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THE USE OF SEMISUBMERGED SHIPS FOR OCEANIC RESEARCH

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Abstract

The Naval Undersea Center has developed a new range support surface craft utilizing a design that should offer considerable advantage for oceanic research as compared to a conventional monohull ship. The 190-ton, 25-knot craft is called the SSP (Stable Semisubmerged Platform). It was designed to permit operations under adverse wind and wave conditions in deep water.

Unusual features of the craft include greatly reduced motion in waves relative to a conventional monohull when at rest or underway, a large deck area and internal volume, and sustained speed capability even in large waves.

The 89-foot SSP consists of two submerged, parallel, torpedo-like hulls which support a cross structure above water by means of four streamlined, surface-piercing struts. A stabilizing fin spans the gap between the hull tailcones. Small fins attached near the hull noses and flaps in the stabilizing fin provide control over heave, pitch, and roll when underway. A 12½-by-23-foot well in the center of the cross structure permits devices to be raised and lowered from the platform.

The craft has thus far operated as predicted in preliminary trials. The concept scales readily to larger sizes. Possible 500-ton and 3000-ton versions for oceanic research are also discussed.

INTRODUCTION

The Naval Undersea Center (NUC) designed and developed the 190-ton SSP in response to the need by its Hawaii Laboratory for supporting various kinds of oceanic research projects. A deep-water craft was needed which would have relatively small motion in sea state 4, both at rest and underway.

The SSP design was selected on the basis of prior research at NUC on the S^3 (Semi-Submerged Ship) concept [1][1] shown schematically in Figure 1. This general type of design can be modified in many ways and made larger or smaller to suit a variety of needs. The Navy is interested in future applications of semisubmerged ships and has initiated investigations under the SWATH (Small Waterplane Area Twin Hulled) ship program.

Some features which make this concept attractive for oceanic research are its greatly reduced motion in waves, large deck area and internal volume, possible inclusion of a central well, ease of installing underwater sonar and viewing windows, and its adaptability for handling helicopters and various kinds of surface and subsurface vehicles or devices.

[1]Numbers in brackets indicate references.

The reduced motion in waves is due to a number of factors, primarily the small waterplane area which minimizes buoyancy changes as waves pass. The aft stabilizing fins provide dynamic stability at moderate-to-high speeds and act together with the smaller forward (canard) fins to provide sizable damping which significantly reduces ship motion in waves. The optional use of automatic control [2] will further reduce pitch, heave, and roll motions at moderate speeds and above, especially in large following waves where motion at high speed without automatic control can be significant.

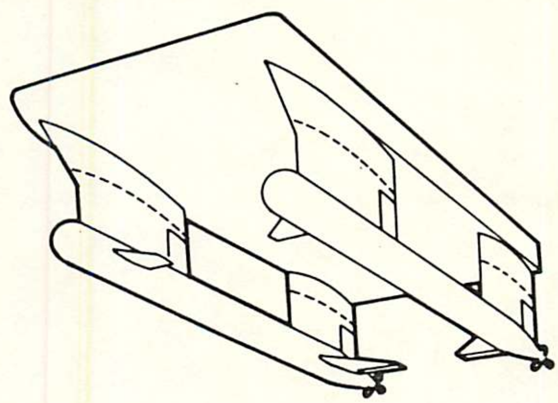

Figure 1

Maneuverability should be good at all speeds. The widely-spaced propellers provide excellent control when docking or station keeping. They also improve reliability since the craft will operate with only one propeller with negligible yaw and with only about a 7° rudder deflection in the case of the SSP. Maneuverability at the higher speeds is also good, owing to the spacing between fore and aft struts and the relatively large rudders. A further maneuverability feature is that the SSP-type of design will bank into the turns without roll control.

Cross-structure impact in waves can be minimized by trimming the control surfaces so that the craft "flies" at the optimum height in the particular sea condition. In the case of automatic control, the trim would be continuously changed to minimize impacts. Impacts in extremely large waves can be further reduced by following the wave contour. Since drag changes very little in waves, and impacts can be minimized, full speed can be sustained in most wave conditions.

Perhaps the greatest disadvantage of this concept is the greater structural weight resulting from its relatively diffuse design form. Studies have shown, however, that the structural fraction of an all-aluminum version would be about the same as a conventional monohull made of steel. Since the aluminum structure tends to be more costly, the various advantages of this new ship type must be traded off against the possibly higher cost. On the other hand, the cost would reduce in some cases, such as those where the equivalent monohull would have to be designed much larger in order to provide the required payload volume or sea state capability.

The following paragraphs describe the 190-ton SSP and the proposed 500-ton and 3000-ton versions.

190-TON SSP

Design of the SSP [3] began at NUC in March 1970, following 1-½ years of research. A large portion of the structural and mechanical design was conducted by the Pearl Harbor Naval Shipyard under the direction of NUC. Construction of the SSP began in June 1972 at the U.S. Coast Guard Yard located at Curtis Bay, MD. Launching took place on March 7, 1973, and was followed by installation of the engines and further outfitting. The SSP operated at full speed for the first time in November 1973.

The SSP dimensions are shown in Figure 2. The submerged hulls and struts are made of high tensile steel, and the struts are welded directly to the aluminum cross structure with a Detacouple aluminum/steel explosion-bonded strip. Propulsion is provided by two gas turbines that drive controllable and reversible pitch propellers. Heading control is provided by twin rudders at higher speeds and differential thrust at the lower speeds. Provisions for dynamic motion control is incorporated in the design and consists of forward port and starboard canards and aft port and starboard flaps in the stabilizing fin. All control surfaces are hydraulically powered.

Figure 3 shows the compartment layout of the SSP which provides for manned access down each of the four struts. The pilot house space and the compartments aft are watertight with the exception of the aftermost outboard compartments which house the propulsion machinery and two small starboard compartments near the bow. The forward compartments in the submerged hulls are designed for interchangeable nose sections: a transparent acrylic dome for underwater observation, special sonar domes, and steel domes for normal use.

In addition to the forward section, each submerged hull is divided into six 2000-gallon ballast tanks and an aft tailcone. The forward three tanks contain fuel cells which separate the turbine fuel from the ballast water. The three aft tanks are designed to contain ballast water only, and the tailcone section contains the propeller shaft and thrust bearing.

At the continuous rating of 4200 hp, the maximum speed is about 25 knots. The payload and fuel capacity of the SSP is 25 tons. This will soon be increased to 50 tons by the addition of streamlined blisters to the inner side of each hull. With the full fuel complement of 18.8 tons, the range of the SSP is about 400 nautical miles at 25 knots.

The SSP structural design is based on a safety factor of 2.0 minimum. This, when coupled with the generally-conservative load assumptions and the analytical assumptions, has resulted in a heavy structure. Tests at sea are expected to show that a

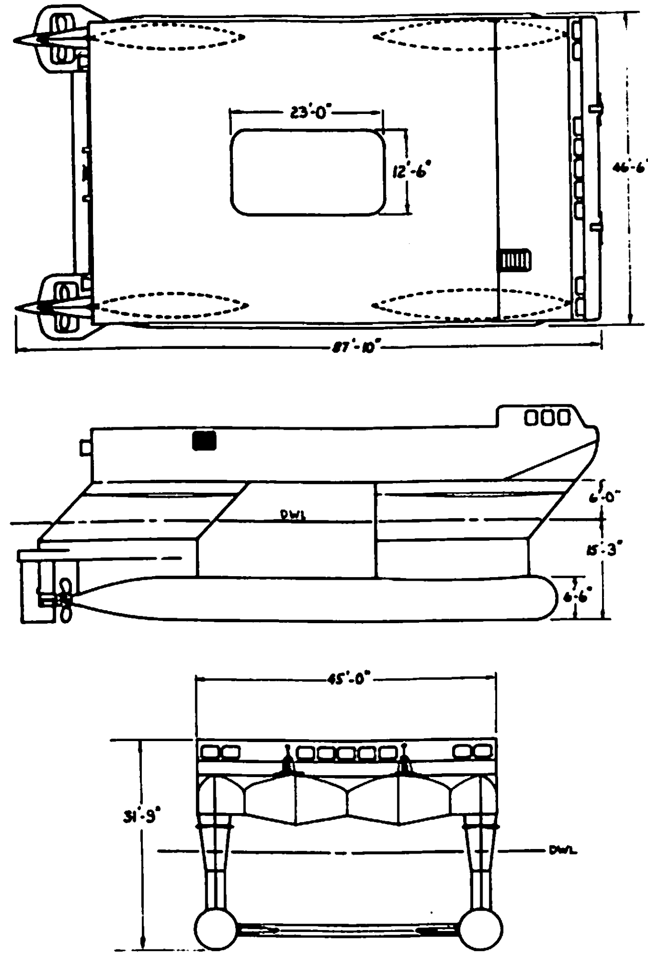

Figure 2

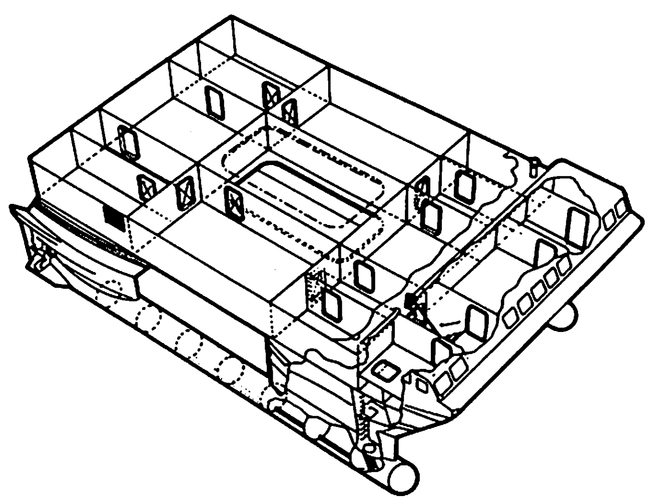

Figure 3

significant reduction in structural weight fraction is possible in future versions.

The SSP is equipped with a pair of 4-blade, 78-inch diameter Wilkinson CRPs (controllable, reversible pitch propellers). The Wilkinson CRP differs from other CRPs in that pitch change is accomplished by mechanical rather than hydraulic means. This leads to a simpler overall design, which provides lower initial cost and greater potential reliability.

The SSP would satisfy the requirements of various oceanographic operations in coastal regions. Operations including seismic, biological research, bottom profiling, or bottom exploration would be typical.

OCEANOGRAPHIC RESEARCH VESSEL REQUIREMENTS

The most basic requirement for an oceanographic ship is the provision of a stable platform from which data can be taken. Other basic requirements include a deck area sufficient to locate equipment and conduct work effectively, laboratory facilities suitable in size and equipped to efficiently conduct scientific investigations, extended cruising range, and comfortable living accommodations for the crew and research personnel. In addition, user surveys indicate an increased interest in space for modular laboratory vans.[2]

The general requirements for oceanographic ships suggest semisubmerged ship displacements of 500 and 3000 tons, in addition to the 190-ton version. A candidate 500-ton design [4,5] and a 3000-ton design [6] were originally proposed as Navy ships to carry out a variety of naval roles. With certain modifications, such as a reduction in required speed to obtain more payload, these two vessels can provide many new capabilities for supporting oceanic research.

500-Ton Design

A 500-ton displacement represents a minimum design size that is compatible with an adequate combination of payload weight and endurance, yet is not weather limited for open-ocean applications.

The 500-ton semisubmerged oceanographic research vessel illustrated in Figure 4 has a length overall of 146 feet, a beam of 66 feet, and a full-load draft of 16.5 feet. The carrying capacity of this design is 150 long tons with a wide range of payload/fuel tradeoffs available (88% capability in fuel). For example, with a payload of 50 long tons, the operating radius would be 600 miles at 21.5 knots with a 20-day on-station (loiter) endurance.

The oceanic research facilities are contained in standard transportable intermodal containers and provide a total internal laboratory/storage deck area of 960 square feet. These units, 7 in number, are installed within the cross-structure and become structurally integrated through their corner fittings. A centrally located interfacing bay allows quick utilities hook-up for the modules. Total module removal and replacement can be accomplished within a 24 hour period. This feature allows rapid turn-around capability for an extremely wide range of

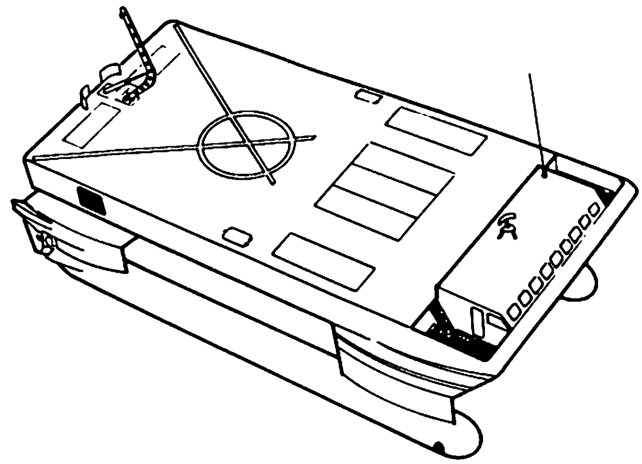

Figure 4

oceanic research applications. Accommodations are provided for 7 crew members and up to 28 research personnel.

One of the more attractive features of this design is the capability to maintain a 21.5 knot cruising speed through sea state 5. An essentially near-level ride in these conditions allows rapid transit capability for a much higher percentage of the operating year, thereby improving overall cost effectiveness. This low-acceleration, low-motion environment will also be highly attractive to on-board personnel.

Candidate missions for this craft include coastal hydrography, dredging and coring, trawling, biology, gravimetric observations, acoustic and seismic research. When outfitted with a helicopter, aerial survey work would be practical.

3000-Ton Design

An important oceanic research application of this size of semisubmerged ship is the Hydrographic Survey and Charting (HYSURCH) system proposed by the U.S. Naval Oceanographic Office in 1968 [7]. Typical ship dimensions would be a length overall of 275 feet, a breadth at the waterline of 119 feet, and a draft of 31 feet. It would have a total payload and fuel capacity of approximately 1000 tons. Its operational profile, subject to fuel/payload trade-offs, would indicate a mission radius of 1600 miles, with an on-station endurance of 15 days unrefueled. The craft would transit at 20 knots in seas through Sea State 5 and into Sea State 6 and operate on-station with an auxiliary propulsion system at speeds to 10 knots.

A clear topside deck area of 19,000 ft^2 would be used to stow the survey craft (such as hydrofoils & ACV's) and the data buoys. Space would be available to operate 2 helicopters simultaneously from adjacent landing pads. Hangaring and organizational maintenance facilities for 4 aerial survey helicopters, comparable in size to the Sikorsky SH-3, could be provided.

Interior payload volume, located in a central, two-deck bay would provide approximately 18,000 square feet of laboratory,

[2] Data on oceanographic research ship general requirements was provided by Capt. Robertson P. Dinsmore, Woods Hole Oceanographic Institution.

workshop, and storage area. This interior payload space would be highly adaptable to a removable and replaceable mission module arrangement scheme. Comfortable hotel facilities would accommodate the 275 mission and ship operating personnel.

A semisubmerged ship configured for this HYSURCH mission is depicted in Figure 5.

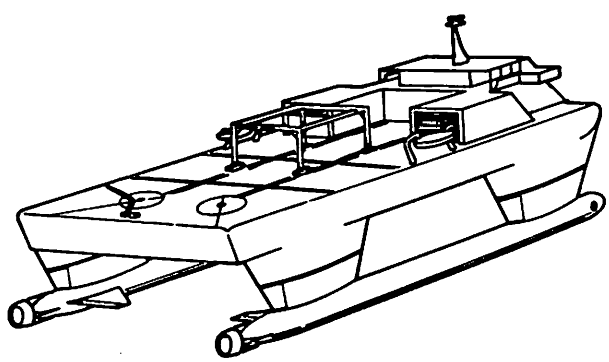

Figure 5

CONCLUSIONS

This new concept appears to be well suited for oceanographic ships. The many advantages, however, must be traded off against the expected higher cost of aluminum construction. The concept features relative to monohulls include: operations in higher sea states; improved ability to handle helicopters and small surface and subsurface devices; improved potential for sonar operations and underwater viewing; greater sustained speed in high sea states; more flexibility in top speed selection; greater topside load-carrying capability; larger deck area and internal volume, and the possibility of utilizing a smaller craft for the same task, in which case the cost could be lower relative to a monohull.

190, 500 and 3000-ton sizes appear to offer the choices needed for satisfying a wide variety of oceanographic needs. Designing the ships to be selectively outfitted would permit mission flexibility and hopefully lower costs since more vessels of the same design would be constructed.

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