MiG-29 Fulcrum

CFD Case Study

CFD study performed in June-July 2020 had its goal to verify DCS MiG-29 landing behavior and was conducted using full-scale 3D model of the plane. The model in landing configuration had deployed landing gear and was equipped with fully movable stabilator, slats and flaps.

During the tests the model was set at desired angle of attack (AoA, α) and C_L, C_D, C_m (In Russian notation - C_y, C_x, m_z) were calculated. Wind velocity was 245 kph with air density 1.225 kg/m3. CoG position was 24% MAC.

Research task was the following:

1. Evaluation of CFD results applicability by comparing obtained by CFD C_L and C_D coefficients to available data from documents.

2. Find the airplane stability margin in landing configuration and stabilator deflection required to trim the airplane at landing AoA out of ground effect (OGE).

3. Find the airplane stability margin during flaring in ground effect(0.5 m from the main wheels to the surface, in the ground effect - IGE) and trimmed stabilator deflection at landing AoA.

4. Find out what actually represents Fig 8.9 “Stabilator deflection ON LANDING” in “Practical aerodynamics of MiG-29” (PA).

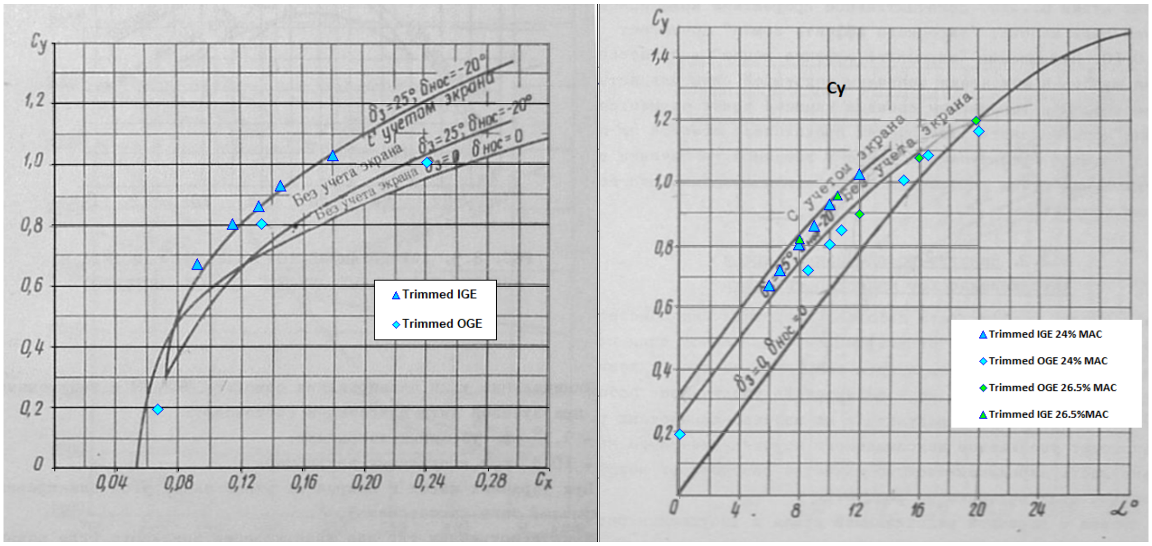
Due to the fact that CFD calculations take much time, the model initially was tested OGE with a large steps of AoA changing for a several stabilator deflection. It was found that the plane in landing configuration has its neutral point (~33% MAC) determined using stability margin and CoG position very close to clean configuration. With stabilator angle -20 and -35 degrees the plane is trimmed at AoA, respectively, 16 and 30 degrees.

However, IGE the C_m curves shows very significant increase of stability margin and, as a consequence, very noticeable decrease of trimmed AoA – 9 and 13 degrees for the same stabilator deflection.

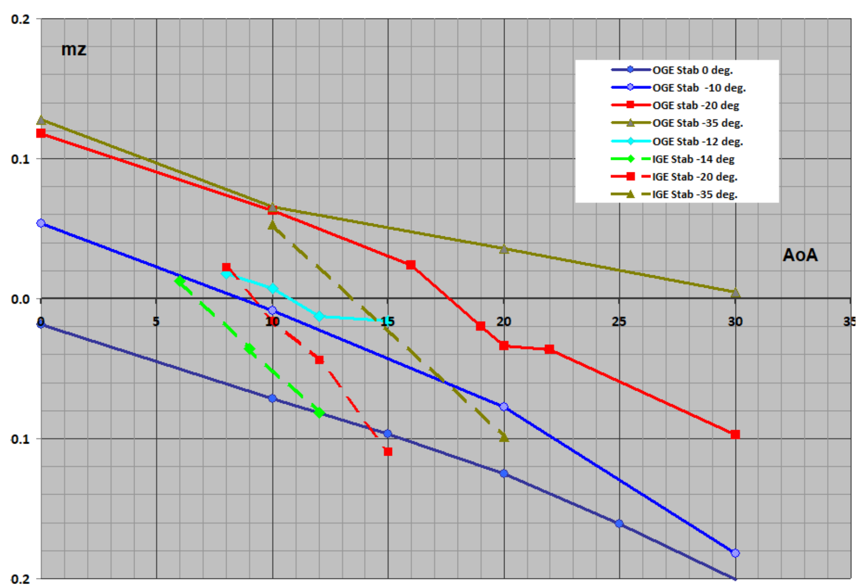
The points of untrimmed $C_L(\alpha)$ и $C_D(\alpha)$ curves, where it was possible, were corrected for trim losses and overlaid to PA graphs.

The consistency of the data obtained from the CFD and the graphs showed sufficient accuracy of the CFD modelling and allowed the calculations to be continued to detail the results. For this, the stabilator deflection was set to -20 degrees (it corresponds 260-265 kph touchdown speed according Fig 8.9) and AoA was set to 8, 10, 12 and 15 degrees. For stabilator deflection -14 degrees AoA was set to 6, 9 and 12 degrees. For comparison OGE computation was performed for AoA 6,9,12 and 20 degrees with stabilator angle -12 degrees and AoA 16, 19, 22 degrees for stabilator at -20 degrees.

All these points after trim losses correction were placed at the trimmed drag polars from PA.

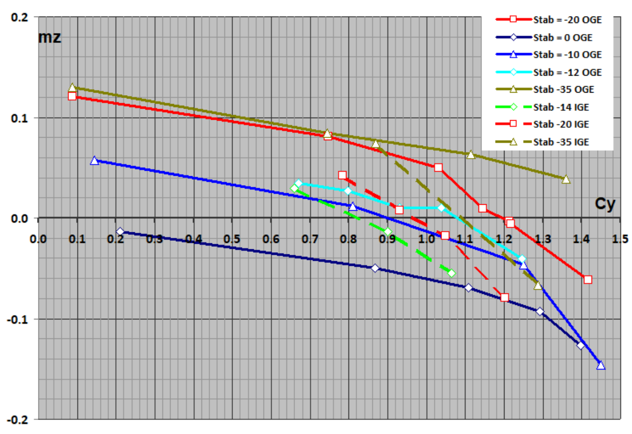


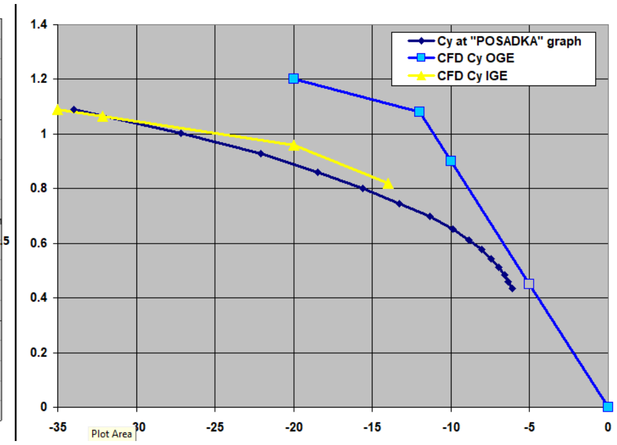
Stability margin derived from IGE computations is about 26% MAC.
The graphs clearly show that stabilator control authority $dm_z/d\varphi_{CT}$ is almost the same for OGE and IGE, and the noticeable increased stabilator deflection required for aircraft trim is due to significant rising of stability margin IGE.



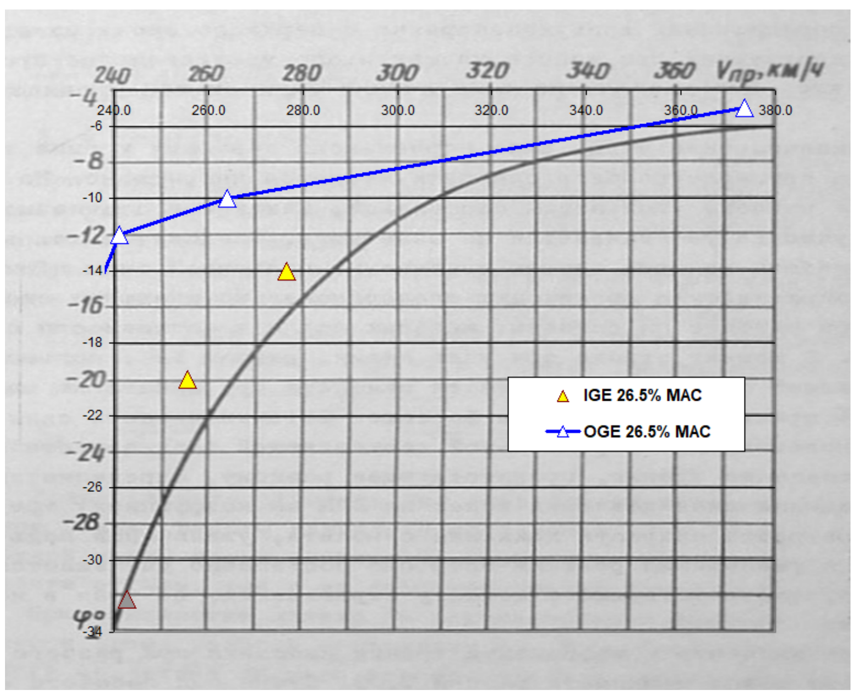
For further comparison with the graphs from PA the graphs computed for CoG position 24% MAC were recalculated to 26.5% MAC. The curves for longitudinal moment coefficients were plotted versus corresponding CL values

In order to have a proper comparison we had to bring PA graph to common coordinates using C_L for normal landing weight. Then all calculated values of C_M IGE and OGM were recalculated from AoA abscissa to C_L. After that, for all points of φ_{CT} with Cm=0 we have got corresponding $\varphi_{CT} = f\,(C_L)$ function and combined all the graphs in single chart.





We also recalculated CFD functions $\varphi_{ст} = f\,(C_L)$ to $\varphi_{ст} = f$ (IAS) and combine them for clarity with discussed graph Fig.8.9 from the PA document.



At this point we've come to better understanding of the remark "НА ПОСАДКЕ" (AT LANDING) for that graph Fig. 8.9 from the PA document. It was the common way to provide landing and take-off graphs with the information about gear position and actual flaps/slats deflection. There are some examples when extra IGE graph is also provided as found in MiG-23ML and MiG-21bis manuals.

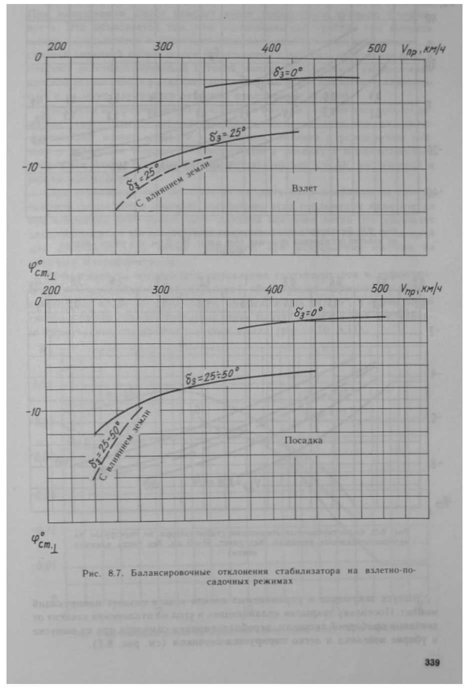


Рис. 8.7. Балансировочные отклонения стабилизатора на взлетно-посадочных режимах

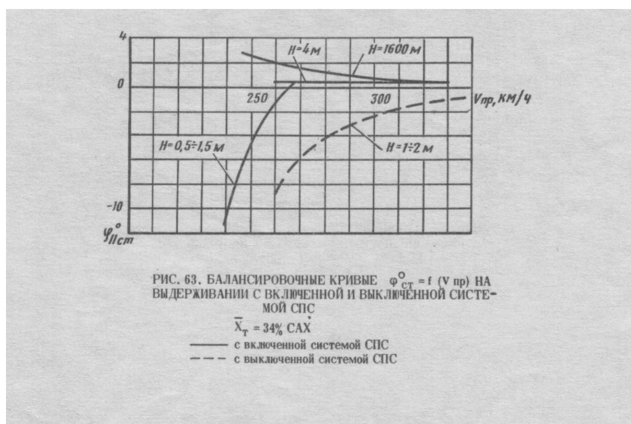


РИС. 63. БАЛАНСИРОВОЧНЫЕ КРИВЫЕ $\varphi^{o}_{ст} = f\ (V\ пр)$ НА ВЫДЕРЖИВАНИИ С ВКЛЮЧЕННОЙ И ВЫКЛЮЧЕННОЙ СИСТЕМОЙ СПС

$\bar{X}_т = 34\%$ САХ

——— с включенной системой СПС

– – – с выключенной системой СПС

Obvious, that graph on Fig. 8.9 from the PA is far from being OGE trim curve because of big differences in the low speed area, where it resembles IGE curve. Despite of that, the full graph is hardly to be the IGE curve also, because of the highest speed values not typical for flaring right before touch down. Those speeds are normal for initial phase of landing pattern before entering glideslope

As shown above, the graph “НА ПОСАДКЕ” (landing) asymptotically approaches OGE trim curve at high speeds (at the start of the landing pattern), and resembles IGE trim curve at the low speeds. Therefore, we can make the only logical assumption - this graph displays the averaged position of the stabilator, recorded during standard landing procedures with constant and simultaneous drop in altitude and speed.

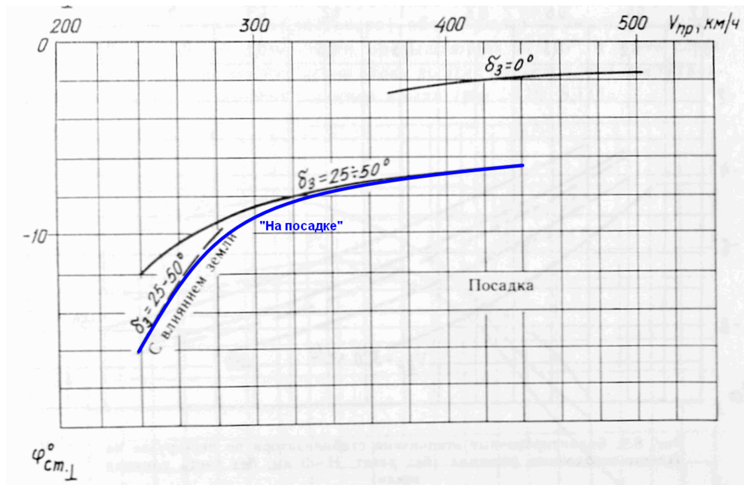
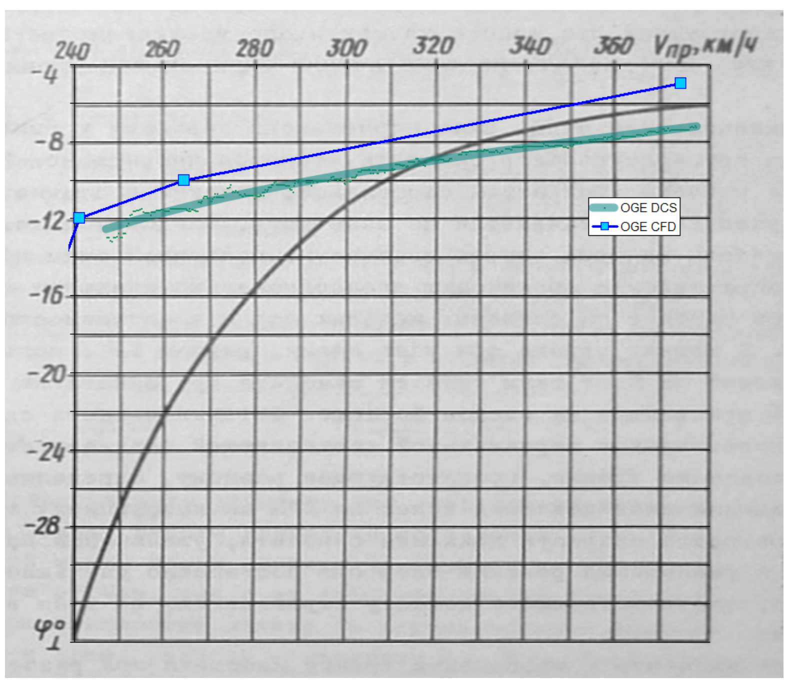
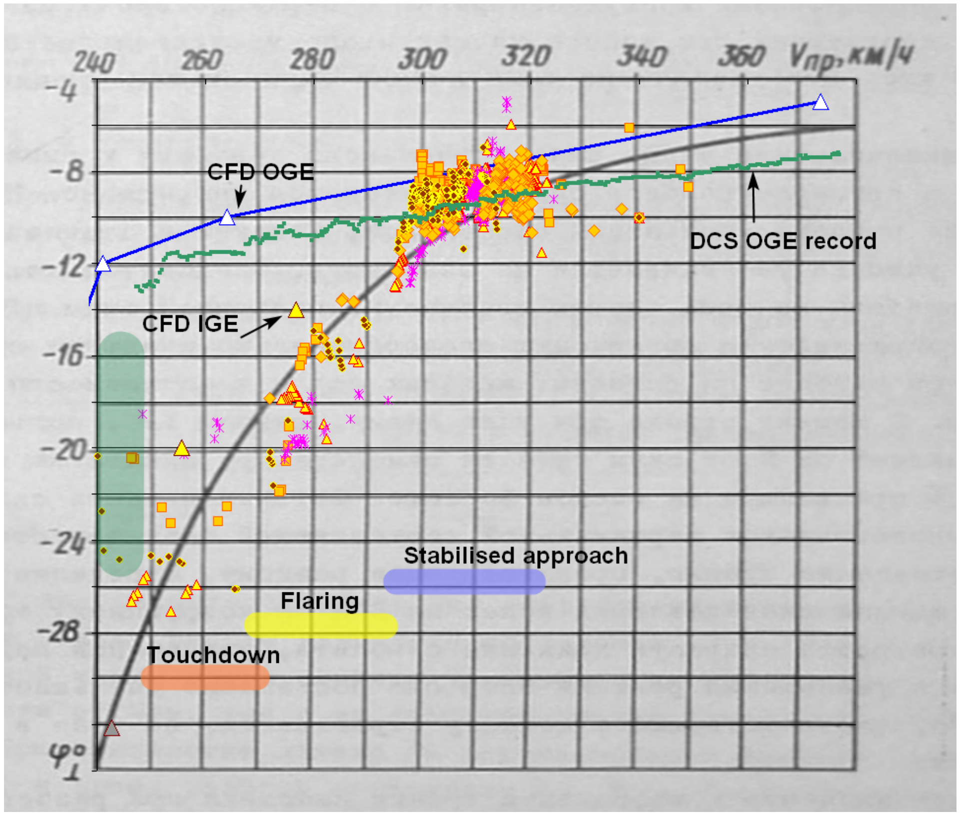


Рис. 8.7. Балансировочные отклонения стабилизатора на взлетно-посадочных режимах

Now it’s time to check DCS stability margin curve in landing configuration OGE. It is easy to see that it well duplicates the graph obtained in CFD with only small constant shift.



Having accepted the opinion that graph 8.9 is the averaged stabilator deflection, it is possible to export the flight speed and stabilator position from DCS and place these points on the graph 8.9, having previously selected the balancing points by $n_y = 1 \pm$ delta, where delta is chosen as small as possible so as not to clutter the graph.

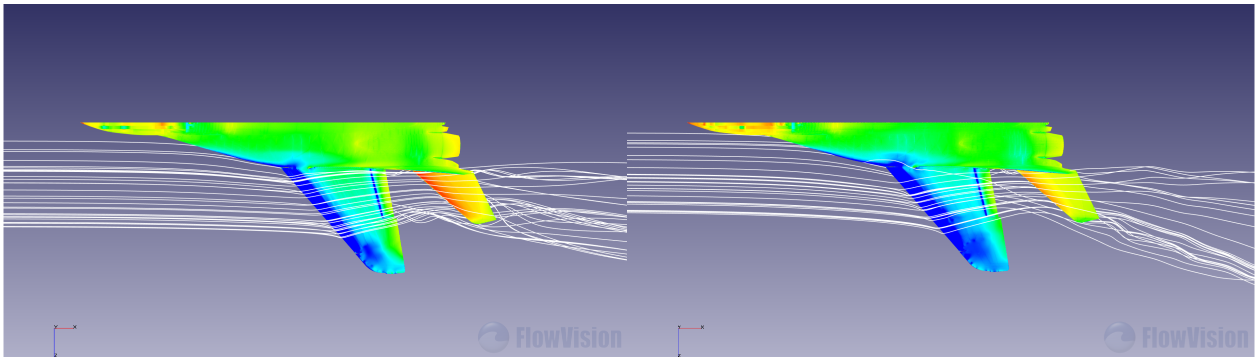


Points of different color on the graph refer to records of different landings. Landings, whenever possible, were carried out with accordance to the recommendations of the Flight Manual and standard landing weight. The green area on the graph refers to the position of the stabilator on the run after touchdown.

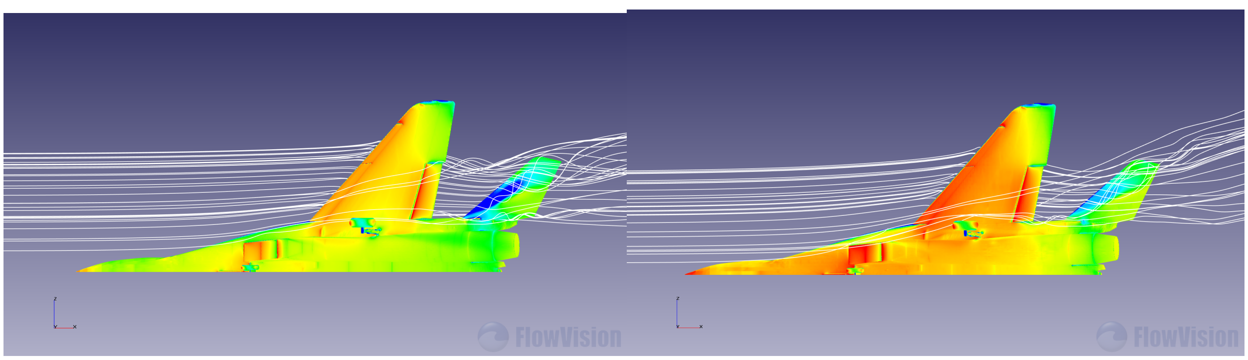
Appendix

The following CFD images of pressure distribution and flow lines illustrate the reason for the significant change in the longitudinal moment of the plane flying IGE. They clearly show that the impact of the ground effect (right images) leads to a significant change in the pressure distribution both on the wing and fuselage of the aircraft (the area of increased pressure is shifted to the tail of the aircraft) and on the stabilator (on the upper surface the pressure decreases, on the lower surface - increases, and with a noticeable shift of the pressure backward).

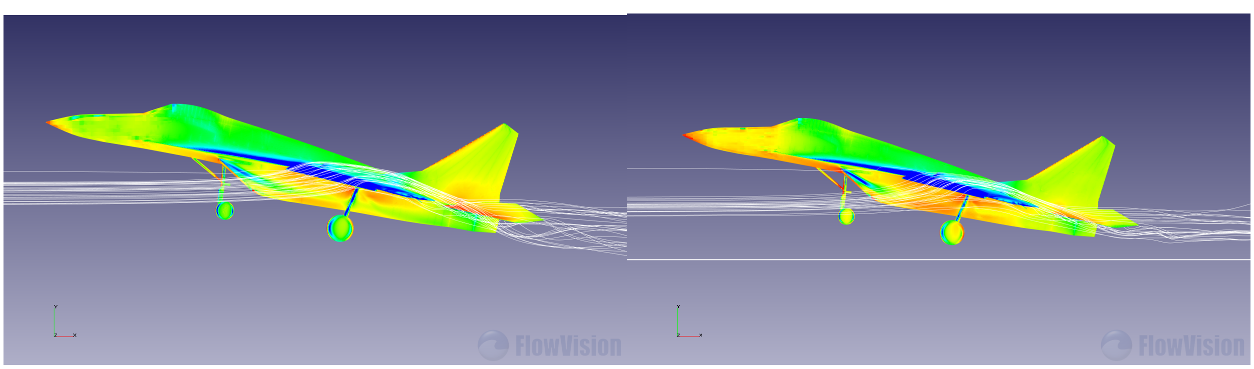
Upper view:



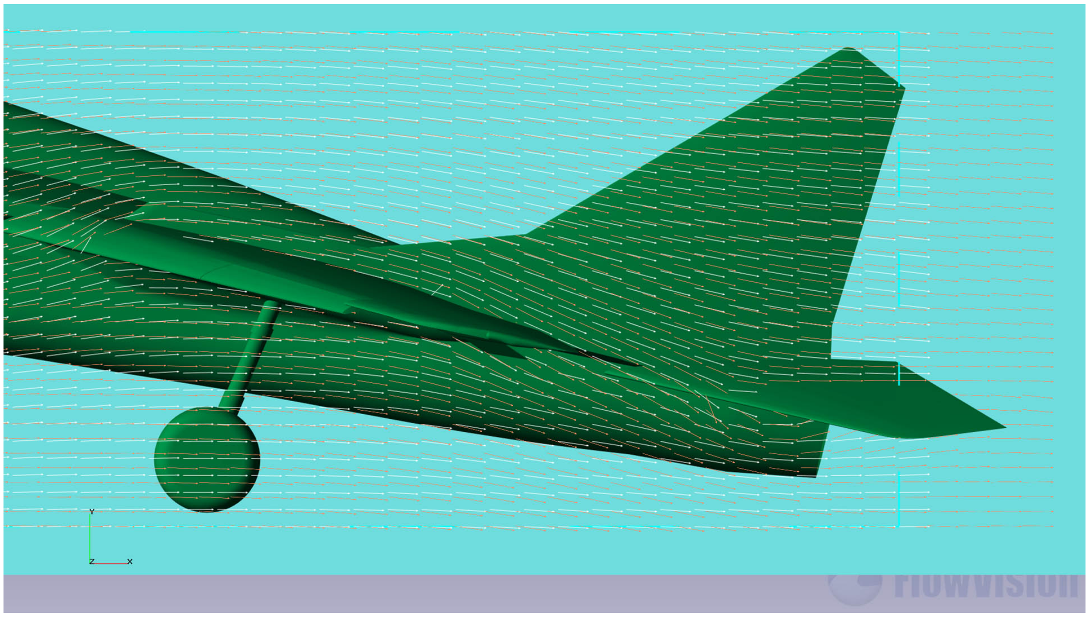
Bottom view:



Side view:



As expected, the reason was a significant change in the flow direction (up to 10-12 degrees) behind the flap, which is clearly visible on the vector field in the longitudinal section, passing approximately in the middle of the flap (see below: white arrows - IGE, orange - OGE).



An increase of the IGE longitudinal stability is caused by a significant increase in the derivative of the flow downwash angle with respect to the AoA, which reduces the longitudinal stability. (With the zero lift AoA, the downwash angle is close to zero for both OGE and IGE, and with AoA increase, the difference between that angle in OGE and IGE modes increase).