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Safety problems of anchoring in restricted areas in extreme hydrometeorological conditions

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Abstract

The aim of the following article is to analyse the lying of a vessel at anchor in extreme hydrometeorological conditions. As an example it describes the situation of the Panamax type bulk carrier anchoring in Prince Rupert harbour restricted area. The investigation takes into consideration the impact of strong wind on the safety of anchoring in sheltered waters. The presented calculations concern problems of slewing which result in changes of heading. The analysis also includes a description of the wind and current forces. The final part focuses on conclusions whose aim is to improve anchoring safety standards in areas managed by harbour authorities.

Introduction

In recent years, the number of merchant vessels has gradually increased. It is observed that this tendency is accompanied by an increasing frequency of extreme hydrometorological conditions caused by global climate changes. The increase of the intensity of shipping has especially been noticed in the Asia-Pacific area. More and more ships sail through the same navigation area and are at the same anchorage. The necessity of keeping up with the competition and constant cost reduction pressure results in an increase of ship operations. Thus, the margins of navigation safety are continuously decreasing and consequently, conflicts of interests among owners, charterers, shippers and port managements seem to be more frequent.

The article was inspired by anchoring of the Polish Steamship Company m/v "Karpaty" (Figure 1), Panama/Kamsarmax size bulk carrier in light ballast conditions on the Prince Rupert inner road, stand No. 7. For this anchoring place, the radius of 620 m was calculated as the safe area in good weather conditions (Gucma & Jagniszczak, 2006). In fact, the distance from the centre of stand No. 7 to the nearest danger is only 684 m. To sum up, there is not sufficient safety margin in adverse weather.

The situation described and analysed happened in winter 2015. According to the weather forecast, south-easterly winds were to be of 7 degrees on the Beaufort scale with gusts to 9. In fact, wind reached 10 degrees Beaufort with gusts to 12. All seven anchorages were located inside the fjord, well sheltered from sea waves, where the maximum tide range equals 6.4 m and tide currents reach four knots maximum.

Figure 1. Panamax size bulkcarrier on the Prince Rupert inner anchorage stand No. 7

This type of vessel is equipped with two anchors with high holding efficiency: "Stockless Anchor KHAC-14" with 35° of fluke deflection, weight 8340 kg and proof load test 1090 kN. The anchor is attached to flash-butt welded stud link chain made from steel grade 3 with proof load test 3160 kN.

Pilotage is compulsory in the area owned by Prince Rupert port authorities over a distance of 27 Nm, up to Dixon Entrance. On the one hand this means that all ship's self-manoeuvres in dangerous situations are forbidden without the presence of a pilot, including heaving up the anchor. On the other hand, the relocation of the vessel without the pilot's assistance is against the law (Port Information Guide, 2015) even if this is as a result of the anchor failing to hold the ground. In heavy weather conditions, the most efficient way of ensuring the safety of anchoring in case of dredging is to drop the second anchor and to run the main engine. It should be noted that it is highly unwise to use the second anchor in the area of tidal flow and changeable current directions because of the high probability of anchor chain fouling. Therefore, appropriate use of the main engine seems to be the most effective reaction to observing the vessel drifting. Additionally, the second anchor can be dropped not only as a method of increasing the holding ground forces, but it also gives us the possibility to reduce the ship's slew.

As per situation shown on the Figure 2, the anchor was pulled out of the ground due to the increase of wind strength up to 12 degrees Beaufort. The event took place when the slew arch (deviation of the ship's course from the line of the wind) reached the value of 35°. Loosing of the ground holding caused uncontrolled astern drift of the ship over a distance of about 50 m. In order to prevent further drift, the captain immediately dropped the second anchor, started the engine and operated the rudder. Then, the pilot was called, in accordance with harbour area restrictions concerning self-pilotage, to move the ship from the anchorage area.

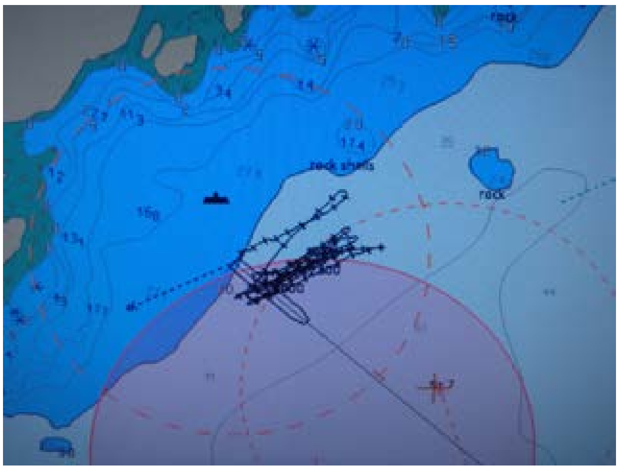

Figure 2. Screenshot from ECDIS showing the event of dragging the anchor

What is worse, the problem of uncontrolled drift on anchor affected all the ships occupying the inner road of Prince Rupert. Such a situation may be extremely dangerous and in many cases it is the direct cause of breaking out the anchor from the bottom. The following section is devoted to the mathematical analysis of the observed phenomenon. Its aim is to verify the safety limit of wind force conditions during anchoring.

Description of the slew phenomenon

During strong winds, an anchored ship does not maintain a fixed course opposite to the direction of the wind, but it slews (Nowicki, 1992). Assuming constant wind speed and direction, the formation of the above-mentioned movements can be explained in the following way. Due to the fact that anchor pipes are not along the centreline, the vessel takes a non-parallel position to the direction of the wind. The anchor chain, the hawse pipe and the centre of flotation take the straight line. This causes exposure of the side of the ship on which the hawse pipe is located to the wind. Thus, under the influence of the wind, the vessel moves toward the opposite side, and at the same time, slightly along the arc of specified radius dependent on the anchor chain length. The movement in this direction continues until the inertial force of the ship is balanced by the wind pressure force. At this point, the prevailing wind pressure force stops the movement and shortly afterwards moves the ship in the opposite direction. The vessel passes the initial position due to the inertial force, which causes its movement to continue to the opposite side. These movements repeat as long as the external conditions remain. In such a situation, the bow of the ship traces a path similar to the shape of a flattened eight.

In practice the slewing is caused not only by the inertial forces and wind pressure forces but also by changes in the tension of the anchor chain. It also happens due to variable speed and direction of the wind, variable speed and direction of the current and finally, forces resulting from wave motion.

Wind pressure forces FW

The equations found in the m/v "Karpaty" shipyard documentation (Tsuneishi Shipbuilding Co.,

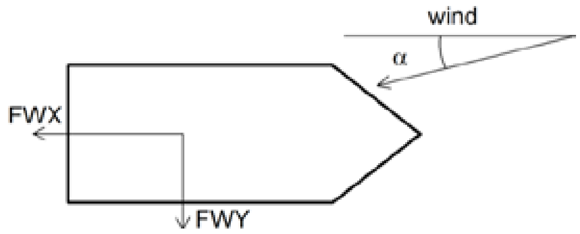

Figure 3. The transverse and longitudinal wind forces acting on ship (Tsuneishi Shipbuilding Co., Ltd., 2013)

Ltd., 2013) concerning ships' manoeuvring capabilities enable estimation of wind pressure forces. For wind blowing at an angle α to the centreline, shown on the Figure 3 the longitudinal force FWX and transverse force FWY acting on ship's hull are defined in the following way:

$$\text{FWX} = CX_w \cdot 0.5 \cdot \rho \cdot X \cdot Vw^2$$
$$\text{FWY} = CY_w \cdot 0.5 \cdot \rho \cdot Y \cdot Vw^2 \quad (1)$$

where:

CX_w, CY_w – wind coefficients defined in m/v "Karpaty" shipyard documentation and presented in Table 1;
ρ – density of air [kg/m^3];
X – windage front view area above-water profiles [m^2] (Full loaded 550 m^2, Ballast 910 m^2);
Y – windage side view area above-water profiles [m^2] (Full loaded 2000 m^2, Ballast 4300 m^2);
Vw – wind velocity [m/s].

Table 1. Wind pressure forces coefficients for ship in loading and ballast conditions (Tsuneishi Shipbuilding Co., Ltd., 2013)

α [°]	Vessel in ballast		Vessel loaded	
	CX_w	CY_w	CX_w	CY_w
0	1.060	0.017	1.060	0
5	1.084	0.064	1.011	0.028
10	1.110	0.117	1.024	0.060
15	1.150	0.189	0.970	0.092
20	1.183	0.266	1.022	0.140
25	1.186	0.345	1.008	0.187
30	1.178	0.428	1.016	0.250
35	1.174	0.512	1.094	0.342
40	1.167	0.596	0.948	0.366
45	1.151	0.672	0.977	0.457
50	1.133	0.748	0.973	0.536

During non-slewing conditions, all of the anchor chain and the anchor shank are in the line of the wind. According to good seamanship practice, it is assumed that the part of the anchor chain close to the shank is always lying firmly on the ground, in the same line as during non-slewing condition. Moreover, in any slewing conditions, the part of the anchor chain close to the shank and anchor shank direction are in the same line. The angle between this line and the centreline is defined as the slewing angle α. Wind pressure forces FW are calculated alongside the part of the anchor chain close to the shank on the basis of the formula presented below:

$$\text{FW} = \text{FWX} \cos\alpha + \text{FWY} \sin\alpha \quad (2)$$

Current pressure force FC

On the one hand, the current forces acting on a ship depend on two factors, namely the type and size of the ship. On the other hand, it should be noted that calculations of tides and currents are often significantly disrupted due to severe weather conditions. Thus, the calculations of the force generated by the current presented below should be treated only for illustration purposes only and not as an accurate calculation of their value in the described incident. In fact, testing seems to be the best way to obtain more precise results. The following general standard formula presents the simplified calculations for longitudinal FCX [kN] and transverse FCY [kN] current pressure forces (Thoresen, 2014):

$$\text{FCX} = CX_c \cdot \gamma_w \cdot D \cdot L_{PP} \cdot \frac{Vc^2}{2012}$$
$$\text{FCY} = \left(CY_{Fc} + CY_{Ac}\right) \cdot \gamma_w \cdot D \cdot L_{PP} \cdot \frac{Vc^2}{2012} \quad (3)$$

where:

CX_c – longitudinal current force coefficient depending on the angle of the current and the underkeel clearance presented in Table 2;
CY_{Fc} – lateral or transverse forward current force coefficient depending on the angle of the current and the underkeel clearance presented in Table 2;
CY_{Ac} – lateral aft current force coefficient depending on the angle of the current and the underkeel clearance presented in Table 2;
γ_w – specific density of seawater, taken as 1025 kg/m^3;
D – mean draught of the ship [m];
L_{PP} – length between perpendicular [m];
Vc – velocity of the current [m/s].

Table 2. Current pressure forces coefficients for ship in loading and ballast conditions (Thoresen, 2014)

[°]	Vessel in ballast			Vessel loaded		
	CY_{Fc}	CY_{Ac}	CX_c	CY_{Fc}	CY_{Ac}	CX_c
0	0.00	0.00	0.04	0.00	0.00	0.04
15	0.08	0.03	0.05	0.73	0.22	0.04
30	0.19	0.10	0.05	1.05	0.47	0.05
45	0.30	0.18	0.03	1.05	0.60	0.09

For a very rough calculation of the current total forces FC in the direction of current (anchor chain), a similar formula may be applied as in the case of wind pressure forces:

$$FC = FCX \cos\beta + FCY \sin\beta \quad (4)$$

where: β – angle between the longitudinal axis of the ship and the current direction considered from the bow.

From the captain's perspective, in extreme weather conditions it is impossible to estimate the real value of current pressure forces due to unknown and changeable current speed and direction. Thus, it is only possible to estimate the value of current pressure force FC. According to pilots, the maximum observed current value in Prince Rupert Bay was Vc = 2.06 m/s. However, the calculations would not be possible without taking the following data into consideration: the width of m/v "Karpaty" B = 32.26 m, distance between perpendiculars L_{PP} = 222 m and ship's draft T = 7.50 m.

The simplified reasoning assumes that current and wind have the same direction in heavy weather conditions. This assumption ($\alpha = \beta$) may be confirmed by the same symmetrical course deviation on both sides during slewing.

The anchor holding force

The anchor holding force FH is defined as the ratio of the weight of the anchor, its type and the structure of ground where the ship anchors. For the "Stockless Anchor Khac-14" lying on the sand and clay bottom this ratio is defined in the tables as 12 (Nowicki, 1999) or 10.7 (Sato, 2005). In practice, the anchor holding force is dependent on properties, structure and construction of the bottom which may be specific for each location. These facts should be taken into consideration while calculating anchor holding force. However, the results should be approached with great caution. It is advisable to treat the calculations as an illustration of the phenomenon rather than the estimation of the exact values. The value of 11.5 was adopted as an average factor from the above-mentioned two sources and consequently the value of the holding force FH is calculated as 941 kN.

Safe anchoring clause

Safe anchoring of the ship requires that the anchor holding force must always be greater than the sum of wind and current pressure forces when all forces are in the same line.

$$FH \geq FW + FC \quad (5)$$

Figure 4 shows the above mathematical relation for the different angles at which the ship slews at anchor in the situation of the weather forecasted conditions. The figure shows the maximum value of the forecasted wind gust of 25 m/s – 9 on the Beaufort scale. On the basis of the analysis one may conclude that the anchor holds the ground firmly in these weather conditions. It is worth noticing that only slewing exceeding 30° risks taking the anchor out from the ground. On the other hand, it turns out that such a large angle of slewing would not have occurred if the force of wind had not exceeded 9 Beaufort. Slewing over 30° was observed only when the wind reached the value of 12 Beaufort.

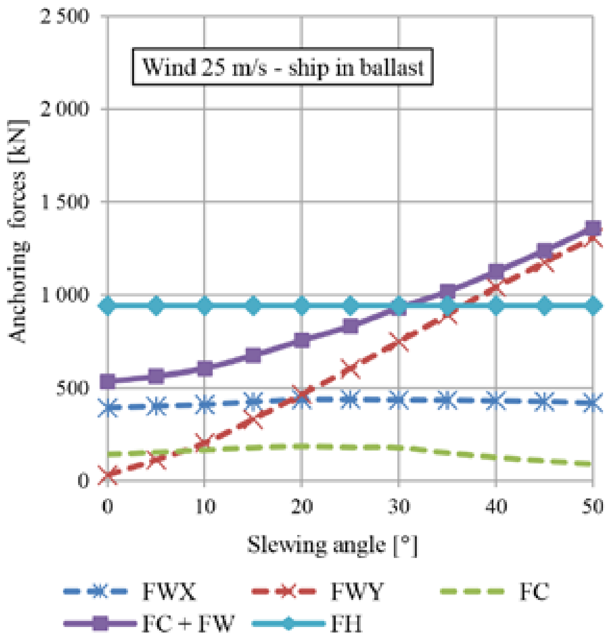

Figure 4. Forces acting on the ship in ballast condition at 25 m/s wind speed (10 in Beaufort scale)

Figure 5 illustrates the dependencies between the values FH / FW / FC for wind speeds reaching 30 m/s (11 Beaufort). The graph clearly shows that slewing over 15°can pull the anchor out from the ground. The only effective way of keeping the vessel safe at anchor in such weather conditions is proper running of the main engine and proper setting of the rudder. An extremely similar goal could also be achieved by dropping the second anchor.

Figure 6 illustrates only a theoretical possibility of preventing the anchor from pulling out when the value of slewing is less than 10° and the ship is lying only on one anchor at 33.5 m/s wind speed

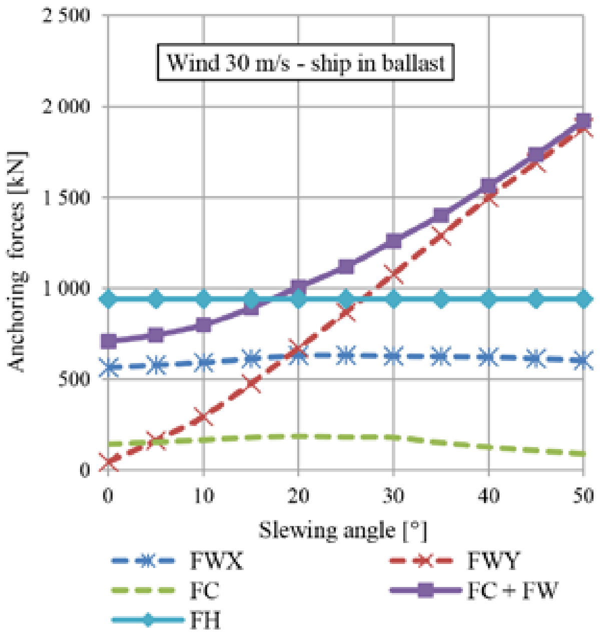

Figure 5. Forces acting on the ship in ballast condition at 30 m/s wind speed (11 in Beaufort scale)

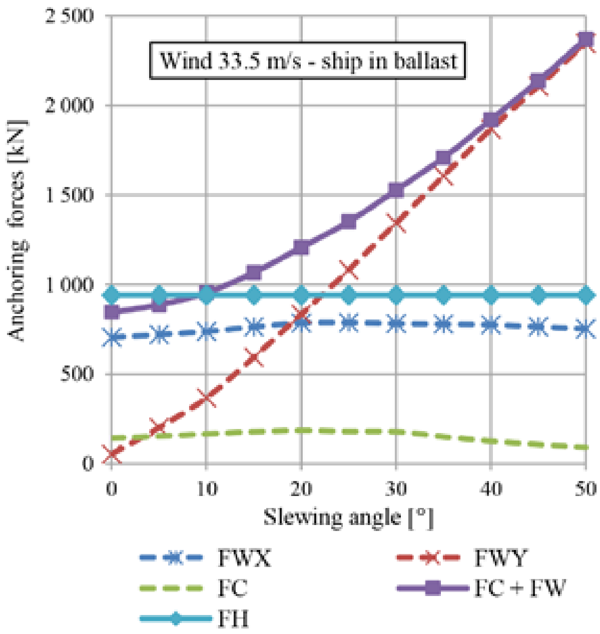

Figure 6. Forces acting on the ship in ballast condition at 33.5 m/s wind speed (12 Beaufort)

(the maximum observed value of the wind speed in the described case – 12 Beaufort). Thus, it is impossible to reduce the value of slewing below 10° at all in such situations.

Finally, Figure 7 presents forces which have an influence on fully laden Panamax size bulk carrier at 33.5 m/s wind speed. In comparison with Figure 6 it is observed that current force has more critical influence on anchoring safety than on a ship in ballast in the same wind conditions.

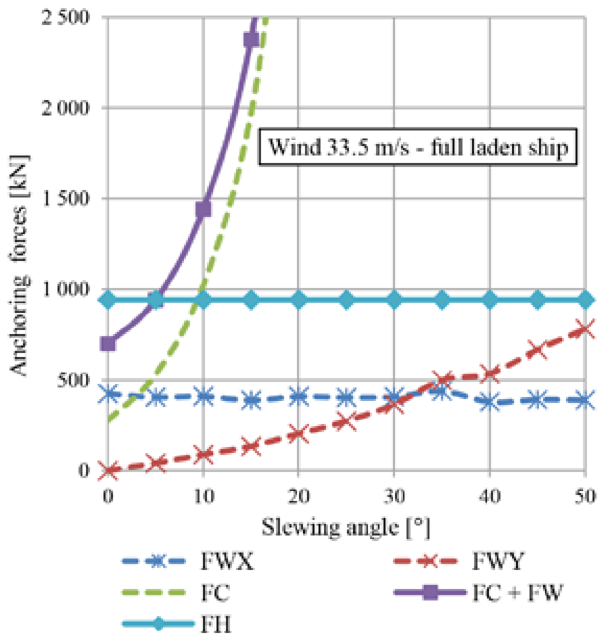

Figure 7. Forces acting on the ship in ballast condition at 33.5 m/s wind speed (12 Beaufort)

Laden ships anchoring in sheltered waters seem to be definitely less safe than those which are only in ballast in the described extreme wind conditions. Thus, it may be observed that slewing up to 5° determines only a theoretical safety margin of anchoring, because the angle of slewing always exceeds this value during 12 Beaufort winds.

Conclusions

What the above calculations clearly prove is that slewing is the main cause of pulling the anchor out of the ground in difficult weather conditions. The sum of values of wind and current pressure forces always cause slewing of the ship. The presence of extreme slewing may be an indication of dredging the anchor. Unfortunately, in the described case, the weather forecast was not precise enough. The wind reached 12 Beaufort whereas it was forecast to be 9 Beaufort. In this situation, the available counteraction may be as follows: parallel operation of the engine and the rudder and/or dropping the second anchor. However, the best way to avoid dangerous situations in the event of an adverse weather forecast is always to heave up the anchor and run to the open sea.

The danger was caused by the lack of proper port regulations on manoeuvring during difficult weather conditions. To be more precise, port regulations do not take into consideration the possibility of underreporting of weather forecasts. According to port regulations (Port Information Guide, 2015) any self-pilotage is forbidden in Prince Rupert harbour area.

But in this situation only one pilot was available and this one pilot could not be responsible for movement of all vessels anchoring in Prince Rupert. Moreover, the dimension of anchoring stand No. 7 seem evidently too small for safely anchoring of Panamax size vessels in extreme hydrometeorological conditions. All anchoring ships managed to avoid marine casualty and environmental risks due to the efficiency of their crews.

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