PROPULSION CHARACTERISTICS OF MULTI-MODE SHIPS IN ASPECT OF SHIP'S DYNAMIC POSITIONING APPLICATION

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Abstract

The dynamic positioning systems require multi-element ship propulsion application. The chosen solutions have decisive effect on propulsion system possibilities, in ship dynamic positioning accuracy also. The automation system has an essential influence on it, because it is an integral part with propulsion system responsible for this process. The most often ship propulsion solution based on unconventional thrusters driven by electric motors also. A few independent propulsion systems is essential but it complicates this system, it is limited the number (most often to 4, seldom more up to eight). There are no solutions with traditional rudder and steering gear. These functions take over azimuthing thrusters because they can generate directional thrust force. It must be settle the question of the number of thruster choose and the span angle of azimuthing (most often by thruster turning). In that case it gets the possibilities of ship positioning, they may display as propulsion system characteristics, giving a view on quality of positioning process. The last verification is made in real sea conditions when it may test if chosen solution of ship propulsion system fulfils the requirements of positioning accuracy. It was presented the examples of multi-mode ship propulsions and parameters of theirs propulsion plants.

***Keywords**: ships propulsion, propulsion characteristics, multi-mode ships, dynamic positioning systems*

1. Initial remarks

The first vessels with dynamic positioning system, EUREKA and CALDRILL, were equipped with small rotatable thrusters. Since the early 1970s, the larger (1500 kW and above) rotatable thrusters became the predominant propulsion devices for self-propelled drilling semisubmersibles. The first DP semisubmersible, SEDCO 709, was built in 1975 with eight rotatable thrusters of 2250 kW each. Ship-shaped vessels also utilized rotatable thrusters: the converted DP vessel WIMPEY SEALAB was retrofitted with retractable thrusters for stationkeeping propulsion. New designs of DP drillships (Amoco/Transocean, Conoco/R&B) use azimuthing thrusters exclusively for stationkeeping as well as for transit. The major advantage of a rotatable thruster is its capability to deliver thrust in every desired direction [5].

The first full-size DP drill vessel exclusively equipped with propulsion devices which allow control of thrust in 360 degrees is the SAIPEM DUE. This vessel is equipped with Voith-Schneider cycloidal (VSP) propellers. A new trend in the design of DP drillships started in 1996. Amoco in cooperation with Transocean Offshore Inc., as well as CONOCO in cooperation with Reading & Bates, designed a new generation of DP drillships [5, 10]. These vessels are considerably larger than any previously built drillships. They all differ in several features:

- the hull is optimized for the application as drillship, not for transit speed;
- the vessels are not equipped with a conventional main propulsion system augmented by transverse thruster for stationkeeping. They are exclusively equipped with azimuthing thruster which is used for stationkeeping and transit propulsion. This feature increases the stationkeeping efficiency, but increases considerably the draft of the vessels.

New conversions include the Diamond Offshore OCEAN CLIPPER. This vessel uses the stern propulsion system in conjunction with five transverse tunnel thrusters and one azimuthing thruster [5]. The upgrade of the Glomar EXPLORER (Fig. 4c), originally equipped with a main propulsion system and five transverse tunnel thrusters, includes the installation of four additional azimuthing thrusters.

Propellers with fixed pitch and variable RPM are used on most U.S. drillships (Transocean Offshore Company, SEDCO, Global Marine); European drill vessels (PELICAN series) use controllable pitch propellers operating at constant RPM [5].

2. Installation types of rotatable thrusters of multi-mode ships

There are some possibilities for installation types of rotatable thrusters of multi-mode ships:

- Bottom mounted thrusters: In a ship-shaped hull, the simplest type of installation of a thruster is a permanent bottom mounted type. The thrust unit is mounted into a base in the bottom or stern of the vessel. This type of installation requires drydocking of the vessel for maintenance on the underwater part of the thruster (Fig. 1).

Fig. 1. Podded CRP propulsion is used in Hamanasu, built at MHI [2]

- Encapsulated thrusters: The first installations of rotatable thrusters featured the encapsulated type. The thrust unit is installed in the bottom of a watertight container. The prime mover and auxiliary machinery for cooling, lubrication, pitch control and steering hydraulic are installed inside of the capsule. For navigation of the semisubmersible in shallow water, the entire capsule is retracted into a shallow water stowage position. The retraction is accomplished with the assistance of a crane barge or a special onboard lifting arrangement (this is not a "retractable thruster"). For major overhauls, the entire capsule is lifted on the upper deck of the semisubmersible. The weight of an encapsulated thruster of 1500 to 2250 kW is 100 to 120 tons. This type of installation is also applied on the DP drillships GLOMAR EXPLORER. She will be equipped with 4x2250 kW encapsulated thrusters in addition to the transverse tunnel thrusters [5]. During manufacture, the entire propulsion system is assembled, with all cabling, piping, etc. The system can be functionally tested -the power train with full propeller RPM, the azimuth drive, the pitch control system, etc. The interface with the shipyard is minimized, thus reducing construction time.
- Rectractable thrusters: This type of propulsion is often offering as a option of bow or stern thruster with additional possibility as emergency propulsion but on DP ships seldom applied (DP drill vessels: SEDCO 445, Transocean SUPER DISCOVERER and DISCOVERER 534, SEDCO 471 and 472 use custom designed retractable transverse thrusters or AUDACIA rectractable electric thrusters) (Fig. 2).

Fig. 2. Ms. Audacia – a bulkcarrier "Geeview" (built in 2005) converted (2007) into DP pipe-lay vessel [6]

- Detachable thrusters: Today, the standard type installation of large thrusters in semisubmersibles, and (since approximately 1996) on DP drillships (Transocean, Diamond Offshore, Conoco-R&B), is a thruster which can be mounted and detached underwater while the vessel is afloat in shallow draft. The technique of this type of installation was developed by KaMeWa in the 1970s. Every major thruster manufacturer adopted the idea and is offering now its own version of a underwater detachable thruster. This type of thruster is installed in the bottom of the hull. For maintenance and/or repairs, the lower thrust unit including gear housing, propeller, and nozzle can be separated from its seating, lowered on guide cables, and removed with lifting gear. The azimuth drive, the prime mover, and the auxiliary machinery systems remain installed inside the vessel.
- VSPs thrusters: The PELICAN DP drill vessel series was originally designed with VSP propulsion. Propulsion tests with model VSPs were conducted at the Netherlands Ship Model Basin. The performance of the VSPs was far below the expected values. The design was subsequently changed and a conventional propulsion system was installed in conjunction with several tunnel thrusters. Shortly afterwards the DP drill vessel SAIPEM II was built with VSP propulsion; two VSPs were installed in the stern of the vessel and two propellers in the bow. After several years of operation a retractable and rotatable thruster was installed in the bow to replace one (or two) of the VSPs [7, 11]. VSP thrusters are often applied on offshore vessels (Fig. 5).
- Azipod electric thrusters: Today, numerous vessels, ranging from offshore service vessels to cruise ships, are equipped with variable speed AC propulsion drives in conventional, in-line motor-shafting arrangements. Only a few years ago, several large electric companies started with the development of a modular steerable or azimuthing propeller drive. In this drive, the drive motor is installed inside a streamlined housing (pod). The motor drives directly (or, in some cases, through a reduction gear) a propeller. The entire housing is watertight and azimuthing for directional control of thrust. This podded propulsion device is available from approximately 3750 kW to 18500 kW. ABB recently installed 18500 kW drives. CEGELEG and SIEMENS are working on designs and proposals for electric thrusters of various sizes. This type of thruster may be applied for stationkeeping applications in power ranges above 3750 kW per thruster [5].

3. Performance and efficiency of rotatable thrusters propulsion systems

Rotatable thrusters have been built up to 5250 kW, and are available up to approximately 6000 kW, with propeller diameters up to 5.0 meters. The capability of generating directional thrust together with the high thrust output of the nozzled propeller make a well designed and optimized rotatable thruster the most efficient propulsion device for DP applications. The following possible problem areas need to be observed:

- though the propeller is not installed behind a hull (in the majority of the applications), a hull/propeller interaction can occur,
- a rotatable thruster installed on one hull of a twin hull semisubmersible may cause negative hull effects while aiming its wake toward the second hull,
- the propellers of multiple thruster installations may interfere with each other (Tab. 1).

A propeller exposed to the wake from another thruster produces a lower level of thrust. The thrust allocation logic of the DP control system has to take this fact into account by applying an "anti-spoiling logic" [5].

Tab. 1. Thrust deduction (t) fraction values for stationkeeping propulsion [5]

Speed [knots]	0	1	2	3	4
Ahead/ t	0.05	0.075	0.1	0.125	0.15
Astern/ t	0.18	0.21	0.25	0.30	0.34

For DP applications, model tests create many problems. The typical DP vessel either a semisubmersible or a conventional ship-shaped vessel is equipped with a multitude of propulsion devices. While the performance of a commercial vessel is only investigated in longitudinal direction, the performance of a DP vessel must usually be explored in every direction. A large model scale must be selected for the propulsion devices in order to achieve accurate results from propulsion tests and to limit the influence of scale effects. The hull must also be scaled to the same ratio, which leads to a model of a size which exceeds the physical boundaries of practically every model basin [1, 3].

To be effective for yaw maneuvers, the thrusters are often grouped at the bow and stern of the vessel (SEDCO 709, SEDCO 710) (Fig. 3). In response to certain vector commands, situations can occur in which the thrusters are positioned in such a way that the exit jet of one thruster is directly aimed into a second thruster. The second thruster operates in a condition of a higher advance coefficient. The thrust generated by a propeller is maximum one at zero inflow velocity or at an advance coefficient of zero. Thrust decreases with increased inflow velocity. This applies even if it is possible to maintain the power load on the propeller by increasing the pitch of an CP propeller or the RPM of a fixed pitch propeller. The minimum azimuthing angle of rotatable thruster for positioning possibility is 45° but it is preferred 360° [4, 6].

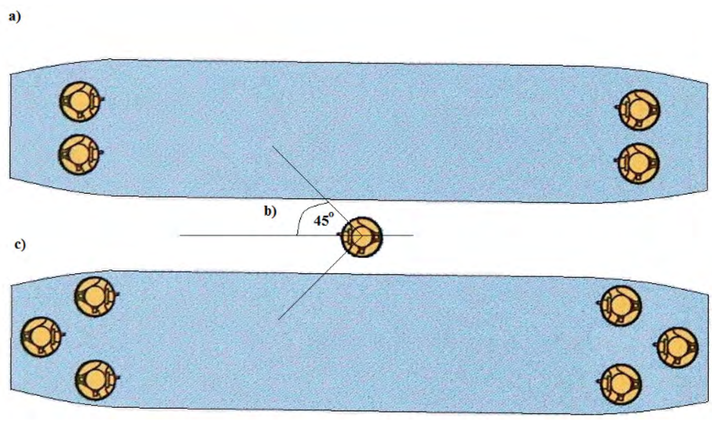

Fig. 3. Dislocation of thrusters on DP vessels: a) for 4 thrusters, b) minimum azimuthing angle for positioning, c) for 6 thrusters

On ms AUDACIA (Fig. 2) the original propulsion system has been extended with six rectractable electric thrusters, each converting 5 MW electric power. The power for these thrusters is generated in two added engine rooms. Each 5850 kW generators is base on Wartsila 9L38B engines with the six Wartsila thrusters type FS3500 of 800 kN thrust each. The total new installed electric power is 35100 kW. The original non-electric propulsion delivered only 10500 kW. The vessel is classed as a DP (AAA) vessel, which means that it can be still positioned even one of two engine rooms goes totally off-line. During sea voyage, the Audacia sails on the original direct-drive diesel propulsion system. While pipe-laying, the diesel-electric propulsion is used for dynamic positioning and propulsion. The conventional propulsion system is taken off-line.

The efficiency of the electrical system can be determined as follows: AC generators 97%, SCRs 98%, propulsion DC motors 94%, total system efficiency about 89%. In the case of a multiple high speed DC motor arrangement, the efficiency of the reduction gear must be considered (98%).

The examples of multi-mode ships were presented on Fig. 4 a, b, c and Fig. 5. There are: field development ship, cable layer ship, drill ship and offshore supply vessel. The field of versatility is wide but all the ships possess dynamic positioning systems, multi-element electrical propulsion systems and they have to operate at very low speed near zero during their typical work [9]. These multi-mode ships will be more often built because of an increase of demand for offshore specialization. The industry part of these ships may varied depend on specific type of work but the DP and propulsion systems are common and very similar.

a)

b)

c)

Fig. 4. An example of: a) field development ship SAIBOS FDS b) cable layer KNIGHT [6] c) drill ship Glomar Explorer [8]

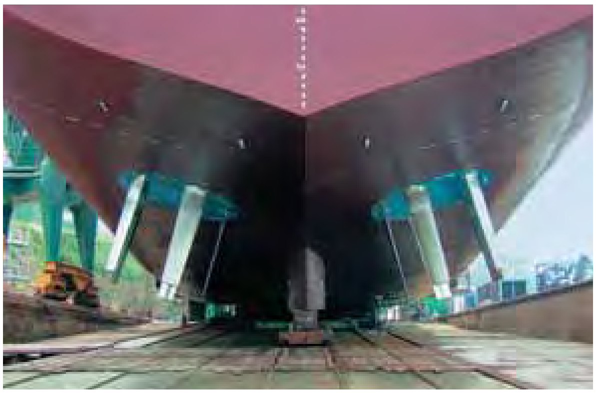

Fig. 5. Ms PSV (offshore supply vessel) with two VSPs in dry dock [11]

The technology of DP and electrical propulsion systems are still new one. It needs an experience in sea operation which it will develop and probably make many changes.

4. Characteristics of multi-mode ships propulsion

The characteristics of multi-mode ships are very useful for analysis of theirs behaviour in bad sea conditions including: the wind force and its direction, the height and type of waves, the force and direction of sea current, the ship stability etc. It allows to make an estimation of DP and propulsion systems requirements to fulfils the accuracy of positioning, often needed better than 1m. It needs special GPS system also because the differential signal from GPS and real ship position is the input signal to DP system.

It must be remembered that the possibility of fulfilment of positioning accuracy is determinate up to maximum levels of sea conditions. An example of roll stabilization test is presented on Fig. 6. It was made for offshore supply vessel PSV (presented on Fig. 5).

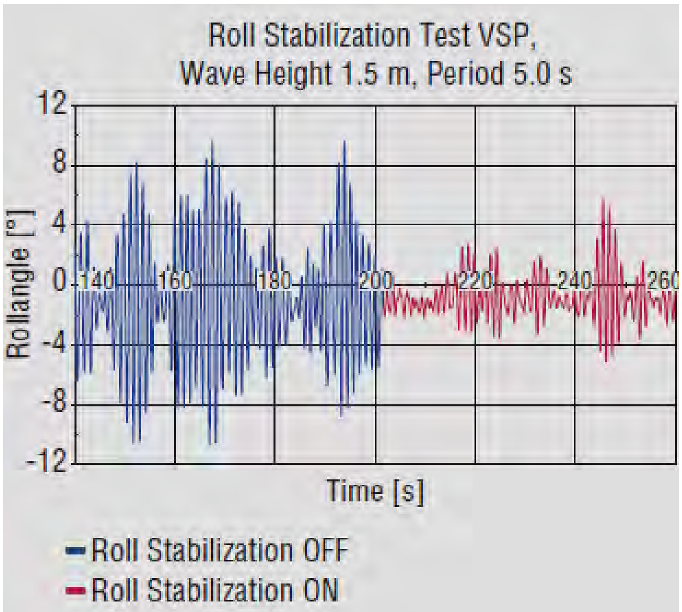

Fig. 6. Roll stabilization test of VSP for ms PSV (made by MARLIN) [11]

An example of maximum levels of sea conditions for 100% power capacity is presented on Fig. 7. The fulfilment of positioning accuracy (in that case) is possible up to 2 knots of sea current and from about 20 knots for cross-wind up to 62 knots for head-wind.

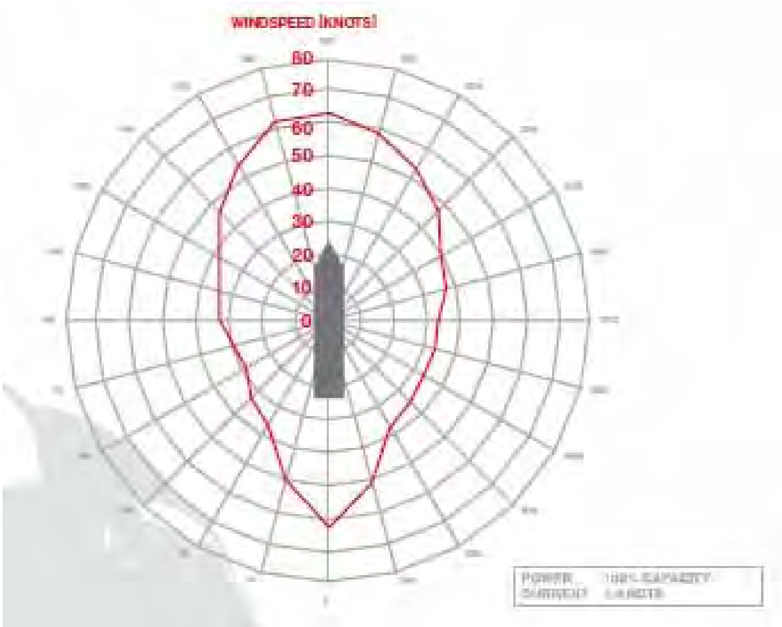

Fig. 7. Maximum levels of sea conditions for fulfilment of positioning accuracy [11]

It must be mentioned that the demand for power of DP propulsion system depends on sea conditions. During good sea conditions the demand for power is very small and the positioning accuracy depends only on the accuracy of DP automation system. When the sea conditions changes for the worse it must be increased the propulsion power for standing on. When the sea conditions are over approved levels it is necessary to abandon the normal work of ship and change for weathering.

The manoeuvring and propulsion systems of ms Jumbo Javelin (a DP2 offshore construction vessel) was presented in Tab. 2.

Tab. 2. Manoeuvring and propulsion systems of The Jumbo Javelin [6]

Main engines	2 x MAN - B&W 9L 32/40 8640 kW HFO
Auxiliary PTO generator	2 x Leroy Somer LSA56 ZL8/4P 6000 kW
Generator set	1 x MAN Holeby 8L16/24 760 ekW MGO
Emergency generator set	1 x MAN D2848LE201 368 ekW MGO
Main Propulsion Controllable pitch propellers	2 x LIPS
DP system	2 x 2000kW and 2x 3920 kW
Spade rudders (independent)	2 x Bot 16 m^2
Thrusters Bow tunnel thruster (CPP)	1 x LIPS CT200-M 1450 ekW
Bow tunnel thruster (CPP)	1 x Rolls Royce TT2400DPN-SS-CP Aft. 1500 ekW
Retractable azimuth thruster	1 x CAT 3516B 1825 ekW MGO and 1 x Wartsila FS225-240/MNR 1700 ekW

5. Final remarks

The determination and knowledge of propulsion characteristics of DP multi-mode ships are very important for the planning of work needed the positioning accuracy. The chosen solutions have decisive effect on propulsion system possibilities, in ship dynamic positioning accuracy also. The automation system has an essential influence on it, because it is an integral part with propulsion system responsible for this process. The last verification is made in real sea conditions when it may test if chosen solution of ship propulsion system fulfils the requirements of positioning accuracy.

References

[1] *The Specialist Committee on Unconventional Propulsors*, The Final Report and Recommendations to the 22nd ITTC.

[2] Sasaki, N., *The Specialist Committee on Azimuthing Podded Propulsion Report and Recommendations*, ITTC Fukuoka 2008.

[3] Rawson, K. J., Tupper, E. C., *Basic Ship Theory, Ship Dynamics and Design*, 5th Edition, B&H 2001.

[4] Leavitt, J. A., *Optimal Thrust Allocation in a Dynamic Positioning System*, 2008.

[5] Dietmer, D., *Principal Aspects of Thruster Selection*, Dynamic Positioning Conference, Houston 1997.

[6] *Lips Steerable thrusters*, Steerable Thruster Solutions, Wartsila 2005.

[7] VSP Brochure 2008.

[8] Skandi Marstein Brochure, DOF 1996.

[9] Nienhuis, U., *Analysis of Thruster Effectivity for Dynamic Positioning and Low Speed Maneuvering*, University Delft Dissertation, 1992.

[10] *American Bureau of Shipping*: *Guide for the Certification of Thrusters*,1984.

[11] *Voith Schneider Propeller for Offshore Supply Vessel*, Voith Turbo, Heideheim 2006.