Closed Wing Aircraft Classification

Dimo Zafirov
Technical University-Sofia, Branch of Plovdiv

Abstract

The ever increasing requirements that the aircraft must meet demand the use of new aerodynamic configurations because the ones that are currently in use have exhausted their potential for further improvement. The closed wing has a number of advantages that might address the requirements for economic efficiency and reduced ecological. At the conceptual design stage a large number of variants are created, from which, after being analyzed, the base variant is selected. In the process of variant creation a proper classification should be used, so that all possibilities to be properly assessed. Until now no closed wing aircraft classification has been published. The classification proposed in this article allows the creation and exploration of a large number of variants at the conceptual design stage, from which the optimal base variant, in regard to given criteria, to be selected.

1. Introduction

The earliest closed wing aircraft is Blériot III of tandem configuration with two oval wings built in 1906 by Louis Blériot and Gabriel Voisin.

In 1924 Prandtl [1] theoretically proved the box wing advantages, a variant of the joined-wing type. According to Prandtl the lifting system with the minimum induced drag, is a box wing (named „Best Wing System “), satisfying the following conditions:

- Identical lift distribution along the span of the upper and lower wings;
- The lift on the horizontal parts of the wings has a distribution that might be represented as the sum of a constant and an elliptical component, and for the vertical parts the lift distribution changes linearly. The efficiency of this wing system is improved as the relative gap between the wings is increased. The induced drag ratio for a box-wing and an optimal monoplane with the same lift and optimal distribution along the span was calculated in 1920 and published in NACA TN 182 during 1924. Prandtl used an approximate procedure, and an exact solution was provided by Frediani and Montanari in 1999. It confirmed Prandtl's results, for a gap/span ratio of 10-20% the induced drag is reduced by 20% - 30%. Munk's theorem provides ground for the expectation, that the box wing could be used for transonic transport aircraft.

Frediani [2] points that the box wing could be useful both for large aircraft, which will be able to transport higher payload than the A380 while using current size airports, and for small aircraft and unmanned air vehicles.

The modern joined wing configuration was developed by Julian Wolkovitch [3]. He patented a joined-wing aircraft in 1976, with wings that formed a structural frame which provided both the necessary lift and balance. On the wings are also the control surfaces.

It might be assumed that the configurations known as "closed wing", "box wing", "Prabdtl plane" and "strutted wings" are particular cases of joined wings.

Ligeti Stratos [4] utilizing the joined wing configuration performed its maiden flight in 1985.

The joined-wing configuration takes a leading place among the unconventional aircraft arrangements being investigated for new aircraft. It possesses both flight performance and size advantages over the other configurations.

In published papers are presented the following assertions about the joined wing advantages:

- less weight of the wing structure;
- higher stiffness of the wig structure;
- lower induced drag than that of an equivalent cantilever wing;

- improved transonic pressure distribution;
- high glide ratio;
- reduced wetted surface and lower parasite drag;
- direct lift control;
- direct side force control;
- good stability and control.

These assertions are supported by independent analyses, design investigations and wind tunnel experiments.

The above mentioned advantages make the joined-wing configuration especially attractive for different type of aircraft.

By utilizing this configuration the aircraft designers might vary much more parameters than with the conventional configurations. This provides greater freedom and flexibility while satisfying the design requirements, but at the same time, makes the selection of an optimal set of aircraft parameters much more complex.

The variation of the basic parameters influences simultaneously the aerodynamic, aeroelastic, dynamic, structural and mass properties of the aircraft, which demands the application of multidisciplinary optimization for the selection of an optimal set of parameters.

The joined wing is a highly integrated configuration in which parts of the aircraft perform several functions simultaneously and this allows the achievement of lower empty weight with better aerodynamic characteristics and performance, compared to the other arrangements.

The reduction of the fuel burn is directly related to the empty weight of the aircraft and the drag. The drag reduction is of great importance for the commercial success of any transport aircraft program, because of the need for higher efficiency and low emissions. The improved aerodynamic efficiency at low speeds is also a challenge, necessary for the reduction of noise and harmful emissions in the airports' vicinity. At cruising conditions the aerodynamic drag is made up of friction drag (about 47% with Airbus) and induced drag (about 43%). The reduction of the friction drag for the joined wing is due to the smaller wetted surface, because with one and the same wing loading as a comparative conventional aircraft, it will have the same body and wing surface, but without horizontal tail.

One of the most important stages of aircraft design is the conceptual design when about 70% of project tasks are resolved, parametric optimizations are performed, which are strongly dependent on the design models, methods and algorithms.

The joined wing weighs 65% to 78% of the weight of aerodynamically equivalent cantilever wing and horizontal tail [3].

It should be noted that the joined wing has a weight advantage at all sweep angles. For example at a sweep of 15º the joined wing weighs only 58% of the weight of a 15º sweep cantilever wing and horizontal tail and about 60% of a straight wing.

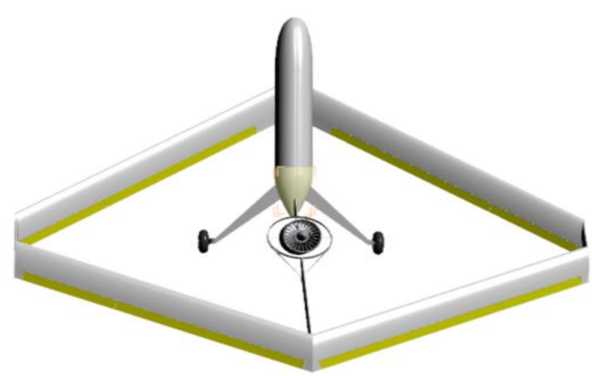
Gallman and Kroo [5] investigate joined wing configurations to satisfy the requirements for a medium range transport aircraft They apply a simplified algorithm for the weight model by substituting the wing with an aluminum box consisting of several finite elements, and for the calculation of the aerodynamic loads they apply the vortex lattice method – the LinAir program. The simplified model is optimized with an objective - minimum weight, with different constraints and the optimum designs prove to be with a joint location at 70% of the semispan. If the weight economy is used for increase in span (aspect ratio), then the drag is reduced by 11%, and the direct operational costs are reduced by 1,7% for a transport airplane with 2000 nm range.

2. Classification indicators

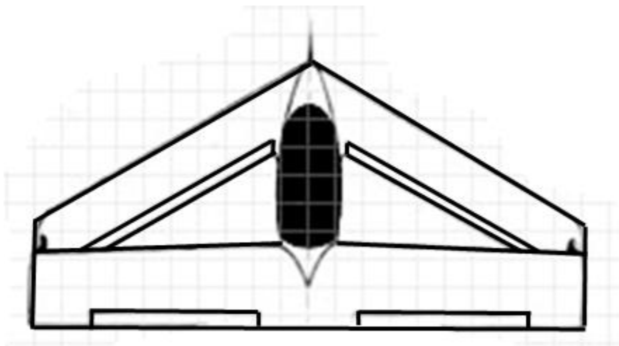
The following classification of closed wing aircraft has seven basic indicators. As is the case with all classifications of objects that are rapidly developing it can be improved and expanded, in order to be successfully applied for the conceptual design of aircraft.

2.1. Wing planform

2.1.1. Rhomboidal wing



2.1.2. Triangular wing

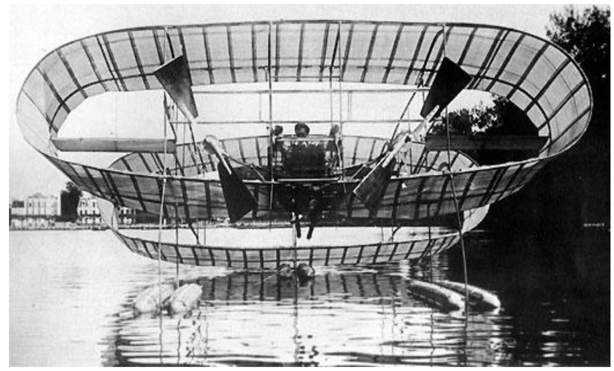


2.1.3. Straight wing

2.2. Wing shape when looked from the front

2.2.1. Cylindrical wing

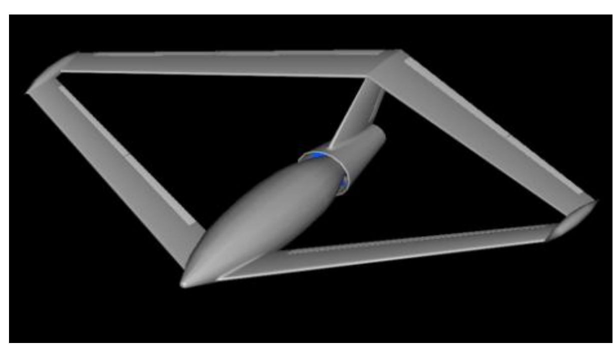
2.2.2. Annular wing



2.2.3. Elliptic wing

2.2.4. Box wing

2.2.5. Diamond-shape wing [6]



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2.2.6. Trapezium-shaped wing

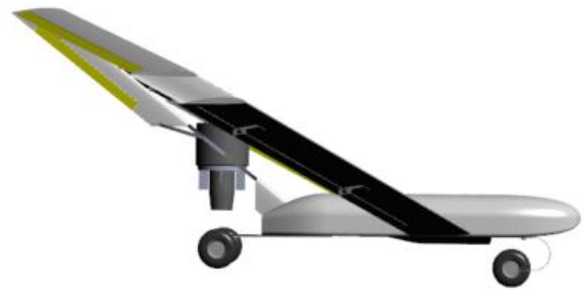
2.2.7. Flat wing

2.2.8. Joined wing with winglets

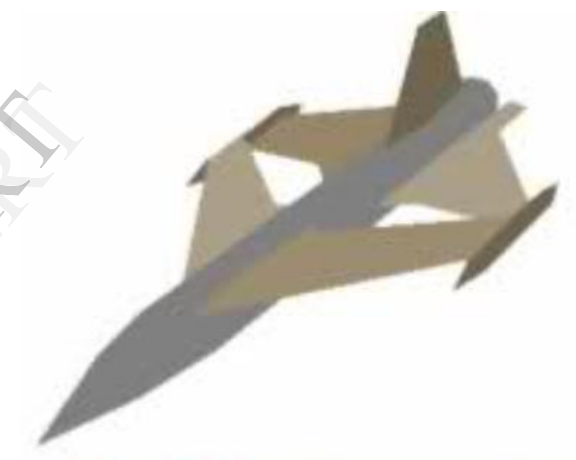
2.3. Wing shape when looked from the side

2.3.1. Front wing lower than the rear wing

2.3.2.



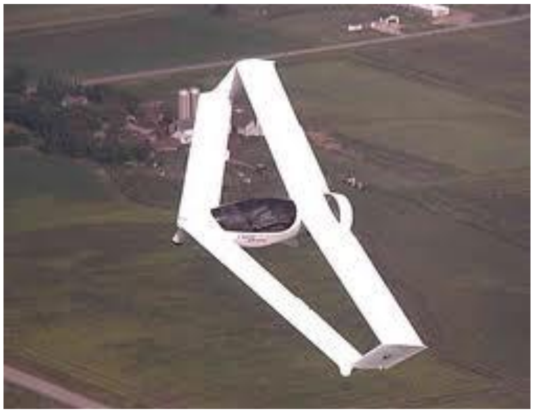
2.3.3. Front wing higher than the rear wing



2.3.4. Front wing in the same plane with the rear one

2.4. Joint location

2.4.1. At the tips

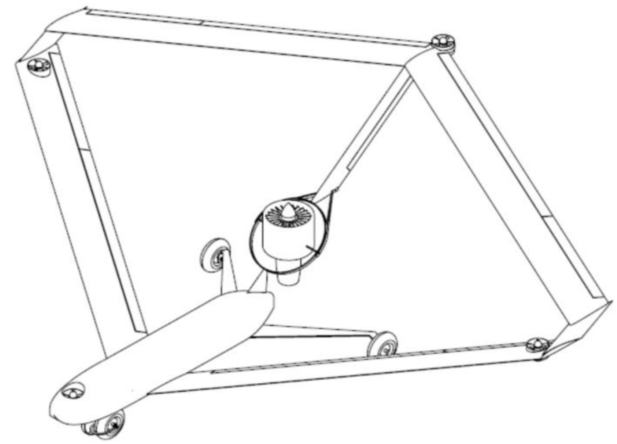


2.2.2. Along the span

2.5. Takeoff and landing type

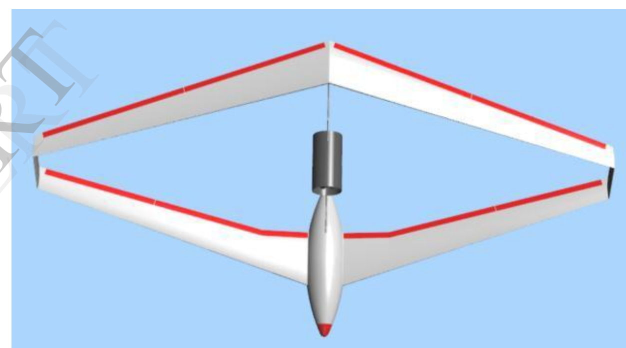
2.5.1. Conventional takeoff and landing airplanes

2.5.2. Vertical takeoff and landing airplanes

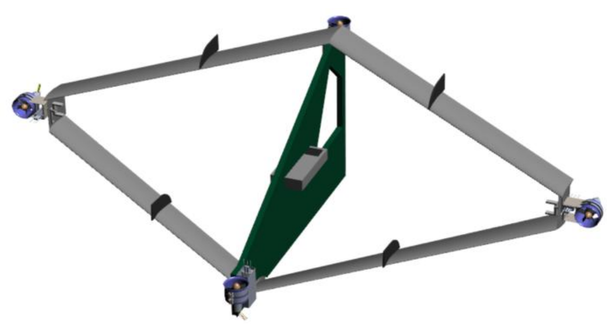


2.6. Flight control method

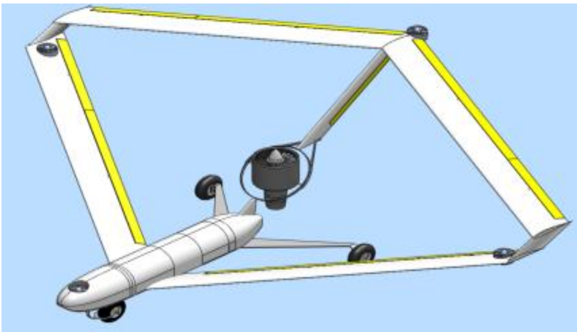
2.6.1. With control surfaces



2.6.2. With control propulsors

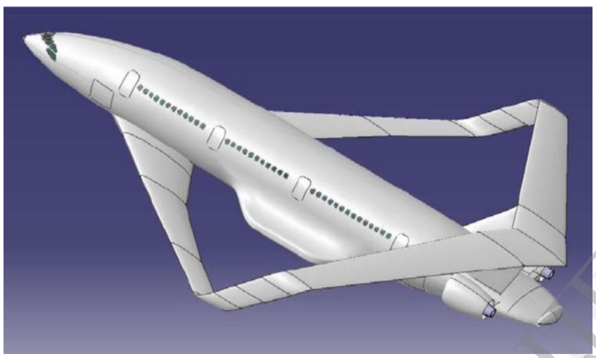


2.6.3. Combined - with control surfaces and propulsors



2.7. Payload arrangement

2.7.1. In a fuselage



2.7.2. In the wing

3. SYNTHESIS OF VARIANTS

At the conceptual design of aircraft a formal approach can be applied for the synthesis of variants through generation of numerical strings in which the position of each number corresponds to a classification indicator and the value points to the possible variant for this indicator.

4. CONCLUSION

The proposed classification can be applied for the variants creation during the conceptual design of aircraft and following analysis.

ACKNOWLEDGEMENTS

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