# CONCEPTUAL DESIGN AND OPTIMIZATION OF WING BOMBUSING OPENVSP - OPEN-SOURCE PROGRAM FOR COMPUTER MODELING

NIKOLA G. RAIČEVIĆ, MILOŠ D. PETRAŠINOVIĆ*, ALEKSANDAR M. GRBOVIĆ, MIHAILO G. PETROVIĆ

*Facility of Mechanical Engineering of the University of Belgrade, Serbia,*
*e-mails: mpetrasinovic@mas.bg.ac.rs*

**Abstract.** This paper will present the process of creating a wing bomb model. This UAV is completely designed in OpenVSP and analyzed in the VSPAERO tool. These analyses are very important to get preliminary results that will be used for the next steps of the design and the optimization of the wing bomb. During the development of the conceptual design of this UAV, it was necessary to create several different versions of the model. The OpenVSP program was chosen because it allows engineers to quickly and easily create and modify a model of aircraft.

Keywords: conceptual design, optimization, OpenVSP, computer modeling, UAV

## 1. INTRODUCTION

In the modern age of designing and constructing Unmanned Aerial Vehicles (UAVs), projectiles, and satellites, time is one of the most important factors. To save time during the design, it was necessary to develop a program that would enable quick modifications to aircraft models. In addition to time, this also enables significant savings in money that would be spent on re-creating the model. Numerous programs can be used to create a model of the aircraft to the smallest detail and analyze its geometric, aerodynamic, and other characteristics. In the conceptual design, it is necessary to determine the shape and geometry of the aircraft. This simple model of the aircraft is created in a program that can analyze the aerodynamic characteristics of the aircraft, which could later be used when optimizing the structure. To create a model, it is necessary to use an aerodynamic solver that allows simulation of the environment of the aircraft. Since this is the initial phase, the OpenVSP program was chosen [1] [3].

* Corresponding author
http://doi.org/10.7546/EngSci.LXII.25.01.03

OpenVSP (Open Vehicle Sketch Pad) is an open-source parametric aircraft geometry tool that can be used to create an aircraft model and analyze it. Besides the geometry, OpenVSP contains multiple tools such as: mesh generation, a center of gravity and moment of inertia computation, Vortex lattice method (lift and drag aerodynamics coefficients computation), flight dynamics analysis, estimating wave and parasite drag of geometries, and more others [2].

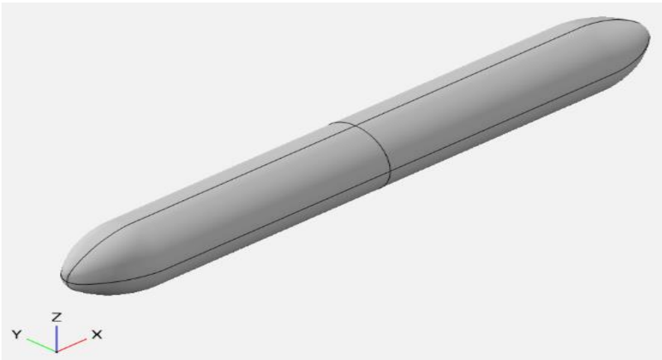


**Fig. 1.** Fuselage model created in openVSP

All the geometric tools available in the program were used to create the preliminary shape of this wing bomb. Other tools were used in the part related to model optimization. It should be noted that the results obtained are not final but should be used just as information on what should be corrected in the model. Also, this information is a good starting point for more detailed tests in other programs that will be used in the further stages of aircraft development.

## 2. CREATING A MODEL IN OPENVSP

A wing bomb is an aircraft that can't take off independently. The aircraft does not carry fuel or any other element (engine, propeller, etc.) that would allow it autonomous and long flight. The wing bomb is tied to a carrier located under the wing of the plane from which it can be detached at the desired moment, after which the bomb would fly autonomously for a certain time until it hits a target. The classic concept of bomb construction consists of the fuselage and tail surfaces.

The fuselage has a classic cylinder shape that is rounded at the ends (as shown in Fig. 1). The roundings are very easily formed in this program by changing the diameter of the circular cross-section. For an easier and more precise definition, the model should be divided into several sections. Each section is defined and given dimensions (section width and section diameter).

The main purpose of tail surfaces is to provide stability and maneuverability for the bomb. Tail surfaces consist of a vertical and a horizontal tail [4].

The vertical tail consists of two parts: the integral vertical tail and the vertical stabilizer (as shown in Fig. 2). The integral vertical tail has a symmetric airfoil along the entire span. This can be set directly in the program that independently forms the airfoil with all its characteristics (curvature, relative thickness, and others). Also, it is necessary to specify the length of the chords of the sections (only three sections). The vertical stabilizer is located on the underside of the bomb, between the bomb fuselage and the integral vertical tail.

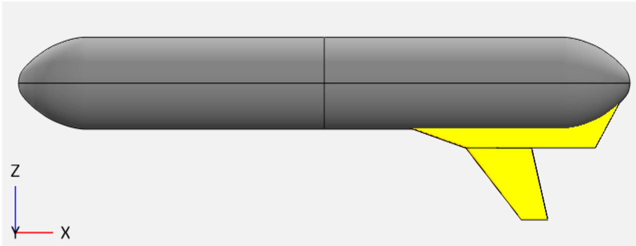


**Fig. 2.** The vertical tail model created in openVSP

The integral horizontal tail has an inverse airfoil along the entire span, and it is preliminarily attached to the symmetry of the fuselage (as shown in Fig. 3). The inversion of the airfoil is achieved by selecting the "inverse" option, after which the initially selected airfoil will be automatically modified.

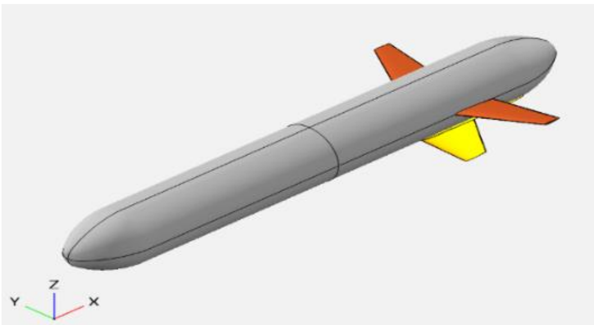


**Fig. 3.** The horizontal tail model created in openVSP

For the autonomous flight to be longer, the classical concept of the bomb has changed, and wings were added to the construction, whose basic task would be to create additional lift that would enable a slightly longer flight of the bomb. Initially, while the bomb is still attached to the carrier under the wing of the plane, the wings are folded (as shown in Fig. 4). In that way, the bomb does not affect the stability of the aircraft that carries it, nor does it affect the appearance of additional parasite drag. The geometry of the wing is simple. The wing has the same airfoil along the entire span. Due to the compactness of the model, it was decided that the chord does not change along the span.

In this phase of conceptual design, at the end of the wing, there is also the same airfoil but with a variable length of the chord. This is possible by dividing the structure into several cross-sections, which are given dimensions (section width and chord length). In this case, a large number of cross-sections were chosen to achieve the desired shape at the end of the wing. In the following phases of design, after aerodynamic analysis, it will be decided whether this concept will be retained or simplified. Also, in this phase of design, there will be no flight control surfaces on the wings. The only control surfaces are tail surfaces that can be deflected over their entire surface.

The blue part of the model (as shown in Fig. 4) is an auxiliary part of the structure, and it is used to tie the wings to the fuselage. This part must be modeled so as not to deform the aerodynamic shape of the bomb to avoid additional drags. The contour of the part perfectly fits the shape of the fuselage.

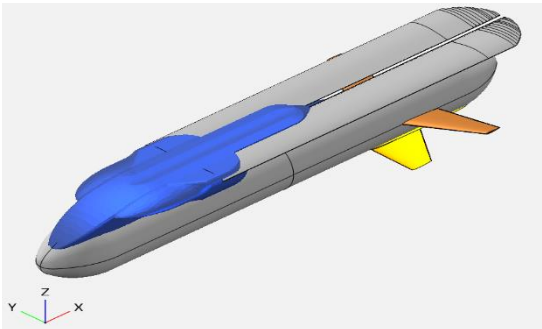


**Fig. 4.** Complete model of wing bomb with folded wings

When the bomb is untied from the wing of the plane and aimed at the target, the wings of the bomb need to be unfolded (as shown in Fig. 5). In that case, the wings must be positioned so that they achieve a certain sweep angle. The optimal size of the sweep angle will be determined after additional tests (aerodynamics, stability, etc.).

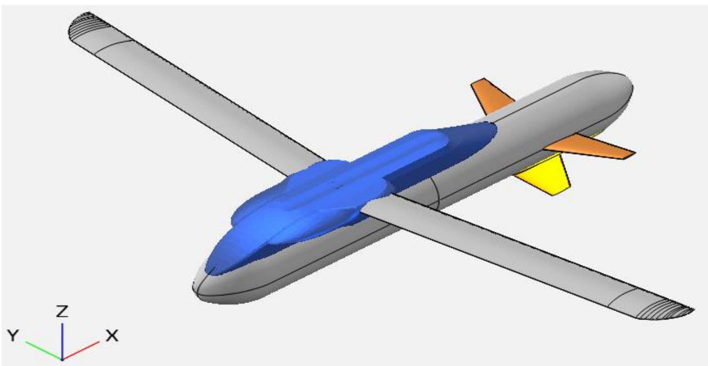


**Fig. 5.** Complete model of wing bomb with unfolded wings

## 3. OPTIMIZATION TOOL - VSPAERO

OpenVSP has a great number of modeling and analysis capabilities to help engineers in the conceptual design process [5]. VSPAERO is one of the most used tools in the process of optimization and data collection that can be used in the later stages of aircraft development. In this case, VSPAERO was used to collect data about airflow disturbance at the wingtips for different airflow angles (as shown in Fig. 6). The reason for this test is to determine how it is possible to modify this part of the wing so that no additional drag is created during flight. The two most important parameters for this analysis are the different angles of attack of the airflow and the expected flight speed.

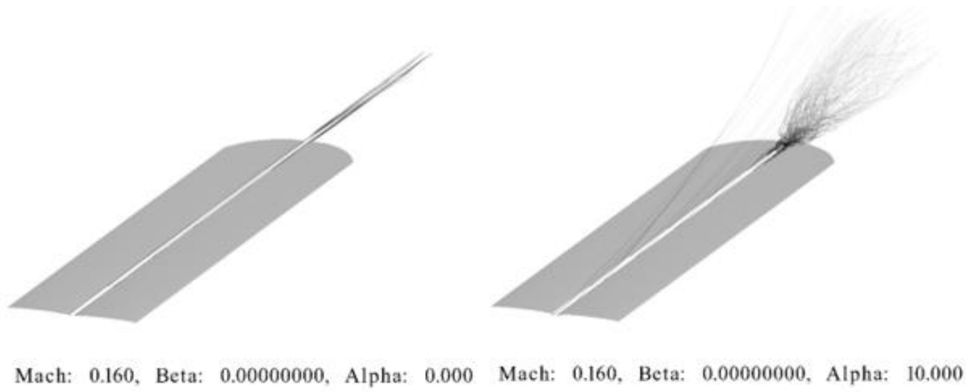


**Fig. 6.** Disturbance at the wingtips for different airflow angles

## 4. CONCLUSION

Although modeling in this program is quite simple and does not require experience in CAD programs, this doesn't mean that the program can't be used for serious engineering tasks and problems. OpenVSP significantly accelerates the first steps of designing an aircraft model and, with the help of numerous tools implemented in the program, provides guidelines for further development. The program is an ideal solution for the training of young engineers who need to get the first knowledge and skills in this field.

This paper gives a short procedure on how to easily create the initial version of the model based only on the idea and requirements that the aircraft should meet. Also, this paper lists many possibilities that the program offers and which can help in optimizing the aircraft model. It should be noted that the results obtained by these analyses are not final but are used only as parameters that engineers can use in the further development of the aircraft.

## REFERENCES


[1] M. SEGUI AND R.M BOTEZ, Aerodynamic Coefficients Prediction from Minimum Computation Combinations Using OpenVSP Software (2018) *International Journal of Mechanical and Industrial Engineering*, **12** (1) Conference: ICEER at Innsbruck, online: https://zenodo.org/record/1315609/files/10008474.pdf.

[2] OpenVSP, http://openvsp.org/ [Accessed 5.2022].

[3] S. HERBST AND A STAUDENMAIER, Using OpenVSP in a Conceptual Aircraft Design Environment in MATLAB (2016) 30th Congress of the International Council of the Aeronautical Sciences, online: https://www.icas.org/icas_archive/ICAS2016/data/papers/2016_0174_paper.pdf.

[4] N. KANKANAWADI, G KARINAGSHETRU, L PATIL AND AL. Conceptual Design of a Fixed Wing Vertical Take-Off and Landing Unmanned Aerial Vehicle (2021) AIP Conference Proceedings, online: http://dx.doi.org/10.1063/5.0050366.

[5] R. MCDONALD, Advanced Modeling in OpenVSP (2016) American Institute of Aeronautics and Astronautics, online: http://dx.doi.org/10.2514/6.2016-3282.


*Received January 10, 2025*