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EXPERIMENTAL STUDY OF AERODYNAMIC CHARACTERISTICS OF CLOSED PARABOLIC WING

Abstract. The article presents the results of experiment model with closed parabolic wing in the wind tunnel T-5 of the National Aerospace University – Kharkov Aviation Institute (KhAI), made in order to assess its overall effectiveness. Performed comparison of results obtained in wind tunnel T-5, with the results and the panel-vortex method and finite element method.

Keywords: aircraft, closed parabolic wing, panel-vortex method, finite element method

Formulas: 0, fig.: 12, tabl.: 2, bibl.: 13

Introduction. The main driving factor in the development of designs of aircrafts include: requirements for the home, storage and transportation of products. A large number of developed aircrafts [Jackson 2003] is a sufficient proof of this.

For efficient simultaneous implementation of the requirements of portability and the aerodynamic efficiency of our proposed concept of a ring airfoil. Based on the results in the open press flight test aircraft with closed parabolic wing (CPW) [Semenov 1983], you can make an educated guess about the relevance of the research.

Flow around aerodynamic configuration CPW**,** which is proposed by the authors, has a rather complex structure and can not be reliably determined by empirical or numerical methods, which justifies the objective need for experimental research and determines their scientific novelty. Application of the computational aerodynamic method requires verification of the results in the design of these arrangements to obtain reliable results, which is, obviously, the main purpose of the work and clearly defines its relevance.

In previously published studies [Rahmati, Zinchenko 2012, 2014, 2014; Rahmati 2015] have been carried out serious work on the numerical simulation of flow CPW, identified a number of characteristics, fully confirmed on wind turbine experiments.

Literature review and the problem statement. There are closed wings, which were used in the aircraft when flying at high speeds. A variation of this type of lifting surfaces is half annular wing with propeller engine inside, the so-called Custer wing [Ukrainetc 2010; Ukrainetc 2006; Patent US2006].

In [Ukrainetc 2006] the results of the parametric studies of the effect on the aerodynamic characteristics of the position of the propeller in the channel

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arched wing was considered. On the basis of the results worked out practical recommendations for the location of the propeller. Despite the fact that the use in arrangements of the arched wing aircraft is no longer anything exotic, flow characteristics of such lifting surfaces are still insufficiently studied.

The disadvantage of this semi closed wing wing(custer) [Ukrainetc 2006; Patent US2006] is that its outer shape is optimized for cruising flight mode, unable to maintain an effective mechanization of wing, resulting in deterioration of the characteristics of the take-off and landing with this type of wing compared to classic aircraft. Semi closed surface with the engine operating within channel is able to ensure optimal engine operation and is designed to fly at low speeds. Therefore, a common drawback is the lack of peers considered the optimal solution to the flight of the aircraft at small and at high speeds.

In [Ukrainetc 2010] presented aerodynamic layout of the propeller with arch-ring-wing(custer), designed aircrafts, long-term use low speed flight. A comprehensive semi-empirical method for determining aerodynamic characteristics of complex spatial layouts, reflecting the difficulty of weighing experiment with propellers in the wind tunnel.

A characteristic feature of the propeller with arch-ring-wing(custer) is the lack of elements that are not exposed to the working propeller. This feature greatly complicates the weighting experiment in a wind tunnel:

- There are problems to ensure the similarity criteria for working propeller;
- The impossibility of ideal balancing of propeller at weight experiment leads to the presence of vibration, the level of which depends on uncontrollable factors.

Thus, the possibility of weighting experiment of arrangements with propellers in the wind tunnel are limited, which makes it advisable to use integrated experimental and numerical aerodynamic methods.

The main disadvantages of the custer wing layout [Ukrainetc 2010; Patent US2006] is its complex geometry, which is a complicated spatial form, in the manufacture of non-technological, conservation demands on theoretical contour by the action of aerodynamic loads during flight, which leads to high construction costs due to need to ensure high rigidity of the wing form and the use of expensive materials and technologies. Also disadvantages include loss of efficiency of semicircular wing in case of engine failure, a significant increase of aerodynamic drag and, as a result, deterioration of performance of the aircraft.

The relevance of the research results presented in this article is not in doubt, as the authors of the proposed, arrangement of lifting surface of the aircraft is able to implement a number of unique characteristics of flight. Especially should note the possibility of implementing a high ratio of the maximum and minimum flight speeds, high structural strength and mass perfection. Applied research methods by authors are tested which substantiate the validity of the results.

Formulation of the problem. Using physical experiment in a wind tunnel to qualitatively and quantitatively determine the aerodynamic characteristics of the CPW. Perform analysis and generalization of experimental and theoretical results obtained previously.

The purpose of research is comparative assessment of changes in aerodynamics: lift coefficient Cy and Cx drag, the maximum value of the aerodynamic qualities of the K criterion of maximum range $K/c_y^{0.5}$, critical angle αS attacks, and as a comparison of results obtained in wind tunnel T-5, with the

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results, obtained using the panel-vortex method (PVM) and finite element method (FEM).

Experimental models. A model ring wing with asymmetrical profile from the National Aerospace University – Kharkov Aviation Institute (KhAI) was made for carrying out the experiment in a wind tunnel in accordance with recommendations [Pankhurst, Holder 1955].The materials include - balsa, aircraft plywood and ABS plastic , also steel 30HGSA. The experimental model of the design and process are identical to that in the experimental studies [Pankhurst, Holder 1955]. Fig. 1 shows a conceptual diagram of the models under study on Fig. 2 - the appearance of models in the working part of the wind tunnel T-5.

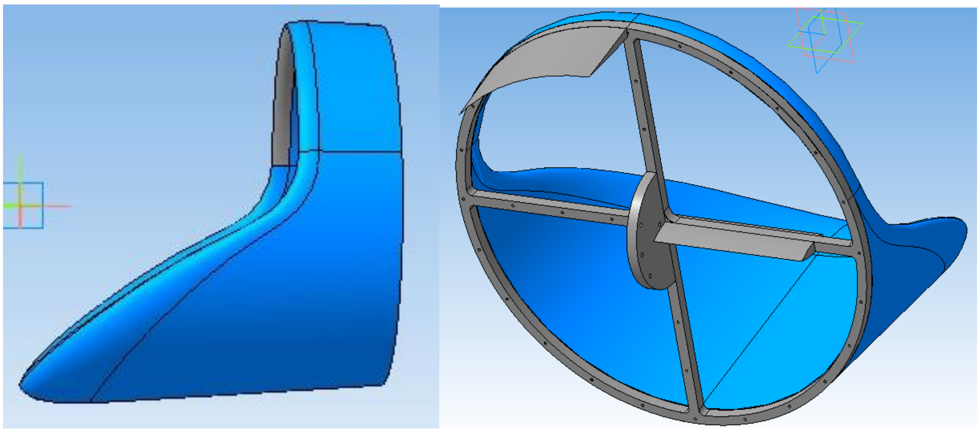

Figure 1 - Overview of a CPW

Source: authors' own development

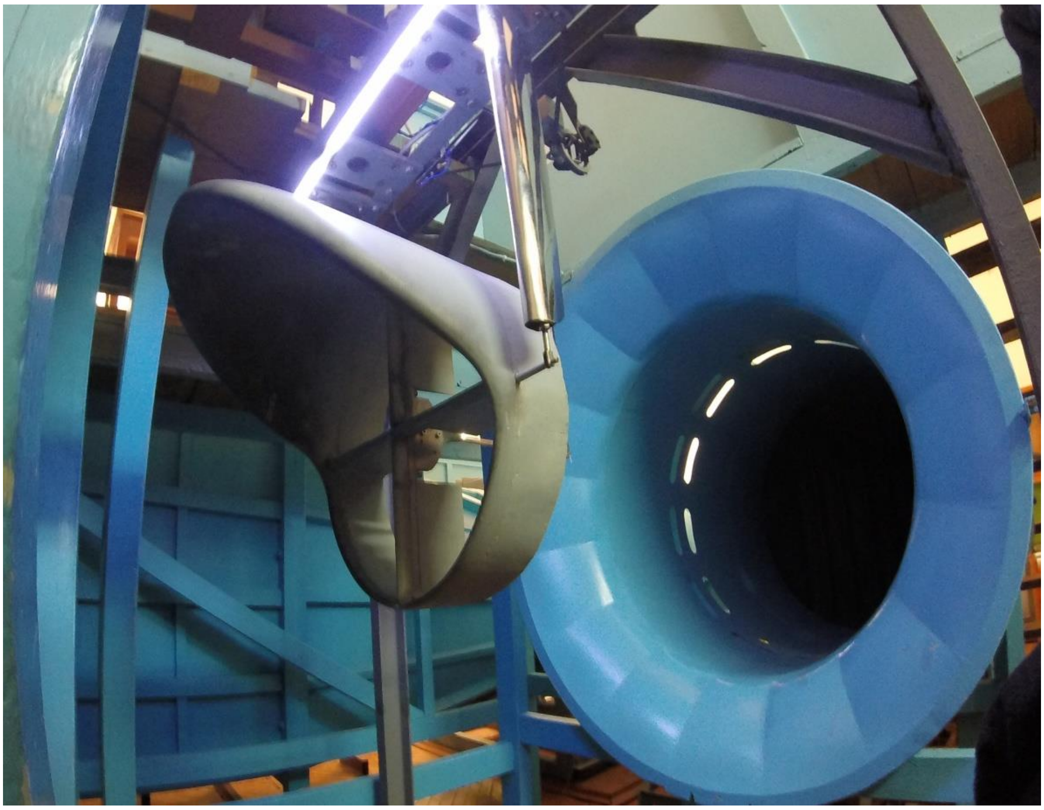

Figure 2 - CPW model in the work space of the wind tunnel T-5 KhAI

Source: authors' own development

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The experimental setup. The educational aerodynamic installation T- from the aerodynamics department of the KhAI [Ukraine Department of aerodynamics; Chmovzh, Kasyanenko 2012] represents a closed tube type with open working part (fig. 3,4). Below in table 1 are the characteristics of the wind tunnel.

Table 1 – Features of Wind tunnel

WT DESIGNATION	T-5
Test Section (m)	∅0.75 m
Length of Test Section	1.5 m
Max. Flow Velocity	40 m/s
Typical Value of Turbulence Intensity	0.8%
Balances	3-component
engine power	32KW

Source: Ukraine. Department of aerodynamics and the Kharkiv Aviation Institute

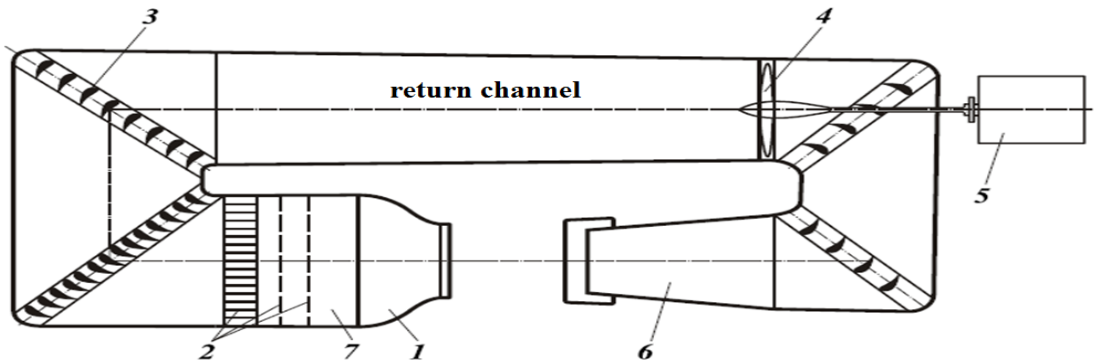

Figure 3 - A ring type low speed tunnel with open operating part .1 - collector; 2 - honeycomb; 3 – guide blades; 4 – ventilator ; 5 – electric motor; 6 - a diffuser; 7 - prechamber

Source: Chmovzh, Kasyanenko. 2012

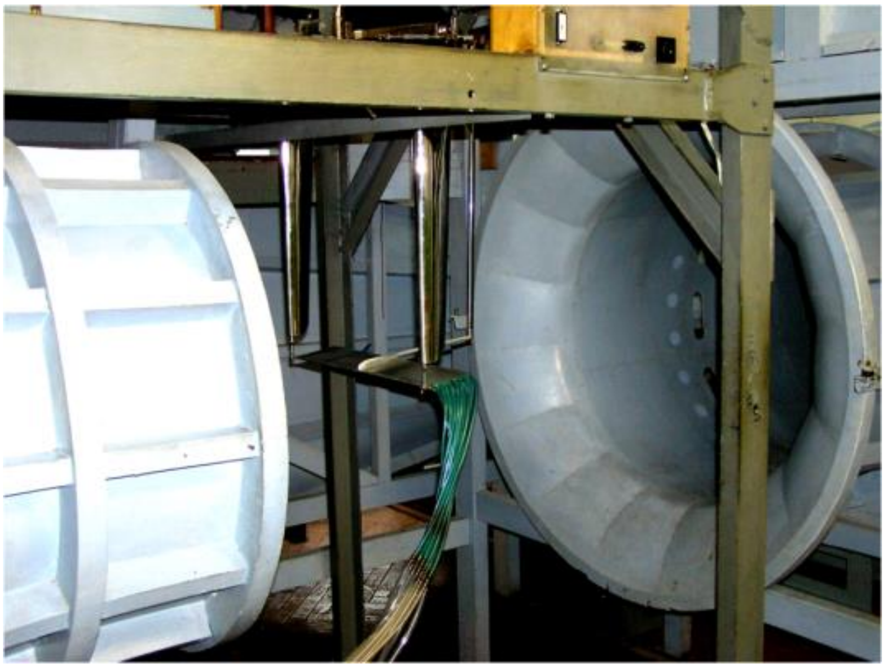

Figure 4 - Ring type wind tunnel- T - 5 KhAI

Source: Ukraine. Department of aerodynamics and the Kharkiv Aviation Institute

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Wind tunnel provided with the necessary research equipment includes various static and dynamic pressure coordinate devices, and others.

Installation allows you to:

– to determine the distribution and overall aerodynamic characterics of the aircraft models;

– explore the perturbed velocity field around the model;

– explore the practical features of the complex aerodynamics of the aircraft in terms of form.

With the application of the above, experimental models CPW of the performed aerodynamic experiments in the laboratory of the aerodynamics department of KhAI.

Experimental results. In our work we present an analysis of the research results of the CPW in a wind tunnel, made in order to assess its overall effectiveness.

Below, in тable 2 shows the experimental test program model.

Table 2 – The definition of the aerodynamic characteristics of the model.

α	V	Re
$-12^0 \ldots 40^0$ $\Delta\ \alpha = +2^0$	35 m/s	$1.21 * 10^6$

Source: authors' own development

Figure 5 - CPW model with airflow at $\alpha = 12$

Source: authors' own development

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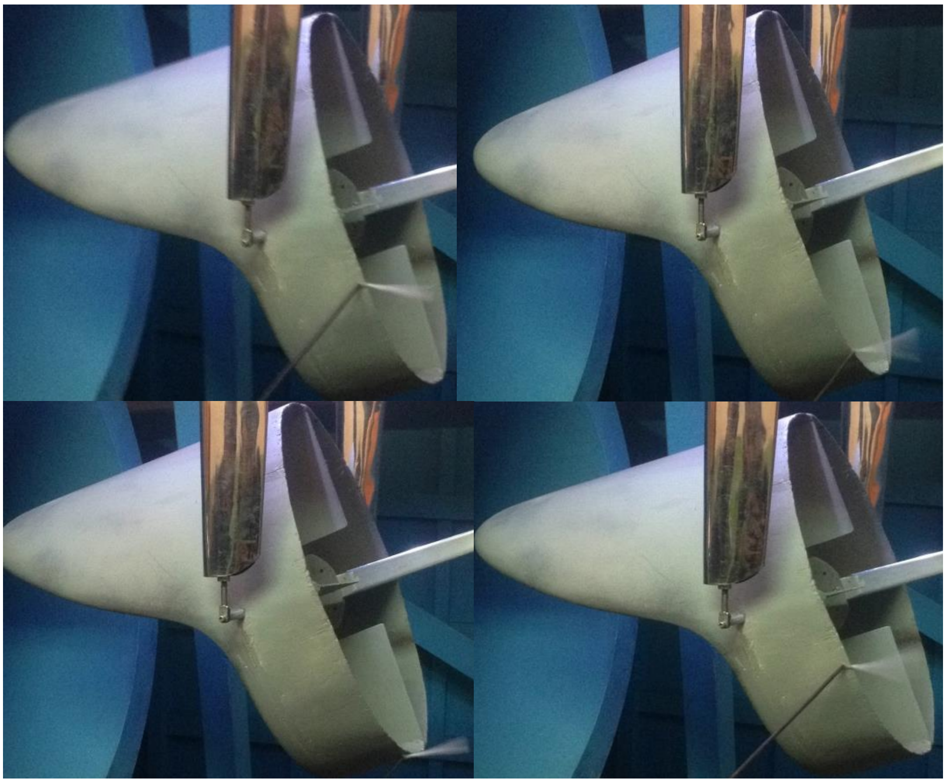

Figure 6 - CPW model with airflow at $\alpha = 20$

Source: authors' own development

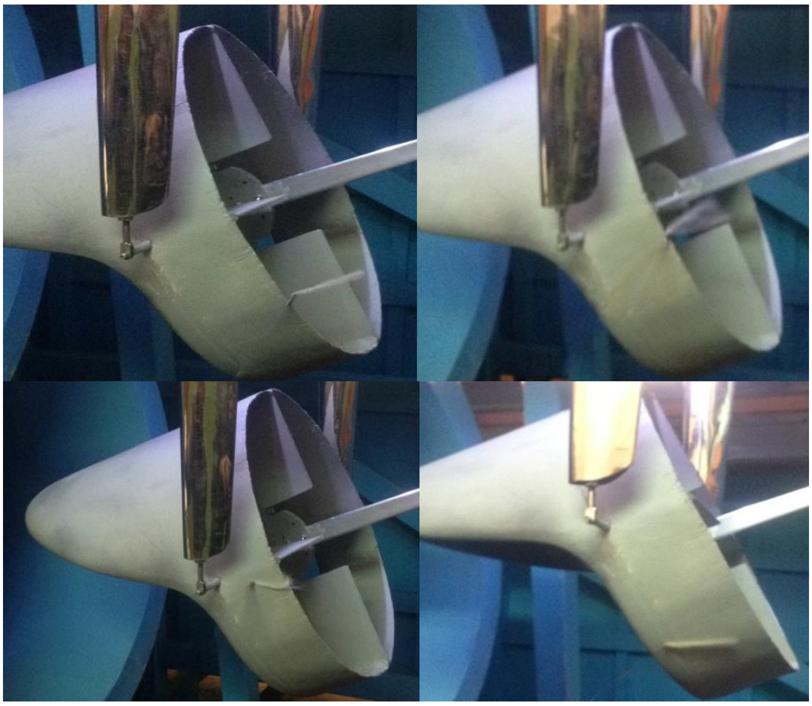

Figure 7 - CPW model with airflow at $\alpha = 24$

Source: authors' own development

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Figure 8 - CPW model in wind tunnel T-5, airflow V=35 m/sek. Smoke visualization

Source: authors' own development

Below, in Fig. 9 - Fig. 12 shows the results of the trial tests as described in the above experimental models, and as a comparison of results obtained in wind tunnel T-5, with the results and the PVM and FEM [Rahmati, Zinchenko 2012; 2014, 2014; Rahmati 2015].

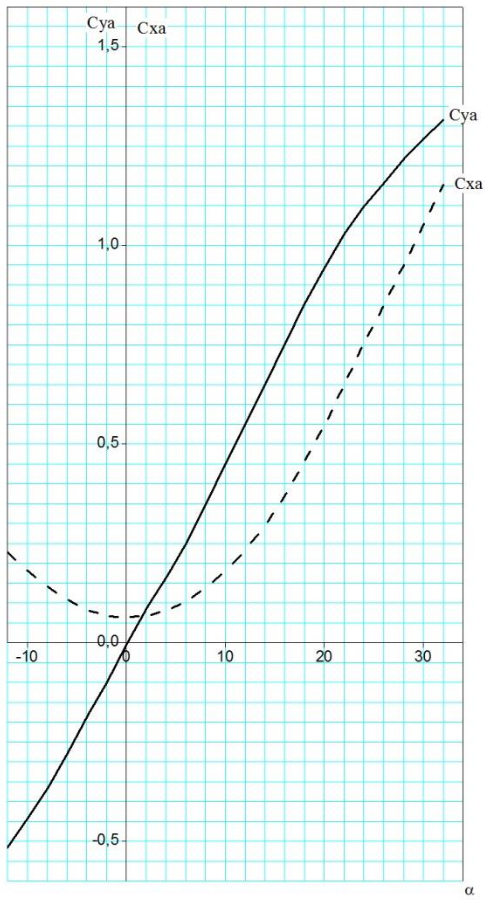

Figure 9 - c_{ya}, c_{xa} = *f(α)* data.

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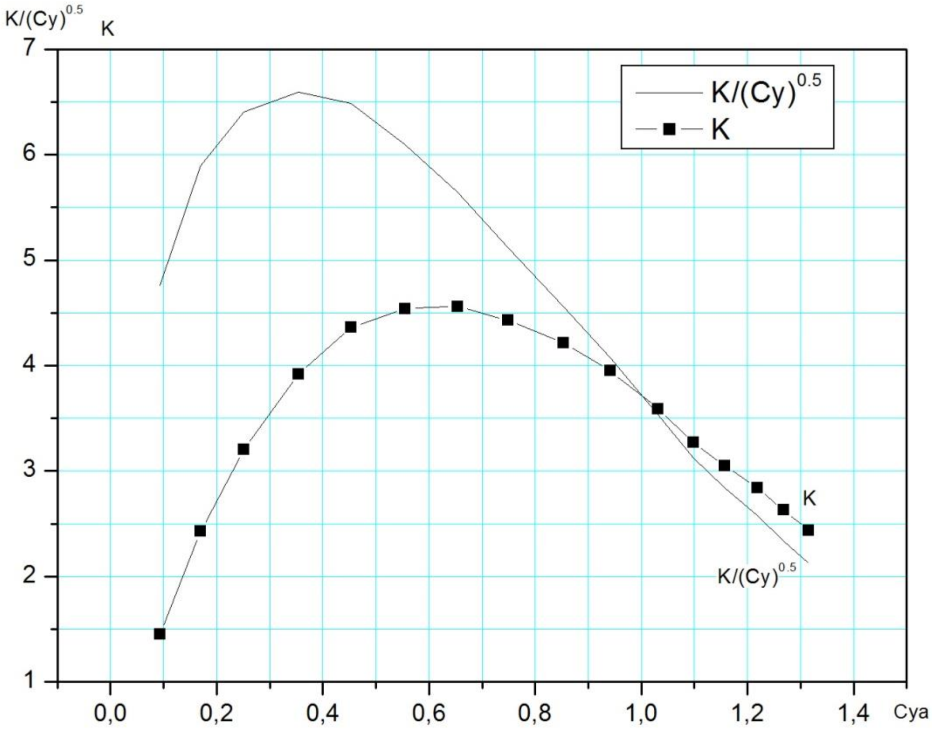

Figure 10 - *$K/(c_y)^{0.5}$, $K = f(c_y)$* data
Source: authors' own development

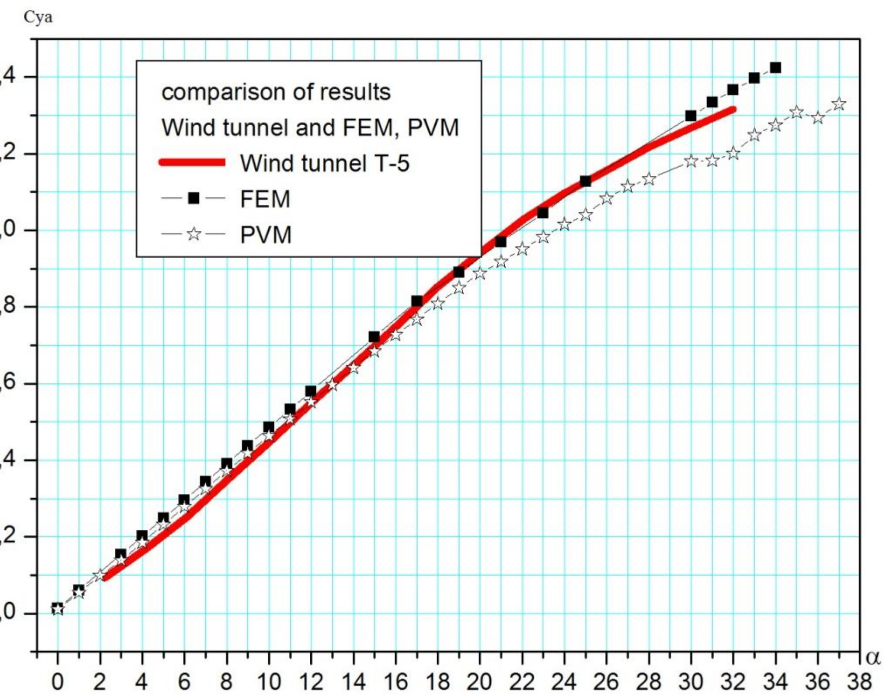

Figure 11 - $c_{ya} = f(\alpha)$ data
Source: authors' own development

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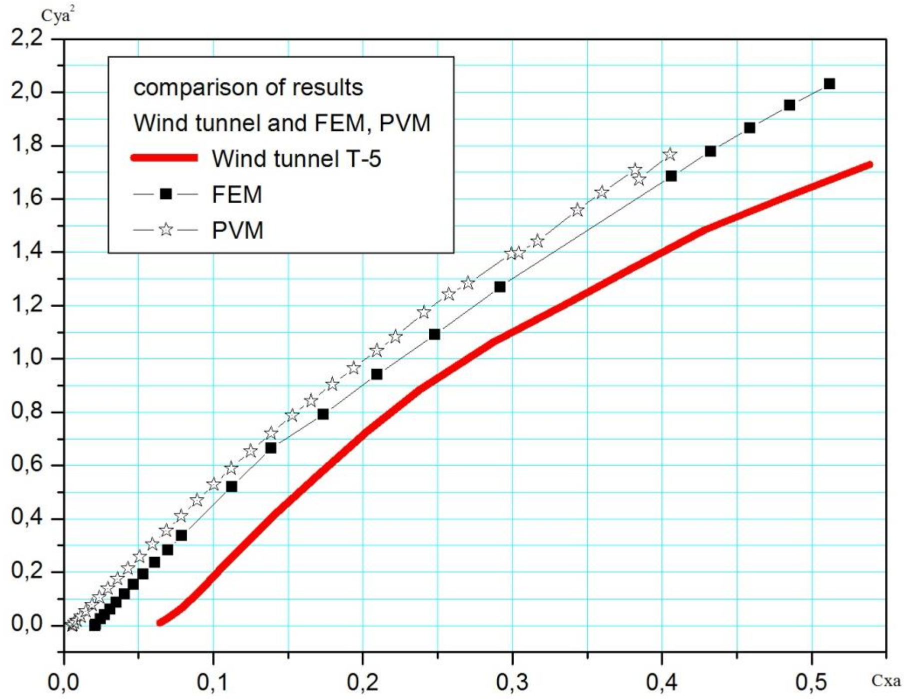

Figure 12 - Dependence $c_y^2 = f(c_x)$

Source: authors' own development

Conclusions.

1. The results of the experiment (Fig. 9) clearly demonstrate that the proposed arrangement is substantially greater value of the critical angle of attack (α_S = 32^0) than classic airplane. This differs from the two sections of constant values of the derivative c_y^{α}, indicating a change in the vortex circuit bearing surface by increasing the angle of attack, but with preservation of unseparated flow;

2. Dependencies of lift-to-drag ratio (*K*) and criteria for maximum range $K/c_y^{0.5}$, determined based on the results of the experiment have the same characteristics as that previously defined on the basis of calculation results [Rahmati, Zinchenko 2012, 2014, 2014; Rahmati 2015] - the maximum *value* of $K/c_y^{0.5}$holds for values of $c_{ya} \approx 0.25$, which corresponds to high speed cruising;

3. Visualization of the surface flow and the trailing edge of the experimental model by using soie and smoke generator (Fig.8) demonstrates conformity with the calculated flow models schemes outer surface received streamlines the appearance of bound vortices zones and separated flows. This allows with sufficient accuracy to be used for aerodynamic design PVM and FEM the assumptions implemented in model k-ε and SST;

4. Comparison of the experimental and numerical simulation of flow around geometrically complex CPW (Figure 11. Figure 12) confirms the adequacy of PVM and FEM (SST) for the aerodynamic design of the wings of small aspect ratio of the closed type, ie, .K. Dependence $c_{ya}(\alpha)$ are almost identical, and the polar model, presented in the form of dependence $c_{ya}^2 = f(c_{xa})$ are equidistant to each other. It confirms the identity of determining the effect of inductive vortex flow on the ramps as the method as the PVM and FEM (SST). The difference in

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c_{x0} caused by the quality of construction experimental models and mathematical assumptions in determining the frictional drag out the methods;

5. The experimental results confirm the hypothesis in general, we have taken at the beginning of the research - implementation of high load-bearing properties and high values of the critical angle of attack, the possibility of achieving the same aerodynamic configuration of small minimum flight speeds (resp. Small distance off and landing) and high cruising flight speeds (and high transport efficiency respectively).

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Data przesłania artykułu do Redakcji: 27.06.2016
Data akceptacji artykułu przez Redakcję: 18.07.2016

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