# Experiences with Azipod® propulsion

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Azipod® is an azimuthing thruster system where the electric propulsion motor is located on a short shaftline in a submerged pod with the propeller typically placed in its forward end. The pod can be rotated around its vertical axis freely allowing thrust to be directed in any selected direction. The propeller is of fixed pitch type. The speed of the electric motor is controlled by a frequency converter. The propeller shaft can be rotated in both directions.

The Azipod propulsion concept was introduced on the market some 20 years ago. Today there are some 100 vessels using Azipod propulsion. Operational experience has been gained from more than seven million operating hours. Azipod propulsion has been selected for many different types of ships, such as cruise ships, icebreakers and icegoing cargo vessels, ferries, megayachts, offshore supply vessels, research vessels and drilling rigs.

The main benefits of Azipod propulsion are improved fuel economy and excellent manoeuvrability. More than thirty different shipyards have applied Azipod propulsion for their newbuildings and a great number of shipowners have gained extensive experience of its operation, maintenance and crew training.

Based on the operational experience gained it is possible to derive at some conclusions of the feasibility and reliability of the Azipod concept. This paper looks at the experiences learned from vessel operations, focusing on system availability and reliability, and on the technical developments and improvements done over time.

## The Azipod product family

The Azipod product family consists of two basic product series. They are based on different technologies and solutions although their basic system principle is the same. The Azipod C series is for the lower power range up to 4500 kW. Azipod C comes in two versions; an open propeller version for ship applications and a nozzle version for high thrust applications, such as for drilling rigs or vessels. The Azipod V series is for higher power of up to 20 MW and above. The Azipod V series has versions both for open water and for use in heavy ice conditions. Whereas Azipod V is based on the product developed in the early 1990's, Azipod C was introduced in the beginning of this millennium. The newest generation, Azipod X, or Azipod XO which has now replaced Azipod V in open water applications, was launched for sales just recently. The first units of the Azipod X type have been delivered and are currently being installed on a number of newbuilding ships. Both the hydrodynamic efficiency and the maintainability have been further improved on Azipod X. The design has been improved with a number of new innovative solutions, including those of the bearing and seal arrangement.

## Operator experience

What regards fuel savings and ship manoeuvrability, the expectations set by ship operators have typically been fulfilled or exceeded. Particularly the ship captains have been enthusiastic about the ease of operation and the good manoeuvrability of their vessels. Concerning energy efficiency, some operators have claimed fuel savings of more than 20 % compared to their vessels provided with conventional propulsion. The Azipod concept has been recognized as an unbeatable concept for icegoing ships. It has also proven to suit perfectly for DP operations. Dedicated ship operation simulation facilities have been set up to provide training in how to operate ships with Azipod propulsion.

Seven million operating hours with Azipod propulsion over a time span of, soon, two decades have resulted in a vast experience on how the system shall be used and maintained for trouble-free reliable operation.

We have identified the components and systems that are critical for undisturbed ship operation. These need some special attention when designing and selecting the solutions as well as in their operation and maintenance. Technical issues have been approached through systematic analysis and root causes for unwanted behavior have been identified. New solutions have been developed, over the years, when necessary.

The maintainability of the propulsion unit has proven to be an essential factor in providing reliable uninterruptable operation of the critical components of the system, which are the shaft seals, shaftline bearings, steering system, slewing seals, slewing bearings and the propulsion motor itself. These components and their subsystems are discussed below.

## Shaft seals

In Azipod C the propeller shaft seal assembly combines a water lubricated face type seal and two grease lubricated lip-type seals running on a steel liner. The set air pressure inside the motor prevents sea water from entering into the propulsion module. The solution has proven to be reliable and today the Azipod C sealing system is still of the same design as when originally selected.

In Azipod V the seal is formed of inner and outer lip-type seal rings. Between the seals there is the propeller bearing oil sump, which is partly filled with oil. There have not been any major issues of leakages due to the shaft seals. However, the Azipod V seals have been continuously improved to meet the increasing environmental requirements. Thus the Azipod XO has a new shaft seal design where the bearing oil seal is separated from the water seal. The new design brings with it better maintainability, increased life time and the possibility to use biodegradable lubrication.

## Propeller bearing

In Azipod C the propeller bearing is a grease lubricated cylindrical roller bearing directly cooled by sea water. There have not been any major issues with the propeller bearing and the same design is used as in the original design.

In Azipod V the propeller bearing is a splash lubricated cylindrical roller bearing. The cruise ship ms Paradise, which has a Azipod V propulsion system, experienced a bearing failure in year 2000. After a deep root cause analysis a complete bearing system re-design was done. All the ships delivered with the same bearing system were modified according to the new design in their following scheduled dry-docking. The new design has functioned flawlessly and that design is used also in the new Azipod X product.

## Thrust bearing

In Azipod C the thrust bearing is an oil sump lubricated spherical roller bearing directly cooled by sea water. There have not been any major issues with the thrust bearings and the same design is used as originally selected.

In Azipod V the propeller bearing is a splash lubricated spherical roller bearing. The Azipod V thrust bearings have faced some limitations regarding wear, mainly in the bigger power range. Two new thrust bearing designs have been developed and are being heavy-duty tested for better reliability and maintainability, one for Azipod V and one new hybrid bearing for the new generation Azipod X. The hybrid bearing design includes a radial roller bearing and a slide thrust bearing. The results so far have proven to be good and they satisfy all the requirements set.

Steering system

The Azipod C steering system is fully electric whereas Azipod V has a hydraulic steering system. Both systems have proven to be reliable and fulfill their technical requirements. Thanks to the good experience from Azipod C with improved efficiency, reduced noise and vibration and simpler yard installation, also the Azipod X generation received an electrical steering system.

Slewing seals

The challenge in the Azipod V slewing seals has been with the maintainability. For that reason the Azipod X has a new slewing seal design with improved maintainability. In the new design an emergency seal has been added as well. The Azipod C has still its original design.

Slewing bearings

In Azipod C there have not been any issues with the slewing bearing. Only some failures have been recorded on Azipod V. Root cause analysis pointed at failures in connection with heavy operation. A new steering module design with better maintainability was designed for the Azipod XO. Now the slewing bearings can be replaced from below, with less work and time consumed.

Propulsion motor

The propulsion motor of the Azipod C is a permanent magnet synchronous motor directly cooled by sea water. The majority of the Azipod V motors are brushless synchronous motors. There are some lower power deliveries with an induction motor. These motors are air cooled with an air-water heat exchanger placed in the ship. The motor type selections have proven to be justified both from efficiency and performance points of view as well as when looking at reliability.

Service aspects

In order to avoid system failures of Azipod propulsion much effort has been directed at improving maintainability as well as on developing condition monitoring features. This has also helped clients in providing reliable operation of their existing Azipod systems. As an example the new Azipod X design (except the smallest unit) allows the change of shaft seals and thrust pads from inside the pod unit without the need to dry dock the vessel. A condition monitoring system for the critical elements like bearings, seals and lubrication oil etc has been developed. This system can be used locally and also remotely.

Based on our experience from systematically gathered data the component wear and failure phenomenon is now understood in detail. Combined with continuous condition monitoring it is possible to forecast the component lifetime well in advance so that ship owners can plan the overhaul schedules in good time before there is any risk for failure.

Conclusions

Extensive cooperation with ship operators and shipyards on a wide range of different Azipod applications for various demanding operating environments have complemented our understanding of the Azipod concept. Mostly the Azipod propulsion systems exceed expectations resulting in customers selecting Azipod also for their consecutive newbuildings.

We have identified the components and systems which are critical for undisturbed ship operation. These need somewhat more attention what regards their design, selection, operation and maintenance.

The technical challenges have been approached by systematic analysis and the root causes for some unwanted behavior have been identified and new solutions have been developed where necessary. These improvements have proven to be correct and successful.

The Azipod units installed on icegoing vessels operating in the high Arctic have not encountered any failures due to heavy ice loads.

Our conclusion is that a correct operation of the vessel combined with maintenance routines according to defined instructions are essential to guarantee faultless operation of the systems. Good maintainability and condition monitoring have proven to be efficient in optimizing ship owners' operations and maintenance work.

The Azipod propulsion and thruster units are designed for five years drydocking and maintenance intervals. For some applications a longer maintenance interval of even up to ten years has proven justified. This conclusion is based on results of a well-documented operational and maintenance history.

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