



Abstract. Ocean routes are recommended for ships based on economic criteria. Under the influence of waves, during sailing of the ship, various dangerous phenomena arise which can lead to marine crashes. Although weather sites are known to provide short-term weather forecasts (wave and wind parameters), this information is not used to calculate corrections of ocean-route guidelines. A captain based on his knowledge and experience can make such adjustments. The article presents the results of calculations of the values of dangerous parameters of phenomena which may occur during a cruise on example ocean routes. For the calculation of dangerous phenomena, the average statistical long-term (seasonal) parameters contained in weather atlas were used.

Keywords: forecasting ocean routes, irregular long-term (seasonal) waves, dangerous phenomena occurring during sailing at waves

INTRODUCTION

One of the most important tasks that has a major impact on operating costs is the forecasting of an ocean shipping route when operating a transport ship.

Current forecasting of ocean shipping is conducted according to the following criteria (Wiśniewski, 1991):

- minimizing travel time.
- minimizing fuel consumption.
- minimizing fuel consumption at the assumed time of ship travel.

Various computer programs offered by specialized companies are used to forecast ship navigation. However, despite considerable progress in weather forecasting as well as the ship's sailing route, sea-related crashes caused by wind and wave effects on the flowing vessel continue to be recorded. According to published statistics, the number of crashes is growing (Fig. 1). (Singh, 2014).

The number of emerging crashes is also influenced by lack of full and useful information on the size of safety risks of a sailing vessel. Ocean based forecasting systems use weather data to recommend these routes according to the criteria mentioned, meaning that operational or billing requirements are taken into account. Although these systems have access to forecast weather data, they do not analyze the behaviour of a ship during a cruise, and if there is a potential risk to cargo safety or the entire ship, they do not make corrections to the recommended shipping route. There are also no clear criteria for assessing when the intensity of a dangerous phenomena from waves is a threat to the ship that could lead to a sea crash.

The article presents the results of the calculation of dangerous parameters of the phenomena that occur during the sailing of the ship after the waves is corrugated. The calculations were chosen:

- these phenomena, which are most frequently mentioned in the literature and for which the relevant criteria have been defined (Ghaemi, M. H. and Olszewski, H. 2017, Karpinen, 1997).

- examples of ocean shipping routes between Europe and North America on which transport vessels.
- and calculations were made for the sample transport vessel and for the statistical mean long-term (seasonal) weather conditions. (Hogben et al. 1986).

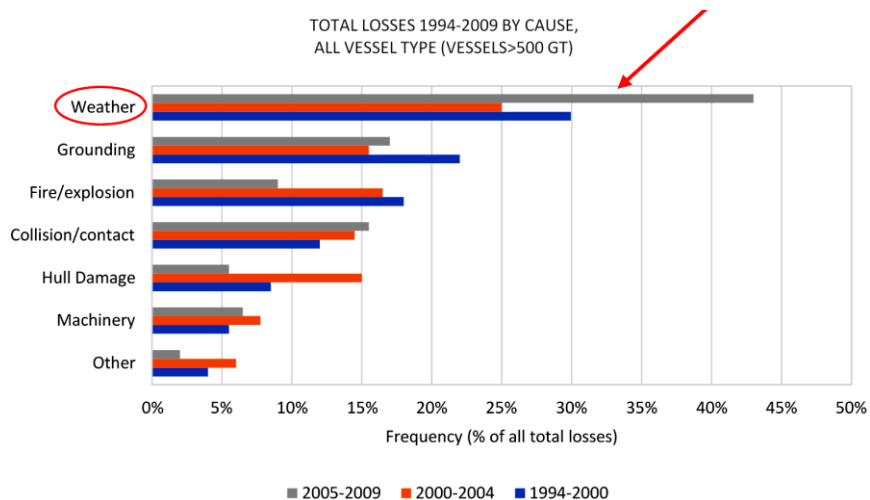


Fig. 1. Statistics on the causes of marine disasters.

Source: own elaboration based on (Singh, 2014)

DANGEROUS PHENOMENA OCCURRING WHEN THE SHIP SAILING AT WAVES

During the cruise of the ship on the ocean route. waves are cause of motions and many different dangerous phenomena. which at high intensity can cause sea crashes. If the intensity of dangerous phenomena exceeds the permissible criteria. then the course of the ship relative to the wave changes and/or the speed of the ship is reduced.

Table 1. Criteria for selected seakeeping.

	Merchant vessels	Warships	Fast small units
Vertical accelerations at the bow (RMSD)	0.275 g small 0.1 g large	0.275 g	0.65 g
Vertical acceleration in the bridge (RMSD)	0.15 g	0.2 g	0.275 g
Horizontal lateral acceleration in the bridge (RMSD)	0.12 g	0.1 g	0.1 g
Rolling (RMSD)	6.0	4.0	4.0°
Slamming - probability of occurrence for 100 waves - number per hour	0.03 small 0.01 large 20	0.03	0.03
Flooding the deck - probability of occurrence for 100 waves - number per hour	0.05 30	0.05	0.05

Source: (Karppinen. 1987).

The most commonly taken account of the wave behaviour of the ship is considered (Girtler et al. 1995, Karppinen 1997, Lloyd 1989, Mudronja et al. 2015, Prpic-Orsic et al. 2016, Szlangiewicz 1999):

- rolling.
- pitching.
- vertical acceleration.
- transverse horizontal acceleration.
- flooding of the deck.
- slamming.
- emergence of the propeller.

The criteria set out in Table 1 are used to assess the intensity of dangerous phenomena caused by waves.

Marine properties that have the greatest impact on vessel safety (Table 1) are calculated for the points shown in Figure 2.

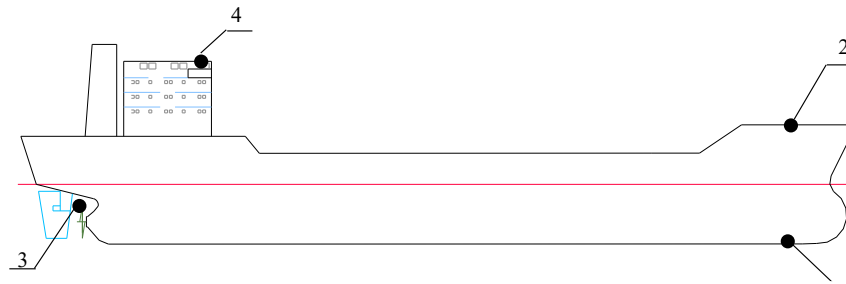


Fig. 2. Points for which seakeeping parameters have been calculated
1 – slamming, 2 – deck flooding and bow accelerations, 3 – propeller emergence,
4 – accelerations in the bridge.

Examples of calculated of seakeeping for a container ship ($L = 140.14$ m. $B = 22.3$ m. $T = 8.25$ m. $D = 1729$ m³) for different speeds V . Fig. 3.

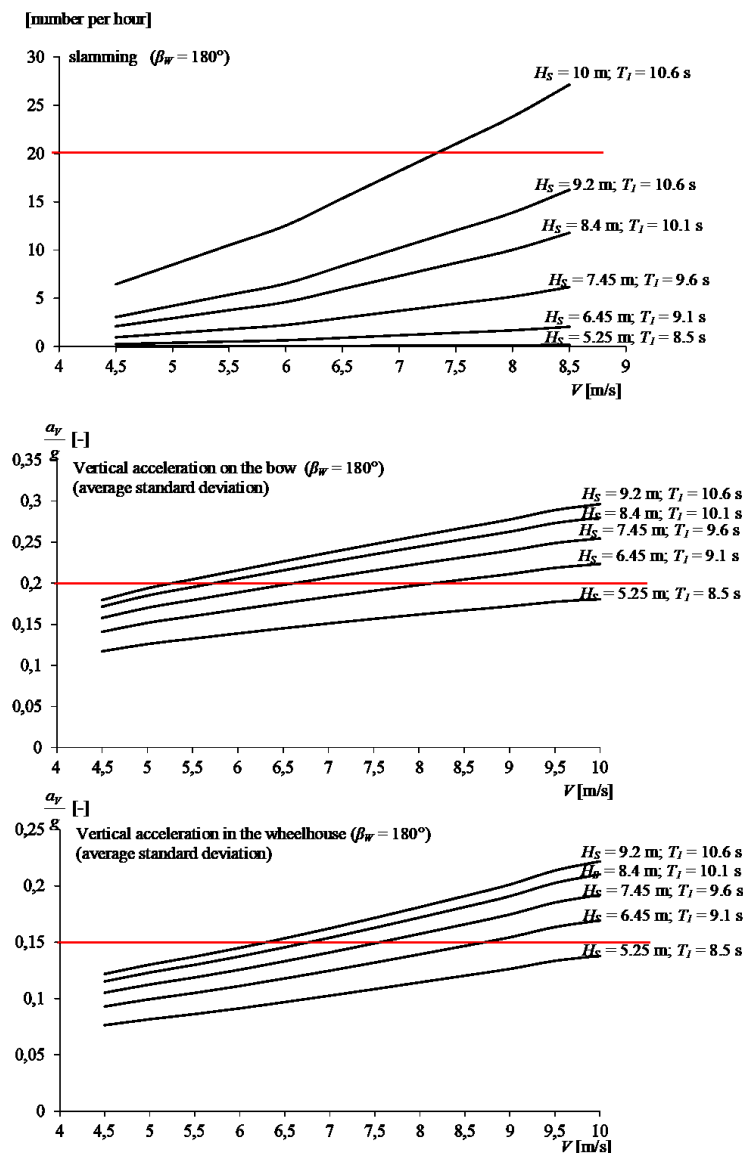


Fig. 3. Influence of speed of container ship and sea level on selected marine properties.

ANALYZED OCEAN ROUTES AND WEATHER PARAMETERS

For the calculation of the parameters of dangerous parameters phenomena were selected exemplary of actual ocean routes. Fig. 4. after which vessels sail between Europe and North America.

Calculation of the parameters of dangerous phenomena was made for average statistical parameters (seasonal) recorded in the waters areas which run analyzed ocean routes. Fig. 4. For these areas. the weather parameters are included in the atlas (Hogben et al. 1986). Sample weather data (wave probability) is shown in Table 2.

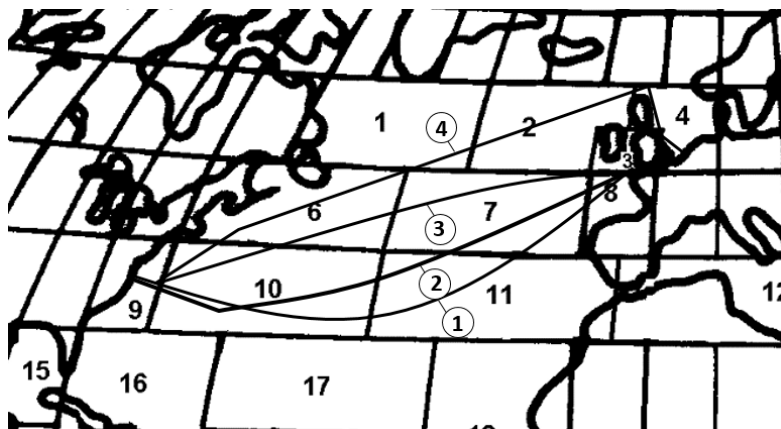


Fig. 4. Examples of ocean routes that vessels sail between Europe and the USA.

Table 2.

Probability of occurrence of wave height H_S and period T_1 for a given direction at a given water area. Fig. 4.

Water area: 10											
Season of the year: all year											
Direction of waves: $\mu = 240^\circ$											
T_1 [s] \ H_S [m]	calm	<5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	>21
0.25		0.093	0.071	0.059	0.133	0.200				0.066	0.050
0.5		0.082	0.095	0.139	0.143	0.058		0.142		0.428	0.060
1.0		0.094	0.088	0.101	0.109	0.125		0.058		0.111	0.190
1.5		0.090	0.109	0.124	0.068	0.133					
2.0		0.102	0.105	0.137	0.123	0.128	0.081	0.091			
2.5		0.137	0.129	0.147	0.151	0.109	0.119	0.210			
3.0		0.125	0.131	0.155	0.124	0.161	0.225	0.261			
3.5		0.147	0.153	0.195	0.192	0.189	0.151	0.117			
4.0		0.316	0.203	0.234	0.188	0.160	0.246	0.157	0.500		
4.5		0.273	0.257	0.160	0.154	0.155	0.236	0.310	0.062	0.500	
5.0			0.091	0.271	0.228	0.175	0.307				
5.5		0.333	0.286	0.158	0.182	0.142					
6.0		0.333	0.207	0.254	0.223	0.142	0.200	0.166			
6.5			0.261	0.240	0.272	0.231	0.091	0.500		0.500	
7.0			0.333	0.143	0.368	0.500	0.166	0.333			
7.5				0.188	0.111	0.444		0.166			
8.0				0.333	0.091	0.375	0.666	0.500			
8.5		1.000			0.176			0.500			
9.0				0.500	0.461		0.200				
9.5			0.250	0.142	0.312	0.333				0.500	

Source: (Hogben et al. 1986)

CALCULATION RESULTS

Calculation of the parameters of the parameters of dangerous phenomena was made for the container ship for individual parts of the ocean routes (Fig. 4) and average statistical, long-term (seasonal) weather parameters (Hogben et al. 1986). The calculation results for each oceanic route (Fig. 4) are shown in Figures 5 and 6, and detailed examples are given in Table 3.

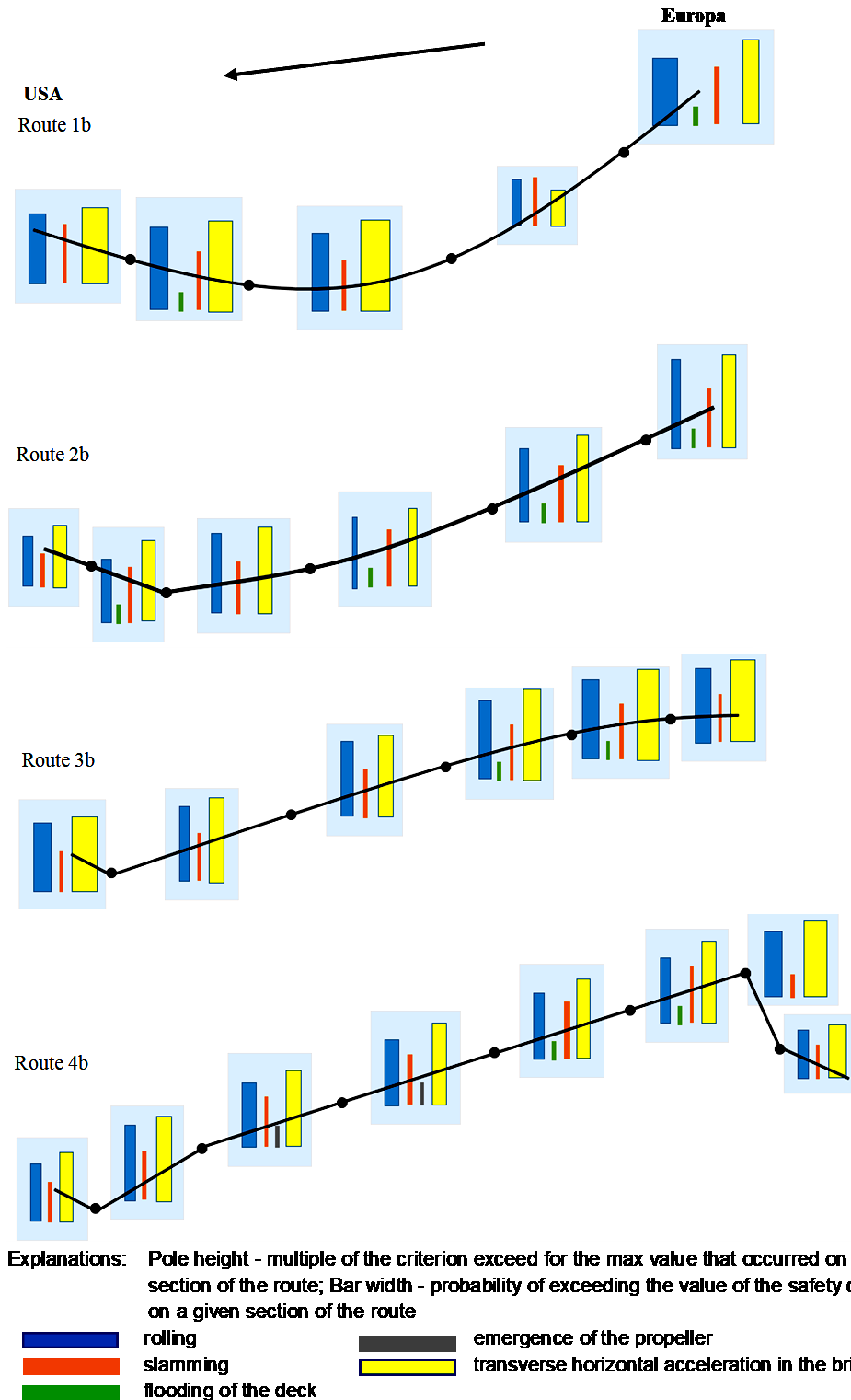
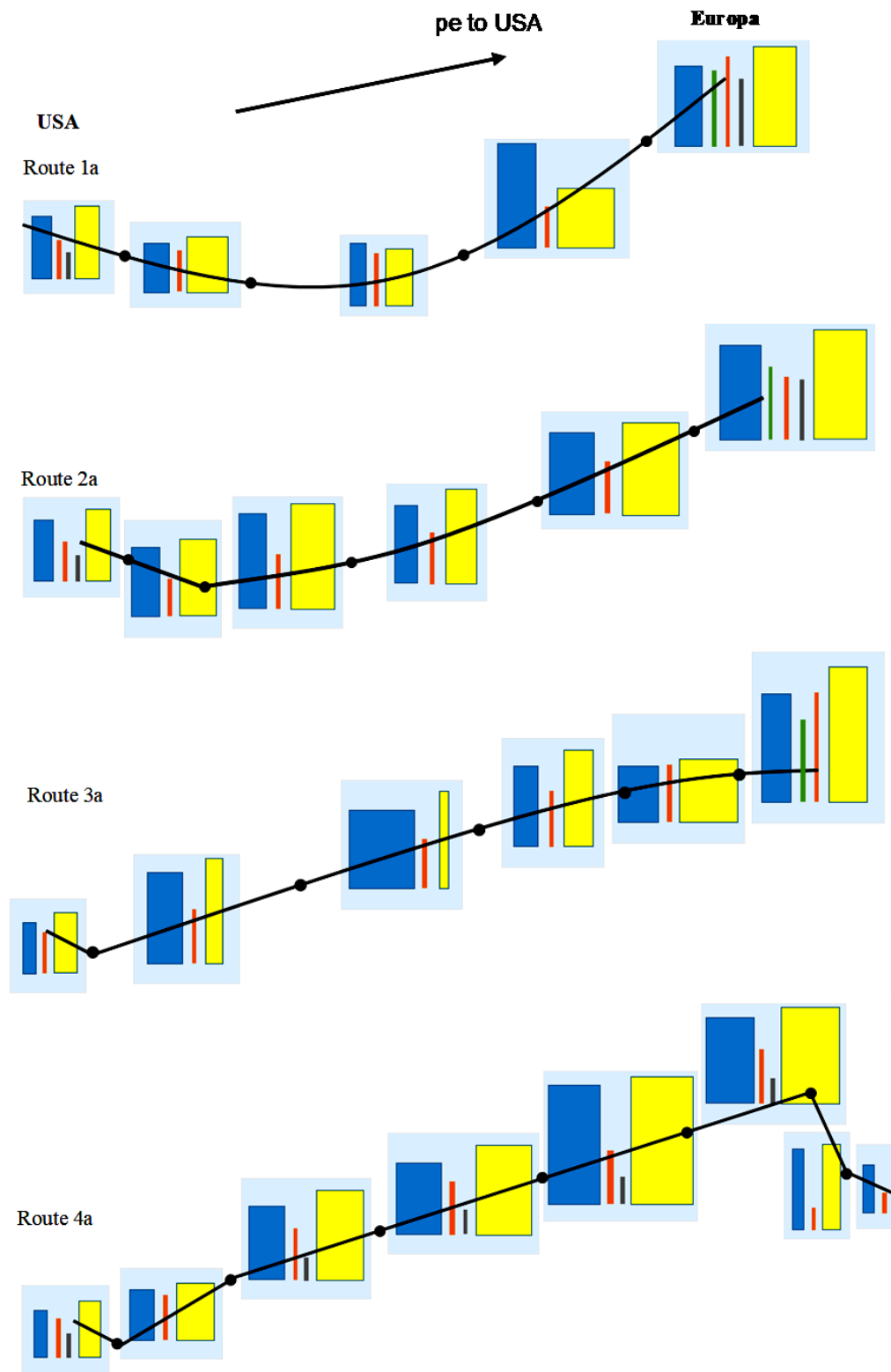


Fig. 5. Graphical representation of the values of parameters of dangerous phenomena on particular sections of selected ocean routes – Routes from Europe to USA.



Explanations: Pole height - multiple of the criterion exceeded for the max value that occurred on section of the route; Bar width - probability of exceeding the value of the safety on a given section of the route

- rolling
- emergence of the propeller
- slamming
- transverse horizontal acceleration in the bilge
- flooding of the deck

Fig. 6. Graphical representation of the values of parameters of dangerous phenomena on particular sections of selected ocean routes – Routes from USA to Europe.

Table 3.
Results of calculation of parameters of dangerous parameters of phenomena on selected ocean routes from Europe to USA.

Dangerous phenomenon	Route sections 1b							
	8/220°	7/225°	11/215°	10/180°	9/180°			
Rolling	25.14 8.89%	17.11 2.75%	28.00 5.20%	30.60 5.20%	25.50 5.32%			
Slamming	22.17 >0.01%	N	N	23.33 >0.01%	N			
Flooding the deck	103.16 0.42%	89.90 1.00%	91.58 0.52%	106.00 0.21%	76.50 0.14%			
Emergence of the propeller	N	N	N	N	N			
Vertical acceleration on the bow	N	N	N	N	N			
Vertical acceleration in the bridge	N	N	N	N	N			
Horizontal lateral acceleration in the bridge	0.77 5.78%	0.49 4.40%	0.83 8.66%	0.81 7.15%	0.69 7.79%			
Dangerous phenomenon	Route sections 2b							
	8/240°	7/235°	11/235°	10/240°	10/260°			
Rolling	32.30 2.69%	26.88 2.46%	26.06 1.28%	28.9 2.94%	23.14 2.85%			
Slamming	23.33 >0.01%	22.75 >0.01%	22.75 >0.01%	N	22.17 >0.01%			
Flooding the deck	106.00 0.48%	104.56 1.28%	104.56 0.32%	94.53 0.62%	103.16 0.60%			
Emergence of the propeller	N	N	N	N	N			
Vertical acceleration on the bow	N	N	N	N	N			
Vertical acceleration in the wheelhouse	N	N	N	N	N			
Horizontal lateral acceleration in the bridge	0.85 4.17%	0.79 3.51%	0.70 2.31%	0.79 4.45%	0.72 4.00%			
Dangerous phenomenon	Route sections 3b							
	8/185°	7/185°	7/215°	6/215°	10/215°			
Rolling	28.00 4.90%	29.41 4.87%	29.15 3.84%	26.88 3.37%	27.76 3.00%			
Slamming	N	22.75 >0.01%	22.75 >0.01%	N	N			
Flooding the deck	89.71 0.25%	104.56 0.60%	104.56 1.03%	91.58 0.95%	89.71 0.46%			
Emergence of the propeller	N	N	N	N	N			
Vertical acceleration on the bow	N	N	N	N	N			
Vertical acceleration in the bridge	N	N	N	N	N			
Horizontal lateral acceleration in the bridge	0.76 7.42%	0.84 6.77%	0.85 5.29%	0.76 4.60%	0.79 4.60%			
Dangerous phenomenon	Route sections 4b							
	4/135°	4/110°	2/200°	2/220°	1/220°	6/220°	10/215°	9/230°
Rolling	16.54 3.18%	24.67 5.29%	24.93 3.11%	24.03 3.14%	24.91 4.20%	23.87 3.39%	27.76 3.00%	21.06 3.08%
Slamming	N	N	22.17 0.01%	22.17 0.01%	N	N	N	N
Flooding the deck	31.61 0.03%	43.48 0.01%	103.16 1.02%	103.16 1.34%	90.39 1.58%	90.39 0.91%	89.71 0.46%	74.14 0.31%
Emergence of the propeller	N	N	N	N	55.8 >0.01%	47.14 >0.01%	N	N
Vertical acceleration on the bow	N	N	N	N	N	N	N	N
Vertical acceleration in the bridge	N	N	N	N	N	N	N	N
Horizontal lateral acceleration in the bridge	0.49 5.57%	0.71 6.96%	0.77 4.07%	0.72 3.87%	0.76 4.20%	0.69 4.35%	0.79 4.59%	0.63 3.98%

Explanations:

Section 8/240: 8 – water area (Fig. 4). 240° – ship course

Hazardous phenomena. eg. rolling 25.11/8.89%: 25.14° – maximum mean standard deviation (Table 1).

8.89% – probability of exceeding the criterion in Table 1.

N – no criterion for dangerous occurrence

CONCLUSIONS

- Calculation of the parameters of dangerous parameters that may occur on ocean shipping routes was made for average statistical. long-term (seasonal) weather conditions (these are not instantaneous weather conditions that occur during the sailing of the ship).
- Parameters of dangerous phenomena were calculated for individual sections of selected shipping routes.
- The results of the calculation show that the intensity of the resulting dangerous phenomena is different:
 - a) on individual routes between Europe and the USA.
 - b) on a given shipping line during a European trip to the USA and a return trip from the USA to Europe.
- For average (seasonal) weather conditions. the intensity of dangerous phenomena for a given shipping line is lower during a US-Europe trip than from Europe to the USA.
- Comparing the results of the calculations. it can be seen that there are shipping lines where the transgression criteria are the smallest. but when cruising from Europe to the USA and vice versa. these will be different shipping lines.
- The calculations show that the values of dangerous phenomena may exceed the criteria and that. in order to limit their impact on the safety of the ship. adjustments to the forecasted shipping routes (change of course and/or change of ship speed).

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