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EXPERIMENTAL RESEARCH INTO AERODYNAMIC CHARACTERISTICS OF THE MODEL OF A MANEUVERED AIRCRAFT WITH AN AIRFLOW PASSAGE THROUGH ENGINES

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Проведено експериментальне дослідження аеродинамічних характеристик моделі маневреного літака типу МиГ-29 з протоком повітря через двигун. Представлена методика комплексного аналізу поправок і визначення величини найбільш важливих поправочних коефіцієнтів. Новизною розробленої методики є використання змінних сопел імітаторів двигунів і внесені поправки на опір довгих внутрішніх каналів мотогондол моделей

Ключові слова: аеродинамічна труба, аеродинамічні характеристики, газотурбінний двигун, маневрений літак, ваговий експеримент

Проведено экспериментальное исследование аэродинамических характеристик модели маневренного самолёта типа МиГ-29 с протоком воздуха через двигатели. Представлена методика комплексного анализа поправок и определения величины наиболее важных поправочных коэффициентов. Новизной разработанной методики является использование сменных сопел имитаторов двигателей и внесённые поправки на сопротивление длинных внутренних каналов мотогондол моделей

Ключевые слова: аэродинамическая труба, аэродинамические характеристики, газотурбинный двигатель, маневренный самолёт, весовой эксперимент

1. Introduction

Full-scale flight experiment has remained until now a reliable way of obtaining genuine information about actual possibilities of a projected aircraft (AC), its dynamic properties, controllability and flying features, AC capabilities during its flight in the atmosphere. This is explained by a number of reasons, which include a failure to:

– on its model's wind-tunnel test (WTT) and subsequent calculations [1–3];

– accurately estimate at the design phase a degree of deformation of an actual AC during flight and take into account elastic effects of its structure [4, 5];

– adequately reproduce on the ground real operating conditions of an aviation complex;

– obtain accurate data on the extent of possible deterioration of the traction engine characteristics after mounting it on the projected AC [6–9].

Determining the aerodynamic characteristics (ADC) of AC based on the wind-tunnel testing of its models remains the most reliable tool when developing new, and improving the existing, configurations. Any suggestions on the formation of configurations, as well as recommendations aimed at improving the ADC of existing AC, are implemented only after wind-tunnel testing of the models [1, 2].

Results of WTT of the models intended for research purposes are used for a comparative analysis of ADC of different configurations of AC and their elements. To calculate flight-technical characteristics (FTC) and maneuvering characteristics (MC) of specific configurations of aircraft, results of WTT of geometrically similar models are reduced to real conditions by introducing corrections. The magnitudes of corrections, their accuracy and determining methods depend both on the characteristics of WTT and specifics of the configuration of an aircraft. Comparing ADC derived from WTT of models leads to the establishment of estimated ADC of an aircraft. These characteristics form the basis for all subsequent analyses and calculations [1].

Relevance of the present work is in developing a procedure of comprehensive analysis of corrections and determining the magnitude of the most important correction coefficients. Such a technique will make it possible to reduce the time and cost for conducting theoretical research, as well as for the refining and designing new configurations of AC.

When modeling a flow around bodies with jets, it is required, in addition to the general conditions of similarity, to meet specific requirements. Analysis and description of these requirements can be found in papers [10–17]. In this case, in order to determine integral aerodynamic loads, the tests can be carried out on cold jets, which considerably simplifies modeling [11]. A power plant (PP) is typically modeled using simulators of various type and purpose [11].

For a model of nacelle with a passage, the channel cross-section is selected so that the relative air flow rate at the inlet corresponds to the full-scale under the estimated PP operation mode. A model with ejector simulates a degree of two-circuit engine, flow conditions at the inlet and outlet. A gondola with blowing models flow conditions at the outlet from nozzle. A gondola with rotary simulator models conditions at the inlet and outlet, maximally approaching the full-scale ones [11]. It should be noted that the models with ejector, with blowing, with rotary simulator are difficult to implement and designed for studying distributed aerodynamic characteristics, as well as the subtle aerodynamic effects.

In order for the results obtained during WTT of models to apply for the full-scale conditions and to use them to estimate aerodynamics of an aircraft and in the calculations of FTC and MC, the known criteria of similarity must be fulfilled:

– geometric similarity (permanence of linear scale);

– kinematic similarity (permanence of magnitude of time, velocities, and accelerations in similar points);

– dynamic similarity (permanence of the magnitude of forces of different nature);

– similarity considering compressibility of medium (permanence of Mach numbers $M=V/a$, V is the flight speed (flow rate), a is the speed of sound in the air medium);

– similarity taking into account the forces of viscosity (permanence of Reynolds numbers $Re=b\times V/\nu$, b is the characteristic linear dimension, v is the coefficient of kinematic viscosity of air);

– similarity considering periodicity of phenomena (permanence of the Strouhal numbers $Sh=L/V\times T$, L is the characteristic linear length of an object, T is the characteristic time of a nonstationary process).

These criteria should be complemented by initial turbulence of the flow, which flows around the model during WTT and the plane during flight, $-\varepsilon$. At flow velocities, when there are no thermochemical kinetic effects ($M\leq 5...6$), a dependence of any aerodynamic coefficient is represented as a function of the angles of attack and slip (α and β), aircraft configuration (δ_i, ϕ_i are the angles of deviation of the moving elements of bearing surfaces) and similarity criteria $c_A=F$ (geometric similarity, α, β, δ_i, ϕ_i, M, Re, Sh, ε) [1–3].

Should all the similarity conditions be satisfied, experimental ADC would not differ from the aerodynamic characteristics of a full-scale aircraft. However, a complete simulation is almost unreal. In the aero-tube experiment it is possible to implement only a geometric similarity (with accuracy to the distortions of models), connected to the need of fixing the model at scale during WTT. Similarity for the Mach number, which corresponds to maintaining similarity for compressibility, is implemented only during high-speed WTT; for the Reynolds number – only for takeoff and landing modes and for the flight conditions at high altitudes during WTT with a variable air density.

In a general case, conditions of WTT do not fully correspond to the full-scale ones. Therefore, results of experimental studies require the introduction of methodological corrections for a transition from ADC of the model obtained on the scales during WTT under flow conditions, limited by wind tunnel walls, to ADC, implemented under conditions of limitless flow and elimination of influence from suspended devices.

The magnitudes of corrections depend on the extent of difference in geometric parameters of the model and the aircraft, ways of fixing a model during WTT, and differences between test conditions and flight conditions. To determine them, experimental techniques for WTT, as well as methods for converting results to the full-scale conditions, are being developed and improved [1–3].

Modeling of air passage through the engine is a separate task. The total force acting on the plane during flight is difficult to divide into separate components of the aerodynamic force and engine thrust, which would not include results of the interaction between the flow streamlining an aircraft, an air intake, and a nozzle [1].

Passages that model PP of an aircraft make it possible to maintain the character of the outer flow, but do not enable a simulation of exhaust jet of the engines. Even active passage with an ejector or fan does not provide fully-fledged modeling of a jet over the entire range of the M numbers. Active passage with modeling the flow of a jet requires a supply of air from the outside, which inevitably leads to a distortion in the external configuration of the model.

A jet from reaction engine on a plane causes ejection and acceleration of the external flow in a nozzle area. During WTT of models, a jet from reaction engine is sometimes modeled using a rigid simulator of geometrical shape that matches the shape of the jet. In this case, an equality of static pressure on the bottom section in the presence of a jet and a simulator must be fulfilled. There is a specific imitator for each operating mode of the engine.

When comparing ADC, derived on the basis of experimental studies of models during WTT, with ADC, obtained from flight tests, a conclusion follows that they should be brought to comparable form. Characteristics should contain methodological corrections predetermined by a similar pattern of distribution of the resultant force acting on the plane in flight. To determine other corrections, theoretical and engineering methods of calculation are employed. For example, it is required to take into account the impact of deformations of bearing surfaces on the aircraft ADC, as well differences in geometrical configuration of the model from the configuration of an actual aircraft.

It should be noted that it is practically impossible to fully take into account the effect of all deviations in geometrical, physical parameters and WTT conditions of models from the aircraft's flight parameters and conditions in the transition from results of aero-tube tests to the full-scale conditions. By applying integrated analysis of corrections (the accuracy of methods for their determining and influence on the results of calculations of FTC and MC), we found the most important ones. These are the methodological corrections that are taken into account in test results for each model, as well as corrections that enable transition from the model to the full-scale conditions.

2. Literature review and problem statement

There are many systems of model stings employed in the studies in the wind tunnel [18]. It is substantiated that the support system and support obstacles become one of the main research areas of experimental aerodynamics. A substantial impact of model stings on the accuracy of test results was substantiated. There are results of experimental study into the influence of model stings on determining aerodynamic coefficients of the model during WTT. However, the paper fails to specify magnitudes of corrections for a transition from the model's ADC under conditions of WTT to the model's ADC, implemented under conditions of unlimited flow.

Article [19] analyzes specific aerodynamic effects that influence the interference of wing and fuselage, as well as nacelle and wing aircraft. The work shows preliminary assessment of stability and controllability of the aircraft, in both in longitudinal and transverse channels when implementing required geometrical parameters of the bearing and controlled surfaces of a tail unit. The article does not, however, give assessment of the impact of characteristics and conditions of the flow around a nacelle on the aircraft's ADC.

Experimental and numerical research into a low-velocity flow field for an unmanned AC were undertaken [20]. Experiment during WTT was conducted statically with different angles of attack up to 70°. The paper's authors report and discuss characteristics of vortex formation and interaction of flows in flight, including the nonlinear AC ADC. However, there is no information about the impact of PP characteristics on the flow field around the unmanned AC.

WTT was employed to implement virtual flight testing of configuration of a modern aircraft at low velocities [21]. The object of the study was represented by an actively controlled and dynamically similar model of the configuration of an actual airplane, which was statically unstable in the longitudinal direction. In addition, the model was equipped with an inertial measurement unit, orientation system, built-in computer, a servo-mechanism, and drives. Experimental results demonstrate satisfactory control over the model an its orientation. However, the paper does not give assessment of the impact of all deviations in the geometrical and physical parameters under conditions of the model's WTT from the full-scale conditions of an AC flight.

In article [22], the authors discuss test AC in terms of ensuring their stability and controllability. Here, each AC is assigned with a tabular wind tunnel model that is based on calculations using software complexes. The data are then compared with the results of experiments during WTT and measurements during flight tests, with consideration of AC maneuvering characteristics. The article does not quite clearly describe conditions for the comparison of obtained results, and it does not fully disclose terms of the experiments conducted.

Paper [23] outlines procedure for testing and designing the model of an AC half-wing. The authors explore the aeroelastic simulation at a non-stationary aerodynamic loading with starting and fully developed vortices at subsonic and trans sonic speeds. However, the paper does not specify the magnitudes of coefficients and tolerances when studying characteristics of the model of an airplane wing.

Article [24] describes WTT of the airplane, model IAR 99 SOIM, to a 1:14 scale. Wind tunnel is equipped with a means to identify and control aerodynamic phenomena. The authors derived ADC of a new configuration of the aircraft. But they failed to fully disclose the terms of experiments and provide information about the magnitudes of corrections for a transition from the model's ADC under conditions of WTT to the model's ADC, implemented under conditions of an AC flight.

An analysis of data from known sources of the scientific literature reveals that almost all studies in the wind tunnel are performed with certain deviations from the required test conditions.

Therefore, given the above considerations, it is necessary to determine in the future the magnitudes of correction coefficients based on the results of a wind tunnel experiment.

3. The aim and objectives of the study

The aim of present article is to develop a procedure for aerodynamic tests of the models of maneuverable aircraft with a simulation of the work of engines' PP.

To accomplish the set aim, the following tasks have to be solved:

– to conduct an experimental study of the model's ADC of a maneuverable aircraft of the MiG-29 type with a passage of air through the engines and without the passage;

– to devise a procedure for the comprehensive analysis of corrections and determining a magnitude of the most important correction coefficients.

4. Materials and methods of research

We used the wind tunnel for small subsonic velocities T-1 for experimental studies, of the closed type with an open working part that has a section in the form of an octahedron, and equipped with the three-component scale ZKT-1. The tunnel is equipped with a smooth control system over the flow rate in a range from 1.5 m/s to 50 m/s. Aerodynamic contour of T-1 with titles of the basic parts is shown in paper [10], main technical specifications of the wind tunnel are given in Table 1.

To conduct the experiment in the T-1 wind tunnel, we used a model of the fighter aircraft made of wood, with nacelles of the model fabricated in the profiled form with a passage; photograph of the model in the working part of the T-1 wind tunnel is shown in Fig. 1.

The chosen method for research into ADC is a weight experiment. Flow rate in the working part of the wind tunnel, at which the research was conducted, amounted to 24.4 m/s, which corresponds to the Reynolds number $Re=1.9\times10^5$ calculated by the mean aerodynamic chord of the model's wing.

When processing experimental data, we employed a method of corrections with the corrections introduced for:

– heterogeneity of the flow in the working part of the wind tunnel;

– interaction with a suspension system of the model (supporting devices);

– flow bevel in the working part of the wind tunnel;

– "horizontal buoyancy" (static pressure gradient);

– intensity of the flow turbulence;

– blocking-effect;

– clogging of the working part of the wind tunnel by the model and the slipstream;

– wind tunnel's induction;

– resistance of the inner channel of the model's nacelles.

Fig. 1. Photograph of physical appearance of the working part of the T-1 wind tunnel with a model of the fighter aircraft

Table 1

Main technical specifications of the tunnel for small subsonic speeds T-1

Name of characteristics	Value
Flow rate in the working part:	
Maximal	50 m/s
Minimal	1.5 m/s
Reynolds number per 1 m	to 3×10^6
Full pressure	atmospheric
Speed head	to 2.05 kPa
Range of the angles of attack	–15°...25°
Working part dimensions:	
Width	1.0 m
Height	0.7 m
Length	1.3 m
Compression degree of the nozzle	5
Fan diameter	1.5 m
Relative diameter of the fan hub	0.5
Fan rotation frequency /maximal/	1000 rpm
Power of drive electric motor	30 kW
Aerodynamic performance	2.7

Heterogeneity of the flow in the wind tunnel's working part is estimated by the quality of air flow in the wind tunnel's working part, which is determined by the degree of homogeneity of velocity fields, speed heads, and pressures by the sections of the tunnel's working part, local flow bevels, by the intensity and scale of turbulence [12]. A model of the fighter aircraft was placed in the core of airflow. In this case, speed head of the undisturbed flow q in the working part without the model was determined by measurements in the control section:

$$q = q_k\,\mu,$$

where q_k is the speed head in control section; μ is the coefficient of the tunnel's field defined experimentally [10].

Interaction with a suspension system of the model. A supporting device causes perturbation in the spatial flow of the wind tunnel's working part, thereby affecting aerodynamic loads determined in the experiment. This effect manifests itself in different forms and is typically determined using a calculation-experimental method. To determine a contribution of the model's suspension system into a total resistance of the configuration "AC model – suspension system", we obtained experimentally a dependence of the coefficient of front drag of the model's suspension system on the magnitude of alcoholic column of a liquid micromanometer (Fig. 2). This micromanometer is used to measure flow rate in the T-1 wind tunnel's working part by a pressure drop method [10].

Coefficient of frontal drag with respect to this correction is

$$X_a = X_{a\,meas} - X_{a\,SS}.$$

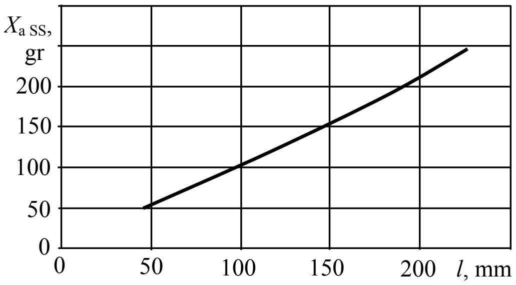


Fig. 2. Dependence of the coefficient of front drag of the model's suspension system on the magnitude of alcoholic column of a liquid micromanometer

"Horizontal buoyancy". Correction for the longitudinal pressure gradient is taken into account in the resistance measured using aerodynamic balance. The need to account for this correction is due to the fact that as a result of static differences in pressures in the frontal and aft parts of the model there occurs a longitudinal force, which is perceived by the aerodynamic scale. This force is missing under natural conditions [12]. It was subsequently assumed that a change in the static pressure along the tunnel's working part longitudinal axis occurs in line with a linear law with the gradient dC_p/dx constant along the length. Given such an assumption, the longitudinal force is determined as follows:

$$\Delta Q = (dC_p/dx)q_\infty,$$

where q_∞ is the speed head of undisturbed flow, W is the body volume equal to $W = S\times l\times\eta$, S is the mid-section area of the model, l is the length of the model, η is the coefficient of fullness taken for the model equal to 0.6.

Frontal drag coefficient with respect to this correction will be determined from the following expression:

$$C_{xa} = C_{xa\,meas} - (dC_p/dx)\times W/S.$$

Accounting for the effect of *flow turbulence intensity* was conducted at near- and supercritical angles of attack of the model. In this case, processing the experimental material was carried out based on the effective Reynolds number, derived from formula

$$\mathrm{Re}_{ef} = \mathrm{Re}\,K_m,$$

where Re is the Reynolds number, calculated by the characteristic parameter values in the experiment, K_m=1.8 is the turbulence factor determined in accordance with a chart provided in [12], depending on the intensity of flow turbulence in the T-1 wind tunnel's working part.

When determining intensity of the flow turbulence in the T-1 wind tunnel's working part, we employed a sphere sensitivity property to turbulence. It was experimentally determined that the initial flow turbulence in the T-1 wind tunnel's working part was of magnitude ε=1.2 % [10].

As it is known [12], a *blocking-effect* manifests itself in a wind tunnel of the closed type with an open working part and is caused by the influence of disturbances introduced by the model into a flow, which are propagating through a return channel to the tunnel's working part. Flow bevels at large angles of attack of the model result in that part of the air mass flows through the diffuser, escaping the return channel and the tunnel's working. In addition, the flow that returns to the working part possesses elevated unevenness [12]. This causes a change in the field coefficient of wind tunnel with the model in the working part by magnitude $\Delta\mu$ compared to the wind tunnel without a model in the working part; in this case, the value of $\Delta\mu$ depends on the lifting force of the model and its dimensions. Correction for the blocking-effect was take account for in the measured aerodynamic coefficients, calculated from formulae:

$$C_{\text{xa}}=C_{\text{xa meas}}\,\mu/(\mu+\Delta\mu);$$

$$C_{\text{ya}}=C_{\text{ya meas}}\,\mu/(\mu+\Delta\mu),$$

where $C_{\text{xa meas}}$, $C_{\text{ya meas}}$ are the measured value of coefficients of frontal drag and lifting forces; μ is the coefficient of the wind tunnel's field without a model in the working part; $\Delta\mu$ is the (Fig. 3), borrowed from [12].

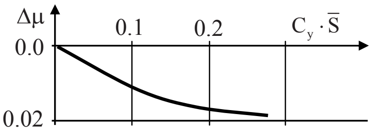


Fig. 3. Change in the field coefficient of wind tunnel under the influence of lifting force of the model

Clogging the wind tunnel's working part with the model and the slipstream. The flow around the model in the T-1 wind tunnel's working part of the open type is limited by a free surface of the stream; the stream's surface pressure is constant and is equal to pressure in the premises of an aerodynamic laboratory. In this case, longitudinal velocity in the place of model's location decreases and becomes less than the modal velocity V_p:

$$V_{\text{tr}}=V_p\,(1-\varepsilon_{\text{m}}),$$

where ε_{m} is the correction for speed reduction due to clogging a working part by the model, determined experimentally.

Clogging the working part of the open type tunnel by the slipstream is missing.

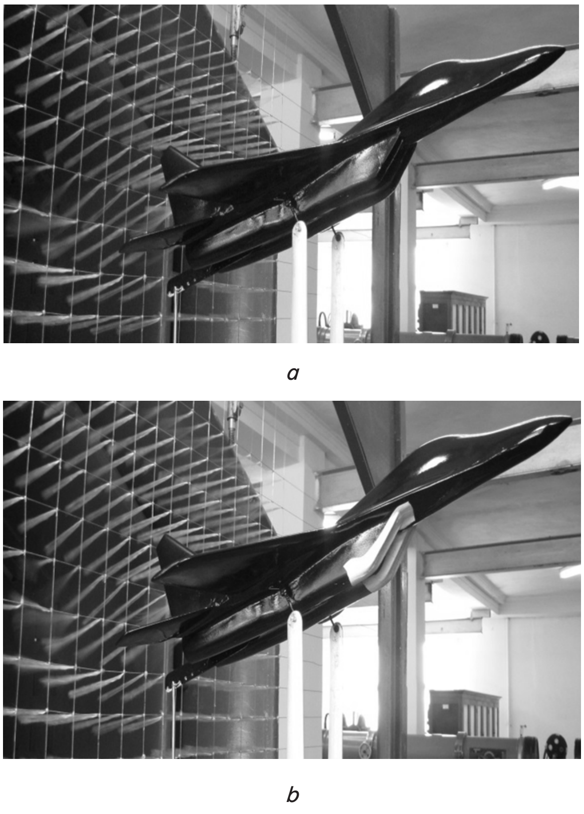
Wind tunnel's induction. The effect of lifting force manifests itself in the interaction between a vortex system generated by flow around the model with a nonzero lifting force and the borders of stream. This changes the field of inductive velocities, section angles of attack, lifting force coefficients, and inductive resistance. In the wind tunnel with an open working part the flow bevel in sections of the wings increases, leading to a certain reduction in lifting force and to decreasing inductive resistance compared with corresponding characteristics in an unlimited flow. In this case, corrections depend on the shape of the wind tunnel's working part, on relative dimensions of the model:

$$\Delta\alpha_i=\delta_{\alpha i}\cdot\overline{S}\cdot C_{ya\,meas},$$

$$\Delta C_{xa\,i}=\delta_{Cx\,\alpha i}\cdot\overline{S}\cdot\left(C_{ya\,meas}\right)^2,$$

where $\delta_{\alpha i}$, $\delta_{\text{Cx}\,\alpha\text{i}}$ are the correction coefficients that take into account the influence of the shape of the wind tunnel's working part on the inductive flow bevel and on the inductive resistance factor, respectively; $\overline{S}=S/F$, S and F are the characteristic area of the model, and cross-sectional area of the tunnel's working part, respectively.

Resistance of the inner channel of the model's nacelles and flow around bodies with a passage. For the model, in this case, corrections depend on the shape of the channel, relative air flow rate through it and the angle of attack. When processing results of the experiment, we took into account corrections for the frontal drag coefficients ΔC_{xa} and the lifting force ΔC_{ya}. For models without passages of the nacelles, those corrections are taken into account that make it possible to obtain summarized ADC, similar to the model with a passage. However, the character of flow around the stern of the model can greatly differ from the flow in its bow unit. Fig. 4 shows photograph of a model of the fighter aircraft with a passage, behind which there was a steel grid with soie in the grid nodes. The presence of soie allowed us to visualize direction of the flow lines, as well as location of the regions of detachment currents.


a

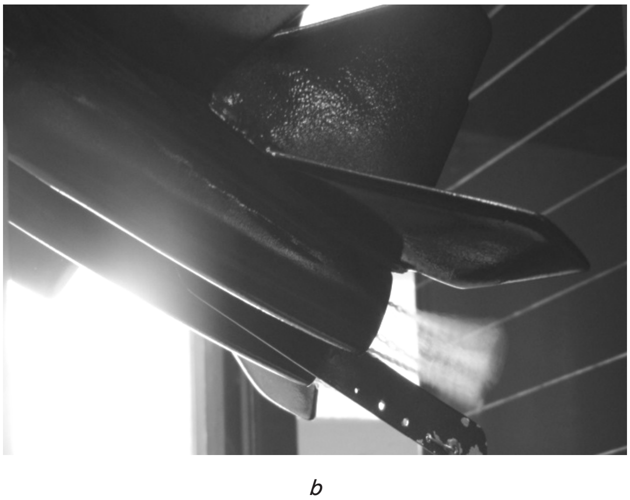
b

Fig. 4. Photograph of physical appearance of the T-1 wind tunnel's working part with a model of the fighter aircraft: *a* — with a passage; *b* — without a passage

During aero-tube experiment we investigated models of the aircraft with a nacelle with different shapes of nozzles: round and rectangular. The shapes of nozzles are represented by different removable structures with different ratios of sides. The presented photographs do not display removable nozzles. Fig. 4, *b* shows photograph of the aircraft-fighter model; in this case, the inlet channels of nacelles sealed with a tight adhesive plaster demonstrating the absence of engine operation. In this case, at large angles of attack one observes a detachment of the flow behind the nacelles, which, in the presence of a passage, was not detected even at supercritical angles of attack during aero-tube experiment.

The absence of a flow detachment at supercritical angles of attack of the model shows is shown in Fig. 5, *a*, where one can see soie at the cut of nacelle, oriented along the flow exiting a nacelle's channel. The presence of a flow detachment in the aft unit at the same angles of attack of the model is shown in Fig. 5, *b*. The detachment can be observed by the "blur" of soie.

a



b

Fig. 5. Photograph of a tail unit of the fighter aircraft's model: *a* — with a passage; *b* — without a passage

Such a technique of flow visualization in the characteristic region of an aircraft is quite simple and makes it possible to predict possible zones of detachment currents.

5. Results of research into ADC

Fig. 6–8 show dependences of coefficients of lifting force on the angle of attack, polar curves and aerodynamic quality of the aircraft model on the lifting force coefficient. Dependences are derived as a result of processing experimental data and are denoted by lines with markers.

Recalculation for the Re numbers was performed in line with the procedure given in papers [2, 12]. In the presented dependences, data obtained from well-tested semiempirical dependences from article [13] are indicated by solid lines.

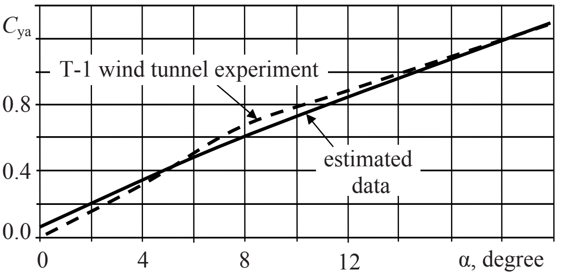


Fig. 6. Dependence of lifting force coefficient of a fighter aircraft on the angle of attack

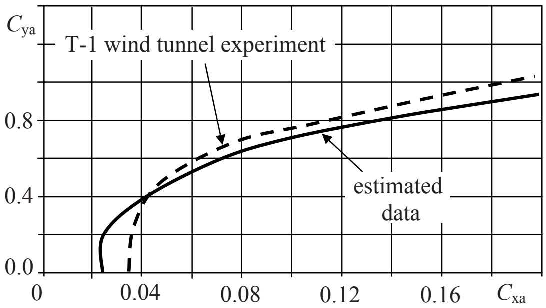


Fig. 7. Polar curve of a fighter aircraft

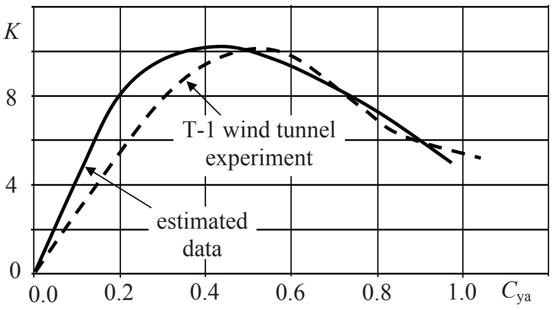


Fig. 8. Dependence of aerodynamic quality of a fighter aircraft on lifting force coefficient

Based on a comparative analysis of the obtained experimental and estimated data, it should be noted that the best agreement of results was received at large values of the lifting force coefficient.

6. Discussion of results of aero-tube experiment

The maximal quality of an aircraft at $M=0.6$, retracted chassis and flaps, obtained in line with [13], is 10.3 units ($Re\approx1.9\times10^7$); when recalculating by the same number of Re, a maximum quality of the aircraft at $M=0.6$ during aero-tube experiment amounted to 10 units. Thus, the relative error of determining maximum aerodynamic quality during WTT was $\delta \approx 3$ % compared to the results of calculation.

The angle of zero lifting force, obtained in line with [13] is $\alpha_0 \approx -0.5°$, according to the results of aero-tube experiment, the angle $\alpha_0 \approx 0°$, which can be explained by taking into account the impact of engines work and imprecision in the manufacturing of the model. It should be noted that a small scale of the model and limited dimensions of the wind tunnel's working part hinder conversion of the obtained results into full-scale Re numbers.

The main benefit of the study conducted is considered to be a creation of simple and reliable procedure for a comprehensive analysis of corrections. As a drawback, we note the impossibility of modeling distributed ADC and small-scale aerodynamic effects. However, the results obtained could be applied in the development and adjustment of mathematical models for the fighters aircraft flight at the supercritical angles of attack, as well as when studying detachment phenomena on the elements of an airframe and aircraft's nacelle.

The studies we conducted are a continuation of previously performed research with various structural-component AC configurations. By improving the methodology for conducting an experiment, we intend in the future to prepare and conduct aerodynamic testing of the fighters aircraft models with non-axisymmetric engine nozzles. It is planned to investigate the effect of engine operating mode and the shape of a nozzle on the summary and distributed ADC of fighter airframe. In addition, we intend to conduct aerotube research into fighter aircraft models with a separation of bodies from an aircraft carrier, for example, disposable fuel tanks, different types of airborn means of destruction, etc.

7. Conclusions

1. Thus, the research we conducted allows us to improve a technique for aero-tube experiment in the wind tunnel with an open working part. We conducted experimental study into ADC of the model of a maneuverable aircraft of the MiG-29 type, with and without a passage of airflow through the nacelle's engines. Methodology for a comprehensive analysis of corrections has been devised. Using experimental research results, we identified magnitudes of the most important correction coefficients: frontal drag $\Delta C_{xa,}$ and lifting force ΔC_{ya}. For the models without passages of nacelles, we took into account those corrections that make it possible to obtain summarized ADC similar to the model with a passage.

2. It should be noted that ADC of a fighter aircraft obtained during given aerotube experiment satisfactorily agree with data on aerodynamic characteristics of the aircraft MiG-29. A comparative analysis of research results allows us to make a conclusion about adequacy of accounting for experimentally-determined corrections for the interaction between a suspension system of the model and resistance of an inner channel of the model's nacelles.

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