Gliding Farther and Faster

A 3D rendering of the new AS 33 sailplane is shown gliding over Wasserkuppe Mountain.

To reduce the drag on the wings of a sailplane (glider) so it could go faster and farther, engineers needed to shave a small amount of surface area from the wing. This complex task involved fluid, structural and composite material challenges that had to be solved in parallel, and which could only be done using engineering simulation.

By **Ulrich Simon**, Alexander Schleicher Segelflugzeugbau, Poppenhausen, Germany

While most people consider a sailplane to be more dangerous than a motor-powered aircraft, gliding aficionados say it is safer because there is no engine that can fail and cause a disaster. A skilled glider pilot can currently ride the “thermals” — the updrafts of warm air that keep the aircraft aloft — for up to 1,000 km over a 10-hour flight. But increasing the speed and range requires reducing the overall drag on the glider. Engineers at Alexander Schleicher Segelflugzeugbau (AS Sailplanes) used ANSYS fluids, structural and composites simulation software to design a wing with a new composite structure and with a smaller surface area to reduce the drag of the AS 33 aircraft.

> ***“Without ANSYS CFD, they would not have been able to settle the long-standing argument about the optimal attachment location of the wing to the fuselage.”***

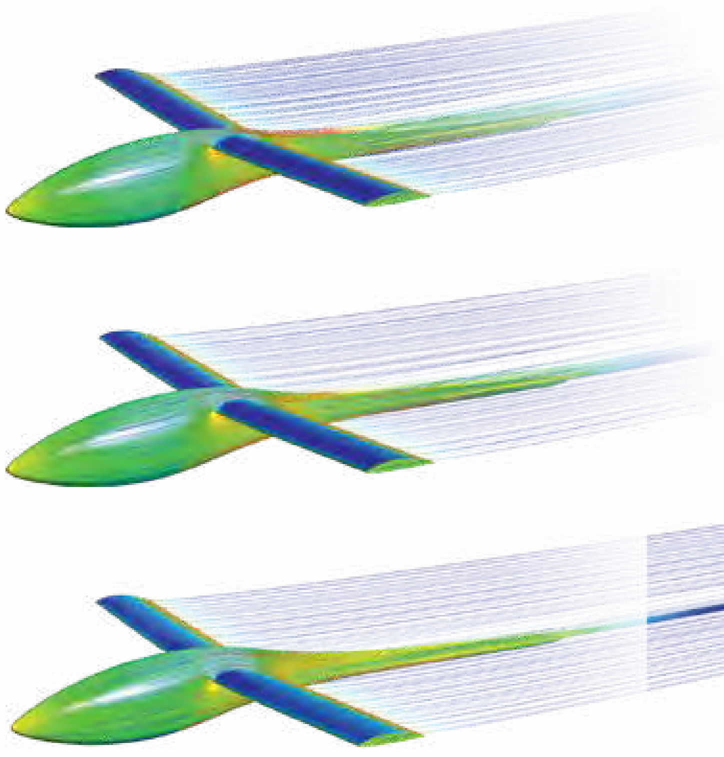
AERODYNAMIC, STRUCTURAL AND MATERIALS CHALLENGES

Best-in-class gliders used in competitions weigh from 400 kg to 600 kg. They have an 18 m wingspan and a 10.5 m^2 wing surface area, with a wing thickness of only 10 cm — about 4 inches. While the wing span and thickness are very close to practical limits, AS Sailplane engineers believed the surface area had some room for optimization. Reducing the surface area, even by a small amount, can cut the aerodynamic drag significantly. So, they decided to reduce the surface area from 10.5 m^2 to 10 m^2. By keeping the 18m wingspan constant, they produced a wing with a smaller average chord (front-to-back width) and therefore a reduced wing thickness.

While that may not sound like a big change, it is massive in an aircraft that has been around for a long time and is already close to its optimal design. This required the team to overcome a host of challenges.

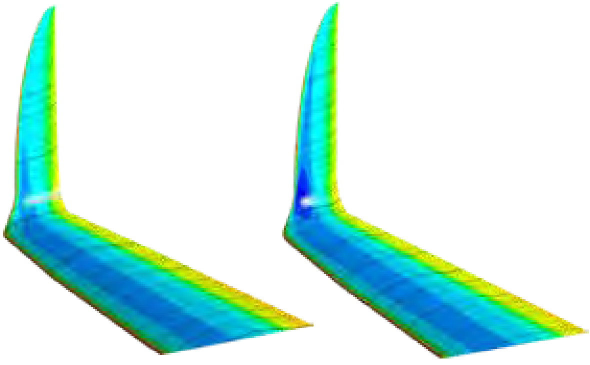
Reducing the wing surface area produces less lift so the aerodynamics of the system must be improved to compensate. A smaller wing also has less space for structural elements, so engineers needed to improve the design so that the wing can carry the same loads while maintaining strength. Engineers also wondered whether connecting the wing high up on the fuselage was better than a mid-fuselage join in terms of strength and drag. An additional challenge was to optimize the winglets — the small, upturned tips of the wings — which reduce vortex airflow at the ends of the wing, further reducing drag.

Because most of the sailplane is made of composite materials, except for the metal landing gear and mechanical control system, engineers explored an all–carbon-fiber design instead of the commonly used combination of glass fibers and carbon fibers embedded in a polymer matrix.



Configuration investigated for the wing–fuselage junction including a high-wing position (top) to a mid-wing position (bottom). Calculations revealed minimum drag for the mid-wing position, especially at high airspeeds.

ANSYS Fluent proved to be crucial for aerodynamics calculations, ANSYS Mechanical for structural considerations, and ANSYS Composite PrepPost



ANSYS Fluent CFD revealed unfavorable pressure peaks in the area of the wing–winglet junction, which was originally designed with classical aerodynamic tools. After design iteration with Fluent, it was possible to alleviate this problem and gain some aerodynamic efficiency.

for analyzing the stresses and strains by means of composite failure criteria on the new material.

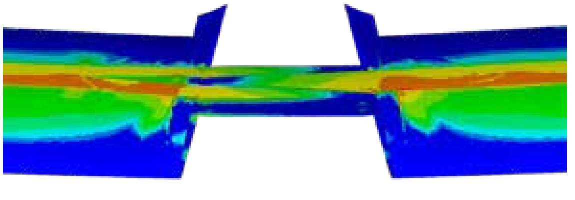
USING SIMULATION TO OVERCOME THE CHALLENGES

AS Sailplane engineers started the project with an in-house analytical tool that the company had been using for several years, but they soon realized that this tool would be insufficient for the task. Contracting the work out to universities proved to be too expensive, inflexible and not conducive to building in-house expertise. One of the engineers had used ANSYS simulation solutions earlier in his career and suggested that ANSYS finite element analysis solutions would be up to the challenge. A particularly compelling argument was that ANSYS had computational fluid dynamics solutions in Fluent, structural solutions in Mechanical and composite solutions in Composite PrepPost, so only one software supplier was required.

ANSWERS FOR AERODYNAMICS

First, the engineers applied ANSYS Fluent to solve a question that had been puzzling sailplane engineers for years: What is the best place to connect the wing to the fuselage for the least drag? Some had argued that attaching the wing at a high position on the fuselage prevents detachment of the boundary layer airflow from the aircraft body, leading to less drag; others contended that attaching the wing to the middle of the fuselage requires a smaller connection cross section, thus reducing drag, while simultaneously increasing the undesirable boundary flow detachment phenomenon. The discussion had persisted for years because there was no way to answer the question definitively using wind tunnel testing. Standard calculations were also insufficient, so simulation was needed.

After analyzing six wing–fuselage connection positions using Fluent 3D CFD calculations, the engineers determined that the mid-wing configuration produced less drag, especially in high-speed cornering situations, so they settled on the mid-wing–fuselage connection point for the AS 33. The detachment of the boundary layer airflow proved to be a smaller factor than previously thought. Without CFD, they would not have been able to settle this long-standing argument. A similar simulation process was used to determine the optimal positioning of the winglets.



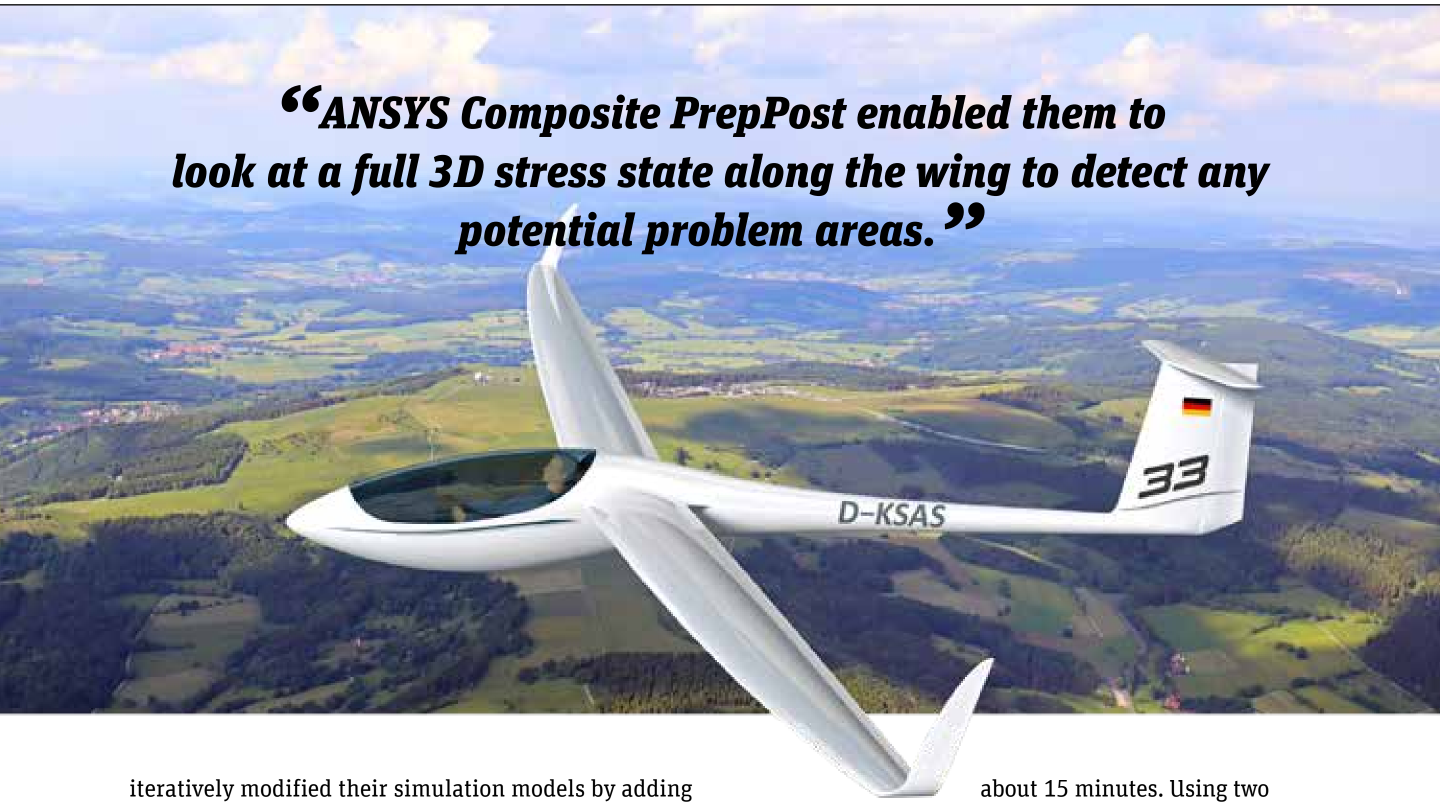
Safety factors for the carbon fiber–reinforced plastics structure in the area of inner-wing junction were analyzed with ANSYS Composite PrepPost.

STRUCTURES AND MATERIALS

The smaller wing of the new AS 33 sailplane must support equivalent or even higher loads than its predecessors because the weight of the fuselage of the AS 33 was increased to accommodate an enhanced, crash-optimized cockpit, and pilots now carry more electronic equipment with them. Supporting higher loads with smaller wings requires structural improvements. Engineers decided to use an all–carbon-fiber composite material instead of the carbon and glass fiber mix used previously. Carbon fibers are stronger than glass ones and can support higher loads. AS Sailplane engineers realized that they needed finite element analysis and composite simulations available to prove that this new composite construction would be strong enough for the task at hand.

Because of the needle-like proportions of the fibers, the strength of the resulting composite has directional properties based on the fiber orientation and layered plies of the composite. This adds complexity to the design process. AS Sailplane engineers decided to solve this problem using ANSYS Composite PrepPost simulation with its “model as you build it” approach. Composite PrepPost was used to model the individual composite plies and get a close-up, detailed view of the resulting layup. The engineers explored five different composite models in the entire assembly, with the total number of plies ranging from 100 to 300. They then analyzed the structural integrity using composite failure criteria and any problems with the structure. With the combination of very high loads, a small wing and little space for support structure, it was necessary to calculate the stresses and strains in the materials accurately for each ply using Composite PrepPost. Most other analytical tools cannot calculate the stresses precisely and do not reveal the critical stress peaks caused by composite failure modes that could possibly destroy the wing. Engineers then

"ANSYS Composite PrepPost enabled them to look at a full 3D stress state along the wing to detect any potential problem areas."



iteratively modified their simulation models by adding more plies or changing already existing ply properties such as ply extent, fiber orientation or materials at high load points to eliminate any weak points in the design.

They also used ANSYS Composite PrepPost to design the spar that runs the length of the wing on the interior and withstands the bending forces to which the wing is subjected. The spar is made of the same composite material as the wings and fuselage. To create a robust structure, engineers experimented virtually using the ply-wise modeling capabilities of Composite PrepPost, benefiting from the easy-to-use solid modeling features to evaluate this difficult structural part. With Composite PrepPost, they could study the 3D stress state along the wing and detect any potential problem areas. Finally, engineers performed modal analyses to prevent vibrations that lead to wing fluttering in flight — a dangerous situation.

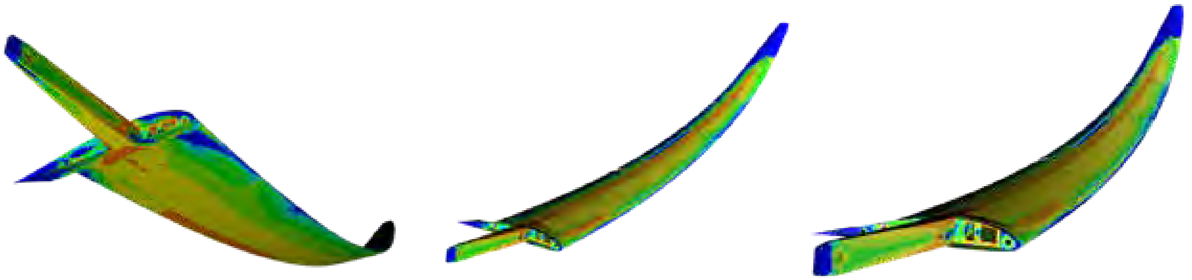
In the largest model used to simulate the vibration modes of the entire glider, engineers produced a mesh consisting of 1.5 million cells, which were mostly quadratic elements. The automated meshing process took about 15 minutes. Using two computer cores, the simulations lasted 20 minutes for a linear solution and 10 hours for a nonlinear solution. They typically performed 10 to 50 simulation runs to optimize the design, detect problems and calculate multiple load cases.

VALIDATION

Ultimately, AS engineers tested the wing structure for the European Aviation Safety agency to gain approval for its use. ANSYS simulations played a major role in demonstrating the structural integrity of the new design that led to the agency's approval.

It would not have been possible for AS engineers to reduce the sailplane's wing surface area by 4.7% (to 10 m^2) and pass this test without ANSYS simulation solutions. The ability to perform numerical calculations to see the high stress areas of the model made this innovation in sailplane design possible.

Some information for this article was supplied by CADFEM Journal.



Safety factors for the composite wing were analyzed with ANSYS Composite PrepPost. The center of the wing's chord has the lowest safety factors (orange color) because of the compression-loaded spar flange in this area.