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Flying Wing Conceptual Design and Flight Testing

The main aim of this paper is to present a method for the conceptual design of a flying wing unmanned aerial vehicle using open-source software for rapid airfoil comparison and design and parametric geometry design and analysis. After adopting the final geometry the aerodynamic characteristics have been estimated including control derivatives. The obtained results have been compared to the results for similar flying wing projects to confirm that the presented method can give satisfying results. As the calculated results indicated that UAVs possess adequate flying qualities the prototype UAV was assembled using simple construction methods consisting of a hot wire cut styrofoam structure reinforced with plywood sticks, powered by a single pusher-propelled electrical BLDC motor. Calculated flight polar was then compared with data obtained from flight tests, verifying estimated stability and control characteristics of UAV design. The flight test results show that UAVs are controllable without a stability augmentation system, validating the use of methods described in this paper.

Keywords: *UAV, flying wing, conceptual design, flight test, aerodynamics, stability, control.*

1. INTRODUCTION

Unmanned aerial vehicles (UAVs) are usually designed according to the requirements defined by a buyer or by the market requirements estimated by the company that is producing the UAV. Certification of the UAV system should demonstrate that the system is safe for flight according to the regulatory criteria [1-3]. The flying wings are well known as the tailless fixed-wing aircraft. Such design enhances aerodynamic characteristics by reducing the drag compared to classic aircraft design, eliminating drag caused by the fuselage, empennage, and interference drag between wing and fuselage and fuselage and empennage [4]. Despite the mentioned advantages that make it possible to achieve very low zero-lift drag coefficients, some of the main disadvantages are that flying wings are prone to being unstable and difficult to control if not well designed, with the inherent airfoil pitching moment required for stability canceling out some of the previously mentioned benefits. Flying wings was a popular configuration many years before the first successful flight [5]. Special interest in this configuration happened during the Second World War [6-8]. The most successful flying wing designs at that time were accomplished by Jack Northrop [9] and Horten brothers [10]. This aircraft configuration is still very popular. Many new projects and PhD dissertations have shown special interest in this configuration [11-16]. The best summary of flying wing design is given in [17]. The book, originally written in German language-discusses the full range of tailless designs, from hang-gliders to stealth bombers. It includes a detailed look and explanation of the particularly significant design solutions. The author's own experience in this field of flying wing design has enabled them to explain and illustrate the topic in a way that can satisfy the professional aeronautical engineer's needs. It has been used as a guide for the conceptual UAV design presented.

The initial UAV requirements have been given in Table 1. Maximum UAV mass was estimated based on experience and similar existing UAVs. The wing span was defined by transportation requirements. The UAV cruise speed has been defined by UAV mission requirements. The main requirements were that it could cooperate with the existing small UAV developed in the Military Technical Institute and small UAVs on the market. This class of UAVs usually have cruise speed in the range from 15 m/s up to 25 m/s.

Table 1. Initial UAV requirements

Flying wing configuration	
Wing span	≤1.5 m
Maximum mass of UAV	≤ 2.5 kg
Length	≤1 m
Cruise speed	≈20 m/s
Endurance	≥10 min
Engine	Electrical BLDC
Stall speed	≤10 m/s

Initial endurance requirements were to have sufficient time to test the system in possible cooperative search and rescue missions. For this class of UAVs, the electrical BLDC (brushless direct current) motor is a well-proven solution. Finally, the stall speed has been defined as the value that will enable the hand-launching capabilities.

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2. UAV GEOMETRY

As it is mentioned in [17] perfect aircraft design still does not exist. So, it is impossible to design an ideal flying wing UAV and the selection of the geometry and airfoils will always have some pros and cons. The main reason for this is that airfoil and wing geometry must accomplish different tasks that provide different UAV solutions [17]. All aircraft or UAVs need to have the lowest possible drag and a high lift-to-drag ratio in cruise configuration. The aircraft must be trimmed at a minimal speed and must be controllable in all flight regimes [13, 17, 18]. As it is well known, the airfoil that has the best lift-to-drag ratio at some angle of attack possesses negative pitching moment characteristics [19]. In order to trim the flying wing aircraft elevon (which functions as an elevator and an aileron) control surface deflection is necessary [14]. This additional deflection negatively affects airfoil characteristics and this is the reason why it is more complicated to design and optimize flying wing configuration than classical tail after configuration.

Despite all of the above-mentioned flying wing UAV configurations being very popular in the last 20 years [20-23]. One of the most important benefits of small UAV systems is take-off by catapult or hand launching take-off. It removes the problem of designing take-off aircraft configuration and aircraft controls that exist in civil aviation. Eliminating this problem, the flying wing UAV configuration becomes very popular and interesting solution for some problems in military and civil applications. As it is mentioned in [24] larger wing span is always the best solution for better aerodynamic efficiency. It enables a higher wing aspect ratio and higher lift curve slope. So, the starting wing span was chosen to be 1.5 m. After a few iterations initial UAV wing geometry was defined with the data given in Table 2.

Table 2. Initial UAV wing geometry

Wing span	1.5 m
Wing root chord	0.42 m
Wing tip chord	0.28 m
Aspect ratio	4.286
Taper ratio	0.667
Mean aerodynamic chord	0.355 m
Surface area	0.525 m^2
Leading edge swept angel	25 deg

For the defined wing geometry, the lift force coefficient has been estimated by the equation:

$$C_L = \frac{L}{qS} = \frac{mg}{0.5\rho V^2 S} . \quad (1)$$

For a maximal UAV mass of 2.5 kg and predefined speed limit range from 8 m/s to 20 m/s the estimated lift force coefficient should be in the range from 1.19 to 0.2. The estimated required maximum lift force coefficient is in good agreement with the state-of-the-art data given in [22, 23]. The estimated value of 1.19 is just a few percent less than 1.25 given in [22]. The stall speed was defined with the assumption that a speed of 8 m/s is the maximum speed that can be delivered to the UAV by hand launching. The corresponding Reynolds numbers are 176 000 and 425 000. In this manner, the input data for wing airfoil analysis have been defined, in order to design a configuration that performs well both in stall conditions and in cruise conditions.

3. AIRFOIL SELECTION

The airfoils play a most important role in the aircraft design and optimization. Airfoil data can be found at [25] and an excellent summary of the low-speed airfoil data is given by Michael Selig et al. [26]. Flying wing airfoil optimization is very good summarized in the work of [27-29]. The most popular tools for airfoil analysis and modification at low Reynolds numbers are probably XFOIL [30] and XFLR5 [31]. In this paper, the XFLR5 has been used to analyze airfoil characteristics. The airfoil should be selected so that it has the lowest possible drag coefficient in the given cruising conditions, and on the other hand, it should have the highest possible lift coefficient in the take-off and landing conditions. This will provide the lowest possible take-off and landing speed. For the purpose of airfoil selection, a list of 56 (Table 3) airfoils that are used or were used on aircraft of this type has been considered.

Table 3. List of possible airfoils for wing geometry

Airfoil name		
TL 56	HS-144	MEG 64
TL 55	HS-132	Mdhwk
Sipkill	HS-130	KN 198117
SD 7003	HS-120	KN197957
S 5020	HS-117	jwl-097
S 5010	HS-8	jwl-065
Roncz Low Drag	HS-7	HS-190
PW 106	HS-6	HS-164
PW 75	HS-5	HS-160
PW 51	HS-522	E182
Phoenix	HS520	Clark YS
NACA 23112-75	Goe-765	CJ-25(2)09
MH 64	Fx 66-H-80	CJ 3309
MH 62	Fauvel F2	CJ 2309
MH 60	Fauvel 14%	CJ 5
MH 49	EMX-07	BW 05 02 09
MH 46	EH 1.5/9	AR 2610-S80
MH45	E186	AR 2411-S77
MH 44	E184	

All the airfoils have been analyzed by XFLR5 software. As it is mentioned earlier there is no single airfoil that has the best desired characteristics. The designer must choose one of the possible good solutions that have pros and cons. The two possible choices for conditions presented in this paper were MH 60 and SD 7003. The output XFLR5 data for these two airfoils is given in diagrams (Figures 1-3). As it can be concluded from the airfoil data presented in the just mentioned diagrams, the SD 7003 airfoil has better lift force capabilities, but on the other hand, has a higher pitching moment coefficient. In order to trim the aircraft, it will require greater control surface deflection than the MH 60 airfoil. Taking all the mentioned into account it was decided that MH 60 airfoil is the optimal solution for the flying wing design.

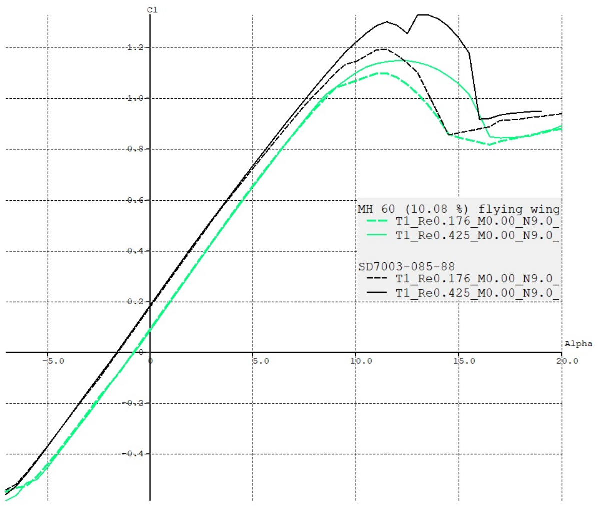

Figure 1. Lift force coefficient vs angle of attack

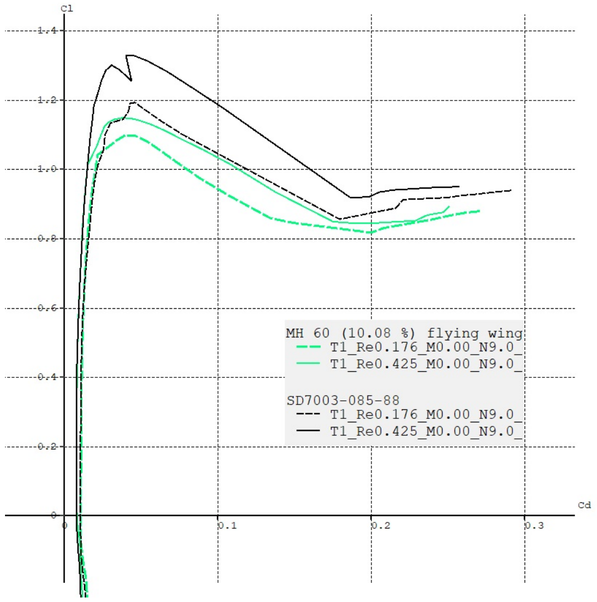

Figure 2. Airfoils polar

4. UAV GEOMETRY DEFINITION AND ESTIMATION OF UAV AERODYNAMIC CHARACTERISTICS

As it is well known, the flying wing aircraft are blended wing body aircraft and that means that defined wing geometry needs to be changed in order to put equipment in the UAV airframe. In order to fulfill these requi–rements, the initial wing geometry has been changed to enable the installation of equipment (flight control computer, RC receiver, battery, BLDC motor, and camera).

The final UAV geometry has been defined in Open VSP software [32]. After a few necessary modifications Figure 4. shows the conceptual design flying wings UAV model. As can be seen from Figure 2, the maximum lift force coefficient of MH60 airfoil is 1.1 at a low Reynolds number. In order to have sufficient lift force at low airspeed the wing surface area has been increased by 10.86%. The final UAV geometry has been defined with the mean aerodynamic chord of 0.464 m, wing span of 1.5 m, and wing surface area of 0.582 m^2.

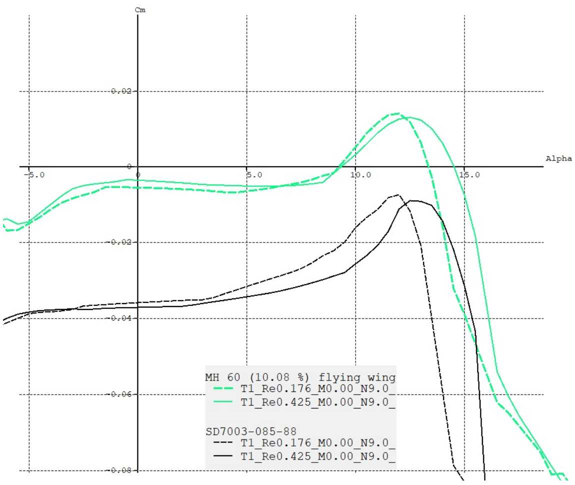

Figure 3. Pitching moment coefficient vs angle of attack

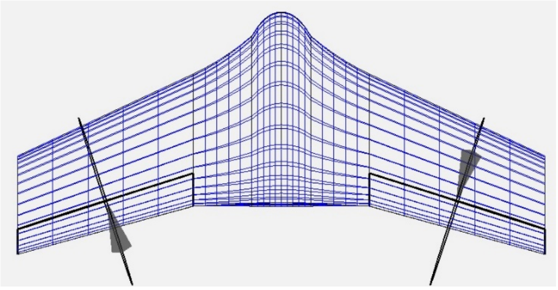

Figure 4. Flying wing UAV geometry from Open VSP

The evaluation of UAV aerodynamic design has been done by calculated methods and software tools that are in detail described in [33, 34]. The maximum lift force coefficient of 1.011 has been estimated and the corresponding minimum airspeed needed for UAV to produce sufficient lift with maximum UAV weight is 8.25 m/s. This value is in excellent agreement with the predefined value of 8 m/s that should enable the hand-launching capabilities. The numerically estimated value of 1.011 is in excellent agreement with the CFD results for UAV flying wings given in [35, 36].

5. UAV DRAG POLAR

UAV drag polar has been estimated by using the software Open VSP and analytically by the data given in [37]. Parasite drag force coefficient estimate by Open VSP is 0.01547 and excellent agreement with the theo–retical result of 0.01683 from [37] has been obtained. Analytically calculated drag polar data has been given in Figure 5. The estimated results are in excellent cor–relation with the graphically presented results for drag force coefficient vs angle of attack given in [36]. Unfortunately, the parasite drags force coefficient could not be exactly determined from the presented diagram given in [36]. The most precise estimation from the presented diagram in [36] suggested that the parasite drag force coefficient has a value in the range of 0.015 to 0.016.

6. UAV FLIGHT TESTING

In Figure 6 the UAV is shown during the take-off phase after successfully hand launching. The prototype UAV during flight tests had a mass of 1.5 kg. In the first few tests, it was decided to test UAV stability and control characteristics.

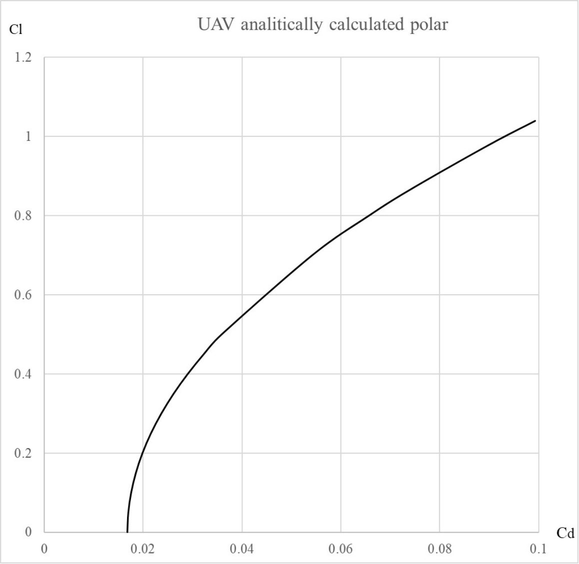

Figure 5. Flying wing drag polar

In the following phases of UAV development, the UAV structure will be greatly improved (composite fiber-reinforced foam instead of the foam and plywood combination), additional equipment (optoelectronic payload, military-grade flight computer, larger battery) will be fitted, resulting in increased mass, which will be closer to initially defined 2.5 kg.

Figure 6. Flying wing UAV during take-off phase

The way to evaluate whether an aircraft or UAV possesses adequate stability characteristics is through the change of the pitching moment with respect to the lift force coefficient. For UAV to be stable this derivative should be negative. For tailless aircraft or UAVs, it is well known that the center of gravity has to be forward of the aerodynamic center [14, 17, 38]. The center of gravity position has been defined in such a way that the static stability margin of flying wing UAV had the value of -0.0967 or 9.67% of the mean aerodynamic chord. This value has been chosen based on the previous experience with the aircraft Lasta [39-42]. As it is shown in [39] the longitudinal stability reserve by the single tractor propeller at high engine power settings should be greater than 6% of the mean aerodynamic chord. Destabilizing effects of both high angle of attack and high propeller thrust are present when the aircraft is propelled by a single-engine tractor engine. As the flying wing is a pusher-propelled UAV it was concluded that a longitudinal stability reserve of 9.67% of a mean aerodynamic chord should be sufficient to provide adequate longitudinal stability characteristics. It must be mentioned that a static margin of 10% is acceptable only for small UAVs that operate at low airspeed. As mentioned in [12, 14] the larger the static margin, the larger the deflection of the elevator angle to trim the aircraft or UAV for the given lift force coefficients. Large aircraft or UAVs with high airspeed will have smaller static margins to decrease trim drag. Modern flight control computers and fly-by-wire systems augment the basic aircraft or UAV stability and enable adequate flying qualities.

Before flight testing the control surface design has been done. The experience of the previous flight tests of flying wing UAV models and the successful develop–ment of UAVs have been used to estimate initial elevon geometry. The relative elevon chord has been defined with a value of 25% and a relative span of 66.67%. The change in pitching moment coefficient with the changes in elevon (elevator power or elevator effectiveness) deflection has been estimated by using open-source software [32]. The value of -0.554 1/rad has been estimated. The estimated elevator power is quite small compared to the standard tail configuration. It is the consequence of a relatively small distance from the UAV center of gravity to the elevon hinge line. This is the main reason why the MH 60 airfoil has been chosen despite its slightly worse characteristics than the SD 7003 airfoil. On the other hand, estimated aileron effectiveness, or aileron power that is a variation in the rolling moment coefficient with the change in aileron deflection has the value of 0.32 1/rad. The typical values of this derivative range from 0.1 to 0.25 1/rad. As flying wings have just elevon to control rolling and pitching motion, the larger relative control surface area has been necessary than the standard aileron confi–gurations. The excellent agreement with the estimated data by the analytical method given in [43] has been reached (-0.5588 1/rad, 0.303 1/rad).

7. FLIGHT TEST RESULTS AND DISCUSSION

The flight test data has been obtained by Blackbox flight data recorder tools [44]. The sample rate was 32 Hz. Flight test results for the flying wing prototype UAV are provided in the diagram (Figures 7 to 11). In the diagram (Figures 7 and 8), the GPS speeds and altitude of the UAV during flight have been given. The battery voltage and current consumption are given in the diagram (Figure 9). It can be evident that for a speed greater than 30 m/s, the current consumption is between 36 A and 40 A, and for a speed of 20 m/s (cruise speed), the current consumption is less than 10 A. This data will be used to define the final battery capacity according to the required endurance.

In Figure 10 the UAV attitude during the flight test has been given and in Figure 11 elevon flight control deflection is shown. Combining diagrams (Figures 8 and 11) it is possible to obtain elevon control deflection vs GPS speed. It is shown in the diagram (Figure 12).

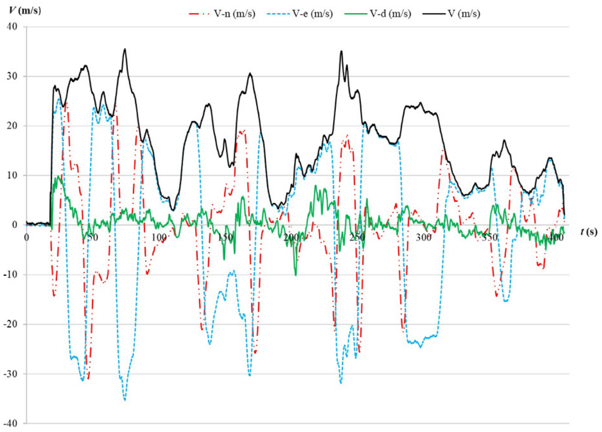

Figure 7. UAV GPS speeds during the flight test

Figure 8. UAV Altitude during the flight test

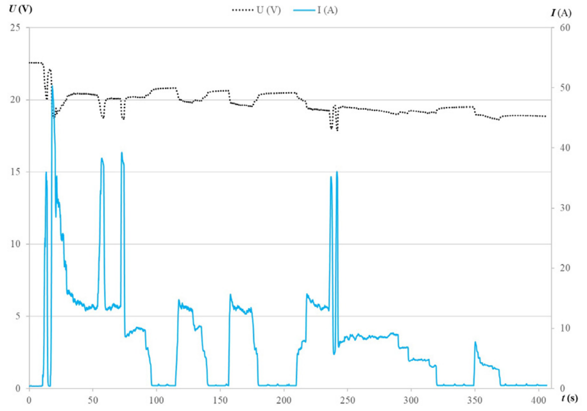

Figure 9. UAV voltage and current consumption during the flight test

The experimental results for the flying wing UAV prototype shown in the diagram (Figure 12) indicated that for trimming the UAV in a level flight at a speed greater than 10 m/s the flight control deflection is usually less than 12 deg. Additional elevon deflection is necessary for maneuvers (lateral-directional control) or to compensate propeller torque effect.

The difference in left and right elevon deflection during horizontal straight flight defined aileron deflection necessary to compensate propeller-motor torque. During the take-off phase, the maximum differential deflection of the elevon has been less than 3 degrees. It is the consequence of relatively higher aileron power than the typical values. For detailed, lateral-directional flight control analysis the data from the dissertation given in reference [45], and papers [46-48] should be used. This is especially important and necessary to apply in the terminal stages of the flight and in cases of all asymmetries that may arise, such as sudden gusts of side wind, sudden failure of one of the engines in multi-engine aircraft, recoil due to the effect of weapons, asymmetrically placed cargo, or aircraft damage, etc.

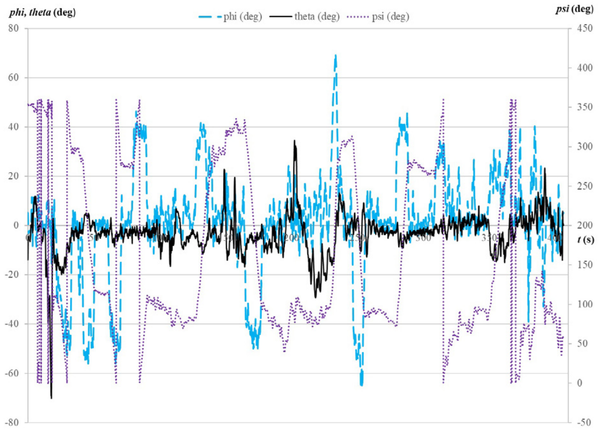

Figure 10. UAV attitude during the flight test

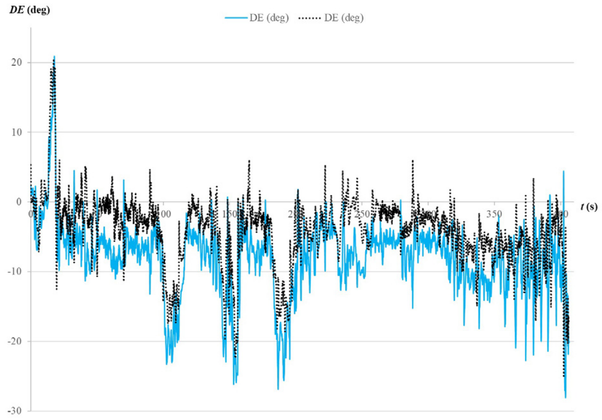

Figure 11. UAV elevon flight control deflection during the flight test

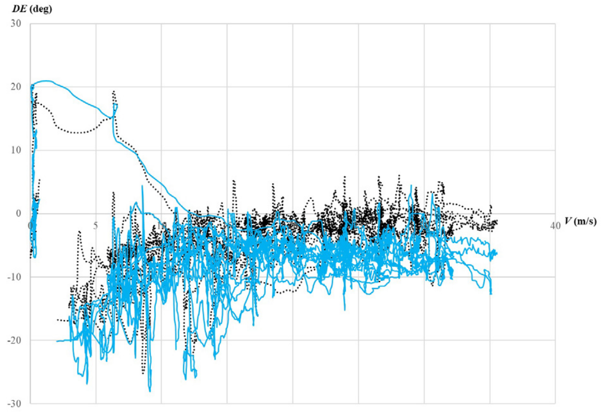

Figure 12. Elevon flight control deflection vs GPS speed

The flight test RC operator did not have any problem operating the UAV in FPV (first-person view) mode during flight testing. This confirms that UAVs possess adequate stability reserves and elevon power that enable adequate flying quality. This is an excellent result for the first flying wing UAV prototype design. It should be noted that during the flight phase, it was evident that UAV is very sensitive to the lateral wind. To improve the lateral-directional flying quality during the landing flight phase the winglets at the tip chord could be added as the vertical tail surfaces.

8. CONCLUSION

The flight-testing data indicates that at low airspeeds the longitudinal stability reserve of 10% of the mean aerodynamic chord will provide adequate stability characteristics of flying wing UAV. The results suggested that the authority of the control surfaces provides adequate stability and control of the UAV without the need for a stability augmentation system.

The method for flying wing design presented in this paper has proved to be time efficient when testing many different airfoils and design parameters, providing reliable results that show good comparison with obtained flight test data. The method provided fast and precise results of the stability and control characteristics that can be easily estimated in the preliminary design phase. The obtained are in good agreement with the flight test data and the data given in currently available literature [22, 23, 35, 36]. It will be used in future aircraft and UAV projects in VTI.

In the next phase of UAV development, it is necessary to integrate domestic flight control computers and to test the developed flight control law [49] in order to verify final UAV capabilities [50].

REFERENCES

[1] STANAG 4671: Unmanned aerial vehicles systems airworthiness requirements, 2009.

[2] AEP-80: Rotary wing unmanned aircraft systems airworthiness requirements, 2016.

[3] AEP-83: Light unmanned aircraft systems airworthiness requirements, 2014.

[4] Harsha, S., Kumar, V. and Shrepal, A. M.: A study on Flight Mechanics of Tailless Aircraft, TMLA02 Exper Conference, 2019.

[5] Bill, R.: Secret projects flying wings and tailless aircraft, Ian Allan Publishing Ltd, 2010.

[6] NACA ACR No. L4H19: An interim report on the stability and control of tailless airplanes, 1944.

[7] Franc, D.: The design of Tailles airplanes, Thesis for the degree of Aeronautical Engineer, California Institute of Technology, 1947.

[8] NACA REPORT No. 837: Notes on the stability and control of tailless airplanes, 1941.

[9] https://en.wikipedia.org/wiki/Jack_Northrop.

[10] https://en.wikipedia.org/wiki/Horten_brothers.

[11] Rahman, N.: Propulsion and Flight Controls Integration for the Blended Wing Body Aircraft, PhD Thesis, Cranfield University, 2009.

[12] Chukwuemeka Okonkwo, P. P.: Conceptual Design Methodology for Blended Wing Body Aircraft, PhD Thesis, Cranfield University, 2016.

[13] De Castro, H.V.: Flying and Handling Qualities of a Fly-by-Wire Blended-Wing-Body Civil Transport Aircraft, PhD Thesis, Cranfield University, 2003.

[14] De Castro, H.V.: COA report No. 0018/1, The Longitudinal Static Stability of Tailless Aircraft, Cranfield University, 2001.

[15] Cook, M.V. and De Castro, H.V.: The longitudinal flying qualities of a blended-wing-body civil transport aircraft, The Aeronautical Journal, February 2004.

[16] Martinez-Val, R., Flying Wings. A New Paradigm for Civil Aviation, Acta Polytechnic Vol. 47 No. 1, 2007.

[17] Nickel, K. and Wohlfahrt, M.: Tailless Aircraft in Theory and Practice, American Institute of Aeronautics and Astronautics, 1994.

[18] Perkins, C.D. and Hage, R.E.: *Airplane performance stability and control*, John Wiley& Sons, New York, 1949.

[19] Abbot, I. and Alber Von Doenhoff A.: Theory of wing section Including a Summary of Airfoil Data, 1959.

[20] Sandapeta, S.V., Parre, S.K., Dedeepya, Y., Aidroos, H.J. and Krishna Reddy, M.V.: Design and Analysis of Flying Wing UAV using XFLR5, International Journal of Advancements in Mechanical and Aeronautical Engineering, Volume 6, Issue 1, ISSN: 2372-4153, Publication Date: 10 May, 2019.

[21] Sandapeta, S.V., Parre, S.K. and Mitta, V.N.C.N.: Conceptual Design and Analysis of Flying Wing Drone, International Journal of Scientific & Engineering Research Volume 9, Issue 8, August 2018.

[22] Chung, P.H., Ma, D.M. and Shiau J.K.: Design, Manufacturing, and Flight Testing of an Experimental Flying Wing UAV, Appl. Sci. 2019.

[23] Dagur, R., Singh, V., Grover, S., Sethi, N. and Arrora, B.B.: Design of Flying Wing UAV and Effect of Winglets on its Performance, International Journal of Emerging Technology and Advanced Engineering, Volume 8, Issue 3, March 2018.

[24] Raymer, D.: Aircraft Design: A Conceptual Approach, Fifth Edition, AIAA education series, 2012.

[25] http://airfoiltools.com/search/index.

[26] Selig, M.: Summary of Low-Speed Airfoil Data Book, https://m-selig.ae.illinois.edu/uiuc_lsat.html.

[27] Dinh, A.B., Ngo, K.H. and Nguyen, N.V.: An efficient low-speed airfoil design optimization process using multi-fidelity analysis for UAV flying wing, TAÏP CHÍ PHAÙT TRIEÅN KH&CN, TAÄP 19, SOÁ K5- 2016.

[28] Prisacariu, V., Performance Analysis of the Flying Wing Airfoils, Recent, Vol. 18, No. 1(51), March, 2017.

[29] Edi, P., Yusoff, N. and Yazid, A.A.: Airfoil Design for Flying Wing UAV, Proceedings of the 4th

WSEAS International Conference on Applied and Theoretical Mechanics, 2008.

[30] https://web.mit.edu/drela/Public/web/xfoil/.

[31] https://www.xflr5.tech/xflr5.htm.

[32] https://openvsp.org/start.shtml.

[33] USAF Stability and Control DATCOM, Air Force Flight Dynamics Laboratory & Douglas Aircraft Company, Inc, Wright-Patterson Air Force Base, Ohio, 1965/1978.

[34] Kostić, I., Stefanović, Z. and Kostić, O.: Aerodynamic Analysis of a Light Aircraft at Different Design Stages, FME Transaction, Vol. 42, No 2, pp. 94-105, 2014.

[35] Pepelea, D., Cojocaru, M.G., Toader, A. and Niculescu, M.L.: CFD Analysis for UAV of Flying Wing, Scientific research and education in the air force, AFASES, pp.171-176, 2016.

[36] Winter, A., Hann, R., Wenz, A., Gryte, K. and Johansen, T.A., Stability of a Flying Wing UAV in Icing Conditions, 8th European conference for Aeronautics and aerospace sciencies (EUCASS), 2019.

[37] Roskam, J.: Methods for Estimating Drag Polars of Subsonic Airplanes, 1971.

[38] Theory and Practice of Using Flying Wings, https://apogeerockets.com/education/downloads/Newsletter15.pdf.

[39] Milenković-Babić, M., Samardžić, M., Antonić, V., Marjanović, M. and Stefanović-Gobeljić, V.: Longitudinal stability characteristics of the LASTA airplane, Aircraft Engineering and Aerospace Technology, Vol. 89 Issue: 6, pp.911-919, 2018.

[40] Milenković-Babić, M., Samardzić, M., Stojaković, P. and Rašuo. B.: Stability characteristics of the single-engine tractor propeller airplane in climb, Aerosp. Sci. Technol. 46, 227–235, 2015.

[41] Milenković-Babić, M.: Propeller thrust force contribution to airplane longitudinal stability, Aircraft Engineering and Aerospace Technology, Vol. 90 Issue: 9, pp.1474-1478, 2018.

[42] Milenković-Babić et al.: Aircraft Lasta Take-Off and Landing Performance, Scientific Technical Review, Vol.69, No.1, pp.32-38, 2019.

[43] Smetana, F.: Computer Assisted Analysis of Aircraft Performance Stability and Control, McGraw-Hill, New York, 1984.

[44] https://github.com/cleanflight/blackbox-tools.

[45] Stojaković, P.: Analysis of the External Stores and Asymmetric Loads Influence on the Airplane Flight Dynamics, PhD Thesis, University of Belgrade, Faculty of Mechanical Engineering, 2012. [in Serbian]

[46] Stojaković, P., Rašuo, B.: Single propeller airplane minimal flight speed based upon the lateral maneuver condition, Aerospace Science and Technology, Vol. 49, February 2016, pp. 239-249, doi: 10.1016/j.ast.2015.12.012

[47] Stojaković, P., Velimirović, K., Rašuo, B.: Power optimization of a single propeller airplane take-off run on the basis of lateral maneuver limitations, Aerospace Science and Technology, Vol. 72, Jan. 2018, pp. 553-563, doi: 10.1016/j.ast.2017.10.015

[48] Stojakovic, P., Rasuo, B.: Minimal Safe Speed of the Asymmetrically Loaded Combat Airplane, Aircraft Engineering and Aerospace Technology: An International Journal, Vol. 88, Issue 1, 2016, doi: 10.1108/AEAT-03-2014-0033

[49] De Simone, M. C. and Guida, D.: Control Design for an Under-Actuated UAV Model, FME Tran–saction, Vol. 46, No 4, pp. 443-452, 2018.

[50] Marin, M. and Mirosavljević, P.: Analysis of the performance and kinematics of the movement of UAV, FME Transaction, Vol. 51, No 4, pp. 627-636, 2023.

КОНЦЕПТУАЛНИ ДИЗАЈН БЕСПИЛОТНЕ ЛЕТЕЛИЦЕ ТИПА ЛЕТЕЋЕ КРИЛО И ЛЕТНА ИСПИТИВАЊА

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Главна сврха овог рада је да презентује методологују за концептуални дизајн беспилотне летелице типа летеће крило коришћењем бесплатних софтверских програма за поређење карактеристика аеропрофила и њихов дизајн као и софтwер за параметарски моделовање димензија летелице и аеродинамичку анализу. После дефинисања финалне геометрије летелице израђена је прототип од стиропора исеченог врелом жицом ојачаног шпером погоњеног јеномодорним БЛДЦ електромотором са потисном елисом. Упоређена је прорачунска полара летелице са резултатима летних испитивања и верификоване су стабилносне и управљацке карактеристике летелице. Остварени резултати показују да се летелицом може управљати без потребе за коришћењем система за повећање стабилности чиме се потврђује валидност описане методологије у овом раду.