UDT 2019 – Platform Design for leading edge AIP submarines

Abstract — The object of this paper is to describe the silent propulsion mode for the new S-80 Submarine programme awarded by the Spanish Ministry of Defence to Navantia. The S-80 Submarines will have performance, in ocean-going force projection in "blue water" warfare scenarios, only available in current nuclear-powered attack submarine (SSN), including a three-week anaerobic range and the ability to fire submerged land-attack cruise missiles. This new concept in a conventional Submarine brings an excellent capability in covert operations and first strike. In particular it excels in stealth and littoral water performance, including bottoming & discrete transit and insertion in negated waters.

1 Introduction

Underwater warfare domain is key for any countries defence strategy, given the specialized operations developed by submarines from their low detectability and their many means of action. They enable missions, which are unattainable by surface or aerial means. The place to remain stealth (collect Intel or strike disruptively) is under a depth of water. Consequently, the Spanish Navy has put forward its recapitalisation programme to replace its veteran Agosta class submarine fleet for a new generation of leading edge design non-nuclear AIP submarines, the S-80 class. The construction of four S-80 class submarines is well underway, with the first unit to be put afloat in 2020, and delivered in 2022.

The S-80 will be a state-of-the-art 3000+ tonne non-nuclear submarine, featuring the most capable and innovative AIP system to date. The Spanish Navy will operate four units, whilst derivate designs are being offered in international tenders for the benefit of other Navies.

2 S-80, a highly technical submersible

Navantia has in the new S-80 Class submarine the most avant-garde product in its catalogue. It is a new generation submarine representing a qualitative step forward with respect to conventional non-nuclear submarines.

Some of the S-80 submarines exceptional capabilities are: extremely low acoustic signature, excellent manoeuvrability at low speed, high degree of automation and high range Air Independent Propulsion (AIP). The S-80 can carry out support operations integrated in the Force, for which it will have a system of communication and exchange of information in real time that is 100% reliable and safe. It is particularly suited to other types of missions such as: surveillance, deterrence and confrontation threats including; minefields, ships of surface and other submarines, both conventional and nuclear.

2.1 S-80 design drivers

The main missions of the S-80 submarine are ocean going and littoral operations:

- Anti-Surface Warfare (ASuW).
- Anti-Submarine Warfare (ASW).
- Support to Special Operations Forces (SOF).
- Selective Land Attack.
- Designed for Full Combat Group Integration in First Strike Action.
- Shallow Water Operations.
- Intelligence, Surveillance and Reconnaissance (ISR).
- Sequential Mine-laying.
- Deterrence.

An analysis of the related mission scenario shows the need for a sustained covert presence in littoral waters, where it is critical to avoid, as much as possible, the acoustic and non-acoustic signatures when submerged. The S-80 submarine AIP capability avoids the risk of detection as on snorkel operation for its radar, IR or wake traces. To achieve this operative performance the period of submerged operation has been significantly increased by the selected AIP concept. This has the outstanding advantage compared to other AIP systems that the signatures (magnetic, noise, heat dissipation…) are not affected by the fuel cell operation – mainly thanks to the lack of moving parts, the high efficiency of the exhaustion system and the use of bio-fuel which avoids any kind of chemical trace in the stratified wake when submerged.

Despite continuous advancements in the industry of fuel cell systems, the high-level requirements of the Spanish Navy has required Navantia to develop a new generation of compact reformer for the selected fuel-cell concept which has no equivalent on the submarine market. In this article the system is explained and an outlook on its tactical advantages, design and main features are presented.

3 The AIP tactical advantage.

As previously noted, conventional diesel-electric SSK shall perform periodic snorkel operations to recharge submarine battery by means of power generators driven by diesel engines (aerobic). During this operation, the submarine is more vulnerable to detection and potential attack due to visual, infrared and radar signatures. In addition, during this condition submarine's acoustic signature increases significantly because of diesel engines operation and flue gas exhaustion.

According to the snorkel time versus total diving time ratio (Indiscretion Ratio), battery recharge operations may take up to a 25% of the sailing. These periods represent a

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relevant weakness for the natural stealthy service of a submarine. The AIP alternative have been devised on the last decades to generate power while the submarine is diving, providing the energy required for recharging the battery when submerged to support propulsion and platform hotel load. Therefore, the AIP plant, typically embarked reinforcing other conventional issue (diesel electric generation devoted to long transits) provides a reduction of the Indiscretion Ratio during patrol operation, or when required, with reasonable acoustic detectability.

An SSK equipped with an AIP, capable to choose time and location to perform the 'indiscrete' snorkel scheduled operation cycles, provides a significant tactical advantage against anti-submarine warfare or, most relevant for 'peace times', absence of 'presence'.

4 S-80 AIP: Design to Performance

4.1 The S-80 Class AIP Power Plant

The S-80 Class AIP Power Plant is based on low pressure fuel reforming and Proton Exchange Membrane (PEM) fuel cell technologies.

Bio-Ethanol, pure Oxygen and process water are supplied to the Fuel Processor System (FPS) to generate a Hydrogen enriched stream (Bio-Ethanol reformate). The FCPM is fed with Bio-Ethanol reformate and pure Oxygen to generate unregulated electric power and pure water, as a reaction product.

Product water and process unconsumed reactants are supplied back to the FPS (open anode/cathode configuration), closing the process cycle. A DC/DC converter converts the unregulated power generated to the submarine battery network conditions while process waste gases are managed and diluted in the sea water by the CO_2 Disposal System. Extreme low 'visibility' of bubbles created by gaseous exhaustion has been addressed to acquire probably the best with respect to any similar approach. The submarine trim tanks compensate submarine weight loss due to reactant consumption and waste products rejection off-board.

Platform services provide support to the AIP operation by supplying electrical power, consumables and rejecting the minimal process waste heat to a cold sink to be as infrared stealthy as on battery sailing.

4.2 A bet for Bio-Ethanol

For a real oceanic submarine, claimed to be collaborating in international task-forces all around the world in long-stage operatives, consumables availability to deploy the mission anytime is demanding. The S-80 Class AIP consumables have been down selected with this key requirement, avoiding exotic or highly processed consumables. Bio-Ethanol availability is immediate at any country with a strongly developed agro-industry (as common alternative to the fossil fuel) while medical grade Liquid Oxygen is a common supply for Hospitals. So, long periods in unprepared harbours, such as civil ports used as naval base, are focused on the initial AIP concept design.

The bet for Bio-Ethanol has also into consideration new threats (i.e. null chemical traces) and the process sustainability through the system life span (CO_2 footprint). This selection provides, as well, a simplified safety scheme to design, maintain and operate the power plant, since the bioethanol handling and stowage are simple, well known by industry and compatible with human operation, even in a military platform when surviving to a combat incident.

4.3 Focus on the end user

The S-80 Class AIP has been designed for the same crew as for a non AIP SSK, requiring minimum human intervention due its full automation and the upgraded version of Navantia's Integated Platform Management System (IPMS) installed on board. Installed power is sized to support extended diving with same level of comfort as a standard SSK mission.

In regards to the Life Cycle Support (LCS), the S-80 Class AIP is designed to be compatible with an SSK standard Integrated Logistic Support (ILS). No major component substitution is required between overhauls (6 years/>5000 h), while no complex maintenance operation is required on-board as equipment is configured in kits embarkable through the logistic hatch. No programmed maintenance is required during mission.

4.4 Invigorating state-of-the-art performance

The S-80 Class AIP provides the following main features to support submarine operation at defined attitudes:

- Full depth range (periscope to Maximum Operating Depth).
- Long submerged endurance (up to three weeks supporting different navigation profiles).
- Minimum contribution to submarine signature.
- Installed power (300 kW) sized for systems support and battery charge.

Author/Speaker Biographies

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