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CONVENTIONAL AND UNCONVENTIONAL MANEUVERING OF CONTAINER VESSELS WITHOUT TUGBOAT ASSISTANCE AT SELECTED TERMINALS IN THE PORT OF ROTTERDAM

Summary. This paper describes the unberthing of container ships using conventional and unconventional maneuvers. The research has been carried out in the Maasvlakte in the Port of Rotterdam (Netherlands). This research analyzes the departure of ships with the onshore wind (various weather conditions) without tug assistance. The analysis of unberthing maneuvers, taking into consideration external conditions, draft, and load onboard, is based on the knowledge gained from the theory and experience in the performance of unconventional maneuvers without the assistance of a tugboat. Challenges posed to the maritime industry by developments in shipbuilding technology are discussed. This paper also presents the specifications of the ships under analysis and describes quays at the Port of Rotterdam that have been adapted for the berthing of container vessels. Unberthing maneuvers are also explained in detail. Additionally, the optimum unberthing method to be used in the Port of Rotterdam is presented. The results provide recommendations for captains of vessels of similar navigational and operational parameters.

1. INTRODUCTION

Despite improvements in ship maneuvering techniques and the application of state-of-the-art engineering solutions, the risk to the safety of navigation does not diminish. Many factors affect the risk, including insufficient expertise and training of crew members and harbor personnel; poor maintenance of harbor tugboats; inefficient communication among the parties involved in a vessel's entry into or exit from the port or mooring operations, as crew members, the harbor pilot, and tugboat masters speak different native languages; obsolete tugboat equipment; and poor safety culture [1].

The growing size of ships launched for operation, of various intended uses and power of propulsion, has called for modification of the conventional maneuvering techniques. This requirement is reflected in the optimization and automation of decision-making systems in navigation, aimed at considering the kinematics of movement and dynamic characteristics of vessels [2].

Previous practical research studies into ship maneuvering techniques have been based on conventional literature on maneuvering ships. Drawing on experience and familiarity with the specific features of the Port of Rotterdam, the authors of this paper conducted an analysis of unmooring operations by an unconventional method. Unlike traditional maneuvering techniques, this method does not involve the use of tugboats, thus reducing harbor fees. The safe and effective maneuvering of a container ship strongly relies on whether the ship is fitted with appropriate maneuvering equipment.

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One of the available solutions is thrusters, which are designed to maneuver the vessel laterally to the port or starboard side at a slow speed. Captain Hensen, author of many scientific publications in the field of navigation, has analyzed new training systems for efficiency in the training of crew members and ship masters [3]. Hensen suggests consolidating the training path for ships' officers under the guidance of the International Maritime Organization[4]. Captain Hensen also analyzes maneuvering operations with or without the use of a tug [4]. Drawing on extensive experience and expertise, he describes conventional and unconventional methods of maneuvering a vessel without tug assistance, taking into account the rules of physics governing the behavior of a ship in the water in various weather conditions, as well as the size of the ship and its equipment (bow/stern thruster).

Ship Handling and Manoeuvring [2] is a textbook addressed to advanced learners at various levels of professional training. Its focus is on selected technical and operational concepts. The publication includes analyses of outcomes of observations carried out in real-life situations on ships of various tonnages. The topics are discussed clearly and illustrated with practical examples where navigation conditions are taken into consideration. In the era of rapid development of marine engineering, it helps navigators master their knowledge of technical and operational aspects of ships while improving their situational awareness and decision-making skills.

2. SPECIFICATIONS OF THE SELECTED CONTAINER SHIPS AND THEIR MANEUVERABILITY

The size of a container ship employed in liner shipping is determined based on the number of transported twenty-foot equivalent units (TEUs). Ship A, one of the two ships under analysis, has a length overall of 158.08 m, a beam of 23.5 m, and molded draft amidships of 8.6 m. With a cargo carrying capacity of 1084 TEUs, it can carry a maximum of 372 TEUs under and 712 TEUs above the main deck. Its key limitation during berthing and unberthing is the cargo-carrying capacity. When fully laden, the vessel can carry a maximum of six tiers of containers above the main deck. This not only restricts visibility in narrow passages but also increases the windage area. Therefore, when fully laden and in strong winds, the ship requires tug assistance during maneuvers in the harbor. Nevertheless, with the use of unique maneuvers, in most cases, Ship A can be successfully maneuvered without tug assistance. The ship is fitted with a 700-kW bow thruster and the Wartsila/6RT – flex 50-B, 9960 KW main engine [5]. A multi-sequence Becker flap rudder helps keep it on course and boosts its maneuverability. Ship A is equipped with a Becker rudder, a controllable pitch propeller with a 700-kW bow thruster. Its maximum speed with the propeller set at 84% is 16.8 knots. With the engine order telegraph set in position 0, it moves forward at a speed of ca. 1 knot.

Ship B is a partly open-top container vessel. It has both closed and open cargo holds and can carry containers on the main deck. Its overall length is 134.44 m, its beam is 22.5 m long, and its maximum draft is 8.9 m. Its cargo carrying capacity is 862 TEUs, of which 77 TEUs can be carried in closed cargo holds, 328 TEUs can be carried in open cargo holds, and 241 TEUs and 108 forty-foot equivalent units (FEUs) can be carried on the main deck [6]. Two derricks mounted on the port side restrict visibility in narrow passages and during berthing/mooring operations.

Similarly to Ship A, Ship B can be maneuvered without tug assistance. The vessel is equipped with a 720-kW bow thruster, a 450-kW stern thruster, and a MAK 9M43 main engine (500 RPM, 8400 kW) [6].

[4] The International Maritime Organization is a specialized the United Nations agency responsible for the safety of maritime navigation and the protection of the marine environment from pollution caused by ships. The organization establishes international regulations for maritime transport, coordinates cooperation between states, and supports the development of safe and efficient shipping.

3. OVERVIEW OF AND NAVIGATION CONDITIONS IN THE PORT OF ROTTERDAM

The Port of Rotterdam is one of the world's major cargo flow hubs and by far the largest seaport in Europe. It is located at the Maas River estuary on the North Sea (latitude = 51º55.0'N, longitude = 004º30.0'E). Stretching over a distance of 40 km from the city center to the North Sea coast, the harbor and its industrial zone cover an area of 10,500 ha. The port comprises several canals and several dozen major port basins. The oldest part is situated in the city center, with the adjoining ports of Delfshaven, Maashaven, Niew-Mathenesse, Waalhaven, Vondelingenplaat, Eemhaven, Botlek, and Europort. Its excellent accessibility for transport is due to, inter alia, the harbor basin of a maximum depth of 24.0 m. The port has been built and developed for 60 years. However, the launch of works on Maasvlakte II, a new harbor and industrial development, in 2008 marked a true breakthrough in the flow of containerized cargo. Maasvlakte II is a follow-up on Maasvlakte I, an investment project aimed at the reclamation of land south of the River Maas estuary.

Maasvlakte II was designed to increase the share of rail and inland waterway transport in the flow of goods handled at the harbor terminals. The targets for 2033 are 35% of cargo carried by road, 20% by rail, and 45% by inland waterways. Incorporated into Maasvlakte II, these targets can be achieved only with appropriate access infrastructure. Therefore, all the terminals built at Maasvlakte II are equipped with mooring stations for barges and feeder vessels. These facilities are bound to help reduce the amount of cargo stored at storage yards. Fig. 1 shows the spatial arrangement of Maasvlakte I and Maasvlakte II within the Port of Rotterdam [7,8].

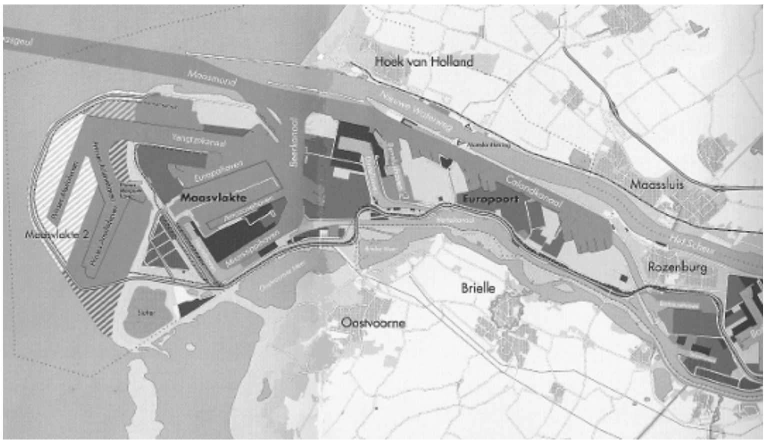

Fig. 1. Spatial arrangement of Maasvlakte I and Maasvlakte II in the Port of Rotterdam [9]

Regarding the safety of navigation, when entering the Port of Rotterdam, vessels should be cautious about the transverse north-eastern tidal current beginning two hours before high water at Hoek van Holland and prevailing up to four hours and 15 minutes after high water. During this period, the port entrance is affected by a unique phenomenon referred to as the Massvlakte effect. Due to the shape of the entrance, the tidal current gains strength at the heads. The Massvlakte effect must be taken into account when entering the port, as the ship is strongly pushed towards the northern side of the approach canal. After the period mentioned above, the tidal current sets south-west and the Massvlakte effect occurs off the heads, pushing the entering ships towards the south.

3.1. Navigation conditions at the Rotterdam World Gateway terminal

The Rotterdam World Gateway (RWG) in the Port of Rotterdam (bearing 176º), one of the world's most advanced container terminal, is located in Maasvlakte II (Fig. 2). Navigation conditions at the RWG depend on several factors, including the depth of water. A depth of 20 m in the area is sufficient for safe berthing of the latest generation container vessels. However, daily tidal variations in sea water level must be taken into account when planning maneuvers. Another factor is the size of the terminal: ca. 100 ha of land, 1150 m of deep-sea quay, and 550 m of barge/feeder quay [10, 11].

Fig. 2. Location of the Rotterdam World Gateway (RWG), Euromax and APM terminals in Maasvlakte II [12]

3.2. Navigation conditions at the Euromax terminal

The Euromax terminal at Rotterdam (bearing 270º) is located in both Maasvlakte I and Maasvlakte II (Fig. 2). It has a berthing quay of 1800 m and a surface area of ca. 84 ha. Both the length of the berthing quay and the surface area of the terminal are planned to be doubled by 2030. The extension will make it possible to handle many more vessels and develop the port hinterland [10,11]. A water depth of 19.65 m ensures excellent navigation conditions and the safe berthing of large-draft container ships even at low water. Similarly to the RWG terminal, moderate tidal streams of up to one knot at southerly or south-easterly winds of a force of 3–4 Beaufort scale (slight to moderate) occur at the quay. If maneuvers are performed during strong northerly winds, the ship will be pushed away from the quay.

3.3. Navigation conditions at the Amazonehaven

The Amazonehaven Multipurpose Terminal (AMT) (bearing 258º) is located entirely within Maasvlakte II (Fig. 2) and has a berthing quay of 1600 m. The water depth in the area is normally up to 17 m, which is sufficient for the berthing of medium- to large-draft ships. The canal is planned to be deepened to 20 m to permit the berthing of ocean-going ships. Moreover, the AMT will be extended over an area of 162 ha with a berthing quay of 2800 m. As a multi-purpose terminal, it facilitates the handling of various types of cargoes, including containers, along with bulk and general cargoes [10]. The terminal offers good navigation conditions. Located at the same harbor basin as the RWG, it is characterized by moderate tides and sea currents. Northerly and north-westerly winds with a strength of 3-4 Beaufort scale, however, can impede navigation and berthing.

4. BASIC MANEUVERING OPERATIONS WHEN APPROACHING THE EUROPORT TERMINAL

Most container ships are able to enter Europort (comprising Massvlakte I and Massvlakte II), which offers mainly container terminals. The area is controlled by the Vessel Traffic Services (VTS) sector of Europort on channel 66. The approach is characterized by heavy traffic, including sea-going vessels and inland barges. When approaching the port, all passing and overtaking maneuvers are performed upon prior approval by the VTS Europort sector. Pilots are required to have excellent familiarity with the port topography, the characteristics of the quays, and landmarks. Both extensive experience and skills are required to maneuver the ship, as the quay is always crowded, and the distance between the bow of one ship and the stern of the next one usually varies between 15 and 20 m. When maneuvering in such a confined space, a key decision is whether to unberth bow first or stern first. Unmooring requires close monitoring of the wind and current at the quay. Ship A, referred to above, is characterized by the effect of a left-handed propeller (rotation to starboard) when the engine is set to full astern. The procedure of unmooring

Ship A from a bird's eye view (North oriented) is presented in Figs. 3–5. The ship is located between two other vessels alongside the quay (presented as 2D outlines with active forces vectors marked in red and the position of rudders in black). The black lines in Figs. 3–5 present mooring lines (solid line = before unberthing, dashed line = during the second phase of unberthing). Thus, the moored starboard side alongside the ship can unberth, singled up to one forward spring (Fig. 3). When the engine runs astern, the ship's stern can be pulled away from the quay, thus making it possible to unberth in the confined space. The same maneuver cannot be applied when the ship is moored port side alongside, as the engine running astern will pull the ship's stern towards the quay and the vessel moored behind.

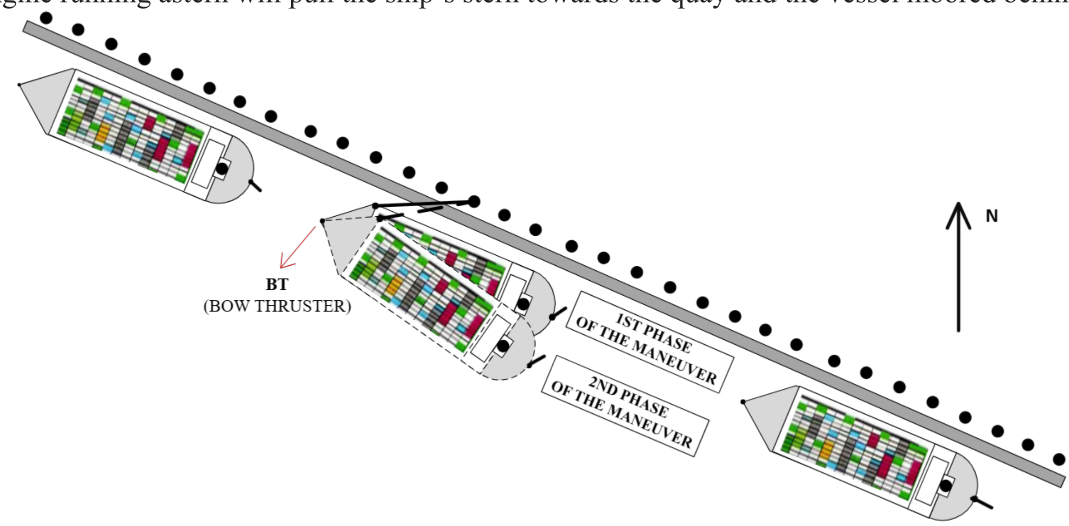

Fig. 3. Procedure of the departure operation using the forward spring [own study based on [2]]

Another conventional maneuver is to unberth the ship singled up to one aft spring (Fig. 4).

This maneuver starts by singling up to aft spring, followed by the movement of the ship's bow away from the quay using the bow thruster and running the engine very slowly astern. Once the bow is away from the quay at an angle of ca. 30°, the engine is stopped, and the aft spring is let go.

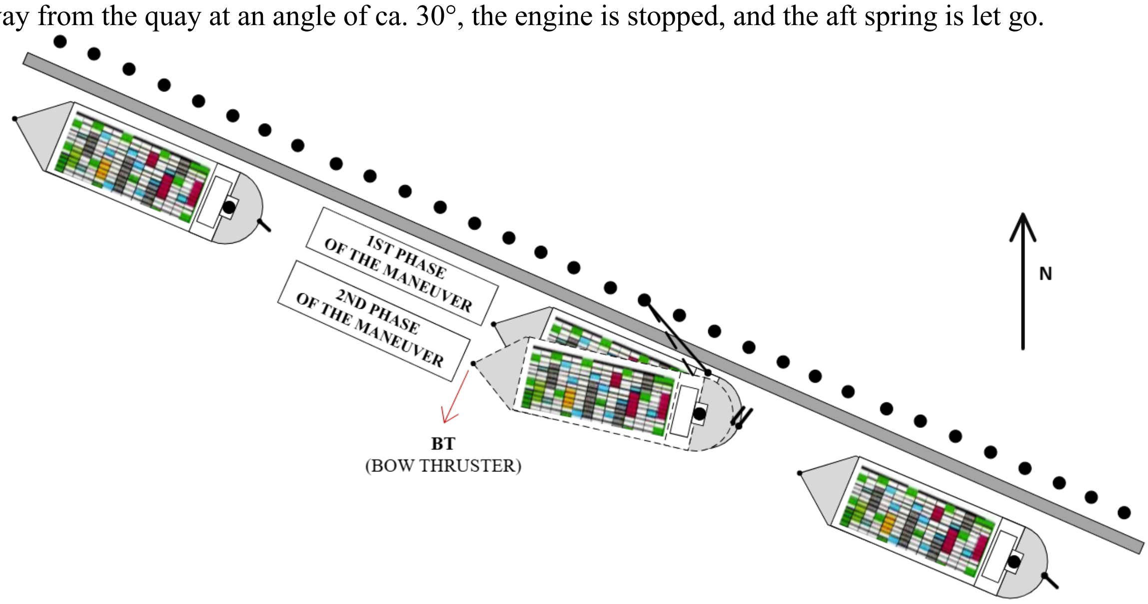

Fig. 4. Procedure of the departure operation using the aft spring [own study based on [2]]

5. MANEUVERS DURING BERTHING AT THE ECT-DDE TERMINAL: AN OVERVIEW OF AN UNCONVENTIONAL MANEUVER

The Europe Container Terminals Delta Dedicated East (ECT-DDE) at Rotterdam has a berthing quay of length of 2600 m and bearing 258º. A turning basin of diameter of 600 m for large deep-sea vessels is located in front of the entrance to the Amazonehaven. The canal width varies from 280 to 310 m, and the distance between bollards is 21 m. Similarly to the aforementioned Euromax terminal, the ECT-DDE quay is exposed to northerly and southerly winds. The maneuvering possibilities when unberthing in southerly winds are strongly limited. In practice, a wind of a speed of 12 m/s marks a limit at which Ship A needs tug assistance if the wind pushes it towards the quay. The performance of maneuvers is also conditioned upon the ship's load (the greater the load, the smaller the maneuverability of the ship). The conventional maneuver of unmooring using the forward spring may fail due to insufficient capacity of the bow thruster. Alternatively, unberthing can be carried out using the so-called 'negative aft spring maneuver.' This term is widely used by pilots in the Port of Rotterdam to describe a technique that is frequently used in daily maritime practice.

The negative aft spring maneuver helps pilots assess whether the ship can be unberthed without tug assistance. The concept is based on sending the aft spring to a distance of at least 30 m astern, followed by moving the bow away from the quay (Fig. 5). In this way, the ship's movement away from the quay with both the bow and the stern is controlled. Figs. 6a-6h show the stages of the unmooring operation of a ship moored port side alongside using the negative aft spring maneuver.

Figure 6a shows the stage of sending the aft spring to the bollard through the fairlead at the quay side, in the position of the stern line (Fig. 6b). In Fig. 6c, the aft spring has been sent astern to a minimum distance of 30 m. Figs. 6d–6h show the increasing angle of the bow moving away from the quay.

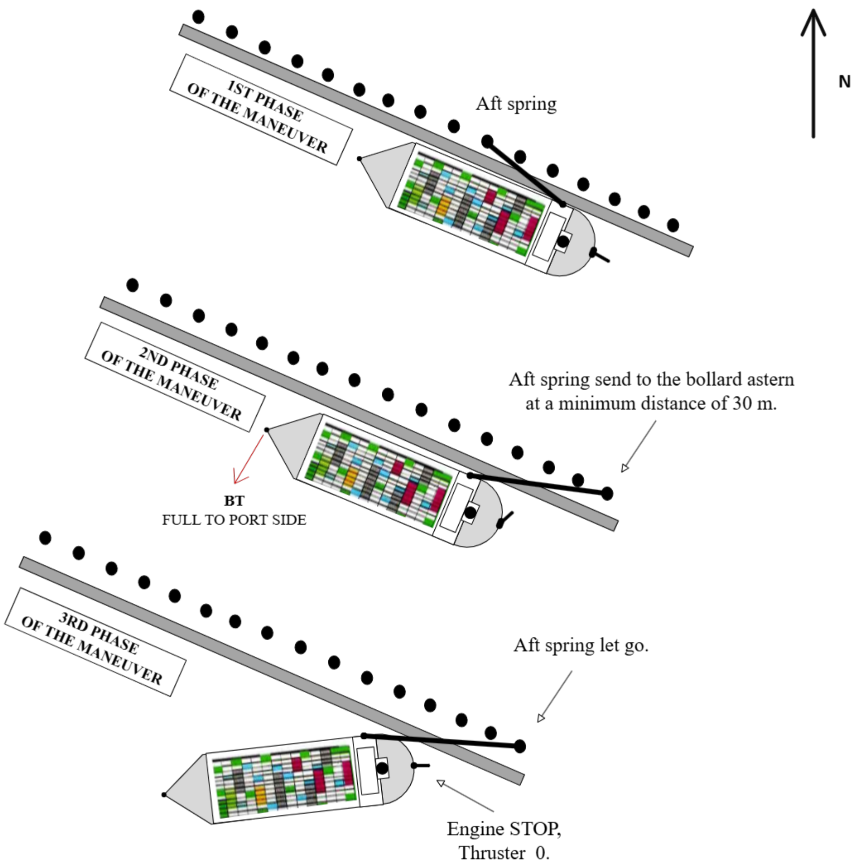

Fig. 5. "Negative Aft Spring" unberthing: Rotterdam Method [own study]

6. ANALYSIS OF THE SAFETY OF MANEUVERS OF SELECTED CONTAINER SHIPS

The study was conducted on Ship A and Ship B (described in Section 2) in 2023 and 2024, in various weather conditions (including wind direction and force, sea current). During maneuvering several initial parameters of the ship like ship-to-quay position, draft, loading condition, usage of the bow and stern thrusters were taken into account. The study was carried out at the Port of Rotterdam at several container terminals in Maasvlakte, where a small current was observed only at the Euromax terminal. The collected data represent unberthing maneuvers with various cargo loads (20 maneuvers of each vessel, listed in Appendix A (Ship A) and Appendix B (Ship B).

6.1. Methodology of the survey

Maintaining the safety of maritime navigation in a confined water area covers the safety of a specific ship and environment protection during maneuvers, in view of the possibility of a navigation accident [13]. Navigation safety can be assessed in terms of navigation risk and is understood as the risk that an accident will occur during maneuvering in a confined water area [13]. Navigation conditions are the main parameters that impact the safety of navigation, usually quantified by the risk of navigation as the following function (1):

$$R_i = f(A_i,\ Q_i,\ N_i,\ H_i,\ M_i,\ I_i,\ Z_i) \tag{1}$$

where:

R_i – navigation risk in the i-th section of the waterway,
A_i – area parameters,
Q_i – ship parameter,
N_i – parameters of the position determination system,
H_i – hydrometeorological parameters,
M_i – parameters of the maneuver,
I_i – parameters of the traffic intensity,
Z_i– parameters of the traffic control system.

For the values of A_i, a depth of up to 20 m was assumed, as were the following lengths of the examined terminals: RWG = 1222 m, DDE = 2648.4 m, EUROMAX = 1926 m, AMP = 1092 m, KRAMER = 463 m. Values of Q_i present each ship's parameters such as the type of container vessel with a cargo carrying capacity of 1084 TEUs, overall length of 158.08 m, beam length of 23.5 m, and moulded draft amidships of 8.6 m (Ship A) and an overall length of 134.44 m, beam length of 22.5 m, maximum summer draft of 8.73 m, and cargo carrying capacity of 862 TEUs (Ship B). For value N_i, a visual assessment was used while maneuvering from the wing console position. For the values of H_i prevailing hydrogeological conditions according with (Appendix A and Appendix B). The values of M_i determination of the possibility of maintaining a given position. The values of I_i traffic intensity. The values of Z_i represent parameters of the traffic control system. During the maneuvers, each approach to the berth was assessed from the aft by the Officer of the Watch and from the forward station by the boatswain. In this case, the value of distance was assessed up to 1 m just off the quay as the ship departed. Despite the strong relationship between perception and reality, the judgments of many individual observers were inaccurate.

Moreover, based on the research of Norman et al. [14], with the increase of distance the judgments of many individual observers were inaccurate. Studies [14, 15] showed that the influence of the change in the context on the perception of distance value by observers is significant. Linear perspective plays an important role in determining the ultimate effects of variations in environmental context [14]. Younger and older adults perceive physical distance ratios reliably and with reasonable accuracy. The relatively good performance obtained in the current study contrasts with the large inaccuracies previously obtained in studies on visual distance perception [15].

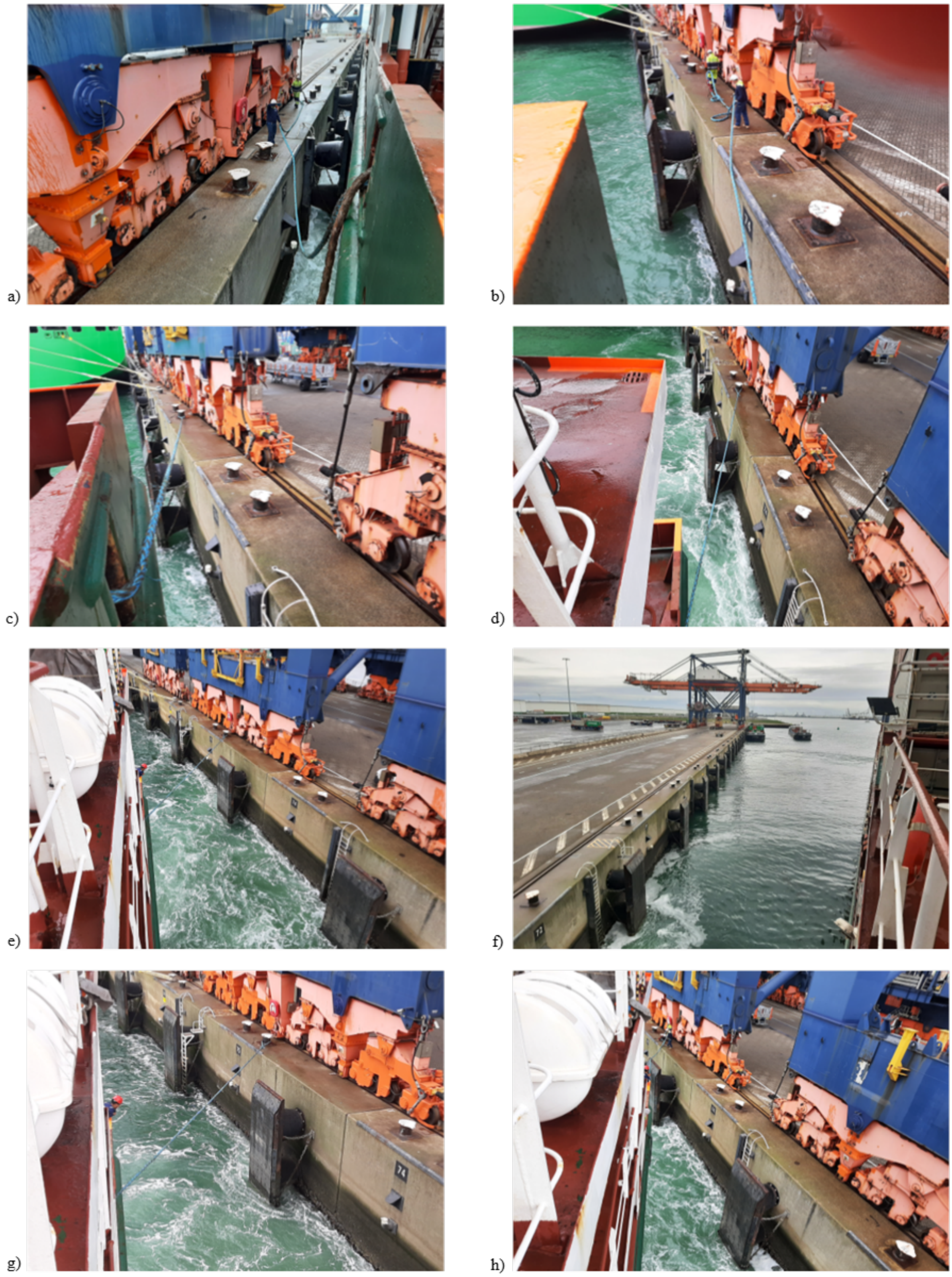

Fig. 6. Procedure of unberthing using the aft spring: (a) sending the aft spring to the quay in the position of the stern line; (b) the aft spring sent to the quay in the position of the stern line; (c) taking in the slack on the mooring line; (d) moving the bow away from the quay; (e) moving the bow to the largest possible angle away from the quay – the view from the stern; (f) moving the bow to the largest possible angle away from the quay – the view towards the bow; (g) moving the bow away from the quay to the maximum angle of

30 degrees; (h) letting go the aft spring (own study)

In practice, it was be observed that during maneuvers, more experienced masters and pilots assessed the distance to the quay more accurately and with greater care. In both cases, the distance at the bow was additionally confirmed by the Boatswain. In both cases, the maneuvering point of the bridge was located closer to the stern, which gave greater visual control of the approach of the stern to the quay for an experienced captain with a PEC certificate.

Ship A was equipped with a Becker rudder, a controllable pitch propeller with a 700-kW bow thruster. Ship B was equipped with a 720-kW bow thruster, a 450-kW stern thruster, and a classic rudder.

6.2. Statistical analysis

The tables in Appendix A and Appendix B present the data from 20 unberthing operations of the ship moored: SS – starboard side alongside and PS – port side alongside. The data comprise drafts forward (F) and aft (A); the ship's heading in degrees relative to the North, equal to the berth direction; and wind speeds coded in the Beaufort scale, which in terms of knots and meters per second (m/s), are categorized into the following ranges:

- Beaufort 0; knots: < 1; m/s: 0–0.2.
- Beaufort 1; knots: 1–3; m/s: 0.3–1.5.
- Beaufort 2; knots: 4–6; m/s: 1.6–3.3.
- Beaufort 3; knots: 7–8; m/s: 3.4–5.4.
- Beaufort 4; knots: 11–16; m/s: 5.5–7.9.
- Beaufort 5; knots: 17–21; m/s: 8.0–10.7.
- Beaufort 6; knots: 22–27; m/s: 10.8–13.8.

The last two columns of the table show the type of the maneuver (either using the forward spring – M/FS – or using the aft spring – M/AS), and the result is described as a success (S) or a failure (F).

6.3. Findings

The graphs in Fig. 7 and Fig. 8 show the relationship between wind speed on the Beaufort scale and the results for 20 unberthing trials based on the data in the appendices (Fig. 7 for Ship A – data from Table 1 in Appendix A – and Fig. 8 for Ship B – data from Table 2 in Appendix B). The graphs include the total number of failures, the number of failures in the 1st M/FS maneuver, the number of failures in the 2nd M/AS maneuver, the total number of successes, the number of successes in the 1st M/FS maneuver, and the number of successes in the 2nd M/AS maneuver.

The research focused on the analysis of the unberthing of ships with onshore wind without tug assistance. This study examined the maneuverability of both vessels using two different types of maneuvers. In the first phase, a classic departure maneuver using the forward spring was executed. If the ship was unable to depart from the quay on its own because a strong wind pushed the ship towards the quay, the alternative second type of maneuver was executed using the "negative aft spring". Data were divided into successes and failures for both the first attempt using the forward spring (M/FS) and the second attempt using the aft spring (M/AS) maneuver.

Ship A was equipped with a Becker rudder and a 700-kW bow thruster. For Ship A during winds of Beaufort 2, each unberthing maneuver was performed using a classic forward spring maneuver. While the wind force was Beaufort 3, only two unberthing attempts were successful using the classic maneuver, mainly due to the lower forward draft of 7.2 m for unberthing no. 3 and 7.8 m for unberthing no. 6, which had a significant impact on the effectiveness of the bow thruster. Of the six attempts, the next four unberthing operations were successful using the aft spring. The wind force intermediate between light and a moderate Beaufort value of 3.5 is presented in the tables as an intermediate value of wind speed between 10 and 11 knots. Considering the above-wind force value recorded in two unberthing operations, two successes were noted on the second attempt.

An analysis of nine unberthing operations carried out in Beaufort force 4 wind conditions showed that the classic maneuver was unsuccessful in every first attempt. The second unberthing attempt failed in operations no. 7 and no. 11 as well.

After gaining practical experience with the maneuvering limitations of the vessel while subjected to wind of Beaufort 4, the decision of the captain of Ship A was to use tug assistance if there was an in-berth pushing wind of 4 or above on the Beaufort scale. It should be noted that the total of seven successes with winds above Beaufort 4 were achieved without tug assistance anyway. Considering the draft and wind force, it should be stated that this was the limit of the maneuvering capabilities of Ship A, and for such values, the use of tug assistance should be required for safe and responsible unberthing operation.

Fig. 8 shows the results of the unberthing operations of Ship B, taking into account the number of successes and failures for two types of maneuvers, corresponding to the M/FS and M/AS. The moderate wind approaching 4 to 5 Beaufort (speed of 16 to 17 knots) is marked on Fig. 8 as 4/5. While the wind was Beaufort 2 and 3, the vessel had no problem unberthing using the classic maneuver. Only at a wind force of Beaufort 4 did failures occur on the first attempt, while on the second attempt, the vessel was able to unberth without tug assistance. In seven attempts at a wind force Beaufort 5, only once was it possible to unberth, mainly due to the wind direction from the bow side, which caused the hull to be positioned more quickly into the wind. After gaining practical experience with the maneuvering limitations of the vessel while subjected to the onshore wind of Beaufort 5 or more, the captain's decision for Ship B was to use the tug assistance while subjected to such environmental conditions.

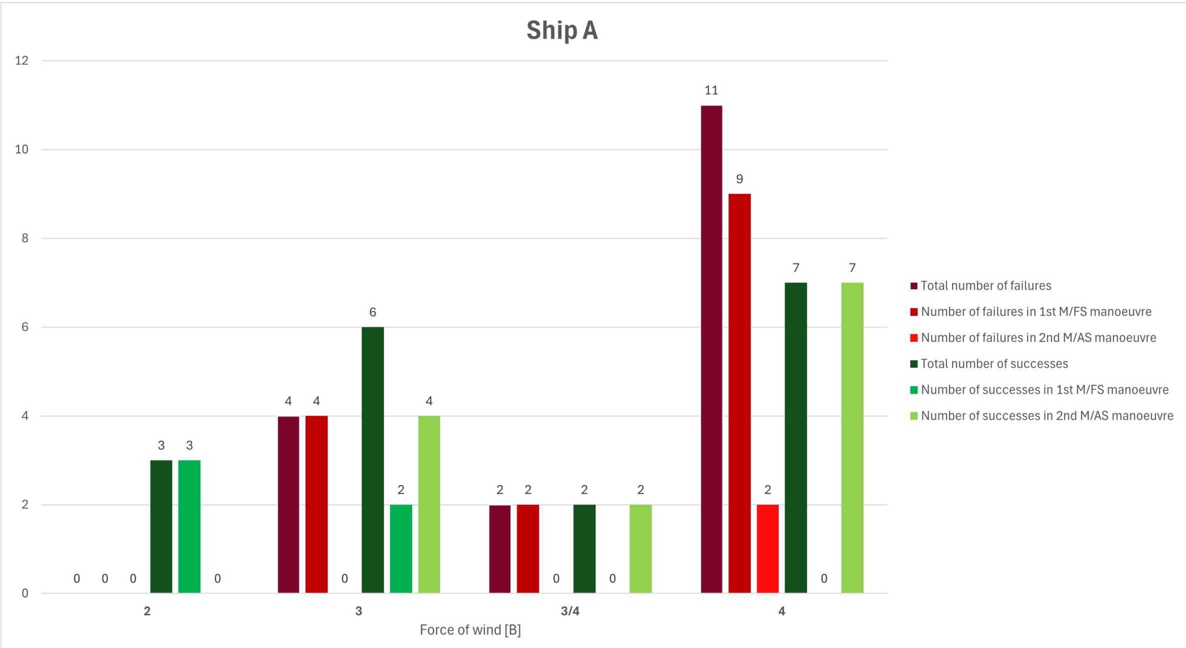

Fig. 7. Graph presenting the relationship between wind speed on the Beaufort scale and the maximum number of passes out of 20 [based on Table 1 in Appendix A]

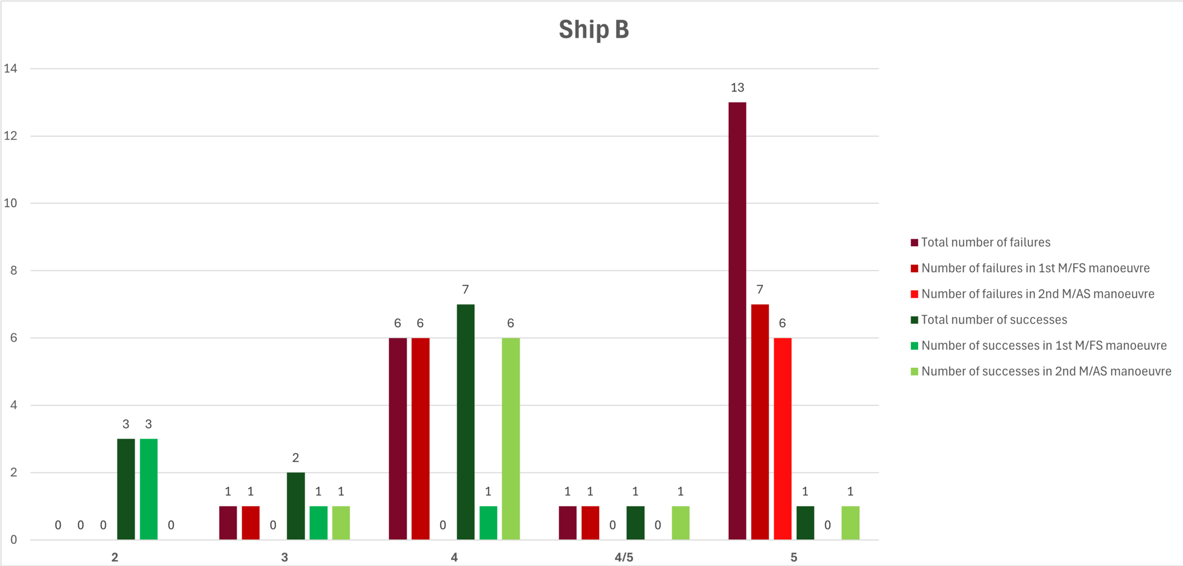

Fig. 8. Graph presenting the relationship between wind speed on the Beaufort scale and the maximum number of passes out of 20 [based on Table 2 in Appendix B]

7. CONCLUSIONS

This research was focused on the wind direction and force as key factors to consider when deciding whether to request towing assistance while unberthing. The actual values of physical forces resulting from windage and submerged ships' surface areas were not calculated, as they were operationally taken into account using the Beaufort scale. Fully loaded container ships have a large windage surface, which makes maneuvering in strong winds difficult with the ship's thrusters and generators. Maneuvering in adverse weather conditions is difficult, and in certain circumstances, tug assistance is required.

The maneuver presented in the trials using aft spring, referred to as the "negative aft spring," aimed to assess whether the stern thruster is strong enough to overcome the wind. The "negative aft spring" maneuver is not described in the literature, and therefore, knowledge of this maneuver is not possessed by pilots outside the Port of Rotterdam. The purpose of this research was to evaluate the maneuvering capability of the vessel in comparison to the classic maneuver using the "forward spring," including the ship's ability to maintain heading under challenging conditions. Unlike other maneuvers, the "negative aft spring" did not result in pulling the vessel's stern toward the quay.

An additional finding is that the 20 unberthing operations for each vessel proved to be sufficient for the captain to become familiar with the maneuvering capability of the vessel, as although the analyzed ships were of a similar size and type, they were equipped with thrusters of various performances and different types of rudders. The captain's situational awareness played a key role in decision-making processes related to safety.

The results of this study are intended to help captains make the right decision regarding the request for towing assistance and ultimately optimize the costs for the shipowner without compromising the safety of a vessel.

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APPENDIX A

Table 1

Ship A: research results of unberthing operations

	SHIP A	Current		Wind		Quay features [m]		Draft [m]		Load	Maneuver	
	Terminal name	Current direction	Speed [kt]	Wind direction	Force [B]	Heading	Ship side	Fwd	Aft	DWT [t]	1st M/FS	2nd M/AS
1	**Euromax**	WNW	0.5	S	3	110º	PS	7.4	8.2	12,383	F	S
2	**Euromax**	WNW	1	SE	4	290º	SS	7.7	8.5	12,380	F	S
3	**RWG**	None	None	SE	3	213º	SS	7.2	7.5	10,654	S	
4	**RWG**	None	None	SE	2	213º	SS	5.5	7.4	7840	S	
5	**ECT/DDE**	None	None	S	2	258º	SS	7.3	8	10,949	S	
6	**ECT/DDE**	None	None	S	3	258º	SS	7.8	7.6	9696	S	
7	**AMP 2**	None	None	NW	4	217º	PS	7.9	7.9	11,620	F	S
8	**AMP 2**	None	None	W	4	217º	PS	7	8	10,548	F	F
9	**Euromax**	ESE	0.7	SSW	4	290º	SS	7.9	8.3	12,384	F	S
10	**Euromax**	ESE	1	SW	4	110º	PS	7.4	8.7	12,412	F	S
11	**ECT/DDE**	None	None	S	4	258º	SS	8.3	8.9	13,962	F	F
12	**ECT/DDE**	None	None	SE	3	258º	SS	8.2	8.3	12,737	F	S
13	**RWG**	None	None	E	3/4	033º	PS	8.3	8.7	13,699	F	S
14	**Euromax**	ESE	0.8	SSE	3	290º	SS	8.4	8.7	13,995	F	S
15	**ECT/DDE**	None	None	NE	2	258º	SS	5.7	7.4	7990	S	
16	**RWG**	None	None	S	4	033º	PS	7.2	7.5	10,183	F	S
17	**ECT/DDE**	None	None	SW	4	078º	PS	8.3	8.8	13,635	F	S
18	**RWG**	None	None	SE	3/4	033º	PS	7.5	8.6	12,383	F	S
19	**ECT/DDE**	None	None	ESE	4	078º	PS	7.2	7.8	10,654	F	S
20	**Euromax**	WNW	0.6	SE	3	290º	SS	7.9	8.6	12,904	F	S

Key:					
Abbreviations	**Wharf name**	**Depth**	**Wind speed in:**		
F- negative result	RWG	1222 m	**Beaufort**	**Knots**	**m/s**
S- positive result	DDE	2648.4 m	0	<1	0–0.2
SS – starboard side	EUROMAX	1926 m	1	1–3	0.3–1.5
PS - port side	AMP	1092 m	2	4–6	1.6–3.3
F- forward	KRAMER	463 m	3	7–10	3.4–5.4
A- aft			4	11–16	5.5–7.9
FS - maneuver using the forward spring			5	17–21	8.0–10.7
AS - maneuver using the aft spring			6	22–27	10.8–13.8

APPENDIX B

Table 2

Ship B: research results of the unberthing operations

	SHIP B	Current		Wind		Quay features [m]		Draft [m]		Load	Maneuver	
	Terminal name	Current direction	Strength [kt]	Wind direction	Force [B]	Heading	Ship side	Fwd	Aft	DWT [t]	1st M/FS	2nd M/AS
1	**Euromax**	WNW	1	SSW	5	290°	SS	7	7.1	7520	F	F
2	**ECT/DDE**	None	None	SE	2	258°	SS	7.2	7.6	8265	S	
3	**ECT/DDE**	None	None	S	5	258°	SS	7.5	7.6	8482	F	F
4	**RWG**	None	None	SE	3	213°	SS	7.7	8.1	9285	F	S
5	**Kramer**	None	None	E	4	168	SS	7.8	8.1	9415	F	S
6	**ECT/DDE**	None	None	SE	2	258°	SS	7	8.5	9176	S	
7	**Euromax**	WNW	1	N	3	290°	SS	6.4	8.8	8896	S	
8	**RWG**	None	None	S	4	213°	SS	8.2	8.5	10,375	F	S
9	**ECT/DDE**	None	None	SE	2	258°	SS	8.3	8.5	10,510	S	
10	**Kramer**	None	None	ESE	5	168°	SS	8.4	8.5	10,900	F	F
11	**Euromax**	ESE	0.5	SE	5	290°	SS	5.2	7.5	6028	F	F
12	**ECT/DDE**	None	None	SW	4	258°	SS	5.3	7.4	6102	F	S
13	**RWG**	None	None	SSW	4	213°	SS	6.6	7.1	7049	F	S
14	**Kramer**	None	None	NNW	4/5	168°	SS	6.5	7.3	7207	F	S
15	**ECT/DDE**	None	None	SE	5	258°	SS	6.2	7.9	7564	F	F
16	**RWG**	None	None	ESE	4	213°	SS	6.7	8.3	10,841	F	S
17	**ECT/DDE**	None	None	SE	5	258°	SS	8.4	8.8	13,871	F	F
18	**ECT/DDE**	None	None	S	4	258°	SS	7.3	7.9	10,859	F	S
19	**Kramer**	None	None	NE	3	168°	SS	6.5	7.8	7354	S	
20	**ECT/DDE**	None	None	SW	5	258°	SS	7.3	8.2	10,125	F	S

Key:					
Abbreviations	**Wharf name**	**Depth**	**Wind speed in:**		
F- negative result	RWG	1222 m	**Beaufort**	**Knots**	**m/s**
S- positive result	DDE	2648.4 m	0	<1	0–0.2
SS – starboard side	EUROMAX	1926 m	1	1–3	0.3–1.5
PS - port side	AMP	1092 m	2	4–6	1.6–3.3
F- forward	KRAMER	463 m	3	7–10	3.4–5.4
A- aft			4	11–16	5.5–7.9
FS - maneuver using the forward spring			5	17–21	8.0–10.7
AS - maneuver using the aft spring			6	22–27	10.8–13.8