Processes of a Freely Drifting Vessel

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ABSTRACT: The article describes the rules for planning a ship's navigation in the event of loss of propulsion. A disabled ship drifting freely at sea is a potential danger to the crew and the marine environment. Lack of propulsion means that the ship cannot give way to other ships/keep out of the way of another vessel. One of the main elements of danger for a drifting ship is the possibility of grounding in restricted areas. The aim of the article is to draw the attention of navigators to the dangers to navigation resulting from ships drifting without their own propulsion, disabled ships.

1 INTRODUCTION

Failure of a ship's own propulsion is a serious danger not only for the ship not under command but also for other vessels. From the definition of a ship underway, you can define the drift process and then go to the definition of a free-drift ship.

Influence of the vector of disturbed motion VZ on the vessel VS results in the resultant drift vector ΔV as shown in Figure 1a.
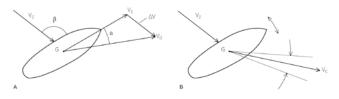

Figure 1. Ship drifting on the water surface
VZ – external disturbances vector, Vd – vector of object movement over ground [Vd = f(VZ, A)], ΔV – resultant ship's drift vector, A – extended section of the ship

When the ship loses the ability to move ahead the vectors VZ and Vd are observed (Fig. 1b). During external disturbances, a vessel or other free-floating object loses its intended direction of movement. A ship without its own propulsion cannot counteract external disturbances, i.e. drift, thus becoming an object not under command.

The value of the motion of a disabled ship depends on:
– disturbing parameters (VZ)
– ship's geometric parameters (A).

2 COMPONENTS OF EXTERNAL DISTURBANCES

General division of ships in terms of external disturbances according to geometric parameters:
– A1 – vessels with large windage areas – more sensitive to wind load influence
– A2 – vessels with low free board – more susceptible to current influence.
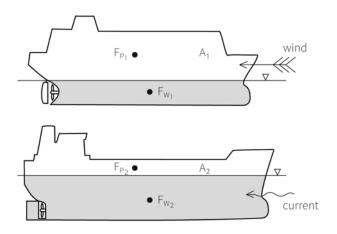
Figure 2. A1 and A2 Vessels and various FP/FW ratios

An example of a container ship surface is given for comparison. The pressure from the wind on its different side surfaces depending on the number of layers of containers is surprisingly high. For example: a container ship with a length of 400 m and a side height of 35 m gives a lateral windage area of 14,000 m2. Table 1 gives wind load values on the ship's hull .

Table 1. Wind load on the side area of 14,000 m²

Wind speed [m/s]	Pressure [t]
16	199
20	311
26	526
30	700

Drifts which are influenced by two major elements, i.e. currents and winds of two different ships have been analyzed here. Ships with A1 geometric structure are much more strongly influenced by wind (passenger ships, ro-ro vessels, etc.), whereas ships with A2 geometric structure (bulk carriers, tankers, etc.) are affected more by the influence of sea currents (tidal streams).

Ratio:

FP1/FW1 > 5/1 – (A1)

FP2/FW2 > 1/5 – (A2)

2.1 *Components of external disturbances*

The components of external disturbances are the following:
- wind vector – VW, KW [knots, degrees]
- wave vector – hi, TF, KF [m, sec, degrees]
- swell vector – hM, TM, λp, KM [m, sec, m, degrees]
- ocean current vector – Vp, Kp [knots, degrees]
- tidal current vector – Vpp, Kpp [knots, degrees]
- wind current vector – Vpw, Kpw [knots, degrees].

Additionally large vessels are influenced by a Coriolis force.

2.2 *Hull inclination of a drifting disabled ship*

Location of the FP and FW gravity centers determines the hull in motion in the process of free drift. Shifting the FP point aft relative to the position closer to the bow will cause the hull to turn windward, assuming that the wind factor will be stronger than the current. The vessel is said to tend to be windward.

The situation will be the opposite when the FP point is closer to the forward part of the vessel than the FW point – the ship will be leeward. It will also depend on the value of wind and current forces as well as the Coriolis force.

The pattern of the wind direction acting on large ships and the direction of drift also depend on the ship's trim, usually small on large ships. Such arrangements are shown in Figure 3a and 3b.
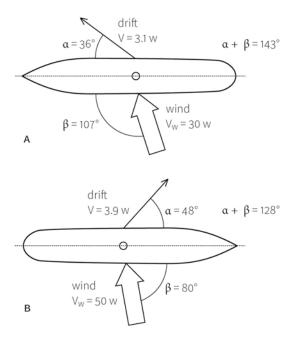

Figure 3. Position of hulls depending on wind when the vessel is adrift
a) with trim 1/50 by the stern and wind speed 30 knots
b) under ballast with trim 1/50 by the stern at 50 knot wind speed

The drift velocity of a tanker depends on the loading condition of the vessel such as ballast or full load.
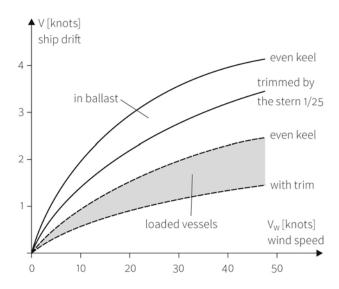
Figure 4. Graph of drift velocity of VLCC tanker loaded and in ballast .

Figure 4 presents the drift velocity of a tanker in ballast and loaded to capacity conditions as a function of wind speed. In ballast condition vessels have a larger windage area (FP) in relation to the submerged part (FW).

Plan of the ship's drift close to dangers to navigation is shown in Figure 10.
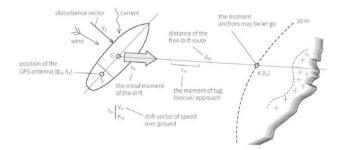

Figure 5. Situational plan of a disabled ship's drift

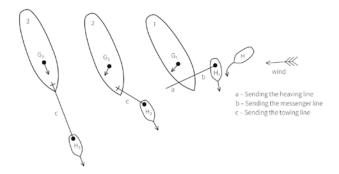The method of letting go the towing line onto a ship in a drift is shown in Figure 6.

Figure 6. Chosen method of sending the tow onto the disabled vessel

Three phases of sending the towline from the port side of the tug H onto the vessel adrift where a heaving line was sent to the disabled vessel and then a towing line onto the vessel 1. Phase 2 – making the tug fast. The last phase is towing and agreeing on the speed of the tow VS(H3).
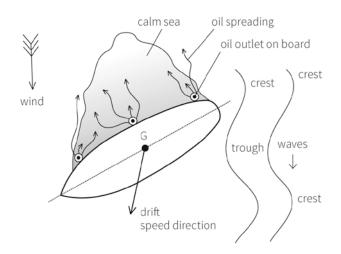

Figure 7. In bad weather pouring wave quelling oil in lateral drift

2.3 *Calculation of the bollard pull needed to tow a disabled vessel*

The formula can be used to calculate the bollard pull for a free drifting vessel:

$$M = \left\{ \frac{D^{2/3} V_H^3}{120 \times 60} + \left(0.06 \times B \times h\right) \right\} \times K \qquad (1)$$

M – required bollard pull in tonnes
D – full displacement of towed vessel in tonnes
VH – tow speed in knots
B – breadth of towed vessel [m]
h – height of the exposed transverse section of the towed vessel including deck cargo, measured above the waterline [m]
K – a factor that reflects potential weather
K = 1.0–3.0 – for exposed coastal tows
K = 0.75–2.0 – for sheltered coastal tows
K = 0.5–1.5 – for protected water tows

Another formula can also be used to calculate the bollard pull for towing a disabled ship

$$M = 7.4 \times \left(DWT\right)^{0.6} \qquad (2)$$

In bad weather, ships over 100,000 (DWT) require 3 to 4 tugs of 3000 HP each .

The result of determining the bollard pull will allow deciding on the number of tugs to stop the ship's drifting and the method of holding the ship in position when assistance of more tugs is required for towing the ship to the place of refuge. In order to reduce seaway parameters when the towing lines are sent to the drifting vessel a method of wave quelling oil spread on the sea surface may be used. See Figure 7.

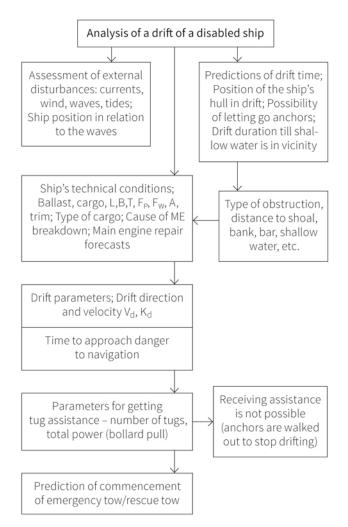## 3 OPERATION DIAGRAM FOR PREPARING A TOW PLAN FOR A DISABLED SHIP

Figure 8. Operation diagram for preparing a tow plan for a disabled ship

4 MATHEMATICAL BASIS FOR A MODEL OF THE SHIP'S DRIFT

The ship's drifting movement is of a stochastic nature, it results mainly from the nature of the elements disrupting the free drift of ships. The random nature of the ship's drift can be described as the Makarov process. This movement can be determined by the formula (3) :

$$d_x = V(x,t)dt + d_\varepsilon \qquad (3)$$

d_x – motion of the drifting ship
x – position
t – time
d_ε - error of motion determination

If it is assumed that the drift results from the impact of wind and current then formula (3) can be represented as a formula (4) :

$$x(t) - x_0 = \int_0^1 V(t)dt - \int_0^1 \left[L(t) + U(t) \right]dt \qquad (4)$$

$x(t)$ – route for a specific moment t
x_0 – initial drift path
$L(t)$ – wind drift
$U(t)$ – sea current drift

The drift velocity can be obtained using the following formula:

$$V = V_0 + \int_0^{\Delta t} adt \qquad (5)$$

V_0 – is the initial drift velocity
Δt – the time of drift
a – is drift acceleration

The method of obtaining short distance of the drift path can be calculated using the formula:

$$y = x = x_0 + \int_0^1 Vdt \qquad (6)$$

V – drift velocity

Figure 9 shows the model of the ship's drift under the influence of sea current and wind. External disturbances may also be affected by waves. An important element of drift control is the use of simulation. In such cases, a wide range of prognostic information about hydro-meteorological factors should be used whereas the details of drift model description can be found in .
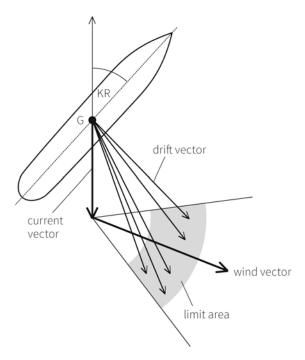

Figure 9. Pseudo ship's drift

5 FREELY DRIFTING VESSELS – CASES TO BE SOLVED

5.1 *Information on the weather condition in drift areas*

Knowledge of weather factors is an important element in safe towing of disabled ships. The following is the minimum scope of meteorological data in planning and implementing ship towing.

Standard information on facsimile maps transmitted to ships in international navigation includes such information as :
1 Analysis of sea surface weather.
2 Sea surface weather forecast.
3 Analysis of the windage area.
4 Analysis of sea waves.
5 Seaway forecast.
6 Analysis of surface water temperature.
7 Forecast of surface water temperature.
8 Information regarding ice cover and icebergs.
9 Significant weather condition.
10 Information on sea currents.

Information on the weather forecast onboard a drifting ship is needed to reduce the risk of ship's damage when navigating in difficult areas. A high risk of failure arises when a ship without shelter drifts freely in the regions oil rigs and platforms. Similar situation is observed when a drifting ship carrying dangerous cargo approaches navigational obstacles.

The repair function is a probability function for the duration on an engine failure.

$$P_{EF}\left(t > t_s\right) \tag{7}$$

$P_{EF}\left(t > t_s\right)$ – probability of an engine failure of t_s hour or longer

In case of such event on board a vessel there must be another function to be used, i.e. repair function .

$$P_{ER}\left(t > t_s\right) \tag{8}$$

$P_{ER}\left(t > t_s\right)$ – is the probability of the main engine repair in t_s hour or longer

This assessment will allow you to make a decision to call for external assistance to tow the ship away from navigational dangers & navigational obstacles.

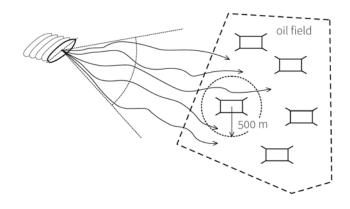An example of a ship's drift near oil rigs is shown in Figure 10.

Figure 10. Risk of drifting towards an oil field

5.2 *Ship's data recording*

With the change of weather parameters the parameters of the ship's drifts also change, therefore it is necessary to monitor the ship's drift all the time.

A practical method of assessing the control of the ship's position and the parameters of the ship's drift, speed and direction over ground must be recorded in the Ship Logbook.

Data Recording of ship's event in the operating process in accordance with SOLAS Convention 174 Reg. V/28 is the duty of the captain of a merchant ship in international shipping. Data on the ship itself and its operation can be divided into groups in individual phases of navigation in various operating conditions in a continuous system.

Entries include:
− general information during normal ship operation
− information on the description of special or unusual events .

The daily record in the tow log should include details such as:
1 Ship's geographical position.
2 Weather conditions (sea state).
3 Tug(s) status.
4 Speed of the tow.
5 ETA at the port of refuge.
6 Technical condition of the towed ship.
7 Towing route.

These records can be made as follows:
− manual entry in the Ship Logbook
− constant automatic voyage data recording (VDR)
− electronic recording in the central ship computer (Log Towing).

During free drift of a ship, records must reflect the exact chronological sequence of events of the entire ship failure process.

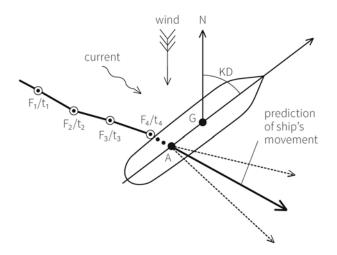Figure 11 shows how to register a ship's drift path.

Figure 11. Assessment of the ship's motion in the drift
Fi – position of the ship
t_i – moment of observation
A – position of the bridge (antenna)

Observation of ship's position at frequent intervals allows to control the motion of the ship. On this basis, further parameters of the ship's drift can be predicted based on external disturbance conditions (prediction).

5.3 *Predicting the track of a disabled vessel drifting in tidal areas*

In tidal regions, values of current change within an hour, so a graphic picture of current changes over time should be made. Additional drift resulting from a wind of constant direction is added to get the plan of the track of ship's drift. This example is shown in Figure 12.
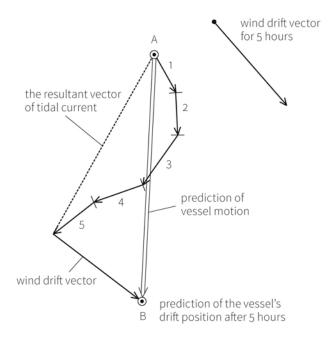

Figure 12. Way of predicting the ship's drift path in tidal areas

5.4 *Types of options of vessels' failure in the drift*

1. Damage to the ship's propulsion away from navigational obstacles and away from assistance (tugs), in deep waters without the possibility of using anchors to control the drift.
2. Ship's drift far from assistance in shallower waters with the possibility of lowering the anchors to control the drift.
3. 1st and 2nd case of the ship's drift with the possibility of the propulsion system to become operational within specified time.
4. Ship's drift in shallow water in the vicinity of navigational obstacles without the possibility of repairing the propulsion system failure in a short time which may result in risk of collision with the navigational obstacle.
5. Ship's drift near obstacles without tugs assistance and without the possibility of repairing propulsion systems in the vicinity of dangers to navigation.
6. Drifting ship in tow with a tug not powerful enough; there is a drifting system near dangers to navigation.
7. A drifting system that is at anchors and the tug while waiting for assistance of greater towing power.
8. Drifting tow with tugs unable to remain on the planned route to the port of refuge in conditions when wind and currents are increasing.

6 SUMMARY

− Ship's drift may occur in bad weather as a result of a limited propulsion system or a reduction in its power.
− Ship's drift may result from the ship's breaking off the anchor in bad weather (after damage to the anchor system).
− Ship's drift is caused by damage to the steering and/or propulsion system.
− Ship's voyage planning should also include contingency plans showing how to act in case of lost propulsion or steering system.
− In any case there is a phase of rescue or towage to ports of refuge when it is not possible to repair damage to the ship's technical systems.
− Rescue of a freely drifting ship is carried out with the help of professional rescue teams or with the participation of merchant ships (see Annex 1) . Annex contains the ANNEX to the IMO MSC/Circ. 884 publication from 21 December 1998 under the title Guidelines for Safe Ocean Towing. The annex presents the method of towing a ship by a commercial ship.
− Towing plan based on the tow contract must be prepared before towing.
− The main points of the contract are the efficiency of towing operation.
− The towing plan covers a safe towing route and speed to the port of refuge.
− The weather is constantly monitored on the towing route and the place of towing, as well as the ETA.

- An important element of towing planning is establishing a method of communication and cooperation regarding management of the tow.
- An equally important element of the towing plan is risk assessment of towing process.
- The level of towing risk throughout the entire towing operation depends on the following elements :
  1 Quality planning of the route of the tow.
  2 Quality and reliability of communication in the tow and outside the system.
  3 Good supervision of the operation (operation management).
  4 Experience of tug crews.
  5 Technical condition of tugs (towlines, winches, engine power, etc.)
  6 Lack of commercial pressure on the tugs crews from outside.
  7 Unexpected changes in the marine environment, such as sudden changes in weather (high seaways).
  8 No unexpected increase in ship traffic along the towing route.
  9 Area free from pirate attacks.

ANNEX

Basic safety elements of the towed ship

Prior to towing operation, the towed vessel must meet certain technical parameters in order to be accepted on the tow in order to move from position A to position B.

1 Training the crew in the safe operation of technical systems related to the tow.
2 Before towing, the vessel must prepare lights and signs prescribed for towing.
3 The vessel must have a specified draft (trim) for the entire towing period.
4 The towed vessel must be watertight (when making heavy weather).
5 The towed vessel must have a well secured cargo (ballast water with no free space) etc.
6 The towed vessel must have safe stability in all wave conditions and external disturbances.
7 Steering system, propeller (the rudder to be held in the forward and aft position- midships). If possible, the propeller should be secured against turning.
8 Details on the technical and operational condition of the ship should be collected on an ongoing basis and ready to be reported.

9 Weather forecasts and sea state are to be controlled. The captain must establish constant contact with the mainland (shipowner, SAR, etc.).
10 Special Towing Booklet throughout the entire towing passage must be kept.

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