S e a W o l f

Hernando County Schools

11th International Human Powered Submarine Race – June, 2011

TECHNICAL REPORT

SEA WOLF
EXECUTIVE SUMMARY

Sea Wolf's sister submarine, Sublime, has, in one form or another, participated in the International Human Powered Submarine Races since 1991.

Sea Wolf was conceived by Springstead High School's 2007 Submarine team. Through much refurbishing and redesign, this year's Submarine team has cultivated a new design for Sea Wolf in the hopes that our engineering prowess will be sufficient to win.

INTRODUCTION

Sea Wolf ran for the first time in 2007 and like most new engineering ventures, had a significant number of "bugs" to be worked out. In 2009 we realized that the recombinant position for the pilot hindered vision to the point of making her unsteerable. The decision was made to totally rethink the design using only the bare hull from the original sub.

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DESIGN PHILOSOPHY

To take on a new challenge, we decided to reconfigure Seal Wolf from a propeller drive to a non propeller driven power train.

Sea Wolf's design is a single pilot wet sub. Fiberglass was the primary construction material, although steel and plastics were also used. Hull dimensions are 24 inches in height, 18 inches in width, and 10ft, 4 in. in length. These measurements may have varied slightly with the addition of new fins and control surfaces.

The first premise when Sea Wolf was originally designed for the 2007 race was to build a "teardrop" type of hull shape. The second premise was that the largest diameter of the drive mechanism should be located where the largest diameter of the hull is. We decided to continue with the first two premises. This configuration could lend itself to the pilot being in a prone position with the crank mechanism located in the middle of the submarine. With the pilot in the prone position, with the head in the front of the submarine, the problem of visibility should be improved.

Additionally, we wanted to take on a new challenge of a non-propeller entry. We first explored the idea of an actuating wing or a flexible fin, and set out to determine each one's efficiency. Again, we wanted to try something we hadn't seen in ISR before. Two hypotheses emerged that were unique – a squirrel cage from an air conditioner and a turbine from a hydroelectric dam. We questioned the judges about the acceptability of these in the non-propeller category, and both ideas were acceptable in this category. Testing, which will be described below, caused us to settle upon the turbine as the most efficient.

We repositioned the cranking system amidships. The pilot, in prone position, would now, unlike last year, have a clear view in front of him.

Because of the absence of a propeller, our submarine lacked the turning mechanism required to steer left and right. To compensate, we affixed a cylinder to the stern of the submarine to affect a vector thrust.

Design philosophy had to include as many off-the-shelf and self fabricated items as possible. This was dictated not only by our limited budget, but by the desire to make this a real learning experience for the students.

DESIGN AND FABRICATION

Hull Construction

The sub began as a male plug constructed from plywood. The horizontal and vertical surfaces are two different NACA wing sections. The horizontal surface has a much larger cord than the vertical one. The area where the two wing shapes meet was rounded on a 3 inch radius to flow between the two surfaces. Since the side is almost vertical, and the top is almost horizontal, it gives the submarine a rectangular profile from the bow.

After all the station bucks were carefully placed on a central beam, foam was added between each station to give a rough form to the male plug. Plaster was added over the foam and carefully crafted into a true shape.

The male plug was coated with three layers of varnish. It was sanded a final time and given multiple coats of form release agent. One layer of 8 oz. bi-directional e-glass was placed over the plug, followed by three layers of 1.5 oz.unidirectional. Polyester resin was liberally added. The result was a female mold of ½ of the sub. Since the sub is symmetrical, only one female mold was necessary. The female mold was given finish work and placed into action.

The female mold was treated with mold release agent and two layers of 14 oz. bi-directional e-glass were placed at 45 degrees to the chord axis. The bow was built up with 10 layers of cloth. Two layers of 1.5 oz unidirectional mat were placed at a 30 degree bias and additional layers of mat were placed at critical areas. Marine polyester resin was liberally applied to the e-glass. A second shell was made in a similar manner, except a joggle was molded in to aid in joining the two halves.

The halves were mated. Openings for a window and a hatch for entrance and egress were cut. The areas around the openings were strengthened with additional layers of mat. Much time and effort was put into making the sub smooth. In revamping the body for the new propulsion configuration the hatch was enlarged to allow for better entrance and egress for safety.

A male plug was made off the female mold for the window. A piece of ¼ in. plexiglass was heated and drawn over the mold. It was trimmed and installed on the sub body.

One of Sea Wolf's educational goals is for all of the students to participate in as many of the aspects of submarine construction and operation as possible. This necessitates that the submarine design be adaptable from 5 ft, 90 lb girls to 6ft boys.

Control Surfaces

With the installation of the new propulsion system, came the need for new dive planes and rudders. The installation of twin athwart ship turbines posed some problems. Since the jet had to escape out of the stern of the vessel, there would be no place for a rudder there. After much thought, we concluded that we would place dive planes in the bow and handle left/right steering with a directional thrust deflector.

The hydroplanes for our vessel were made from steel plates that were shaped in order to minimize drag and promote the unobstructed flow of water over and under them. Once shaped, a final coat of polyester resin was applied and sanded in order to strengthen and smooth the dive planes. Two holes were then drilled on both sides of the vessel in the bow. The holes, in port and starboard respectively, were lined up and reinforced with aluminum blocks. Once positioned, a U-shaped steel bar was welded on either side of the dive planes in order to control them.

This repositioning of the dive planes was to improve the steerability which we had problems with in the previous configuration. The planes were placed as far forward as possible in order to give the maximum lever action around the midship pivot fins. In order to avoid potential stalling, we added stops on either side of the U-shaped bar in order to stop it before the dive planes reached 15 degrees in either direction, with respect to the horizontal plane.

For left/right steering, we added a cylinder of polyester resin that was controlled by an aircraft cable to a jointed aluminum square. When force is exerted on the square, towards the hull of the vessel, the aircraft cable extends, thus pushing the cylinder and deflecting the thrust to port or starboard. When the square is pulled, the square tightens up and pulls the cable, thus pulling the cylinder. This allowed us to completely remove a stern rudder.

Hatch and Safety

The hatch lock is a simple slide bolt mechanism easily accessible to the pilot and easily released from the outside of the sub.

An outside lever was also incorporated into the mechanism so that outside help has immediate access to the pilot of the sub. An emergency float system is spring loaded and must be held at all times on the control lever.

Propulsion

Because our focus for Sea Wolf for this race was innovation in a propulsion system we began by researching various possibilities and narrowed it down to two which seemed to hold the most promise. We constructed a 4x4x8 test tank at the school to evaluate the comparative efficiency of our two concepts.

The first was a squirrel cage removed from an air conditioner. It quickly became obvious that the blades would not work in water. We removed the blades and constructed hydrofoils which we put in their place. We ran this at a steady speed using a slow speed electric drill and evaluated the output with a pito tube.

The second proposed system was a water turbine designed off the concept that drives a hydroelectric generator. On a wood lathe, we turned cones and then attached metal blades to them. The object of this design was to have the metal blades pull the water into the hull and the cone to redirect it to the center-line of the hull.

After repeated testing of each concept, we determined that the turbine produced the most thrust.

A bicycle crank was determined to be the most efficient method of transferring the pilot's leg motion to rotary motion to drive the turbines. Due to our hull design, and the crank mechanism requiring the area of the hull where the largest diameter is, the crank mechanism had to be located amidship in the submarine. With the chain coming back to a sprocket, one common drive shaft drives two athwart ship mounted turbines. We are using a 7 to 1 sprocket ratio to get higher speeds.

Because of the configuration of the drive train, the pilot will be in the prone position. This maximizes visibility while only slightly reducing RPM.

Our research supports the fact that, under human power, between 50 and 80 revolutions of the bicycle crank are possible under water, thus yielding 200 to 400 shaft rams. At 50-80 rams, a 7 to 1 chain ratio increases the turbine shaft rpm to almost 600 rams.

The turbine consists of 4 aluminum blades angled at about 19 degrees in relation to the base. This allowed for maximum water input. Fiberglass walls were added behind and above the turbine to reduce drag and allow for more water to enter the system. Aluminum walls also encase the turbines inside the hull of the submarine so that no water escapes other than through the jet. Foam was also added at the top of the hull, above the aluminum walls, to restrict the water from entering the front of the sub.

Visibility and Pilot Position

Because of the configuration of the drive train, with the pedal mechanism in the center, and the pilot in the prone position (i.e. head in the front) the pilot has better visibility than in previous races.

Since the crank mechanism is behind the pilot, he/she can sit right next to the lean window. A triangular shape was cut out of the hull in order for the pilot so see in front of him. Unlike last year, the pilot can observe his surroundings with ease.

Life Support and Safety

Life support is scuba. An air tank is strapped below the diver in the front of the sub, and the pilot is serviced by a regulator. Air exhaust is vented through holes in the top of the sub. An emergency air system is placed on the diver for immediate access.

Safety has been a primary design concern. Collisions are possible, so the bow is heavily reinforced. The hatch is placed in the side. The hatch floats free very easily. Any area of the sub in which the pilot might get caught up has been re-engineered with safety fixes. The turbine blades are painted red for visibility. The interior volume of the sub has enough room to perform, but is kept to an absolute minimum to reduce displacement. The sub has a strobe light that provides for easy location.

In the nose of the submarine, in front of the pilot's head is a 6" diameter emergency buoy. It is attached with a spring-loaded release designed to deploy should the pilot become unconscious.

Perhaps the most important safety device has been the constant attention to the question of how to make the sub safe – we came to the race, not to get anyone hurt, no matter how small the injury.

TESTING

Sea Wolf’s two primary testing locations are the Gulf of Mexico and the Weeki Wachee Spring.

Measurements of air consumption under stress have been made. The air supply system has twenty to twenty-five minutes capacity depending on the pilot on board.

TRAINING

Stationary bicycles, actual bicycling, and running are the primary training tools. Several of our students compete in high school athletics such as track and soccer. Each pilot is required to train according to his/her own needs.

All pilots not previously certified have completed the necessary courses and have been scuba certified. Chasing the submarine around the Gulf of Mexico and Weeki Wachee Springs has provided all involved with a lot of scuba and swimming time.

PROJECT SUMMARY

Sea Wolf debuted at the 9th International Human Powered Submarine Races.

Our goal is to inspire students to pursue careers in engineering. Sea Wolf is a “work in progress” and as such has been a great learning tool for the students. It has allowed them to experience frustration and failure and rise above it to analyze what went wrong and develop “fixes” in the hope of doing better in 2011.

As always, funding is minimal and Sea Wolf works on a tight budget. The good that comes out of this is that the students realize that all projects are constrained by their budgets and that they have to manage to make the most with what they have. Also by having the students physically fabricate almost all parts of the submarine, they get real hands-on experience.

The bottom line, as always, is for high school students to learn a lot, gain exposure to a broader world and the possibilities it holds, produce a viable contender and carry it through to success in the field, and, above all, have fun.