Benchmarking takes off for NASA CRM & Tupolev Tu-214

FloEFD™ Simulation of External Aerodynamics

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External aerodynamics is a theoretical basis for aerospace technology, and aerodynamic calculations of modern aircraft and other vehicles. This branch of hydro-gas dynamics is becoming increasingly important in modern life due to the development of a new generation of commercial and military aircraft and unmanned aerial vehicles. CFD simulations in this area now play a very important role. Panel and other methods for preliminary estimates are still useful but a modern CFD approach allows for more accurate results and better information on vehicle performance, earlier in the design cycle.

FloEFD™ has been successfully used to simulate external aerodynamics in various studies, ranging from aerofoils to whole aircraft modeling, for physically feasible range of Reynolds numbers including subsonic, transonic and supersonic cases. Compared to a traditional CFD approach, FloEFD arrives at valid results with ease. There are also several additional mathematical models employed in FloEFD for detailed analysis. These are a unique model of laminar/turbulent transition, and, also an innovative and effective model of boundary layer. FloEFD offers various methods for visualization of results, allowing the investigation of a complex 3D flow structure and presenting aerodynamic parameters in an understandable form.

Two models of aircraft will be discussed in this article. The first is the NASA Common Research model in the wing/body/horizontal-tail configuration and the second one is the Russian commercial aircraft Tu-214. The main purpose of this investigation was to obtain aerodynamic characteristics of the vehicles such as lift, drag, pitching moment coefficients and pressure coefficient which were compared with experimental data.

The external flow simulation around the wing/body/horizontal-tail configuration of the NASA CRM with focus on aerodynamic coefficients is presented here. The genesis of an open geometry NASA CRM was motivated by a number of interested parties asking NASA to help develop contemporary experimental databases for the purpose of validating specific applications of CFD [1]. A transonic supercritical wing design is developed with aerodynamic characteristics that are well behaved and of high performance for configurations with and without the nacelle/pylon group. The horizontal tail is robustly designed for dive Mach number conditions and is suitably sized for typical stability and control requirements. The fuselage is representative of a wide body commercial transport aircraft; it includes a wing-body fairing, as well as a scrubbing seal for the horizontal tail. The model of the NASA CRM is presented in Figure1.

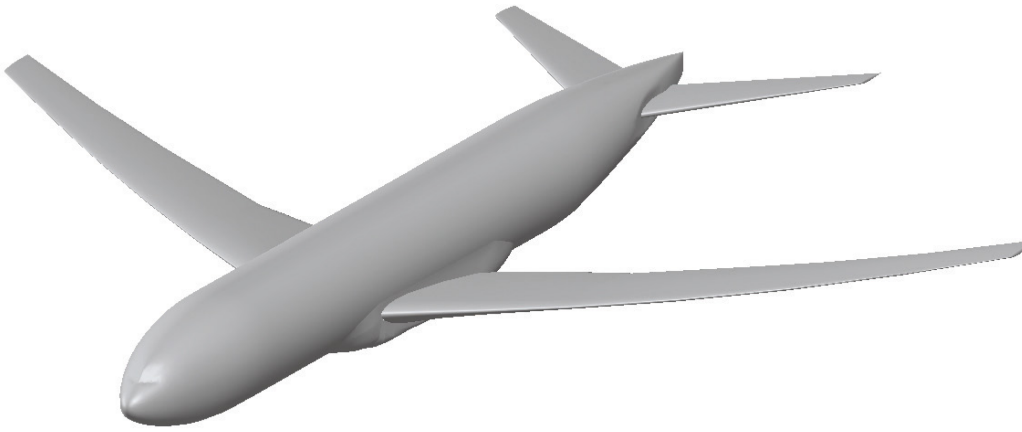


Figure 1. The model of NASA CRM

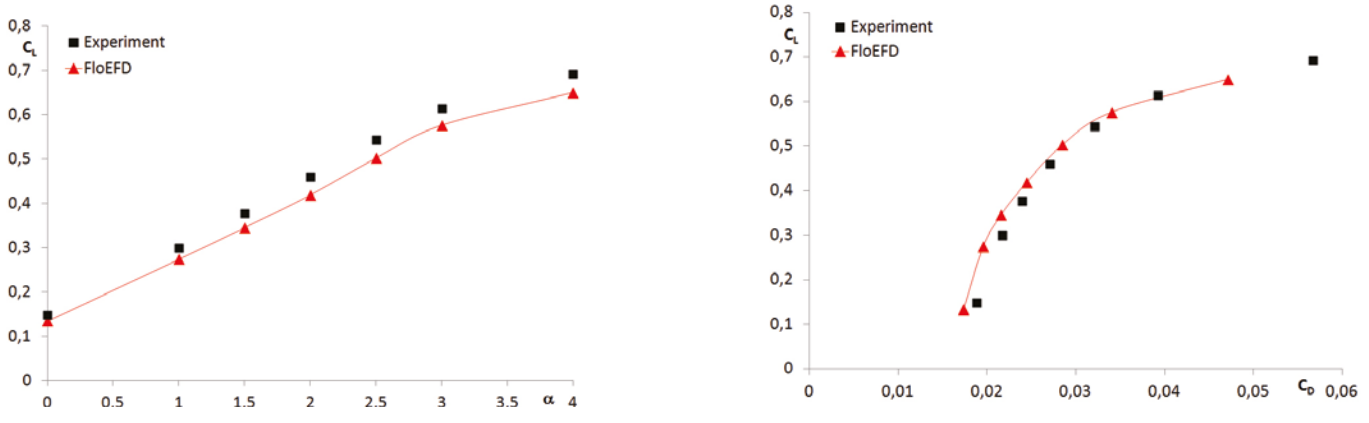


Figure 2. Lift coefficient (left) and polar (right) of NASA CRM

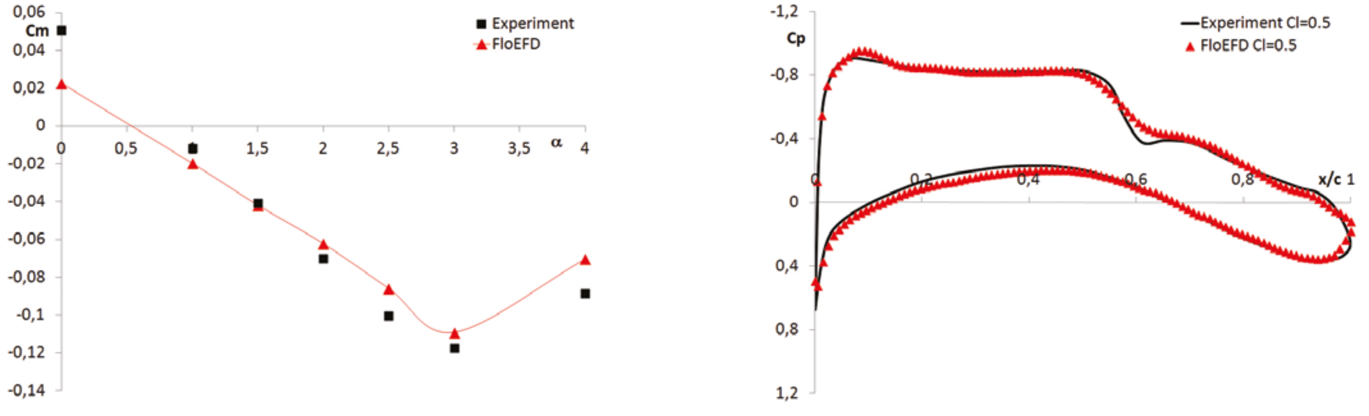


Figure 3. Pitching moment coefficient (left) and chordwise pressure coefficient distribution at 49.9% semispan (right) of NASA CRM

Calculations were provided at the following far field conditions: M = 0.85, P∞ = 201300 Pa and T∞ = 210.9 K. The angle of attack varies in range from 0° to 4°. The best results were obtained on the model with local mesh around the aircraft and several refinements during calculation by Solution Adaptive Refinement (SAR) technology in FloEFD. Attention should be paid to fine mesh resolution in the neighborhood of wing leading edge.

Lift coefficient, polar, pitching moment coefficient and chordwise pressure coefficient distribution at 49.9% semi-span were obtained from calculations and experiments [2] and are presented in Figures 2 and 3. Good FloEFD prediction of the lift and drag coefficients in linear area were achieved. For pitching moment coefficient, discrepancy is bigger. Also there is some insignificant departure in Cp between calculation results and experiment. The pressure distribution with flow trajectories colored by Mach number at M =0.85 and angle of attack 4° is displayed in Figure 4.

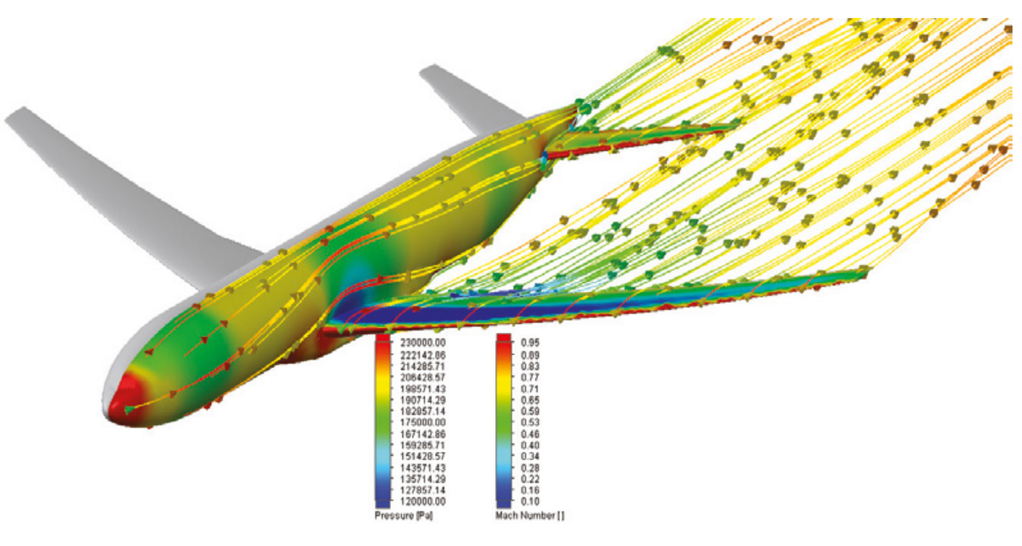


Figure 4. Pressure distribution with flow trajectories colored by Mach number at M =0.85 and angle of attack 4° of NASA CRM

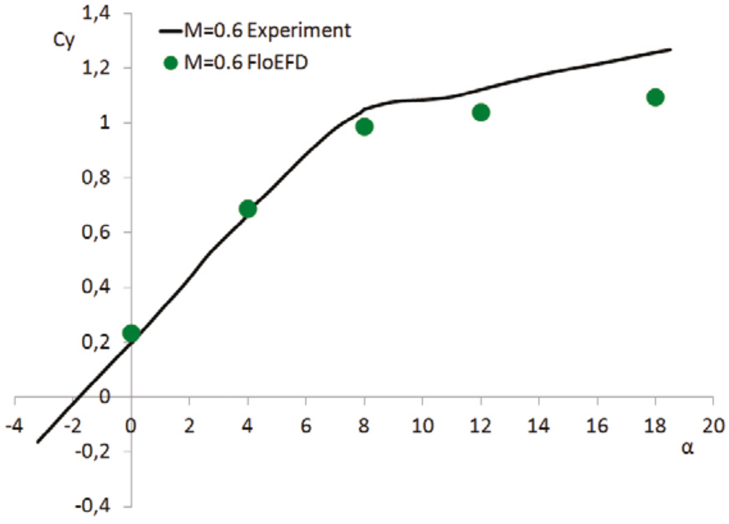
Figure 5. The model of Russian commercial aircraft Tu-214

The second aircraft which is considered here is the Russian commercial aircraft Tupolev-214 (Tu-214) developed by well-known Russian Aircraft Design Bureau PSC 'TUPOLEV' (Figure 5). This vehicle is a cantilever monoplane of a normal scheme with a low-set swept wing and a tail assembly placed on a fuselage with two turbojet engines mounted on pylons under the wing.

The Tu-204/214 was designed as a family of aircraft incorporating passenger, cargo, combi and quick-change variants and relates to a fourth generation of aircraft which have a higher level of reliability and fuel efficiency [3]. For developing this family of aircraft the latest science and technological developments in aerodynamics, strength, propulsion engineering, materials, electronics and ergonomics were applied.

Calculation of this task was provided at the following far field conditions: M = 0.6, P_∞ = 101325 Pa and T_∞ = 288.15 K. The angle of attack varies in range from -3° to 18°. Work of the propulsion system was taken into account in these investigations.
The FloEFD predictions align with the wind tunnel's tests of the Tu-214 aircraft scale model. Comparison was made with respect to integral parameters such as lift coefficient and drag coefficients, etc. All of these parameters were compared with experimental data.

Lift coefficient and polar are presented in Figure 6. It should be pointed out that good FloEFD prediction of these coefficients were achieved at Mach number



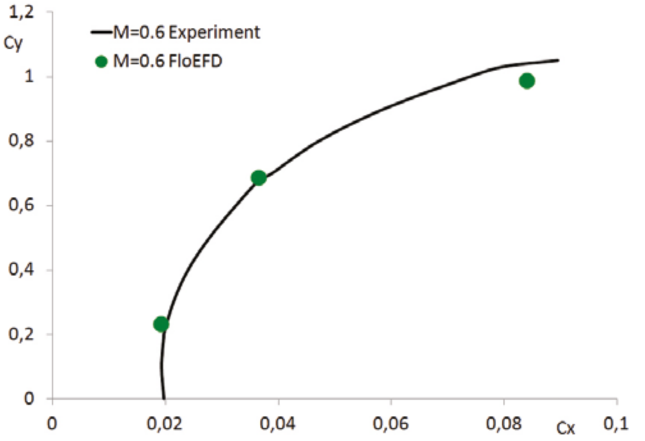


Figure 6. . Lift coefficient (left) and polar (right) of Tu-214 (results were provided by PSC TUPOLEV)

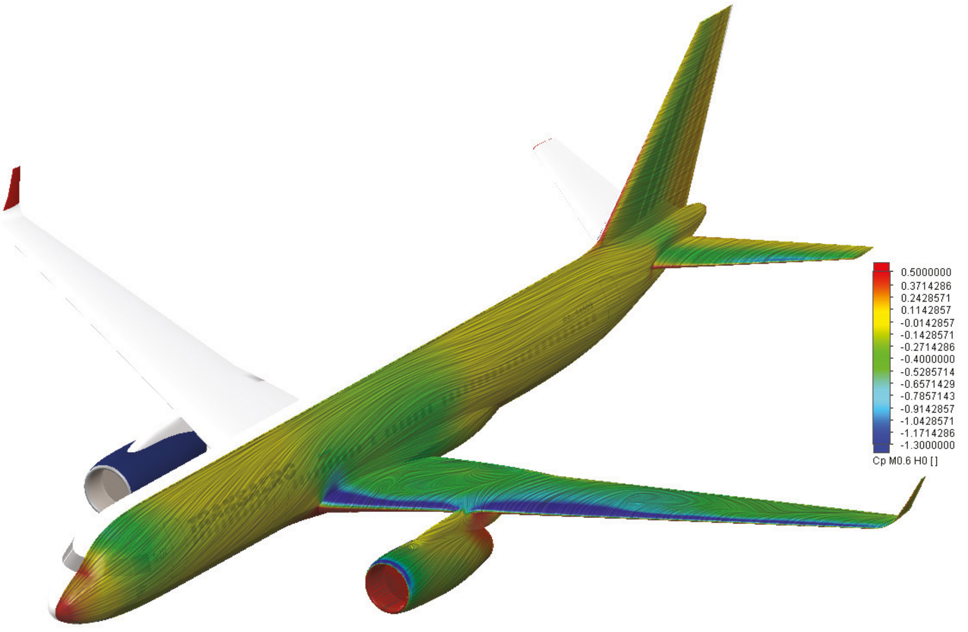


Figure 7. Pressure coefficient distribution with LIC at M =0.6 and angle of attack 10° of Tu-214 (results were provided by PSC TUPOLEV)

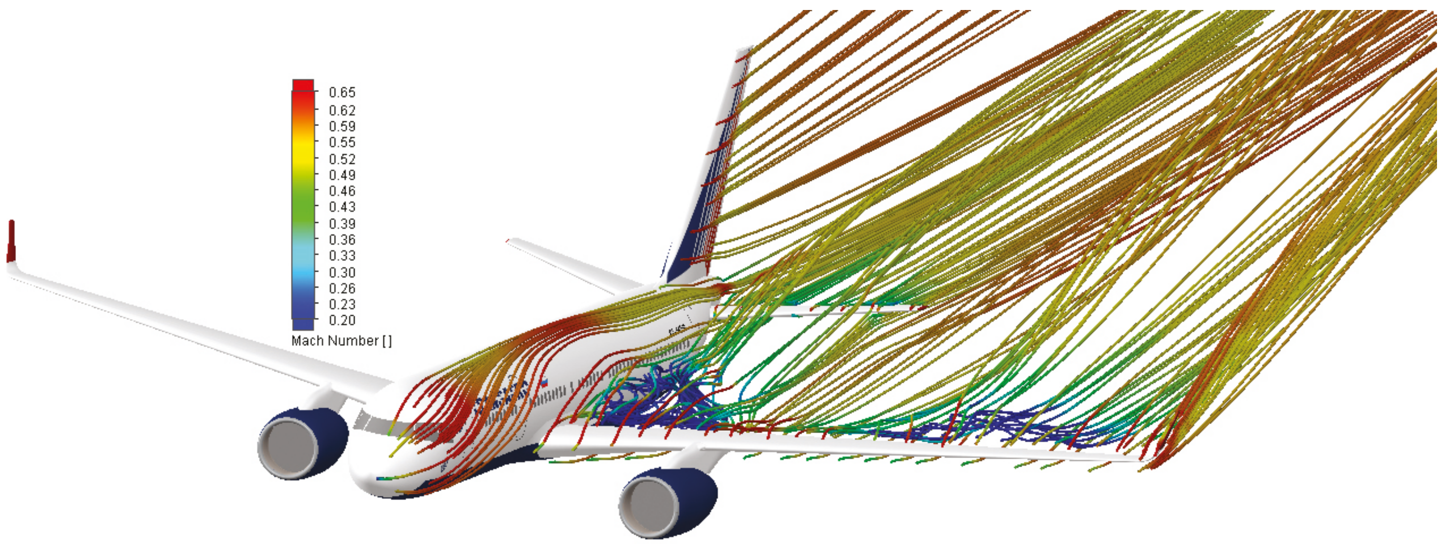


Figure 8. Flow trajectories colored by Mach number at M =0.6 and angle of attack 10° of Tu-214 (results were provided by PSC TUPOLEV)

under study. There is also agreement in aerodynamic derivative obtained in FloEFD and experiments with a discrepancy of approximately 1.7%.
Pressure coefficient distribution with LIC in FloEFD at M =0.6 and angle of attack 10° is presented in Figure 7 as oil flow lines. Using LIC technology allows for good observation of clear flow structures near the aircraft's surfaces.

Comparison of measured and predicted values of the main integral parameters such as lift, drag and pitching moment coefficients show agreement for the investigated class of tasks. Thereby FloEFD yields a series of 'what-if' aerodynamic analyses. It should be pointed out that FloEFD provides export of pressure and temperature as loads for structural analysis, on a structural mesh in NASTRAN format directly, allowing automatic parameter changes rather than a manual approach.

References

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