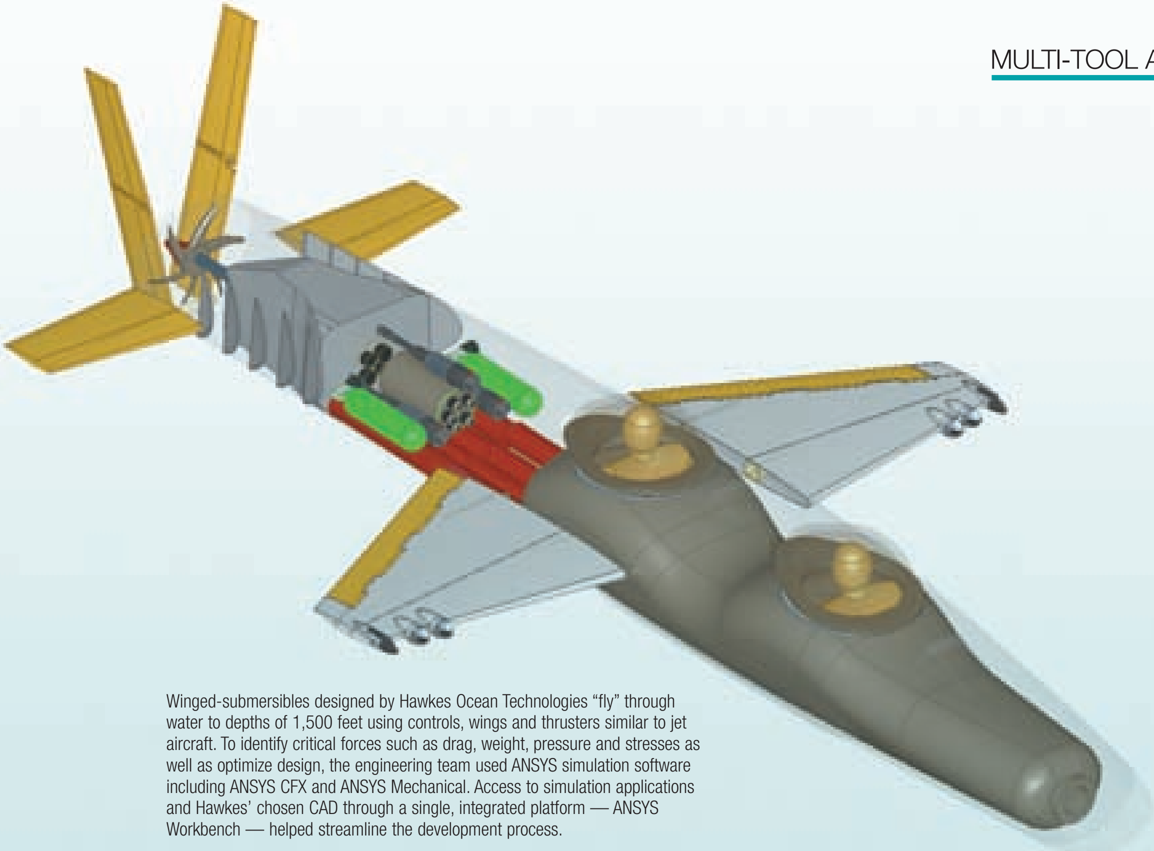

Winged-submersibles designed by Hawkes Ocean Technologies "fly" through water to depths of 1,500 feet using controls, wings and thrusters similar to jet aircraft. To identify critical forces such as drag, weight, pressure and stresses as well as optimize design, the engineering team used ANSYS simulation software including ANSYS CFX and ANSYS Mechanical. Access to simulation applications and Hawkes' chosen CAD through a single, integrated platform — ANSYS Workbench — helped streamline the development process.

Taking **Next-Generation Submersibles** to New Depths

ANSYS simulation tools help minimize drag and reduce weight by half in two-man oceanographic craft.

By Adam Wright
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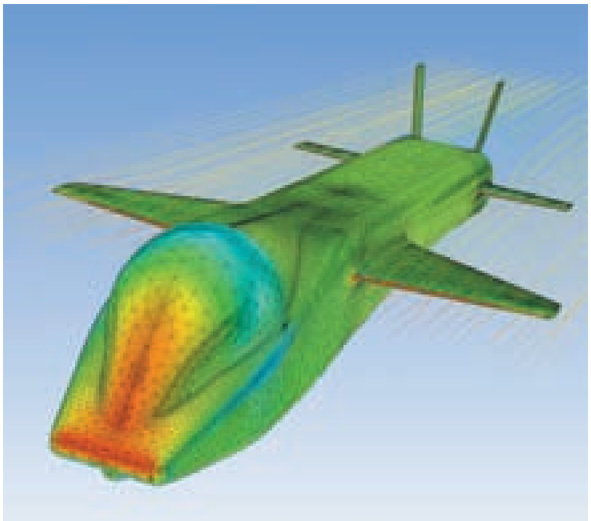
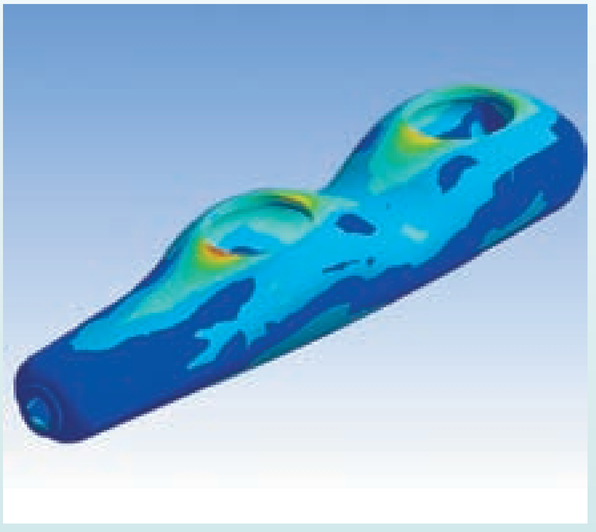
The world beneath the ocean surface is teeming with most of earth's animal and plant species. While three-quarters of our planet lies under water, less than 5 percent has been explored, mainly because of shortcomings in today's research equipment. Scuba limits divers to the topmost slice of the oceans. Conventional submersibles, on the other hand, are designed to drop like bricks into the ocean depths using variable buoyancy to control dive depth with bulky air tanks, compressors, pumps and piping. As a result, they have limited maneuverability and need a dedicated mother ship to transport and maintain them. Furthermore, the loud operational noise and bright lights associated with these crafts scare away many sea organisms.

Hawkes Ocean Technologies has come up with a solution to move beyond these constraints: a new class of small, highly maneuverable craft that can be piloted through the water to a desired depth using controls, wings and thrusters for undersea flight similar to that of a jet aircraft.



ANSYS CFX computational fluid dynamics software helped develop the overall streamlined shape of the external fairing to minimize underwater drag.



ANSYS Mechanical software was used extensively for stress analysis in ensuring that the pressurized pilot compartment hull could safely withstand 700 psi at quarter-mile depths without overdesigning components with excess material.

The Wet Flight is a high performance one-person sub designed for underwater filming.

In this way, the company's winged-submersible concept combines the vision and low-intrusiveness of scuba diving with the depth capability of a conventional submersible.

An internationally renowned ocean engineer and explorer, company founder Graham Hawkes holds the world record for deepest solo dive of 3,000 feet and has been responsible for the design of hundreds of remotely operated underwater vehicles and manned underwater craft built for research and industry worldwide. The Deep Rover submersible, for example, is featured in James Cameron's 3-D IMAX film "Aliens of the Deep," and the Mantis craft appeared in the James Bond film "For Your Eyes Only."

Based near San Francisco Bay, California, U.S.A., Hawkes Ocean Technologies is an award-winning design and engineering firm with a small staff of dedicated professionals who use ANSYS software to help them develop their innovative craft. Hawkes' winged submersibles, which are based on the concept of underwater flight, are rated for a depth of 3,000 feet; the next-generation submersibles already have been tested down to 20,000 feet. The model currently being designed and built is a next-generation two-man craft with lightweight carbon-reinforced composite material replacing the aluminium parts of the previous model. A pressurized pilot compartment hull and electronic equipment housings are made of a filament-wound composite, while the streamlined exterior skin of the craft is made of layered fabric composite. Transparent acrylic domes provide 360-degree visibility and minimize distortion due to water boundary refraction.

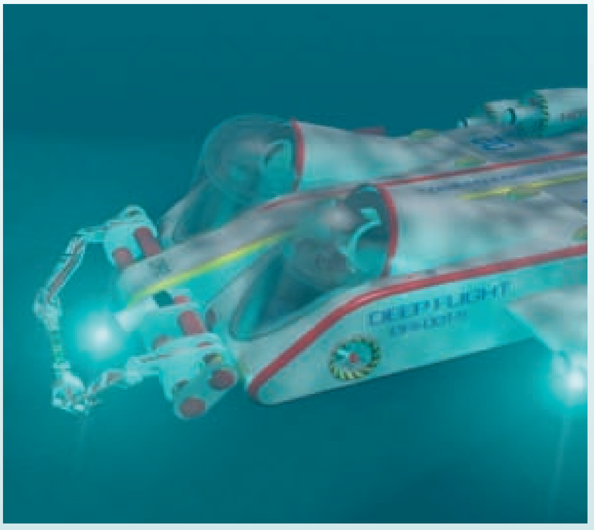
Challenges of Withstanding Pressure

One of the most difficult aspects of designing the new craft involved the determination of stresses in the complex geometries of the composite parts that must withstand pressures of nearly 700 psi. In particular, the compartment hull protecting pilots from this crushing pressure is a cocoon-like contoured structure designed to maximize space in order to maintain comfort: a significant design factor because an occupant tends to become cramped and possibly claustrophobic after an hour or two beneath the great mass of water above. Another complicating factor in determining component stress distribution was the anisotropic nature of the composite material properties, which have different strengths in each direction depending on the orientation of the carbon fiber.

In addition to ensuring adequate strength of the craft, designers had to optimize tradeoffs between power and weight. One problem to be addressed was that of minimizing the underwater drag of the external fairing to achieve maximum speed with minimal power consumption. The right balance allows the craft to sustain the speed needed by the airfoils to overcome positive buoyancy while extending the range. Since the winged craft must keep moving at about two knots to remain submerged, this was a critical consideration.

The Solution

To address these design issues, Hawkes engineers turned to simulation tools within the ANSYS Workbench environment. To minimize drag, ANSYS CFX computational fluid dynamics software was used to develop the overall streamlined shape of the external fairing. The analysis defined the flow around the fairing and enabled researchers to readily pinpoint any areas of excessive turbulence. The results helped them configure the shape for minimum hydrodynamic resistance and maximum lift and effectiveness of the airfoil surfaces for allowing the craft to dive and maneuver underwater.



The Deep Flight II can house one or two persons in a prone position and can travel for up to eight hours.

The Wet Flight submersible rises to the surface.

When diving to 1,500 feet and deeper depths, there is no room for error, so Hawkes used ANSYS Mechanical software for stress analysis to ensure that composite parts could withstand underwater pressure without being overdesigned with excess material. The program readily accounted for the anisotropic material properties of the composite parts and clearly showed directional stresses graphically as well as numerically with precise von Misses values. The capability helped engineers determine the proper carbon fiber orientation and wall thickness needed to strengthen high-stress areas of composite parts, particularly the pressurized pilot hull.

The stress levels of assemblies of individual parts made of different materials also were analyzed. For example, one assembly included the metal locking ring that clamps the fittings and seal of the acrylic dome to the composite hull, along with the dome and hull. In generating these assembly models, the ANSYS surface-to-surface contact element feature automatically detected the contact points, allowed for different material properties and adjusted mesh densities instead of requiring users to perform these tasks manually. Moreover, convenient element-sizing functions enabled engineers to readily increase mesh density in localized regions in which they wanted to study stresses in greater detail.

Easy access to computer-aided design (CAD) software and simulation applications through the integrated ANSYS Workbench platform allowed Hawkes engineers to become productive on the first day. Simulation models were created based on part geometry from the Autodesk® Inventor™ design system. Direct associativity with the CAD system enabled engineers to readily change the design based on an analysis and quickly perform another simulation on the new part geometry without having to re-apply loads, supports and boundary conditions. For some cases, more than 40 design iterations were tested. The approach saved considerable time and effort, allowed numerous alternative configurations to be studied, guided engineers toward the uniquely contoured compartment hull shape, and, perhaps most importantly, minimized mistakes. In this way, the researchers were able to quickly arrive at a not-intuitively-obvious optimal design for a craft that could withstand prescribed pressure limits with minimal weight and fit within the tight space constraints of the two-man submersible.

Significant Weight Reduction

By using ANSYS software in the design of components to be made with composites instead of aluminium, engineers were able to reduce the overall weight of the craft by 50 percent. This significant weight reduction is expected to increase maximum underwater speed and save battery life to increase the time the craft can spend underwater. Because the lightweight submersible does not need a dedicated mother ship, operational costs are reduced by 70 percent and the craft can operate freely worldwide off of a variety of launch platforms. This greatly expands the underwater exploration possibilities of the craft. Furthermore, these next-generation submersibles hold the potential of unlocking new biotechnology from the ocean depths that may help cure disease, discovering new aquatic species, finding new mineral and food reserves, studying weather, and providing a means to monitor and prevent further pollution at sea. ■