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STUDY ON AERODYNAMIC CHARACTERISTICS OF LIGHT CONVERTIBLE AIRCRAFT MODEL

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Abstract

This paper presents the results of wind tunnel investigations of a light convertible aircraft scale model. Tests were carried out in TsAGI low speed wind tunnel. As part of the test, the slipstream effect of running propellers was investigated. The total aerodynamic characteristics of the light convertible aircraft model in main flight configurations are obtained. The effectiveness of flaps and flight control surfaces (elevator, rudder, ailerons) are determined. The influence of empennage options on longitudinal stability is investigated. The influence of an external cryogenic fuel tank on the scale model is considered. The slipstream effect of propellers on model aerodynamic characteristics is shown.

Keywords: turboprop aircraft, aerodynamic model, wind tunnel, control surfaces, empennage

1. Introduction

Light convertible aircraft (LCA) with two TV7-117ST turboprop engines is proposed for the transportation of 48-52 passengers or 6 t of cargo at a speed 450-480 km/h on local and regional routes, with capability of operations on paved (concrete, bituminous concrete) and unpaved runways (Figure 1). The feature of LCA is an optimized cabin for passenger transportation with maximum comfort or cargo in standard containers (or pallets) without changing basic airframe structure (Figure 2). The aircraft is equipped with aft cargo ramp for easier cargo loading. The cryogenic fuel aircraft option is considered.

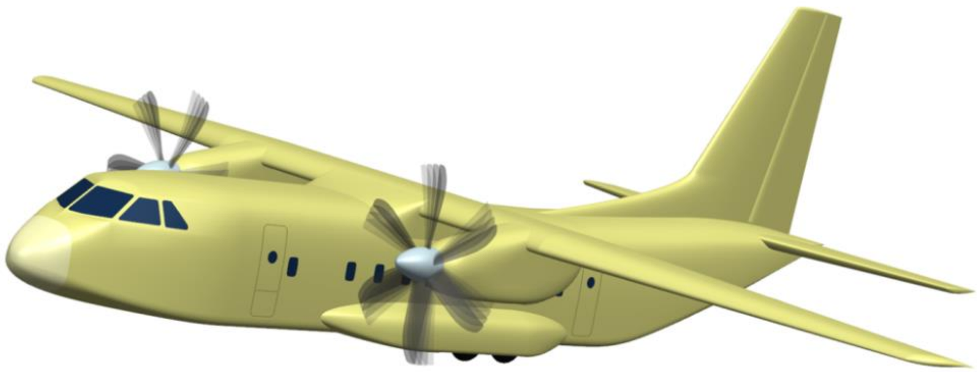

Figure 1 – Light convertible aircraft

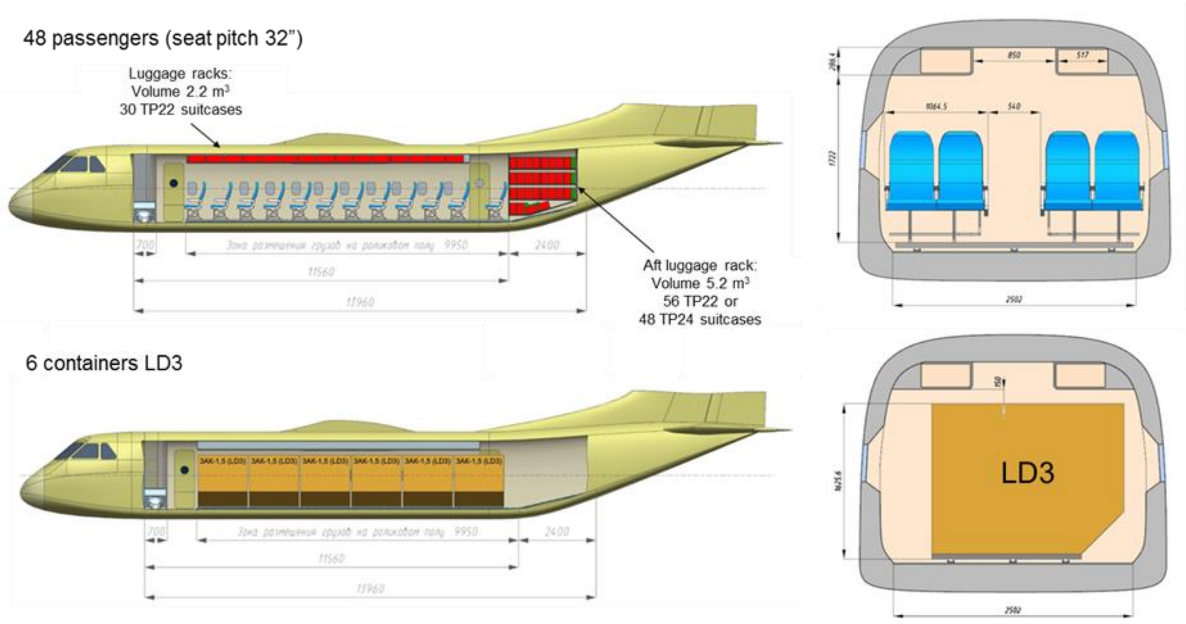

Figure 2 – Transport capabilities of LCA

This paper presents the results of windtunnel tests of LCA scale model. Tests were aimed for determining of:

- high-lift devices effectiveness;
- effect of different horizontal stabilizers on model aerodynamics;
- flight controls effectiveness: elevator, rudder, ailerons;
- influence of over-fuselage fuel tank for cryogenic fuel on model aerodynamics;
- influence of propellers slipstream on model aerodynamics.

2. Aerodynamic model and test conditions

2.1 Aerodynamic model

The aerodynamic model of LCA was produced in 1:10 scale (Figure 3). Aerodynamic layout of LCA model is based on classic high-wing scheme with wing aspect ratio AR=9.68, fuselage with trapezoidal cross-section, classic empennage with one vertical tail and fuselage-placed horizontal tail [1, 2]. Wing equipped with single-slotted Fowler flaps with a chord of 30% (Figure 4), spoilers and ailerons (with a span of 30% of wing). Reference geometry parameters of the LCA model for aerodynamic coefficients are presented in table 1.

Table 1 – Reference dimensions of LCA model.

Parameter	Value
Wingspan, m	2.616
Mean aerodynamic chord (MAC), m	0.285
Wing area, m^2	0.707

Figure 3 – LCA model in the TsAGI low speed wind tunnel

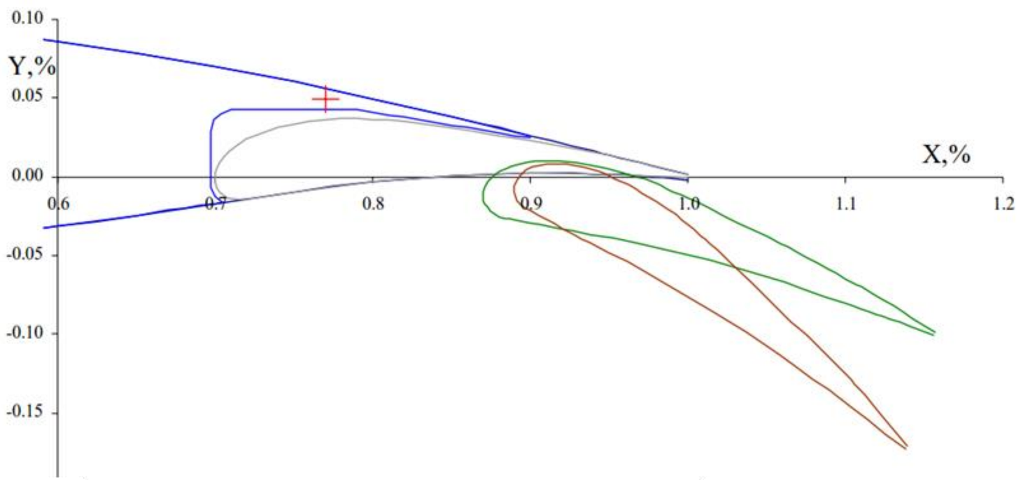

Figure 4 – LCA model flap geometry

2.2 Test conditions

Experimental studies of the LCA model were carried out in the T-102 TsAGI subsonic WT [3]. T-102 is continuous-operation, closed layout WT with two reverse channels and an open test section designed to investigate aerodynamic characteristics of aircraft models at take-off, landing and low-speed flight. Elliptical test section is characterized by 4 m x 4 m x 2.33 m size.

Investigation of longitudinal aerodynamic characteristics was conducted for the angles of attack (AoA, α) ranged from -10° to 20° at zero sideslip angle. Investigation of lateral aerodynamic characteristics was conducted the sideslip angles (β) ranged from -20° to 20° at a fixed AoA 5° and 8°.

Flow velocity was varied from 19 to 50 m/s in tests, which corresponds to the Reynolds number Re=0.37…0.98×10^6.

To identify the features of interaction between propellers and the airframe, TsAGI uses an experimental method based on simultaneous measurement of forces and moments on the propeller (using six-component strain gauges built into the model powerplant) and the total forces and moments acting on the model aircraft with operating propellers (using external six-component balance system) [4]. Rotation direction of propellers is clockwise.

Additional similarity parameter for test cases with running propellers is propeller swept surface area load factor (further – load factor) *B*.

Load factor *B* was determined by the equation (1).

$$B = \frac{P_0}{q_\infty \cdot F} \tag{1}$$

where P_0 is a propeller thrust, q_∞ is an dynamic pressure in windtunnel, *F* is a blade swept surface area.

The in-test values of load factor *B* and flow velocity V_∞ at propeller rotation frequency 5000 rpm are presented in table 2.

Table 2. Load factor *B* vs flow velocity V_∞

Load factor *B*	Flow Velocity V_∞, m/s
0.2	36
0.5	31
1	26
1.5	22
2	19

3. Results and Discussion

3.1 Aerodynamic characteristics of LCA including Various Horizontal Tailplanes

Flap defection increases lift force at linear part and in area of high AoA (figure 5). In windtunnel tests of LCA model following increments received: growth of lift coefficient at AoA 0° is $\Delta CL_0 \approx 0.53$ at $\delta_{flap}=18°$ and 1.01 at $\delta_{flap}=35°$; raise of maximum lift coefficient is $\Delta CL_{MAX} \approx 0.51$ at $\delta_{flap}=18°$ and 0.78 at $\delta_{flap}=35°$. Flap defection increases nose-up pitching moment of the model.

Figure 5 also represents the influence of horizontal stabilizers with different planform and area on LCA model aerodynamics. The option №1 of stabilizer with asymmetric airfoil, relative area 21.7% and leading edge sweep angle 16° provides static longitudinal stability with static margin 22.8% in cruise configuration. The option №2 of stabilizer with symmetric airfoil, enlarged relative area 24.8% and leading edge sweep angle 26° provides static longitudinal stability with static margin 27% in cruise configuration. The option №2 provides higher lift-to-drag ratio ($\Delta L/D \approx 0.5$) with larger wetted area.

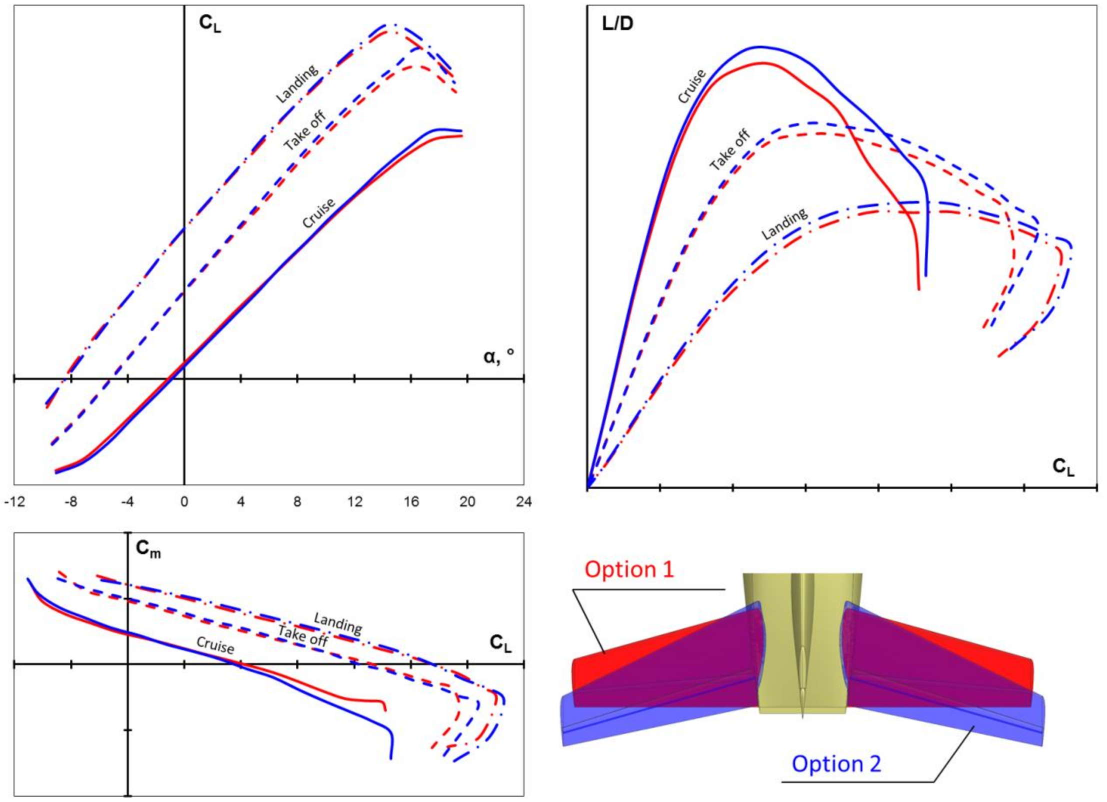

Figure 5 – Aerodynamic characteristics of LCA model in cruise, takeoff and landing configurations with different variants of horizontal stabilizer

3.2 Control Surfaces Effectiveness

Each variant of LCA model horizontal stabilizer was tested with deflection of elevator.

Elevator of option №1 stabilizer is designed with relative chord 35%, axial compensation 20% and deflection angles δ_{ELEV}=-30…25°. Elevator of option №2 stabilizer is designed with relative chord 37.7%, axial compensation 28.6% and deflection angles δ_{ELEV}=-30…25°.

Results of elevator effectiveness investigation are presented in figure 6. As we can see, elevator of variant №2 stabilizer is more effective.

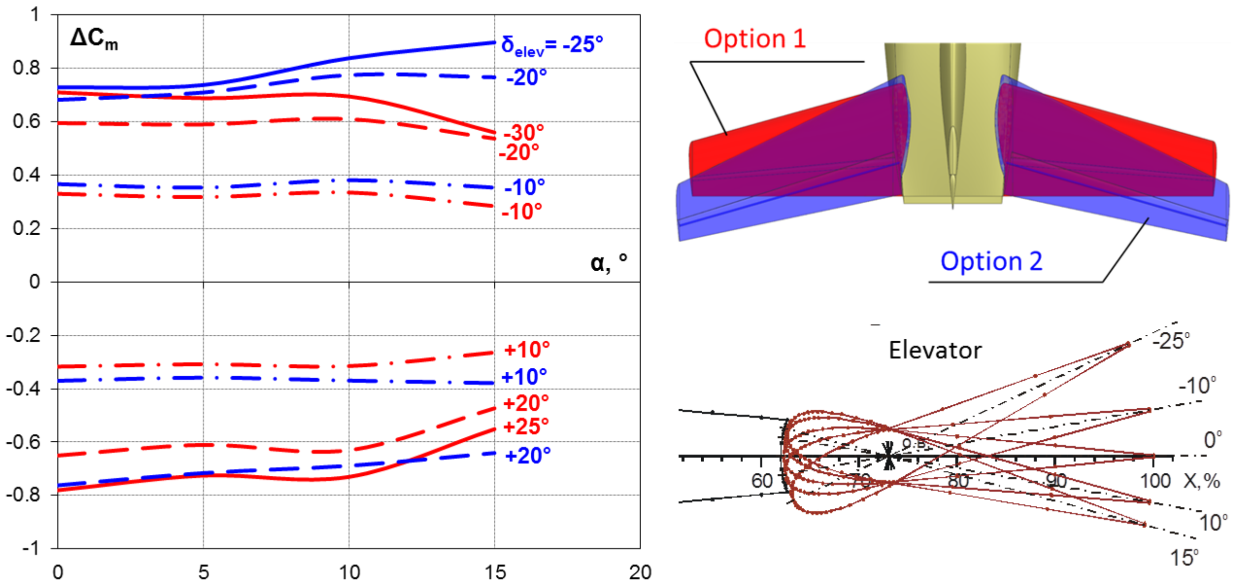

Figure 6 – Elevator effectiveness of LCA model with different stabilizers

Ailerons of LCA model are designed with relative area 7.4%, relative span 30% and axial compensation 29%. Maximum deflection angles are δ_{AIL}=-30…30°.

Figure 7 represents the results of aileron effectiveness investigation in longitudinal and lateral directions at deflection angles of left aileron $\delta_{AIL\ left}$=-20° and right aileron $\delta_{AIL\ right}$=20°. The rolling moment of deflected ailerons slightly reduces with growth of angle of attack. Aileron effectiveness in lateral direction is close to constant in sideslip angle range β=±10°, at higher sideslip angles rolling moment decreases.

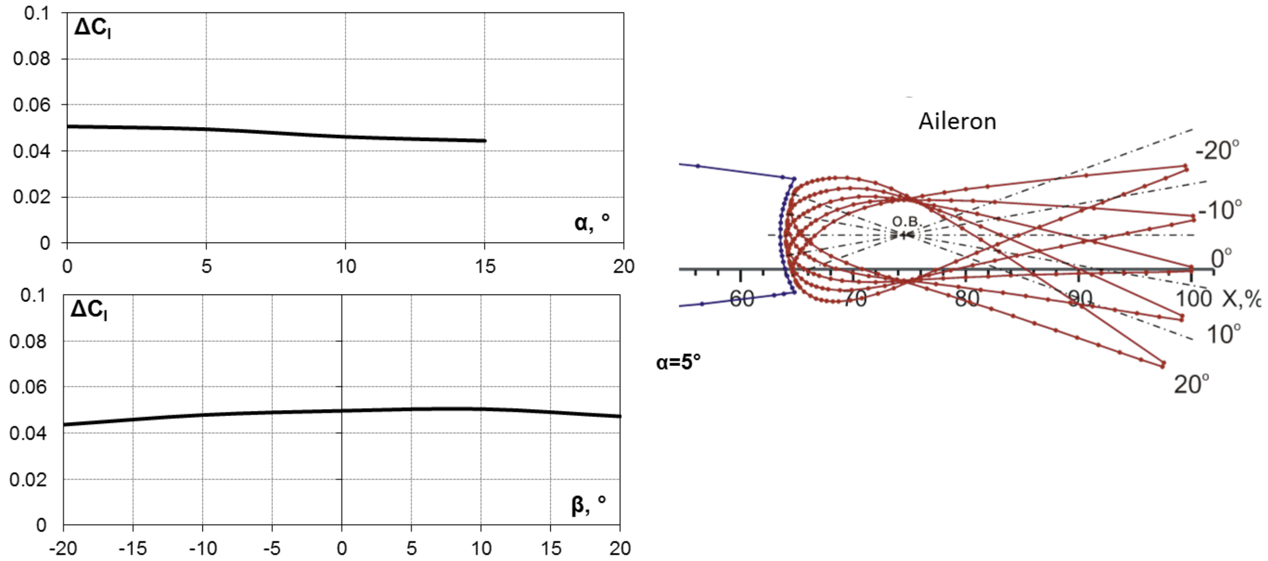

Figure 7 – Ailerons effectiveness of LCA model (deflection angles: $\delta_{AIL\ left}$=-20°, $\delta_{AIL\ right}$=20°)

The vertical tailplane of LCA model has relative area 24.8%.

Figure 8 represents the results of rudder effectiveness investigation in lateral direction for deflection angles δ_{RUD}=-10°, -20°, -30°. Yawing moment increment of deflected rudder at δ_{RUD}=-30° reduces significantly in comparison with lower deflection angles. It's worth noting that yawing moment dependencies on sideslip angle have asymmetry at δ_{RUD}<-10°, when rudder deflects on leeward.

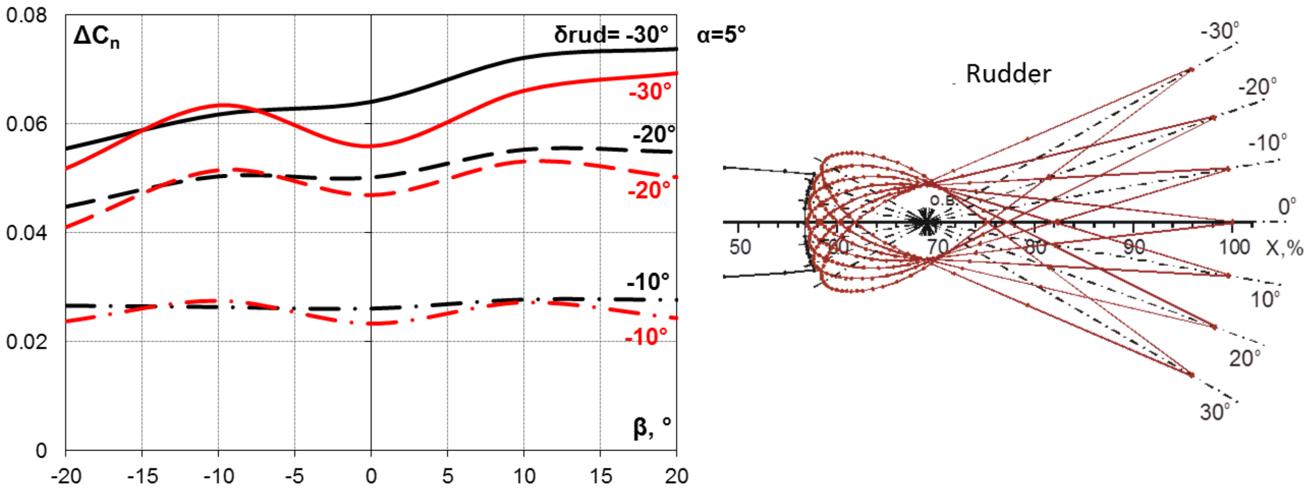

Figure 8 – Rudder effectiveness of LCA model (red curves – with external fuel tank)

3.3 Cryogenic Fuel Tank Influence

External fuel tank for cryogenic fuel is a body of revolution with fineness ratio 5.175 and relative cross-sectional area 4.4%, placed over the fuselage outside the propeller blades spread zone.

Figure 8 represents influence of external fuel tank on the rudder effectiveness. As we can see, the yawing moment increment of deflected rudder significantly decreases at low sideslip angles due to slipstream behind fuel tank. Also, fuel tank slipstream reduces local sideslip angle in front of vertical tailplane and its effectiveness, especially at high sideslip angles.

In longitudinal direction major effect of external fuel tank is a growth of drag coefficient, which decreases lift-to-drag ratio (figure 9).

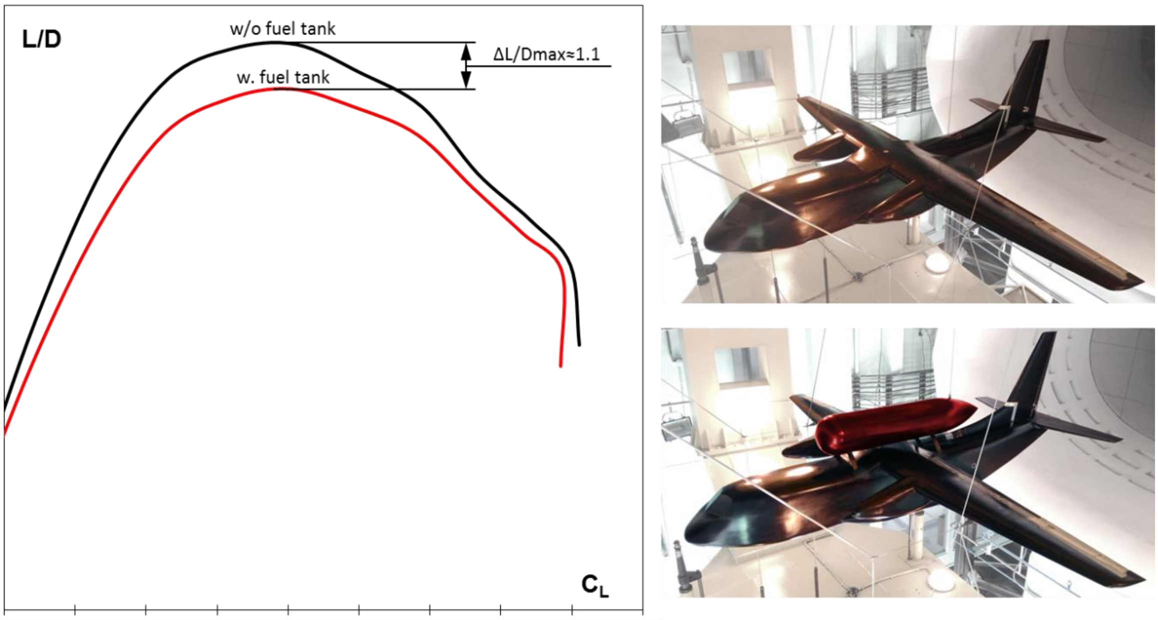

Figure 9 – Reduction of LCA model lift-to-drag ratio due to external fuel tank installation

3.4 Interaction with propellers

Figures 10, 11 and 12 represents several test results of LCA model with running propellers in cruise, takeoff and landing configurations and horizontal stabilizer option №1. Interaction of propeller slipstream with layout significantly changes aerodynamic characteristics of the model and influence depends on flaps deflection angle. Propeller slipstream induces appreciable increase of maximum lift coefficient and pitching moment in takeoff and landing configuration due to deflection of propeller jet by flaps.

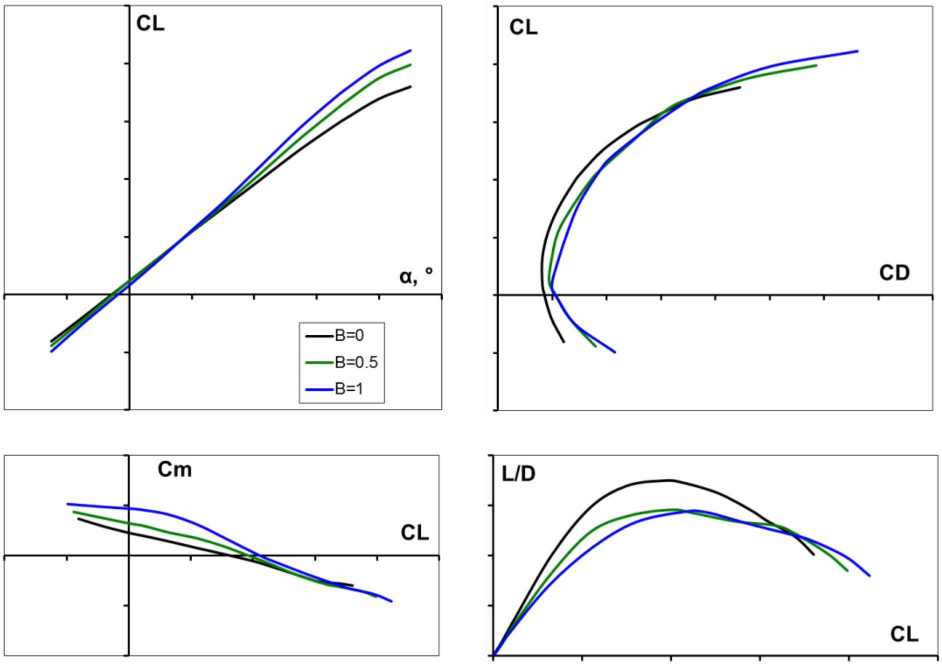

Figure 10 – Influence of propeller slipstream on aerodynamic coefficients of LCA model in cruise configuration

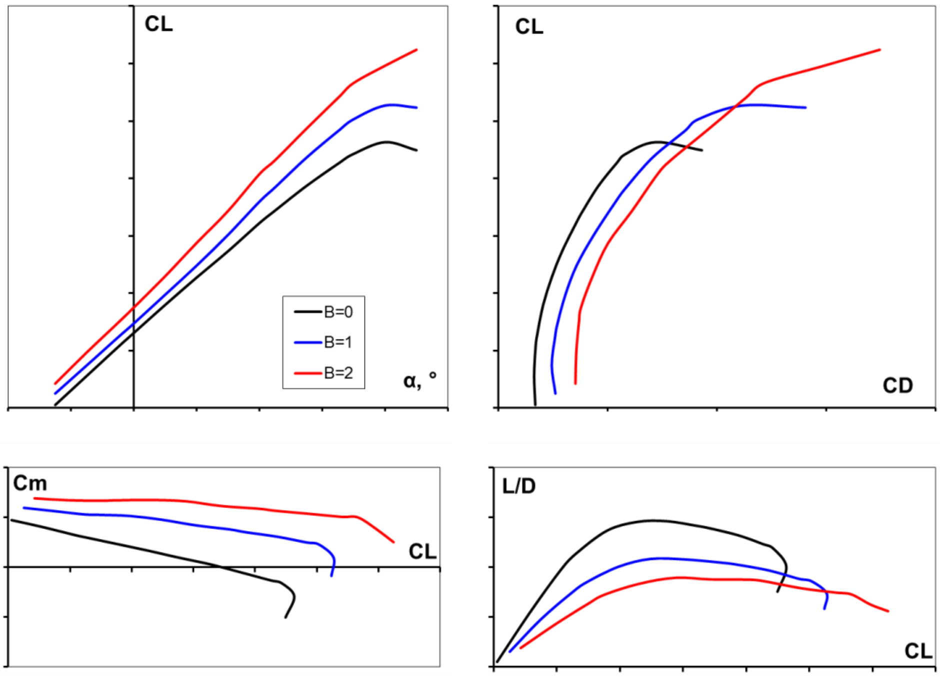

Figure 11 – Influence of propeller slipstream on aerodynamic coefficients of LCA model in takeoff configuration

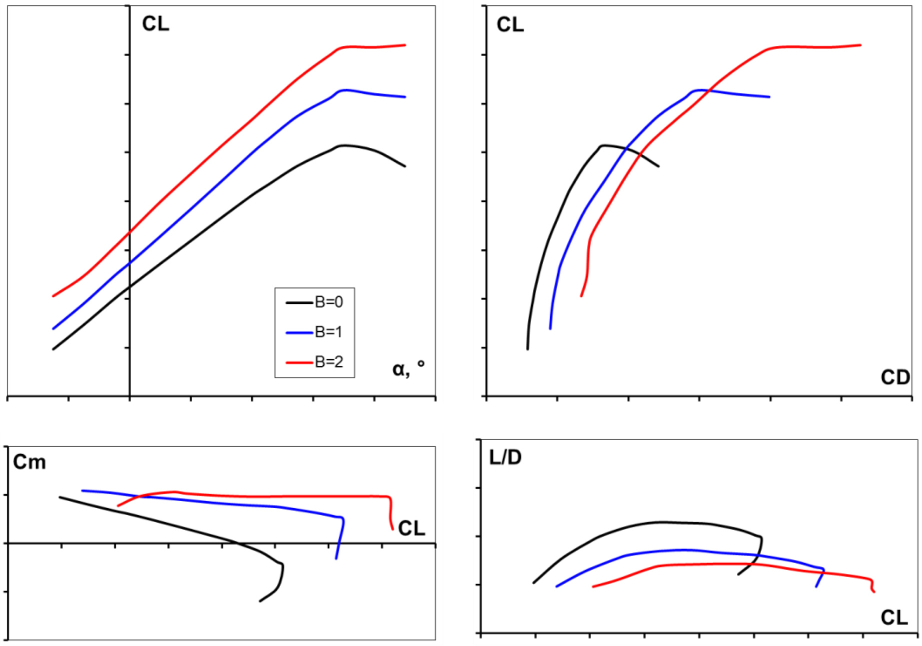

Figure 12 – Influence of propeller slipstream on aerodynamic coefficients of LCA model in landing configuration

Figure 13 shows that aerodynamic parameters of the model changes nonlinearly from load factor B and different for each flap position. Propeller slipstream affects on LCA model aerodynamics as follows:

- lift coefficient derivative on AoA increases to 15…30% (at B=2 for different flap deflection angles);
- Static margin in cruise configuration increases 2 times. With deflected flaps static margin decreases, and at B=2 in landing configuration it is near neutral;
- minimum drag coefficient grows ($\Delta C_{D\ min}$≈0.076 at B=2 in takeoff configuration);
- maximum lift-to-drag ratio decreases approximately the same for all flaps positions ($\Delta L/D_{MAX}$≈3…4 at B=2 for different flap deflection angles).

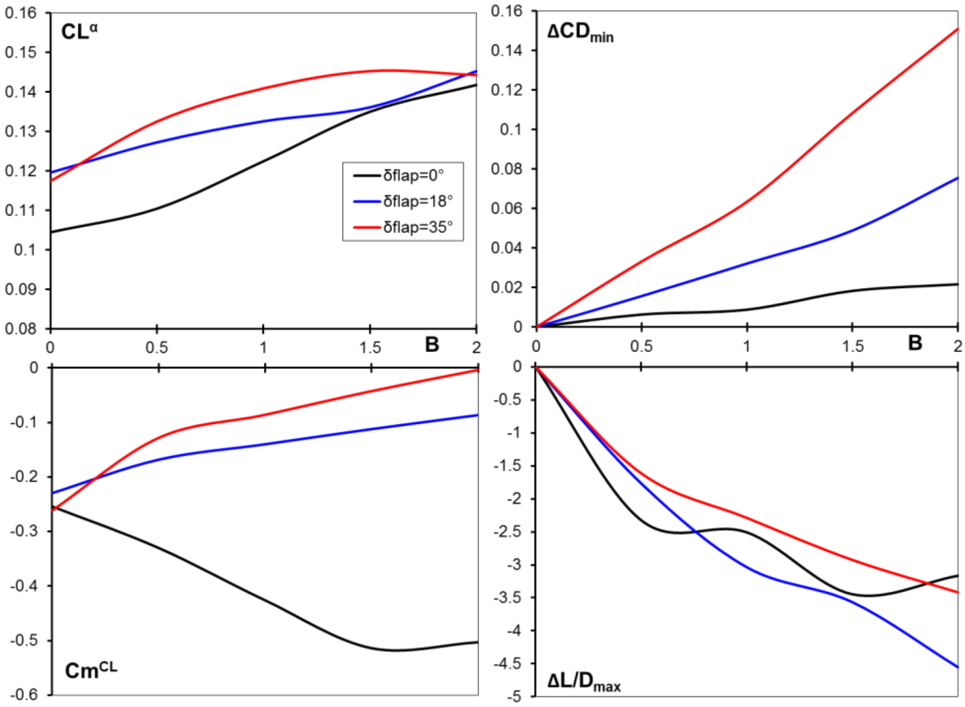

Figure 13 – Influence of load factor B on aerodynamic coefficients of LCA model in different flap configuration

4. Conclusion

A large amount of test data about LCA aerodynamics was obtained in this research.

The results of LCA model windtunnel tests shows high enough level of aerodynamic characteristics of model using fuselage with trapezoidal cross-section. Flight controls effectiveness values are received. Their sufficiency will be clear after mathematical simulation of LCA flight dynamics.

Presented experimental results will be used in complex research of perspective regional turboprop development.

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6. Copyright Statement

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