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Future Submarine Technology

Today and in the future, the submarine is more and more tasked to perform a wide range of missions, ranging from counter-terrorism at sea, ASW, ASuW to supporting operations ashore. These missions will most likely be in the very difficult maritime environment of the littorals, but combined with extended transits to the scenes of today's expeditionary warfare. By integration of state of the art technology the submarine will meet these new operational demands. On the basis of the synergy of the submarine design experience of Germany and Sweden including the design of the "Collins" class TKMS today is the solution provider for non nuclear submarines. This paper handles the main aspects and recent developments in submarine platform technology


The AIP Systems of TKMS, the Stirling Engine.
Grafics/Pictures: Authors

Propulsion

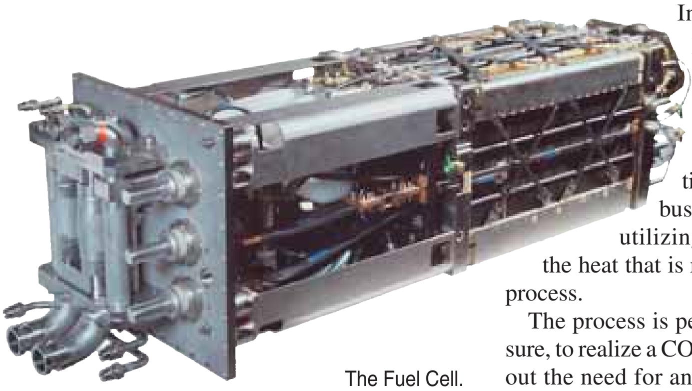
Air -IndependentPropulsion – AIP

Non-nuelear submarines are highly manoeuvrable and well suited for littoral operations. With a modern air independent propulsion the submarine can remain underwater and on station throughout the time span of a major military operation AIP is the key to "deniability": The submarine can do missions like intelligence, surveillance and reconnaissance or deployment of Special Forces with an extreme low risk of interception. TKMS can today offer the only mature AIP systems: The Stirling Engine, the AIP system which is operational for the over twenty years and the PEM Fuel Cell system (FC), the most sophisticated AIP system which is today most widely used.

There are still continuous developments on both systems. For instance in order to increase the system efficiency of the Stirling engine even more, the engine as such is fine-tuned at the same time as the efficiency of other components, e.g. the electrical generator is increased. Excess heat will be used for different purposes onboard the submarine, e.g. for regenerating a potential solid-amin system used for air purification.

Both systems have been presented on former occasions and shall not be handled in this paper in detail, but is there any mayor continuous development in the area of AIP? Driven by the demand for prolonged mission times and higher AI P speed there is a demand of so me navies for a higher amount of AIP energy stored on board. Both systems mentioned are limited in this respect, the Stirling engine mainly due to the required amount of oxygen, the FC mainly by weight constraints of the hydrogen storage in metal hydride cylinders.

To overcome the limitations of the FC system, TKMS is developing a methanol reformer. The methanol reformer produces the hydrogen required for the fuel cell plant onboard, replacing the metal hydride storage cylinders. The amount of AIP-energy stored onboard can be easily enlarged, without further increasing the submarines size. Further advantages are the simplification of the reactant logistics because Methanol is easily available worldwide at low prices The system being under development is based on steam reforming of Methanol, to produce a hydrogen-rich gas mixture inside the reformer. In a further step the major part of the hydrogen is separated from the reformate by using a membrane purification unit. The off-gas of the membrane purification still contains some combustibles, which are oxidised utilizing pure oxygen to provide the heat that is required for the reforming process.


The Fuel Cell.

The process is performed at elevated pressure, to realize a CO2-dissolution system without the need for an additional compressor at most diving depths The hydrogen produced by the reformer has a very high quality, suitable to be used directly in the existing and proven Siemens Fuel Cell Modules. A functional demonstrator of a Methanol Reformer has been built up at HDW several years ago. At the moment HDW develops all components to be suitable for use onboard a submarine, which is very challenging having in mind the integration of a process engineering plant into the closed atmosphere of a submarine. The Methanol Reformer itself will be operated in an encapsulation comprising several safety features, to prevent the crew from any harmful gases and liquids. With the development of the Methanol Reformer HDW combines the advantages of fuel cell AIP systems with the advantages of a liquid fuel as energy carrier, offering the cus-


Functional Demonstrator of 240kW Methanol Reformer.

New Lithium Battery for Submarines.

tomer a very promising alternative in the field of AIP-Systems at TKMS.

High Energy Batteries

A further milestone in submarine design is about to enter the market in form of Lithium based high energy batteries. In combination with High Energy Batteries based on Lithium Polymer technology the future submarine will have increased capabilities not only in long term slow speed endurance but also in flank speed and transit. Since Lithium Polymer Batteries have entered our daily life inside consumer electronics like mobile phones, handhelds or laptops the safety problems of the first days have become obsolete. Today modern types of construction in combination with polymer electrolyte and battery management systems have solved these problems. A necessary step is the up-scaling by one or two orders of magnitude. The challenges in production technology have been overcome in a joint development with the German company GAIA.

With these new battery modules it is possible to increase the battery capacity in the same volume by a factor of approximately two for long time discharge and a factor of four for a maximum speed discharge compared to traditional lead-acid technology. Furthermore the batteries are by far lighter than lead acid cells and are therefore ideal for combination with the metal-hydride hydrogen storage cylinders of Fe AIP, giving the designer the freedom to increase the amount of energy in AIP without significantly changing the submarine design.

Besides the capacity Lithium Polymer cells bring a lot more advantages to the submarine:

- The cells can take very high charging currents which can enable lower indiscretion rates.
- The cell capacity can be used by 100% which gives an even lager capacity advantage compared to lead acid batteries.

The batteries are maintenance free:

- They can be stored at any loading condition
- They don't consume distilled water
- They don't release gases
- No water cooling is required
- The battery efficiency is very high due to low internal resistance.

The last advantage is at the same time the only disadvantage to the designer. The very low internal resistance causes very high short circuit currents which have to be handled by appropriate measures in the design of the ship's network.

At present time TKMS and GAIA have tested the first 500Ah cells and are testing the first full scale battery modules and partial batteries including the battery monitoring system.

New Composite Propeller on a Class 212A Submarine.

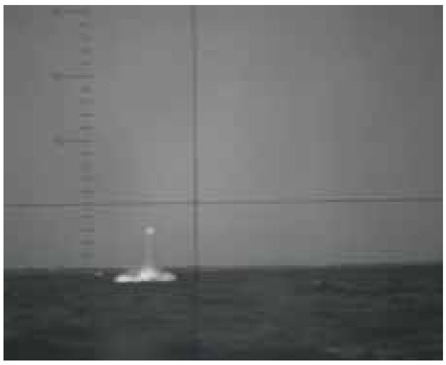
Composite Propeller

A limiting factor of the typically used material, bronze or sonoston, is their relatively low material damping to reduce propeller induced noise, which becomes more and more important due to new sensors which are able to detect also noise of very low frequency, another material was needed.

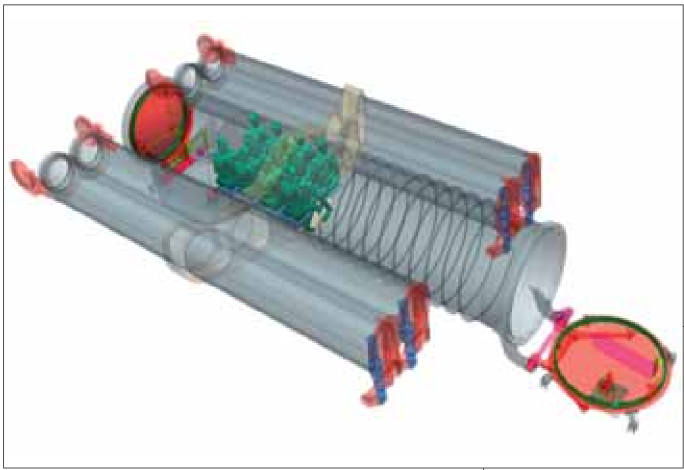
Anticipating big advantages in composites, a development on composite propellers was started. As a first step, technical feasibility was demonstrated by building a CRP based propeller in exactly the same shape like the established class 206a propeller. The long term tests on board an operational 206a class submarine of the German Navy showed feasibility, especially concerning the attachment of the CRP blades on the propeller hub made from metal. As logical continuation a new propeller with a high material damping was build and is being tested on class 212a. At present time improvements on the attachment of the blades to the hub are evaluated and TKMS is already offering the composite propeller as standard equipment on future submarines

Flexible Payload

The torpedo has been the standard submarine weapon for over half a century. Modern torpedoes are quiet and locate their targets by passive sonar, making not only the torpedo itself but also the submarine difficult to locate. For a modern submarine, a flexible payload consists of much more than the heavy weight torpedo. A wide range of weapons is equally essential for the submarine to exercise self-defence and to act offensively. A modular submarine can be fitted with a wide variety of



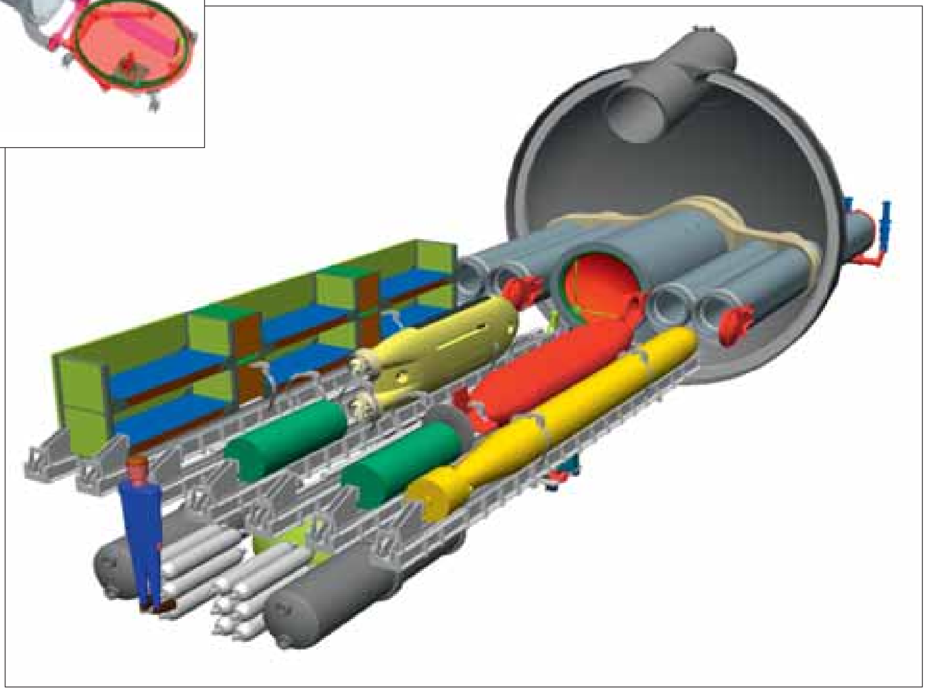
Test Firing of IDAS Missile through the Submarines Periscope.



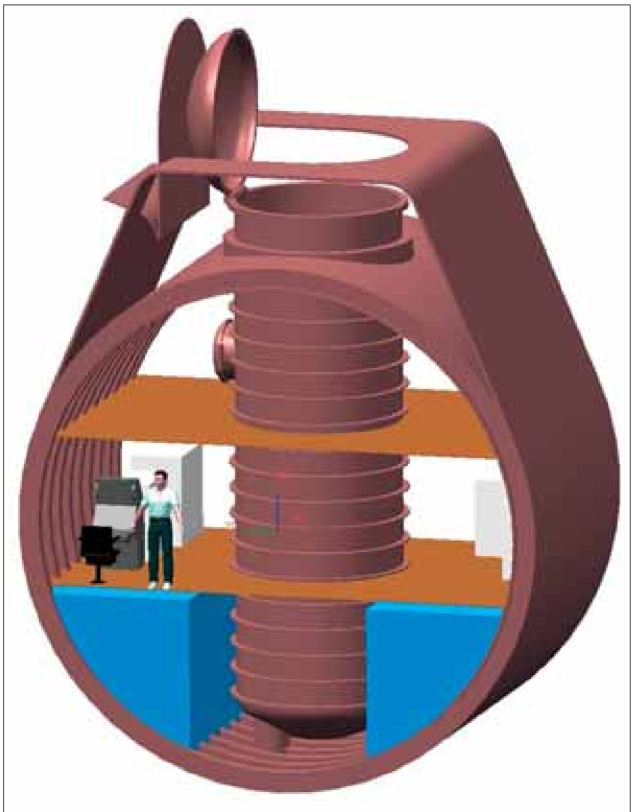
Flexible Payload Lock and Payload Compartment of A26.

weapons, mines, sensors and other equipment, depending on the likely mission profile. In the last 30 years, increasing importance has been attached to missiles as a submarine weapon for use against surface ships or land-based targets. Furthermore Special Operations Forces (SOF) have become an important asset within many forces, and the submarine would be the ideal clandestine delivery system for sea borne SOF missions. Therefore a modern submarine must be able to deploy: Torpedoes, Ship to Ship Missiles, Land Attack Missiles, Self Defence Decoys and Weapons, Mines, Unmanned Vehicles, Special Forces.

Today the weapon tubes and reserve storage can accommodate not only torpedoes but mines, divers as well as heavy and light missiles and AUVs of appropriate shape. To have more flexibility some of the torpedo tubes can be replaced by a large versatile tube called Flexible Payload Lock (FPL), which enables the submarine to carry large and odd shaped UUVs or larger groups of Special Forces with their equipment. The FPL will be an important part of Sweden's next submarine project A26.



In addition to this the traditional reserve storage has, in A26, been transformed into a Flexible Payload Compartment serving the weapon tubes and the FPL with storage and maintenance space for different types of payloads, e.g. torpedoes, mines, divers as well as heavy and light missiles and UUVs of unconventional shape. It can also serve as living quarters for Special Forces or other additional personnel. In addition a vertical cylindrical tube, penetrating the pressure hull could incorporate various payloads like cruise missiles, Special Forces equipment, mines or simply additional fuel.



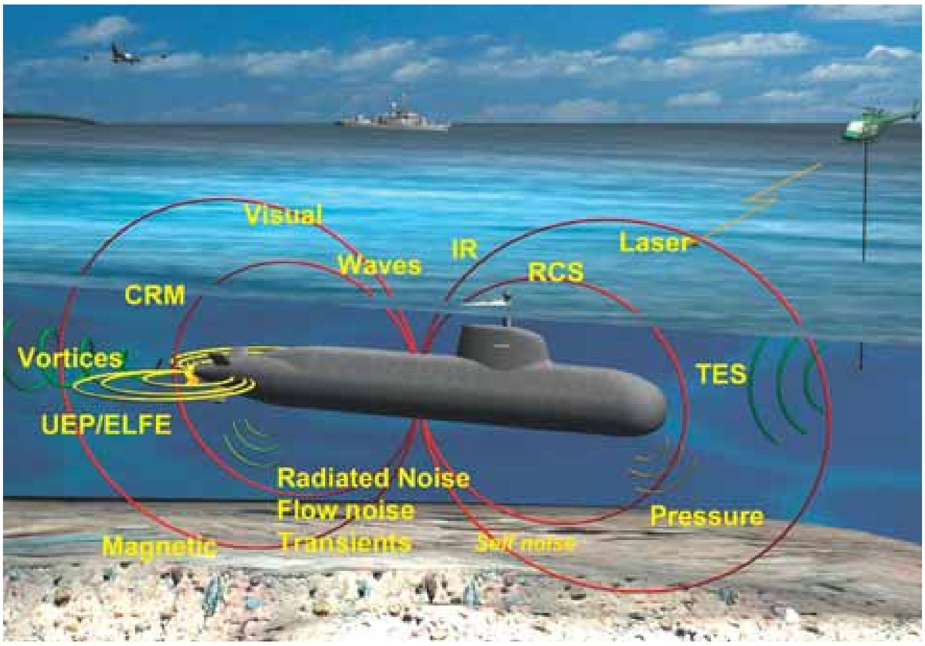
Vertical Payload Tube.

A new generation of lightweight fibre-optic guided missiles for submarines is currently being developed The System IDAS (Interactive Defence and Attack System). IDAS is connected to the submarine by fibreoptic link during its entire mission duration. The missile transmits a constant stream of images from its IR camera to the consoles of the submarine Combat System. The missile is intended for use against the modern submarine's deadliest enemy: the ASW helicopter However, the degree of precision with which the missile can be controlled makes it suitable far operations against surface ships and coastal targets as well. The IDAS missile is launched from a launching container that can be loaded in a torpedo tube like any heavyweight torpedo. The system can therefore be retrofitted into an existing submarine with relatively little difficulty

Signatures

In recent decades a lot of effort has been spent by TKMS on minimizing all signatures emitted by our submarines. The improvements achieved during this period have been enormous and, although they always have to be mirrored against the similarly developing sensor technologies, it can clearly be stated that our submarines are nowadays less detectable than ever since INW 11. In fact, today TKMS is producing the stealthiest submarines ever built. These submarines are nowadays more or less undetectable for opponents by passive means.

Consequently the opponents are forced to think of active means of detection, even though this means giving away their own position first. Against this background it is obvious that the use of active means will become more and more common again.



Submarine signatures.

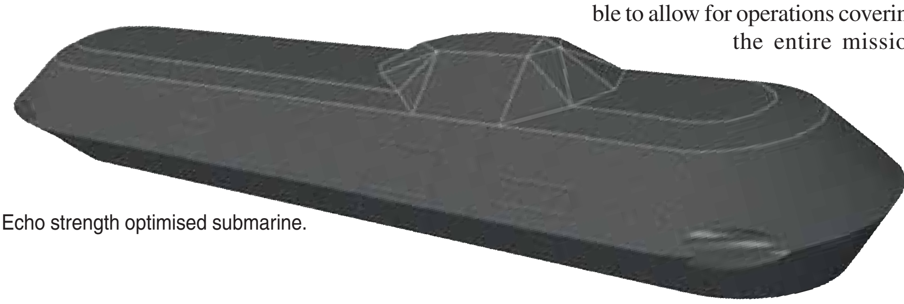
Having analyzed-this changed threat scenario the attention is turned to an adequate defence. There are two main threats through active detection for a submarine: in periscope condition it is radar and in submerged condition it is active sonar. Especially for AIP submarines, radar is a minor threat as compared to surface ships due to the fact that modern AI P submarines operate submerged (hidden from radar below the sea surface) most of the time.

Nevertheless, as the demands concerning stealth are much higher for submarines, some effort is spent on minimizing the remaining risk of being detected that way by application of radar-absorbing materials to the masts. This leaves the main threat for modern submarines, the opponent's active sonar. In the following sections it will be discussed what can be done about shaping and what about coating in order to minimize the target strength.

Shaping

The first thing that is done about shaping is to make the submarine as small as possible This does not only help maneuverability but also decreases the size of sonar reflecting surfaces. However, the related reduction of the target strength is not very pronounced, so that further steps, ie. the optimization of geometrical details, also have to be taken.

In to do this, the direction of the approaching sonar signal with respect to the submarine and the likelihood of certain directions have to be considered. In case the opponent is far away, it is obvious for geometrical reasons that the sonar signal will impinge on the submarine nearly horizontally (0°). Even at relatively short distances, e.g. opponent 1000m away from the submarine submerged at a depth of 100m, the elevation angle stays below 6°. Since the probability of a threat at such short distances is negligible (and under most circumstances avoidable by the submarine's crew), an optimization for elevation angles of the incoming signal in the range between 0° and approximately 6° is self-evident. The prevalence of these very low elevation angles is further increased by the influence of salt and temperature layers resulting in horizontal acoustic channels.



Echo strength optimised submarine.

The first consequence is to avoid reflecting vertical surfaces wherever possible. Since the pressure hull has to withstand the diving pressure at high depth, it is not possible to deviate from the circular cross-section. The side faces of the sail, superstructure and keel should also be inclined. The influences of all these modifications on the submarine's resistance, maneuverability, ease of operation and flow noise have been studied by TKMS in detail. In the end a compromise between the different requirements posed on a submarine has to be found.

Coating

The second or additional option to reduce the submarine's target strength is the application of acoustic coatings. On principle all acoustic coatings are compressible materials. Their compression with increasing diving depth must be taken into account for the layout of the submarine's compensating tanks.

TKMS has developed and is using a reflective coating to cover bow, stern and tilted surfaces. The material is reflecting and scattering the incoming sound energy, thus preventing the sound energy from entering free flooded areas were structures which form excellent reflectors are situated. The shine line of the pressure hull itself can be covered with an absorbing material, which needs a significantly higher material thickness for physical reasons. An absorbing material for this purpose is currently under development with TKMS.

Conclusion

More and more changes in the geopolitical environment influence maritime strategies and result in alterations in operational demands and requirements – adding up to new technical and non-technical challenges. Wherever such a challenge is identified there is on the one hand a risk, but on the other hand there are chances for substantial renewals and developments.

The non-nuclear submarine is currently undergoing a dual transformation in development, design and production as well as in associated technologies that expand the mission capabilities of the submarine. Together, these transformations will make the conventional submarine more robust, harder to detect, and more flexible to allow for operations covering the entire mission spectrum – from peacetime to high-intensity war fighting.

Thus the evolution of non-nuclear submarines has to some extent overtaken their giant nuclear sisters simply because they do not feature the manifold shortcomings of these boats, e.g. with regard to signature management and cost.

The added capabilities and extended operational endurance will make the submarine even more important in the twenty-first century as it was in the twentieth. The submarine has a variety of uses in the coming decades. While its premier role as a first rate naval asset remains, the submarine will extend it usefulness into the arena of MOOTWs. This will ensure that the non-nuclear submarine will remain a premier tool for world wide security policy. ■

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