Aces High for Team Velarde

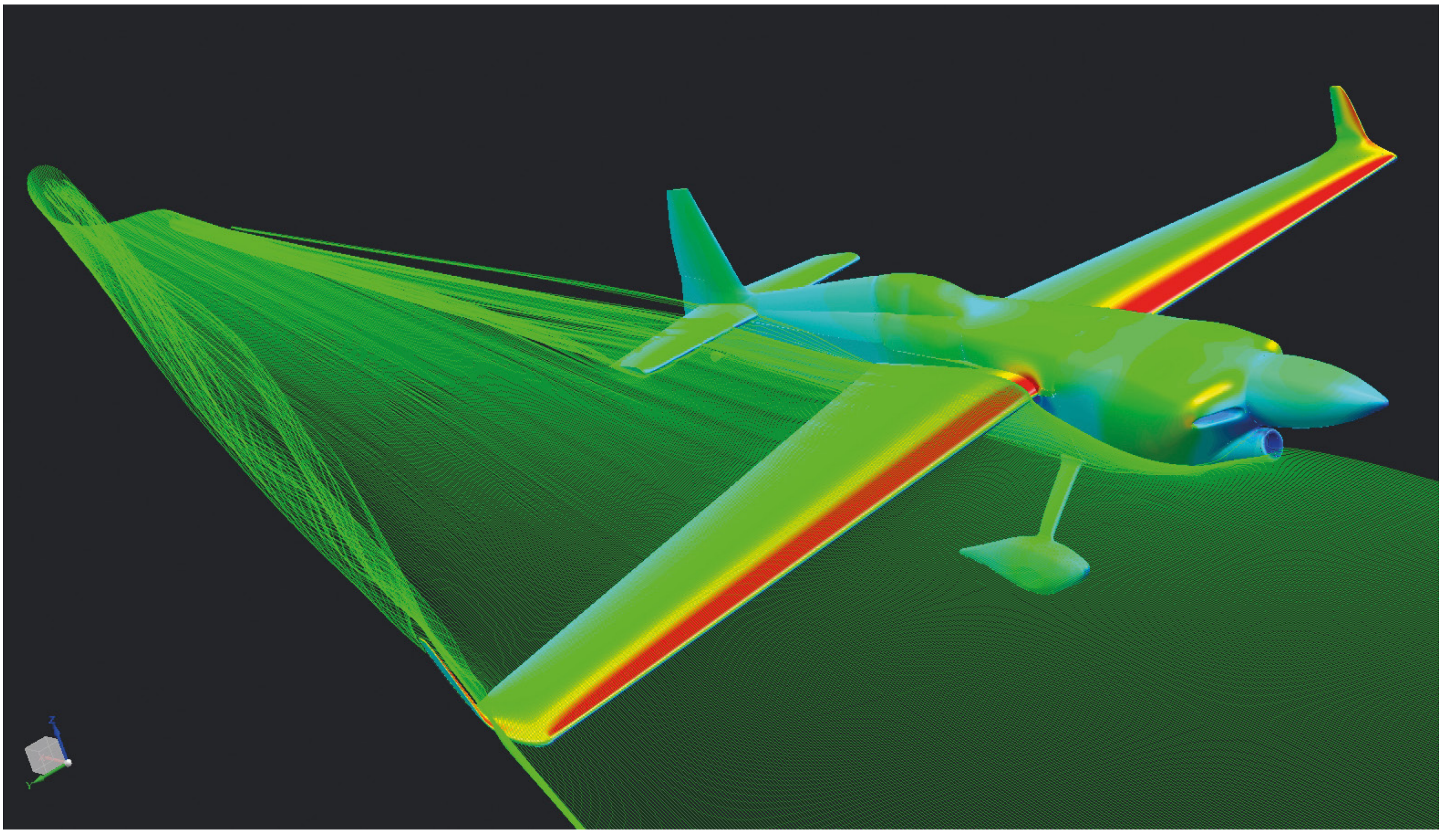
FloEFD® explores external aerodynamics for Team Velarde in the Red Bull Air Race World Championship

By Matt Milne, Application Engineer, Mentor Graphics

I don't know about you but I'm partial to a bit of Iron Maiden now and then. And if there's a more fitting, more intense, higher energy soundtrack than "Aces High" to accompany the Red Bull Air Races then I want to know about it! Established in 2003, the Red Bull Air Race World Championship sees pilots from around the world compete against the clock as they navigate their aircraft through a challenging obstacle course in a breath-taking combination of high-speed low-level flying.

2017 sees Team Velarde begin their third year in the championship. Pilot Juan Velarde is looking to build upon his impressive 2016 record where he took the top spot in qualifying in one round and proved he could be competitive against the other more experienced pilots.

It is often said in racing that to stand still is to go backwards. With this in mind, Team Velarde continued working hard through the off-season to make their goal a reality. "Regarding the race plane, we are



aiming to have a new set of winglets and a few other aerodynamic improvements ready by the second race of the season," explained Velarde. "We are working with a team of engineers to optimize the performance of the plane," he added.

Team Velarde approached Mentor Graphics for help investigating the aerodynamics of the race plane. Specifically they wanted to use CFD to investigate the performance benefits of the new winglets. Working with CAEsoft in Madrid, Team Velarde used 3D scanning technology to create a 3D CAD model of the aircraft which was then provided to Mentor Graphics for CFD analysis.

While modern 3D scanning techniques are without question impressive, it turns out that the technology does a rather better job than some might desire for CFD analysis. Close inspection of the CAD model revealed a number of excrescences and other lumps and bumps. For traditional CFD, such features might be the cause of considerable pain, requiring time and effort to modify the CAD geometry to a state where it is suitable for meshing. However, with FloEFD these features are simply not a problem.

During my time in aerospace research, a lot of effort was spent working on the CAD geometry to get it into a suitable state for meshing - the process was well developed but it still had to be done manually. And then came meshing. For conceptual models with a relatively clean shape some degree of automation was possible, but for more complex models meshing had to be completed manually. I remember clearly some cases where meshing alone took more than a month.

This is all in stark contrast to the situation today with FloEFD. Put simply, the SmartCell™ meshing technology employed by FloEFD addresses meshing challenges with minimal user effort. Regardless of whether the geometry is a clean conceptual model, or dirty with lumps, bumps and excrescences, FloEFD can mesh it. With less time spent on geometry preparation and meshing, the user has more time to think about the results, what they mean and how to improve performance.

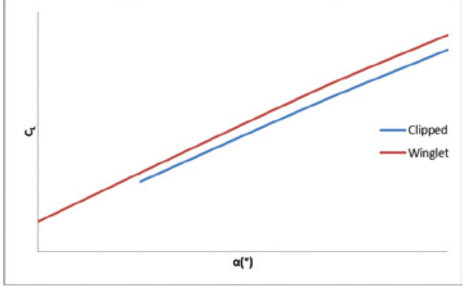


Figure 1. C_L vs. α (Full span model)

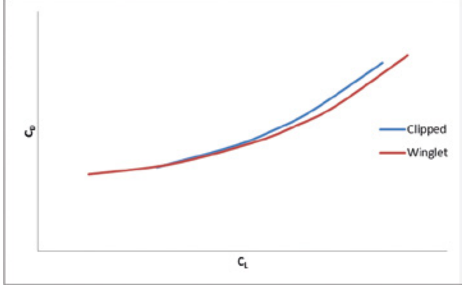


Figure 2. C_D vs. C_L (Full span model)

A new simulation was set up using the CAD geometry supplied by Team Velarde. The time taken to prepare the model, generate the mesh and begin the first flow calculation was less than one hour. Furthermore, our previous work on a wide range of well-known external aerodynamics test-cases meant we could follow a set of well documented best practices for this class of simulation and be confident of obtaining consistent and reliable results.

Initial calculations were run at low-medium angle of attack (AoA) at M=0.25, comparing the original clipped wing and revised "winglet" designs. These calculations were run using the complete aircraft span (i.e. port and starboard sides) but omitting the propeller blades. It was assumed that the propeller wash has only an incremental effect on the overall wing performance and that since the wing leading edge is unswept any interaction between the propeller and wingtip flows is negligible. Each calculation used approximately 1.9 million cells and took around two hours to run using 12 cores (Intel Xeon E5-2643 v3).

It can be seen from Figure 1 that the "Winglet" design yields a slight increase in lift curve slope ($dC_L/d\alpha$). Figure 2 shows that there is also a reduction in drag. These predictions are expected from basic aerodynamic theory, since both designs effectively increase wing aspect ratio.

Further simulations were run to quantify performance of the "Winglet" design at medium-high AoA at M=0.25. It is noted that this area of the flight envelope (i.e. accurate prediction of onset and development of flow separation and associated effects) continues to be a challenge for all CFD methods today. While validation against well-established aerospace test-cases has shown FloEFD to perform acceptably in this regard, caution is nevertheless advised when interpreting computed predictions in this part of the flight envelope - the ability to obtain plausible looking solutions is no guarantee of accuracy.

To increase computational efficiency, only the starboard half of the aircraft was simulated. The effects of asymmetry in the model were assumed to be negligible and the propeller blades were again omitted. Appropriate revisions were made to the aircraft reference

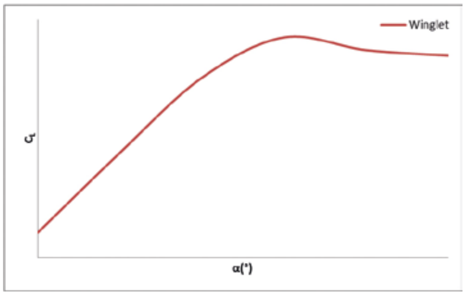


Figure 4. C_L vs. α (Half span model)

dimensions used to non-dimensionalize the integrated forces and moments. Each calculation used approximately 5.6 million cells and took around seven hours to run using 12 cores (Intel Xeon E5-2643 v3).

Predictions of integrated forces are shown in Figures 4 and 5. As expected the lift curve slope remains linear at low-medium AoA before becoming non-linear as flow separations develop. A thorough investigation of the predictions obtained using FloEFD is ongoing. This will give more insight into the development of the flow topology, and hence ways in which the "Winglet" design might be optimized to improve performance.

The improvement from the original clipped wing to the "Winglet" design is expected and indeed is predicted by basic aerodynamic theory. Performance of the "Winglet" design has been quantified for a wider range of AoA. Further improvement of the "Winglet" design may be possible through the use of

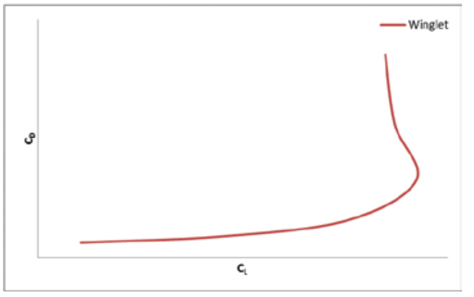


Figure 5. C_D vs. C_L (Half span model)

optimization and further work in this regard is recommended for the future. Based on these findings, the team are currently working on modifications to the race plane.

The first race of the 2017 Red Bull Air Race World Championship took place in Abu Dhabi on 10-11 February. After setting an impressive fifth fastest time in qualifying, Team Velarde took a sensational second place finish in the race, a best ever result for the team. The second race takes place in San Diego on 15-16 April. With luck, FloEFD will prove to be the ace in Team Velarde's hand and help them on their way to success in the 2017 Red Bull Air Race World Championship.

More information:

www.juanvelarde26.es
www.redbullairrace.com