Technical Physics, 2025, Vol. 70, No. 12

Parametrical study of long-haul aircraft high-lift devices on small-scale half-model

© E.A. Pigusov, A.I. Volkov, A.A. Krutov, S.A. Kuzin

Zhukovsky Central Aerohydrodynamic Institute,
140180 Zhukovsky, Moscow oblast, Russia
e-mail: pigusoff@gmail.com

Received May 5, 2025
Revised May 5, 2025
Accepted August 19, 2025

Results of the parametrical experimental studies of the long-haul aircraft high-lift devices on small-scale half-model are presented. A maximum lift coefficient Cya max dependence on the Reynolds number was obtained for the tested model, which allows to estimate the value of the Cya max under full-scale conditions. The influence of high-lift devices parameters on the lift coefficient is shown.

Keywords: long-haul aircraft, high-lift devices, windtunnel, aerodynamic characteristics.

DOI: 10.61011/TP.2025.12.62494.242-25

To design and improve the long-haul aircraft (LA) high-lift devices is a complex and resource-intensive task of aerodynamic designing. Aerodynamic designing of the long-haul aircraft requires a large scope of research for selecting reasonable parameters of slats and flaps [1]. Currently-common CFD (computational fluid dynamics) methods do not allow performing parametric studies in the wide ranges due to high requirements to quality of computational grids and long duration of computational modeling. In turn, parametric studies in industrial windtunnels (IWT) is often unavailable due to high cost of an aerodynamic model and tests. In order to increase availability of IWT use for the parametric studies within the framework of designing the high-lift devices and to test local aerodynamics of a promising long-haul aircraft that is characterized by an oval cross section of a fuselage and a middle arrangement with developed leading-edge extensions, it is proposed to use a small-scale half-model realized by widely applying additive technologies.

A specific feature of a long-haul aircraft layout that has the developed leading-edge root extension is a reduced sweep of the high-lift devices in relation to classic passenger aircraft and, consequently, reduction of bearing properties during take-off and landing, thereby negatively affecting a required length of a runway.

A required value of a maximum coefficient of lift in the landing configuration $C_{ya\,\max\,landing} \geq 2.8$ with taking into account design limitations and aerodynamic characteristics of the long-haul aircraft layout as well as with taking into account an increment of the maximum lift from the slat $\Delta C_{ya\,slat\,\max} \approx 0.78{-}0.8$ can be provided when applying a double-slot high-lift devices of a rear edge with the total deviation angle of the double-slot flap $\delta_{flap} \approx 50^\circ$ and with a value of overlapping of the flap with a basic profile in a retracted position $\bar{d} \geq 0.6$ (in fractions of a flap chord). In order to provide the required value of the maximum coefficient of lift during take-off $C_{ya\,\max\,take\,off} = 2.4{-}2.45$ the flap shall be deviated by the angle $\delta_{flap} \approx 25^\circ$ in a single slot position.

For the long-haul aircraft (Fig. 1, a), the wing high-lift devices were aerodynamically designed (Fig. 1, b) with the following solutions:

– the take-off position: the slat has no slot, which shall have a favorable effect on its noise level, while the flap in the take-off position has a single slot;

– the landing position: the slat is extended to form a slot for increasing a critical attack angle, while the flap is divided into two links to form the second slot, wherein the first link remains in the take-off position.

The solution with the zero-slot slat in the take-off position is applied, for example, in A350XWB [2]. Outlines of the wing high-lift devices were formed according to recommendations specified in the study [3].

Flow over the long-haul aircraft layout with the extended wing high-lift devices was computationally studied according to a procedure specified in the study [4]. CFD-simulation resulted in obtaining values of the maximum coefficients of lift, which are close to design ones (Fig. 1, c). The increment of the maximum coefficient of lift is $\Delta C_{ya\,\max\,take\,off} \approx 1.28$ in the take-off configuration and $\Delta C_{ya\,\max\,landing} \approx 1.74$ in the landing configuration. The critical attack angle in the take-off configuration $\alpha_{\max\,take\,off} \approx 16^\circ$ and this angle int he landing configuration $\alpha_{\max\,landing} \approx 18^\circ$.

In order to experimentally confirm the results of aerodynamic designing, a small-scale half-model for the long-haul aircraft with the wing high-lift devices was designed and manufactured for IWT tests. The half-model makes it possible to perform tests with a schematized (shortened) full-scale fuselage with the tailplanes (Fig. 2, a). The tests were performed at incoming flow velocities $V = 20{-}60$ m/s, which corresponded to Reynolds numbers Re from $0.19 \cdot 10^6$ to $0.56 \cdot 10^6$ within the range of the attack angles α from -6 to 36° for the schematized fuselage and from -6 to 22° for the full-scale fuselage. A difference

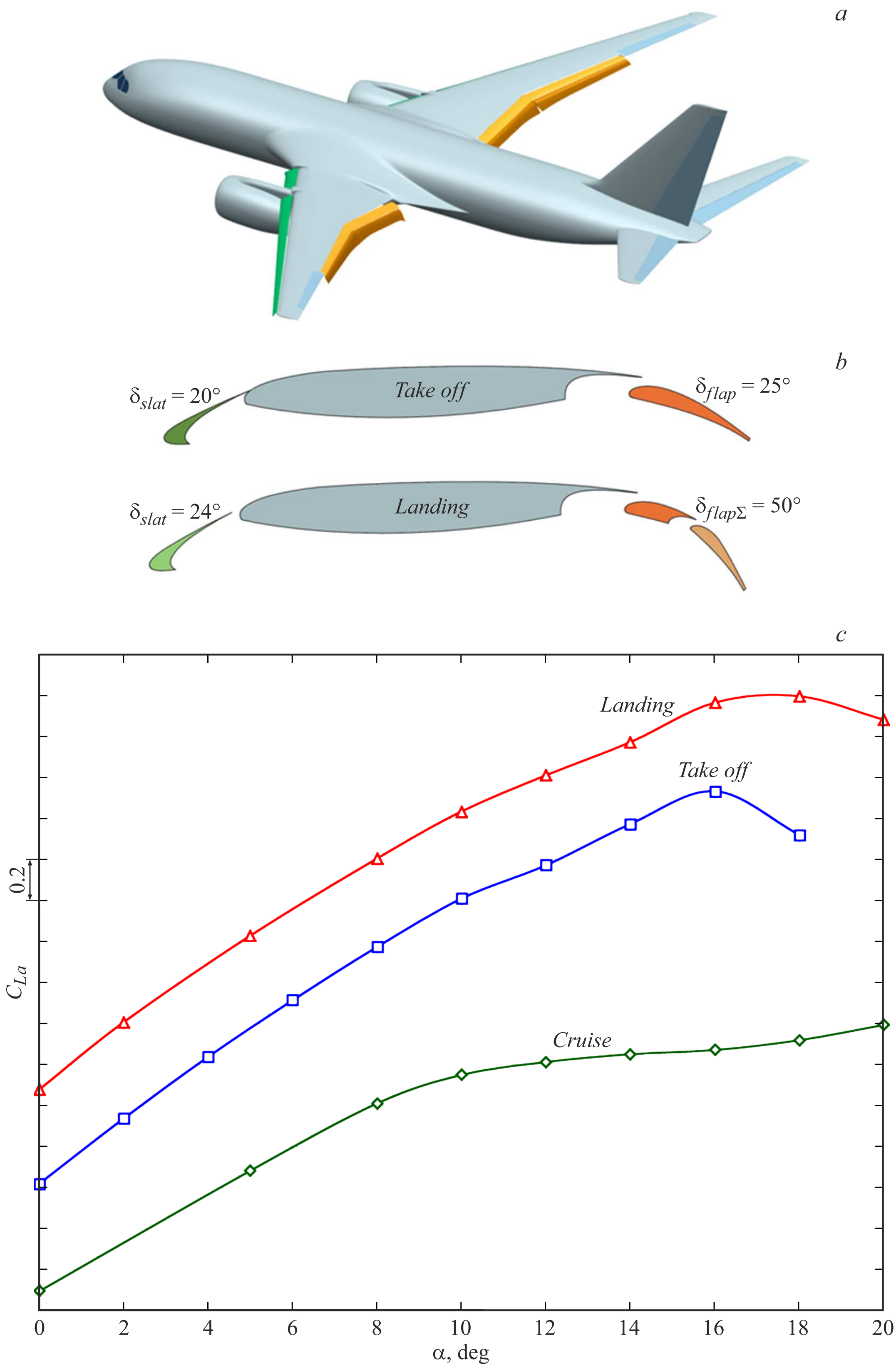

Figure 1. Results of aerodynamic designing of the high-lift devices: *a* — the layout of the long-haul aircraft with the high-lift devices, *b* — sections of the wing with a take-off and a landing position of the high-lift devices, *c* — calculated dependences $C_{ya}(\alpha)$ in cruising, take-off and landing configurations.

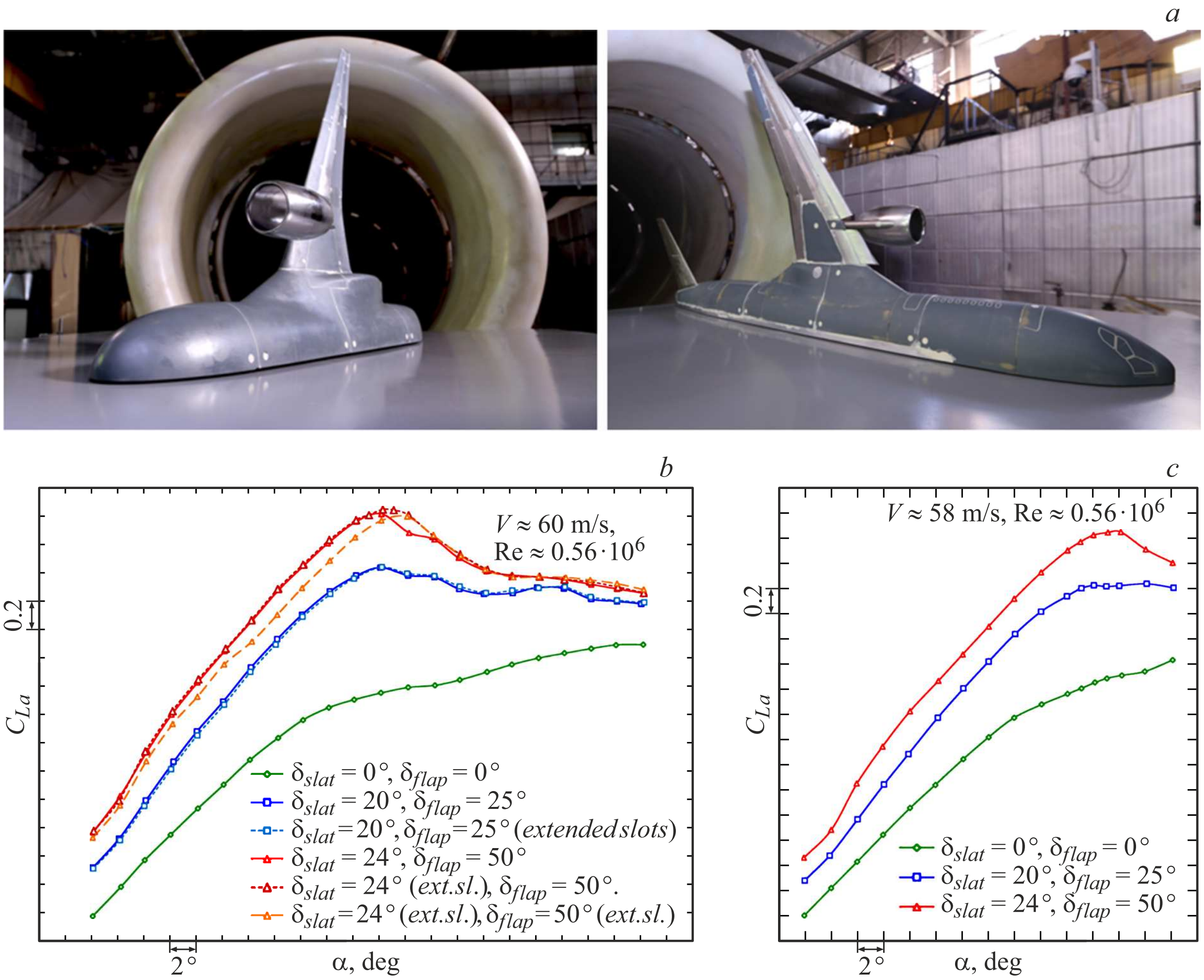

Figure 2. Experimental studies of the high-lift devices of the long-haul aircraft wing on the half-model: *a* — options of the half-model in the working part of the IWT, *b* — the dependences $C_{ya}(\alpha)$ for the half-model with the schematized fuselage, *c* — the half-models $C_{ya}(\alpha)$ with the full-scale fuselage and tailplanes.

in the studied ranges of the attack angles is related to the fact that it is necessary to provide a position of the model inside a flow core in the working part of the IWT.

Within the framework of the experimental studies of the high-lift devices, we have considered the options of the slats and the flaps with slots that correspond to the full-scale ones and are increased in 1.5 times, in order to check operability of the full-scale slots at the low numbers Re. As a result of the tests of the half-model with the schematized fuselage, it is determined that the highest increments of the bearing properties are achieved in the take-off configuration with the full-scale slots on the flaps and in the landing configuration with the increased slots on the slats and the full-scale slots on the flaps (Fig. 2, *b*). These configurations are selected for subsequent tests.

Then, the half-model was tested with the full-scale fuselage and tailplanes. The obtained results are typical for the modern long-haul aircraft (Fig. 2, *c*). The increment of the maximum coefficient of lift is $\Delta C_{ya\,\max\,take\,off} \approx 0.71$ in the take-off configuration and $\Delta C_{ya\,\max\,landing} \approx 1.13$ in the landing configuration. The critical attack angles are close to those obtained in the computational studies.

Results of the tests of the half-model with the high-lift devices with variation of the number Re from $0.19 \cdot 10^6$ to $0.56 \cdot 10^6$ are analyzed to demonstrate an exponential function of the maximum coefficient of lift $C_{ya\,\max}$ on the number Re (Fig. 3). It allows estimating possible values of $C_{ya\,\max}$ at the full-scale number Re $\approx 25 \cdot 10^6$. These results well agree with the calculated values of $C_{ya\,\max}$ obtained on the designed high-lift devices for the long-haul aircraft layout.

Conflict of interest

The authors declare that they have no conflict of interest.

References

[1] H. Strüber. *The Aerodynamic Design of the A350 XWB-900 High Lift System*. 29th Congress of the International

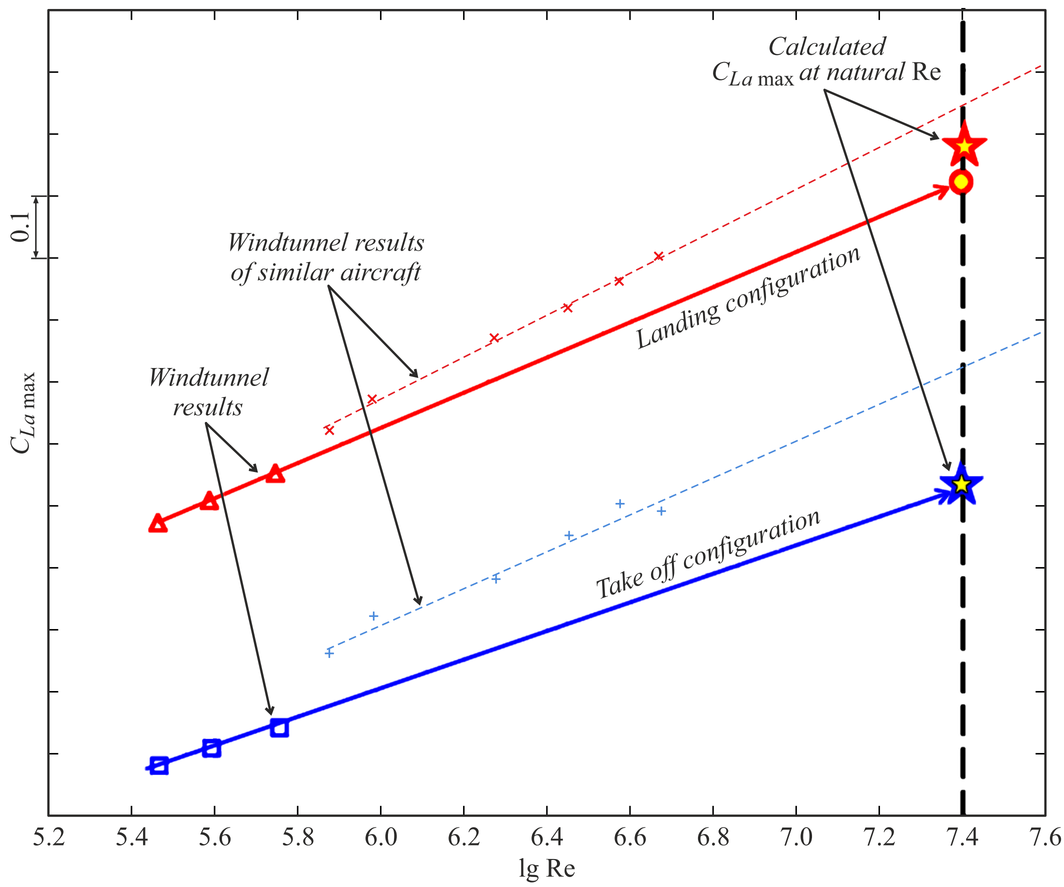

Figure 3. Estimation of the full-scale values of $C_{ya\ \max}$ and comparison with the calculation.

Council of the Aeronautical Sciences, International Council of the Aeronautical Sciences (ICAS) (St. Petersburg, Russia, 2014)

[2] D. Reckzeh. *Multifunctional Wing Moveables: Design of the A350XWB and the Way to Future Concepts*. 29th Congress of the International Council of the Aeronautical Sciences, International Council of the Aeronautical Sciences (ICAS) (St. Petersburg, Russia, 2014)

[3] K.P. Petrov. *Aerodinamika elementov letatel'nykh apparatov* (Mashinostroenie, M., 1985), s. 125 (in Russian).

[4] V.V. Vozhdaev, A.I. Volkov, A.A. Krutov, E.A. Pigusov. Polet. Obshcherossiiskii nauchno-tekhnicheskii zhurnal, **1**–**2**, 43 (2023) (in Russian).

Translated by M.Shevelev