مجلة دجلة • المجلد ٦ ،العدد ٣ (٢٠٢٣)، ص: ٣١ - ٤١
ISSN: 2222-6583

Assessing the Impact of Vortex Generator Positioning on the Aerodynamic Characteristics of a Wing Section.

Abbas Fadhil Mahmood
Department of Power Mechanical Engineering Technologies ،Dijlah College University
abbas.aldoory@duc.edu.iq

ABSTRACT

The experimental results of studies of the effect of vortex generators installed on the RSG–36 wing model in an open wind tunnel are presented. The influence of the design and various position options of vortex generators, as well as their mutual arrangement in the longitudinal and transversal directions on the aerodynamic characteristics of the wing model, is investigated. The parameters of the vortex generators are revealed, at which the greatest influence on the aerodynamic characteristics of the specified wing model is found.

Keywords: CD Drag coefficient, CL Lift coefficient, M_Z Pitch moment coefficient, vortex generator.

1. INTRODUCTION

Vortex generators (VGs) are an effective method to control flow separation in the boundary layer, The first use of VG was done by Taylor [1]. The vortex generator brings energy from the external flows into the boundary layer and is mainly used to control already separated flow on the wings. Recently, intensive research separate types of coherent vortex structures arising from the flow of real tel. [2]

Initially, methods of controlling the bearing characteristics of the wing profile with energy supply or using various types of wing mechanization were investigated. Examples of the first method can be suction and injection of liquid into the boundary layer. The second method includes interceptors, deflecting slats and flaps mounted on the profile, and other types of wing mechanization.

It is known that each blade-vortex generator, installed at its angle of attack to the local flow, generate forms a single attached vortex behind itself. The prevention of separation of the boundary layer depends mainly on the intensity and location of individual vortices located directly in an unfavorable pressure gradient area[3]. When a correct selection of the geometric parameters of the vortex generators and their location on the surface, it is possible to achieve a backward displacement along the flow and, in some cases, complete elimination of the separation of the boundary layer that occurs with an unfavorable pressure gradient [aa].

For more accurate assessment of the effect of vortex generators on the aerodynamic characteristics of the wing compartment, these characteristics were experimentally determined for the studied model of the wing compartment without vortex generators.

ISSN: 2222-6583

In the presented work considers, four options for installing a vortex generator to the flow and along the chord of the profile. The vortex generator selected for the experiment with the wing compartment has the most optimal geometric characteristics obtained during pipe tests on a flat plate.

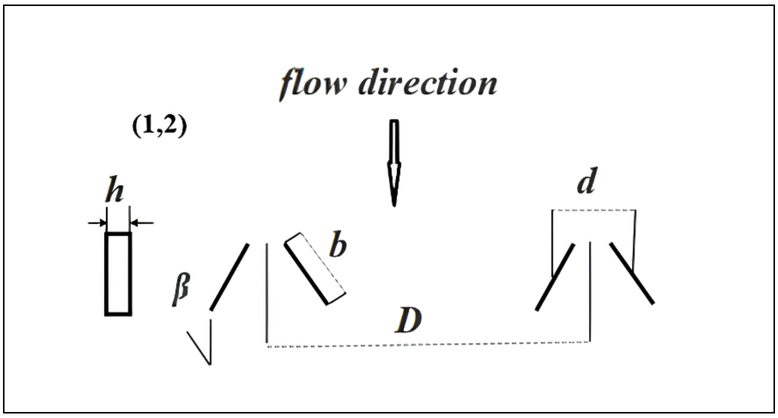
2. EXPERIMENTAL INSTALLATION AND EQUIPMENT TO STUDY THE EFFECT OF GW ON THE CHARACTERISTICS OF THE WING MODEL

2.1 Experiment work

The experimental setting and the analysis of this results studies about the effect of vortex generators on the boundary layer are given in [4] demonstrates that confirmed the optimum effectiveness corresponds to the value of the D/b ratio equal to 4. Where (D) is the distance between two pairs of VG, and (d) length of VG.

Similar measurements were subsequently performed for all (VG) locations on the wing model are shown in fig (1).

In option -1, the wing model was fitted with six diffusion types (VG) $\bar{\boldsymbol{D}} = \mathbf{4}$; D=72.8 mm;$\bar{\boldsymbol{X}}_{\boldsymbol{VG}} = \mathbf{10}\%$. Option -2 accommodated the same six diffusions (VG) at $\bar{\boldsymbol{D}} = \mathbf{4.5}$; D=82 mm;$\bar{\boldsymbol{X}}_{\boldsymbol{VG}} = \mathbf{20}\%$. In contrast to option 1, the finite (VGs) was in a transversal direction along the span of the wing mole near the vertical end washers and influenced the formation of angular vortices between the washers and the surface of the wing profile. For option -3, the wing model was provided with 17 (VGs) in vertical records at $\bar{\boldsymbol{D}} = \mathbf{1.44}$; D=26.2 mm;$\bar{\boldsymbol{X}}_{\boldsymbol{VG}} = \mathbf{20}\%$. For option 4, the (VGs) were arranged as in options 1 and 3, but for option 1 only, there were nine instead of six. The ratios have changed accordingly $\bar{\boldsymbol{D}} = \mathbf{2.75}$; D=50 mm.



ISSN: 2222-6583

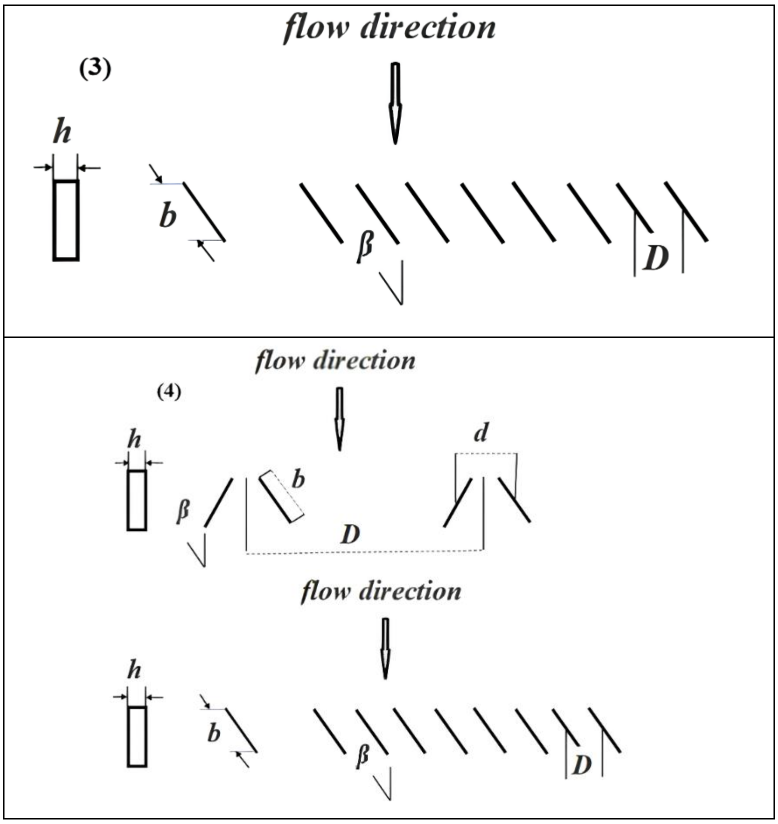


Fig. 1. Types (VG) of investigated configurations.

2.2 Description of models for experimental studies

The model of the wing section was tested in the wind tunnel with chord (b=200 mm) and wingspan 410 mm as shown in Fig1. The profile of model RSG-36 has the greatest thickness C_{max} =30 mm at the coordinate of the greatest thickness xc =54mm, the maximum curvature f_{mac}=8mm, is presented in the figure:

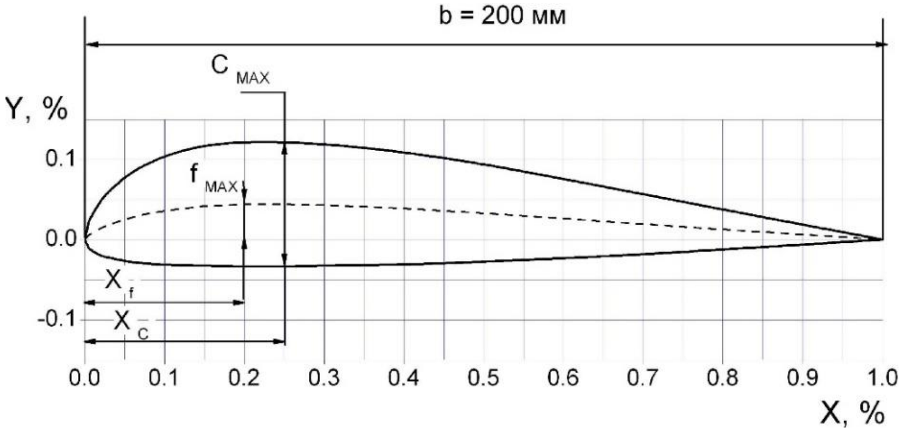


Fig.2.The geometry of RSG-36 profile.

مجلة دجلة • المجلد ٦ ،العدد ٣ (٢٠٢٣)، ص: ٣١ - ٤١
ISSN: 2222-6583

A vortex generator (VG) is an aerodynamic device consisting of a small blade, usually attached to a bearing surface (or an aerodynamic profile, such as an airplane wing) or the rotor blade of a wind turbine.

An experimental study of the susceptibility of the boundary layer to three-dimensional perturbations on the wing profile was carried out in the wind tunnel UTAD-2 National Aviation University - Kyiv – Ukraine.{5} УТАД-2 – wind tunnel with an open test section.

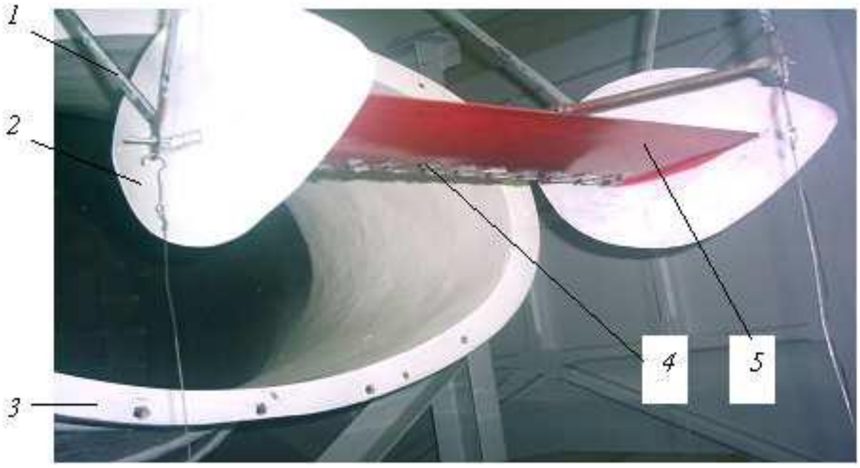


Fig. 3. The Placement of the wing model in the working section of the wind tunnel:

1-strain gauge suspension;2- wing model end washers;3- a cross-section of the working area;4- vortex generators; 5- RSG–36 wing model.

2.3 Analysis of the test results of vortex generators in various configurations.

a) Increment of the maximum lift coefficient (C_L).
b) Increment of the critical angle of attack $\boldsymbol{\alpha_{cri}}$.
c) Changing the aerodynamic quality of the wing compartment model K.
d) Change in the aerodynamic torque coefficient of the model mz.

3. RESULTS

The characteristic effect of different configurations of vortex generators on the lift coefficient properties of the model is shown in Fig.4 and Table 1:

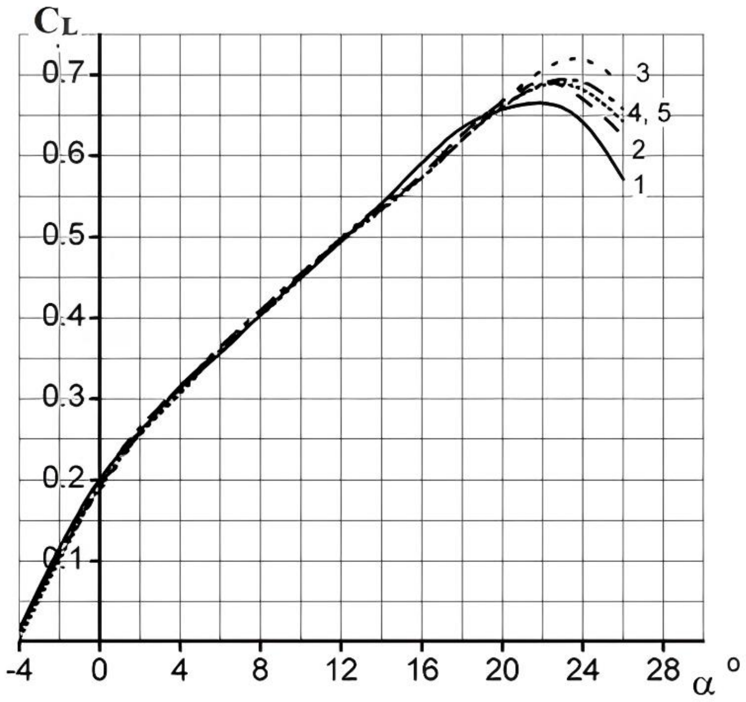


Fig 4. The Wing section model with RSG-36 profile. Dependencies $C_L = f(\alpha)$:

1 -without vortex generators; 2 – configuration No. 1; 3 – configuration No. 2; 4 – configuration No. 3; 55 – configuration No. 4.

Table 1. Comparison of the efficiency of vortex generators in various configurations.

configuration	$C_{L\,max}$	α°_S	$\Delta C_{L\,max}$	$\Delta\alpha^\circ_S$
-	**0.67**	**21**	**0**	**0**
D=20h	**0.69**	**23.8**	**0.02**	**2.8**
D=30h	**0.74**	**25**	**0.07**	**4**
D=40h	**0.685**	**24**	**0.015**	**3**
D=50h	**0.675**	**23.5**	**0.005**	**2.5**

The characteristic effect of different configurations of vortex generators on the aerodynamic quality of the model is shown in Fig.5 and in Table 2:

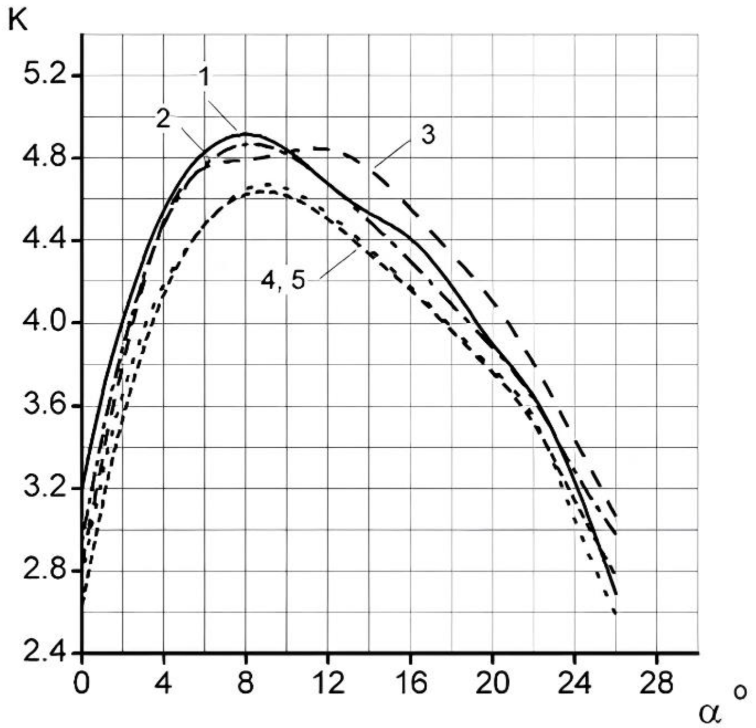


Fig 5. The Wing section model with RSG-36 profile. Dependencies k = f (α):

1 -without vortex generators; 2 – configuration No. 1; 3 – configuration No. 2; 4 – configuration No. 3; 55 – configuration No. 4.

Table 2. Comparison of the efficiency vortex generators in various configurations.

α^0	ΔK №1	ΔK №2	ΔK №3	ΔK №4
-4	-0.071	-0.06	0.022	-0.209
0	-0.476	-0.442	-0.302	-0.63
4	-0.365	-0.013	-0.065	-0.414
8	-0.252	-0.163	-0.05	-0.29
12	-0.131	0.192	0.012	-0.157
14	-0.158	0.239	-0.028	-0.19
16	-0.259	0.122	-0.131	-0.266
18	-0.203	0.146	-0.1	-0.226
20	-0.109	0.242	0.008	-0.115
22	-0.073	0.135	-0.025	-0.135
24	-0.232	0.181	0.008	-0.12
26	-0.106	0.377	0.287	0.081

The characteristic effect of different configurations of vortex generators on the aerodynamic moment coefficients of the model is shown below in Fig. 6:

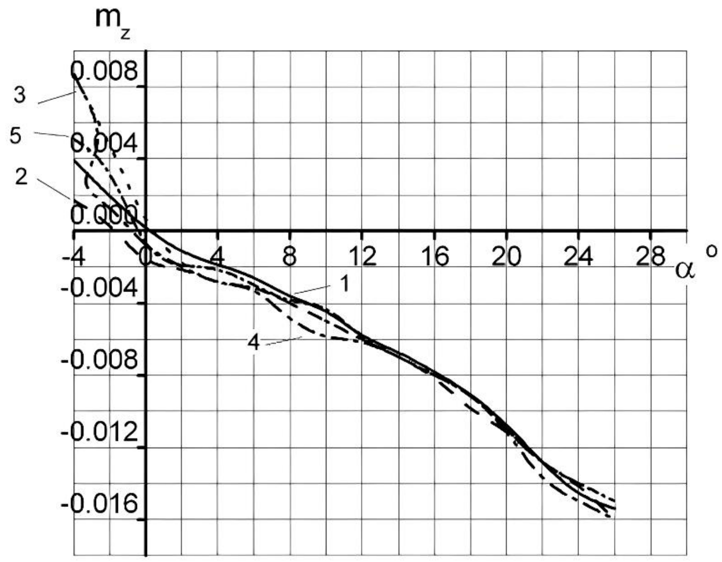


Fig.6.The Wing compartment model with RSG-36 profile. Dependence $m_z = f(\alpha)$:

1 -without vortex generators; 2 – configuration No. 1; 3 – configuration No. 2; 4 – configuration No. 3; 55 – configuration No. 4.

As follows from the above dependencies, the vortex generator in configuration No. 2 has a significant positive effect on the bearing properties of the wing model and its aerodynamic quality. To determine a more optimal position of the vortex generator, it is advisable to perform parametric studies of the efficiency of the vortex generator depending on the distance between two pairs of vortex generators D.

Below, in Fig.7 – 8. And Tables 3.8–3.9 show the test results of the wing compartment model with parameter values D = 20h; 30h; 40h; 50h. A comparison of the efficiency of the vortex generators of configuration No. 2 by parameter D is shown below in Table.3.10-3.11.

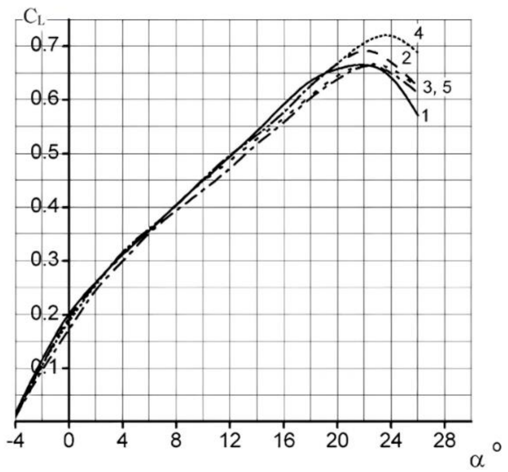


Fig.7. The Wing compartment model with RSG-36 profile. Configuration №.2.

مجلة دجلة • المجلد ٦، العدد ٣ (٢٠٢٣)، ص: ٣١ ـ ٤١
ISSN: 2222-6583

Dependencies $C_L = f(\alpha)$.1 -without vortex generators; 2 – D = 20h; 3 – D = 30h; 4 – D = 40h; 5 – D = 50h.

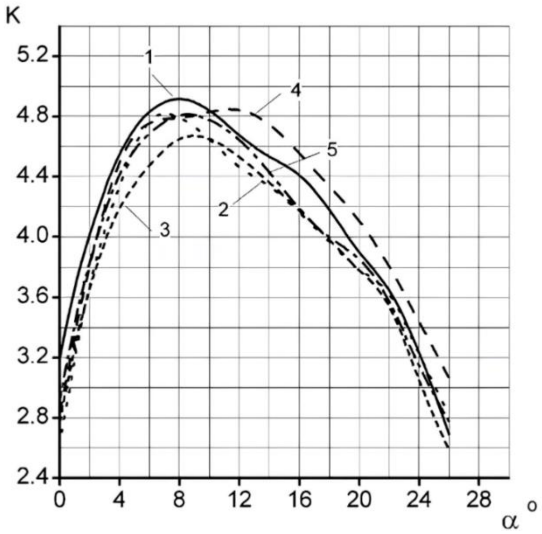


Fig.8.The Wing compartment model with RSG-36 profile. Configuration №2.

Dependencies $K = f(\alpha)$.1 -without vortex generators; 2 – D = 20h; 3 – D = 30h; 4 – D = 40h; 5 – D = 50h.

Table 3. The Results of studies of vortex generators of configuration No. 2 by parameter D. Dependencies of $C_L(\alpha)$

α^0	C_L D=20h	C_L D=30h	C_L D=40h	C_L D=50h
-4	0.0141	0.0098	0.0141	0.0098
-2	0.1072	0.1	0.1072	0.1082
0	0.1988	0.171	0.19	0.1981
2	0.2561	0.251	0.2561	0.2591
4	0.32	0.298	0.32	0.3118
6	0.36	0.3555	0.36	0.3555
8	0.4019	0.394	0.4019	0.4068
10	0.453	0.432	0.453	0.449
12	0.4978	0.47	0.4978	0.485
14	0.5343	0.5206	0.5343	0.529
16	0.575	0.5554	0.575	0.565
18	0.6294	0.6069	0.6294	0.609
20	0.6683	0.638	0.6683	0.648
22	0.702	0.71	0.71	0.6706
24	0.673	0.654	0.729	0.663
26	0.626	0.613	0.688	0.622

Table 4. Results of studies of vortex generators of configuration No. 2 by parameter D. Dependencies of Cx (α).

α^0	Cx D=20h	Cx D=30h	Cx D=40h	Cx D=50h
-4	0.0701	0.0649	0.0666	0.0662
-2	0.0673	0.0636	0.0652	0.0648
0	0.0701	0.0649	0.0662	0.0659
2	0.0687	0.0667	0.0665	0.0667
4	0.0756	0.0684	0.0698	0.0697
6	0.0803	0.0731	0.0751	0.0756
8	0.0857	0.082	0.0841	0.084
10	0.097	0.0926	0.0937	0.0938
12	0.1097	0.1058	0.104	0.104
14	0.1223	0.1195	0.1168	0.1192
16	0.1377	0.1335	0.1299	0.1352
18	0.1578	0.1527	0.1491	0.153
20	0.1773	0.1698	0.167	0.167
22	0.1944	0.1817	0.1859	0.1859
24	0.2226	0.2037	0.2122	0.2122
26	0.2421	0.2171	0.2242	0.2242

Table 5. Parametric study of the effect of vortex generators in configuration No. 2 on aerodynamic quality according to parameter D.

α^0	ΔK D=20h	ΔK D=30h	ΔK D=40h	ΔK D=50h
-4	-0.071	-0.06	0.022	-0.209
0	-0.476	-0.442	-0.302	-0.63
4	-0.365	-0.013	-0.065	-0.414
8	-0.252	-0.163	-0.05	-0.29
12	-0.131	0.192	0.012	-0.157
14	-0.158	0.239	-0.028	-0.19
16	-0.259	0.122	-0.131	-0.266
18	-0.203	0.146	-0.1	-0.226
20	-0.109	0.242	0.008	-0.115
22	-0.073	0.135	-0.025	-0.135
24	-0.232	0.181	0.008	-0.12
26	-0.106	0.377	0.287	0.081

Table 6.A comparison of the efficiency of vortex generators in configuration No. 2 at the critical angle of attack by parameter D.

vortex	C_{Lmax}	α°_{S}	ΔC_{Lmax}	$\Delta\alpha^{\circ}_{S}$

generators				
-	0.67	21	0	0
D=20h	0.69	23.8	0.02	2.8
D=30h	0.71	24.2	0.03	3.2
D=40h	0.74	25	0.07	4
D=50h	0.675	23.5	0.005	2.5

3.1 Visualization of tests of a wing model with RSG-36 profile.

Presented characteristic features flow around the experimental wing model at angles of attack, are closed to critical. Photographic materials perfectly recorded the moment of the beginning of (VG), the development of an attached vortex, and the separation of the flow as shown in Fig.9. The results of the visualization experiment demonstrate the features of (VG). The two photos are for the same wing model and same angle of attack (22^0), picture (a) wing model without (VG), and the second picture (b) with (VG) It is clear here that the effect of (VG) Which led to the delay of the separation of the boundary layer.

(a) (b)

Fig.9. The nature of the flow around the upper surface of the wing.

a- A model without vortex generators. The angle of attack $\alpha = 22^0$

b- A model with vortex generators. The angle of attack $\alpha = 22^0$

4. CONCLUSIONS

1. The installation of (VG) of all types on the experimental model of the wing compartment has a positive effect on its wing lifting force. The increment of the maximum lift coefficient for all tested variants of (VG) is within ΔC_{Lmax}= 0,005 – 0,07 units. The increment of the critical angle of attack for all tested variants of (VG) is within $\Delta\alpha = 2{,}5^0 – 4^{0}$. The most optimal is the vortex generator in configuration

No. 2, which creates an increment of the maximum lift coefficient ΔC_{Lmax}= 0,07 units, and the increment of the critical angle of attack $\Delta\alpha = 4^0$.

2. The effect of (VG) of various configurations on the aerodynamic quality of the experimental model of the wing compartment is different. As follows from Fig.3.30, configuration No. 1 practically does not change the value of aerodynamic quality. Configuration No. 2 has a significant positive effect on the aerodynamic quality of K at angles of attack α greater than the most advantageous angle of attack for a model without vortex generators α HB. The increment of aerodynamic quality for the range of angles of attack $\alpha = 12^0 \ldots 20^0$ compose ΔК = 0,19…0,24. Configurations No. 3 and No. 4 have a significant negative impact on aerodynamic quality. To the wing model in the entire range of angles of attack α. In the range of angles of attack corresponding to flight $\alpha = 4^0 \ldots 12^0$ ΔК = -0,4 …-0,2.

References

1. United Aircraft Corporation. Research Department, & Taylor, H. D. (1950). Summary report on vortex generators.
2. Li, X. K., Liu, W., Zhang, T. J., Wang, P. M., & Wang, X. D. (2019). Analysis of the effect of vortex generator spacing on boundary layer flow separation control. Applied Sciences, 9(24), 5495.
3. Lin, J. C. (2002). Review of research on low-profile vortex generators to control boundary-layer separation. Progress in Aerospace Sciences, 38(4-5), 389-420. استخدمت APA
4. Lin, J. C. (2002). Review of research on low-profile vortex generators to control boundary-layer separation. Progress in aerospace sciences, 38(4-5), 389-420.
5. МАХМУД, Аббас Ф.; БАБЕНКО, В. В.; ИЩЕНКО, С. А. Влияние генераторов вихрей на аэродинамические характеристики модели самолета" Аэропракт А-20". Прикладна гідромеханіка, 2012.
6. Babenko, V. V., Chun, H. H., & Lee, I. (2012). Boundary layer flow over elastic surfaces: compliant surfaces and combined methods for marine vessel drag reduction. Butterworth-Heinemann.
7. Velte, C. M., Hansen, M. O. L., & Cavar, D. (2008). Flow analysis of vortex generators on wing sections by stereoscopic particle image velocimetry measurements. Environmental Research Letters, 3(1), 015006.