Smooth Sailing with AGPS™

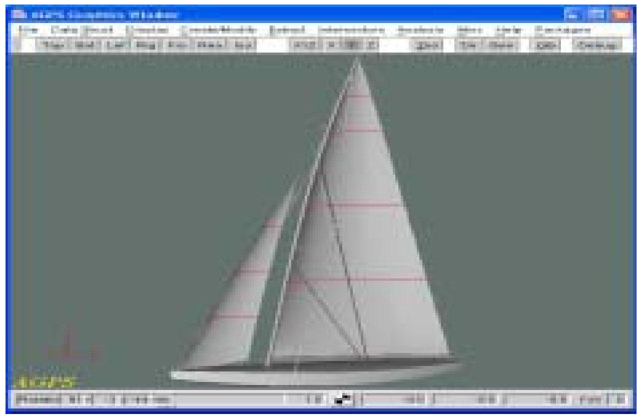
ode to renowned Aerodynamicist Arvel Gentry

Star racer courtesy of North Sails One Desi

History of AGPS with Sailing Applications – America's Cup

Boeing's involvement with sailing and the America's Cup actually began back in 1981. America's Cup skipper, Dennis Conner, asked Boeing if Arvel Gentry, an engineer in the aerodynamics department, could be made available to help support his designers to defend the '83 America's Cup. Not wishing to divert Gentry from his Boeing work, the chief of aerodynamics, Mark Kirchner, formed the Flight Research Institute (FRI). The FRI allowed both Boeing and outside engineers to work on approved outside tasks on their time, and included the use of Boeing computers and proprietary advanced computer programs. Over subsequent years the FRI became associated with the Seattle Museum of Flight where studies expanded to a number of engineering-technology projects ranging from man-powered flight, Olympic bobsleds, rowing shells, and riblets on America's Cup boats.

During the 1981-83 time period Gentry and an associate, Robert Eilers, developed a suite of small AGPS programs to generate geometry and surface paneling for boats. In subsequent years these paneling tasks were archived as AGPS packages for other America's Cup design efforts. AGPS was used by Boeing engineers for each America's Cup from 1987 through the last Cup defense in San Diego in 1995 (see IACC Appendage Studies, E.N. Tinoco, et al, The Eleventh Chesapeake Sailing Yacht Symposium, 1993).



Complete Star configuration lofted in AGPS. Courtesy of Arvel Gentry.

Design of the New Star Mast

With the advent of the commercialization of AGPS, the latest sailing related use of AGPS has been in the design of a new mast for the North Sails, Star boat. The Star is a popular one-design class throughout the world and is used extensively in the Olympics. The Star was originally designed in 1911. The design of the boat and its rig has evolved over the years to keep it at the leading edge of sailing development. To date over 8000 Stars have been built.

Recently, the Spar Tech Company, Redmond, Washington, asked Arvel Gentry to design a new mast for the Star. Gentry, now retired from Boeing was helping beta test the new Java version of AGPS and jumped at the task.

The approach would be to represent the complete Star boat, rig and sails within AGPS. AGPS could then make a horizontal cut through the sails and mast to provide the desired two-dimensional definition of the jib/mast/mainsail for use in a CFD code. The CFD code would calculate the flow around the airfoil combinations, determine the boundary layer and the separated flow regions behind the mast, and give the final lift and drag characteristics of the shapes. Design iterations on the mast shape would then be performed using AGPS to improve the sailing efficiency of the boat system. Each design would always be compared with a matching analysis of the existing standard mast for the Star boat (the F-mast). Gentry had already used AGPS in preparing illustrations for an article on Sailmaking Technology for his Ranger 23 Newsletter.

Since he did not have a hull lines drawing for the R-23 he decided to take a shortcut in generating a computer representation of the R-23. He started with a similar hull-cabin design shown in John Letcher's MultiSurf program and wrote an AGPS procedure to scale and modify the design within AGPS so that it accurately represented his own Ranger 23, Kittiwake.

The mast and rigging were then accurately represented in AGPS. Sail shape data was obtained from a sail design program (SmSw6), read into the AGPS R-23 model and fit with AGPS surfaces. Since he did not yet have Star boat sail definition data this furnished a head start in developing and testing the AGPS and CFD interface tools necessary to design the new Star mast.

Dave Watt, a Seattle area Star sailor, took Gentry sailing on his boat to better understand Star sail shape and trim adjustments (jib and mainsail shape in varying wind conditions). A set of Star sail designs was provided by Sandy Goodall using his SmSw6 sail design program. AGPS was then used to modify the initial trial sail design shapes to better match the latest sail designs obtained from North Sails Star photographs.

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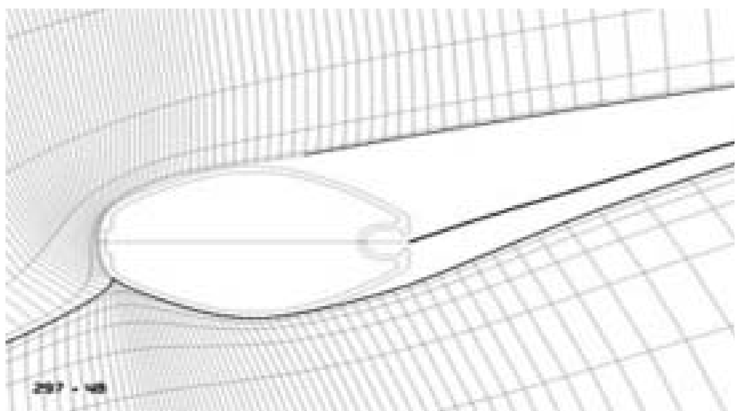
The mast cross-sectional shape was defined from a drawing of the standard Star F-section mast. The external shape of the F-mast was a simple shape consisting of parts of three circular curves with different radii. It was easy to rebuild this exact shape in AGPS and then to also generate the more complex internal shape of the mast section that included the mainsail luff track. The internal shape would be important later on in calculating the moments of inertia of the mast.

Access to a powerful Computational Fluid Dynamics Euler/Viscous code was arranged through David Lednicer, of Analytical Methods Inc, Bellevue, WA. Since the CFD code had its own field grid generation capability it was not necessary to use AGPS for this purpose. The CFD code did however have its own limitations. The starting field grid was generated from an initial panel method solution. Panel methods don't work very well on zero thickness airfoils so it was necessary to slightly thicken the jib and mainsail airfoils to avoid this problem. Also, the CFD code did not like sharp breaks in the shape where the mainsail meets the aft edge of the mast. Both of these problems were easy to solve using AGPS.

The output from the AGPS procedures was a file containing the airfoils ready for input to the CFD code. The CFD code calculated the details of the airflow about the airfoils including viscous and separated effects and produced final values for the pressure distributions about the airfoil combinations and the lift and drag. The CFD solutions were repeated for different sailing conditions (angle of attack and wind speed). The entire process was also repeated using different sail trim parameters (jib sheeting angle and mainsail flatness parameters).



Once the optimum external mast shape was finalized attention was turned to defining the internal shape necessary to provide the desired mast stiffness. A quick method was needed to calculate the section moment of inertias. There was no time to write a new AGPS moment of inertia program from scratch. The solution was to obtain a small unstructured grid generation program from NASA (the Trumpet program). It was easy to convert Trumpet to also calculate the moment of inertia of all the little grid rectangles. Again, AGPS came to the rescue. AGPS was used to output the internal and external shapes of the mast to the moment of inertia program and was very important in debugging the program.

The new G Low Drag mast section for the Star is currently available from the Spar Tech Company (www.spartechco.com). It is already winning races!

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