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UNMANNED AERIAL VEHICHLE WING FUSELAGE JUNCTION OPTIMALISATION WITH FINITE ELEMENT METHOD

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Abstract

Nowadays one of the main lines of development in aerial craft is the design and construction of unmanned aerial vehicles (UAV's). Within this wide topic, development of ultralight (UL) aircrafts is especially popular because of their versatility and relative low cost. My task was to design the shape of an airplane wing-fuselage junction, which will be classified as an ultralight and unmanned aerial vehicle. The most optimal wing-fuselage junction is made with the Ansys sim-ulating program, including model calculations. Based on the calculations and results, solutions can be recommended. With CAD geometry models, first stage of testing of the aircraft with 3D printed models, is prepared.

Keywords: *wing-fuselage junction, finite element method, unmanned aerial vehichle, ultralight, simulation.*

1. Introduction

These days – along with the „traditional" on-board, pilot controlled airplanes and helicopters – many aircraft and tools have appeared, which are able to fly without an on-board pilot, being remotely or self-controlled. Fixed wing aircraft and helicopters – without on-board pilots – have been developed and used in different variants with maximum take-off masses ranging from a few decagrams to as much as ten tons.

Today there are several types of aircraft that are controlled and driven without human intervention, the use of digital technology enabling them to fly. These aircraft are able to detect their environment, navigate and be controlled by themselves. [1]

This report aims to optimise an aircraft's wing-fuselage junction. The aircraft – which is under development – is to be classified as an „Ultralight" (UL) and „Unmanned Aerial Aircraft" (UAV) – wing-fuselage junction optimisation utilising the Ansys simulation program including model calculations. The cross-section of the fuselage of this airplane is not „traditional" but hexagonal.

Resources concerning wing-fuselage junction, alternate fuselages and wing configurations were studied, including the position of the main planes. Only well-known and well-tested fillets and shapes were used to build up some of the aircraft wing-fuselage junctions. For these variants flow simulation models were set up, then simulation and evaluation was made. Based on the results, suitable wing-fuselage junctions were determined.

For achieving the minimum amount of drag, a suitable wing-fuselage junction should be used, because it can improve the aircraft flying characteristics and lifetime. [2]

A suitable wing-fuselage junction can be achieved by:

– wing configuration including position of the plane;
– use of fairings;
– fillets at the wing-root junction;
– use of extensions (LERX) [2].

1.1. Base information

Mass:	~ 450 kg (predicted)
Wingspan:	~10.6 m (planned)
Fuselage length:	7 m
V shape:	3°
Cruising speed:	40 m/s (144 km/h)
Fuselage diameter:	1.07 m

The chord length at the root of the wing is limited to between 1000 mm and 1600 mm, because of the geometrical characteristics of wing and fuselage connection.

Junction rounding and shaping (fillet) must fall between 50 mm and 280 mm (radius), and this depends on the wing chord length

2. Analysing the wing-fuselage junction with the finite element method

The wing-fuselage junction could be analysed using many methods. Nowadays one of the most used and efficient methods (regarding not just the time factor, but the economy factor) is a model simulation using the finite element method.

Simulation usually starts with the so-called preprocessing step.

The first step before simulating the model is to divide the geometry into many small finite parts, which is called mesh or meshing. While creating a new mesh, we should consider its element type, size, desired precision and the solution time. Most programs, which contain simulation with the finite element method, can complete the meshing automatically with default configuration, but manual settings are also available. [3]

There are programs which contain a finite element module, for example: CATIA V5, SolidWorks, Autodesk Inventor, etc.

Better known programs including finite element module: Analysis3D, CalculiX, Nastran and this investigation was completed with the aid of Ansys.

2.1. Wing-fuselage junction types

Shaping and forming the junction was based on „Jirapat Supamusdisukul: Experimental Investigation of Wing-Fuselage Integration Geometries Including CFD Analyses" [4] and „Darrol Stinton: The Design of the Aeroplane" [5].

2.1.1 Optimal position of the wing

Jirapat Supamusdisukul analysed 5 wing configurations with 8 different pitch angles using finite element method simulation, then he checked if the simulation and the wind tunnel measurements were the same. Based on the results, he advised which wing configuration should be used.

Supamusdisukul began analysing the mid-wing configuration, –which is about half of the fuselage height – then he continued with shoulder wing and high wing.

2.1.2. One type of the optimal wing-fuselage junction

Based on „Darron Stinton: The Design of the Aeroplane", the wing-fuselage junction should look like this: around the leading edge wing-fuselage, the radius must be between 5-10% of the wing chord length, around the trailing edge, this value is 10-20%. We used this information to build up different wing-fuselage junctions.

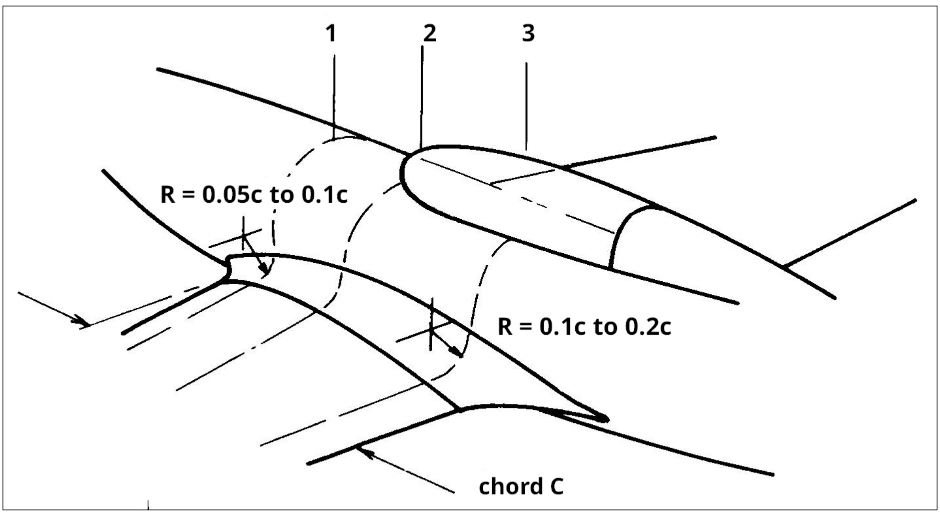

Figure 1. *The values of wing-fuselage junction radiuses* [5]

Table 1. *Presenting the 2 types*

1000 mm	1400 mm
0 mm	0 mm
50-100 mm	70-140 mm
100-200 mm	140-280 mm

3. Planning the wing-fuselage junction

3.1. Preparations and 3D models

The first task was to choose the appropriate length of the wing root and wing-fuselage junction radius. The firm – which ordered the work – did not mention any limitation concerning the junction; therefore, using imagination along with the books, 6 3D models were created in SolidWorks. 3 of the models' wing-root lengths are 1000 mm, and 3 of them 1400 mm.

Models were created in Solidworks, and imported into Ansys. In Ansys, the space for the airflow was added. To achieve it, the Solidwork model subtraction is made from a 1,5 m (width) x 7 m (length) x 2 m (height) solid body. This body will be the space where air-flow could be analysed.

The body for the air does not involve the whole airplane – symmetry option is used during simulations, so the same results could be obtained using less elements and less time, because the airflow effects at the wing-tip do not make big difference around the wing-root.

The **Figure 2.** radiuses from leading edge to trailing edge: 50 mm, 60 mm; 70 mm; 80 mm; 90 mm; 100 mm.

The **Figure 3.** radiuses from leading edge to trailing edge: 100 mm, 120 mm; 140 mm; 160 mm; 180 mm; 200 mm.

The **Figure 4.** radiuses from leading edge to trailing edge: 70 mm, 84mm; 98 mm; 112 mm; 126 mm; 140 mm.

The **Figure 5.** radiuses from leading edge to trailing edge: 140 mm, 168 mm; 196 mm; 224 mm; 252 mm; 280 mm.

4. Results

The results produced with aerodynamic simulations are shown in **Table 2.** and **Table 5.** Meshing and simulation data are given in **Table 3–4.** and **6–7.**

Based on the **Table 2.** results, the 70 mm fillet junction is the most optimal for the 1400 mm wing-chord type. A 70 mm fillet means the

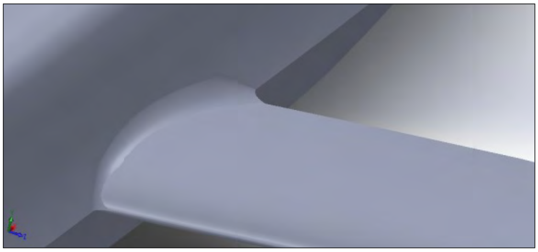

Figure 2. *Smaller radius for the 1000 mm type*

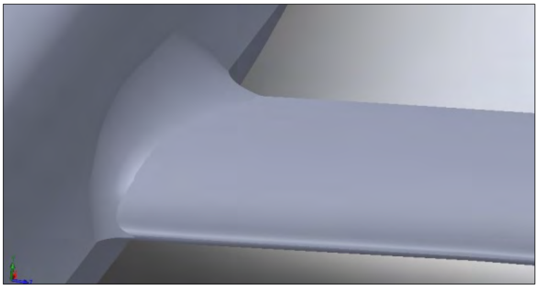

Figure 3. *Larger radius for the 1000 mm type*

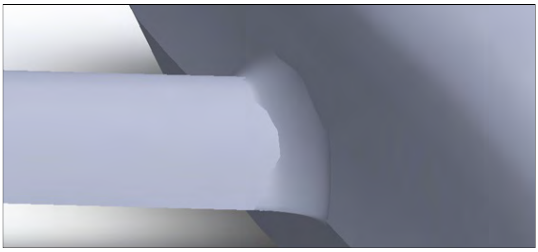

Figure 4. *Smaller radius for the 1400 mm type*

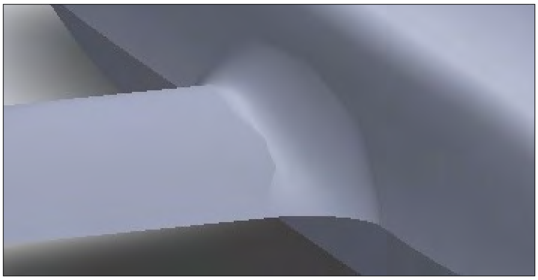

Figure 5. *Larger radius for the 1400 mm type*

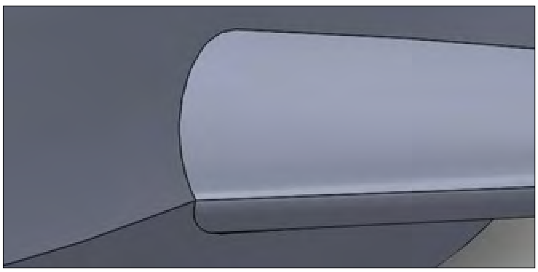

Figure 6. *Wing-fuselage junction*

Table 2. *The results of the type „1400 mm"*

Radius [mm]	Lift [N]	Drag [N]
no fillet	240.577	16.4413
70	247.447	16.5220
140	231.084	25.0226

Table 3. *Simulation data for the 1400 mm type*

Radius [mm]	Time elapsed [s]	Iteration
-	1765	38
70	2031	37
140	1568	35

Table 4. *Meshing data for the 1400 mm type*

Radius [mm]	Elements	Nodes	Faces
nincs	2174615	411018	189598
70	2249888	425435	202754
140	2252722	425721	195940

Table 5. *The result of the type "1000 mm"*

Radius [mm]	Lift [N]	Drag [N]
no fillet	213.026	12.2747
50	214.627	12.2671
100	208.656	11.9574

Table 6. *Simulation data for the 1000 mm type*

Radius [mm]	Time elapsed [s]	Iteration
-	1753	37
50	1918	38
100	1833	38

Table 7. *Meshing data for the 1000 mm type*

Radius [mm]	Elements	Nodes	Faces
-	2185674	412768	189068
50	2272646	428672	194336
100	2274477	428686	193308

leading edge shaped radius value of the wing-fuselage junction. Around the trailing edge the value is 140 mm and between those transient (about 50% of the chord, the radius is around 105 mm).

There are no big differences between the junction with "no fillet" and the „70 mm" type when comparing their „Drag" data, but there is more than 1% difference for the „70 mm" type at „Lift", so the latter could be more effective.

Based on the results and the type "1400 mm", the 50 mm radius is recommended from the 3 types of shape for the 1000 mm type.

5. Summary

Based on the results, We can recommend a radius of 50 mm or 70 mm shaped wing-fuselage junction, depending on the final length of the wing-chord and it would be manufactured with 3D printers.

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