Cleared for Landing

Numerical Methods for the Definition of the Hinge Moments of the Nose Landing Gear Doors of the Commercial Aircraft

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To investigate the impact of the fluid flow on the aircraft's units CFD (Computational Fluid Dynamics) methods based on the numerical calculation of the hydrodynamic equations becomes widely used along with the conventional analytical approaches and experimental tests. Continuously developed and improved CFD methods can serve as a good alternative of the natural experiments in solving many practical problems [1].

Thus, at the design stage of the landing gear doors production often without being able to carry out the natural experiment, designers need to have level of aerodynamic loads acting on the closed doors at high speed of aircraft as well as during aircraft's maneuvers with the opened doors and gear release/retraction. The aerodynamic loads data obtained from CFD analysis gives the possibility to estimate the doors strength and define characteristics of the opening actuator, run the optimization of the kinematic connection between small rear doors with the landing gear strut. For instance, for the considered aircraft the initial variant of the small landing gear door rod mounting to the landing gear main fitting has been replaced

Mentor Graphics
Mechanical Analysis

by the mounting to the landing gear strut to reduce the loads on the rod. The calculation results obtained for the selected variant of the doors were confirmed experimentally that indicates good accuracy of the modern software.

The results of the numerical study of aerodynamic loads on the nose landing gear doors demonstrated in this paper were obtained in ANSYS® Fluent and Mentor Graphics FloEFD™ software, based on the solution of the Reynolds averaged and Favre averaged Navier-Stokes equations accordingly.

The calculation in ANSYS Fluent software (license number 501024) was done using the structured computational mesh (about 6 million cells) with « κ - ε realizable» turbulence model (κ - ε method based on a simultaneous solution of the momentum transport equations, the kinetic energy and the dissipation rate equations) with the enhanced modeling of turbulence parameters near the wall and with taking into account the influence of the pressure gradient. The solved equations were approximated with a finite-volume scheme of the second order.

The numerical study in FloEFD software was performed using rectangular computational mesh adapted to the surface (about 2.5 million cells) [3]. To speed up the calculations the local meshes with the increased mesh resolution around the nose of the fuselage and landing gear doors were used. The automatically adapting computational mesh with concentration in the areas of high gradients of velocity was applied. It should be noted that FloEFD uses a relatively small number of cells of the computational mesh as far as in case of a low resolution of the boundary layer the theory based on the Prandtl boundary layer hypothesis is applied. Turbulence model used in FloEFD bases on the modified model with damping functions proposed by Lam and Bremhorstom [4].

The calculations of the hinge moments of the nose landing gear doors were performed for the three-dimensional model of the part

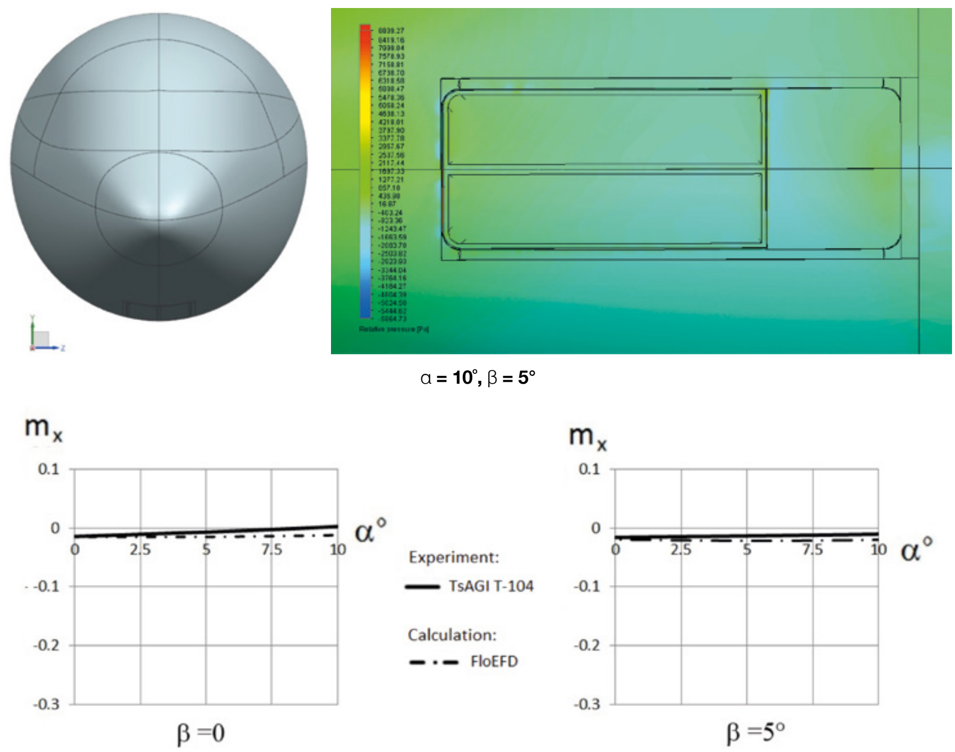
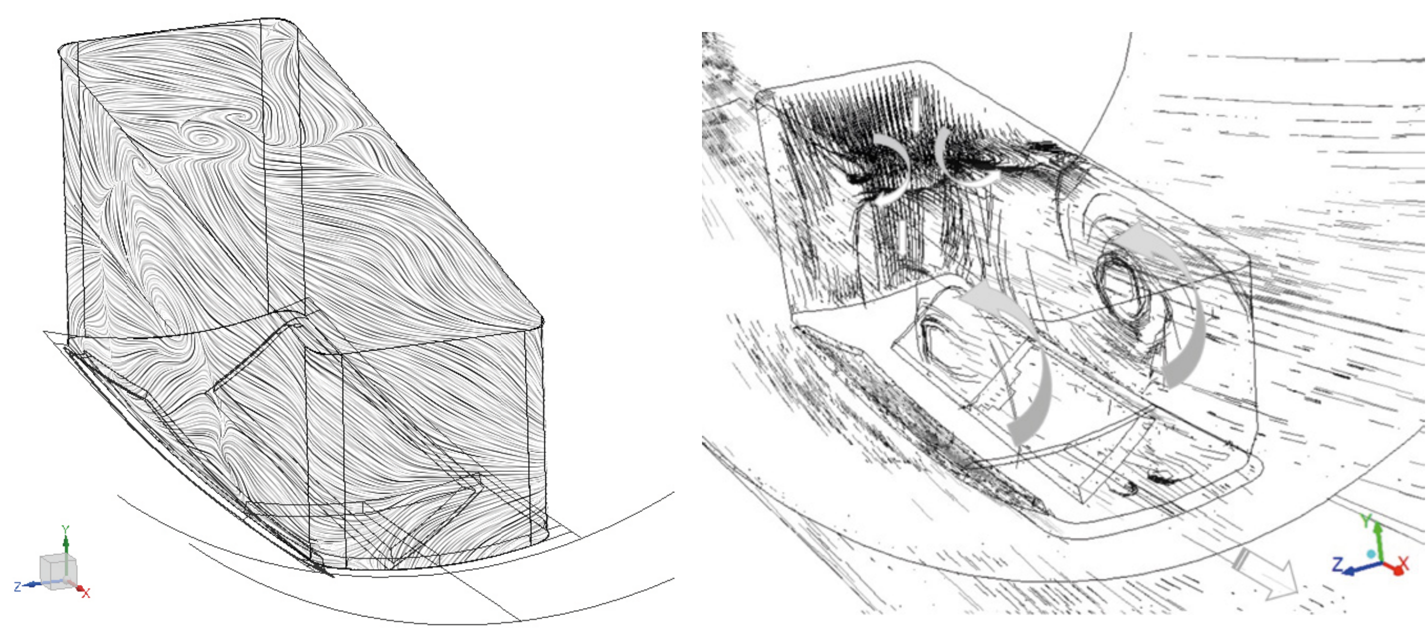


Figure 1. The model with the closed landing gear doors and hinge moments of the large left nose landing gear doors at $\delta_{door1} = 0°$, $\delta_{door2} = 0°$, $\delta_{strut} = 0°$, $\beta = 0°$ and $\beta = 5°$.



FloEFD

Fluent

Figure 2. Streamlines on the doors and in the niche at $\delta_{door1} = 30°$, $\delta_{door2} = 0°$.

of the commercial aircraft in the scale of 1:1 which includes the fuselage, large front and small rear nose landing gear doors as well as the nose gear and the wheel well. The calculation results were obtained for the stage of release – retraction of the landing gear at Mach number M = 0.34 and impact air pressure q = 771 kg/m^2. Experimental data was obtained by Andreev G.T. in the TsAGI wind tunnel T-104 for the full aircraft model in the scale of 1:8.16 at Mach number M = 0.2. All of the graphs below are related to the left landing gear doors, hinge moments of the right (windward) landing gear doors are less usually.

1. Flow around the large nose landing gear doors at their opening

The calculations and the experimental investigations have shown that in the closed position ($\delta_{door1} = 0°$, $\delta_{door2} = 0°$, $\delta_{strut} = 0°$) hinge moments of the nose landing gear doors are minimal (Figure 1).

This fact is due to the presence of gaps along the doors which balance the static pressure on the outer surfaces of them near their edges and in the landing gear niche. A calculation of the loads without taking into account these gaps leads to an overestimation of normal forces acting on the detachment of the doors because nose gear of the considered aircraft are located in the flow acceleration zone from the nose of the fuselage to the regular part. Since at the sideslip angle of 5° nature of the flow around the fuselage nose does not change much the hinge moments of the closed doors are practically independent on the sideslip angle within a specified range.

During opening of the large doors ($\delta_{door1} = 30°$, $\delta_{door2} = 30°$, $\delta_{strut} = 0°$ - experiment, $\delta_{door1} = 30°$, $\delta_{door2} = 0°$, $\delta_{strut} = 0°$ - calculation) airflow circulation occurs in the niche of the landing gear (Figure 2), which leads to slow down the flow over the doors and increase the pressure on the inner surfaces of them.

As a result, the hinge moments of the opened doors are significantly higher than of the closed ones even in the absence of the sideslip angle, which is confirmed by the results of calculations as well as experiments (Figure 3). The right chart in figure 3 shows the influence of the sideslip angle on the loads. It is seen that even at the initial stage of opening of the doors the presence of sideslip angle of 5° leads to the drastic (up to 4 times) growth of the hinge moments.

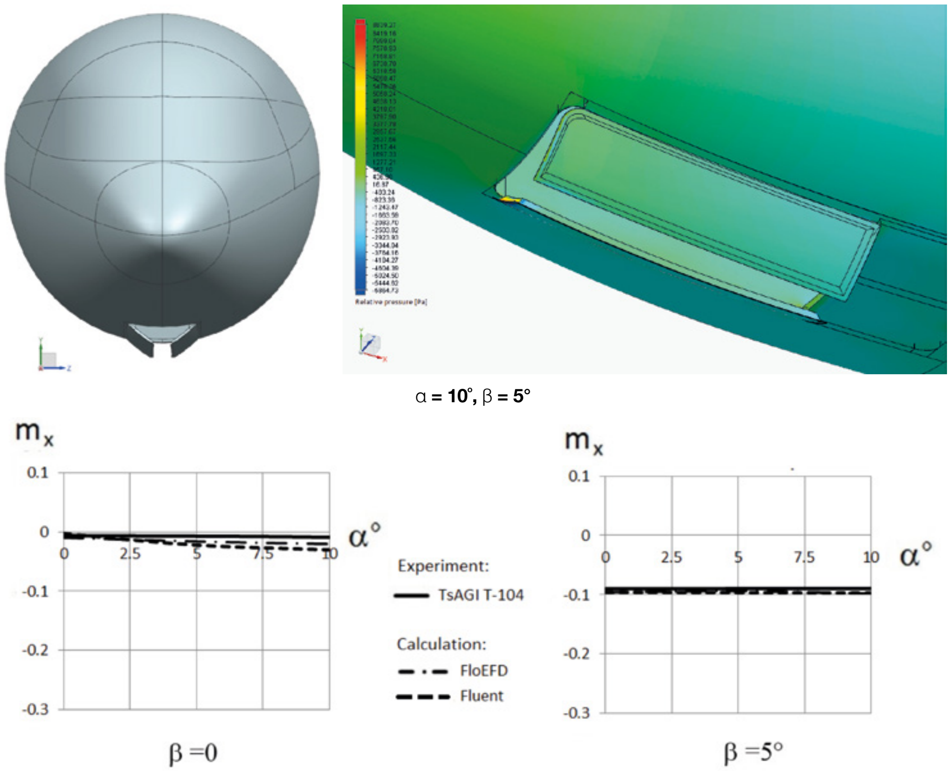


Figure 3. The model with the opened large landing gear doors and the hinge moments of the large nose landing gear doors at $\delta_{door1} = 30°$, $\delta_{door2} = 30°$, $\delta_{strut} = 0°$ for the experiment, $\delta_{door1} = 30°$, $\delta_{door2} = 0°$, $\delta_{strut} = 0°$ for the calculation, β = 0° and β = 5°.

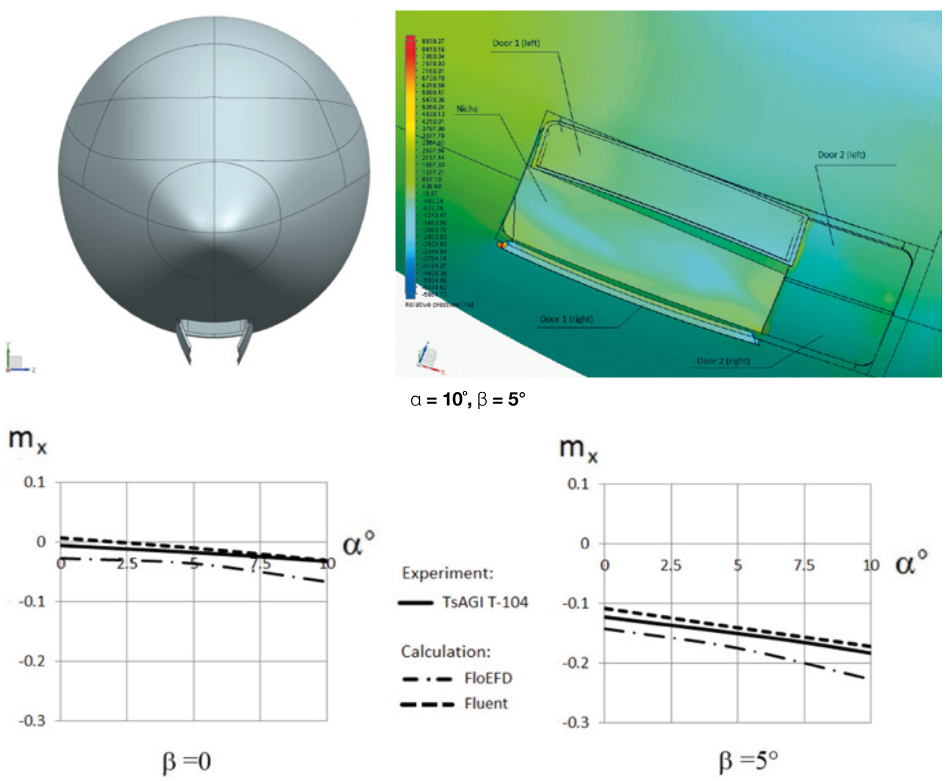


Figure 4. The model with opened large landing gear doors and the hinge moments of the large nose landing gear doors at $\delta_{door1} = 60°$, $\delta_{door2} = 60°$, $\delta_{strut} = 0°$ for the experiment, $\delta_{door1} = 60°$, $\delta_{door2} = 0°$, $\delta_{strut} = 0°$ for calculation, β = 0° and β = 5°.

From the calculations and the experiments it was obtained that the greatest values of the hinge moments of the doors are observed in their open position in a range of angles $\delta_{door1} = 60° \div 90°$ (Figures 4 and 5).

Increasing of the sideslip angle up to 5° leads to increase values of the hinge moments approximately in four times. It can be concluded about the constancy of the relative increase of the aerodynamic loads on the doors in the presence of the sideslip angle at all stages of their opening. This pattern can be observed on the charts of the hinge moment coefficients of the nose landing gear doors depending on the angle of their opening as shown on Figure 6. Presented dependencies relate to the angle of attack of 12° in the experiment and 10° in the calculations. The chart below for the sideslip angle of 5° shows nearly linear dependence of growth of hinge moments on the deflecting angle of the doors (with a slight dip in the region of δ = 60° in FloEFD).

2. Flow around the small landing gear doors during the release of the nose landing gear

The computational models of the small rear doors at the release of nose landing gear are shown on figure 7.

The models are made in strict accordance with the kinematics of the connection between the strut and the small door. The hinge moment coefficients of the small door depending on its angle of deflection are shown on figure 8.

Since the left door considered in the article is in the "shadow" of the landing gear by having a kinematic connection with the strut at all stages of the opening, the dependence of the hinge moment on the opening angle of the door is not obvious. The increase of the sideslip angle up to 5° leads to increase of loads only in two times. There is no experimental data of wind tunnel tests for the small doors considering simultaneous release of the landing gear strut.

Conclusions

Computational study of flow around the large and small nose landing gear doors of the commercial aircraft showed that the effect of increasing of the sideslip angle and the opening angle is the most noticeable

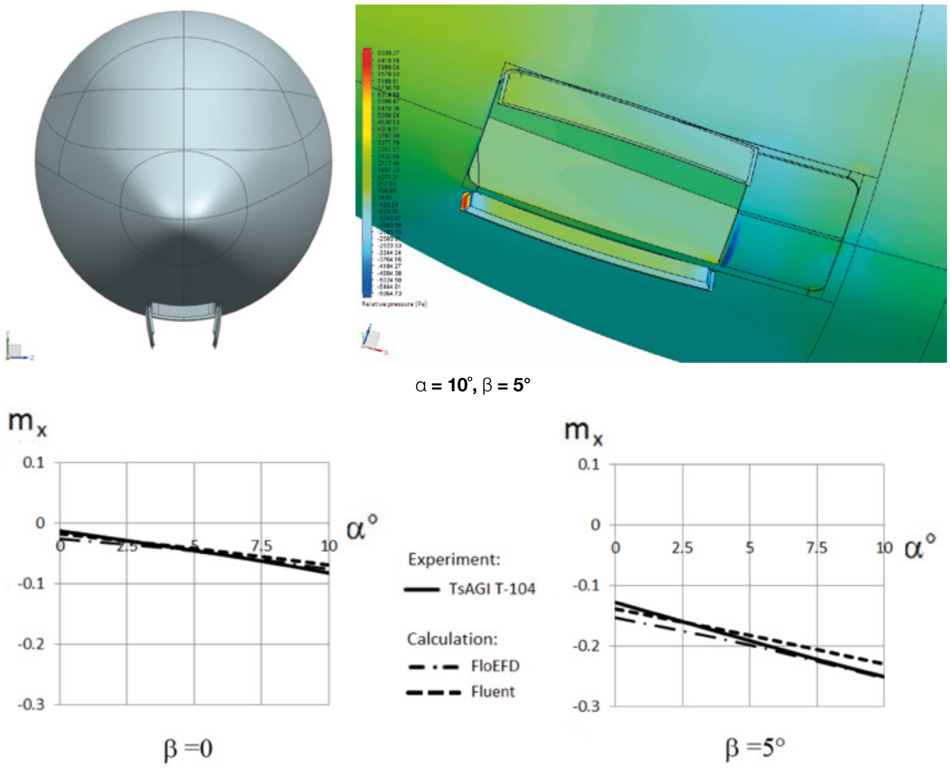
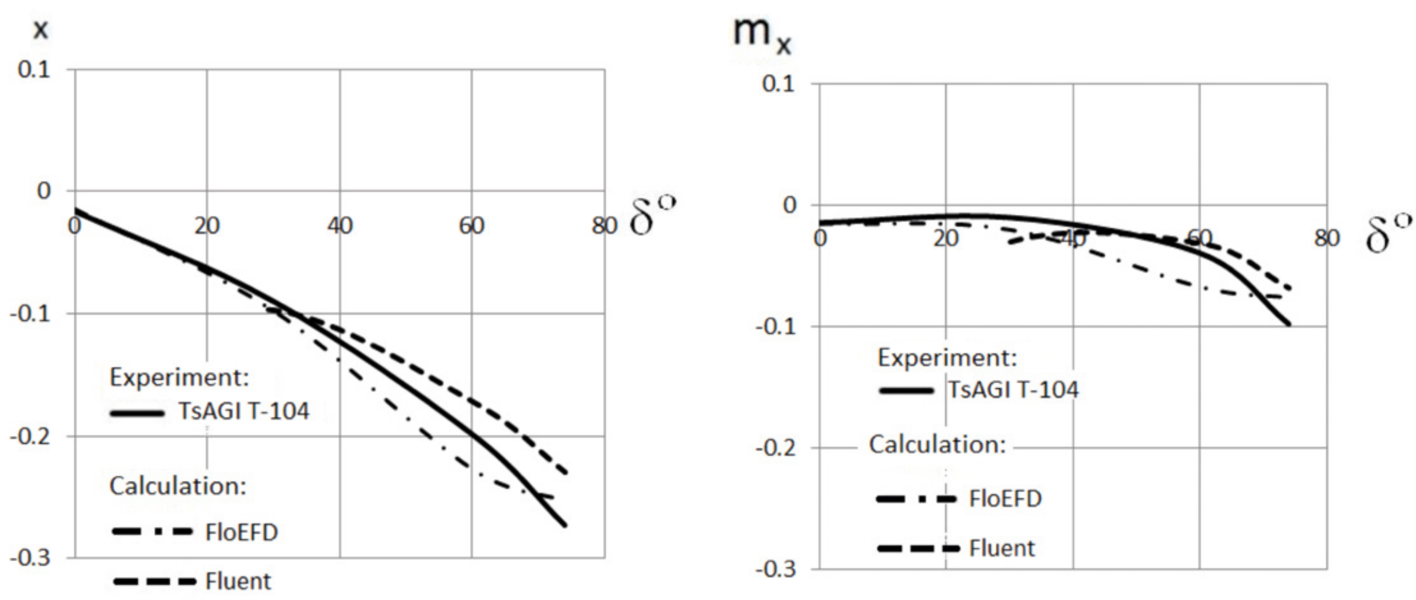
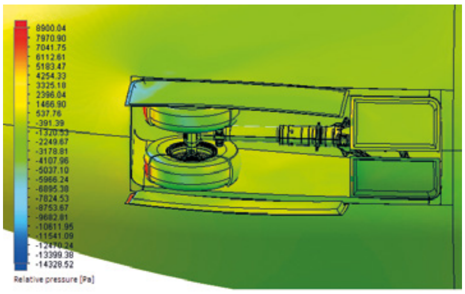


Figure 5. The model with opened large landing gear doors and the hinge moments of the large nose landing gear doors at $\delta_{door1} = 90°$, $\delta_{door2} = 90°$, $\delta_{strut} = 0°$ for experiment, $\delta_{door1} = 74°$, $\delta_{door2} = 0°$, $\delta_{strut} = 0°$ for calculation, β = 0° and β = 5°.

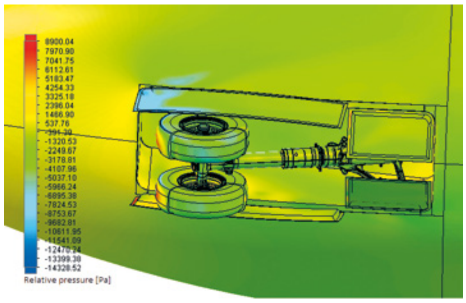


β = 0° β = 5°

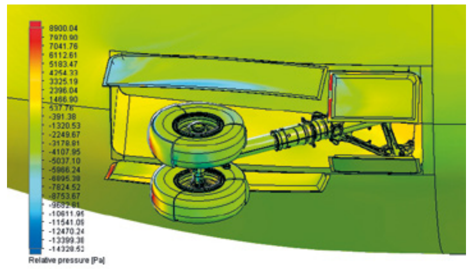
Figure 6. The hinge moment coefficients of large left nose landing gear doors depending on their deflecting angle.



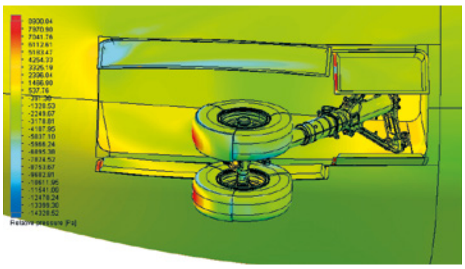
$\delta_{strut} = 15°$, $\delta_{large\ door} = 74°$, $\delta_{small\ door} = 14.304°$



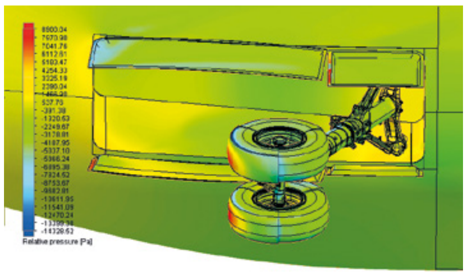
$\delta_{strut} = 30°$, $\delta_{large\ door} = 74°$, $\delta_{small\ door} = 27.846°$



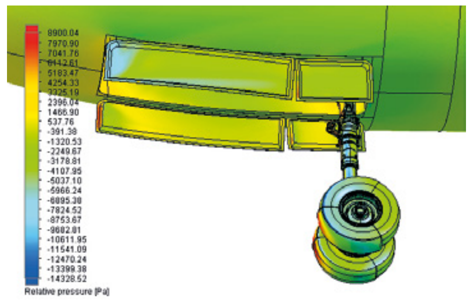
$\delta_{strut} = 45°$, $\delta_{large\ door} = 74°$, $\delta_{small\ door} = 41.498°$



$\delta_{strut} = 60°$, $\delta_{large\ door} = 74°$, $\delta_{small\ door} = 55.378°$

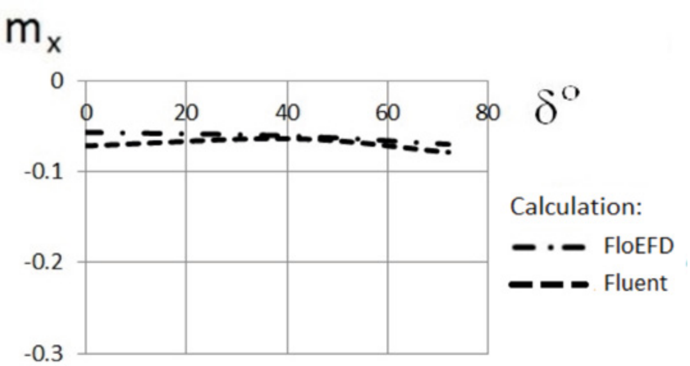


$\delta_{strut} = 75°$, $\delta_{large\ door} = 74°$, $\delta_{small\ door} = 68.125°$

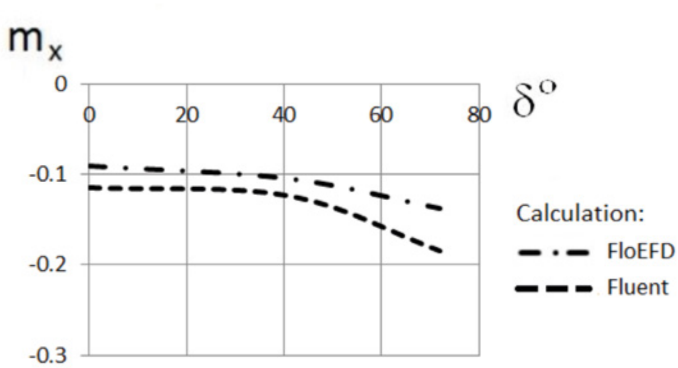


$\delta_{strut} = 100°$, $\delta_{large\ door} = 74°$, $\delta_{small\ door} = 72.232°$

Figure 7. The computational models with different angles of the strut, large and small doors.



β = 0°



β = 5°

Figure 8. The hinge moment coefficients of small left nose landing gear doors depending on their deflecting angle.

for the large doors with a big aerodynamic surface.

Loads acting on the small doors kinematically connected with the landing gear strut depend on the sideslip angle much less. The dependence of the loads on the small doors on their opening angle occurs only in the presence of sideslip angle.

The results of calculations performed in Fluent and FloEFD presented in this article show good agreement with the experimental data and demonstrate the ability to use these software for the calculation of the loads on the landing gear doors during the design stages.

The use of FloEFD software does not require thorough preparation of the computational model as far as this tool uses an automatic meshing and it is embedded in all modern CAD-software. On the contrary the use of Fluent software with structured mesh requires long preparation of the computational model but allows to perform a fast calculation.

References

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