



Article

Possibility of Capsizing of a Dredger during Towing

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Abstract: Small-size dredgers are used as a standard for dredging and maintaining the depth of the fairways to seaports, as well as of the ports themselves. These vessels are characterized by limited draft and a low freeboard. The safety of such craft, in terms of their stability, in relation to the conducted works is ensured by the observance of appropriate regulations and requirements. The use of these ships requires navigation between the ports in which they operate. Open sea navigation poses a threat to such vessels. The article presents two characteristic cases of overturning of vessels during sea towing. The requirements of existing freeboard regulations regarding the stability and stability of dredgers do not provide them with a sufficient level of safety at sea. Phenomena such as longitudinal and lateral swaying, wave boarding and dynamic action of the wind may lead to their overturning. The article deals with the problem of the influence of particular phenomena that threaten the stability of dredgers during sea navigation. The analysis of static and dynamic stability for various characteristic shapes of small dredgers is presented. The possibility of water entering the watertight compartments was also taken into account. The research was presented on the numerical models of dredgers. The main purpose of this paper was to assess the risks and possibilities of capsizing of small dredgers designated for port work and redevelopment during their sea voyage.



Citation: Soliwoda, J.; Kaizer, A.; Neumann, T. Possibility of Capsizing of a Dredger during Towing. *Water* **2021**, *13*, 3027. <https://doi.org/10.3390/w13213027>

Academic Editor: Diego Vicinanza

Received: 23 September 2021

Accepted: 25 October 2021

Published: 28 October 2021

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Keywords: dredging; maritime environment; marine information; stability

1. Introduction

Small-size dredgers are used as a standard for dredging and maintaining the depth of the fairways to seaports, as well as of the ports themselves. These vessels are characterized by limited draft and a low freeboard [1]. The safety of such craft, in terms of their stability, is ensured by the observance of appropriate regulations and requirements [2]. At the same time, the necessity of using dredgers is only a temporary need in a particular port, and the standards of market economy require their transfers between ports. The movement of small dredgers may be achieved either by transport on another vessel or by towing [3]. The use of the dredger's own propulsion on the sea routes is insufficient for safe navigation.

During sea towing, tugs with a bollard pull appropriate for the size of the dredgers are used. However, this is often accomplished with tugs with towing capacity significantly exceeding the required towing load [4].

Towing the dredgers in the sea conditions, exposes them to above-standard risks. These threats can be classified into two groups, which are: environmental threats and threats related to the towing process itself [5].

The impacts of the marine environment are analyzed selectively by assessing the influence of waves which generate longitudinal and transverse rolling, and the influence of wind through constant and dynamic heeling moments [6]. Simultaneous pitching and rolling of the dredger, together with the dynamic impact of the squall on the windward side, creates a very dangerous phenomenon which may result in the dredger capsizing.

The dredger towing process entails also risks related to the impact of the tow on the dredger. The tow load can cause the heaving of the dredger's bow in the waves and also, in the event of a sharp change in the course of the dredger, the tow can induce the

transverse heeling moments [7]. Both of these phenomena, occurring either separately or in combination, may lead to the dredger capsizing.

Another aspect of the threats during sea towing is ensuring that the dredger's hull does not leak [8]. When working in the ports or on the roadsteads, the tightness is preserved only to a limited extent, resulting from the nature of the work and the construction of the dredgers. Sea towing requires a tightness inspection as well as additional sealing safeguards. Such safeguards may be temporary and also provisional. Seals are usually made using sealing tapes, plywood or similar materials [9]. During longer journeys or worse weather conditions, there can be flooding of the watertight compartments of the vessel. As a result, the dredger can undergo a large trim or tilt which generally reduces the parameters of stability and increases the probability of capsizing.

The aim of this analysis was to assess the risks and possibilities of capsizing during seagoing towing of the small port-roadstead dredgers. The study was based on the deterministic simulation of events that threaten dredgers' stability, which may occur during their towing. The external dynamic heeling moments generated by wind and the action of tow were taken into consideration. The examination of occurrences threatening the stability of the dredger was carried out for the operational condition with the tightness of the hull and for the conditions with leakage of watertight compartments, with symmetrical and asymmetrical flooding [10].

The first part of the article presents the requirements of the regulations on the stability of dredgers according to the "Code on Intact Stability of Ships" (ISC'2008), which constitute the basis for determining the minimum safety parameters during sea towing. The chance of loss of stability during sea towing has been presented in relation to an analysis of two capsizing accidents with the participation of dredgers "Kuokka Pekka 5" and "Rozgwiazda" which had taken place in the Baltic Sea [11,12].

The analysis of the probability of the stability damage was conducted for the three most characteristic single hull and double hull port dredgers. To estimate the risk of capsizing of the watercraft, the critical event coefficient, based on the achieved stability parameters of the vessel and on the values of external heeling moments, was used. In addition, the survey also took into account the longitudinal pitching and transverse rolling of the dredgers.

The conducted research and analyses show that small port and roadstead dredgers are exposed to the risk of stability damage and capsizing during sea towing. Critical states may occur when there is a simultaneous increase in the amplitudes of longitudinal pitching and transverse rolling. The accident which accelerates the risk of capsizing of these vessels is the flooding of watertight compartments. The investigation indicates that there is a necessity to implement a detailed analyses of dredgers' stability in the presence of threatening events during towing, and a need for verification of the tightness condition before starting a sea voyage.

2. Freeboard and Stability Requirements for Dredgers

The simulation analysis applies to small dredgers with a length of more than 24 m used for work in ports or on roads, not intended for independent sea voyages. The model adopted in the study is 30 m long as it is relative for this group of dredgers. For the stability assessment, the ISC regulations for ships with a length of more than 24 m were used.

Dredgers which conduct dredging may work with the reduced freeboard in accordance with the requirements of the recommendations: "Guidelines for the assignment of reduced freeboards for dredgers, DR-68" [13].

For sea towing operations, dredgers must maintain the minimum freeboard as required in the regulations of the ICLL 1966 Convention [14].

The stability requirements for dredgers result from: Code Of Safety For Special Purpose Ships, 2008 (SPS) and Code on Intact Stability of Ships (ISC'2008 Section B, chapter 2.5) [15,16].

In practice, this means that during towing they must fulfill the requirements of the code: ISC'2008 A paragraph 2.2 or ISC'2008 B paragraph 2.4.5 [17] (see Table 1).

Table 1. Criteria of intact stability.

	ISC'2008 A 2.2	ISC'2008 B 2.5
The area under the righting lever curve from 0° to 15° if the maximum righting lever occurs at an angle of 15°.	-	0.07 m·rad
The area under the righting lever curve from 0° to 30° if the maximum righting lever occurs at an angle of 30° or more.	0.055 m·rad	0.055 m·rad
The area under the righting lever curve from 0° to the maximum righting lever angle if the maximum righting lever occurs between 15° and 30°.	-	$0.055 + \frac{(30^\circ - \varphi_{GZMAX})}{1000} \text{ m·rad}$
The area under the righting lever curve counted from 30° to 40° or to the angle of flooding.	0.030 m·rad	0.030 m·rad
Righting lever value for an angle of heel of 30° or more than 30°.	0.20 m	0.20 m
The angle of the maximum righting arm.	25°	15°
Initial metacentric height with free liquid surface corrections.	0.15 m	0.15 m

In addition, according to the DR-68 guidelines, the dredgers must fulfill the requirements of the weather criterion (ISC'2008, par. 2.3) for the wind pressure reduced to 270 N/m².

The regulations concerning the stability assessment of dredgers refer to threatening events during their dredging works and during their sea navigation. However, while at sea, dredgers are considered to be independent vessels. Whereas, it is worth mentioning that during their exploitation, they go on sea voyages as towed vessels. This generates a different range of threats than the standard ones, considered by the ISC regulations.

3. Accidents of the Dredgers

The accidents connected with dredgers capsizing during sea towing sometimes occurs. Mostly, the sequences of events leading to the disaster are initiated by leaking of the hull during sea towing. Insufficient knowledge of the impact of the marine environment on the towed vessel and its provisional sealing results in flooding of the watertight compartments. The resulting trim and transverse heel deteriorate the stability parameters of this vessel and ultimately lead to the loss of its stability and capsizing.

3.1. Accident of the Dredger “Kuokka Pekka 5”

The accident took place on 19 April 1997, when this dredger was being towed from the Kotka port to Mäntyluoto by the tugboat “Nico”. While towing in the open sea, sea water from the waves drained down into the left compartment of the winch through the hatch. As a result, this led to the dredger capsizing, which however remained buoyant (Figure 1).

The post-accident analyses indicate that the left winch compartment was being flooded for about 4.5 h. Finally, about 35 tons of water got into it. This caused the tilt and, together with the weather conditions, resulted in the dredger capsizing. Before the cruise, no stability analysis had been performed and the vessel's tightness had not been verified.



Figure 1. Dredger “Kuokka Pekka 5” capsized. GRT 104, Length 21.0 m, Breadth 9.4 m, Draught 1.7 m.

3.2. Accident of the Dredger “Rozgwiazda”

The incident took place on 17 October 2008, about eight miles from the coast, between Kołobrzeg and Darłowo. The dredger “Rozgwiazda” was towed by the tugboat “Stefan” belonging to the corporation from Gdańsk, Poland (Dredging and Underwater Works Company Ltd.). Due to the increasing wind force and the sea state, the tugboat “Goliat” joined the towing; it was towing the tugboat “Stefan”. During towing, the towing rope connecting “Rozgwiazda” with the tugboat “Stefan” broke. Twenty minutes later, the detached dredger, with no propulsion, capsized and began to sink. There were five crew members on board, who died as a result of capsizing of the dredger. The direct cause of the disaster, that the vessel sank, was the damage of the dredger’s stability. Most probably it was due to the partial flooding of the boatswain’s store room and the holds located on its starboard side near the bow with outboard water. The leakage was caused by the fact that during the journey the openings through which the line of the working anchor passed remained unsealed. This resulted in the dredger overturning with the keel up and the loss of buoyancy after the interior was flooded with sea water, which also entered through the open skylight to the engine room (Figure 2).

The dredger was not properly prepared for sea towing, which requires ensuring that the hull does not leak.

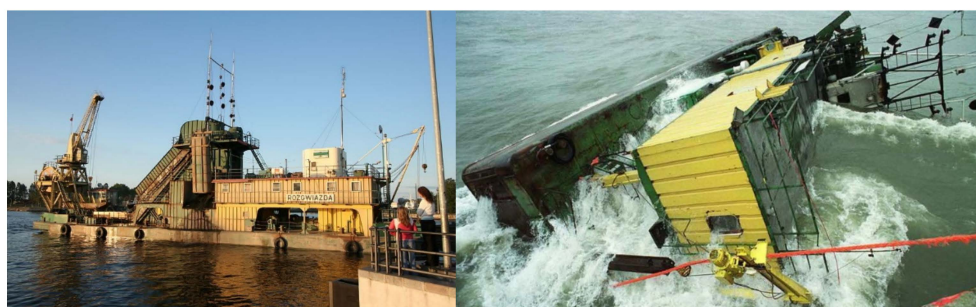


Figure 2. Dredger “Rozgwiazda” capsized. BRT 749, Length 51.4 m, Breadth 12.0 m, Draft 2.45 m.

4. Simulation Test

To estimate the possibility of the dredger capsizing during sea towing, three models of vessels, similar to the currently used port dredgers, have been designed.

The analysis of the risk of capsizing concerns three characteristic hulls of dredgers with equal primary dimensions, differing in the hull structure (Figure 3). Dredgers were divided into watertight compartments with identical dimensions for each model [18]. The hull shape of dredgers is similar to the capsized dredgers “Kuokka Pekka 5”—model 1 (Figure 4)—and Rozgwiazda”—model 2 (Figure 5). Model 3 (Figure 6) is based on existing harbor dredgers. The simulation analysis was carried out for a model similar to the dredgers actually used by PRCIP company in Polish harbors. The shapes and dimensions of the models have been simplified in order to compare the obtained results (Tables 2 and 3).

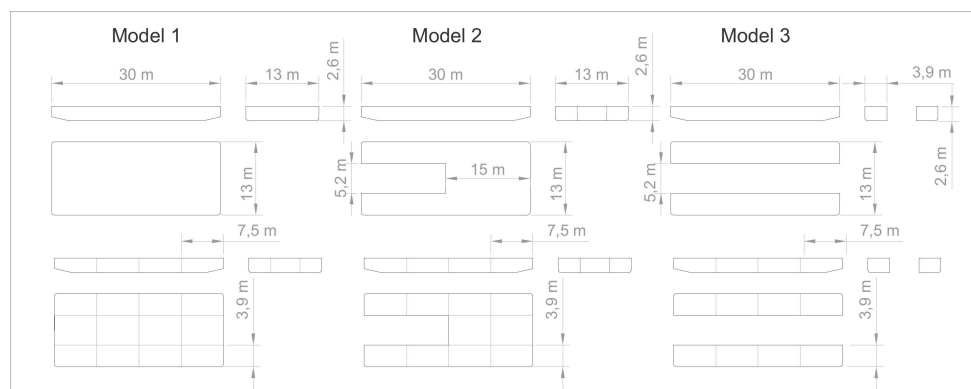


Figure 3. Models of dredgers.

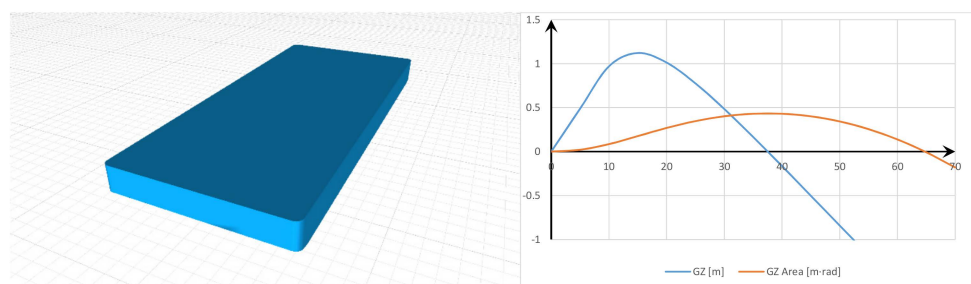


Figure 4. Model 1. GZ and Work (GZ Area) curve for initial condition.

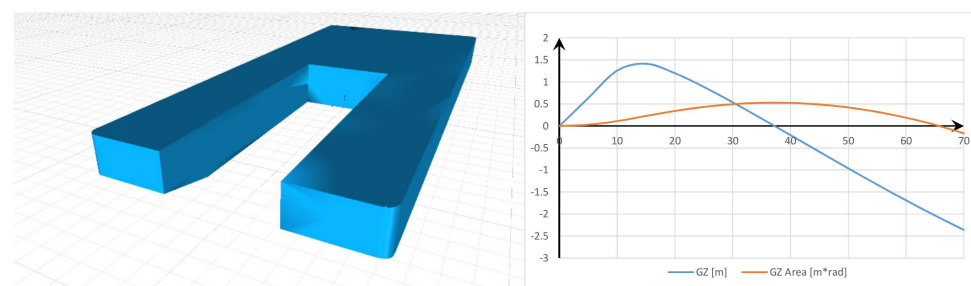


Figure 5. Model 2. GZ and Work (GZ Area) curve for initial condition.

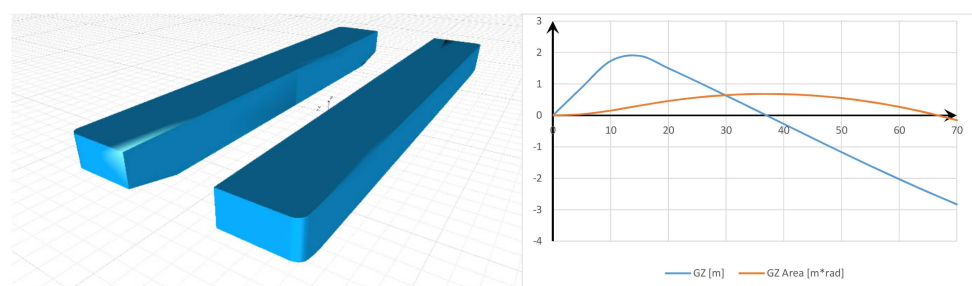


Figure 6. Model 3. GZ and Work (GZ Area) curve for initial condition.

Table 2. Parameters of dredgers' models.

Parameter	Symbol	Model 1	Model 2	Model 3
Length	L	30.00 m	30.00 m	30.00 m
Breadth	B	13.00 m	13.00 m	13.00 m
Lateral Height	H	2.60 m	2.60 m	2.60 m
Draft	T	1.60 m	1.60 m	1.60 m
Freeboard	FB	1.00 m	1.00 m	1.00 m
Displacement	D	608 t	486 t	361 t
Vertical center of gravity	VCG	4.50 m	4.80 m	5.50 m
Longitudinal center of gravity	LCG	0.00 m	1.82 m	0.00 m
The transverse coordinate of the center of gravity	TCG	0.00 m	0.00 m	0.00 m
Longitudinal metacentric height	GM_L	46.62 m	43.17 m	44.02 m
Transverse metacentric height	GM_T	5.56 m	7.21 m	9.72 m
Transverse windage area	A_{WT}	220 m ²	220 m ²	220 m ²

Table 3. Stability criteria ISC'2008, B.2.5.

Criteria	Value of gr.	Model 1		Model 2		Model 3	
$A(0^\circ \rightarrow 15^\circ)$	0.070 m·rad	0.176 m·rad	OK	0.227 m·rad	OK	0.361 m·rad	OK
$A(30^\circ \rightarrow 40^\circ)$	0.030 m·rad	0.030 m·rad	OK	0.037 m·rad	OK	0.182 m·rad	OK
$GZ_{MAX}(\varphi \geq 30^\circ)$	0.20	0.40 m	OK	0.54 m	OK	0.63 m	OK
φGZ_{MAX}	15°	15°	OK	15°	OK	15°	OK
GM'	0.15 m	5.56 m	OK	7.21 m	OK	9.72 m	OK
Weather K	1.0	1.11	OK	1.06	OK	1.02	OK
l_{w1}		0.088 m		0.110 m		0.148 m	
l_{w2}		0.131 m		0.164 m		0.221 m	
φ_1		20.2°		20.2°		20.2°	

4.1. Simulation Assumptions

- Initial draft and freeboard have been assumed to be identical for all models;
- The location of the center of mass in all models has been assumed for the seaworthy condition of the dredger and its characteristic instrumentation;
- The displacement of the dredgers has been determined on the basis of their initial draft;
- The initial trim has been assumed to be 0.00 m;
- The position of the dredger during longitudinal surging has been determined by the trim measured as the difference of drafts to the water surface;

- The watertight compartments of the models have had identical dimensions, but their number has depended on the adopted model;
- In the event of flooding of the watertight compartments, the amount of water has been assumed as a slowly changing value, and in the final stage as a constant;
- Static and dynamic heeling moments have been calculated for different model trims. They illustrate the physical trim of the dredger as well as its temporary longitudinal surging;
- Longitudinal and transverse windage areas have been assumed to be identical for each model.

All dredgers' models adopted for the analysis fulfill the stability requirements ISC'2008.

4.2. Simulation of Watercraft Capsizing

In order to assess the stability of the dredgers, an analysis of the threats that may lead to their capsizing during sea towing, has been carried out. The PolyCAD software was used for stability simulation. The simulation was carried out on the basis of the results of the stability parameters without reference to the transition time between the successive phases of the incident. The threats which have been considered in the study include:

- static heeling moments caused by the action of the tow and the wind;
- dynamic heeling moments caused by the action of the tow and the wind, together with vessel pitching;
- asymmetric flooding of watertight compartments of the vessel.

Dynamic overturning arms have been defined as the work required to overturn a craft per one ton of its mass (Figure 7).

$$l_{CRIT} = w_{CRIT} = \frac{W_{CRIT}}{D} \left[t \cdot m \cdot \frac{rad}{t} \right] \quad (1)$$

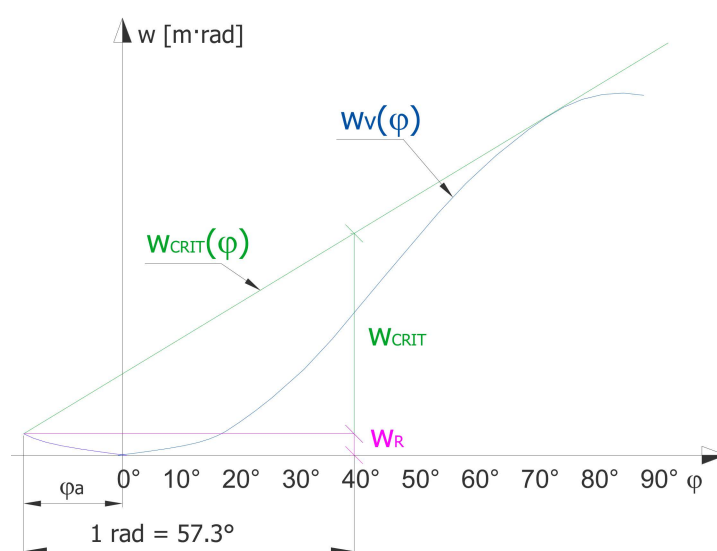


Figure 7. Critical work— W_{CRIT} .

The work obtained by the vessel (w_R) in the form of initial rolling was determined for the assumed angle of heel (φ_0).

External heeling moments that could cause the capsizing of the vessel are:

- heeling moment due to tow jerk— M_T ;
- heeling moment due to gust of wind— M_W .

While conducting the analysis, the most dangerous situation of such moments, i.e., perpendicular to the watercraft's side, was taken into consideration.

The maximum heeling moment due to tow jerk is determined from the formula:

$$M_{TD} = F_T z_T \cos(\alpha) [\text{kN} \cdot \text{m}] \quad (2)$$

where

F_T —bollard pull force, $F_T = 100$ kN;

z_T —vertical distance of tow hitch from the waterline, $z_T = 2.00$ m;

α —vertical angle of the tow, $\alpha = 0^\circ$.

Work of the heeling moment due to the tow jerk per one ton of vessel mass:

$$w_T(\varphi) = \int_0^\varphi \frac{M_{TD}}{g \cdot D} d\varphi [\text{m} \cdot \text{rad}] \quad (3)$$

The bollard pull value for the tug was determined in reference to the minimum requirements for tugs in accordance with the DNVGL-ST-N001 Marine operations and marine warranty, par. 11.12.2 recommendations for the calculated towing resistance of vessels according to Holtrop–Menen method at a towing speed of 6 KN. The required bollard pull for the safe towing of the dredgers is 100 kN.

The maximum heeling moment, due to gust of wind, is determined from the formula:

$$M_{WD} = \frac{P_D A_W z_W}{1000} [\text{kN} \cdot \text{m}] \quad (4)$$

where

P_D —dynamic wind pressure, N/m^2 ;

$$P_D = 0.5 v^2 \rho_A c_H c_s \left[\frac{\text{N}}{\text{m}^2} \right] \quad (5)$$

v —wind speed, m/s ;

ρ_A —density of air, kg/m^3 , $\rho_A = 1.222$ kg/m^3 ;

c_H —height coefficient (windage coefficient related to height), $c_H = 1.0$;

c_s —shape coefficient (windage coefficient related to the shape of the windage area), $c_s = 1.3$;

A_W —windage area, m^2 ;

z_W —distance from the windage area to the waterline, m;

g —acceleration due to gravity, m/s^2 .

In the simulation, the gusts of wind have been assumed to be 29 m/s (constant wind 8° Beaufort, $v = 20.7$ m/s , exceeding 40%).

Work of the heeling moment, due to the gust of wind, per one ton of vessel's mass:

$$w_W(\varphi) = \int_0^\varphi \frac{M_{WD}}{g \cdot D} d\varphi [\text{m} \cdot \text{rad}] \quad (6)$$

To determine the critical work values (w_{CRIT}), due to tow jerk and gust of wind, the following equation has been used:

$$w_v = w_{CRIT} + w_R \quad (7)$$

where

w_v —the work sufficient to capsize the ship, $\text{m} \cdot \text{rad}$;

w_R —work of ship's initial rolling, $\text{m} \cdot \text{rad}$;

w_{CRIT} —work of the external dynamic heeling moment leading to the capsizing of the ship.

In order to standardize the calculations of the work needed to capsize the ship, a reference angle of 1 rad (57.3°) has been assumed. In this case, the value of the work is equal to the value of the dynamic tilting arm.

In order to determine the possibility of capsizing of the towed dredger, the critical event coefficient (C), defined by the following formula, has been introduced:

$$C = \frac{w_W + w_T}{w_{CRIT}} \quad (8)$$

If the C coefficient is lower than 1.00, it means that the ship will survive the simultaneous phenomena of rolling, tow jerking and squall. However, reaching a value above one, indicates the capsizing of the ship (Figure 8).

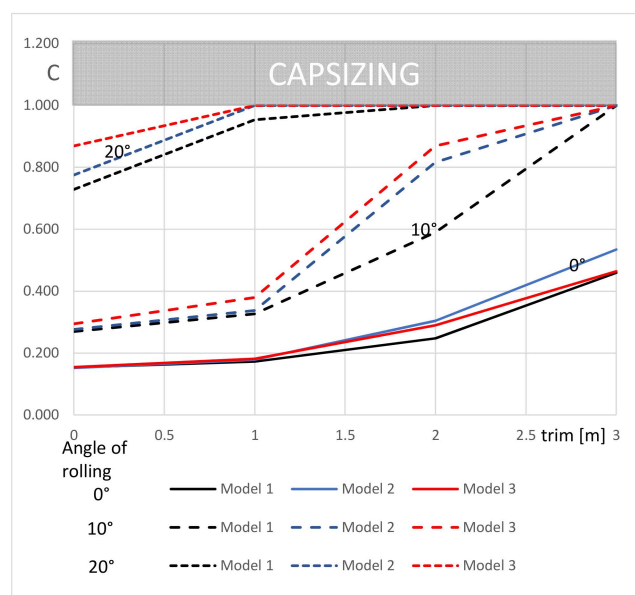


Figure 8. Values of the vessel's capsizing coefficient (C) depending on the trim and its rolling.

4.3. Watercraft in Undamaged Condition

The examined vessel sails undamaged, without heel and trim. It maintains its hull completely without leaks. The simulation assumes symmetrical rolling on both sides with amplitudes: 0° , 10° and 20° . In addition, the vessel is pitching longitudinally, the pitching parameters are presented by vessel's temporary trim.

For all models, capsizing is possible only when rolling exceeds 10° and a trim is up to 3.00 m for bow, and when the rolling is of 20° and the trim is more than 1 m. This means that significant longitudinal pitching, which increases the momentary trim of the vessel (diving), with simultaneous jerk of the tow and gust of the wind, may be a direct cause of vessel capsizing.

4.4. Simulation of Flooding of Watertight Compartments

In the dredger capsizing simulation, the phenomenon of unsealing of bow compartments, and their slow flooding, was analyzed (Figure 9). Two variants of flooding of watertight compartments were analyzed (Table 4):

- symmetrical flooding up to 50% and 95% of the compartment capacity;
- unsymmetrical flooding up to 50% and 95% of the right compartment capacity;
- The same dimensions of watertight compartments have been assumed for all models.

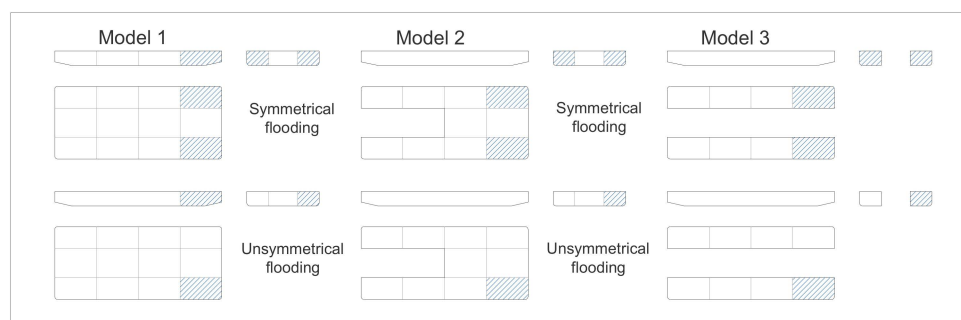


Figure 9. Flooding of watertight compartments.

Table 4. Parameters of water draining down into watertight compartments.

Parameters	Symmetrical Flooding	Unsymmetrical Flooding
Mass of water 50%	60 t	30 t
VCG 50%	0.68 m	0.68 m
Mass of water 95%	120 t	60 t
VCG 95%	1.36 m	1.36 m
LCG	11.20 m	11.20 m
TCG	0.00 m	4.50 m

The capsizing simulation includes the phenomenon of rolling and simultaneous jerk of the tow and the impact of the squall.

In the case of symmetrical flooding (Table 5), flooding of watertight compartments up to 95% of their capacity causes a trim of about 1.00 m for bow in models 1 and 2. On the other hand, in the case of model 3 it is 1.60 m. With increasing trim, the stability parameters of vessels decrease (Figure 10). What is more, when the rolling is greater than 13° , in the case of models 1 and 2, the impact of wind and the jerk of the tow may cause the watercraft to capsize. On the other hand, in the case of model 3 this may occur with the rolling of approx. 3° .

Table 5. Parameters of vessels after symmetrical flooding of compartments.

Parameters	Symbol	Model 1		Model 2		Model 3	
		50%	95%	50%	95%	50%	95%
Displacement	D	668	728	546	606	421	481
Longitudinal center of gravity	LCG	0.66	1.22	2.43	2.92	1.06	1.85
Vertical center of gravity	VCG	4.27	4.13	4.49	4.29	4.99	4.69
The transverse coordinate of the center of gravity	TCG	0.00	0.00	0.00	0.00	0.00	0.00
Draft	T	1.75	1.90	1.76	1.92	1.85	2.12
Trim	t	0.48	0.96	0.48	0.95	0.77	1.60
Draft forward	TF	1.99	2.38	2.00	2.39	2.23	2.92
Draft aft	TA	1.51	1.42	1.52	1.44	1.46	1.32
Heel	φ	0	0	0	0	0	0

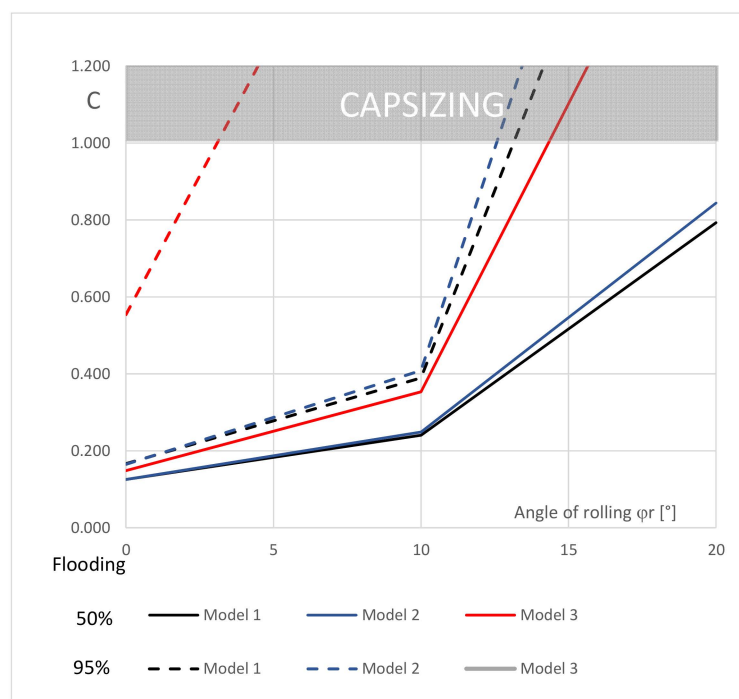


Figure 10. Values of the vessel's capsizing coefficient (C) depending on the trim and its rolling.

In the case of unsymmetrical flooding (Table 6), the flooding of a watertight compartment up to 95% of its capacity, causes heels of about 4° (Figure 11). The capsizing of the vessel 1 and 2 occurs at a rolling of 12° – 13° . On the other hand, the capsizing of the vessel 3 is possible at 10° .

Table 6. Parameters of vessels after unsymmetrical flooding of compartments.

Parameters	Symbol	Model 1		Model 2		Model 3	
		50%	95%	50%	95%	50%	95%
Displacement	D	638	668	516	546	391	421
Longitudinal center of gravity	LCG	0.35	0.66	2.14	2.43	0.57	1.06
Vertical center of gravity	VCG	4.32	4.24	4.56	4.45	5.13	4.94
The transverse coordinate of the center of gravity	TCG	0.21	0.40	0.26	0.50	0.35	0.64
Draft	T	1.67	1.74	1.68	1.75	1.72	1.84
Trim	t	0.24	0.48	0.24	0.48	0.37	0.78
Draft forward	TF	1.79	1.98	1.80	1.99	1.91	2.33
Draft aft	TA	1.55	1.50	1.56	1.51	1.54	1.45
Heel	φ	2.3	4.5	2.2	4.4	2.0	4.1

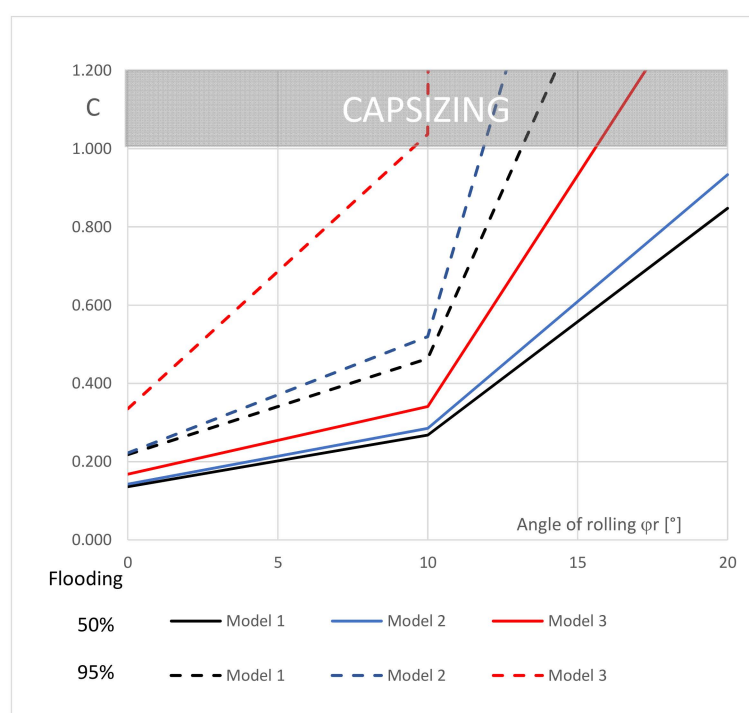


Figure 11. Values of the vessel's capsizing coefficient (C) depending on its rolling.

5. Discussion

Taking everything into consideration, the conducted simulation analysis leads to the conclusion that port dredgers, when they are subjected to marine towing, may capsize, in case of simultaneous occurrence of significant rolling, gusts of wind, and jerk of the tow.

It is also worth mentioning, that if the hull is maintained without leaks, the possibility of capsizing appears only at considerable rolling amplitudes of 20° . Furthermore, flooding of dredgers' compartments, either symmetrical or unsymmetrical, reduces the stability margin, due to the appearance of trim and heel. In such situations, capsizing can occur at a rolling of 10° – 13° .

In terms of the hull shape solutions, the vessels' model 1 and 2 achieve similar stability parameters, while the vessel's model 3 obtains the lowest value of the stability parameters and therefore it can capsize the fastest.

In fact, the current stability regulations for dredgers consider events that may occur during their operational work. Marine towing is not covered by these regulations. What is more, in terms of the stability analysis of dredgers during operation, only sailing in flat water is assumed, without taking into consideration the water waves. On the contrary, during real marine towing, there are significant changes in the dredger's trim due to the waves' shape and the tug's operation. The increase in longitudinal pitching and transverse rolling of these vessels may lead to their capsizing.

In order to ensure that marine towing of port dredger is safe, it is essential to maintain the hull without leaks, in the greatest possible range of heel angles. Due to the construction and operational solutions implemented in dredgers, there is a significant risk that the hull will not be preserved without leaks. During real towing, it has happened that the openings enabling the water to drain down into the vessel have not been secured ("Rozgwiazda") or the sealings have been provisional and have become damaged ("Kuokka Pekka 5").

Taking everything into consideration, it seems necessary to implement a recommendation for the stability analysis of dredgers for marine towing and strict compliance with the guideline to conduct inspection of the hull tightness before starting the voyage.

Information on hazards and operational limitations when towing each dredger should be prepared and presented to the master of the towage operation.

6. Summary

The purpose of this paper was to assess the risks and possibilities of capsizing of small dredgers designated for port work and redeployment during their sea voyage. The tests were based on a deterministic simulation of dredgers' stability-threatening events that may occur during their towing. The external dynamic heeling moments generated by wind and the tow action were taken into account. The investigation of events threatening the stability of the dredger was carried out for the operational condition with the tightness of the hull and for the leakage conditions of watertight compartments, with symmetrical and unsymmetrical flooding.

The result of the conducted analyses was the determination of possible threats to the stability of dredgers during their sea towing. The test units overturned as a result of rolling and dynamic wind blows. The threat to the stability of dredgers increases as a result of flooding watertight compartments caused by the lack of weathertightness of deck closures. The conducted research shows that it is necessary to revise the regulations concerning the stability of small dredgers during sea towing and to introduce a detailed program of safety inspections. Additionally, each dredger should undergo an independent tightness test before commencing the voyage.

Author Contributions: Formal analysis, J.S.; Methodology, J.S.; Resources, A.K.; Software, T.N.; Supervision, T.N.; Validation, T.N.; Writing—original draft, J.S.; Writing—review & editing, A.K. All authors have read and agreed to the published version of the manuscript.

Funding: This study was funded by the Gdynia Maritime University, the research project: WN/2021/PZ/07.

Conflicts of Interest: The author declares no conflict of interest.

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