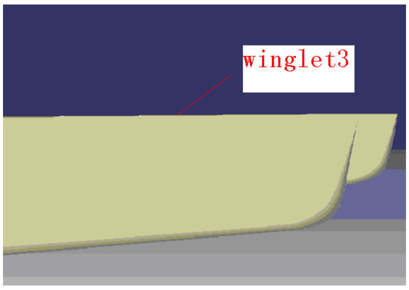


Fig. 1 Three kinds of advanced wingtip devices

2 RESULTS AND ANALYSIS

2.1 The results for aerodynamics

2.1.1 The results for three kinds of advanced wingtip devices

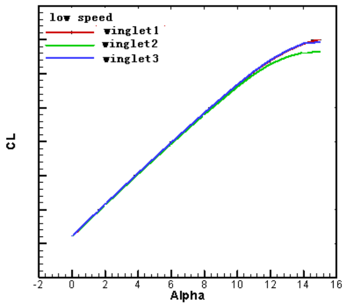
There are the results for three kinds of advanced wingtip devices in the low speed and high speed from figure 2.The figure shows that the maximum lift of winglet1 is the biggest in the low speed, and winglet2 is smallest. In crucise, the drag reduction of winglet1 is up to3%,winglet2 is up to 2.5% the same as the ladder . The moment of nose down increases obviously when adding wingtip devices. In crucise, the increment for winglet1 is up to

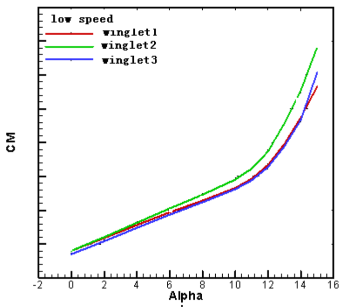
7.8%，winglet2 is 5.7%，winglet3 is 8.6%.The pressure center is outward when adding three kinds of wingtip devices. In crucise, the displacement of the pressure center for winglet1 is up to 0.8% relative to the semi-span, winglet2 is 0.6%，winglet3 is 0.9%.

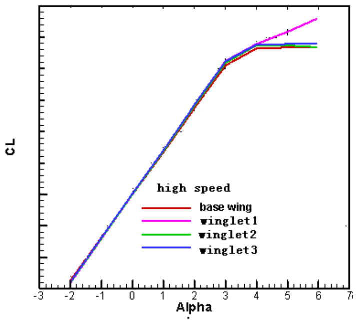
The table 1 shows the aerodynamic performance for different wingtip devices in cruise.

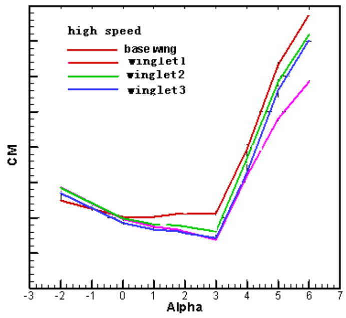
Table 1 The aerodynamic performance for different wingtip devices in cruise

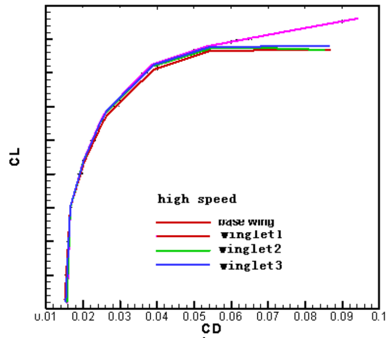
	baseline	winglet1	winglet2	winglet3
drag variation	0	-3.0%	-2.5%	-2.5%
the variation for the moment of nose down	0	7.8%	5.7%	8.6%
the displacement of the pressure center	0	0.8%	0.6%	0.9%











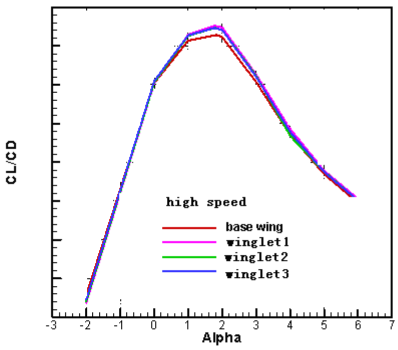


Fig. 2 The aerodynamic performance for three kinds of advanced wingtip devices

2.1.2 The results for different height of wingtip devices

The maximum lift increases as the height increases for winglet1and winglet2 in low speed.Meanwhile the moment of nose down increases.In crucise,the drag reduces and the lift-drag ratio increase as the height increases. The drag reduction of winglet1(1.5m) is up to 0.7% relative to winglet1, winglet1(2.0m) is up to 1.0%. The drag reduction of winglet2(0.6m) is up to 0.1% relative to winglet2, winglet2 (1.1m) is up to 0.8%.

2.2 The results for flutter

2.2.1 The results for three kinds of advanced wingtip devices

From Fig 3, we know adding the wingtip may decrease the flutter velocity and make the flutter characteristic worse. The reduction of the flutter velocity from blended wingtip device is up to 2.5% , the sharklet is 1.5%, the ladder is 1.0%. The mach of transonic flutter " dip" from winglet1 is 0.82,lower than 0.87 of basic wing which is the same as the other two wingtip devices, making the flutter characteristic worse. In subsonic,the flutter velocity from the ladder wingtip device is improved , so the ladder wingtip device has the best performace in flutter characterization.

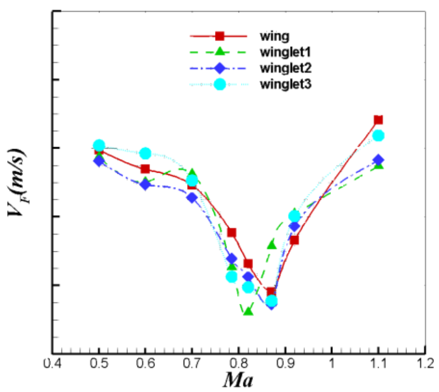


Fig. 3 The flutter boundary for three kinds of advanced wingtip devices and baseline

2.2.2 The results for different height of blended wingtip devices

From Fig 4,when Ma is 0.82, for the wings with different-height blended wingtips, the minimum flutter velocity is reached. This result validates the blended wingtips' flutter characteristic of a typical transonic flutter " dip". Compared with the clean wing, the blended wingtip's transonic flutter "dip" comes earlier.

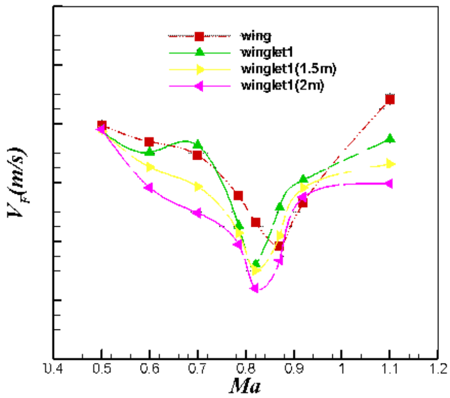


Fig. 4 The flutter boundary of winglet1 in different heights

2.2.3 The results for different height of sharklet wingtip devices

For the wings with sharklet wingtip, just like the clean wing, when Ma is 0.87, the minimum flutter velocity is reached. This result also validates the sharklet wingtips' flutter characteristic of a typical transonic flutter "dip".The reduction of the flutter velocity from winglet2(0.6m) is up to 2.64% , the winglet2 (1.1m) is 5.12%,relative to the clean wing (Fig 5) .

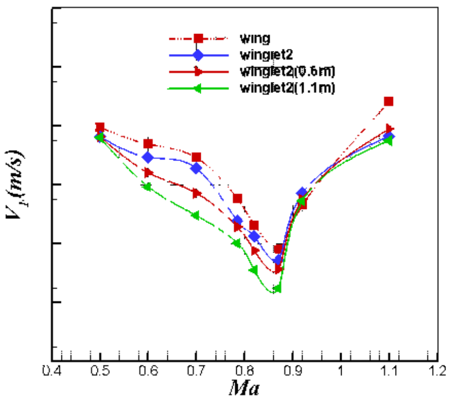


Fig. 5 The flutter boundary for winglet2 in different heights

2.3 The results for weight

The increment for structural weight is in direct proportion to the displacement of the pressure center as the pressure center moves outward.

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

Including: ΔM is the increment for weight;M is the initial weight,M =5000kg here;Z1 is the pressure center which is changed;Z0 is the pressure center which is not changed. K is 2.5.

The drag reduction of 0.0001 is equal to the load increment of 230kg in this study. So based on the pressure center outward and the drag reduction,the table 2 shows the weight benefits for different wingtip devices relative to the clean wing in crucise.

Table 2 The weight benefits for different wingtip devices in crucise(unit:kg)

	the weight equivalent to drag	the weight equivalent to pressure center	comprehensive weight benefits
baseline	0	0	0
winglet1	-1748	244	-1504
H=1.5m	-2116	253	-1863
H=2.0m	-2300	240	-2060
winglet2	-1426	178	-1248
H=0.6m	-1472	161	-1311
H=1.1m	-1863	222	-1641
winglet3	-1403	280	-1123

Note: - reducing weight,+ adding weight.

3 Conclusions

(1) In cruise, the drag reduction of blended wingtip device is up to 3%,the sharklet is up to 2.5% the same as the ladder,so the blended wingtip device has the best performance in aerodynamics.

(2) The reduction of the flutter velocity from blended wingtip device is up to 2.5% ,the sharklet is up 1.5%,the ladder is 1.0%.In subsonic,the flutter velocity from the ladder wingtip device is improved ,so the ladder wingtip device has the best performace in flutter characterization.

(3) The mach of transonic flutter "dip" from blended wingtip device is 0.82,lower than 0.87 of the basic wing which is the same as the other two wingtip devices.

(4) The effect on the flutter velocity of the wing due to the form of the wingtip device is about 1%~7%, which is relatively small,so the flutter boundary is depend on the design of flutter characterization from the basic wing.

(5) The increment of height of wingtip device can reduce flutter velocity, but is small relatively to the reduction from the form of wingptip device.

(6) The flutter velocity of blended wingtip device is the lowest ,but the overall weight benefits from the drag reduction and the displacement of pressure center can provide certain weight capacity for the flutter prevention.

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