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Developing of Balancing Tools for Flight Controls

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Abstract: Wingtip devices may be fitted for various reasons, they often combine more than one function and usually occupy a substantial part of the stabilizer, just belong the aileron spar. Winglets allow decreasing fuel consumption of over 10%. But with the development of new generations of aircraft, it is not always appropriate to take into account the stability and controllability of the flight. Because there is a need to improve the existing designs in the paper proposed new concept of winglets.

Keywords: Winglets, Structure, Flight Controls, Balancing, Design

1. Introduction

Nowadays, all transport aircraft include wing-tip devices prevalently made of composite materials. These tip appendages (blended winglet, tip fences, raked wing tip, and sharklet winglet) must achieve the goal of reducing induced drag; however, the requirements to be met by wing-tip devices throughout the various flight conditions are different. As outlined in Falcao et al. (2010), a static wing-tip device must be a compromise of these various conflicting requirements, resulting in less than optimal effectiveness in each flight condition (e.g. little or great additional surface for low cruise parasite drag and high climb/descent performance, respectively). A morphing device, on the other hand, can adapt to the optimum configuration for each flight condition, leading to improved effectiveness (Falcao et al. [1]).

One of the greatest contributions in both theoretical and experimental investigations of the wingtip physical phenomena was made by Hoerner [2]. He investigated the aerodynamic characteristics of wing tips, and he did experimental investigations concerning the mechanism of the tip vortices and the lift/drag ratio of a wing fitted with several differently shaped tip caps. Hoerner's concept was further developed at National Aeronautics and Space Administration's (NASA) Langley Research Center. During the 1970s, Whitcomb and coworkers (Bower [3], Flechner et al. [4], Whithcomb [5]) designed winglets for modern transport aircrafts. In these works, the effects of the winglets on the aerodynamic forces and moments are highlighted, especially the reduction of the drag coefficient at lifting conditions. Fletchner et al. [4] and Whitcomb [5] indicated that the basic effect of the winglets is a vertical diffusion of the tip vortex flow just downstream of the tip, which leads to drag reduction. The main result obtained by Whithcomb et al. was a 20% reduction of induced drag and a 9% increase in wing lift over drag ratio, both obtained by mounting upper and lower winglets on a jet transport wing characterized by a lift coefficient equal to 0.44 and flying at a Mach number equal to 0.78. These results clearly illustrate the effectiveness of winglets.

As shown in Figure 1 the winglet can be deflected in an almost upright vertical position. Immediately after take-off, or in the event of an aborted take-off, they may be activated either by the pilot or automatically. It could be done in bad weather conditions in case of strong side wind. As a result of the interrupted/ resumed airflow over the flaps, the wing loses some parts of its lift, which increases the moment of normal force on the surfaces and then makes winglet control much more effective.

In addition, they could create considerable drag and these combined effects increase the deceleration by some 10%. Winglet transition may be used in flight when an appreciable increment in drag is required to obtain a high rate of coefficient or improved speed stability with a constant angle of decent.

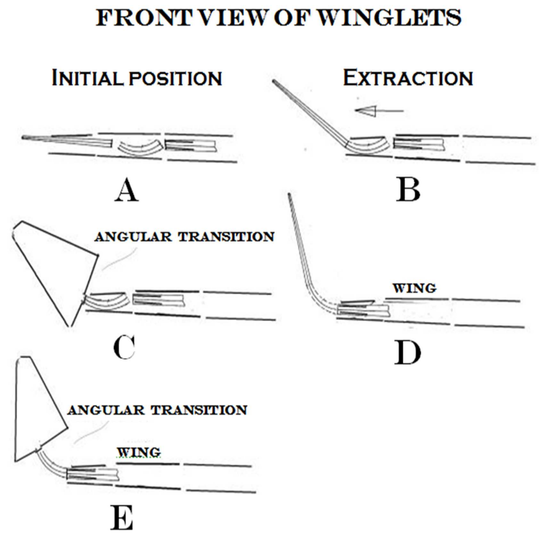

***Figure 1.** The front views of winglets in some steps of deflection.*

Specific winglets are not deflected in this case to avoid disturbing the flow over the wing and prevent buffeting. For this reason specific option are only used to decrease the speed on the ground and are referred to decrease the lift on the ground and are referred to as ground spoilers (lift dumpers).

When acting as drag-producing device, these winglets are referred to as airbrakes (speed brakes) [6].

The location of actuator hinges should be close to prevent structural deflection which will interfere with the adjacent structure (see Figure 2).

2. The Main Concept

The concept of mounting wingtip devices to reduce induced drag as applied to a model commercial Boeing 737-800 wing is investigated through a planned computational study. The design and simulation was done using commercial software. The effect of mounting winglet was seen to have greatly affecting the induced drag and vortices formation at the wing tip.

A flow visualization study substantiates, rather spectacularly, the effectiveness of the concept.

In order to prevent wing surface flutter during high speed flight, the stiffness of the winglet system, made up of the wing surfaces, actuators and actuators support structure (as shown in Figure 2) is required.

These are:

Winglet bending and torsional stiffness (EI&GJ) – reflects minimum acceptable stiffness to meet flutter requirements.

Actuator and support structure stiffness – reflects minimum acceptable stiffness.

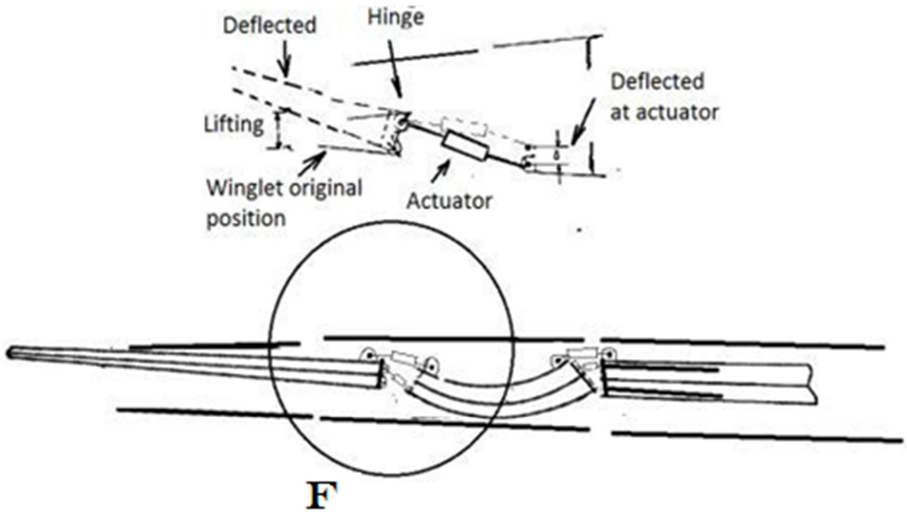

***Figure 2.** The main concept of wingtip retraction and extraction.*

Several of the current jet airplanes have had control problems that resulted from structural deflections caused by the landing gear during the take-off run (upward landing gear loads and than the wing bending down). This deflection has resulting in the spoilers lifting and thereby killing the wing lift during the most critical portion of the take-off run.

Control system design is another must to be established to accommodate the structural deflections.

Attention should be given to the winglet hinge due to the wing forced bending (wing deflection) for three-hinge design as illustrated in Figure. 3 by the se of winglet track.

The winglet is composed of a high speed (low drag & strong) central winglet section with completely retractable high lift sections which move in a span wise direction as opposed to the chord wise direction of conventional flaps.

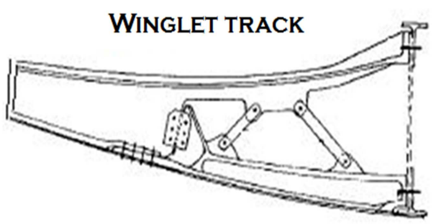

***Figure 3.** Example of the railing track in extraction of winglet.*

It is the same concept of changing lift with conventional chord wise flaps except that the span wise flap increases span & area instead of only the camber. It also increases the aspect ratio instead of decreasing it, which greatly improves efficiency and safety.

3. Performance

Prerequisites for calculation; the component of the resistance does not depend on the magnitude of the lift force created and is made up of the profile drag of the wing, the resistance of the aircraft's structural elements that do not contribute to the lift, and the inducing resistance. This factor is essential when moving with a near- and supersonic speed, and is caused by the formation of a shock wave that takes a significant share of the energy of motion. Inducing resistance occurs when the aircraft reaches a speed corresponding to the critical Mach number, when a part of the flow around the wing of the aircraft acquires supersonic speed. The critical number of Mach is the larger, the larger the wing sweep angle, the more the leading edge of the wing is sharpened and the thinner. Having comprehensively considered the complexity of function and fitting error, we can express the problem as the constrained optimization problem:

$$\mu > \frac{\pi}{2} - \zeta_{2w}. \tag{1}$$

Let's find the Mach angle. μ*=arcsine (M)*.

Hence the angle of sweep of the trailing edge is assumed equal to

$$\zeta_{2w} = \frac{\pi}{2} - \mu. \tag{2}$$

The angle of the trailing edge can be expressed in terms of the characteristics of the winglets in the plan.

$$\xi_{2w} = \frac{\pi}{2} - arctg\left(\frac{b_w}{C_{tipw}}\right). \tag{3}$$

Expressing edge width Ctipw determine the bevel angle of the trailing edge of the winglets.

$$C_{tipw} = \frac{b_w}{tg\left(\frac{\pi}{2} - \xi_{2w}\right)}. \tag{4}$$

The next step is to determine the sweep angle of the leading edge of the winglets.

$$\xi_{1w} = \frac{\pi}{2} - arctg\left(\frac{b_w}{C_{tipw} + C_{tip}}\right). \tag{5}$$

The area and the winglet range are determined by the trapezium formulas

$$S_W = \frac{C_{tip} + c_w}{2} b_w, \tag{6}$$

$$\lambda_W = \frac{{b_w}^2}{S_w}. \tag{7}$$

The inductive resistance is proportional to the square of the lifting force Y, and is inversely proportional to the wing area *S*, its elongation \ lambda, the density of the medium ρ and the square of the velocity *V*: $\rho V^2 \pi \lambda S$.

$$Xin = \frac{2Y^2}{\rho V^2 \pi \lambda S} = \frac{CL^2 \rho V^2}{2\pi\lambda} S. \tag{8}$$

To solve this equation, you must always specify a parameter, either b_w is the magnitude of the winglet span, or C_w is the magnitude of the end edge of the winglet

$$2{b_w}^2 - C_w b_w \lambda_W - \lambda_W C_{tip} = 0. \tag{9}$$

The winglet span is calculated by the use of similar formulae

$$b_w = \sqrt{\frac{\lambda_W C_{tip}}{2}}. \tag{10}$$

Sweep angle of the leading edge of the winglets.

$$\xi_{1w} = \frac{\pi}{2} - arctg\left(\frac{b_w}{C_{tipw} + C_{tip}}\right). \tag{11}$$

The power required to overcome the parasitic resistance is proportional to the velocity rise 3, and the power required to overcome the inductive resistance is inversely proportional to the velocity, so the total power also has a non-linear velocity dependence. As example we can estimate some main geometrical properties (see Table 1).

Table 1. *Performance of Boeing 737 NG.*

	Max. cruise	Long range cruise
Speed (kt)	492	429
Altitude (ft)	26000	35000
Fuel consumption (kg/h)	3574	2100

Weight:	
Design payload (kg)	15200
Operational empty (kg)	41480
Design fuel load (kg)	21540
Wing tip:	
MAC (m)	4.17
Taper Ratio	0.159
Area (mI)	124.60
Span (m)	34.30
Aspect Ratio	9.44
Root Chord (m)	7.88
Tip Chord (m) Ctip	1.25
coefficient CLmax (T/O)	2.49

CLmax (L/D @ MLM)	3.32
coefficient C_D	0.35
sweep angle χ	30°
Mach	0.785
Airfoil and winglet properties:	
Mach angle μ	51
C_L (max K)	0.80
C_D (max K)	0.0203
edge width Ctipw	0.145
angle of LE ∡ ξ1w	66
calc aspect ratio of winglet λw	0.58
winglet span bw	0.6

4. Conclusions

The telescopic winglet is composed of a fixed outer section and three extendable outer sections. An overlapping extension spar system makes this design an improvement over previous attempts at telescopic wing design. This overlapping spar system provides for a 3:1 span ratio, which has never before been attained.

During takeoff & landing the high lift airfoils are extended at the wing tips. When transitioning to a high speed cruise, they are retracted in flight to leave a high- speed low drag wing capable of withstanding high 'g' loads. This system is simple, rugged, and fail-safe. The aircraft can also manoeuvre in flight and land safely with the wings in any position from fully extended through fully retracted. The extension/retraction mechanism is a simple system of cables that prevents asymmetric extension. Redundancy is built in so that failure of any cable does not hinder safe operation. The airfoils are conventional NACA sections.

The mechanism is simple and reliable. The extendable section spars interlock and are guided on rollers to increase the span. Binding under load during transition is prevented by the details of the roller system. This design is actually simpler than conventional high lift devices.

The overall weight of this wing is comparable to that of a conventional compromise wing for a similar size aircraft that is required to produce the same speed range, however, it is stronger and more efficient than the conventional wing.

Acknowledgements

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References

[1] Falcao, L.: Gomes, A. and Suleman, A. “Multidisciplinary design optimisation of a morphing wingtip.” In: 2nd International Conference on Engineering Optimization, Lisbon, Portugal, 6–9 September, 2010.

[2] Hoerner, S. “The Aerodynamic Shape of the Wing Tips.” Dayton, OH: Air Materiel Command, Wright-Patterson Air Force Base, 1952.

[3] Bower R.: “Opportunities for Aerodynamic-Drag Reduction. NASA SP-372. In: NASA/University conference on astronautics, University of Kansas, Lawrence, Kansas, October 23th, 1974, pp. 323–352.

[4] Flechner, S., Jacobs, P., and Whithcomb, R. A. “High Subsonic Speed Wind-Tunnel Investigation of Winglets on a Representative Second-Generation Jet Transport Wing (NASA TN D-8264).” Washington, DC: NASA, 1976.

[5] Whithcomb, R.: “A Design Approach and Selected Windtunnel Results at High Subsonic Speeds for Wing-Tip Mounted Winglets.” National Aeronautics and Space Administration Technical Note. NASA TN D-8260, 1976.

[6] Williams, A. L.: “A New and Less Complex Alternative to the Handley Page Slat.” Technical Paper, Northrop Corp, 1985.

Biography

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