Studio di Ingegneria Navale e Meccanica

FOCUS ON PROPULSION PODS

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Introduction

During the course of 20th century the knowledge of ship hydrodynamics has advanced, leading to substantial improvements in the following hull features:

- Hull form in general;
- Bulbous bow;
- Pram stern;
- Trim wedge;
- Rudders;
- Brackets;

and:

- to increase the propeller efficiency;
- while decreasing the propeller induced excitation;
- to increase the fin stabilizers efficiency.

The last decade has witnessed the introduction of propulsion pods.

Propulsion pods

Propulsion pods are gondola shaped devices, hanging below the stern of a ship, which combine both the propulsive and the steering functions. Propulsion is achieved by means of fix pitch propeller, in pusher, tractor or tandem configuration, driven by an electric AC synchronous motor fitted inside the pod. Steering is achieved by means of slewing gears, fitted in the hull, above the pod, capable of rotating the pod over the entire circumference.

A propulsion pod comprises the following sub systems:

Inside the propulsion pod:

- Fix pitch propeller;
- Electric AC synchronous motor;
- Exciter;
- Propeller shaft;
- Propeller shaft thrust and support bearings;
- Shaft propeller brake;
- Propeller shaft seals;
- Bilge pumps;
- Monitoring and control equipment

Outside the propulsion pod:

- Steering unit;
- Lubricating oil equipment;
- Ventilation and air cooling unit;

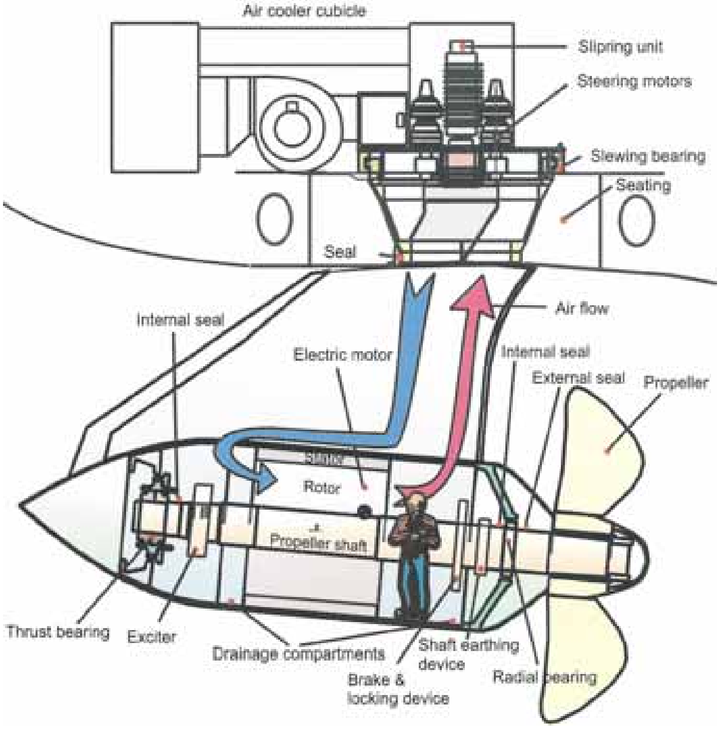

Fig. 1: Alstom – Rolls-Royce Mermaid general arrangement.

Advantages

The following advantages have been claimed for the propulsion pods:

1. Plant and automation simplification by employing the “All Electric Ship” concept;
2. Reduced exhaust gas emissions;
3. Flexibility in machinery arrangement;
4. Reduced number of main components (in particular lack of reduction gears);
5. Fuel savings, through good hydrodynamic efficiency;
6. Low noise and vibrations, due to an almost uniform wake field;
7. Excellent manoeuvring characteristics, also at slow speed and during berthing operation (the steering capability of pods is far superior than that of rudder and stern thrusters);
8. Space savings in general arrangements;
9. Minimised crash stop distance;
10. Easier shipyard logistic and construction.

Looking deeper into the matter it can be observed that points 1 to 4 are typical of the “All Electric Ship” concept, which can be implemented also without propulsion pods; moreover, point 5 is still much controversial and should be evaluated case by case.

It can be therefore concluded that only the last five points are of real importance when considering the installation of a propulsion pod: it comes as no surprise that, to date, cruise vessels have been, by far, the predominant market for propulsion pods.

Disadvantages

Propulsion pods suffers from the following disadvantages:

- Power losses due to electric propulsion;
- Higher capital costs;
- Limitation in power per screw (circa 30 MW vs. 70 MW).

It must also be considered that propulsion pods cannot be fitted on single screw two stroke Diesel engine powered vessels, but this is more of a nuisance, since propulsion pod installation on such vessels should be disregarded, as a general rule, due to the lower propulsion efficiency.

Failures

Propulsion pods cannot be considered a mature product featuring a sound and proven engineering yet; this strong statement can be supported by remembering that: the first propulsion pod was installed on M/V “Seili”, by ABB, in 1990 only and that the power rating of said installation was just 1 MW, well below the latest 30 MW designs.

Despite the fact the propulsion pods are not an innovative product per se, but an innovative packaging of systems and components used for many years both in the industrial and marine field, they have been affected by:

- Electrical failures;
- Thrust and support bearing failures;
- Shaft seal failures;
- Lubricating oil contamination (both by debris and water).

Electrical failures have been determined by high temperature / hot spots on the windings; lower temperature could be achieved by low inductive currents (e.g. using permanent magnet electric motors), adequately dimensioning the windings and the cooling flows. Electrical insulation problems have also been experienced. From a typical case study on a passenger cruise electrical ship it can be observed that the critical components of the electrical system are the electronic switching devices of the converters, whose MTBF is in the range of 30.000 / 40.000 hours.

Thrust and support bearing failures have been determined by arguable bearing choices in arrangement, type and size (exactly as it has been the case for some reduction gears). Whirling and gyroscopic loads have to be correctly accounted for at initial design stage. Temperature rise of shaft, rotor and structure has to be calculated and the bearings have to allow the differential thermal elongation of the shaft. For instance, the old ABB Azipod radial support bearing, of double crown roller spherical type, was allowed to move axially only due to a design radial gap between outer ring and housing, of course, such type of installation gave rise to fretting. Nowadays, ABB, as all other propulsion pods manufacturers, employs SKF CARB bearings, which dispense from such radial gap but require radial gap between tracks and rollers: yet another questionable choice. Also the thrust bearing assembly is not always representative of the state of the art: to install only two thrust bearings in X (face to face) configuration, without any radial support bearing in between, is hardly advisable, not only because of the higher load acting on the loaded thrust bearing, but also because of the possible divarication of the unloaded thrust bearing, worsened still by whirling phenomena. It has to be remarked that all propulsion pods sport, to date, roller bearings only, and that such bearings are much more critical in respect to vibrations and lubrication than plain bearings (which were foreseen on the first propulsion pod patent dating 1955).

Shaft seals of propulsion pods do not differ from the ones of conventional propulsion arrangements but the presence of inaccessible spaces, electrical components and roller bearings make them much more critical. Failures could be related to whirling phenomena neither correctly evaluated in design stage nor adequately supported by bearings and seals. Pneumatic emergency seals are a very effective safety device, their installation should always be requested.

As far as lubricating oil system is concerned every effort must be spent in order to achieve debris and water free lubricating oil. Nowadays automatic self cleaning filters (cartridges filters should be always avoided in propulsion application) can reach down to 10 μm absolute mesh, guaranteeing optimum lubricating oil conditions. Water contamination, both from shaft seals and cooling air humidity, must be avoided either through coalescent filters or separators. To reach NAS 6 quality for lubricating oil, as sometimes required by propulsion pod manufacturers, in connection with filters varying from 12 to 30 μm mesh, is far from acceptable, as can be seen in the table below as per NAS Document N° 1638 – Contamination Criteria.

NAS Document N° 1638, CLASS 6		
Particles dimension [μm]	**Particles per liter**	**Authors' notes**
200	160	**NOT ACCEPTABLE!**
100	900	**NOT ACCEPTABLE!**
50	5.060	Arguable
25	28.500	Acceptable
15	160.000	Acceptable

To find in the lubricating oil system, after a correct flushing, debris and particles having size greater than the filter mesh is possible only if the system is wrongly designed (e.g. no forced lubrication but a "wet sump" instead) or if the filters have some gaps bigger than the mesh (yes, as strange as it might sound, such filters are present on the market). Inspecting lubricating oil schemes it can be found that filter bypass valves are often present: this is, in our opinion, a very poor and very dangerous design solution, that every conscious Owner should refuse (albeit it is accepted by all Classification Societies).

Propulsion pod supporters could claim that also conventional Diesel propulsive installations have been suffering failures, most noticeably reduction gears ones. This is true. Still, a big difference exists, as explained in the following.

Accessibility

Conventional Diesel propulsive systems are known throughout the world, in every port it is possible to find trained personnel and to carry out repairs (temporary if not definitive), very seldom it is necessary to dry dock the vessel in order to perform repairs.

For vessels equipped with propulsion pods the scenario changes completely. Due to the fact that, often, it is not possible to carry out repairs of the pod from within the pod, many failures require the ship to be dry docked, thus, in such case, a free drydock has to be found in the area in which the ship is operating, a task not so easily accomplished.

Due to the same accessibility issue, while the crew can daily inspect the conventional Diesel propulsive system, get the feeling of the status of the various components and perform some maintenance, this is not possible in case of propulsion pods: despite remote monitoring equipment failures can be sudden, unwarned, unexpected, thus very expensive.

Moreover, many propulsion pod repairs require the withdrawal of the propeller shaft / rotor of electric motor from the pod: an time consuming procedure to be performed by highly skilled personnel, usually employed by the maker of pods, personnel who is to be flown to the dry dock together with the special equipment and tools needed to perform such operations.

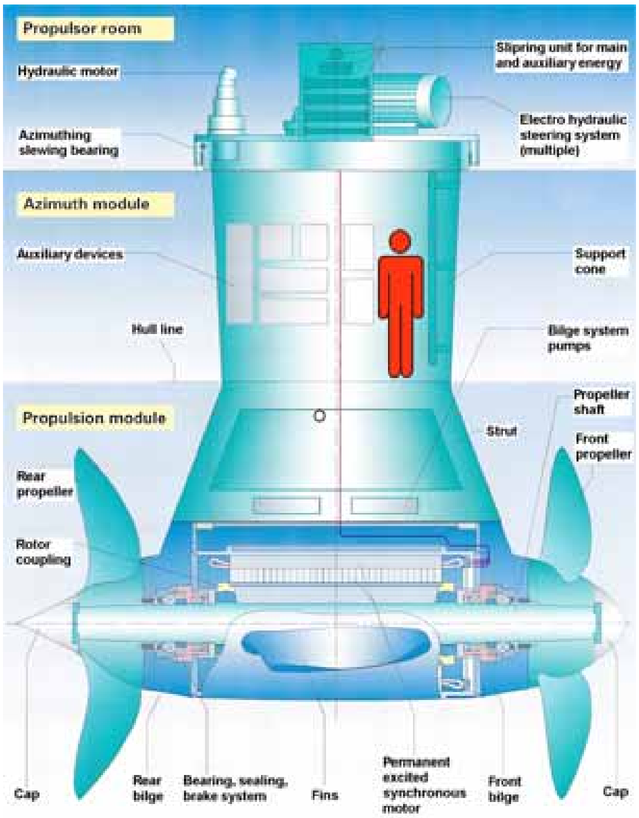

Fig. 2: Schottel – Siemens SSP accessibility.

It is true that pods manufacturer are allowing for more and more maintenance operations to be carried out from inside the pod, still this issue is not completely solved, and it never will, it can only be bypassed assuring the extreme reliability of the propulsion pods and of their components.

Propulsion efficiency

To date it has not yet been ascertained whether ships propelled with propulsion pods have a better propulsion efficiency than ships propelled with conventional shaft lines. Several researches have been carried out in the past but they have been focused on some particular aspects rather than the general one. All such comparison should be made between state of the art configurations, i.e. same main dimensions but possibly different hull lines and different propellers.

As general rule the following table applies, global efficiencies are listed in decreasing order:

Single Screw Ship type			
Propulsion	**Shafting**	**Screws**	**Notes**
Mechanical	Conventional	1	
Electrical	Pod	1+1, contra rotating	Not yet available
Electrical	Conventional & Pod	1+1, contra rotating	
Electrical	Conventional	1	
Electrical	Pod	1+1, tandem	Power limitation
Electrical	Pod	1	Power limitation
Twin Screw Ship type			
Propulsion	**Shafting**	**Screws**	**Notes**
Electrical	Pod	2+2, contra rotating	Not yet available
Electrical	Conventional & Pod	2+2, contra rotating	
Mechanical	Conventional	2	
Electrical	Pod	2+2, tandem	Power limitation
Electrical	Pod	2	Power limitation
Electrical	Conventional	2	

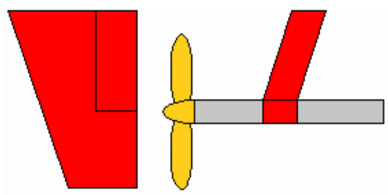

Fig. 3: Conventional shafting.

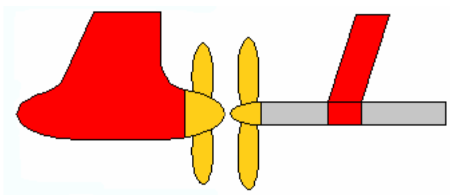

Fig. 4: Contra rotating conventional + tractor pod.

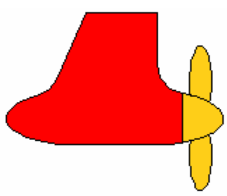

Fig. 5: Tractor pod.

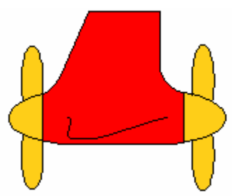

Fig. 6: Tandem pod.

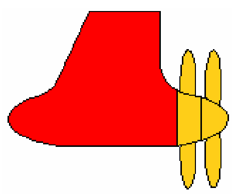

Fig. 7: Contra rotating pod.

Present propulsion pods

Four different propulsion pods are being marketed (low power propulsion pods not being considered):

- ABB AZIPOD
- ROLLS-ROYCE – ALSTOM MERMAID
- SCHOTTEL – SIEMENS SSP
- STN – WARTSILA DOLPHIN

ABB AZIPOD, ROLLS-ROYCE – ALSTOM MERMAID, and STN – WARTSILA DOLPHIN are similar, the main differences are bearing disposition and cooling philosophy; in general it can be observed that ABB AZIPOD more conservative solutions have been adopted. It has to be remarked that STN – WARTSILA DOLPHIN is no longer being marketed.

Fig. 8: MERMAID

Fig. 9: DOLPHIN

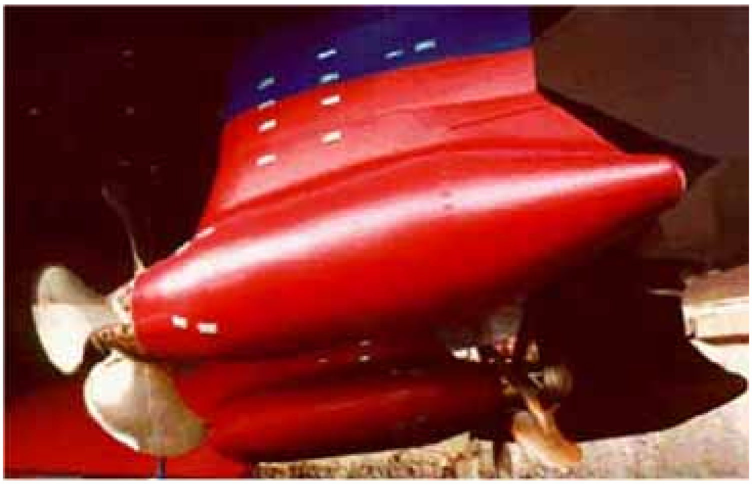

Fig. 10: AZIPOD

SCHOTTEL – SIEMENS SSP sports some unique and distinctive features that deserve attention:

- the permanent magnet motor allows a slender body and eliminates the exciters (which have been source of many problems in the past);
- no air cooling is present: all the heat generated by the stator (permanent magnet rotors are free of Joule effect) is water cooled (internal fresh water on the upper part, just below the strut, external sea water on the remaining part);
- the rotor is fastened to the propeller shaft via two lamellar couplings, which allow the rotor thermal elongation without elongating the propeller shaft and, thus, without stressing axially the bearings;
- the bearing arrangement (two support and two thrust bearings) is very interesting and should prove adequate;
- fins installed between the two propellers are needed to recover part of the swirl of the first propeller, decreasing the inlet tangential velocities of the second propeller;
- the tandem propeller should result in an increased propulsion efficiency.

Fig. 11: SSP.

Future developments

In order for propulsion pods to expand their market share beyond the rich niche of cruise vessels some developments are in order; the most important ones are also the most natural ones, experienced by each and every apparatus:

1. to increase their reliability
2. to increase their efficiency (compared to conventional arrangements)

Little is to be said about reliability: it is already being improved, optimum reliability will be achieved in the very near future.

The efficiency picture is less straightforward, also taking into account the new generation of flow optimised rudders.

Gondolas could be further optimised, both in size and shape; such optimisation could also lead to increased cooling due to torpedo / sea water interaction.

High efficiency / low vibration CLT propellers have to be employed in order to reduce the propulsion power at constant thrust, thus reducing the loads.

The possibility of installing controllable pitch propeller, at the moment negated a priori by all manufacturers, should be investigated. It has to be noted that to install CP propellers would allow much faster and safer emergency manoeuvres. Taking into consideration an crash stop, CP propellers would immediately start decelerating the ship as there would be no need to stop the propeller and to start revolving it in the opposite direction (to keep the shaft revolving while rotating it 180° is out of question due to the very high gyroscopic loads), furthermore the large polar moment of inertia of the revolving shaft plus propeller plus water corresponds to a large amount of energy to be dissipated, in case of FP propellers, by breaking devices, generating large amount of heat to be quickly and efficiently carried away from the pod. Not a nice scenario indeed.

Propeller arrangements should be further investigated, tractor arrangements are the present standard, tandem propellers have been installed, contra rotating propellers installed on a single pod are being studied, the best solution, to date, would seam a conventionally pusher propeller and a podded tractor propeller, in contra rotating configuration (Fig. 4); controllable pitch propeller forward and fix pitch propeller aft or both controllable pitch propellers, the optimisation of the two configurations could be an interesting exercise for propeller designers.

Conclusions

Propulsion pods are a very interesting and promising system, and the first company to design and produce an extremely reliable pod will have a great success in the shipping market, not only in regard to cruise vessels. In order to do so the causes of failures should be thoughtfully considered and the relevant redesign actions should be taken.

The present state of the art allows to design and to manufacture an extremely reliable propulsion pod, free from any recurrent failure.

While waiting for such propulsion pod to be designed, the advantages of pod propulsion over conventional propulsion cannot be blindfoldly accepted: before choosing a propulsion pod, an Owner should always contact his consultants in order to compare the advantages and disadvantages of the various propulsion pods against each other and against other propulsion configurations.

Please contact us for further details

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