Winging It!

FloEFD® provides Accurate and Fast Flight Load Data for Aircraft Wing High Lift Devices at Irkut

By Andrey Chuban, Lead Design Engineer, Irkut Corporation

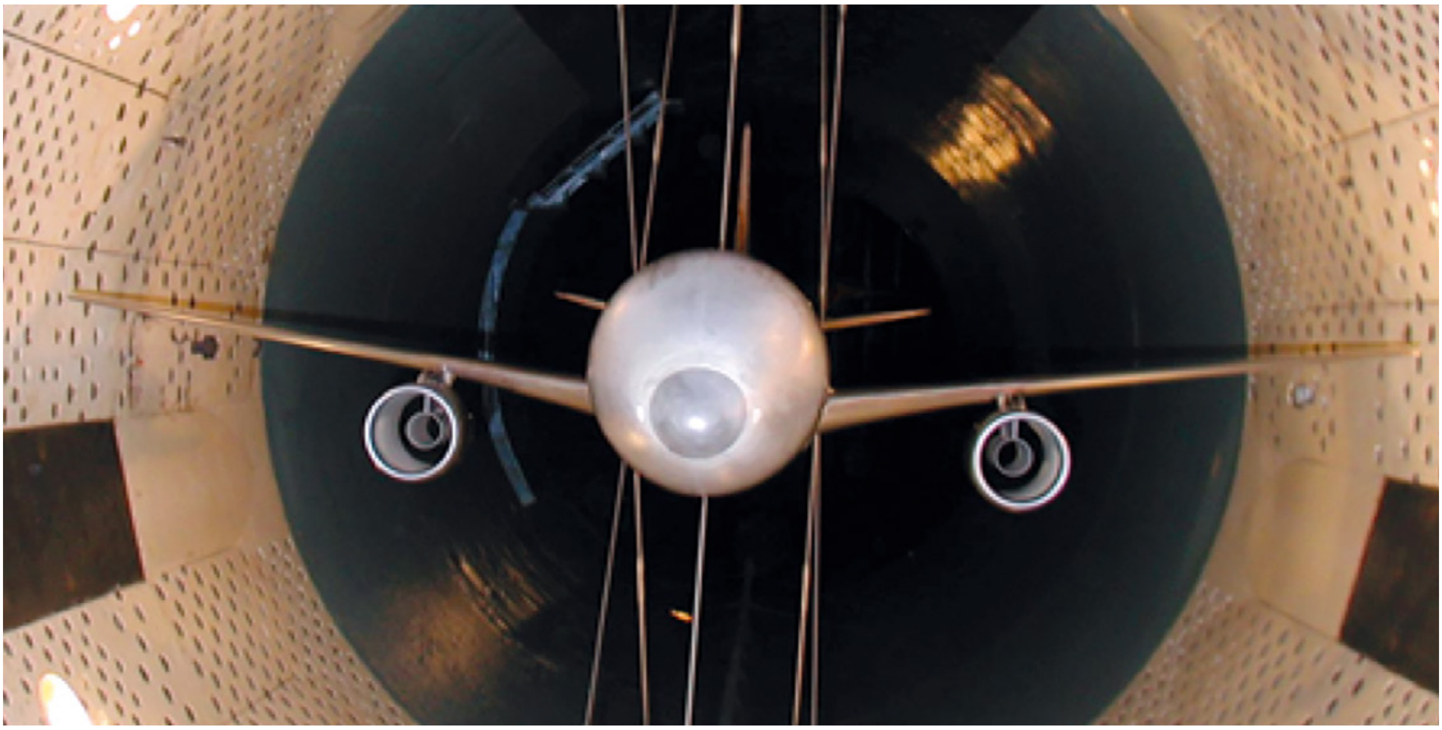

Figure 1. Typical tube experiment for a scale model aircraft

Engineers at Irkut Corporation were looking for a way to get better external aerodynamics data than what they were currently able to get from tube experiments. Tube experiments consist of building scale models of the aircraft and measuring values in a wind tunnel. This approach is expensive and has some inherent disadvantages. These include low Reynolds numbers and higher airflow turbulence intensity for scale models vs. full size aircraft. There are also inaccuracies due to the scaled geometry such as radii and points where different structures such as the wings and fuselage meet. Finally, tests run in different wind tunnels can produce varied results. To solve these issues Irkut turned to CFD as an alternative approach. As part of this the CFD tools needed to be validated for this use, the tools tested included Mentor Graphics' FloEFD and Ansys' CFX.

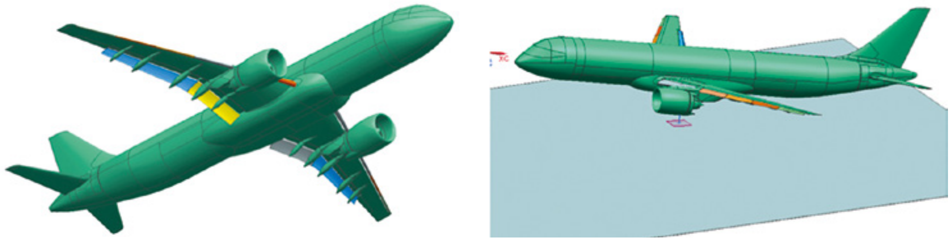

Figure 2. 3D CAD model of aircraft

The criteria for validating the tools were:

- Obtain the computational results close to those of the tube experiment,
- Provide loads for the flight modes and configurations, that were not tested during experiments,
- Compare solutions with or without ground effect simulation screen, and
- Compare the FloEFD results with the load data obtained with CFX.

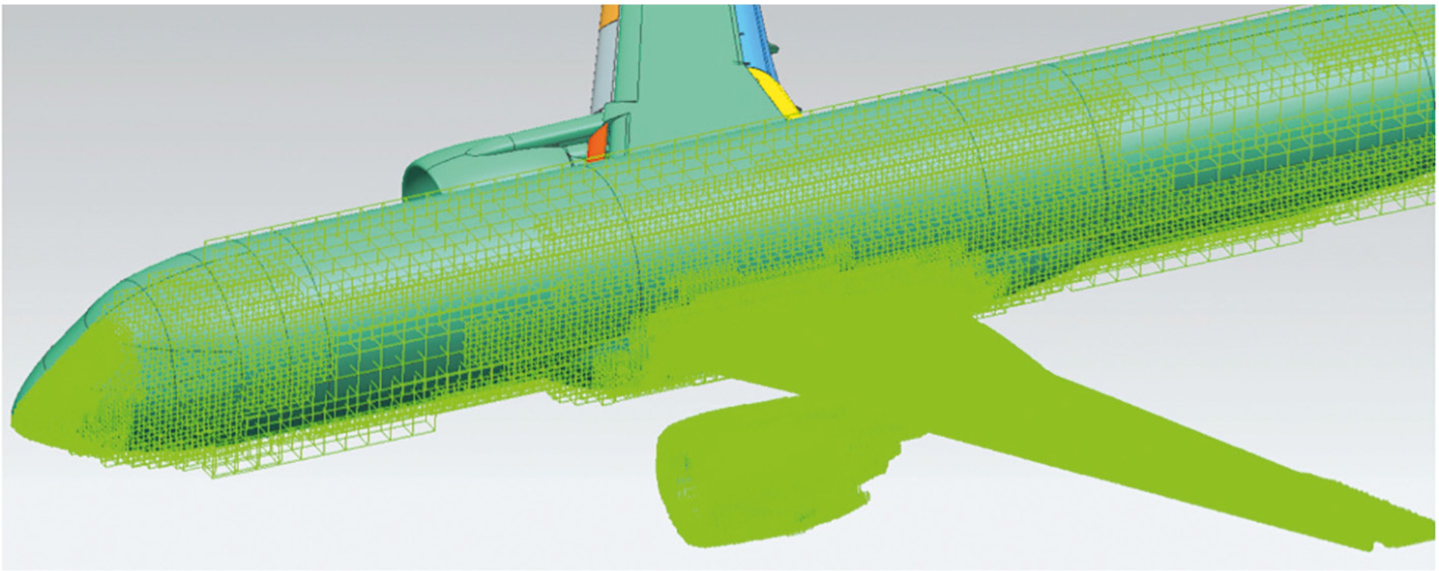

Figure 3. Final Mesh after a single adaption

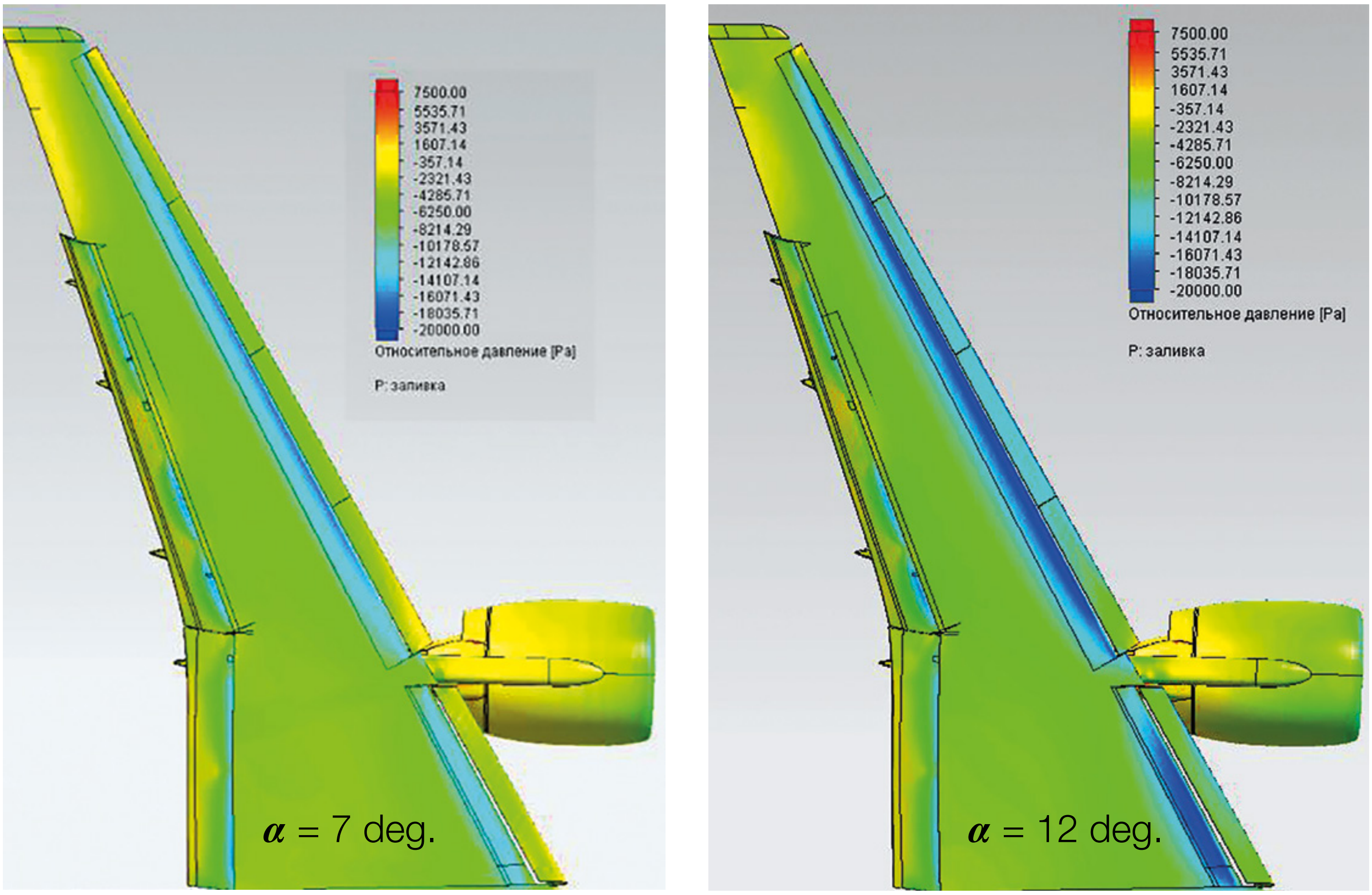

Figure 4. Computation Results: ΔP on Wing Surface

The FloEFD software was installed on a double Xenon powered computer with 48 Gb RAM. The mesh size was limited to 4 million cells (about 1.4 million before mesh adaptation process). The density of the mesh was organized with the help of volumetric zones to meet the basic rule: very dense mesh in areas with large airflow speed gradients.

After construction of volumetric zones around the nose of fuselage, high lift devices, wing with engine and whole aircraft a basic mesh was refined automatically. The picture in figure 3 presents the final mesh after a single adaptation.

The simulation was then run for two angles of attack, 7 degrees and 12 degrees and several computational results were examined. The first result studied was the ΔP on the wing surface. This showed an increase of pitch angle leading to the growth of negative relative pressure along the wing leading edge surface and upper surface of

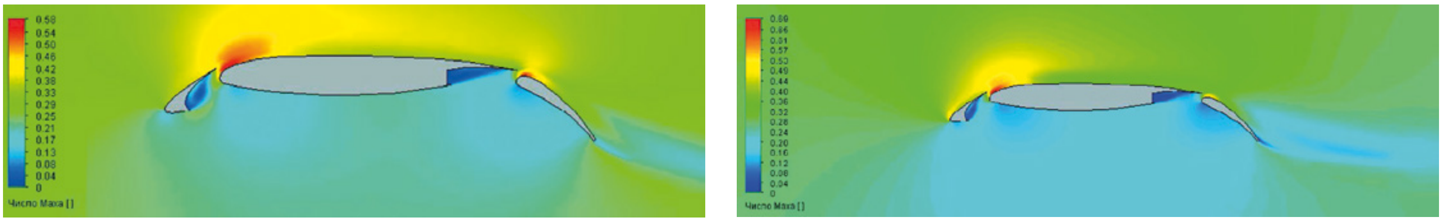

Figure 5. Computation Results: Mach Number Distribution along Wing Airfoil

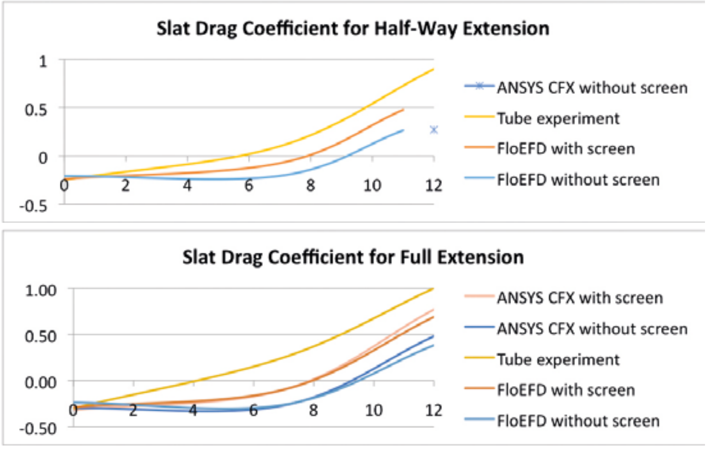

Figure 6. Results Comparison: Slat Drag Coefficient

Figure 7. Results Comparison: Slat Lift Coefficient

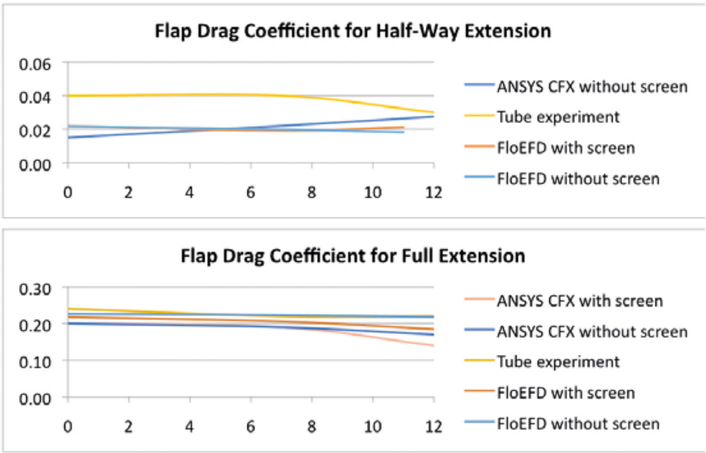

Figure 8. Results Comparison: Flap Drag Coefficient

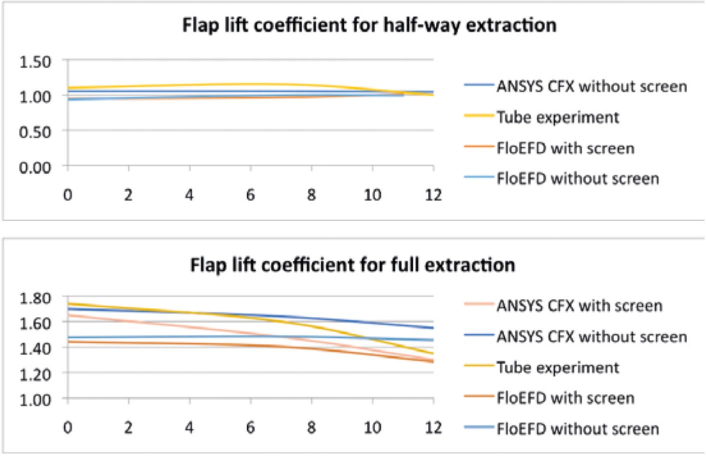

Figure 9. Results Comparison: Flap Lift Coefficient

the slats. So slat loads are the function of an angle of attack.

The relative pressure on a bottom wing surface doesn't really depend on the angle of attack; flap loads are almost independent of the angle of attack.

Next they examined the Mach number distribution along the wing airfoil. In case of a full flap extension, a high pitch angle may provoke flow separation on the flap's upper surface. The relative pressure growth on the upper surface led to flap loads decrease.

Since the experiment was run with the ground effect simulation screen, a plate was added to the FloEFD model to capture the screen effect. This resulted in an almost doubling of drag load level with screen presence.

The drag and lift coefficient plots illustrate that qualitatively identical airflow around

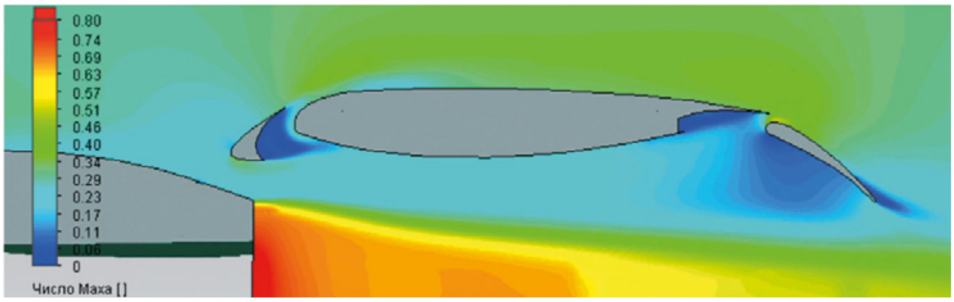

Figure 10. Engine Thrust Effect: Flow Stagnation on the Flap Bottom Surface

the slat in the half-way and fully extended positions.

The addition of the screen also greatly raised the slat loading, but for flap, the opposite is true.

The flap lift coefficient is especially affected by screen, they observed a 15% load decrease at high angles of attack.

The next stage of the validation was to consider the engine thrust effect. The tube experiment was also done with the engine simulator which demonstrated a 10% increase of flap lift at high angles of attack. To investigate the engine thrust, effect the boundary conditions at the inlet and outlet of the engine were added to the model. This led to flow stagnation on the flap bottom surface.

FloEFD also shows a flap load increase during computation with the engine thrust taken into account, but the gap between the results with and without thrust tends to decrease with the angle of attack growth.

The spoilers, release effect at a small angle, (within 10 degrees) results in a substantial increase of outward flap loading. Wherein large spoiler release angles greatly disrupt the flow around the flap, causing a reduction of flap loading. The main problem for the flap release kinematics designer is a huge tangent load increase after spoiler release.

10 degree spoiler release causes flow separation on the flap aft edge and flow acceleration on the leading edge.

The tube experiment and FloEFD calculations show large increase (four times for FloEFD) of flap drag load for half-way extraction configuration and about 20% increase of lift load. For the outward flap tube experiment, results differs from CFD calculations due to slightly different flap release angles of a tube model and real aircraft.

The final criteria studied was the Reynolds number effect. The tube model's small scale leads to a difference in Reynolds number of a flow around the model and the aircraft. To determine the effect of the Reynolds number, the scale model was calculated in FloEFD. The results of the calculation of the aircraft and a scale model were almost identical.

Conclusions

- The FloEFD results satisfactorily correlate with the experimental data which are very close to the results of ANSYS CFX calculations. The size of the CFX mesh used for calculations was about 18 M cells, so these flow computations took too much time and required a very high-capacity equipment. Each FloEFD calculation took about six to eight hours on a standard workstation.
- The ground effect simulation screen greatly affects the drag coefficient of the slat and must be accounted for during calculation. Outward flap loading is highly dependent on spoilers release. The inner flap load growth due to the

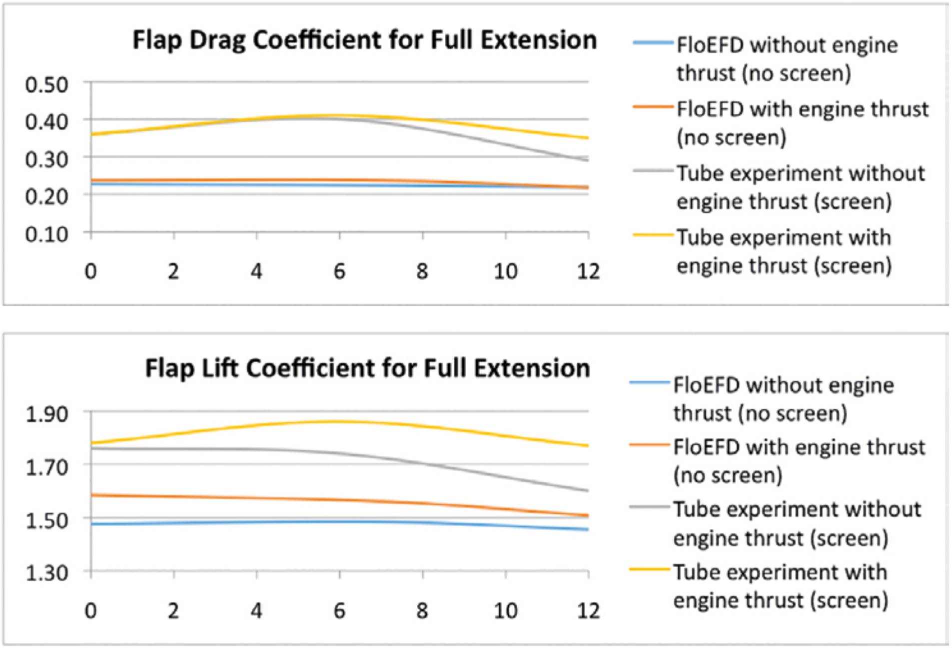

Figure 11. Engine Thrust Effect: Flap Drag Coefficient

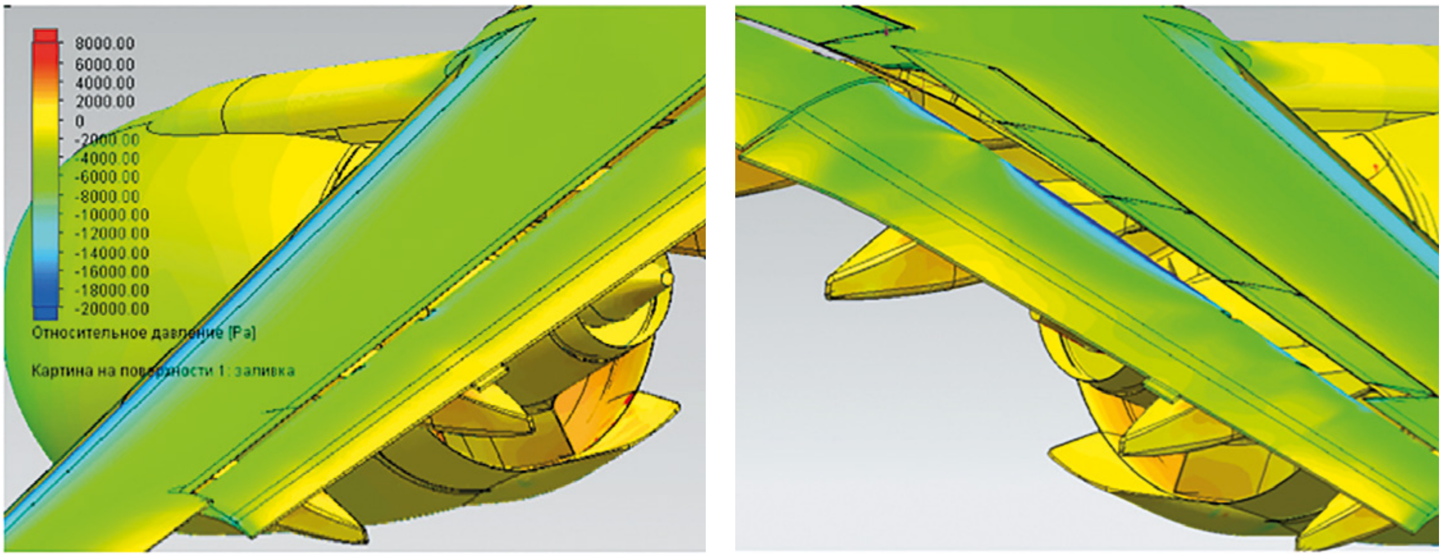

Figure 12. Spoilers Release Effect: Negative relative pressure growth on flap leading edge after spoilers release

engine thrust increase must also be considered.

- The difference between the experimentally defined and FloEFD and ANSYS CFX computed loads raises the question about the load data source at the aircraft design stage. On the one side there is a traditional distrust in CFD results and on the other side there is a difference in Reynolds numbers and geometry between the tube model and the real aircraft.

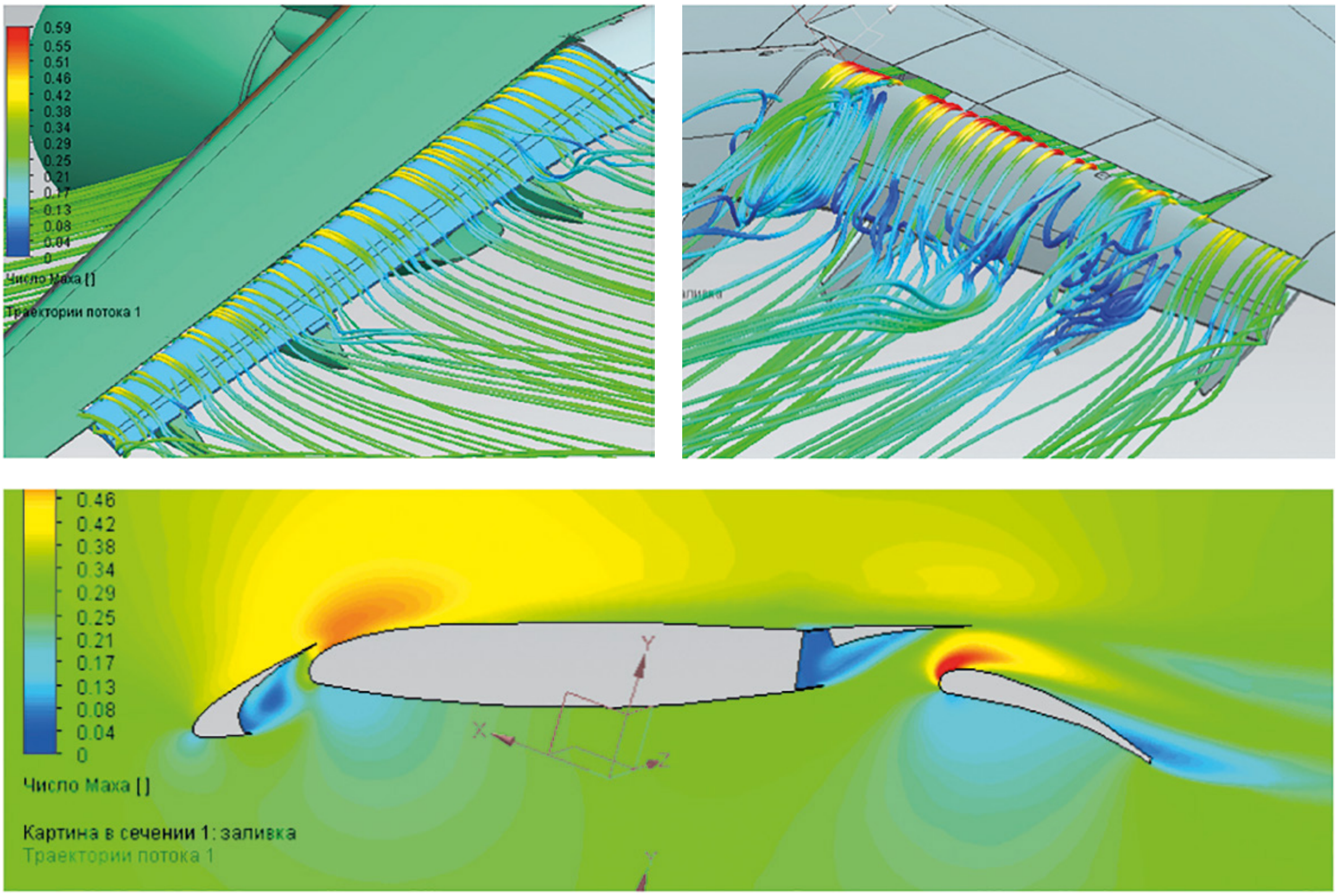

Figure 13. Spoilers Release Effect: Flow separation on the flap aft edge and flow acceleration on the leading edge

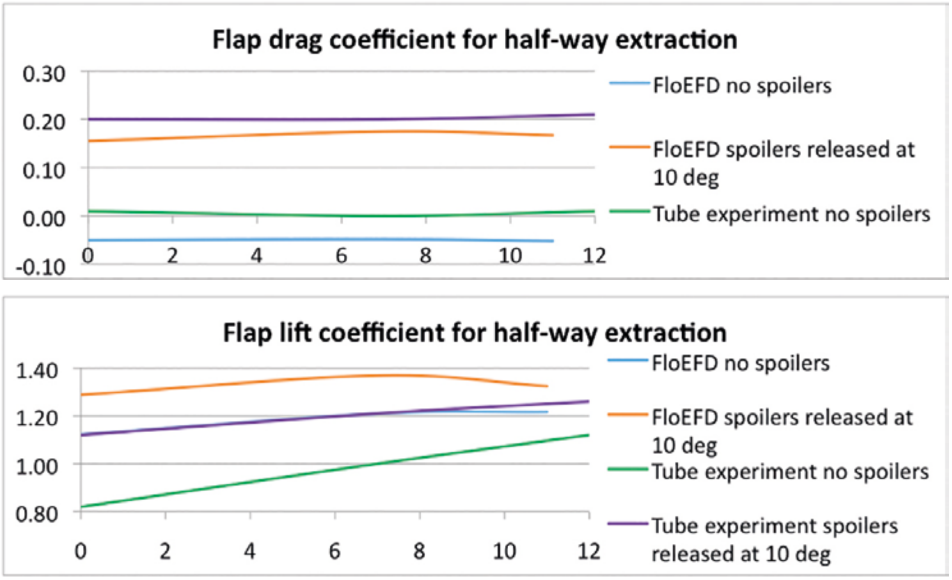

Figure 14. Spoilers Release Effect: Flap Drag Coefficient

	Scale model	True model	Δ
Slat drag coefficient	-0,11	-0,08	37%
Slat lift coefficient	0,91	0,96	5%
Flap drag coefficient	0,02	0,02	0%
Flap lift coefficient	0,89	0,96	7%

Figure 15. Reynolds Number Effect: Comparison of scale model to True Model