DE GRUYTER OPEN
International Conference KNOWLEDGE-BASED ORGANIZATION
Vol. XXIV No 3 2018

PROPULSION SYSTEMS IN MARINE NAVIGATION

Gheorghe SAMOILESCU*, Dumitru IORGULESCU, Robert MITREA***, Laura D. CIZER***

***"Mircea cel Bătrân" Naval Academy, Constanța, Romania**
****Port Crewing, Portugal**
*****CMC SHIPS Company**
samoilescugheorghe@yahoo.com

Abstract: *This paper presents variants of propulsion systems as the main factor in the analysis and design of the power system of a sea-going or river vessel; this topic is also under research study within two doctoral theses. The analysis of the ship - main propulsion- thruster assembly is made according to the requirements imposed by the market economy. The parameters to be considered when choosing a propulsion system are: the cost of the investment, the specific cost of transport that depends both on the specific fuel consumption and on the number and level of pay of the crew members operating the propulsion system, the propulsion efficiency, the high safety in handling, and the control accessibility during operation.*

The Pod and Azipod propulsion systems are analyzed in terms of advantages and disadvantages compared to conventional propulsion systems. The azimuth thrusters can ensure maximum push in any direction regardless the speed of the ship, and thus can change the course of the ship according to its handling needs. The azimuth thrusters do not only operate in horizontal but also in oblique angles, providing the ship with great maneuverability, even at low speeds, where classical rudder systems have poor performance.

Keywords: propulsion system, AZIPOD – Azimuthing Podded Drive, energy system, ship handling, thrusters

1. Introduction

The development of shipbuilding is closely related to the evolution and improvement of propulsion systems. A marine propulsion system converts a primary form of energy into mechanical energy that is conveyed to the propulsion, with a view to overcoming the resistance of ship's advancement in order to set it on the desired direction and at the required speed. From an energy point of view, a marine propulsion system consists of the power source (the main propulsion machine) and the energy consumer (the thruster). Among the current marine thrusters, the propeller best caters for the current naval technique, being the most frequently used and generally the most efficient type of marine propulsion. The propulsion system plays a decisive role in turning a regular ship into an economical and top of the range one. The efficiency of a ship is acknowledged on the basis of several criteria such as: economic, operational safety, crew and passenger comfort ones. The analysis of the *ship – main propulsion system – thruster* combo needs to be conducted during the initial stages of the ship's design, and the propulsion system to be used also needs to be chosen at an early stage since it will have a strong impact on the design of the ship itself.

DOI: 10.1515/kbo-2018-0140

The choice of the propulsion system of the ship involves the integration of a large number of elements into a functional space, the selection of its components (main propulsion machinery, transmission and thruster) and their adjustment according to the constraints imposed by the other elements, as well as their arrangement so that the system comply with the required performance, a satisfactory configuration and an acceptable cost price. In addition, the choice of the propulsion system must reflect the ship's operating profile, and also the analysis of the technical and economic performance of the propulsion system in order to reduce the specific cost of transport and to enhance operational safety. The parameters to be considered when choosing a propulsion system are: the initial investment cost, the specific cost of transport that depends on the specific fuel consumption and on the number and level of remuneration of the crew serving the propulsion system propulsion, the propulsion efficiency, the space allotted to the propulsion system, the operating safety and control availability during operation.
Finally, the choice of a propulsion system involves: determining the power necessary on board to reach the desired speed, choosing the type of propulsion system, the main propulsion machinery and thruster, and setting the propulsion system on board the vessel[1]. The solutions that have been adopted for the propulsion system onboard passenger ships are special due to necessary high comfort[2]. The final choice has been a turbo-electrical propulsion system with gas turbine generators and an electric motor driven propeller; the motor - propeller system has been mounted outside in a unit named AZIPOD[3,4].

2. POD and AZIPOD propulsion systems

A marine propulsion system has a direct effect on the weight, size, speed, maneuverability and layout of the ship. The newer and stricter rules in shipbuilding and sailing have led to the emergence of new naval equipment, new propulsion systems that have changed ship arrangements for economic and efficiency considerations.
An alternative to reducing the space dedicated to the propulsion system onboard ships is to use PODS and AZIPOD propulsion systems[6,7].
Also, an alternative to reducing the space dedicated to the propulsion installation onboard ships is to use this system in which transmission of the rotation moment from the main propulsion engine to the thruster is performed by a mechanical transmission in **L** or **Z**. The propulsion system that uses an **L** or **Z** transmission between the main propulsion and the propeller and that can also steer the ship by turning the thruster is known as the *steerable thruster unit*.
The azimuth thrusters make maximum pushing in any direction, irrespective of ship's speed, while changing its direction depending on the steering needs of the ship. The propellers of azimuth thrusters act not only in axial current but also in oblique current, providing the ship with a particularly high maneuverability even at low speed, where classical rudder systems have poor performance. The azimuth thruster system with counter-rotating propellers is a system that combines two ideas: the idea of the counter-rotating propellers to divide propulsion power on two active discs without performance loss occurring in a conventional twin-screw ship, and the idea of an azimuth thruster system that innovate both maneuverability and compartmentalization by significantly reducing the engine room space.
There is a retractable azimuth thruster version, which in normal operating position can develop maximum push in any direction, the thruster having the ability to rotate 360°. The propeller located in a Kort nozzle can be housed in a tunnel placed in the hull, while the propeller acts in this position as a transversal thruster - the *Bow thruster*. The (orientable) Azimuth thruster is considered to be the most widely spread and also the "oldest" product of the

propulsion and governance systems, yet characterized by low powers. A newly distinct concept is the AZIPOD thruster system, which extended the range of power used. The drawbacks of Z and L transmissions are linked to the power limitation which is transmitted to the thruster and to the mechanical losses that can be avoided by mounting an electric motor in a hydrodynamic body (a "pod") placed under the ship. Here, the electrical energy produced aboard the ship is transferred to the AC electric motor which directly transmits the moment of rotation of the propeller-type thruster. Thus, in the shipbuilding industry a revolutionary propulsion system has appeared, which is known as "Pods - podded drive", and where the shaft line has been replaced by a compact propulsion unit, placed in a bulb with hydrodynamic forms under the ship. These compact propulsion units show a number of advantages related to the small space occupied by the ship system, the flexibility of the electric propulsion, the possibility of continuous speed control, and easy reversibility. A modern propulsion system that successfully fulfills the requirements of flexibility, minimal occupancy and provides the ship with extraordinary maneuverability is the **AZIPOD** (Azimuthing Podded Drive) propulsion system[8].

The propulsion system is embedded in an optimized hydrodynamic module located beneath the ship's hull that can rotate 360°. The high-powered AC electric motor is located in this module and directly transmits the rotation to one or two propellers. This system replaces the classical propulsion and steering systems, and it ensures both the propulsion of the ship and its steering-a new system[9,10]. The POD and AZIPOD thruster systems combine the advantages of different types of propulsion systems. In this respect, they eliminate the classic components of a propulsion system such as: long shafts, reducer, adjustable pitch propellers, etc; they reduce the space occupied by the propulsion system engine room on board the ship, in favor of cargo or passenger spaces; they also reduce noise and vibration levels; they ensure operational safety, low fuel consumption as well as low maintenance costs; in addition, they are solid and easy to build and assembly; they ensure both the propulsion and steering of the ship, provide the ship with special maneuverability in rough weather conditions as well as at low speed, where classical rudder systems have low efficiency; they eliminate the classic components of a steering gear: the rudder, the rudder engine, the bow thruster, etc. The problem regarding the position of the propulsion engines and the shaft lines is also discarded, since the on board space occupied by the engine room is substantially reduced in favor of the space occupied by goods or passengers; finally, the liberty to place the components of the propulsion system reduces design and construction costs.

The hydrodynamic advantages are obtained from the position of the propeller in the thruster in relation to the angle of attack. The position (in the horizontal and vertical plane) and the angle of the propulsion unit can be chosen so as to obtain an optimal distribution of the field gear in the thruster disk. This disposition in a favorable current increases the efficiency of the thruster and has positive effects on the fluctuations of the non-stationary forces induced by the operation of the thruster and the pulsations of the aft vault. This leads to the **reduction in the noise and vibration levels** induced while operating the thruster, which provides crew and passengers with **greater comfort** on board ships; from this point of view the POD thruster system has definite advantages over conventional drive systems with shaft line. From the point of view of power transfer $^{Pd}/_{Pb}$, the shaft line transmission and the POD systems are approximately equal, (Pd - the thruster available power, and Pb - the power delivered by the main propulsion system). The POD type propulsion systems can be provided with one or two propellers, which can be with or without skew. These systems work at different speeds; therefore, the POD and AZIPOD systems do not require variable-pitch propellers because the use of fixed pitch propellers can lead to substantial economy and simplification of the thruster construction. The propeller can be located either before or behind the bulbous bow. A ship equipped with AZIPOD thruster propulsion **provides the ship with a special maneuvering capacity**, and the ship no longer requires classical rudder systems and transversal steering gear such as the bow thruster. From the point of view of maneuverability of the ship, AZIPOD propulsion systems have definite advantages over classic propulsion systems; their use increases the maneuverability of the ship by reducing fuel consumption. For example, by replacing a classical propulsion thruster with an Azipod thruster system, a decrease of 35% in ship diameter was achieved. The astern going of the ship can be achieved by changing the direction of rotation of the propeller or by rotating the Azipod. Due to the use of electric motors, changing the direction of rotation is done by changing the polarity, which requires only 20 seconds to switch the ship from going ahead to going astern. Also, the entire Azipod system can rotate 180 degrees in 22.5 seconds. The crash-stop distance is reduced by half. The SSP consortium formed by Siemens and Schottel have created a new Azipod thruster system with power values ranging from 5 to 20 MW per unit, which can be used successfully for any type of ship requiring high power consumption and outstanding maneuverability. This propulsion system can operate up to 20 MW per unit and can be used for ships requiring frequent power shifts: cruise ships, ferries, etc. The system is provided with two propellers mounted on a common shaft, located in front and behind the hydrodynamic module. The total load is divided on the two propellers that rotate in the same direction. This makes it possible to reduce the diameter of the propellers and the dimensions of the hydrodynamic module that contains the engine, with a positive effect on the increase of the overall efficiency of the thruster[9,10]. Fins are mounted on the hydrodynamic module that smooth the flow and have the role of canceling the tangential speed components induced by propeller 1- located towards the bow before the beginning of the march. There are obvious advantages of Pod and Azipod thrusters systems in terms of hydrodynamic efficiency, use of space on board, etc. The main disadvantage of these propulsion systems is the high price compared to a classic shaft line propulsion system. The Pod system is a compact propulsion unit that has a significant part of the propulsion system preassembled within[11,12] as shown in figures 1,2.

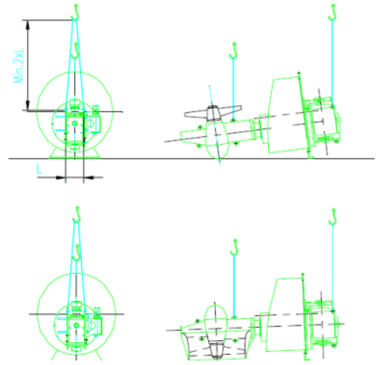

Figure 1:Position of azipod system in rest.

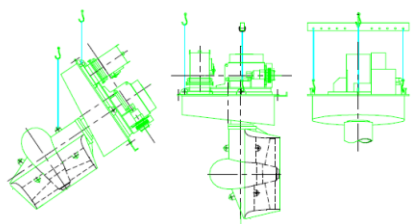

Figure 2:Position of azipod system in use.

3. Conclusions

A Pod system replaces much of the work that is done into the workshop, knowing that this kind of work more productive than the one that is performed on-board. As far as operating expenses are concerned, due to the increase in propulsion efficiency, fuel consumption can be reduced. Reducing the space occupied by the on board propulsion system by moving the large on-board power engines to the module placed under the ship, simplifying the ship's aft shapes, and friendly-user installation make these Pod and Azipod thruster systems be successfully in current use onboard passenger ships, oil tankers, icebreakers, etc. The lack of long shaft lines, rudders and rudder systems will lead to an increase the in the volume destined to carry cargo. This propulsion system is suitable for a wide variety of aft shapes of the ship's hull, making it easier to design the aft extremity of the ship's hull and the engine room. The advantages of using modern propulsion systems, plus the increased ship maneuverability do explain the attractiveness of these propulsion systems despite their initial high costs. It is also expected that by increasing labor productivity and designing, building and assembling expertise in the future, the prices of Pod and Azipod thruster systems drop, and more likely set an important milestone in the history of shipbuilding all around the world.

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