UDC 629.735.33(045)
DOI:10.18372/1990-5548.86.20565

[1]**O. I. Zhdanov,**
[2]**O. A. Sushchenko,**
[3]**N. V. Yakubovskyi**

INFLUENCE OF AIRFOIL LAYOUTS ON UAV AERODYNAMIC CHARACTERISTICS AT HIGH ANGLES OF ATTACK

State University "Kyiv Aviation Institute," Kyiv, Ukraine, State University of Information and Communication Technologies, Kyiv, Ukraine
E-mails: [1]azhdanov@kai.edu.ua ORCID 0000-0001-5273-571X
[2]sushoa@ukr.net ORCID 0000-0002-8837-1521, [3]6349669@stud.kai.edu.ua ORCID 0009-0001-3658-3792

Abstract*—This article represents the study of the influence of airfoil layouts on aerodynamic coefficients at high angles of attack. The review of the previous research on the studied topic is given. The features of experimental equipment are described, including the set of sensors for the aerodynamic balance and the information and measurement system. The features of the described experimental equipment allow to realize the automation of the experimental test. The main features of the experiment technique are given. The main functions of the information and measurement system are listed. The results of the experimental test are represented as graphical dependencies of aerodynamic coefficients on angles of attack. The detailed analysis of the obtained results has been done. The results of the study can be useful for designing unmanned aerial vehicle motion control systems and simulating unmanned aerial vehicle motion, taking into consideration aerodynamic disturbances.*

Keywords—Motion control system; aerodynamic coefficients; experimental test; wind tunnel; airfoil layout; angle of attack.

I. INTRODUCTION AND PROBLEM STATEMENT

The research described in this paper is aimed at expanding the range of flight angles of attack, eliminating the phenomena of aerodynamic hysteresis, stalling, and spin, global separation of the air flow on the wing, and controls of unmanned aerial vehicles during subsonic flight modes using volumetric vortex generators on the leading edge of the wing.

The study of the influence of the vortex generators on the aerodynamic characteristics of unmanned aerial vehicles (UAVs) is necessary to optimize the operating parameters and develop an optimal airfoil of a vortex-active wing.

In this research, it is proposed to use the energy of the incident flow at the leading edge of the wing using volumetric generators, which provide more effective flow acceleration due to the streamlined shape and have a separating vortex-forming edge.

Volumetric vortex generators form a new, not yet sufficiently studied type of unsteady flow around the wing-longitudinal vortex flow. Studying its features will allow us to improve the design of vortex generators and increase the stability and controllability of aerodynamic layouts.

The represented research is of great importance for the control of aircraft in general and UAVs in particular. Studying the influence of volumetric vortex generators on the aerodynamic characteristics enables us to improve the mathematical model of a UAV with vortex generators and, correspondingly, the motion control system procedure. This leads to the efficient carrying out of given missions. Moreover, the flight safety and control accuracy are increased significantly.

The main goal of the research is to describe the features of the experiment in the wind tunnel directed to studying aerodynamic characteristics of UAVs with volume vortex generators. Great attention is given to the behavior of the aerodynamic coefficients in the region of subcritical angles of attack.

II. REVIEW OF PUBLICATIONS

Some features of the information and measuring system, as a part of the equipment necessary for carrying out experiments in the wind tunnel of a definite type used in the experiments under study, are described in publications [1], [2]. The paper [1] deals with the detailed description of the measuring errors of the equipment in the wind tunnel. The general approach to the research of the aerodynamic characteristics in the wind tunnel is represented in the paper [2].

The paper [3] represents the results of a study on the effect of triangular vortex generators on the airfoil aerodynamic coefficients. The experiments were carried out in the boundary layer wind tunnel, only using an aerodynamic balance and a visualization system. In contrast to this research, we use the transducers and information and measurement data, which ensure some automation of obtaining data about aerodynamic coefficients depending on the angle of attack.

Publications [4] and [5] deal with different interesting aspects of carrying out experiments in the wind tunnel.

Papers [6] and [7] are connected with testing UAVs in the wind tunnel. The main subject of the paper [6] is the study of the influence of the airfoil o the UAV aerodynamics for low Reynolds numbers. Whereas the given research is oriented on the study of the UAV's aerodynamics in the region of critical angles of attack.

The interesting study of the aerodynamic process during the movement of a UAV near the ground is described in the paper [8]. The authors researched four airfoils of different shapes, which are used in subsonic the high-speed aircraft. The advantage of this paper is the determination of the aerodynamic performance depending on the angle of attack. Such an approach allows for optimizing the carrying out of UAV missions.

The aerodynamic performance of two distinct airfoils is also researched in the paper [9]. Authors are researching in [9] three protuberance shapes, such as sinusoidal, slot, and triangular. The features of the equipment used in [9] are the subsonic wind tunnel and the sensitive three-component force balance. The processes used in [9] belong to fluid dynamics, but general approaches can be used for the dynamics of other objects.

The analysis and optimization of an airfoil based on global sensitivity analysis are represented in the paper [10]. A study of aerodynamic characteristics in wide operating conditions is described in publications [11], [12].

III. FEATURES OF EQUIPMENT

To determine the dimensionless aerodynamic coefficients of forces and moments of the UAV's blowing model, it is possible to experimentally measure them using a weight experiment in a wind tunnel. Tests are conducted for airflows approaching at different angles. The features of tests correspond to the UAV's operating conditions [13], [14].

The automation of tests is implemented in two aspects. Firstly, the mechanical system of the aerodynamic balance is changed to a strain gauge system. Secondly, an information and measurement system ensures automation of measurements.

The wind tunnel, in which the described research has been carried out, presents a closed-type atmospheric plant with an open elliptical working part. A fan is driven by an asynchronous AC motor with a system of speed smooth regulation. This allows keeping the airflow speed within 5–30 m/s. The tube is equipped with a three-component aerodynamic balance, which allows measuring the three components of the total aerodynamic force and compensating for the weight of the model and counterweights. When there is no airflow, the rods of the force distribution system in the equilibrium state are connected to strain gauge transducers through collet clamps that receive the aerodynamic forces. The process of tests in the wind tunnel is illustrated in Fig. 1. The blowing model is suspended in the aerodynamic balance. Side screens are not shown.

The mechanism for changing the angular position of the model provides a change of the angle of attack in the range –20…+40°.

The important constituent of the applied equipment is the information and measuring system developed in the graphical programming environment LabVIEW.

The information and measurement system carries out the following functions.

- Connecting strain gauges to the force distribution system of the three-component aerodynamic balance.
- Amplification of signals from strain gauges and their transmission to the computer.

Fig. 1. The blowing model during tests on aerodynamic balance in the wind tunnel

- Measurement of the pressure difference between the wind tunnel's previous chamber and the atmosphere to determine the dynamic head.
- Control of the model position (angle of attack) using the standard α-mechanism of the aerodynamic balance, both in manual mode and under computer control.

The strain gauges placed inside the wind tunnel are operated in difficult climatic conditions. To reduce possible temperature errors, calibration and polynomial approximation at the beginning of the research are carried out.

The zero correction before the start of each experiment is also performed. The described equipment ensures carrying out experiments in the wind tunnel to research the influence of airfoil components on the UAV's aerodynamic coefficients.

The obtained results can be useful for creating the mathematical model and, correspondingly, the synthesis of the UAV motion control system. Moreover, the results can be applied for modelling UAV motion in conditions real to operating ones.

IV. Experimental Study and Results

The factors influencing the aerodynamic characteristics of aerodynamic surface layouts with volumetric vortex generators include: the external geometry of the vortex generators, dimensions relative to airfoil, the degree of protrusion beyond the leading edge of the airfoil, the angle of inclination relative to the chord of the airfoil, the step of mounting the vortex generator along the span of the airfoil, and other parameters.

Conducting such multifactorial studies to determine the optimal layout schemes requires a substantial number of model tests in a wind tunnel and the processing of the resulting data.

The installation of vortex generators allows to an increase in the permissible critical angle of attack and an increase in the lift force. Such modification of the aerodynamic characteristics of the airfoil is important for unforeseen subcritical or supercritical angles of attack, regardless of the reasons (atmospheric effects, piloting errors, or other factors) [15], [16].

At the same time, the use of vortex generators should not negatively affect the characteristics in the cruising flight mode; it is desirable to maintain maximum aerodynamic quality and optimal angle of attack. Hence, the criteria for the optimality of the airfoil configuration with volumetric vortex generators can be the features of the change in lift force at subcritical and supercritical angles of attack compared to the version without vortex generators. These features can be characterized by the values of the critical angle of attack α_{cr}, the maximum lift coefficient $C_{y\ \max}$, the gradient in the supercritical region $C_{y\alpha}$, and the angle of attack deviation α_1 from the linear dependence $C_y = f(\alpha)$.

The installation of vortex generators influences the flow around the airfoil by artificially forming an ordered system of large longitudinal vortices along the span of the model.

These vortices interact with the external air flow and provide a gradual, smooth restructuring of the flow structure over the upper surface of the airfoil at supercritical angles of attack. This is significantly different from the situation without vortex generators, when the transition to the supercritical region occurs abruptly and covers the entire surface.

The installation of vortex generators should lead to an increase in the critical angle of attack and the elimination of a sharp drop in lift. To increase lift, the upper surface of the toe of a vortex generator is shaped in such a way that a down force arises in this zone. For example, a certain curvature can increase the local flow velocity. Down force projections increase lift and reduce drag in the wind coordinate system. The effectiveness of the vortex generator is determined by dimensions relative to the airfoil, quantity, and spacing along the span.

These factors together form the surface area of the airfoil. The angle of installation of the vortex generator relative to the chord of the airfoil changes the aerodynamic characteristics of the airfoil depending on the angle of attack.

The object to be studied represents the symmetric airfoil NACA0012 [17]. The technique of tests has some features [1], [2].

Firstly, the airflow velocities cover the transition from the subcritical to the supercritical mode of the flow around the aerodynamic surface. In this range, a significant restructuring of the boundary layer and vortex structures occurs, which causes corresponding changes in the aerodynamic characteristics of the blowing model. Therefore, it is necessary to study the influence of the Reynolds number on the model's aerodynamic characteristics in the specified range. In addition, the degree of turbulence of the flow should be taken into account, since it also determines the change in the flow mode. It is worth mentioning that at low flow velocities, the compressibility of the air does not affect the aerodynamic characteristics of the model.

Secondly, the equipment in the wind tunnel creates conditions for flow around the airfoil with an infinite span due to the installed side screens. This makes it possible to separate the influence of the vortex generator installation on the aerodynamic characteristics of the model, caused by the formation of longitudinal vortices on the airfoil surface, from the influence arising due to the finite vortices.

Thirdly, studies of the change in aerodynamic characteristics are conducted over a wide range of angles of attack, encompassing significant supercritical values, for both forward and reverse movements of the α-mechanism, to investigate the phenomenon of aerodynamic hysteresis during increasing and decreasing angles of attack.

To determine the optimal layouts, the dependence $C_{ya} = f(\alpha)$ on the region of subcritical and supercritical angles of attack, values $C_{y\max}$, α_{cr}, the value and sign of the change gradient C_y^α in the supercritical region must be studied. The desired result of vortex generators' application is to increase the magnitude of the lifting force and eliminate its sharp decrease in the supercritical region. This can be achieved by restructuring the global separation at critical angles of attack by an ordered set of longitudinal vortices created by generators. The above-mentioned dependence is shown in Figs 2 – 4, taking into consideration the influence of vortex generators. Analysis of the dependence in Figs 2 – 4 shows that the use of the vortex generators significantly changes the dependence in the subcritical and supercritical regions, depending on the layout parameters and the shape of the vortex generators. By installing the vortex generators, it is possible to form such a lifting force in the supercritical region, which actually eliminates the concept of a critical angle of attack.

In the zone of large supercritical angles of attack (over 24°), the growth of the lifting force leads to a situation similar to the absence of the vortex generators. However, sometimes situations are observed when the growth of the lifting force without the vortex generator is more abrupt. Hence, the influence of the vortex generators at high angles of attack takes place. This leads to a decrease in rarefaction above the upper aerodynamic surface, or to a decrease in the air pressure under the lower surface of the airfoil. The dependence $C_{ya} = f(\alpha)$ in the presence of vortex generators becomes nonlinear already at lower angles of attack. However, this nonlinearity is not associated with the beginning of flow separation. It is caused by a change in the structure under the influence of interaction with longitudinal vortices created by generators and their departure from the aerodynamic surface.

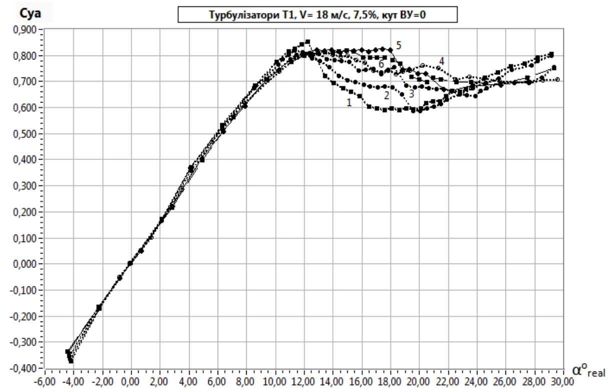

Fig. 2. The dependence $C_{ya} = f(\alpha)$: 1 is a without vortex generators; 2 is the 1 vortex generator; 3 are 3 vortex generators, step 88 mm; 4 are 5 vortex generators, step 70 mm; 5 are 7 vortex generators, step 44 mm; 6 are 9 vortex generators, step 35 mm

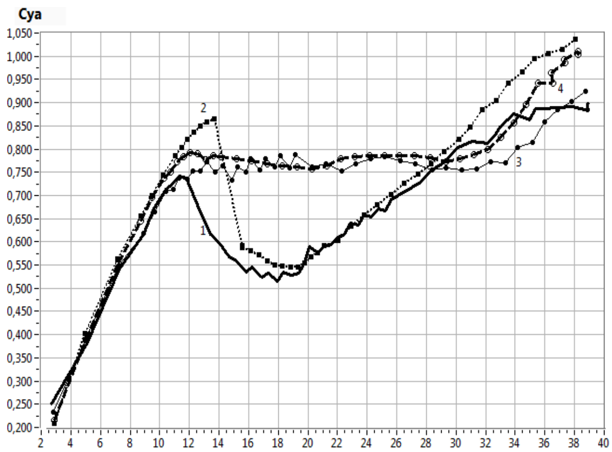

Fig. 3. The dependence $C_{ya} = f(\alpha)$: 1 are without vortex generators, V = 9 m/s; 2 are without vortex generators, V = 27 m/s; 3 are with vortex generators, V = 9 m/s; 4 are with vortex generators, V = 27 m/s

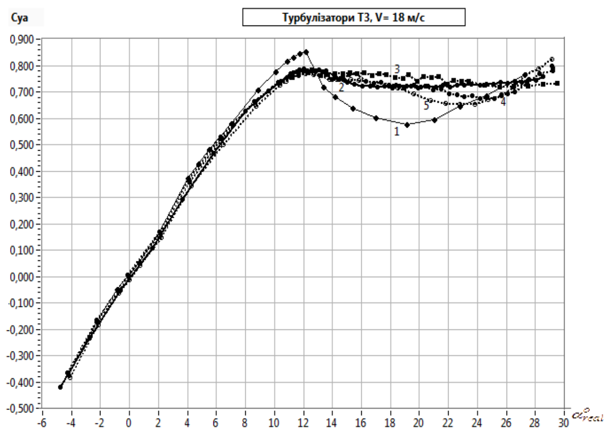

Fig. 4. The dependence $C_{ya} = f(\alpha)$: 1 are without vortex generators; 2 are 5 vortex generators, 2%, step 58 mm; 3 are 5 vortex generators, 14.6%, step 70 mm; 4 are 12 vortex generators, 7.5%, step 27 mm; 5 are 25 vortex generators, 3.5%, step 13.5 mm

In the zone of supercritical angles of attack without vortex generators, global flow separation usually occurs on the upper part of the airfoil. The use of vortex generators prevents a sharp separation of the transverse vortex due to the action of the system of longitudinal vortices. In this case, an ordered set of the vortices in the transverse direction is formed, which gradually moves away from the surface of the airfoil at supercritical angles of attack. As a result, the dependence becomes smoother [18] – [19].

The description of the physical picture of the influence of a vortex generator on the structure of the airflow on its upper surface during a change in the angle of attack is confirmed by visualization of the flow pattern using silkworms. This process is illustrated in Fig. 5.

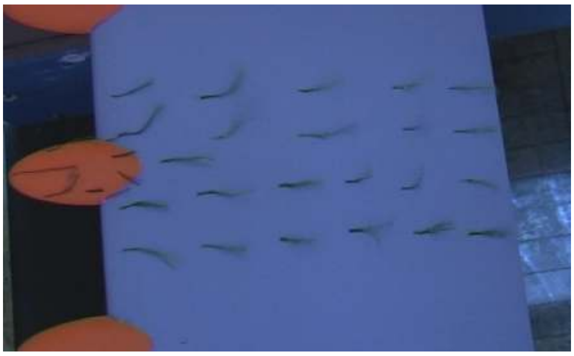

Fig. 5. Representation of the flow around the upper surface of the airfoil with vortex generators during the transition of the angle of attack to supercritical values using the silkworm method

The results represented in Figs 1 – 4 show the effectiveness of using vortex generators in the region of high angles of attack.

The obtained results can be useful for aircraft of the wide class [20] – [22].

V. CONCLUSIONS

The features of the equipment necessary for testing blowing models in the wind tunnel are represented. The features of the aerodynamic balance and the information and measurement system for the weight experiment are described. The possibilities of automation of the weight experiment are discussed. The features of researching aerodynamic characteristics in the wind tunnel are represented. The basic steps of the appropriate technique are given. The graphical dependencies of aerodynamic coefficients on the angle of attack are represented. The analysis of the obtained results is given.

The obtained data explain how large longitudinal vortices formed on the upper surface of the model by volumetric generators affect the air flow structure when the angle of attack increases to large supercritical values and global separation is eliminated.

It is promising to use the inherent aerodynamic features of the UAVs to improve the operating characteristics during flight at supercritical angles of attack, which may occur due to wind gusts, piloting errors, or other factors.

The conducted studies have identified areas for further improvement of the parameters of the aerodynamic layouts of UAVs using volumetric vortex generators. First of all, it is necessary to improve the shape of the vortex generators in terms of increasing the power, creating conditions for vortex adhesion to the surface, and increasing the speed of the airflow flowing around the nose of the airfoil and the vortex generator.

The obtained results can significantly improve the processes of creating a mathematical model and UAV simulation due to the possibility of taking into account nonlinear components of aerodynamic moments and models of disturbances based on experiments in the wind tunnel. The above-mentioned results can also be applied to creating an improved procedure for designing a UAV motion control system.

ACKNOWLEDGMENT

The research has been carried out in the framework of a grant from the Ministry of Education and Science of Ukraine for the scientific and research project “Grounding of aerodynamic layouts of prospective unmanned aerial vehicles with volumetric vortex generators on aerodynamic surfaces” (number of the state registration 0124U000221).

REFERENCES

[1] O. Zhdanov, O. Sushchenko, and V. Orlianskyi, “Analysis of measuring errors during aerodynamic research in wind tunnel,” In: Ostroumov, I., Marais, K., Zaliskyi, M. (eds) *Advances in Civil Aviation Systems Development. ACASD 2025. Lecture Notes in Networks and Systems*, vol. 1418. Springer, Cham. (2025) https://doi.org/10.1007/978-3-031-91992-3_1

[2] O. Zhdanov, V. Orlianskyi, O. Sushchenko, “Researching influence of vortex generators on aircraft aerodynamic characteristics,” In: Ostroumov, I., Zaliskyi, M. (eds.) *Proceedings of the 2nd International Workshop on Advances in Civil Aviation Systems Development. ACASD 2024, Lecture Notes in Networks and Systems*, vol. 992, pp. 410–422. Springer, Cham (2024). https://doi.org/10.1007/978-3-031-60196-5_30

[3] J. S. Delinero, J. M. Di Leo, and M. E. Camocardi, "Vortex generators effect on low Reynolds number airfoils in turbulent flow," *International Journal of Aerodynamics*, 2(1), 1–14, 2020. https://doi.org/10.1504/IJAD.2012.046539

[4] Y. Jia, J. Huang, Q. Liu, et al., "The wind tunnel test research on the aerodynamic stability of wind turbine airfoils," *Energy*, vol. 294, 130889, 2024. https://doi.org/10.1016/j.energy.2024.130889

[5] R. Li, J. Niu, Y. Zhao, et al., "Wind tunnel experiments on the aerodynamic effects of a single potted tree: Hot-wire anemometry and PIV measurements," *Urban Climate*, vol. 62, 102520, 2025. https://doi.org/10.1016/j.uclim.2025.102520

[6] T. Adeyi, O. O. Alabi, and O. A. Towoju, "Influence of airfoil geometry on VTOL UAV aerodynamics at low Reynolds numbers," *Archives of Advanced Engineering Science*, 2024. https://doi.org/10.47852/bonviewAAES42023485

[7] L. Habib, M. Joon, L. Ben-Tzur, et al., "Wind tunnel testing of a wing section for a small UAV," *In: Conference AIAA Aviation*, 2024. https://doi.org/10.2514/6.2024-3764

[8] A. Dreus and O. Kravets, "Rationale for choosing the airfoil of a UAV wing using a dynamic ground effect principle," *Eastern-European Journal of Enterprise Technologies*, 6(1), 6–13, 2024. https://doi.org/10.15587/1729-4061.2024.314844

[9] C. J. Reddy and A. Sathyabhama, "Comparative study on the effect of leading edge protuberance of different shapes on the aerodynamic performance of two distinct airfoils," *Journal of Applied Fluid Mechanics*, 16(1), 157–177, 2023. https://doi.org/10.47176/jafm.16.01.1334

[10] P. Rouco, P. Orgeira-Crespo, and G. D. R. Gonzalez, "Airfoil optimization and analysis using global sensitivity analysis and generative design," *Aerospace*, 12(3), 180, 2025. https://doi.org/10.3390/aerospace12030180

[11] S. Penchev and H. Panayotov, "A wind tunnel study of aerodynamic characteristics of wings with arc-shaped wingtips," *The 14th International Scientific Conference TechSys 2025—Engineering, Technologies and Systems*, 100(1), 2025, 28. https://doi.org/10.3390/engproc2025100028

[12] Y. Zhang, J. Luo, Y. Zheng, and Y. Liu, "Aerodynamic optimization in wide range of operating conditions based on reinforcement learning," *Aerospace*, 12(5), 44, 2025. https://doi.org/10.3390/aerospace12050443

[13] O. Biblarz, "Elements of aerodynamics: A concise introduction to physical concepts," London, Wiley, 2022.

[14] C. Britcher and D. Lanman, "Wind tunnel test techniques: Design and use at low and high speeds with statistical engineering applications," *Cambridge*, Academic Press, 2023.

[15] J. D. Anderson and J. C. Cadou, "Fundamentals of Aerodynamics," *Columbus*, Mcgraw-Hill, 2023.

[16] S. Discetti and A. Ianiro, "Experimental Aerodynamics," London, Taylor & Francis, 2017.

[17] K. Hufnagel, "Wind Tunnel Balances," Berlin, Springer, 2022.

[18] L. S. Zhiteckii, V.N. Azarskov, K.Y. Solovchuk, and O.A. Sushchenko, "Discrete-time robust steady-state control of nonlinear multivariable systems: A unified approach," *IFAC Proceedings*, vol. 47(3), 2014, 8140–8145. https://doi.org/10.3182/20140824-6-ZA-1003.01985

[19] Y. Hryshchenko, V. Romanenko, O. Chuzha, and V. Hryshchenko, "Telecommunication warning of the crew about the failure of on-board radio altimeters," *In: CEUR Workshop Proceedings on Cybersecurity Providing in Information and Telecommunication Systems*, CPITS 3654, 2024, 485–490. https://ceur-ws.org/Vol-3654/short18.pdf

[20] O. A. Sushchenko, "Robust control of angular motion of platform with payload based on H∞-synthesis," *Journal of Automation and Information Sciences*, 48(12), 13–26, 2016. https://doi.org/10.1615/JAutomatInfScien.v48.i12.20

[21] R. Voliansky, A. Sadovoi, and N. Volianska, "Interval model of the piezoelectric drive," in Proc. *14th International Conference on Advanced Trends in Radioelecrtronics, Telecommunications and Computer Engineering (TCSET)*, Lviv-Slavske, Ukraine, 2018, pp. 1–6, https://doi.org/10.1109/TCSET.2018.8336211.

[22] B. I. Kuznetsov, T. B., Nikitina, and I. V. Bovdui, "Multiobjective synthesis of two degrees of freedom nonlinear robust control by discrete continuous plant," *Technical Electrodynamics*, vol. 5, pp. 10–14, 2020. https://doi.org/10.15407/techned2020.05.010

Received 11 August 2025

Zhdanov Oleksandr. ORCID 0000-0001-5273-571X. Candidate Sciences (Engineering). Senior Researcher.
Aerospace Faculty, State University "Kyiv Aviation Institute", Kyiv, Ukraine.
Education: Kyiv Institute of Civil Aviation Engineers, Kyiv, Ukraine, Kyiv, Ukraine (1982).
Research area: wind tunnel experiments.
Publications: 12.
E-mail: azhdanov@kai.edu.ua

Sushchenko Olha. ORCID 0000-0002-8837-1521. Doctor of Engineering. Professor.
Faculty of Air Navigation, Electronics and Telecommunications, State University "Kyiv Aviation Institute", Kyiv, Ukraine.
Education: Kyiv Polytechnic Institute, Kyiv, Ukraine (1980).
Research area: motion control and inertial navigation systems.
Publications: 351.
E-mail: sushoa@ukr.net

Yakubovskyi Nazar. ORCID 0009-0001-3658-3792. Postgraduate Student.
Faculty of Air Navigation, Electronics and Telecommunications, State University "Kyiv Aviation Institute", Kyiv, Ukraine
Education: State University "Kyiv Aviation Institute" (2024).
Research area: aviation transport.
Publications: 1.
E-mail: 6349669@stud.kai.edu.ua

О. І. Жданов, О. А. Сущенко, Н. В. Якубовський. Вплив компонування аеродинамічних профілів на аеродинамічні коефіцієнти БПЛА для великих кутів атаки

У статті досліджується вплив компонування аеродинамічних профілів на аеродинамічні коефіцієнти при великих кутах атаки. Наведено огляд попередніх досліджень з досліджуваної теми. Описано характеристики експериментального обладнання, включаючи набір датчиків аеродинамічного балансу та інформаційно-вимірювальну систему. Характеристики описаного експериментального обладнання дозволяють реалізувати автоматизацію експериментального випробування. Наведено основні особливості методики експерименту. Перелічено основні функції інформаційно-вимірювальної системи. Результати експериментального випробування представлені у вигляді графічних залежностей аеродинамічних коефіцієнтів від кутів атаки. Проведено детальний аналіз отриманих результатів. Результати дослідження можуть бути корисними для проектування систем керування рухом БПЛА та моделювання руху БПЛА з урахуванням аеродинамічних збурень.

Ключові слова: система керування рухом; аеродинамічні коефіцієнти; експериментальне випробування; аеродинамічна труба; компонування аеродинамічного профілю; кут атаки.

Жданов Олександр Іванович. ORCID 0000-0001-5273-571X. Кандидат технічних наук. Старший науковий співробітник.
Аерокосмічний факультет, Державний університет "Київський авіаційний інститут", Київ, Україна.
Освіта: Київський інститут інженерів цивільної авіації (1982)
Напрям наукової діяльності: експерименти в аеродинамічній трубі
Кількість публікацій: 12.
E-mail: azhdanov@kai.edu.ua

Сущенко Ольга Андріївна. ORCID 0000-0002-8837-1521. Доктор технічних наук. Професор.
Факультет аеронавігації, електроніки та телекомунікацій, Державний університет "Київський авіаційний інститут", Київ, Україна.
Освіта: Київський політехнічний інститут, Київ, Україна, (1980).
Напрям наукової діяльності: системи стабілізації інформаційно-вимірювальних пристроїв.
Кількість публікацій: 351.
E-mail: sushoa@ukr.net

Якубовський Назар Віталійович. ORCID 0009-0001-3658-3792. Аспірант.
Факультет аеронавігації, електроніки та телекомунікацій, Державний університет "Київський авіаційний інститут", Київ, Україна.
Освіта: Державний університет "Київський авіаційний інститут, (2024).
Напрям наукової діяльності: авіаційний транспорт.
Кількість публікацій: 1.
E-mail: 6349669@stud.kai.edu.ua