LINKÖPING UNIVERSITY

Strut-braced Wing and Boxwing configurations. A future scenario in air transportation?

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1 Introduction

Most of the lift is produced by the wing. In cruise, this lift is equal to the weight so, because of the forces and the stresses the wings are subjected to, we will have to design the wing structure taking this into consideration.

The most obvious effect will be the bending moment, along with some other, less evident effects. As a result, a shear stress will appear on the union between the wing and fuselage which the structure will have to withstand.

Compression and tension stresses will also appear in the upper and lower surfaces of the wing respectively.

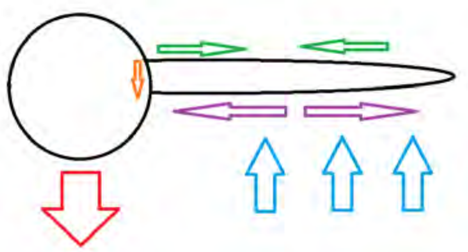

Fig. 1 . Forces: 1.Weight (Red), 2.Lift (Blue); Stresses: 1.Shear(Orange), 2.Compression (Green), 3.Tension (Purple)

Also a torsional moment is produced because of the difference between the position of the center of the lift resultant and the elastic axis of the profiles along the wing. On this basis we have make sure that our wing is designed in ways that guarantee the structural integrity of itself.

2 A strut-braced wing approach

Strut bracing is a design that is result of the structural requirements of an aircraft.

The bending moment that occurs because of the lift that is distributed along the span means that the wing must be rigidized to be able to withstand these loads. The cantilever wing uses a combinations of spars, ribs and strings for this purpose and so does the strut-braced version.

The difference lies in the fact that the strut provides relief to these loads by absorbing part of the loads through tension (if there is a high-wing configuration as seen in Figure 2) or compression (if it is a low-wing configuration).

This means that the structure of the wing can be lighter, or perhaps even bigger for the same amount of mass [1]. This means that a structurally lighter, longer, and thinner wing with a higher slenderness ratio results in an increased aerodynamic efficiency or L/D ratio. Also, the increased efficiency would mean that the aircraft would also need to carry less fuel, thus reducing weight.

Although, there are some disadvantages to this configuration too, since the strut itself also adds mass to the aircraft and it increments the wetted surface of the aircraft, thus incrementing its parasitic drag. The interferences and added structural complexity also must be noted, and the aero elastic problems that can result from this configuration [2].

This design is especially interesting for short-haul aircraft , where a more aerodynamic wing can provide with a higher climb speed and more glided CD (continuous descent).

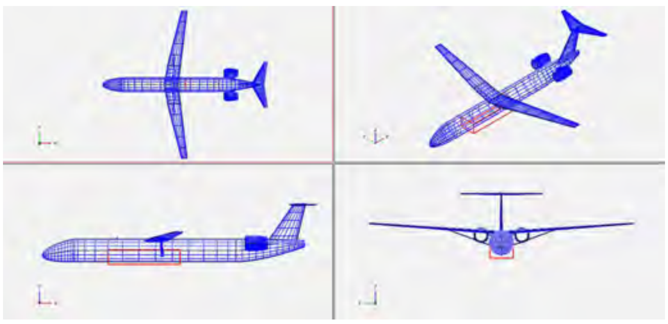

Fig. 2 . Four view of a strut wing aircraft

Also, for short distances (where the time of the trip is not as relevant as for long-haul, and also the stages of climb and descent which comprise a bigger percentage of said flight fly at lower speeds), flying at lower speeds is feasible and would reduce the parasitic drag that is added by the strut.

3 Box wing aircraft

Box wing aircraft are far from being an innovative idea; they are, in fact, an update of biplanes that were dominant in the aviation first years. However, the reason why this type of aircraft claims to be the future of aviation is based on the current trend of trying to increase the whole efficiency of aircraft. Not only in terms of structural behavior and performance, but also in terms of money.

The main characteristic of this aircraft design is that it uses two set of wings in two parallel planes joined by a fin at the tips of each wing. One pair wing configured as usual and a forward-swept second one. The engines in this kind of design are located in the rear part of the plane. An example of this configuration is shown in Figure 3.

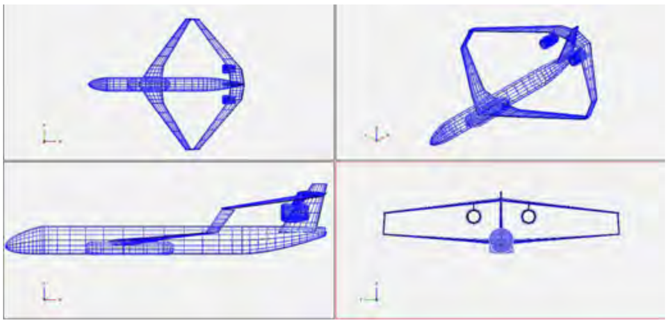

Fig. 3 . Four view of a box wing aircraft.

The objectives pursued by this design-concept are the following: **maximization of lift production** due to the double set of wings producing the lift; **reduction of the lift-induced** (by the reduction of tip vortexes and an increment of the wing slenderness) and **parasite drag** (only if carrying out the rules exposed in [3]; so that these former objectives lead to a significant **increase in the aerodynamic efficiency** (E=L/D) that ultimately results in the craft using less fuel and, consequently, fly the same routes as a conventional aircraft with less cost. This **fuel saving** could also allow the aircraft to fly for longer the same size fuel tank.

In addition, just as it occurs with the strut-braced, this shape allows it to make steeper descents and ascents safely than current conventional jet liners. As a result of the designed shape, there is an improvement in the stiffness of the wing-fuselage structure lightening the wing structural reinforcements. Moreover, box wing aircrafts can be used in the current airports, which is one of the main disadvantages of other future aircraft design, the blended wing body concept.

The increased rigidity of a non-cantilever configuration would limit aero elastic problems compared to a conventional wing, although a more in depth analysis must be performed.

The geometry of the wing results in a greater moment of inertia relative to the longitudinal axis of the aircraft, therefore reducing roll responsiveness, which coupled with the increase in rigidity with negative impacts for the maneuverability of the aircraft.

It also must be noted that the geometry and distribution of lift surfaces must be very carefully studied to avoid aerodynamic interference (which is more complex in these aircraft compared to conventional configurations) and could result in loss of controllability if a control surface is affected.

4 Conclusions

A strut braced-wing allows a span increment for the same aircraft weight and, therefore, an increment in the aspect ratio which results in a more aerodynamic efficient wing. However, the strut adds parasitic drag, aerodynamic interferences and an extra weight.

For the box wing design, in the same fashion, an increment in the aspect ratio is pursued and achieved in a more efficient way, since a decrease in the structural weight and drag performance is reached along with an increase in the lift production, thus reducing fuel consumption.

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