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A first approach of the hydrological factors' influence on the maritime navigation in the Black Sea

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Abstract

Efficient modern navigation is determined, among the other things, by the knowledge of the influence of the main hydrological factors on the movement of the ship, in different sea states. This paper aims to be a first approach on the influence of important hydrological factors such as waves, sea currents, sea level oscillations on navigation in an enclosed sea basin - the Black Sea, with specific physical-geographical and hydrographic characteristics.

Keywords: Black Sea, maritime navigation

1. Introduction

In case the sea state is not taken into consideration, the wrong choice of the ship's route and speed under the conditions of a rough sea, or the inappropriate change of the route in stormy conditions can lead to severe consequences, such: damage of the ship's hull; cargo moving onboard; overturning of the vessel; ship sinkage. The big waves combined with a strong wind (especially gusts) produce a strong tossing with accentuated heelings that, in fact, do not represent a real threat for the ship's security, but it significantly increases the crew's fatigue, reduces the attention and the vigilance of the officer on watch [1].

The waves appear at the sea surface, having different shapes, sizes, and a variable length. For navigation, the wind and swell waves are particularly important, defined as oscillations for a short period into the sea surface layer. In maritime navigation, the agitation of the sea is given by the Beaufort Scale. In navigation the wave amplitude is particularly important, and it depends complexly on the wind speed, V_W [m/s], the wind duration, T_h [hours], the wind range on the sea - D [km, nautical mile], and in the coastal area, it depends on the sea depth, h [m], as well. For practical navigation needs, the state of the sea is coded from zero meaning calm, to 9 - phenomenal, including the main elements of the waves (height and length) [2]. Aboard, the wave elements are analytically assessed, or determined by empirical formulas (i.e., by the geometrical elements in correlation with the cinematic ones), or the graphic-analytical method (i.e., by built monograms for different anemobaric situations).

Also, the wind waves characteristics can be determined using a radar. The radar screen area, including the signals reflected by the wind waves, is limited (e.g., for a sea of degree 5-6 it is of approximativelly two nautical miles, and for a high state sea over 7, the value reaches 3...4 nautical miles, respectively). Related to the waves under the wind, due to their curvature, they reflect the radar signals better than the waves wind, so, the overall radar image has an oval shape with a more substantial part to the wind. The strong swell can be observed on the radar screen from relatively large distances. From the elements presented above, it results that the sea's level, currents and waves influence the ship's safety, both in the Black Sea's coastal zone and off-shore. This influence is manifested by the following effects produced to the ship [3]: ship oscillations increase, especially the rolling motion; ship stability reduction (loss); loss of speed.

2. Materials and methods

Considering the factors that generate the effects previously mentioned, each of them are presented, their consequences on the ship and the practical recommendations to ensure the safety of maritime navigation in the Black Sea. For the conditions in the Black Sea, the following were calculated: the sea currents, the wind's leeway, and the period of the apparent wave the for the prevalent waves during winter and warm seasons, on the east-west routes (and vice versa, also), as well as for the entire sea basin and on the north-south routes (and vice versa, also), for the western basin; during the winter season, the winds from the northern sector prevail, which makes the drift have maximum values.

3. Results

a. The Black Sea's levels

Under the effect of multiple factors, the Black Sea surface is permanently subject to some vertical, periodical or non-periodical oscillations. The level oscillations can be of: volume, caused by the water quantity variation, and deformation, caused by the shape variation of the sea free surface, respectively. Being independent from each other, the level oscillations are produced by the following factors: climatical (precipitations, evaporations); hydrological (flowing waters influx, the water exchange through the Bosphorus and Kerch straits); cosmic (tides); meteorological (level oscillations caused by the wind and seiches, because of the atmospheric pressure variation). The Black Sea is individualized by the regular level oscillations, with a maximum value during the summer season and a minimum one in the cold season of the year. The level increases gradually starting with December to a maximum in July; then it gradually decreases to the minimum in November.

The moment of the maximum sea level is less stable, because, in 70% of the cases, this occurs in the month of June, rarely in July and exceptionally in August. The moment of the minimum sea level is less stable (in 30% of the cases in January, 23% in October, 20% in November and rarely in March and December). The average amplitude of the level oscillations, caused by the water volume variations, reaches values of 20 - 28 cm (Table 1 and Figure 1, 2) [4, 5, 6, 7, 8].

Table 1 Trend and seasonal components of coastal (relative) sea level changes at the tide gauge stations along the Black Sea coast

Tide Gauge Station	Data Period	Trend (mm/year)	Annual Amplitude (mm)		Semi-Annual (mm)	
			Amplitude (mm)	Phase (^{0})	Amplitude (mm)	Phase (^{0})
Constanţa	Jan. 1945 Dec. 1979	3.02 ± 0.46	78.14 ± 6.55	127.94 ± 0.08	15.74 ± 6.55	26.34 ± 0.42
Varna	Jan. 1926 Nov. 1961	1.53 ± 0.48	69.54 ± 6.42	152.73 ± 0.09	27.38 ± 6.41	344.06 ± 0.23
Burgas	Feb. 1981 Jan. 1996	−7.52 ± 1.33	67.23 ± 8.13	141.78 ± 0.12	20.84 ± 8.12	19.83 ± 0.39

Igneada	Jun. 2002 Dec. 2014	6.94 ± 2.18	49.16 ± 11.17	130.14 ± 0.23	16.01 ± 11.22	50.66 ± 0.70
Şile	Jul. 2008 Dec. 2014	5.03 ± 4.84	62.92 ± 12.84	128.86 ± 0.20	22.90 ± 12.84	49.11 ±0.56
Amasra	Jun. 2001 Feb. 2011	3.43 ± 1.42	30.69 ± 5.71	104.70 ± 0.18	3.47 ± 5.66	340.66 ± 1.63
Sinop	Jun. 2005 Dec. 2014	0.43 ± 2.88	49.04 ± 11.26	135.82 ± 0.23	29.53 ± 11.28	12.06 ± 0.38
Trabzon	Jul. 2002 Dec. 2014	2.33 ± 1.75	62.77 ± 8.93	153.45 ± 0.14	27.09 ± 8.93	17.09 ± 0.33
Batumi	Jan. 1925 Dec. 1996	3.52 ± 0.15	78.93 ± 4.43	158.48 ± 0.06	35.19 ± 4.43	22.01 ± 0.13
Poti	Aug.1922 Dec. 2002	7.01 ± 0.12	77.42 ± 4.05	157.76 ± 0.05	35.86 ± 4.05	26.52 ± 0.11
Tuapse	Jan. 1943 Dec. 2011	2.92 ± 0.14	70.42 ± 3.85	142.41 ± 0.06	37.00 ± 3.85	29.78 ± 0.10
Sevastopol	Jan.1925 Dec.1996	1.56 ± 0.22	79.41 ± 4.58	139.65 ± 0.06	30.07 ± 4.59	16.25 ± 0.15

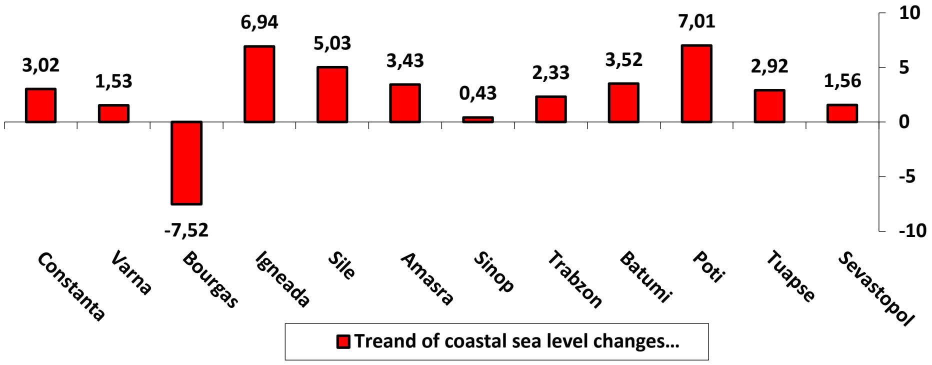

Figure 1

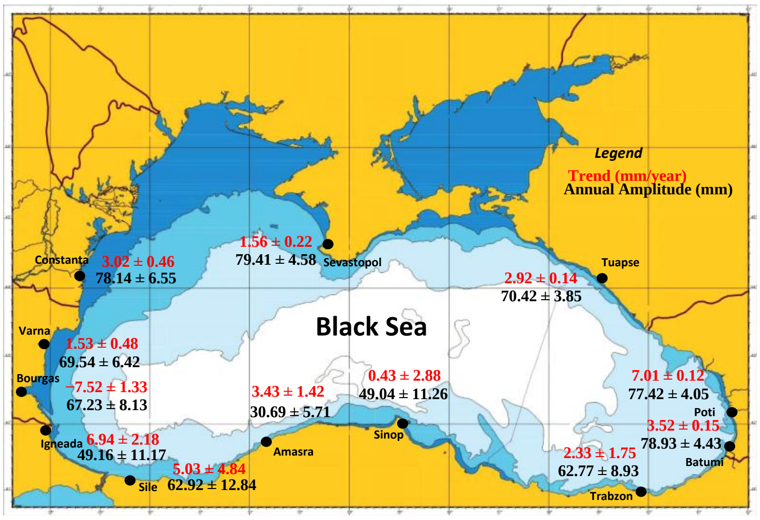

Figure 2

b. The Black Sea's waves

Depending on the formation and propagation conditions, the waves produced by the wind in the Black Sea are of the following types: the wind waves that are higher during the winter and autumn seasons, when the winds from the sea are predominant; in the western basin of the Black Sea, the height of these waves is of 6...8 m, with a maximum value of 14 m; ashore, the value ranges from 4.3 m - Odesa value, to 5.1 m - Tendre, 5.7 m - Sevastopol, 6 m - Constanța, 8 m - on the mountainous shores; the waves energy varies depending on the area; the swell waves is a system of waves left by the wind that stopped blowing, or that has changed the direction in the observation moment, or a system of waves produced by the wind that blows far from the observation zone; a particular case is the swell which propagates in the absence of the wind (e.g. the calm state), called *dead swell*; the resac waves (*Resaca*), that can be observed when the wind or swell waves, propagated from the high seas, reach the shallow waters; in this case, the action of the water bottom changes the waves' characteristics. The *Resaca* is accompanied by the surface and bottom currents, oriented in opposition, and in the case of the steep bottom, it is accompanied by the waves interference phenomena (i.e. they are propagated from the high seas with the reflected ones) [9].

The high waves occur during the cold season (the frequency being 10% in some districts), and during the summer season they are less frequent (3%). In the cold season, the 6 sea state and higher frequency represents over 10%, and 0 and 1 sea state is between 20 - 30%. The main direction of the waves propagation is north and north-east. The wave's height during the winter storms can reach 5 - 8 m. In the transitional season, the waves regime is maintained alike during the winter season, but with an unstable propagation direction and sometimes with heights of 6 - 7 m. In the summer season, the 6 sea state and above frequency is 2%, the strong waves are formed from westen to northern direction, with maximum heights of 6 -7 m, respectively, but the predominant waves have about 1 m. During the transition to the cold season, the agitation of the sea remains similar to that in the summer season, and beginning with October and November, the sea degree of agitation increases, the 4 sea state and above reaching 5-10% in some regions; the main direction of the waves propagation is from NE and east, and sometimes from the south, having the maximum heights of 6 - 7 m.

Generally, the length of the waves in the Black Sea is between 30...50 m, with a periodicity of 6 seconds, but in the eastern and south-eastern regions, longer wind waves are frequently formed, i.e. of approximately 100 m, with a periodicity of 10...12 seconds, as well as the swell waves, having a length of 150...200 m, with a periodicity of 15...17 seconds [10].

c. The Black sea's currents

In the Black Sea the current regime is specific to the currents' regime from an isolated body of water; this is determined by the winds regime, the river water intake, the water density variation, the seabed topography. All kinds of currents are formed, of particular importance being the influence of the resultant of the atmospherical circulation and the temporary winds, that creates drift and wind stationary currents. The current system appears as a closed system, with specific particularities in some areas. The main current includes all the big mainstream that forms a circle with a diameter of 20 ... 50 nautical miles, at a distance of about 2...5 nautical miles from the shore, respectively up to depths of 1,000 meters. This area is characterized by stability and speeds between 0.5...1.09 Kt (2...3 Kt), during the action of strong winds). The movement runs in the counterclockwise direction, i.e. parallel to the shore, and rarely it has a reversed direction. In the central areas of the eastern and western basins of the Black Sea, the currents are circular, with a counterclockwise motion, a low and moderate speed, i.e. of 0.2...0.5 Kt. Inside the bays, circular currents appear, having the motion in the clockwise direction, with speeds of 0.2 ... 0.5 Kt [11]. There are four major branches of this cyclonic movement called: the current of Anatolia, the current of Caucasus, the current of Crimea and the Rumel current (it gets a movement impulse from the rivers' mouth from the north-west of the Black Sea, i.e. along the western shore, carrying the water masses from east to west and then to south).

From Cape Sarych, the marine current has an orientation towards the north-west, to Cape Tarkhankut (the speed being of 0.5...0.7 Kt). Inside the bays Feodosia and Kalamit, there are anticyclonic currents having speeds of 0.3 ... 0.5 Kt. We also determined stable currents (the speed is between 1...3 Kt) at Cape Meganom, Sarych, Aia, Fiolent and Kerson. On the eastern shore of the Black Sea, the current has a general direction to the north-west (the speed is between 0.5...0.7 Kt) and in the bays from here we meet locally unstable currents (the speed is between 0.3...0.5 Kt). The currents from the southern shore of the Black Sea have an eastward movement (the speed is between 0.6...0.8 Kt), following the coastline configuration (inside the bays and at the capes, there are anticyclonic currents (the speed is between 0.3...0.5 Kt) [12, 13].

Shortly, the currents from the Black Sea basin can be characterized as follows: in the cold season, in the entire basin a cyclonic system with two centers is formed, respectively eastern and western, and with two secondary anticyclone centers, i.e. in the north-western respectively south-eastern parts. During the transitional period, the situation is opposite to that during the wintertime, but less developed. In the summertime, a cyclonic center is formed in the western part, respectively, in the eastern part an anti-cyclonic centre in a weak depression, i.e. with an anticyclonic centre in the north-west and a cyclonic center in the south-east (Figure 3).

The average annual situation is similar to the warm season situation, except that the cyclonic centre of the western basin of the Black Sea is ten times stronger than the centre of the anticyclonic eastern basin. The records of the current speeds show their average values at the depth levels of 200, 300 and 500 m, of 10, 8 and 3.2 cm/s, respectively; the minimum recorded speed is 2.8 cm/s at a depth of 750 ... 1,000 m. At a depth of 1,600 m, this speed increases to the value of 3.2 cm/s due to the action of the bottom stream from the Bosporus [13, 14, 15].

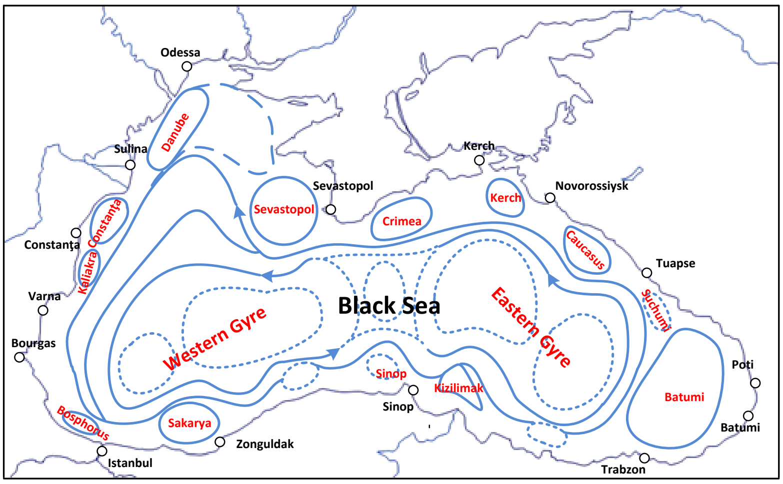

Figure 3 Marine currents evolution in the Black Sea – during the summer season, processed after Eremeev, 1993, circulation of enhanced vortex in the Black Sea based on revised altimetry data analyses (http:/www.ims.metu.edu.tr/cv /oguz/circulation.htm-image retrieved in April 20th 2017), and Marine.Copernicus.eu, 2020. Map support from https://d-maps.com/carte.php?num_car=4447&lang=en

d. Calculus of the wind currents for the Black Sea basin

The calculus of the wind currents for the Black Sea basin diferent areas on the parallels of $42^0 ... 45^0$ N (Table 2 and Figures 4, 5) was made using the relation [16]:

$$V_{CRTW} = \frac{0{,}0127}{\sqrt{\sin Lat}} V_W \qquad \text{[Knots]} \qquad (1)$$

were: V_{CRTW} - speed of the wind current; V_W - speed of the wind; Lat - latitude

The direction of the wind currents is deviated by an angle of 45^0 from the direction in which the wind blows. If the wind has a constant speed and direction, the wind currents become stable after about a day, but it must be remembered that, in real conditions, the wind is constant quite rarely for a longer time and changes your direction and speed at different points of the Black Sea basin.

Table 2 Calculated value of Black Sea's wind currents

Vw **Lat**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
42	0,02	0,03	0,05	0,06	0,08	0,09	0,11	0,12	0,14	0,16	0,17	0,19	0,20
43	0,02	0,03	0,05	0,06	0,08	0,09	0,11	0,12	0,14	0,15	0,17	0,18	0,20
44	0,02	0,03	0,05	0,06	0,08	0,09	0,11	0,12	0,14	0,15	0,17	0,18	0,20
45	0,02	0,03	0,05	0,06	0,08	0,09	0,11	0,12	0,14	0,15	0,17	0,18	0,20
Vw **Lat**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	

42	0,22	0,23	0,25	0,26	0,28	0,29	0,31	0,33	0,34	0,36	0,37	0,39	
43	0,22	0,23	0,25	0,26	0,28	0,29	0,31	0,32	0,34	0,35	0,37	0,38	
44	0,21	0,23	0,24	0,26	0,27	0,29	0,30	0,32	0,34	0,35	0,37	0,38	
45	0,21	0,23	0,24	0,26	0,27	0,29	0,30	0,32	0,33	0,35	0,36	0,38	

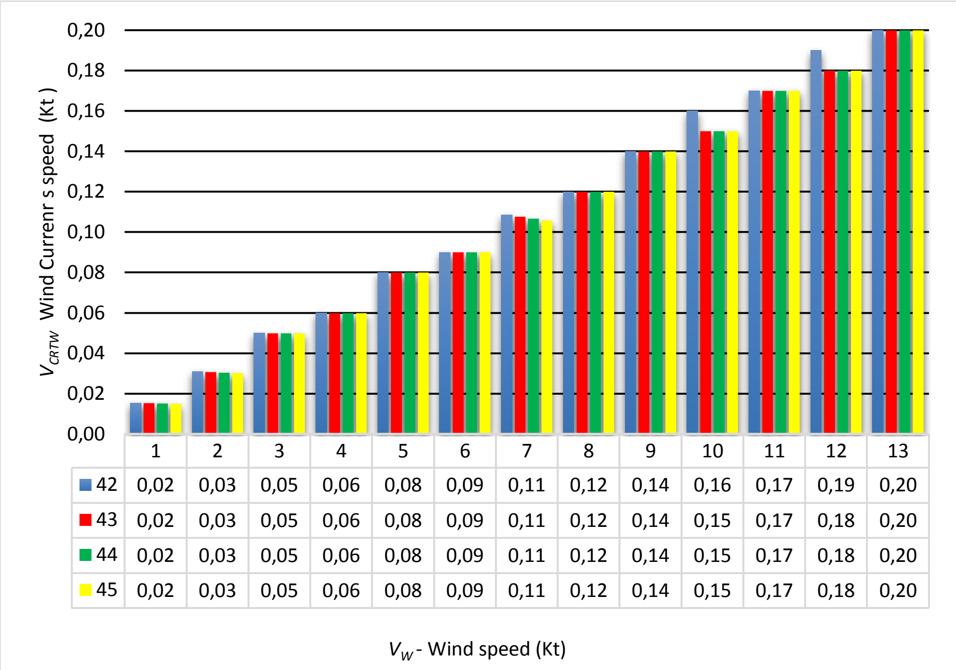

Figure 4

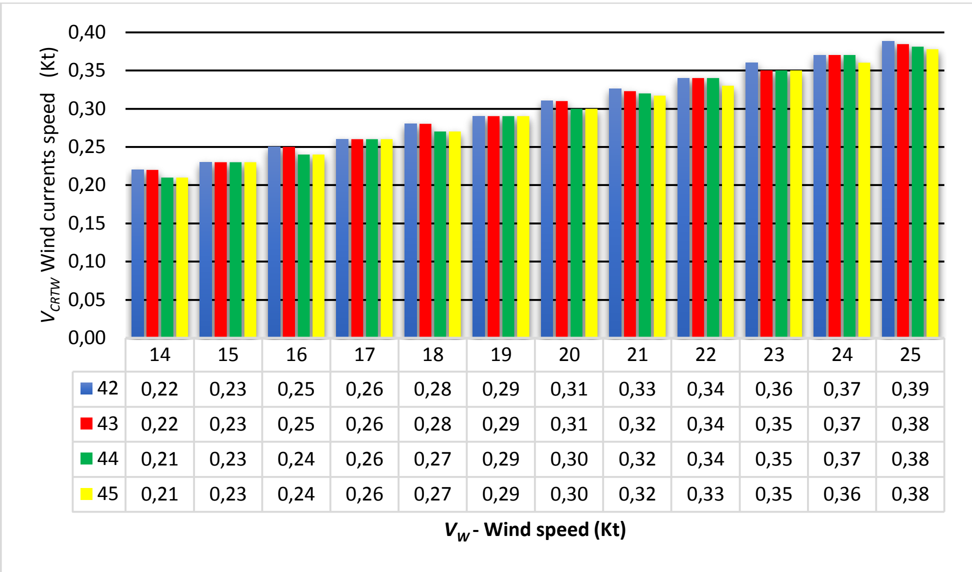

Figure 5

e. Calculus of the leeway angle in the Black Sea basin

The calculus of the leeway angle in the Black Sea is made using this formula [16]:

$$Leeway = k^0 \left(\frac{S_W}{S_S}\right)^2 \sin q_W \qquad (2)$$

where: k^0 is a ship's own coefficient with values ranging within 1.1, 1.2, 1.3, 1.4, 1.5 in ...^{0}; S_W – wind's speed in m/s, with values ranging within 5...25 m/s; S_S – ship's speed in m/s, with values ranging within 1...25 m/s; q_W – wind's angle with values ranging within 5...60, in ...^{0}

The graphs has been made using certain values: k^0 - 1.1, 1.3, 1.5; S_W - 5, 15 25; *Ss* - 4, 10, 20 (Tables 3, 4, 5 and Figures 6, 7, 8).

Table 3 The leeway angle for k^0 = 1.1

k=1.1	S_S					
	4		10		20	
	q_W					
S_W	30	60	30	60	30	60
5	0.86	1.49	0.14	0.24	0.03	0.06
15	7.73	13.40	1.24	2.14	0.31	0.54
25	21.48	37.21	3.44	5.95	0.86	1.49

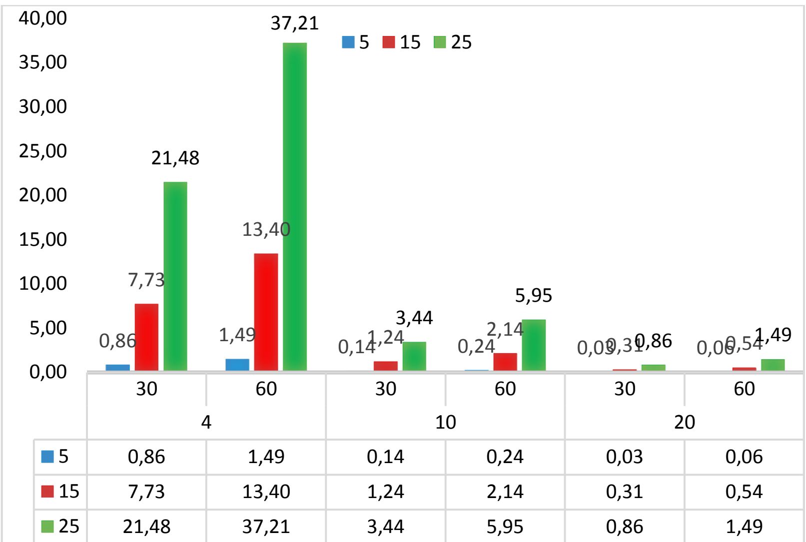

Figure 6

Table 4 The leeway angle for k^0 =1.3

k=1.3	S_S					
	4		10		20	
	q_W					
S_W	30	60	30	60	30	60
5	1.02	1.76	0.16	0.28	0.04	0.07
15	9.14	15.83	1.46	2.53	0.37	0.63
25	25.39	43.98	4.06	7.04	1.02	1.76

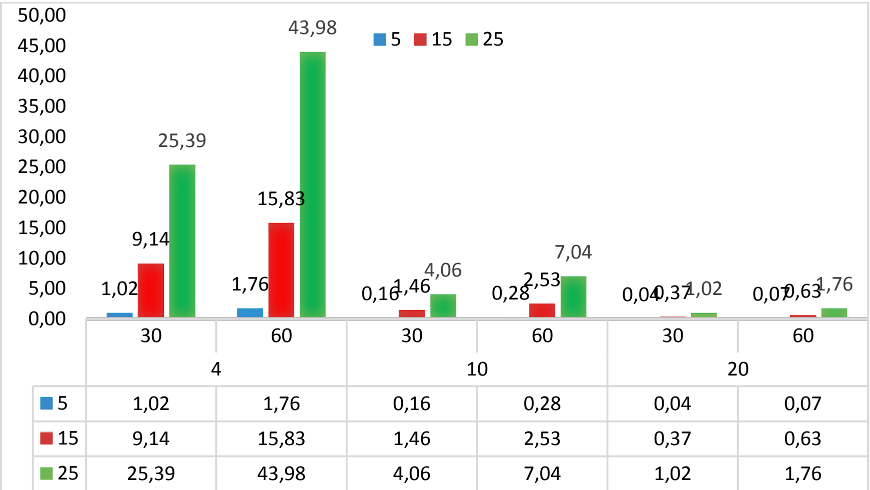

Figure 7

Table 5 The leeway angle for k^0 =1.5

k=1.5	S_N					
	4		10		20	
	q_W					
S_W	30	60	30	60	30	60
5	1.17	2.03	0.19	0.32	0.05	0.08
15	10.55	18.27	1.69	2.92	0.42	0.73
25	29.30	50.74	4.69	8.12	1.17	2.03

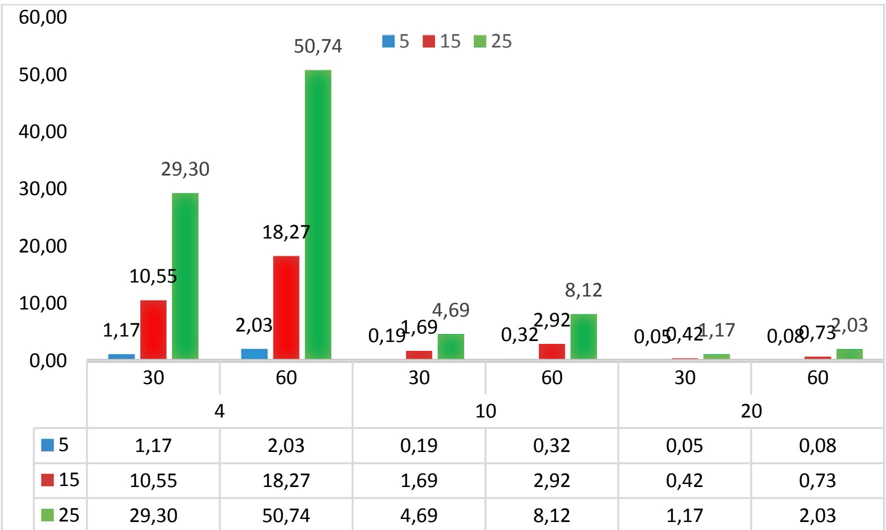

Figure 8

f. Calculus of the period of the apparent wave *Ta*

When the ship's route is perpendicular or nearly perpendicular on the waves' propagation direction, the vessel oscillates around the longitudinal axis, i.e., the phenomenon known as rolling occurs. In case of a rough sea, a ship having a "good attitude" might have the rolling period as long as possible. If the roll is violent, it can become dangerous in case the resonance phenomenon occurs (when the period of the vessel transversal oscillations is equal with the apparent wave period). Regarding the danger represented by the resonance phenomenon, it consists in the fact that the ship may be overturned, because, at each of its crossing through the vertical position it receives a new momentum, amplified by the rolling motion. To avoid the resonance phenomenon, it is necessary to know the vessel own rolling period and the apparent wave period [17].

The real wave period acts on the ship only when this moves on a route perpendicular on the wave. Referring to the other routes, the wave has an apparent period, that depends on the angle between the vessel route and the wave propagation direction.

It results that, during a storm, the most favourable ship's cape (i.e., the orientation towards the wave propagation direction) must be chosen, to ensure the safe movement of the ship.

The practical experience deemed that the most favourable point of sail consists in maintaining of a route having the opposite direction to the waves propagation direction, i.e., to the bow wave, i.e., at 20 ... 30 degrees. It will be necessary to reduce the speed in case of a point of sail when the ship tolerates with difficulty the waves blows and also, the ship crafts much water. If after reducing to a minimum the ship speed, the vessel continues to bear the strong blows of the waves or the machine does not have enough power to transmit to the ship a smaller speed than before, then it's better to assume a route having the same direction with the waves propagation direction, i.e., with the stern wave.If the ship's route coincides with the waves propagation direction, i.e., the ship moves by the bow on the wave or by the stern wave, the pitching phenomenon occurs.

In case of the bow wave, the pitching is very strong, the ship propeller is out of the water and vainly runs, a fact that could result in damage to the machines, at the axial line, the rudder or the propeller, respectively. Also, the vessel bow must support violent strokes and plenty of water, because the relative movement speed of the waves is equal to the sum of the absolute speeds of the ship and the waves. The pitching largely depends on the relation between the ship length and the waves length. If the vessel's length is greater than the wavelength, the ship covers several waves and thus, the pitching is damped out. If the ship length is smaller than the wavelength, the vessel rises up and down on the wave crest; therefore, it has very strong pitching. The most unfavourable situation occurs if the ship's length is approximately equal with the wavelength, because the vessel can be with the bow on a wave and with the stern on another wave, in this case, its center is suspended, i.e., it is on the wave crest having the bow and the stern suspended, therefore, the hull will be subject to maximum efforts.

The pitching is less strong in the case of the stern wave, the propellers and the rudder are less stressed, but the ship tends to lurch in the wind, especially when it receives a wave from aboard. The blows coming from the stern waves are less violent because their relative propagation velocity represents the difference between the waves' absolute speed and the vessel's speed.

The ship should avoid the resonant waves. In practice, depending on the vessel speed value, and the angle value, the ship's position can be determined, and if it is in a dangerous area, the ship motion parameters (i.e., its route and speed) will be changed, in order to protect the vessel against the negative effects of the oscillations.

The calculus of the period of the apparent wave *Ta* was made with the relation [17]:

$$Ta = \frac{\lambda}{S_S + S_W} \qquad (3)$$

where: *Ta* is the apparent period of the wave; S_S is the ship's speed; S_W is the speed of the wave; λ is the length of the wave

For example, for the Black Sea's theoretical wave elements: h = 3 m, λ = 43 m, Sw = 8.2 m/s) [18] for a ship's speed of S_S = 15 Kt = 7.72 m/s, the apparent wave period is Ta = 43/(8.2 + 7.72) = 2.7 seconds.

For certain values: λ = 50, 100, 150 m; S_S= 0-15 m/s; S_W = 0 - 5 m/s the Figure is 9, for λ = 50, 100, 150 m; S_S = 0-15 m/s; S_W = 10 - 15 m/s, the Figure is 10 and for λ = 50, 100, 150 m; S_S= 0-15 m/s; c = 20 - 25 m/s, the Figure is 11.

Table 5 Black Sea basin - Apparent wave period *Ta*, in seconds

c	0	0	0	5	5	5	10	10	10	15	15	15	20	20	20	25	25	25
λ V	50	100	150	50	100	150	50	100	150	50	100	150	50	100	150	50	100	150
1	50	100	150	8,33	16,67	25,00	4,55	9,09	13,64	3,13	6,25	9,38	2,38	4,76	7,14	1,92	3,85	5,77
2	25	50	75	7,14	14,29	21,43	4,17	8,33	12,50	2,94	5,88	8,82	2,27	4,55	6,82	1,85	3,70	5,56
3	16,67	33,33	50	6,25	12,50	18,75	3,85	7,69	11,54	2,78	5,56	8,33	2,17	4,35	6,52	1,79	3,57	5,36
4	12,5	25	37,5	5,56	11,11	16,67	3,57	7,14	10,71	2,63	5,26	7,89	2,08	4,17	6,25	1,72	3,45	5,17
5	10	20	30	5,00	10,00	15,00	3,33	6,67	10,00	2,50	5,00	7,50	2,00	4,00	6,00	1,67	3,33	5,00
6	8,33	16,67	25	4,55	9,09	13,64	3,13	6,25	9,38	2,38	4,76	7,14	1,92	3,85	5,77	1,61	3,23	4,84
7	7,14	14,29	21,43	4,17	8,33	12,50	2,94	5,88	8,82	2,27	4,55	6,82	1,85	3,70	5,56	1,56	3,13	4,69
8	6,25	12,50	18,75	3,85	7,69	11,54	2,78	5,56	8,33	2,17	4,35	6,52	1,79	3,57	5,36	1,52	3,03	4,55
9	5,56	11,11	16,67	3,57	7,14	10,71	2,63	5,26	7,89	2,08	4,17	6,25	1,72	3,45	5,17	1,47	2,94	4,41
10	5,00	10,00	15,00	3,33	6,67	10,00	2,50	5,00	7,50	2,00	4,00	6,00	1,67	3,33	5,00	1,43	2,86	4,29
11	4,55	9,09	13,64	3,13	6,25	9,38	2,38	4,76	7,14	1,92	3,85	5,77	1,61	3,23	4,84	1,39	2,78	4,17
12	4,17	8,33	12,50	2,94	5,88	8,82	2,27	4,55	6,82	1,85	3,70	5,56	1,56	3,13	4,69	1,35	2,70	4,05
13	3,85	7,69	11,54	2,78	5,56	8,33	2,17	4,35	6,52	1,79	3,57	5,36	1,52	3,03	4,55	1,32	2,63	3,95
14	3,57	7,14	10,71	2,63	5,26	7,89	2,08	4,17	6,25	1,72	3,45	5,17	1,47	2,94	4,41	1,28	2,56	3,85
15	3,33	6,67	10	2,50	5,00	7,50	2,00	4,00	6,00	1,67	3,33	5,00	1,43	2,86	4,29	1,25	2,50	3,75

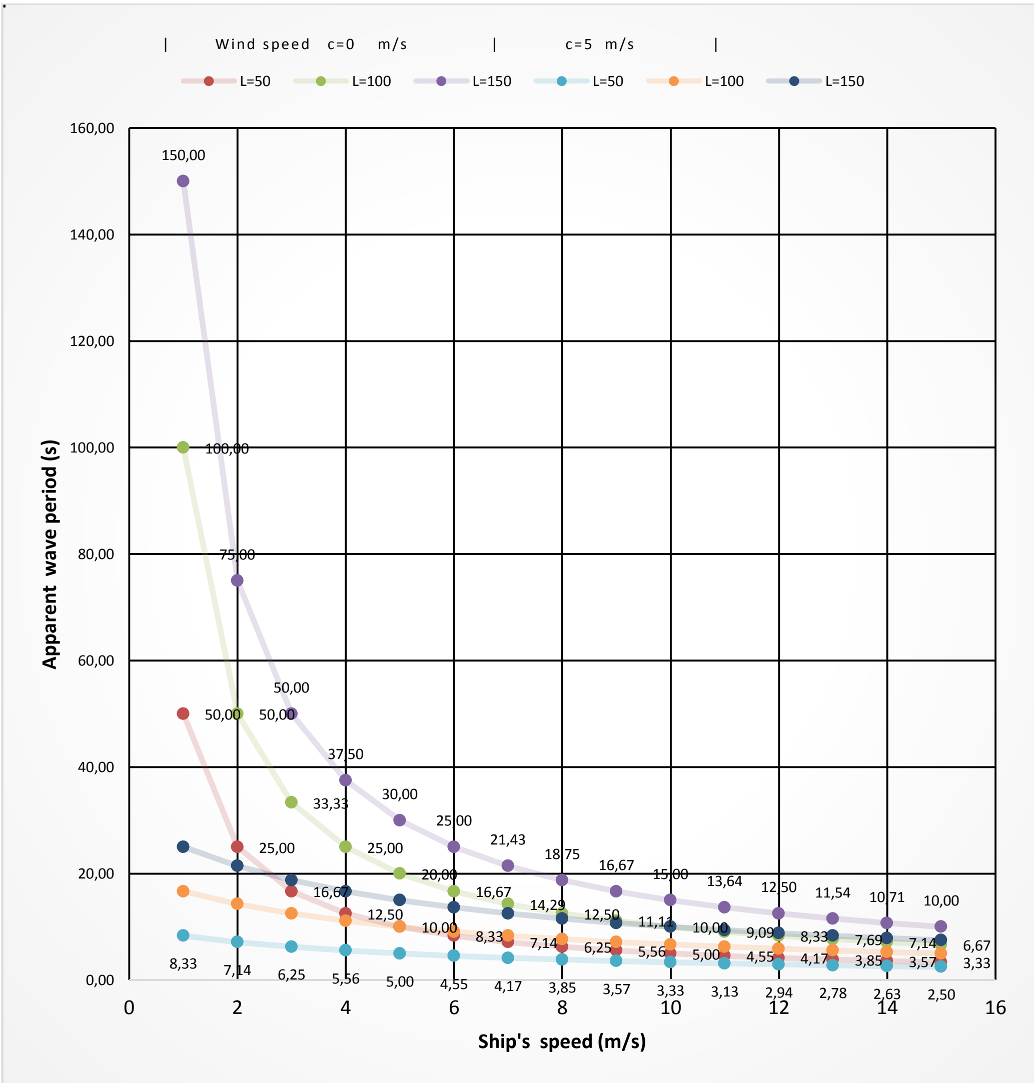

Figure 9

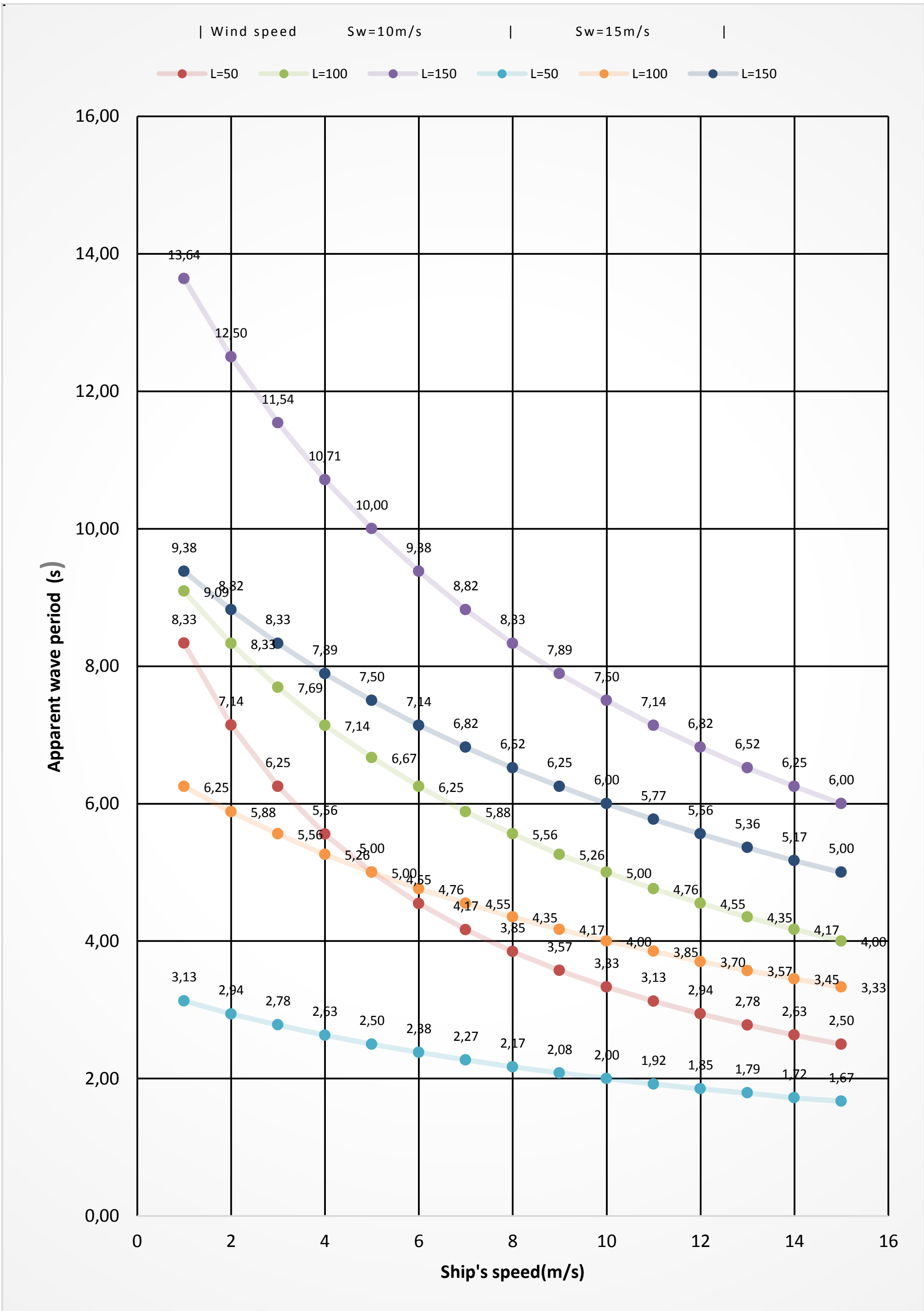
| Wind speed Sw=10m/s | Sw=15m/s |
L=50
L=100
L=150
L=50
L=100
L=150
Apparent wave period (s)
Ship's speed(m/s)

Figure 10

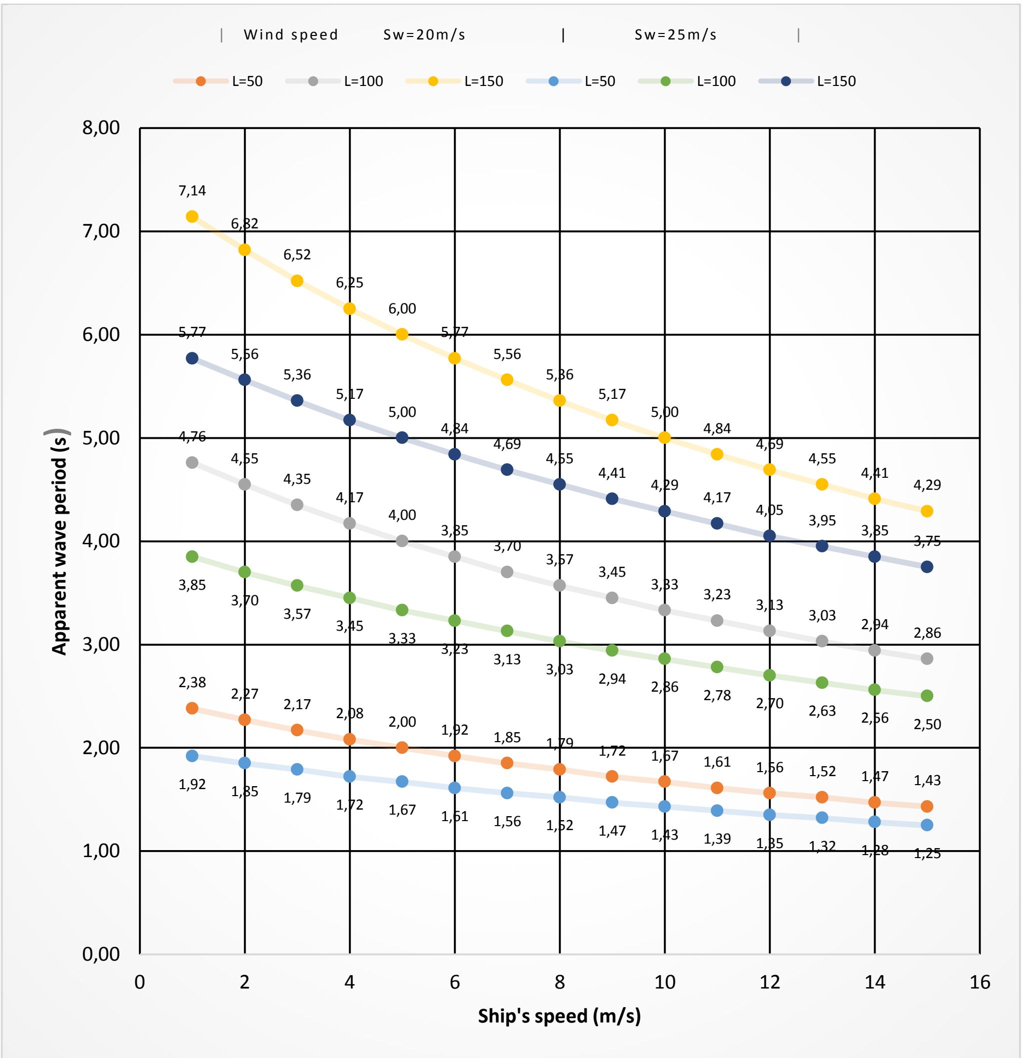

Figure 11

Conclusions

The wind waves (having maximum values during a storm, i.e. of 5 - 8 m or more) represent a main hydro-meteorological factor that has a direct impact on the sea transport - the ship and the navigation management system (e.g. the floating equipment), respectively, that affect the security and the economic efficiency of the maritime transportation.

The main negative effects, caused by the waves to the vessel during its march, are: the fluctuations (that can become extremely dangerous), the ship's speed reduction, the ship's yaw from the established route, the difficulties in determining the ship's position, the destructive effects through the mechanical waves' action to the ship. The most destructive effect on the vessel and its cargo, but also on the psychological-physical condition of the crew is the rolling motion. This motion occurs under the effect of the external momentum caused by the waves, the tilting heel angle in the transversal plan being directly proportional to the force and the waves' period, the ship's point of sail, the ship's anchoring condition, the vessel's speed, etc; once the ship will be more inclined to a board and the other one and the oscillation period will be higher, the tangential breaking out forces of some components from the board will be higher, as well.

As a result of the strong waves' action, the decreasing of the vessel's speed may be important; the determining factors are: the resistance increase to the ship's advance, due to the agitated sea surface; the working regime is under the propulsion system parameters, due to the ship's oscillations, that produce the propeller coming out of water (that also leads to the deliberate march speed reduction in order to avoid the propulsion system premature wear or damage).

The vessel's speed on the wave depends on the following factors: sea state, waves height, and oscillation, vessel's route, displacement, ship's nautical qualities, the ratio between the vessel's length and the wavelength.

As a result of the marine currents' action, the ship is deviated from its route, a phenomenon known as the drift current, that has direct implications on the march speed (the ship speed increase or decrease, depending on the current's direction and the vessel speed in the water).

The direction and the speed of the constant marine currents are specified in the nautical documents. Referring to the Black Sea, the sea currents' speed is significant, i.e., over 1.0 Kt in certain areas and under hydro-meteorological conditions, and their values can be used as such, or they can be practically determined aboard.

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