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COMPUTATION OF AERODYNAMIC OF STRUT-BRACED WING

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Abstract: *This article deals with the computation of aerodynamic characteristic of strut-braced wing. Calculations were performed on L-610 airplane with two proposals of wing with the different aspect ratio. Results of these calculations were compared with the original wing of the L-610. Aerodynamic characteristics serve as the basis for the structure analysis and are used for analyses of flight performance.*

Keywords: CFD, Strut-braced wing, Aspect ratio, Aerodynamic characteristic, Fuel consumption.

1. Introduction

One of the goals of this project was comparison of the L-610 airplane with the different wings. Wings with the longer spans and the struts were compared. Computed variants can be seen in Fig. 1. 3 variants of the wing geometry are compared using CFD.

A) Original geometry. In the next part of this document is labeled as MS.

B) Geometry with the strut and 15, aspect ratio labeled as A_15

C) Geometry with the strut and 20, aspect ratio labeled as A_20

Fig. 1: Methods Computed variants of the L-610. The green colored model is the original airplane. Yellow colored is the new one with the strut and the aspect ratio of 15. The red one is the new model with the strut and the aspect ratio of 20.

2. CFD simulation

All computations were made in the range from -10 to 14 degrees with step of 2 degrees of angle of attack. Aims of these computations were obtain values of aerodynamic forces and coefficients (polars, lift curves, moment curves) and the distribution of the forces and coefficients over the wing span.

2.1. CFD grid

Unstructured grids were generated in POINTWISE program. Surfaces are meshed mainly with hexahedral elements and volume grid was filled by polyhedral elements. Boundary layer was simulated by 60 prismatic layers. Original mesh had 32 millions of cells. Total amount of elements was approximately about 35 (A_15) and 37 millions of elements (A_20).

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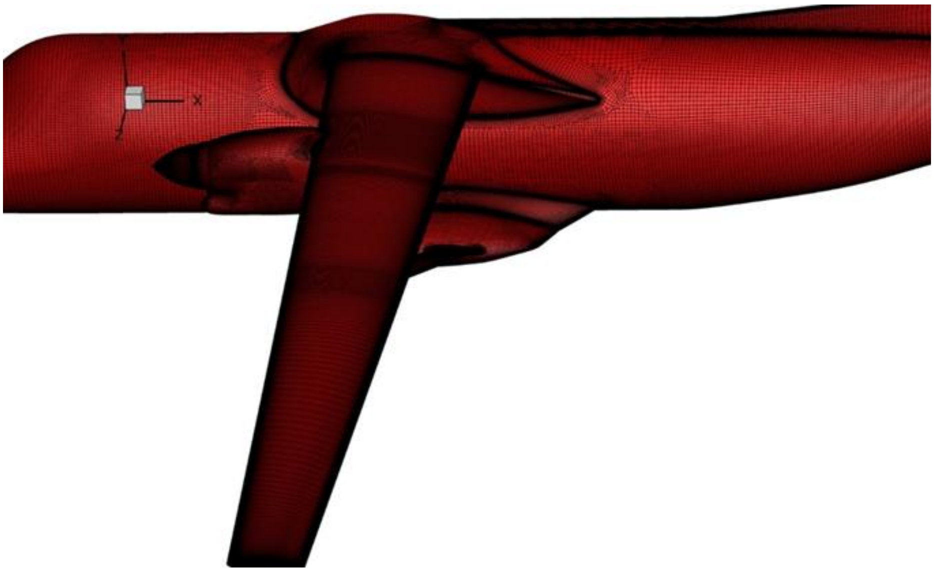

Fig. 2: Example of surface grid over the computation model. It can be seen that main part of airplane is meshed by hexahedral elements. Using of tetra-elements was necessary in complex geometry regions as wing-fuselage transition or wing-nacelle. Usage of hexahedral elements leads to reduction of volume elements that influence the computation time positively. (Shortened computational time etc.)

2.2. CFD computations

All the cases were computed for the 7200 meters of international standard atmosphere. The velocity was 127 ms^{-1}. Mach number was 0.41and freestream pressure 39917 Pa.

For the parts of the airplane was weak boundary condition used. For symmetry (only half model of airplane was computed) was weak Euler, and for the far field external weak characteristic boundary conditions were used.

All computations were made in the EDGE program. This solver can be used for compressible, viscous/inviscid flow. In this project Navier stokes averaged equations were used for all simulations with W&J EARSM + Hellsten k-omega turbulence model and central scheme discretization.

Distribution of aerodynamic characteristics is used to determine a load, bending and torque moment distribution. Then these distributions are used to structural analysis and weight estimation of the wings. Weights of the wings are consequently used to calculate flight performances.

From the graphical output the visualization of streamlines can be seen that in the region of the strut streamlines begin to curve, it influences the flow field behind the wing. At A_20 the flow near the wing tip, tend to curl less than other variants, hence the wing tip vortices are smaller than A_15 and MS variants. This situation is caused by higher aspect ratio of A_20 wing.

Results of the original airplane geometry were compared with wind tunnel testing. Computed values provide sufficient agreement with the experiment.

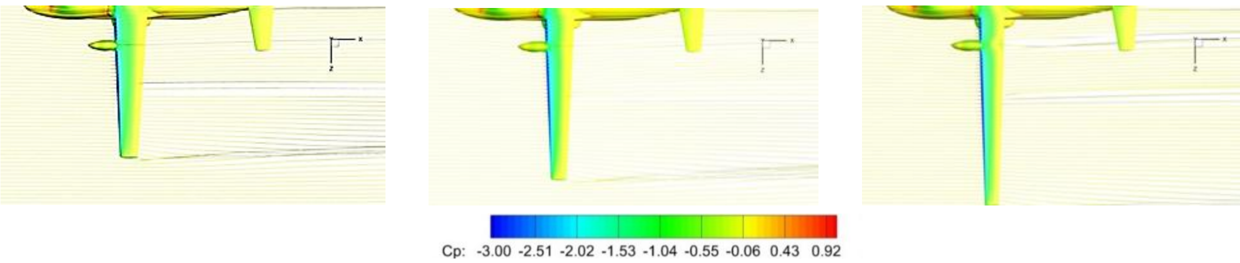

Fig. 3: Variant MS, A-15 and A-20 at 6 deg. Of angle of attack with Pressure coefficient on surfaces and streamlines over the airplane. Upper view.

3. Analysis of aerodynamic results

Aerodynamic computation from the previous part is shown in Fig. 4. There are lift coefficients as a function of drag coefficients. Circles are calculated CFD values and „x“ is value for the required lift.

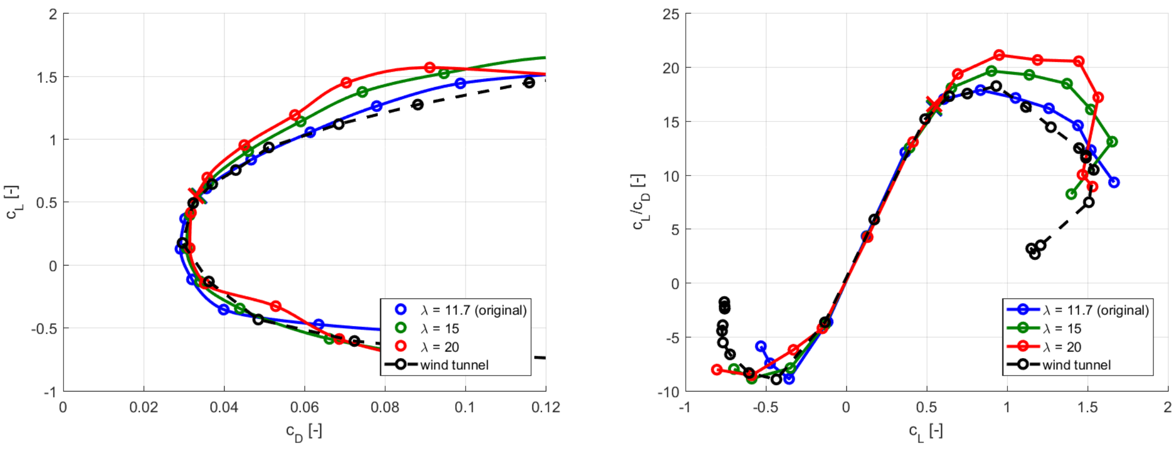

Fig. 4: Aerodynamic polar and lift to drag ratio for three different wing aspect ratio geometry.

For better explanation of consequence between aerodynamic data and flight performance a following case are assumed. We were using the knowledge of specific power consumption of GE CT7-D engine (considered on L-610) SFC = 0.274 [kg/(kWh)]. Then we estimated a propeller efficiency to η = 85 %. And finally, we used calculated weight of wings for different configurations.

Tab. 1: Weight of the wings.

m_{WING} [kg]	Δm [kg]
1025.8	0
1023.8	-2
1276.2	250.4

Total power is calculated from drag and airspeed:

$$P = \frac{1}{2}\rho v^2 S c_D v, \qquad c_L = \frac{(m_{MOTW}(t) + \Delta m).g}{\frac{1}{2}\rho v^2 S}$$

The drag coefficient is a function of lift (fig. 4) and is interpolated every time from the actual weight. Weight is decreasing because of fuel consumption. Actual fuel consumption is:

$$m_{fuel} = \frac{P}{\eta}\frac{SFC}{3600} \quad [kg/s]$$

After that, a new „m_{MOTW} (t)“ is calculated and the process is repeated. The case assume constant airspeed at cruise level flight and range is 2440 [km]. The result is depicted in Fig. 5 and it has to be noted that differences between fuel consumption are minor high. It is because of the minimum difference in aerodynamic drag as mentioned above (Fig. 4). Moreover, the wing with aspect ratio 20 has a higher weight.

This result leads to a conclusion that does not make a sense to produce the wing with a higher aspect ratio than the original wing for this flight regime. To use a benefit of the high aspect ratio wing is possible only for higher lift coefficient (Fig. 4 – lift to drag ratio). There are two ways how to reach it. First one is to increase the weight of airplane (for example additional payload). The second one is the reduction of airspeed. It also plays a crucial role in calculation of the required power because the power is a function of airspeed cubed.

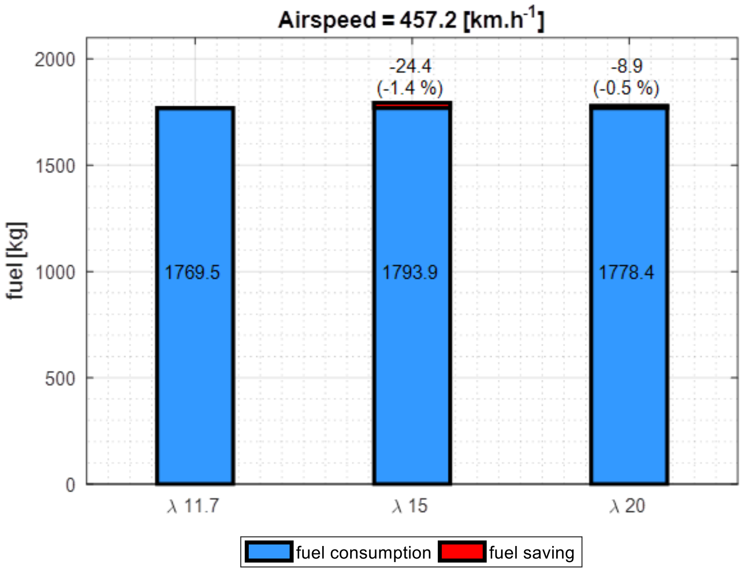

Fig. 5: Fuel consumption for cruise speed.

4. Conclusions

CFD analysis for tree different aircraft geometries are calculated, within this project. The main reason is to investigate the effect of the wing aspect ratio of L-610 aircraft. Wing with a higher wing span produces a higher bending moment. Therefore, two geometries with higher aspect ratio have strut-braced wing geometry to reduce the structure weight of the wing. CFD results and structural analysis are used for the calculation of flight performance. The main conclusion from this analysis is that using the high aspect ratio wing at the required regime does not bring any benefits.

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