Propelling ahead

Developing the second-generation Azipod® propulsion system, Azipod® XO

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Over the years, ABB's Azipod® propulsion system, renowned for its high maneuverability, quick response, fast cruising speeds and smooth, quiet operations, has proven itself in the shipping industry. The unit has led to increased efficiency, lower emissions, reduced building time and improved ship design, and is the market leader in podded propulsion technology. Development of the Azipod system began some 20 years ago, and the product has evolved into a major propulsion system for luxury cruise liners and icebreakers.

But surely the Azipod could do even better?

ABB turned to Azipod users for feedback to help evaluate the system. The result was a comprehensive development program initiated in 2006 to create a new Azipod generation. The strategy was not only to focus on technical issues, but also to address safety, maintainability, reliability, production, human interface, life-cycle costs, environmental factors and other design aspects.

This article describes the development project and highlights the new innovations applied to the final product. The result, Azipod® XO, was put on the market in September 2009.

Innovation on the move

Azipod is a submerged pod containing an electric propulsion unit consisting of a variable-speed electric motor, which drives the fixed-pitch propeller. The pod can rotate freely along its vertical axis to give thrust in any direction. Thus the ship does not need rudders, stern transversal thrusters or long shaft lines inside its hull.

Much development has been done and improvements have been made to the Azipod since its introduction in 1990. Until recently, however, the Azipod was still very much a first-generation product. After the initial revolutionary development the product has undergone only incremental design changes. These have largely been customer oriented, providing optimized solutions for each client. Since the delivery of each system is project based, maintaining uniform operation and design patterns has been challenging.

Because of its remarkable and proven advantages, podded propulsion was projected to expand to new ship types. This expectation, in combination with customer feedback on the existing Azipod system, has provided the impetus to develop a new, second-generation Azipod propulsion system.

Operators, authorities and shipbuilding yards each have their own requirements, thus a comprehensive approach to designing a new system was taken.

Setting priorities

The initial challenge was to determine what is important for a new system, what exactly should be developed, and what the overall target should be. After careful pre-studies, customer questionnaires, and workshops with key industry players, the following goals were set:

- Improve the lifetime earning potential of the ship through improved total operational efficiency
- Enable flexible, controlled and cost-efficient customization through modularization
- Make assembly easier and shorten onboard assembly time
- Reduce engineering lead time and project-specific design time
- Minimize manufacturing lead time and costs
- Enhance the safety of the system
- Reduce fuel consumption and emissions and as a result minimize the ecological impact

A propulsion unit that provides both propulsion and steering functions to a ship is an essential part of a vessel. Of course it moves the vessel from one port to another, but it is also, from a safety point of view, one of the key systems onboard ships. The unit is a combination of both mechanical and electrical engineering, includes modern communication technology, and utilizes hydrodynamic behavior for propulsion efficiency and maneuverability.

Operators, authorities and shipbuilding yards each have their own requirements – the latter, for example, desiring easy installation and efficient commissioning. To help meet this wide range of needs, a comprehensive approach to designing a new system was taken. The project was divided into seven subprojects:

- Modular propulsor family
- Risk and reliability management
- Modular electric steering gear family
- Modular assembly block family
- Condition management system
- Intelligent maneuvering interface
- Development of dimensioning principles

The "modular propulsor family" subproject was the biggest and most challenging, as it focused on the most physically significant part of the Azipod product – the underwater unit – which includes the electric motor, bearings, seals and propeller. The development process of this subproject and the resulting innovative solutions are highlighted here.

A multitude of expertise

Although the core R&D team for the new propulsor unit consisted of only 15 people, the total number of participants, including the interviewed customers, was about 100. Expertise from many organizations, customers, shipyards, ship operators, equipment manufacturers, research laboratories, universities, consultants, designers, etc. from more than 15 different nationalities were involved in seeing this project through.

About 10 customers from a wide range of companies all over the world were interviewed to obtain their opinions on the most important features and needs. These discussions generated a range of new ideas for developing technical solutions, which the customers influenced throughout the development process. In the end, the final solutions fulfilled the interests of all – customers, ABB and subsuppliers.

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Royal Caribbean Cruises, the most experienced user of podded propulsion, was one customer that participated actively in the process. Its long operational history, good knowledge of existing Azipod designs, and its positive attitude toward the discussion of new ideas led to the development of real innovations. Ideas that initially looked promising to ABB were not always the best choice from a customer perspective. Getting this kind of feedback helped ABB to concentrate on features that were essential to customers.

In the design phase, features that would improve human safety during installation, operation and maintenance of the product were given special attention. Design elements that would improve the space restriction for those required to move around inside the Azipod hull during its maintenance were particularly important. In addition, a team of students from the Helsinki University of Technology was invited to develop special work gear for those needing to work in these confined spaces.

The development team also participated in ABB's Marine Academy confined space course, together with the operating crew from several ships, to learn a practical approach to inner-Azipod operations. Training in an Azipod simulator was found to be very useful for people making decisions about the future Azipod.

Visualization is the key

At the beginning of a development project it is important to generate ideas to ensure that set targets are met. With an open-minded approach and a highly motivated team, this phase was very successful. In fact, at the concept-design phase, over 100 ideas were generated. From these ideas, 23 were developed into more detailed concepts, 10 of which resulted in an engineered solution. Five different pod frame concepts also were developed 1.

Once concepts were ranked in order of priority it was time to start the technical investigations – ie, to check out the technical feasibility of those ideas. The challenge at this stage was to create visualizations of the concepts so that potential solutions could be easily discussed with other stakeholders. An industrial designer was a huge help at this stage, being able to illustrate sometimes unknown or "fuzzy" ideas. Also, miniature models and mock-ups were used to clarify the details. How, for example, could the team ensure that changing of shaft seals would be possible inside the Azipod? The answer: Build a wooden mock-up, put design and service engineers inside the mock-up with tools, and ask for their feedback! The input and original idea for this exercise actually came from interviews during the development phase with one of ABB's biggest customers.

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Modular design

The experience gained from the first-generation Azipod units was that future Azipod generations should be of modular construction. This philosophy has a few benefits: Through standardization the product quality is improved, the manufacturing process is improved, and in the long run the total cost will be lower. However, it is essential that each modular solution be designed carefully so that most customers' needs will be satisfied with one or more options from the modular product family.

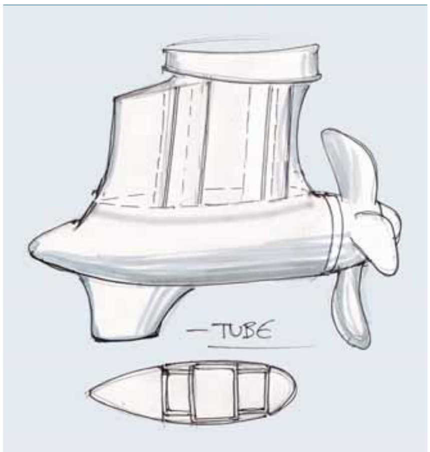
To fulfill the requirements of modularity, the project team had to consider many different approaches and solutions. Customer comments were again of great value. In the end, the Azipod product family was made to include roughly 300 modules and around 50 optional modules. With a product "pallet" like this, fast and reliable response to different customer requirements was ensured.

Hydrodynamic development

Podded propulsion has already improved hydrodynamic efficiency by about 10 to 15 percent, as compared with conventional electric shaft line systems. However, the project team was encouraged to further investigate the possibilities for reduced energy consumption and thus reduced CO_2 emissions of the vessel.

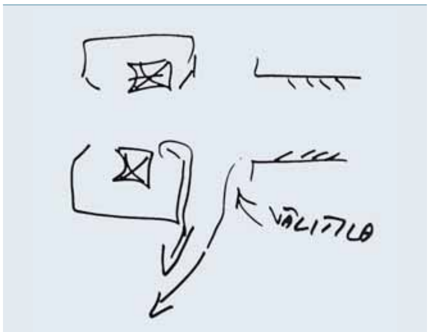
Being a complex product with many different objectives and considerations – eg, maintainability, installations to the ship and cost – hydrodynamic de-

1 Artist's view of one of the initial pod housing designs, which was chosen for the final design of the Azipod XO

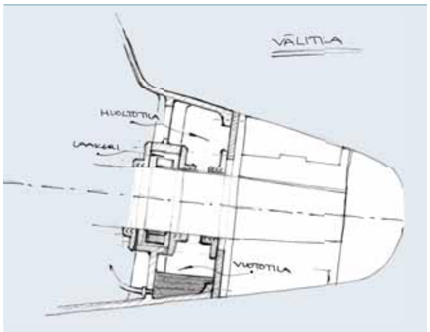


2 Interspace evolution

a The first sketch



b Draft of interspace



c Interspace mock-up

d The final model

Innovation on the move

3 Model of the new hybrid bearing developed for the Azipod XO

4 An inside view of the Azipod XO

sign changes were limited and compromises made. Roughly 15 different hydrodynamic shapes were developed and analyzed with CFD (computational fluid dynamics). Also many test sessions were held at the model basin1) to verify the usability of the original ideas. Finally one shape was selected for the new Azipod. To the outsider, the new hull looks quite similar to that of the previous generation. However, the propeller hub and Azipod hull diameters were reduced and the Azipod strut shape modified. This new shape allows for about a 2 percent improvement in hydrodynamic efficiency in the tested case.

The interspace concept makes seal maintenance inside the Azipod possible and reduces the risks of operation.

Another important finding was that by changing the vertical turning axis of the pod unit the steering torque could be reduced by about 20 percent – even more depending on the ship's speed. This means smaller steering-system dimensioning, greater energy savings and less wear on the steering mechanics.

Creating interspace

One example of an open-minded and innovative solution is the new sealing system for the propeller shaft. It is easy to imagine that if seawater leaks inside the pod and reaches the high-power electric motor, there will be so much damage to the equipment that a costly and time-consuming dry-docking would be needed to repair the motor. Equally important is that the lubricants from the bearing do not leak to the sea, for both environmental as well as financial reasons. If even a small drop of oil is seen around the ship at some cruise liner destinations, the liner companies may be made to pay extremely high fees for the resulting environmental cleanup.

Typically, shaft-seal development work involves seal materials, housing developments and the like. In this project, however, the development team took almost the opposite approach to the problem by completely turning the traditional seal package around – literally. This was established as the interspace concept (patent pending) 2. The concept makes seal maintenance inside the Azipod possible and reduces the risks of operation.

By collaborating with customers and really defining and understanding their needs, a crazy idea was transformed into a revolutionary concept.

Hybrid bearing

As many in the marine business know, podded propulsion bearing solutions are quite famous and not always in a positive way. So, development was mainly focused on extending a ship's dry-docking interval during which time the thrust bearing could be replaced. Eventually, it became apparent that if this replacement could happen without dry docking, there would be no need to focus on increasing a dry-docking interval. This concept was fully supported by the customer, and blossomed into the invention of the hybrid bearing (patent pending) 3.

The result of a systematic search for solutions, a hybrid bearing is in principle a very simple bearing arrangement combining two well-known bearing technologies – a slide bearing for axial forces (thrust bearing) and a roller bearing for radial forces. Until now, this combination of bearings had not been introduced to the marine market. For the new Azipod generation, the hybrid bearing would replace the traditional thrust bearing.

Hydrodynamic developments, such as pod and propeller-hub diameter reduction and strut-shape optimization, increase efficiency by about 2 percent.

Introducing the new Azipod XO

This intensive development project has transformed the Azipod into a truly user-based propulsion system, designed with the customer, for the customer. And the benefits of the new Azipod XO are many 4.

Hydrodynamic developments, such as pod and propeller-hub diameter reduction and strut-shape optimization, increase efficiency by about 2 percent. For a typical cruise vessel application, this alone results in nearly $700,000 in annual fuel savings and a corresponding reduction of 5,000 metric tons of CO_2. That is a lot!

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To illustrate the importance of this improvement, CO_2 emissions produced during the whole Azipod production process are "paid back" within about eight months of operation. Add to this the 10 percent increase in efficiency already achieved with the first-generation Azipod, and the savings are even more impressive!

The Azipod has been designed for optimized maintainability, allowing maintenance of seals and thrust bearings to be performed inside the pod. This is a benefit in itself, but it also allows for extended intervals between dockings, opening up possibilities for future needs in the shipping business.

The use of an electric steering system, which replaces the hydraulic solution, enables easier installation, improved efficiency, reduced need for maintenance and less noise.

Through the intelligent bridge control interface, deck officers get real-time information about the system, allowing them to operate their vessels in a gentle and optimal way, minimizing the stresses to the system and reducing fuel consumption.

Advanced condition monitoring records the condition of the critical subsystems, such as the propulsion and steering systems, bearings and seals, as well as lubrication systems, and allows the optimization of the maintenance operations for the systems.

For shipyards, the benefits include flexibility in integrating the Azipod into the ship hull, easier installation due to modular construction, and avoidance of high-pressure hydraulics in the steering system.

With the new Azipod XO system, ship owners will save even more money, the environmental impact will be even lower, and business operations can be more easily planned as a result of a reliable and maintenance-friendly propulsion system. The first Azipod XO unit is already on the market Factbox.

Factbox Azipod® XO2100 specifications

Type designation	Azipod XO2100–S3000E4
Rated output power	13,000–18,000 kW
Nominal propeller speed at maximum output power	122–170 rpm
Main motor supply voltage	Approx. 3,000 V
Insulation/temperature rise class for stator and rotor	F/F
Propeller design	4 or 5 blades
Propulsion module (excluding propeller)	135,000–155,000 kg
Propeller	22,000–30,000 kg
Steering module	60,000–70,000 kg

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Footnote

[1] A physical basin or tank used to perform hydrodynamic tests

Further reading

Su, B., Rissanen, M. (2008). Saving energy the efficient way: ABB's products are energy efficient helping to reduce energy wastes around the world. *ABB Review Special Report Dancing with the Dragon*, 21–27.