PRELIMINARY DESIGN AGAINST FLUTTER OF A PRANDTLPLANE LIFTING SYSTEM.

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Abstract

In the report “A Vision for 2020" [4], a panel of experts from the European Commission set up a list of challenges for aircraft industry to meet at the horizon 2020. Future aviation will need to respond to restrictive imperatives in terms of costs, environment, safety and security. At the advent of commercial aviation, the aim was to fly faster and higher than ever now the focus is put on flying with reduced impact on environment and on community, all these with lower costs, improved safety and higher efficiency.

The future commercial success will strongly depend on the improvement of aerodynamic design against drag. Due to limitations of conventional designs, new concepts are needed for future aviation to meet the severe requirements imposed by the Vision 2020 report. A new concept is currently developed at Pisa University (Italy), named PrandtlPlane in honour of Ludwig Prandtl. The PrandtlPlane configuration, even though proposed in the 90s, conforms to the “Vision 2020” requirements. This concept is based on the “Best Wing System” found by Prandtl in 1924, the most efficient lifting system with respect to induced drag. The benefits of this configuration are a more efficient aerodynamics, an innovative pitch control, a high efficiency of the operations of embarking and disembarking cargo, easy engine integration (several options are possible, as the one adopted by Bauhaus Luftfahrt [6] shown in Fig. 1.

This lifting system is made of two swept wings connected with vertical wings at their tips and two fins connecting the rear wing to fuselage; the system is over-constrained to fuselage and, thus, the structural design, as well as static aeroelasticity and flutter characteristics, differ totally from conventional aircraft.

One of the critical areas of research to meet the requirement on performance is structural design and, in particular, the structural design of the lifting system. A preliminary study of the lifting system is presented in this paper, referred to a 250-300 passengers civil transport aircraft and is performed in different steps.

First, an optimisation method developed by the Politecnico di Milano, Milan, Italy, is used on the wing box to find the minimum structural weight meeting the constraints of maximum stress, instability of the stiffeners, aileron effectiveness, static aeroelasticity and flutter. Because the optimisation against flutter could depend on the simplified procedure used (e.g. the assumption of fixed Mach number), the structure was thus selected as a basis for specific further analyses. This analysis revealed many interesting and unusual aspects; in particular, contrary to conventional cantilever wings, the constraint of flutter can be satisfied by introducing fuel tanks at the tips of the lower wing, without any weight penalty. The design procedure defined before indicates the relevance which was attributed to flutter in the design of the closed wing system of PrandtlPlane.

Second step, the symmetry constraint, typical of conventional wings, is removed and an optimisation is performed on the asymmetrical beam box. The result is a significant weight saving due to the presence, in any section, of an out of plane bending moment introduced by the connections ot the two horizontal wings.

Finally a preliminary design of some wing sections has been realized, using a second level code of set uo at Milan and a comparison between standard configuration and Prandtl Plane airplanes, concerning the weight of primary wing structure, has been made.

The research allows us to conclude that, even though the results are preliminary, the structural weight of the lifting system is not bigger that the correspondent of a conventional wing (including stabilizer and fin); this appears as a relevant result considering that conventional wings are optimised after half a century of experience. Another remarkable aspect is the need of high thickness skins (this is trivial, by considering that the airfoil thickness is nearly the half of a conventional wing). This suggests to explore the possibility of manufacturing the wings in composites.

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