Azipod Propulsion System

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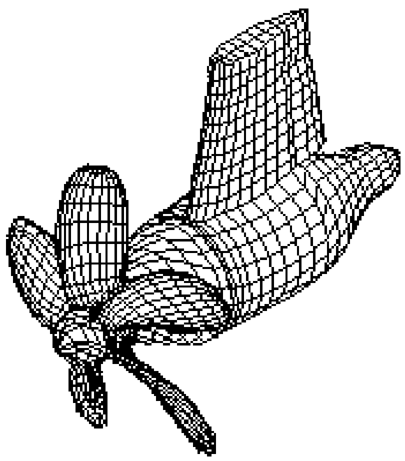
Abstract

At first people used logs tied up together as a medium of transportation through seas. Then the idea of inventing sailing ships was mooted which metamorphosed into steam and diesel powered vessels. Now these two energy sources dominate the others in marine propulsion. It's assumed that ships can only be propelled by propellers either by Steam or Diesel power and steered by Rudders. This paper endeavors to introduce the concept of transportation by sea and the technology behind it, explaining the origin of the idea of transportation. It describes the propulsion system behind it. The recent most developments in marine field which have given Unconventional design to the ships are discussed. If a system has to be adopted in the main streamline and utilized, it is necessary for it to have more advantages then its drawbacks. As every system suffers from discomforts, in this unconventional system there are many advantages along with a few disadvantages which are meager.

Azipod system, combining the propulsion and steering of conventional ships system replaces traditional propellers and lengthy drive shafts and rudders used for more than a century on oceangoing vessels.



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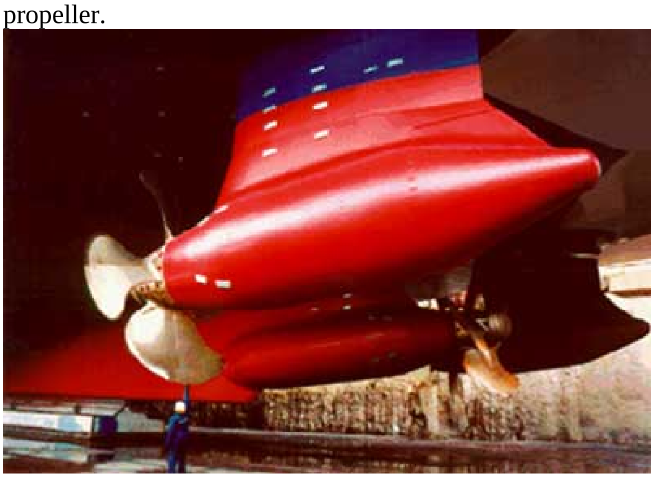
Introduction

The original idea for Azipod system was developed when the Finnish Maritime Administration began to seek better solution for the operation of icebreakers (the type of ships which are used to break the ice as well as they assist the other ships) in ice channels. An important feature of an icebreaker is that it must be able to break out of an existing ice channel as it is important when the merchant ships are being assisted are using the ice channel and icebreker has to move around the operational area. To overcome this problem, the idea of a propulsion motor that could direct the thrust to any direction was created. As a result the first joint R&D project was the conversion of Seili, a waterway service vessel owned bt Finnish Maritime Administration, into first Azipod ship in the world, in 1989. Seili continues to operate faultlessly today. Kvaerner Masa-yards and ABB made an agreement in 1992 to develop the concept and market the unit jointly.In 1993 the name AZIPOD was registered.

The next ship to be converted was a product tanker, the M/T Uikku in 1993 and in 1997 it became the first western cargo ship to navigate through the North-east Sea route.It demonstrated the soundness of the basic design and construction chosen for azipod.Hence, Azipod propulsion is the only way to make North-east Sea route (the shortest sea route from Europe to Pacific ocean and far east, this comes in heavy ice zone specially in Aug to Oct. Its of great importance to the domestic service transport of North Russia.) economically viable because the ship can operate very safely without icebreaker assistance. The real break through came when Carnival Cruise Lines(CCL) choose Azipod in 1995, they switched on the electrical propulsion era for cruise ships. In the late 1990's the demand from the market and good experiences with larger units gave an clear signal to start development work for the unit. Podded drives are now finding growing acceptance beyond the cruise sector to U.K. Royal Navy.

What is an Azipod System?

An Azipod System is combination of propulsion and steering of ships, which replaces traditional propellers, lengthy drive shafts, stern tubes and rudders which were used on oceangoing vessels, passenger cruises. The good thing about Azipods is that they do not have engines inside; instead they have a huge Variable-Frequency Electric Motors (VFEM). It is also known as POD Drive (Propulsions with Outboard Electric Motor), in which the electric motor is used to turn the propeller.



The power plant which provides the electricity to these motors is located in the hull of the ship. This power-generation system also provides electricity to various auxiliary machines and other electrical needs all around the vessel. Azipod system is housed in a submerged propeller unit which is capable of rotating freely. This

‘Rudder-Propeller Unit’ replaces a conventional rudder and ensures excellent vessel steering, even in emergency situations. As propeller speed is controlled electrically, long propeller shafts or separate steering machines are not required as used in conventional one. The POD can be rotated through 360 degrees to provide the required thrust in any direction. In other words, it is electric propulsion which can be used for luxury cruise vessels, Ro-Ro (Roll On-Roll Off) vessels, tankers, offshore and special purposes.

Thus Azipod ships are, basically, vessels, in which from lighting and air-conditioning to cooking, dish-washing, laundry, and all the other comforts we expect are truly electrical. Also, from the generation of freshwater to the processing of waste materials, the ship is an electrically operated, self-contained, ecologically correct community.

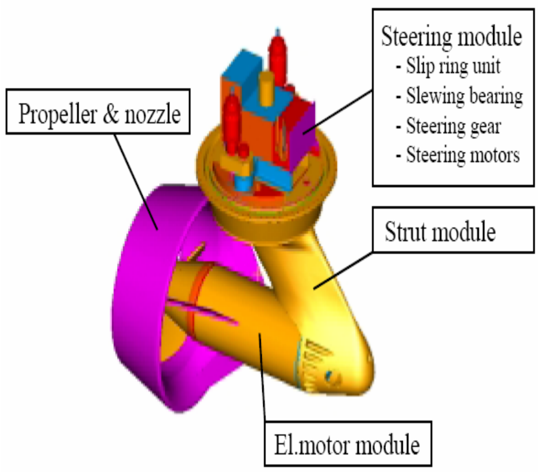
The power needed just to drive the Azipods is as much as 28 megawatts--that's equal to 280,000 100-watt light bulbs! The first full-size unit, rated at 11.4 MW, was installed in 1993 in a 16,000 dwt Finnish tanker, the Uikku vessels.

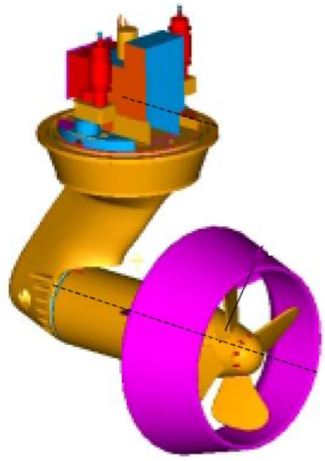
Design Philosophy:

Ship designers in shipyards benefit from inherent modular flexibility providing the possibility to standardize the vessel steel construction. The compact Azipod unit consists of four main modules.

(I) Propeller With or Without Nozzle

Propellers are divided into two groups. The first is Fixed Pitch Propellers (FP). They are cast in one block and normally of a copper alloy. The position of the blades and their pitch is once and for all fixed. And other is Controllable Pitch Propellers (CPP) which has a relatively large hub. This is because the hub has to accommodate space for a hydraulically activated mechanism for control of the pitch. Compact Azipod can be provided with a nozzle as an option for vessels with high pull requirements, vessels used to tow the large ships to the port. Typically vessels equipped with nozzle are designed to operate at lower speeds than vessels with open propellers.

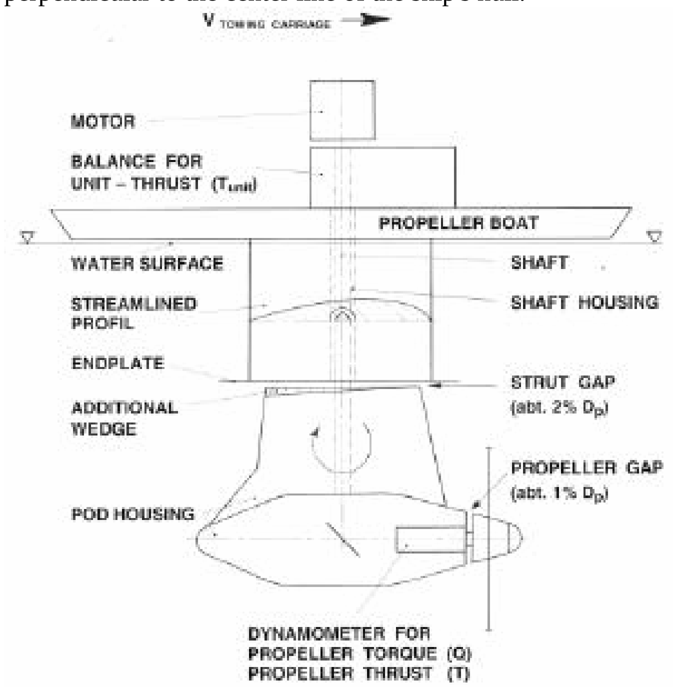




Propeller with Nozzle

(2) Electric Motor Module

The electric power is controlled by an onboard frequency converter, and transmitted to the electric motor via power slip rings at the power transmission and steering module. The compact Azipod incorporates a Permanent Magnet Synchronous Motor with a Fixed Pitch Propeller (FPP) that is mounted directly onto the motor shaft. Permanent magnet technology has many benefits over the conventional one. The outer diameter of POD can be decreased, which improves hydrodynamic efficiency. The uniform frame design enables the motor to be directly cooled via convection to the surrounding seawater, thus eliminating the use of cooling system (and problems attached to it too). The Azipod are suspended beneath the water line at the aft end of the ship. Azipod is mounted on a shaft perpendicular to the center line of the ship's hull.

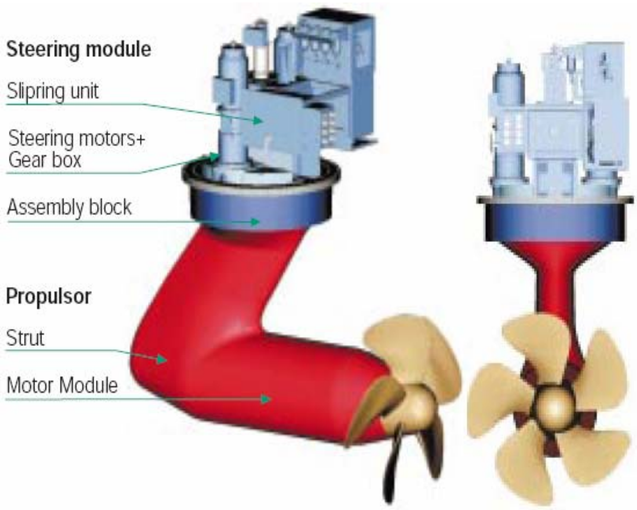


End-View of POD

(3) Strut Module

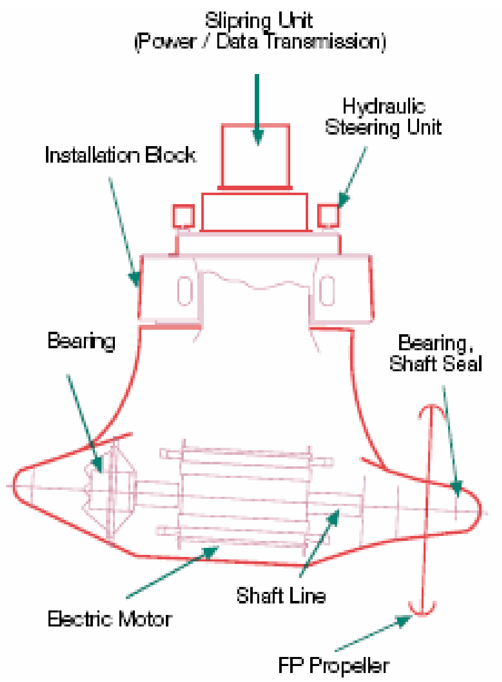
Strut module acts as a connective element in Compact Azipod structure. Control cables, piping and power supply bus bars for propulsion motor are located inside the one -piece cast called strut module.

(4) Power Transmission and Steering Module



Module

Azipod is a Podded propulsion system, azimuthing through 360 degrees. Power transmission and steering module consists of local control and equipment box, cable drum (slipping unit as an option), steering motors with gearboxes and assembly block. This model is located inside the hull of ship. The shaft can be rotated to any position in 360 degrees. The angular position of rotation can change the direction of the ship's movement or keep it sailing straight ahead. Thus, ships with Azipods are steered without a rudder, similarly as small boats use an outboard motor for power and steering (but with their rear-mounted propellers, outboards "push" their vessels, while Azipod, with forward-mounted propellers, "pull" their vessels). The positioning of the Azipod and the speed of their motors are determined by officers on the bridge.



Crossectional View of AZIPOD

<u>Design Features:</u>

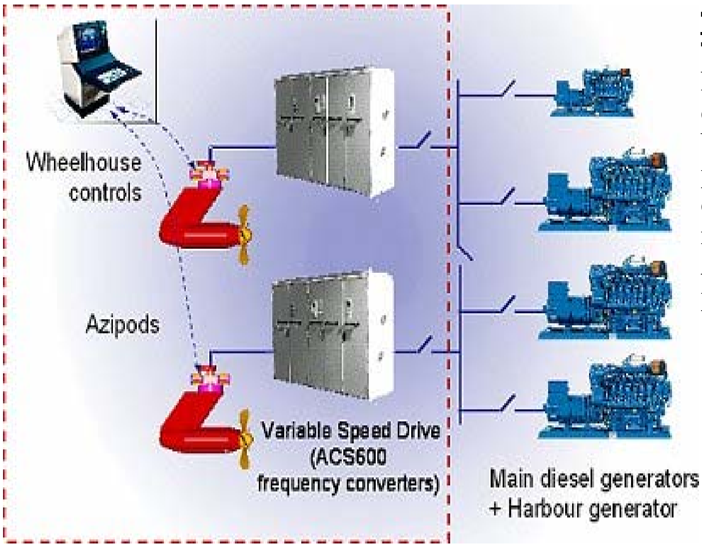
The design of Compact Azipod includes features that make system a reliable and effective for DYNAMIC POSITIONING operation. Power transmission in steering module is installed in the ship hull in the convenient phase of ship construction. Pre-mounted strut and motor modules are delivered and installed and connected to the power and steering module only just before launching of the ship. Reliability, availability and maintainability are important factors during the design phase. Possibility to take full power with reversed RPM, precise azimuthing control, Azimuthing speed, Possibility to tilt the unit are the few essential things to be borne in mind during the design.

The Azipod-propelled ship achieves greater fuel efficiency by the use of the latest materials, many stronger and lighter in weight than were used in construction in earlier designs.

<u>Electric Propulsion:</u>

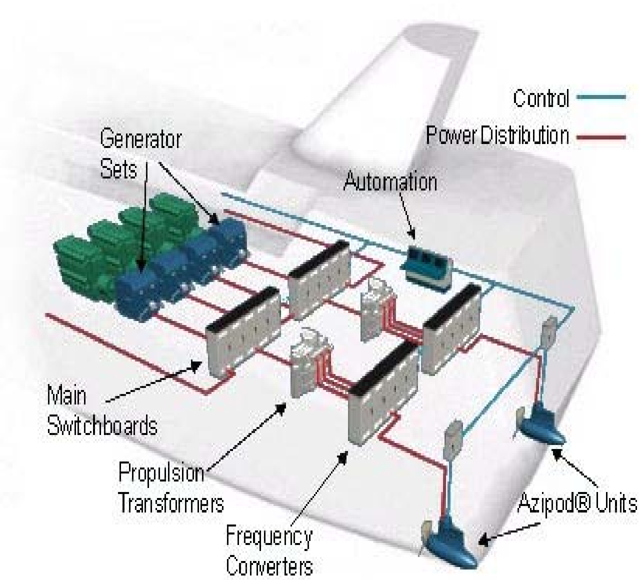
Functionally, the propulsion drive can be divided into following parts:

(I) Supply transformer
(II) Propulsion motor
(III) Frequency converter.



Various Electrical Installations

In an AC drive, a frequency converter is used to control the speed and torque of electric motor housed in the azipod unit. The speed of the AC electric motor can be controlled by varying the voltage and frequency of its supply. A frequency converter works by changing the constant frequency mains electrical supply into a variable frequency output. The frequency converter drive provides step less control of three-phase AC currents from zero to maximum output frequency, corresponding to a desired shaft speed both ahead and astern directions. High torque is available at all speeds. Controller hardware and software are designed for safe operation in all conditions, as well as for high dynamic performance. Optional control parameters are flexibly programmable according to special requirements.

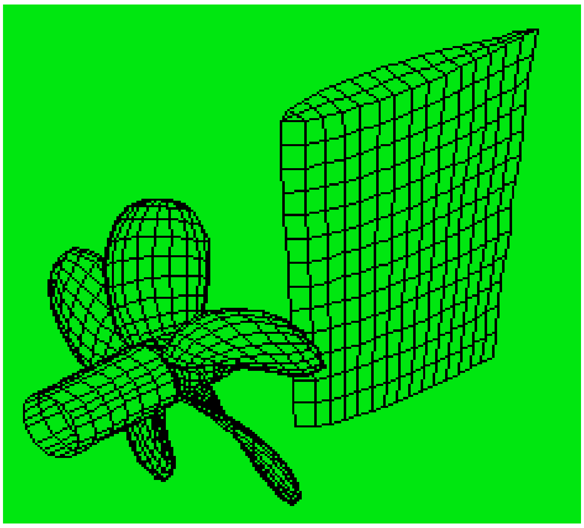


Layout of Various Electrical Installations

The advantages

The reliability and effectiveness of Azipod propulsion has been proven over the last decade in the toughest ocean-going ship applications: Arctic tankers and ice breakers. In those non-passenger-carrying vessels, propulsion was provided by only one Azipod, where as cruise ships may have two for additional maneuverability and redundancy.
Azipod propulsion enhances the merits of electric propulsion in a number of ways:

1. Superior maneuverability and dynamic performance are advantages which are not provided by the earlier system. Excellent reversing capability and steering during astern navigation, and enhanced crash stop performance are the important features. Tests on arctic tankers converted from conventional drive to unconventional one shows a 46% reduction in crash stop distance over the previously installed conventional propulsion system. In conventional drives, where propellers are attached to drive shafts, the rotating shafts set up a swirl in the water preceding the propellers--a situation analogous to sailing upstream.


Conventional propulsion
RUDDER-PROPELLER

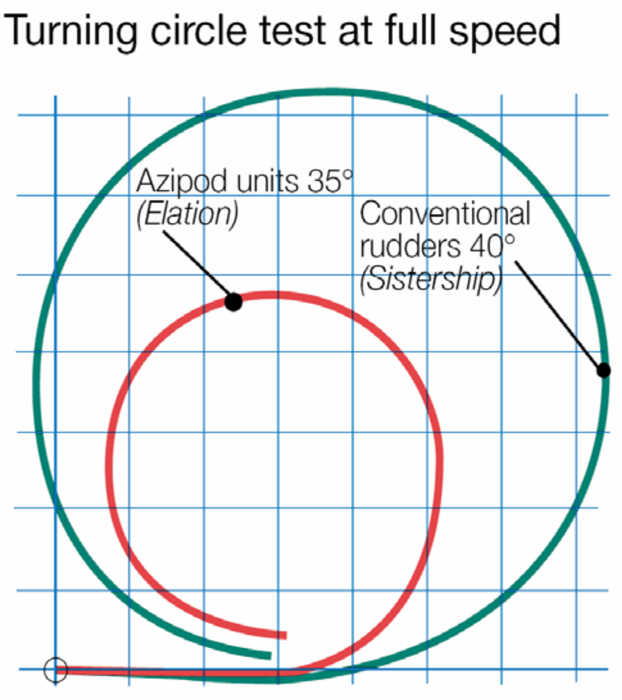
2. The design states that the Azipods are suspended beneath the water line at the aft end of the ship, having the FP-propeller at the front to move the ship through the water. In case of two Azipods, there is one Azipod on the port side (left facing forward) and one on the star board side (right facing forward). Each Azipod is mounted on a shaft perpendicular to the center line of the ship's hull. The shaft can be rotated to any position in 360 degrees. The angular position of rotation can change the direction of the ship's movement or keep it sailing straight ahead. Thus, ships with azipods

are steered without a rudder. For instance, Azipods are capable of moving the ship backwards during docking. In this case pods are rotated to the 180-degree position, or they can be positioned straight ahead (zero degree position) while the motors are reversed.

AZIPOD facing Forward in Twin Screw Vessel

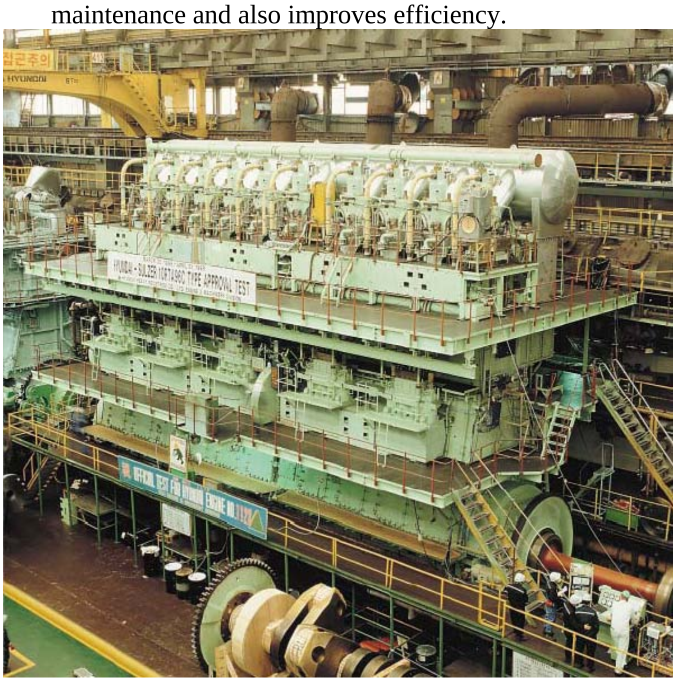
3 Much higher side thrust as the pods can be rotated sideward and the direction propeller can be reversed thus eliminating the use of side thrusters as in conventional drives side thrusters, bow thruster are used to rotate sideward.

4 Each Azipod can be operated independently of the other allowing subtle maneuvering. They have short turning radius as compared to conventional rudder-propellers.



5 Low noise and vibration characteristics associated with the conventional electric drive system are enhanced by Azipod motor's underwater location. Also the hull excitations induced by the propellers are very low compared to the conventional propellers.

6 Azipod system facilitates extra space than the conventional ships. Space within the hull otherwise taken by propulsion motors and shaft lines is saved and can be used either for the cargo storage or any other domestic requirement on board. Azipods allow us to delete shafts, shaft bearings, rudders, thrusters along with the rudder(s) and long shaft line(s), and associated equipment, which reduce maintenance and also improves efficiency.



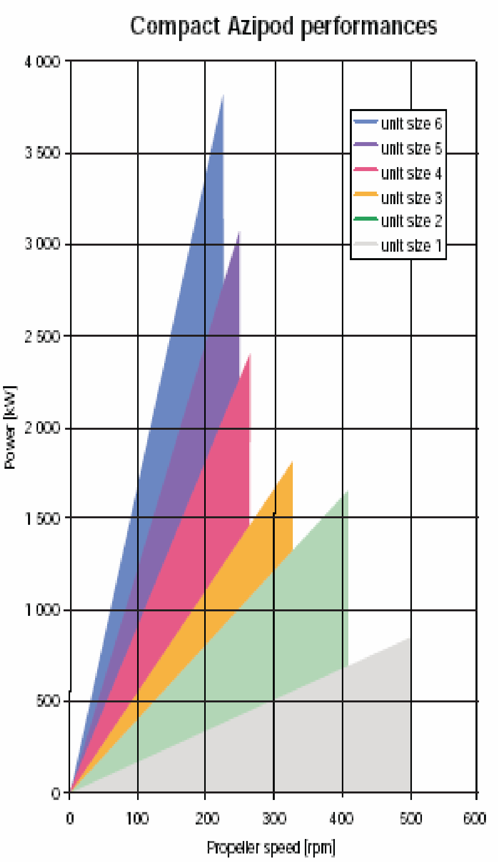
Large engine use to turn propeller in Conventional propulsion

7 Azipod propulsion deliveries can be made late in the shipbuilding process significantly cutting dead-time investments costs. Modular construction reduces installation time and expenses.

8 Azipods offer safer cruising in harsh weather and greater control in restricted passages. Reduced propeller induced vibration of the Azipod propulsion, possibilities to minimize hull noise by optimum layout arrangements, gearless and constant operation of diesels are a boon for the crew. Firstly ships with Azipod systems have higher cruising speeds, not always concurrent with fuel conservation, which may result in more or longer port calls. This also allows some lines to have itineraries with ports at greater distances from each other.

One best example that can be sited for instance is as follows:- Norwegian Cruise Line's Norwegian Star provides year-round Hawaii service with a visit to Fanning Island, Republic of Kiribati, about 600 miles from Hawaii, for a day at the beach. Traveling at about 25 knots, the Norwegian Star covers the distance in just 24 hours, giving passengers two sea days--and a remote island call--on a seven-day cruise.

	Compact Azipod unit sizes						
	1	2	3	4	5	6	Nomination
D1 [mm]	750	915	1050	1200	1350	1470	Motor module outer diameter
D2 [mm]	1350 1700	1700 2100	1900 2350	2200 2850	2450 3200	3100 3500	Propeller diameter (min. / max.)
D3 [mm]	1700	1700	2400	2400	2990	2990	Assembly block outer diameter
L1 [mm]	1000	1000	1100	1100	900	900	Slipring boundary distance
L3 [mm]	3500	4000	4600	5100	5700	6500	Length of Azipod unit
H1 [mm]	1300	1600	1900	2200	2400	2400	Assembly block height to the connection flange lower surface
H2 [mm]	350	350	480	480	650	650	Height from motor module to the assembly block shoulder
H3 [mm]	1600	1600	2000	2000	2100	2100	Height from connection flange lower surface to the top of the steering module
R3 [mm]	2300	2600	3000	3300	3600	4200	Radius from propeller tip to azimuthing axle (in water plane)
M1 [kg]	10500 11500	15500 17000	24500 26500	30000 34000	42000 48000	57500	Total mass of complete Azipod unit (min. / max.)
V [kg]	1300	2400	3500	5000	7000	10500	Underwater displacement mass



Power (in KW) **Vs Propeller Speed** (in rpm)

9 Power requirement for twin-screw ships are less.

10 Operational flexibility gives low fuel consumption, reduced maintenance costs, It is reported that the operational efficiency if 15% more than the conventional propulsion resulting in high annual fuel saving, less exhaust emissions and adequate redundancy with losses installation power. According to available statistics the vessel with carrying capacity of 61,000-grt saves "up to 40 tons of fuel per week." This is primarily due to the overall improved efficiency of the Azipods.

11 It saves lube oil consumption than in shaft driven, some 10 liters of lube oil consumption against 1000 liters in the conventional drives. In the construction of the first Azipod equipped cruise ship, the Carnival cruise Lines Elation, approximately 100 tons was saved over previous ships with conventional drive and an 8% improvement in propulsion efficiency resulted in fuel savings of 40 tons/week.

Disadvantage

- Higher capital loss
- Diesel electric system required (power loss ,the power generation is Diesel based)
- Power requirement is higher for single screw vessels
- Limitation in power
- Limitation in speed

	Limitations uptill now	And in the future
Maximum power per unit	21MW	32MW
Maximum possible speed	26Kts	30Kts
Max. propeller diameter	6m	8m

Limitations uptill now

These limitations reduce the applicability of pod propulsion for fast ships and for the ships with very high power requirement.

Environment and Azipod:

The power plant concept offers an advantage in meeting low emission standards. Emission analysis shows that diesel engines produce considerably more nitrogen oxides when operated at variable speed than at constant speed. Since the Azipod system entails power plant engines (generators) operating at constant speeds and close to optimum power, the exhaust emissions to the environment are reduced. This environmental aspect will obviously become of increasing importance in near future, especially for the selection of machinery for ships operating on costal routes.

Environmental Impact

1 Reduced exhaust emission.
2 Improved safety by :
   - System redundancy.
   - Equipment reliability
   - Excellent maneuverability.

3. Very efficient in dynamic positioning.
   - Need for anchoring and erosion of sea bed decreases.

Other Features

i. The amount of heat generated is far less in the system.
ii. Long lasting equipment.
iii. Recycling.
iv. Easy disposal of material and parts.

Protective Features

The propulsion system includes several protective functions.

Major goal for the protections is to prevent "black out situations". In normal circumstances the propulsion system is the biggest consumer in the electric network of the ship. Therefore the protective function of Azipod is to ensure that propulsion system itself does not generate blackout conditions. In order to know the amount of the available power and the number of generators connected, the propulsion system supervises the status of the supply network, the status signals for the breakers as well as the generators loads are essential for network monitoring.

Overload prevention or component malfunction may require propulsion power reduction. Possible reasons for reduction are explained in the following sections.

(a)Available Power in Supply Network

Azipod control calculates the available power for propulsion system. It depends on the generators and consumers connected to the network.

(b)Prime Mover Overload Limit

The prime mover load limit control works in such a way that the power of any prime mover will never exceed nominal value.

Corrosion Protection:

Azipod corrosion protection is performed with galvanic zinc anodes secured on the shell plating and azipod housing. Material selections are based on both sea and fresh water environments. All material combinations are carefully studied to avoid corrosion.

Machinery Onboard

The power plant's engines that drive the electric generators on today's azipod-propelled vessels are of two basic types:

- Diesel
- Turbine.

Diesel engines operate on the same principles used in cars and trucks that is Interrnal combustion engines. Turbine engines are similar in design to those on jet airplanes. One of the many criteria that the ship consider in choosing the engine type was the environmental impact of the exhaust smoke from ship funnels. Environmentally friendly, smokeless power-generation systems release no soot or visible smoke. Smokeless engines for the power-generation system would be ideal. Today many ships have advanced-design turbine engines that approach this smokeless goal, partly by using a more refined, cleaner-burning fuel.

Latest Developments in Azipod Technology:

The first version of the Azipod system was developed for icebreakers, passenger ships, and tankers. The latest Azipod generation, currently in the launch phase, is known as the CRP (contra-rotating propulsion) Azipod, developed jointly by ABB and Samsung, this is suitable for a wide range of ships, from oil and LNG tankers to RoRo vessels. Based on the principle of contra-rotating propulsion (CRP), this new system consists of a conventional propeller system and an Azipod rudder-propeller rotating in opposite directions. The Azipod unit is located in line with the shaft-driven main propeller, without being physically connected to it, and offers an alternative to designs that use two propeller shafts.

Contra-Rotating Propulsion (CRP)

More than 100 Azipod systems have been delivered to date, for use in liners, ice-breakers, supply ships, drilling rigs, and car ferries; the combined operating life of these units already exceeds 600,000 hours. The majority are first-generation units. A total of eight Compact Azipod systems have been delivered, and orders have been secured for a further 25. The Queen Mary 2 plans to have a maximum speed of 30 knots,which will be helpful in establishing a regular trans-Atlantic schedule of crossings, even in midwinter's stormy weather.

With the launch of the CRP Azipod system, the sales potential of the technology has been further extended. Two RoRo vessels fitted with the CRP Azipod system will be delivered to Japan's Shin-Nihonkai Ferry Company in 2004. Displacing 17,000 GRT, these vessels will be the largest and fastest ships of their size in Japan.

Conclusion:

From the discussions done in the last pages, it is obvious that The Azipod propulsion gives rather noiseless and vibration less, comfortable transportations, more carrying capacity, high maneuverability as well as very flexible layout in terms of design. This system has a very flexible power system and the requirement of spare parts is even low then the conventional ones.

However, there are certain defects and technical flaws in each of the systems be conventional or unconventional one and considering all of the factors involved, we, the authors feel that for the present time Azipod systems will be in vogue and with the development of new technologies.

Vessel	**Type**	**Power** (MW)	**Azipod units**
MV Seili	Bouy Tender	13	1
MT Uikku	Product Tanker	11.8	1
MT Lunni	Product Tanker	11.8	1
IB Rothelstein	Icebreaker	1.1	2
IBSV Arcticaborg	Icebreaking supply vessel	3.3	2
IBSV Antarcticaborg	Icebreaking supply vessel	3.3	2
IB Bothnica	Multi-purpose icebreaker	8	2
MT Newbuilding1	Tanker	20	1
MT Newbuilding2	Tanker	20	1

(details till 2001)

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