

# Some Problems of Berthing of Ships with Non-conventional Propulsions

**W. Koziol & W. Galor**

*Szczecin Maritime University, Szczecin, Poland*

**ABSTRACT:** The berthing manoeuvre of ship is the last stage of navigation process. The safety of berthing depends on velocity due impact the quay. In case of ships with non-conventional propulsion (mainly two stern screws and few thrust propellers) the berthing manoeuvres are different then other ships. The paper presents an analysis the kind of ships power and their manoeuvrability features in aspect of safety berthing.

The process of navigation consists in the safe and effective passage of the ship to the port of the destination. The berthing manoeuvre of the ship to the pier is the last stage of that passage. Then dynamic influence of the ship to the berth causing definite deformations and tensions. The analyses of the manoeuvring tactics of the ship show that first contact of the ship is the most critical moment during berthing. The kinetic energy of the ship in the large part changes in the work of impact in the moment of the first contact of the hull with the berth. It depends on kinetic energy whether mooring will take place without the damages of ship and berth construction or not. It concerns all ships independently from their size, distance done or the kind of the cargo loaded. Therefore it applies to large vessels (bulk carriers, tankers) about the displacement of a few hundred thousands of tons, how and small barges, tugboats, passenger ships, the pleasure crafts (boats, motor boats, yachts) and others as well. In every case the safe end of the trip consists in berthing to the quay without appearing of losses (damages). Safe berthing is defined as such stop of the vessel near the berth so that losses do not happen. Reduction of the ship's speed to zero in the moment of impact to the quay would be the optimum way to avoid of the breakdown while berthing. It means that the kinetic energy of moving

vessel is reduced to zero. Impact is the main reason of losses during berthing where either part or whole energy gives off in the area of contact ship - berth. This energy as the work can cause negative results. It requires special devices with the aim of the improvement of the safety of berthing operations, called fenders or fender systems. The protection of berth construction and the ship when approaching to the berth or already moored to this construction is the main task o fenders.

The size of kinetic energy absorbed by the system berth - fender - ship affects the size of the strengths of the reaction of the system which decide about the failure or failure free realization of the given maneuver. Condition of the safety of the maneuver while berthing the ship to the quay can be as follows:

$$E(t) \leq E_k^{\text{berth}}$$

$$E(t) \leq E_k^{\text{ship}}$$

where:

$E(t)$  – maximum kinetic energy of the ships  
impact absorbed by the system berth –  
fender – ship [kNm]

- $E_k^{\text{berth}}$  – admissible kinetic energy absorbed by the system berth – fender [kNm],
- $E_k^{\text{ship}}$  – admissible kinetic energy, near which the formed strengths of the reaction of the system berth – fender do not cause the durable deformation of the ships hull yet [kNm].

Factors which have the influence on the size of the maximum kinetic energy of the ship's impact against the berth construction are as follows:

- ship maneuverability (kind and the power of the propulsion, thrusters),
- hydrometeorological conditions (wind, current),
- tugs service (the number of tugboats, their power),
- the maneuvering tactics (captain's skill, pilot's skill).

The design process of berth's constructions where berths various type of vessels requires the qualifications of the impact energy of these ships. The main parameters decisive about the value of energy are displacement of the ship  $W$  and the ship's speed while berthing  $v_s$ , at the same time speed comes in to the equation of energy in the square.

According to (Mazurkiewicz 2003) the displacement of the berthing ships is qualified from formula:

$$W = W_s + W_w \quad [N]$$

where:

$W_s$  – displacement of loaded ship [N]

$W_w$  – weight of additional mass of water [N]

Parameters  $W_s$  i  $W_w$  can be determined from formulas:

$$W_s = L_{pp} \cdot B \cdot T \cdot \delta \cdot \rho_w \cdot g \quad [N]$$

$$W_w = (p \cdot T^2 \cdot L_{pp} \cdot \rho_w \cdot g) / 4 \quad [N]$$

From here effective (real) energy of the berthing ship  $E$  can be determined from formula:

$$E = W \cdot v_s^2 / 4 \cdot g \quad [N \cdot m, J]$$

Than taking under the attention above mentioned dependence we can say, that main unknown, however decisive in essential way about the value of energy of the berthing ship is speed at the time contact with berth –  $v_s$ . Determination of that speed still encounters very large difficulties particularly if taking into account fact that tugboats more and more rarely take part in berthing operations in bringing the ship to quay or platform. This results that particularly such ships, as the container ships, ferries, ro-ro ships and cruising vessels, due to

installation of thrusters and more often non-conventional propulsion-steering systems approach to quays or the platforms without tugs. They are able to make maneuvers in different way and fully controlling the speed of the approach.

All these facts induce to consider the necessity of changes existing recommendations for design of port constructions. Particularly that in last years follows both the intensive development of the various kind of fender systems and more installed on ships non-conventional propulsion-steering systems improving the safety of the berthing operations.

## 1 PROPULSION AND STEERING SYSTEMS

### 1.1 *Propulsion systems*

The ship's propulsion systems can be equipped with one or more propellers. The propellers can be different type as follows:

- 1 fixed pitch propeller – called conventional propeller,
- 2 controllable pitch propeller,
- 3 KORT Nozzle.

A conventional, fixed-pitch propeller, when driven by a high or low speed diesel engine with reversing reduction gear and shaft, is perhaps the most economical and mechanically least complex of the many vessel's propulsion system. Efficiency of such conventional systems in the aspect of maneuvering of the ship at the sea speeds is good however it worsens maneuverability on small speeds considerably.

There are variations of the conventional propulsion system that make it more efficiency to control ship's speed. One of the variants is usage of a controllable pitch propeller system. Presently such propeller is used more often, because it provides the operator almost infinite speed variation from nearly zero thrust to max that is ship's speed. In both cases conventional rudder is applied the most often, sometimes Becker or Schelling rudder.

The considerable improvement of driving efficiency on small speeds particularly is got by the location of the screw in a nozzle fixed to the hull – KORT nozzle. These nozzles are the most often used on tugboats and fishing ships in the connection with conventional rudder that is on the vessels with the small speed. However the use of nozzles on large and very large ships also confirmed the significant influence for maneuverability [Nowicki 1999]. The use of movable flaps additionally together with movable Kort nozzle considerably enlarges the maneuvering abilities of the ship.

## 1.2 Rudders

- 1 conventional rudder,
- 2 Schelling rudder,
- 3 Becker rudder,
- 4 conventional bow and stern thrusters,
- 5 directional steerable thrusters.

Equipment of conventional propulsion-steering systems with bow or stern thrusters gives considerably larger maneuvering possibilities. Special type of thrusters is steerable thruster which can direct his thrust in any direction improving ship's maneuverability at low speed.

## 1.3 Propulsion – steering systems

- 1 Z-Drives / Pods,
- 2 Cycloidal Drive
- 3 Water Jet.

### Z-Drives / Pods

Z-drives are type of ship's propulsion in which the device producing the strength moving the vessel is propeller fixed under the hull of the ship on turning around the perpendicular axis the shoulder. The modern Z-Drive propulsion have very large influence for the maneuvering properties of the ships that is why at present are the most popular drive for the small ships of the type offshore and tugboat. Z-Drives are available in fixed-pitch or controllable-pitch propeller versions and with open propellers or in nozzle. Z-Drives may produce the vector of the movement in the any direction what creates the ship with such drive the extremely good in maneuverability. Conventional rudders are not used with Z-Drive installations. Such drive is the most suited to applying on the ships with the system of dynamic positioning -DP. Z-drives make better the maneuverability of the vessel in the relation to maneuverability offered through conventional rudders. Due to above such ships in harbours do not need often to use the services of tugboats.

Different kind Z-Drive very similar in the working is POD-AZIPOD propulsion which from classic Z-Drive differ in location of the driving engine. In the POD engine is electrical and located in POD than directly drives the screw. The electric engine obtains energy from electric generators being in the engine room.

### Cycloidal Drives

The most famous cycloidal drive is Voith-Schneider construction. Such drive possesses vertically oriented blades which can produce the vector of the movement in any direction without the use of rudder. The big disadvantage is that it increases of ships draught and they are less suitable

for shallow water than some other forms of propulsion. They are installed on tugboat mainly.

### WaterJet

The WaterJet drive is considerably more efficient from the conventional propulsion specially when the speeds is more than 25W. Principle of the working is to put considerable quantity the water inside drive through the hole in bottom of the ship to the outlet canal. Water is compressed using the pump then discharged through the outlet, being in the aft part of the canal. WaterJet with fixed reversing buckets allows to do any maneuvers.

Mostly WaterJet Drive is installed on small, fast passenger vessels and also on larger passenger and other ferries.

## 2 PROPULSION-STEERING SYSTEMS AND MANEUVERING PROPERTIES OF THE VESSEL

All types of propulsions and rudders mentioned earlier and various their connection has the use on the ships of the various size as propulsion-steering systems. The more systems are different the more influence on the berthing tactics of the ships they have. But anyway it allows for very good the control of their movement. Connection of the conventional propeller or Z-Drive with bow thrusters allows to obtain the transverse movement of the ship and controlling her speed fully what is very important for size of impact energy. Usage of Z-Drives in example showed on the figure 1 allows to good controls of the ship even at the very strong winds.

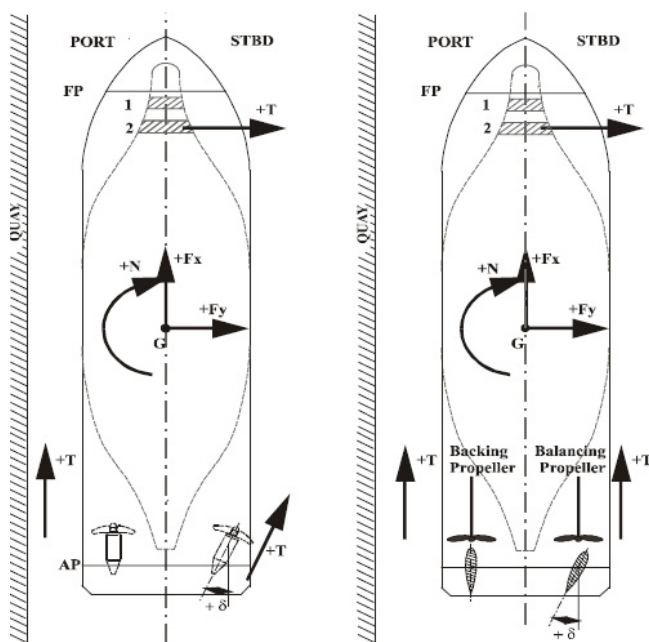


Fig. 1. Example of usage propulsion-steering systems for crabbing test: a) ship equipped with PODs and bow thrusters

b) ship equipped with two propellers with rudders and bow thrusters (Serge & Giedo 2002)

Additionally, it became clear that for the conventional propulsions, the best crabbing results are found when using almost the complete amount of installed power. When using pods, only a limited amount of power is required. For example, some results show that to obtain about the same transverse force in combination with a pure sideways motion (zero yawing moment) about 75% of the installed power is required for the conventional ship against about 30% for the ship with pods. This not only means fuel savings, but also reduces the impact of the ship on the environment, such as quay erosion.

Very large influence on the maneuverability of the ship has the use of Schelling or Becker rudder. On the figure 2 can see the clear influence of the rudder type and his angle on the diameters of turning maneuver.

The connection some of propulsions systems with some of rudders mentioned above cause that such vessels possess considerably better manoeuvrabilities from so-called conventional ships.

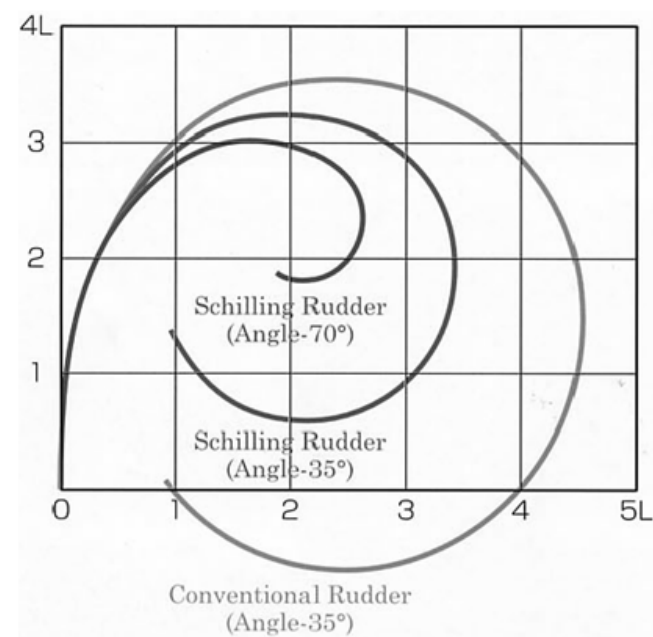


Fig. 2. Comparison of Turning test Results at Sea Trial (Japan Steering Systems)

The example of propulsion-steering system consist of Schilling Rudder and bow-thruster shows on figure 3 the possibilities of the realization of the transverse movement (crabbing of the vessel).



Fig. 3. M/V Esso Plymouth equipped with Single Schilling Rudder provide crabbing ability when used with a bow-thruster (Japan Steering Systems)

### 3 CONVENTIONAL VESSEL AND NON-CONVENTIONAL VESSEL

The presented examples of propulsion-steering systems have the significant influence on the maneuvering possibilities of ships. When take notice of quotes in the literature the most often use of words conventional or non-nconventional is from the attention on the kind of drive or rudder independently as installed on the ship. However in the aspect of port maneuvers and specially when berthing opeartion it is good idea to widen means of words conventional and non-conventional. Considering the safety of port maneuvers and risk of excessive impact against berth we can say that we have to deal with conventional vessels and non-conventional vessels. Such meaning will be use to describe maneuvering possibilities of the vessel or all propulsion-steering system.

Therefore **conventional vessel** is the ship equipped in one fixed or controllable propeller and conventional rudder without thrusters. Maneuvering possibilities relating to the port maneuvers at low speed like berthing or turning of the ship are quite limited.

Therefore **non-conventional** vessel is the ship equipped in at least one propeller different than conventional or more conventional propellers, rudder and equipped in thruster. Maneuvering possibilities relating to the port maneuvers are considerably larger in the reference to the conventional ship. Such vessel is able to approach

the berth under the any angle or even with crabbing movement to berth what has the essential influence on the moment of first contact with berth. Maneuvers can considerably differ from these possible to the realization through conventional ships. Not-conventional ship let on more free choice of maneuvering tactic and her full control even in bad hydrometeorological conditions.

#### 4 CONCLUSIONS

The propulsion-steering systems applied today require regards during design of the berth construction and fender systems with the aim of their optimizing strength and costs. It is necessary continuing simulation and real researches relating to the tactics of maneuvering non-conventional ships and to determine the berthing velocity. Researches are very important to execute the verification of recommendations relating to buildings of the berth structures. So far all such researches of the berthing velocity were based on conventional ships and mainly very large. For such large vessels the selection of fender systems was the very essential parameter for the design of quay, mainly because of very large strengths applied to the berth structure. However is lack of researches concerning berthing velocity new types of ships, described in the article as non-conventional ships. Determination of such parameters has to be done for clearly specified

hydrometeorological conditions and the type of the ship.

#### REFERENCES

- VI Workshops of Maneuvering the Ship- IŁAWA'97. 1997. The Safety of navigation in view of SCTW'78 – the assessment of the safety of port maneuvers. Iława. October 1997.
- Backer Marine Systems. <http://www.becker-marine-systems.com>
- Galor W. 2000. The Improvement the safety level during the berthing the ship to the quay with fender systems. V Conference 'Shipbuilding and Sea Structures, Equipment and transport systems'. Międzyzdroje.
- Japan Steering Systems Co., Ltd., <http://www.japanham.co.jp>
- Kozioł W. 2004. Analysis of the berthing velocity of the ship on the basis berthing to the Chorzowskie quay in the Szczecin. III-rd Sea Forum 'Sea Safety and Protection Natural Environment of the Sea'. Kołobrzeg.
- Mazurkiewicz B. 1997. The recommendation for design sea constructions. Z1-Z46. Studies and Materials. Exercise book of no. 21. Technical University Gdańsk.
- Mazurkiewicz B. 2003.. The berthing velocity of the ships to sea construction. Inżynieria Morska i Hydrotechnika. Nr 5.
- Nowicki A. 1999. Knowledge about manoeuvring sea ships- the basis of theory and practice. TRADEMAR – Gdynia.
- Serge Toxopeus & Giedo Loeff. 2002. Manoeuvring Aspects of Fast Ships with Pods. 3rd International EuroConference on High-Performance Marine Vehicles HIPER'02, Bergen, 14-17 September. pp. 392 – 406.
- The recommendation to design sea construction. Z1-Z46. 1997. The studies and Materials. Katedry Budownictwa Morskiego Politechniki Gdańskiej. The exercise book of no. 21, Gdańsk.