Aerodynamic studies for moderate capacity long-range aircraft in "flying wing" layout

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Abstract

The article deals with the experimental studies of a new aerodynamic model of long-range aircraft in Flying Wing layout. Some results of the experimental studies alongside with preliminary CFD estimates are presented. A description of the layout is given and some thoughts about engine-to-wing interference are given. The paper concludes with suggestions for the most promising nacelles and tail positions and proposals for future research.

1. Introduction

The "Flying Wing" (FW) or blended-wing-body (BWB) configurations are considered by aviation community as a serious alternative to conventional airplanes in the 21st century. Despite of the long list of shortcomings FW/BWB passenger configurations, at least potentially, possess of three serious advantages: high lift-to-drag ratio due to decreased relative wetted area, favorable load distribution along wingspan and possible engine noise shielding [1-3].

There is no established point of view on optimal FW layout at present. Over many years the conventional configuration reached its maturity and refinement, therefore the FW configuration can compete with it on equal terms only with the same thorough consideration of different aspects. Even now, as seen from preliminary investigations, the FW is competitive. There is no doubt that due to FW intrinsic integrated nature benefits provided by MDO will be higher for it as compared with a conventional configuration. That is why in USA [4,5] and Europe [6,7] were initiated large multidisciplinary studies looking for the different aspects of mutual synergism between aerodynamics, structure, propulsion system and controls. Novel ideas and concepts progressively evolve inspiring enthusiasts of FW schemes.

New concept of moderate capacity long-range FW aircraft in a single-deck layout is considered in TsAGI over the last years. Unlike the huge 800-seater configuration [8-10] that could be realized only by international efforts, a small-size airplane features a lower technical risk and requires less investments for its launch.

Special aerodynamic model with flexible arrangement of tail units, wing tips and nacelles (Fig.1) has been designed, manufactured and tested in wind tunnels. Some preliminary results of the experimental studies are presented.

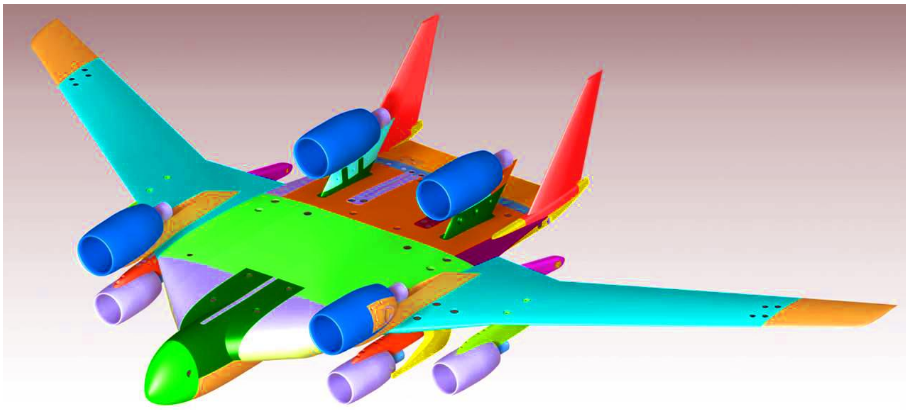

Figure 1: Principle assembly of the aerodynamic model

2. Description of the layout and aerodynamic model

In recent years FW investigations are continued in TsAGI, although not so intensively as under the grant ISTC №548 [8,9] at the threshold of the centuries. In these investigations the emphasis is made on the advanced long-range middle capacity aircraft configuration (200-250seats) with modest requirements for an airfield length. Unlike the 800-seater configuration a small-size airplane features a lower technical risk and requires less investment for its launch. Besides, it meets the 80-meter non-tip-folded box requirement. The problem of a passenger emergency evacuation is solved easier for a smaller FW.

Two points of view compete on the future prevailing transportation scheme. A large-size aircraft of the A-380 type gives the best fit to the hub-and-spoke transportation concept, while the aircraft of smaller size could be exploited for direct links between pairs of cities. Thus, the FW under TsAGI study fits the second concept.

In choosing between conventional and FW configuration the required range is a governing factor. At a very long range (~15000-16000 km) the take-off weight of a conventional aircraft grows exponentially, while for FW aircraft the gradient is less due to a high L/D-ratio. Cruise Mach number as high as M=0.85 is necessary to be competitive with current classical "tube and wing" fleet. An example of the 204-seat designed configuration (3-class arrangement) in a single-deck layout is shown in fig.2. Preliminary estimations show that maximum take-off-weight of the aircraft would be about 150t with maximum span of about 60m.

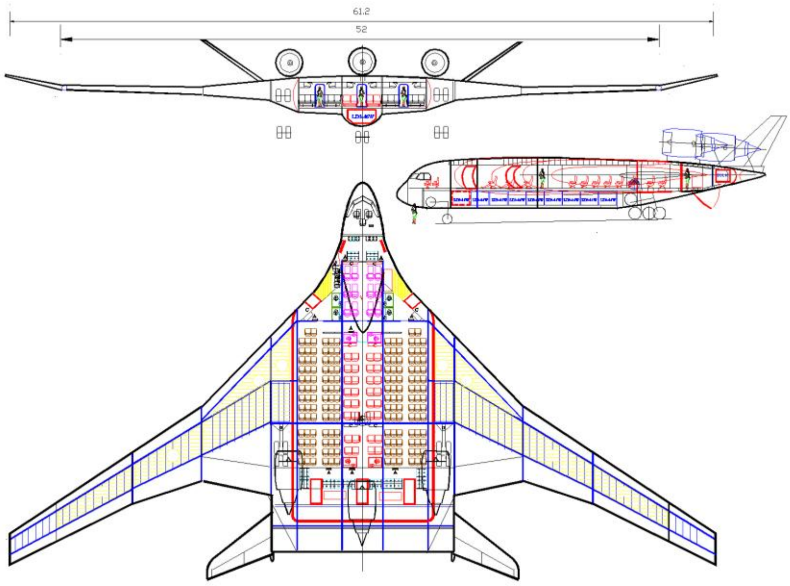

Figure 2: General views of 200-seat long-range aircraft in FW layout

Cabin cross-section is presented in fig.3. The main deck height is 2.1m. There are no windows at all, so the cabin interior problem and entertainment systems arrangement is of great importance. Boarding is provided through the exits in the fuselage nose body and in the leading edge of the center wing section. There are extra emergency exits arranged at the rear of the passenger cabin. LD3-46W containers are located under the central section of the cabin in the pseudo-body continuation of the nose part.

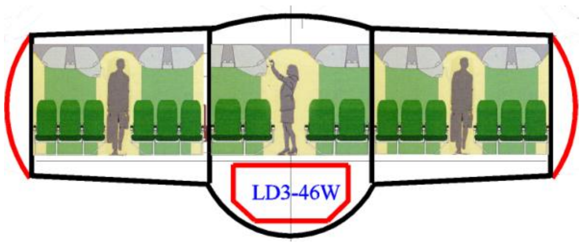

Figure 3: Cabin cross-section

It should be noted that FW configuration strongly depends upon chosen location of the engines. For example, rear position of the engines over the wing shifts centre of gravity rearward that requires a proper adjusting of the wing planform, revision of the center wing structure etc. That is why the problem of wing-engine interference is of the first priority for the design. Another important issue concerns the configuration and designation of control sections along the trailing edge of a wing and, probably, tail/fin units.

Special aerodynamic model with flexible arrangement of tail units, wing tips and through-flow nacelles has been designed and manufactured in TsAGI (Fig.1,4). Besides, 10% elevator deflected by ±25° is placed at the rear of the center wing section. The span of the model of 1.8m gives a possibility to test it in several subsonic and transonic TsAGI wind tunnels with sufficiently large MAC Reynolds number value. The main task of the experimental program is to investigate the sensitivity of different nacelles and tail arrangement at cruise (M=0.85) as well as at low speed regimes and to compare wind tunnel results with CFD data.

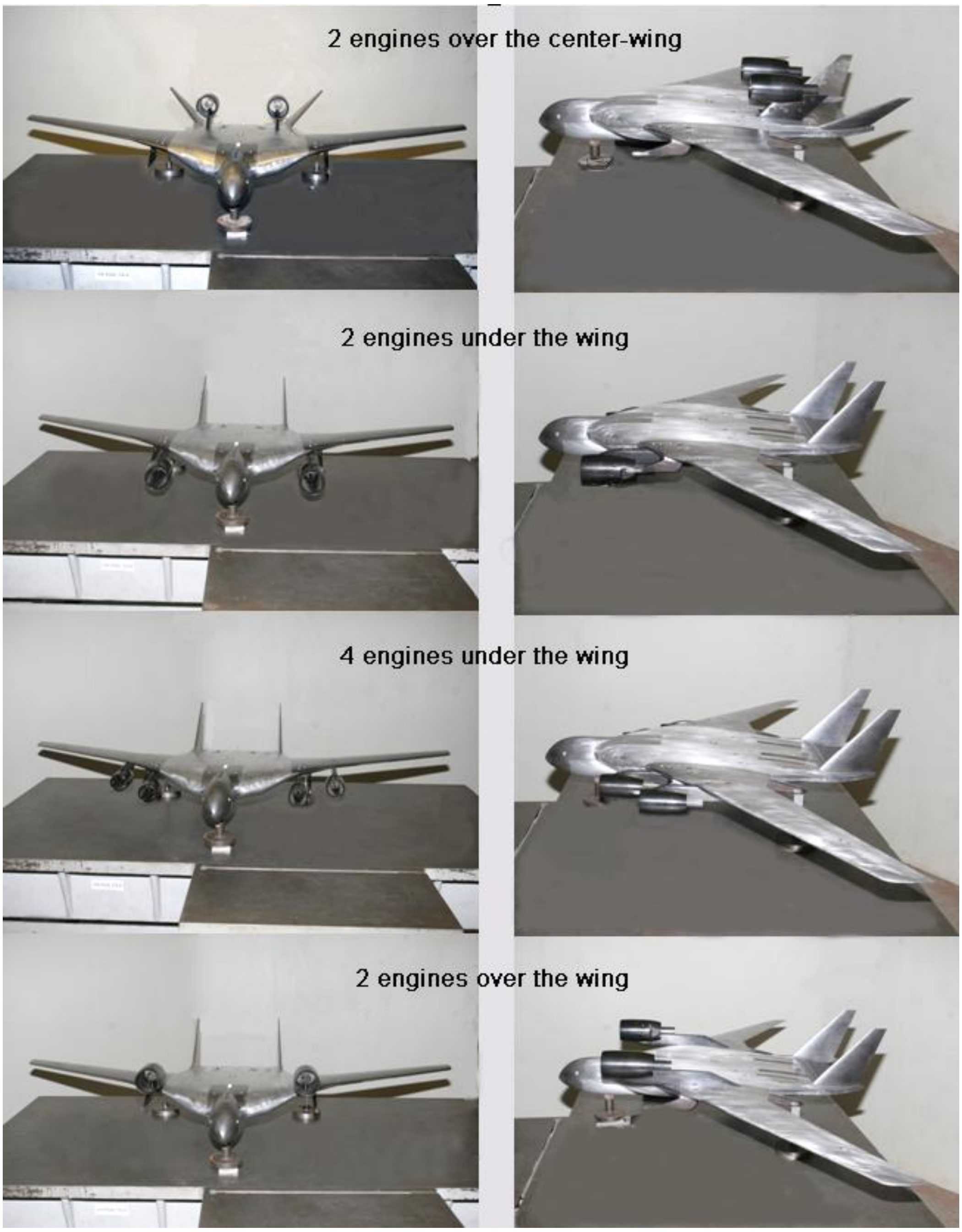

Figure 4: Variants of the aerodynamic model FW-2011

3. Selected results of experimental studies

The experimental studies of the aerodynamic model are in full swing as this paper is being written, therefore only preliminary results may be demonstrated here. Low-speed tests have been carried out in T-102 wind tunnel (Fig.5) at speed V=50m/sec. Encouraging results were obtained concerning effectiveness of the center-wing elevator – it does not lose power at high angles-of-attack (Fig.6), enabling sufficient negative pitching moment for recovering the airplane from stall regimes.

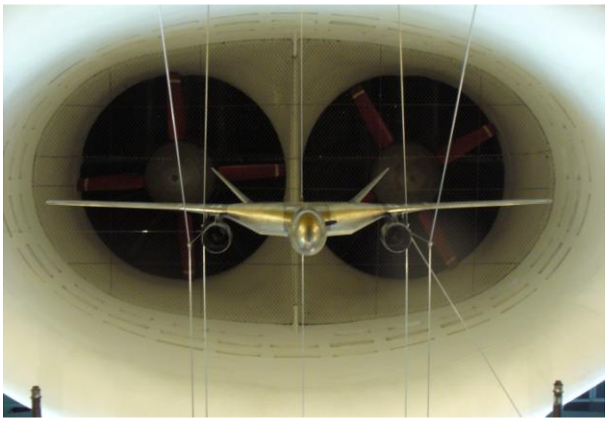

Figure 5: FW-2011 model in T-102 low speed wind tunnel

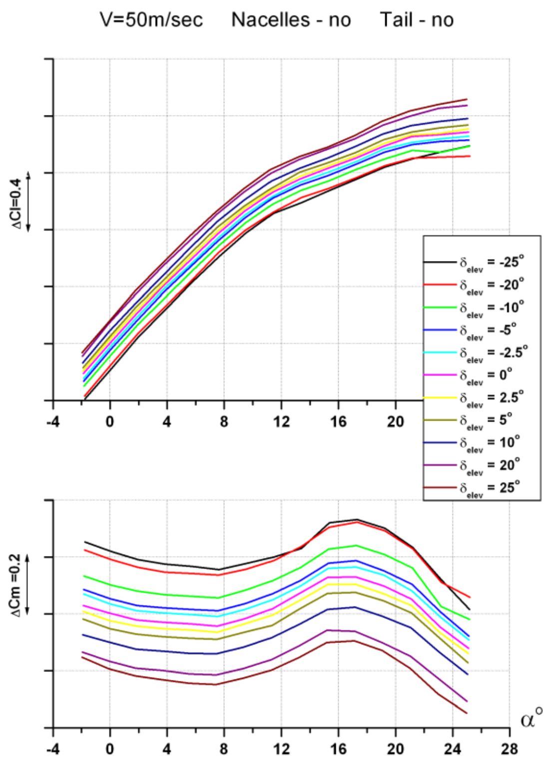

Figure 6: Elevator effectiveness at low speed

Transonic and high-Reynolds-number aerodynamic characteristics were obtained in T-106 wind tunnel with perforated circular test section (Fig.7). Tests with different engine positions reveal configurations with the most favorable aerodynamic interference – two under-wing pylon-mounted engines. Over-wing engine position suffers from the early onset of the wave crisis phenomena. Thorough aerodynamic design work is needed to weaken unfavorable mutual interaction by an appropriate shaping of the neighboring elements in the interference zone.

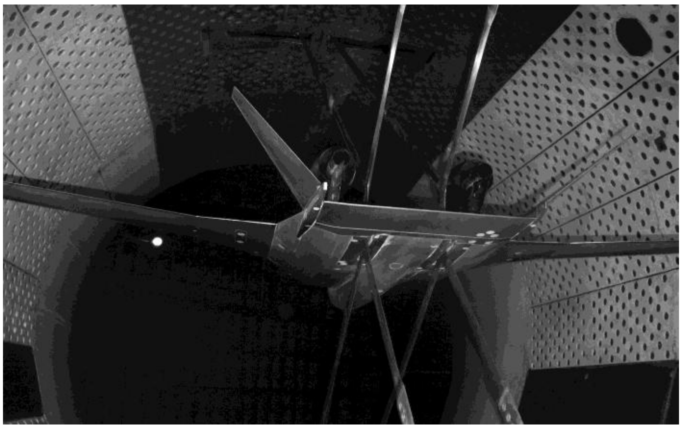

Figure 7: FW-2011 model in T-106 transonic wind tunnel

4. Conclusions

Different FW configurations were studied in TsAGI for 200-seat long-range aircraft. For one of the promising configurations a new aerodynamic model FW-2011 was designed and manufactured. The model has flexible construction that permits nacelles, fins and wingtips geometry variation. The first phase of the wind tunnel campaign is fulfilled at sub- and transonic regimes. Some valuable data for identification of future studies directions and areas of ongoing activities were obtained.

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