Aerospace Science and Technology 73 (2018) 32–47

Contents lists available at ScienceDirect

Aerospace Science and Technology

www.elsevier.com/locate/aescte

Conceptual design of a Blended Wing Body MALE UAV

P. Panagiotou, S. Fotiadis-Karras, K. Yakinthos *

Laboratory of Fluid Mechanics & Turbomachinery, Dept. of Mechanical Engineering, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece

ARTICLE INFO

Article history:
Received 1 September 2017
Received in revised form 19 November 2017
Accepted 20 November 2017
Available online 24 November 2017

Keywords:
BWB
UAV
Design
Layout
Conceptual
Trade studies

ABSTRACT

The current work is an aerodynamic design study of a Blended Wing Body (BWB) Medium-Altitude-Long-Endurance (MALE) Unmanned-Aerial-Vehicle (UAV). Using a combined approach of presizing tools and computational simulations, a step-by-step layout design study was conducted to define the key layout characteristics and select the optimal airframe-engine combination. Trade studies were also carried out to optimize the aerodynamic performance and stability. The traditional sizing and aerodynamic estimation methods were adopted to incorporate the characteristics of the BWB platform, whereas CFD computations were employed in order to calculate the aerodynamic and stability coefficients, during the layout comparison and trade studies. Drawings and tables are provided to show the progression of the design study at each stage. The performance specifications are also compared with a conventional UAV platform to point out the main advantages and disadvantages of the BWB for MALE UAV applications.

1. Introduction

The Blended Wing Body (BWB) is a tailless design that integrates the wing and the fuselage and was initially conceived towards the end of the 20th century to serve as a novel platform for high-speed subsonic commercial airliners [1,2]. In the general case, it consists of a middle section (center body or fuselage) and an outer section (wing), whereas the part in between is the blending area, where the center body smoothly connects (blends) into the wing geometry (Fig. 1). It features several advantages, such as low wetted area to internal volume ratio, potential for elliptic lift distribution, smooth varying cross-section distribution, and adequate space for engine installation on the top of the airframe, to name a few. Hence, there is a wide number of existing studies mainly concerning the BWB as a commercial airliner, dealing with issues related to aerodynamics, structures, and control [1,3–9]. Despite its unique aspects and potential though, the BWB is not expected to enter service before the late 2030s [10], because its revolutionary shape is also responsible for a number of issues that have to do with passenger safety and comfort. Indicatively, cabin pressurization, passenger safety and evacuation are some of the most important issues and, despite the ongoing research [10–13], the BWB concept cannot be considered as a viable option in the commercial airliner layout designers' arsenal, at least for the time being.

However, such a platform can be a promising candidate for other aeronautical applications as well. For example, as also mentioned in a recent announcement by Boeing, the blended wing body can also serve as a cargo airplane [14,15]. There are some issues that have to be solved before this BWB application reaches the skies in this case also, such as the mid-flight opening of the cargo door and the effect it has on the stability of the aircraft. Another possible application is a smaller-scale unmanned platform, as also mentioned in [16]. Unmanned Aerial Vehicles (UAVs) have many advantages, which mainly arise from the lack of crew on board, and can provide solutions to a wide range of applications. Hence, at the present, they are already being operated by several military forces, and civilian organizations [17], whereas there is a wide number of studies that deal with UAV design and optimization [18–24]. Therefore, an innovation in terms of geometry could aid in improving their performance characteristics and, consequently, their operating capabilities. Such an innovative configuration is the BWB. With its aforementioned advantages (increased aerodynamic efficiency and internal volume) it can potentially im-

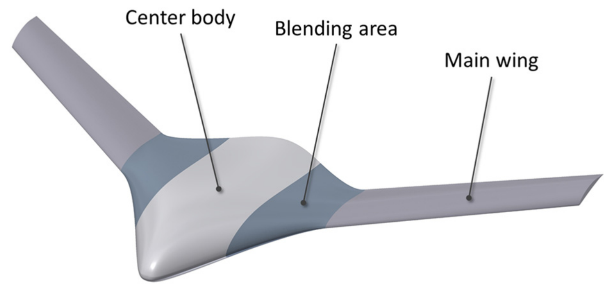

Fig. 1. The BWB concept.

* Corresponding author.
E-mail address: kyak@auth.gr (K. Yakinthos).

https://doi.org/10.1016/j.ast.2017.11.032
1270-9638/

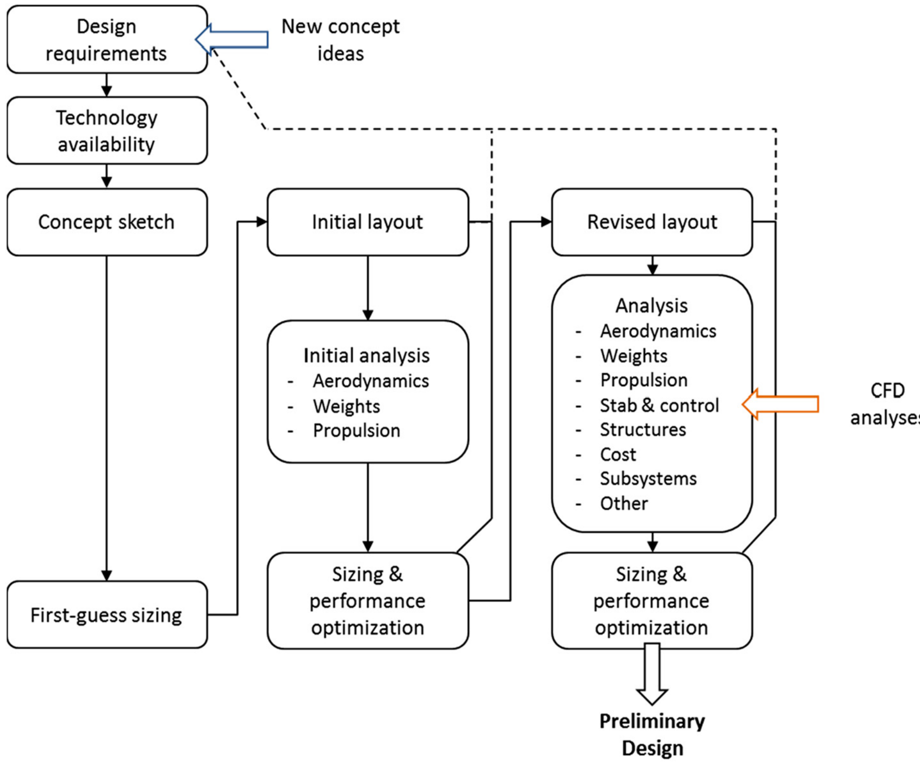

Fig. 2. Conceptual design roadmap.

prove the performance and the operational specifications of aircraft that operate in low subsonic speeds as well, and more specifically in the incompressible flow regime, as is the case of most UAVs [18,25–27].

There is a number of studies, which examine the BWB geometry as a UAV concept either from a designer's perspective or experimentally. For example, Lehmkuehler et al. [16] present the design and testing of a BWB UAV concept, whereas in [28] an experimental study of a BWB UCAV model is shown, including force balance measurements and surface pressure measurements. Moreover, Wisnoe et al. [29,30] in their studies conducted CFD analyses and experimental studies on two BWB configurations. To the best of our knowledge though, all of the BWB UAV-related design studies concern a single concept, and no study goes through a step-by-step design procedure, as the ones presented in [19,20] for conventional configurations. A BWB-related parametric study was recently made in [31], but emphasized on aerodynamics and did not include design considerations.

In the current work, the layout design study of a BWB MALE UAV is presented. The mission requirements correspond to the specifications of a typical surveillance MALE UAV, as also described in [18]. A step-by-step presentation of the design procedure is made, including the presizing methods and CFD methodology. Emphasis is given on the unique aspects of the BWB configuration and the way those are incorporated in the design methodology. The presentation starts with the initial calculations, the layout comparison and engine selection study, to come up with a first configuration i.e., the Dash-One. A number of trade studies and a comparison with a conventional configuration is then conducted to investigate the potential and the limits of the BWB configuration as a MALE UAV platform.

2. Conceptual design methodology

For the conceptual design procedure described in this study, a custom sizing methodology is employed, which combines the traditional aircraft and UAV presizing methods with computational simulations. Moreover, some special considerations are made to incorporate the aspects of BWB into the design procedure, such as the weight estimation and aerodynamic coefficient prediction methods. In the following chapters both the layout design methods and the CFD methodology are briefly described, whereas Section 2.3 is dedicated to the BWB-related elements of the design procedure.

2.1. Traditional sizing methods

Considering the presizing calculations an in-house tool was employed, which has been developed in the Laboratory of Fluid Mechanics and Turbomachinery (LFMT), at the Department of Mechanical Engineering, at the Aristotle University of Thessaloniki (AUTH), Greece. Based on aircraft design methods, such as the ones described in [2,32,33], it also includes the aspects of unmanned aircraft design and is a combination of analytical and semi-empirical presizing methods. It can be used to carry out a complete layout design study and aerodynamic analysis, and has been validated on commercial airliners and unmanned aerial vehicle configurations [18,34]. A roadmap of the conceptual design tool is presented in Fig. 2.

At first, the mission requirements are defined and, along with any new concept ideas and taking into account available technology, they serve as the design guidelines. Then, the first presizing calculations are conducted, based mostly on semi-empirical relations and statistical data, as well as some early concept sketches. The next step is to estimate some key performance parameters and layout elements, such as airfoil specifications, wing area, and propulsion specifications, that serve as the base upon which the detailed configuration layouts/candidates are drawn. Those detailed layouts allow for the refined weight estimations and aerodynamic coefficient predictions to be conducted, which in turn are used to carry out detailed performance analysis studies. Based on the refined numbers, the various configurations are compared and the