sciendo

DOI: 10.1515/aon-2019-0014

A SIMPLIFIED METHOD OF FORECASTING SHIP'S SPEED IN DETERMINING ETA IN MARITIME NAVIGATION

Mirosław Jurdziński
Maritime University in Gdynia
Faculty of Navigation
John Paul II Avenue II
81-001 Gdynia, Poland
m.jurdzinski@wn.umg.edu.pl

ABSTRACT

The work includes a method of establishing ship's speed at various stages of maritime shipping. It describes the influence of the water supply under the keel on decreasing speed in tidal regions. It presents an assessment of ship's speed in oceanic shipping based on the speed characteristics along with the influence of interference from waves in oceanic shipping.

Keywords— determining ship's speed, water level under the keel, assessment of ETA

1. INDRUCTION

Ship's speed in planning navigation plays a significant role. It is of great importance not only as a physical unit, but also as an economic indicator. A ship operates within a planned rotation to ports on established shipping lines. The accuracy of information about ETA is connected with the familiarity with ship's speed on the whole planned ship route.

Ship's speed in various stages of shipping differs in time and position on each segment of the maritime shipping route (fig. 1). Stages of maritime shipping are presented below:

1) **Navigationally difficult stage**, encompassing shallow waters, such as ports, roadsteads, canals, dredged fairways, etc. Distances from navigational hazards which are less than 3 Mm. Traffic is conducted on very low water level under the keel.

2) **coastal navigation stage – shallow waters,** where water depths are less than three times the value of ship's draft. Distances from navigational hazards are between 3 to 50 Mm.

3) **Open waters stage – oceanic shipping.** Distance from the mainland and navigational hazards exceeds 50 Mm.

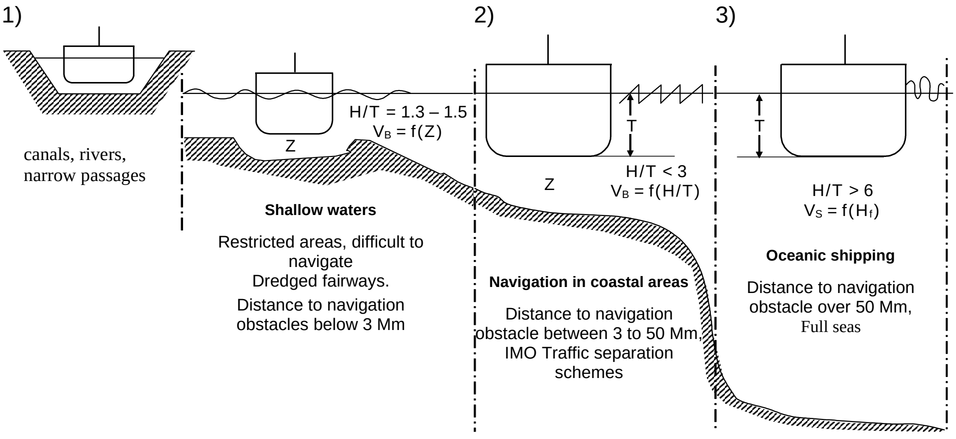

Fig. 1. Types of interferences in different phases of navigation:
1) shallow waters and canals, 2) coastal waters, 3) ocean, deep waters

The current model of maritime navigation allows for high precision in determining ship's speed in each stage of ship's route. The same applies to the assessment of actual interference and its direction in relation to ship's movement. It is different, however, in the case of forecasting ship's speed in each phase of maritime navigation. This stems from the difficulty in forecasting the conditions of external interferences influencing ship's movement on the whole planned route, and especially when it comes to long-term forecasts.

Each and every captain of a commercial vessel in international shipping is obliged to prepare a plan of navigation for the whole route, from the quay of port A to the quay of port B, according to the recommendation of the SOLAS Convention. Similarly, the captain is obligated to notify competent administrative authorities of port B of the ship's ETA. The estimated time of arrival is an important element in every port's operation. It is about avoiding congestion on roadsteads, which diminishes port capacity. The accuracy in determining ETA in a port of destination depends on the familiarity with the ship's exact speed on the whole planned route. The accuracy in determining ETA is one of the most important factors in the chain of economic effectiveness in maritime navigation.

In the last few years a host of positions have been published on establishing ship's speed in the conditions of external interference [11].

The accuracy of the speed forecast in oceanic shipping depends on the accuracy in determining external interference such as winds, waving and ocean currents. A number of computer programs are used for forecasting ship's speed in various stages of shipping. In the remaining part of this work the author presents general elements which might be helpful in the classic solutions to the problem of assessing forecasts of ship's speed in various stages of shipping. Better information about ETA in port streamlines port operations, rendering it more effective and decreasing costs of operations.

Delays in ship's arrival in port usually occur due to changes in hydrometeorological conditions. The route is often changed to avoid high waving, thereby preventing storm damage. The most hazardous phenomenon in the process of punctual arrival in the port of destination is sudden change of weather, including the area of waving. Weather forecasts can facilitate assessing waving in the process of ship's movement on the whole route. Models of waving are used continuously. Forecasts are broadcast with high accuracy [2].

In each phase of navigation, the ship moves at various speeds due to changing external interferences. Forecasting speed depends on the route length, time of route, season of the year, region, currents, winds, icing, limited visibility, shallow waters and ship traffic density.

The topic of this paper is the use of a classic method of forecasting ship's speed in planning navigation and time of shipping, namely preparing the exact ETA in port B.

2. SHIP'S MOVEMENT IN VARIOUS PHASES OF SHIPPING

Classic methods of predicting speed are still applied on board ships, whereas preparing a forecast by specialized advisory centers for captains facilitates decision-making in the process of assessing ETA for ports of destination [3].

The process of forecasting ETA depends mainly on the accuracy of establishing ship's speed, which is connected with the accuracy of hydrometeorological forecasts in a given region. The latest models of waving pose a basis for creating long-term forecasts with a high degree of verifiability, which may facilitate using classic methods of predicting ship's speed. Subsequently, the exact parameters of sea currents become available and this in turn can be used to predict ship's movement on oceanic waters as well as restricted areas.

2.1. Definition of restricted areas.

By definition restricted areas create difficulties in ship maneuvering. The ship is moving close to navigational hazards, additionally under external hydrometeorological interferences. Regions like this are characterized by [5]:

- Limited depth and width of passage;
- Considerable fluctuations in the water level;
- Strong tides and ocean currents;
- Strong winds and waving;
- High probability of limited visibility;
- Water surface icing;
- Considerable ship traffic density;
- Other, unpredictable activities such as: fishing, recreation or extraction industry.

In figure 2 the phenomena influencing ships in restricted areas are shown.

2.2. Phenomena connected with navigation in shallow waters.

Navigation in shallow waters is linked to changes in conditions of maneuvering risks and general navigation processes. What also changes is the conditions of hazard, which is connected with failures due to running aground or a collision with ships in movement or during their stay in the area of anchorage.

The effect of a ship entering shallow waters is felt in the process of navigation:

- Increased waving at the bow;
- Increased load of the main engine;
- Natural decrease in the ship's speed on the water;
- Slowing down of the phenomena of ship maneuvering;
- Increased route of stopping the ship;
- Changes in heave and roll;

- The diameters of circulation are considerably increased with the slowing down of the speed of course changes;
- Ship's vibrations can start with decreasing depth.

2.3. Information on hull activity on a wave in shallow waters.

Waving is one of the dynamic factors in assessing correction regarding water supply under the keel. The hull's response upon waving can be divided into linear-reverse and angular-reverse. The effects of waving on the ship can be depicted based on source material [4, 8, 9 and 10].

2.4. Ship's movement in shallow waters.

In restricted areas the ship's movement is usually connected with the risk of collision failure or running aground. In certain maneuvers or regions the ship's movement is supported by tugs. The ship has to move on her own at safe speeds due to the water level under the keel. Very often changes in the main engine's regime are applied within the range of very slow to full speed ahead.

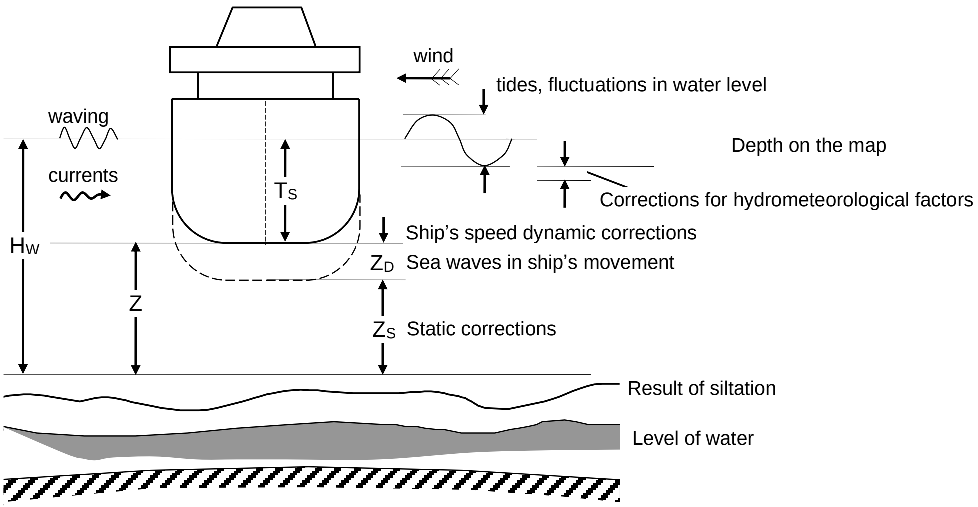

Fig. 2. Deep draft ship movement in shallow water

Based on figure 2. the following relationships can be concluded:

$$HW = TS + Z \text{ [m]} \quad (1)$$

$$H_W = T_S + Z_D + Z_S \text{ [m]} \quad (2)$$

where:

- H_w – safe depth required [m];
- Ts – static draft when the ship is stationary;
- Z – water level under the keel [m];
- Zs – static water level under the keel [m];
- Z_D – dynamic level from the wave and in ship's squat during movement [m].

3. DETERMINING SAFE SHIP SPEED GIVEN THE VALUE OF WATER LEVEL UNDER THE KEEL

The required depth on shallow waters equals:

$H_W = T_S + Z$, [m]

Whereas supply Z is the sum of the values of static and dynamic water level, i.e.:

$$Z = Z_S + Z_D \text{ [m]} \tag{3}$$

The static water level is the sum of corrections (1÷6). The dynamic water level consists of corrections for waving and squat during movement: $Z_D = R_7 + R_8$. Hence the correction for ship's squat during movement according to C.B, Barrass [1] is:

$$R_7 = 0.01 \cdot V^2 \cdot \delta, \text{ [m]} \tag{4}$$

$$R_8 = 0.5\ H_f \text{ [m]} \tag{5}$$

where:

- V_S – ship's speed in knots;
- δ – hull block coefficient;
- H_f – wave height in meters;
- R_S – correction for waving.

$$Z_D = Z - Z_S \text{ [m]} \tag{6}$$

hence

$$0.01 \cdot \delta \cdot V_S^2 = Z - (Z_S + R_8) \tag{7}$$

After transforming the equation (7) we receive a formula for safe speed on shallow waters [7];

$$V_B = \left\{\frac{100}{\delta}\left[Z - \left(Z_S + 0.5\ H_f\right)\right]\right\}^{0.5} \tag{8}$$

where:

- Z_S – a sum of static corrections ΣR_S [m];
- R_S – a correction for waving during movement 0.5 Hf [m].

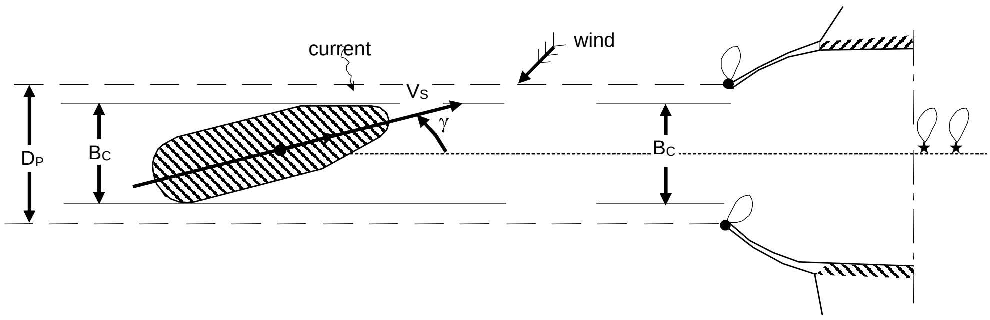

Fig. 3. Width of BC traffic lane and safe ship's path when moving in narrow DP passage

The width of the path shown in fig. 3 is expressed by the following formula:

$$B_C = L \sin\gamma + B \cos\gamma \text{ [m]} \tag{9}$$

where:

- L – length of the ship [m];
- B – breadth of the ship [m];
- γ – a sum of corrections due to wind α and current β.

A safe width of passage in a narrow passage is expressed by the following formula [5]:

$$D_P = k(B_C + R_{95}) \text{ [m]} \tag{10}$$

where:

- k – coefficient (1.6÷2) dependent on the accuracy of assessment of shipping conditions;
- *R95* – mean position error on a fairway with 95% probability.

The width of the traffic lane and safe width of ship's passage in a narrow traffic area depend on ship's speed and the values of external interferences *(α, β).*

A ship moving on a fairway with limited breadth B_C in tidal regions with a determined safe water level under the keel has to meet additional conditions regarding moving at safe speed, with a determined state of external interferences. The question is whether the ship can on its own move on a fairway with the width of B_C at given interferences. This condition has to be fulfilled also if it comes to the duration of a tidal window, namely maintaining safe depth *HW* on a fairway.

By transforming formula (10) into D_P we can determine the limit value of leeway and drift γ during ship's movement in s restricted fairway with the width of DP.

The formula is [6]:

$$\sin\gamma = \frac{\mp 2B_C \mp [(2B_C L)^2 - 4(L^2 + B^2)(B_C^2 - B)]^{0.5}}{2(L^2 + B^2)} \tag{11}$$

where:

- B_C – width of lane [m];
- L – length of ship [m];
- B – breadthof ship [m],

Y – limit of the sum of corrections where the ship remains in a fairway of a given width B_C.

The solution to this problem in practice has to be supported by a comprehensive computer program with a comprehensive approach during all of the ship's safe movement to the port. In ports the systems of *Dynamic Under Keel Clearance* are used.

3.1. Determining ship's speed on restricted shallow water.

A ship entering shallow water from deep waters decreases its speed with the same values for fuel consumption. Similarly, the ship's main engine RPM falls. A ship moving on shallow water in the following ratio: H/T = (1.5÷3.0) decreases its speed in percentage in relation to the speed in deep waters. The value of the decrease of speed in percentage is expressed by the formula (12) [1]:

Speed decrease:

$$\Delta V = 36 - (9 \cdot H/T)\, N \; [\% \cdot V_S] \tag{12}$$

At the same time the RPM falls respectively in relation to the formula:

$$\text{Loss of SG RPM equals } \Delta\ (\text{RPM}) = 18 - (10/3 \cdot H/T)\ [\%\ \text{RPM}] \quad (13)$$

In the next range of the ratio H/T = (1.1÷1.5) the speed decrease in percentage can be expressed by the formula (14) [1]. The formula for speed decrease is:

$$\Delta V = 60 - (25 \cdot H/T)\ [\% \cdot V_S] \quad (14)$$

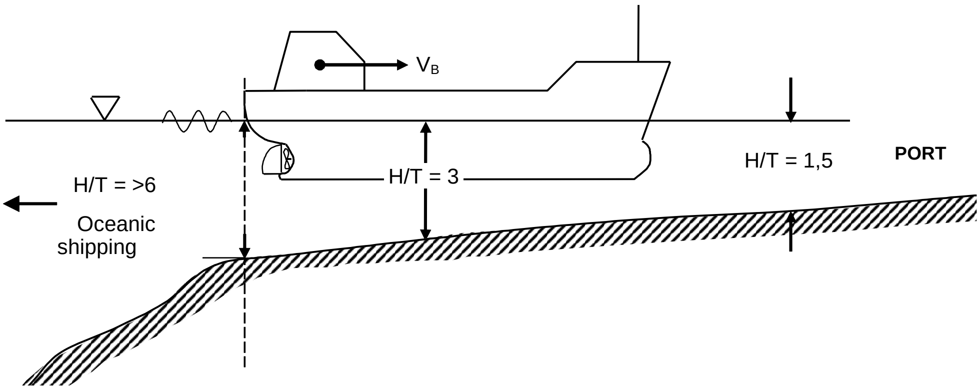

Fig. 4. Ship entrance on shallow water unlimited on both sides

The ship's speed on shallow water must be corelated with the duration of the tidal window on shallow water, taking into account remaining on a limited fairway under a given external interference. It is one of very difficult cases of navigation in regions which are difficult to navigate in limited fairways.

In figure 5 we can see a case of a ship's passage on shallow water with a given length *l [m]* in t_2-t_1 time, through which the ship moves towards deeper water areas just before entering the port.

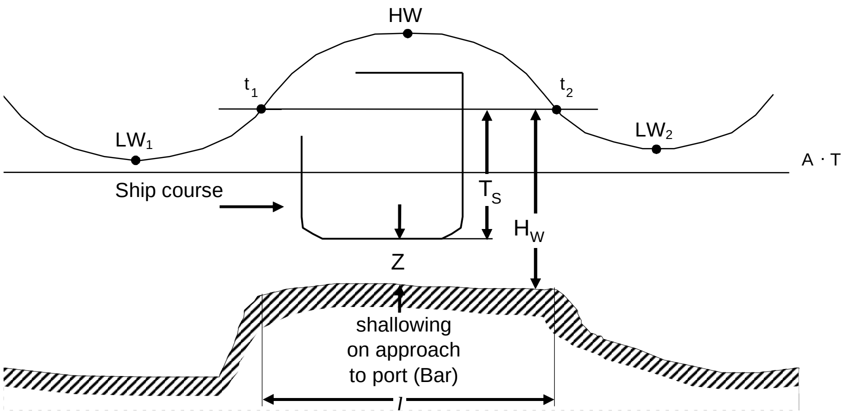

Fig. 5. Ship movement at safe speed in l-long shallow water

Speed in l-long shallow water can be calculated with the following equation:

$$V_M = l/(t_2 - t_1) \quad (15)$$

Safe speed for a given water level under the keel V_B has to be higher or equal to the speed V_M, namely:

$V_B \geq V_M$ [knots]

where:

- t_1 – moment of ship's entering shallow water;
- t_2 – moment of leaving shallow water;
- V_B – safe speed in shallow water.

3.2. Speed decrease in shallow water limited from both starboard and port side.

The ship's speed significantly drops in regions such as port basins, channels and rivers. In rivers, the currents are an additional factor affecting speed. The ship's speed decrease is also influenced by the ratio of cross-section of the draft to the cross-section of the water reservoir (channel or river).

The ratio F_S/F_K – is described by the coefficient k [1].

The ship's speed decrease in percentage value for coefficient k = 0.200–0.275 equals:

$$\Delta V = 300 \cdot k - 16.5 \; [\% \; V_S] \qquad (16)$$

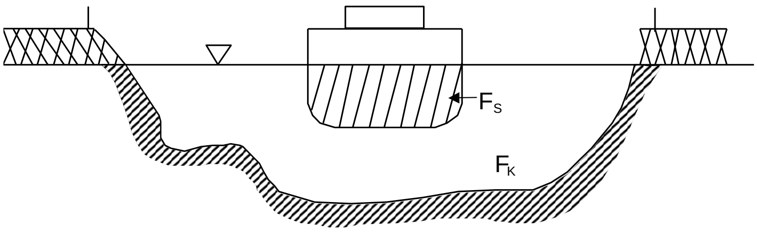

Fig. 6. Cross section of a ship moving in a canal limited by walls on both sides of the ship

The ship's speed decrease in percentage value for the coefficient k = 0.200–0.275 is expressed by formula (17) [1]:

$$\Delta(\mathrm{RPM}) = 24 \cdot k + 11.6 \; [\% \; \mathrm{RPM}_S] \qquad (17)$$

3.3. Ground systems of dynamic water level under the keel.

In the last decades the administrations of ports worldwide have introduced systems for determining the water level under the keel for ships entering ports at long distances in shallow water in tidal regions. (*Dynamic Under Keel Clearance*).

The purpose of the Dynamic Under Keel Clearance is to integrate current parameters of waving, tidal currents, changes in depth with the speed characteristics of a ship to ensure safe shipping in shallow water to maximize effective port capacity.

Monitoring speed characteristics and hydrometeorological conditions taking into account draft during movement in tidal window, can increase the number of entries into port in shallow water.

Modelling is used to determine ships' maximum safe drafts and the accuracy of forecasting – the tidal window allowing ships to safely pass to the quay in the port.

The fact that port authorities use a computer program has significantly facilitated calculations and has reduced the number of human errors during data processing to calculate the water level under the keel as well as ship's speed (*Standard Under Keel Clearance Techniques*).

During their passage in shallow water in tidal areas pilots and captains receive information directly on the bridge about safe speed and a safe water level under the keel throughout the whole route towards the port.

4. DETERMINATION OF SPEED IN OCEAN SHIPPING

The main factor disrupting the movement in ocean shipping is waving and ocean currents. Speed characteristics are used to determine the speed of a ship in the ocean. It is assumed that external resistance from waves reduces the speed of the ship depending on the direction of the wave pressure on the hull and sea currents.

The speed decreases from the pressure of waves in relation to the movement of the ship sailing on calm waters. Therefore:

$$V_S = V_0 - \Delta V \text{ [knots]} \qquad (18)$$

The decrease in the speed of the ship from the waves, can be written in the form:

$$\Delta V = a \cdot H_f + b \cdot H_f^2 + c \cdot H_f \cos q \text{ [knots]} \qquad (19)$$

where:

- a, b, c – function coefficient depending on the ship's draft;
- V_0 – speed on calm water [knots];
- ΔV – decrease in ship speed from external interference;
- H_f – wave height in meters [m].

The graphic form of speed characteristics is shown in Figure 7.

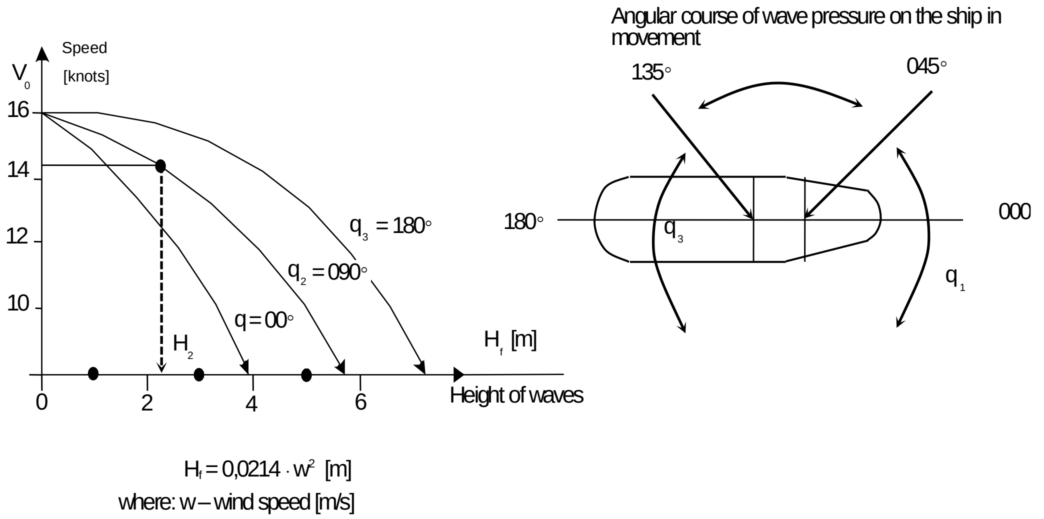

Fig. 7. Simplified ship performance curves

In ocean shipping, the process of planning a ship's speed on a planned route can be developed using several days' forecasts of sea waves and currents. Using the speed characteristics of the ship and wave and currents forecast on the route, one can with a degree of certainty approximate the speed of the ship for the assumed prognostic data (Fig. 8).

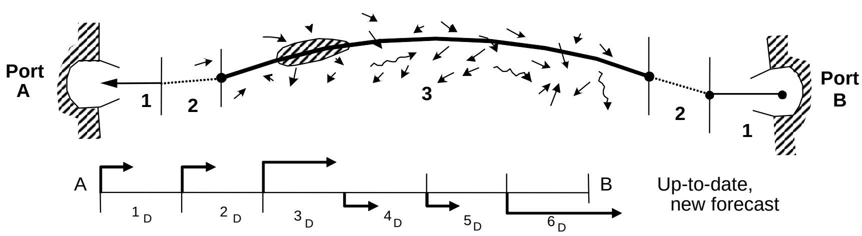

Fig. 8. Weather forecast for a few days in ocean navigation and its daily speed corrections

Difficulties can arise when the ship is sailing in ice-covered areas. Ice drift, compactness, the thickness and age of ice make it difficult to forecast ship's speed.

The planning of ocean navigation and its implementation is optimized according to specific criteria. Accurate speeds are also determined throughout the ship's path optimization process. In the shallow water zone, difficulties may arise due to the influence of hydrodynamics on the ship's movement. Furthermore, it is difficult to forecast the speed of the ship in the area of approach to port B, especially a few days in advance.

Figure 9 shows a method of assessing ship speed based on prognostic data. The monitoring of travel planning takes place during shipping. Within this monitoring the ETA realization process is controlled, which is sent at the beginning of the cruise by the port of destination.

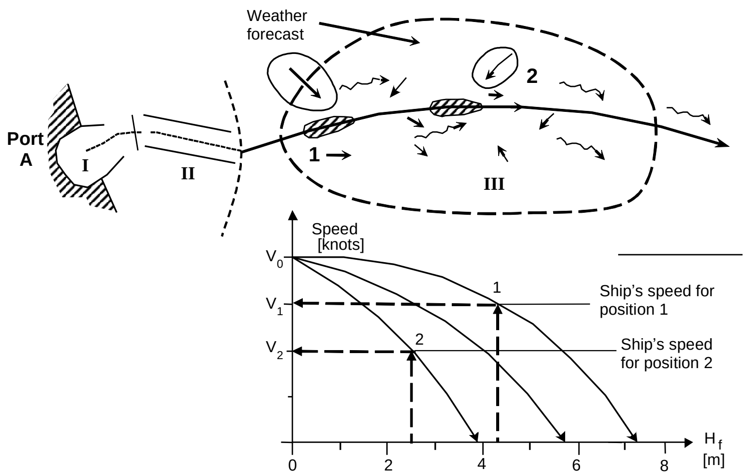

Fig. 9. Speed estimation using a graphic method against wave height for two ship positions.

The main factor of speed correction is determining the speed of the ship by setting the RPM of the M.E. (main engine). This graph is shown in Figure 10.

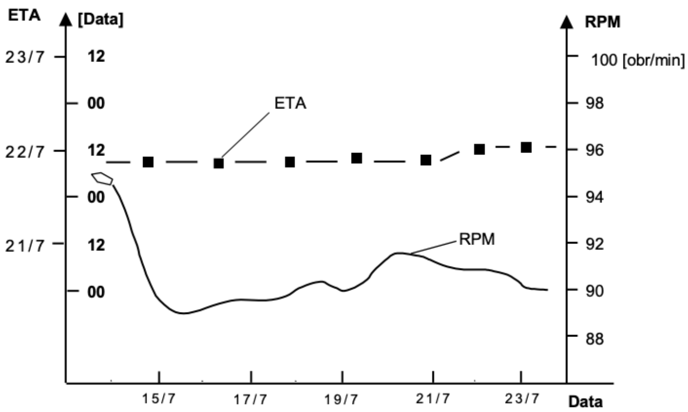

Fig. 10. En-route monitoring of ship ETAs and controlling ship speed by RPM

The procedures for the process of simplified ship speed forecasting in maritime navigation planning.

1. A ship's travel plan shall be determined on electronic or paper sea charts. According to The SOLAS Convention A.893 (21) and the SOLAS Convention Chester V Reg. 34.

2. There is a division into limited, coastal and oceanic phases, including an alternative route.

3. The lengths of individual navigation phases are determined.

4. The weather forecast parameters, water status (tidal windows), wind strength and direction, wave height, active (dead) waves, direct and tidal currents are analyzed.

5. The ship's speed parameters in individual navigation phases are assessed (with a pilot, for river, in channels, etc.). Speeds on shallow water are determined including the water level under the keel.

6. In coastal navigation, the conditions of the depth of water to immersion (H / T) and natural decline in speed and M.E. RPM are determined.

7. In ocean shipping, the distribution and parameters of direct currents and wave conditions using speed characteristics and sea current parameters are determined, then the speed in each section of the ocean route taking into account the change due to the movement of the ship is determined (Fig. 11 and 12).

8. The speed of the ship approaching port B and sailing within the restricted area (with pilot) on the approach to the port B quay shall be considered similarly.

9. The shipping times of the respective phases are added together.

10. An ETA is determined for the port of destination.

11. The process is repeated every day, the speed (RPM) of the main engine is adjusted in terms of control. In the event of forecast changes, corrected dates are sent (ETA) to the port of destination.

5. THE PROCESS OF PREPARING ETA FOR THE PORT OF DESTINATION

The use of the advice on the selection and optimization of shipping routes by specialized institutions, which may determine the ETA to the port of destination with high accuracy does not exempt captains of ships from the preparation of ETA determined directly onboard the ship.

The route optimization process is carried out depending on the wishes of the captain and the charterer. You can also choose the criteria for ship route optimization, such as:

- the minimum duration of the trip;
- minimum damage to the ship and / or cargo;
- constant speed of the ship;
- saving fuel;
- towing the ship;
- passenger comfort.

Regardless of the adopted optimization criteria, the company always determines the ETA to the port of destination.

In ocean shipping, forecasting of ship speed parameters is determined by such elements as [17]:

- large latitude change while shipping;
- shipping only on medium latitudes;
- load line;
- ballast or full load;
- slamming - taking water on board on the wave;
- the eastward or westward movement of the ship;
- shipping in ice-covered waters;

- limited visibility;
- ocean currents;
- the icing of the ship's hull;
- limited water level under the keel on the approach to land;
- hull response to waving, heave, pitch or slamming;
- type of speed characteristic of the ship;
- verifiability of weather forecast on the shipping route.

As can be seen, this range of information makes it difficult for captains to easily predict ship speed. Not including constant ocean currents in the speed forecasting process, to a significant extent degree reduces the accuracy of the ETA assessment. In nautical publications, ocean current parameters differ considerably and may introduce significant errors in the ship speed assessment.

The ETA is sent to the ports of destination when the ship is unmooring at the port of departure or after the ship leaves the regions in which navigation is difficult.

6. BASIC DEPENDENCIES FOR ETA CALCULATIONS

Distance travelled on planned ship route:

$$d = V_S \cdot t_C \text{ [Mm]} \tag{20}$$

where:

- d – A to B distance travelled (planned);
- t_C – duration of sailing during cruise [hours];
- V_S – speed (average) [knots].

Duration of the cruise:

$$t_C = \sum_A^B (d/V) \text{ [days, hours, minutes]} \tag{21}$$

Speed:

$$V_{śr.} = d / t_C \text{ [knots]} \tag{22}$$

Speeds are forecast based on the parameters of hydrometeorological forecasts.

The D_0 value shows the Great-circle distance in Mm. The total sail time t_C is given by the equation:

$$t_C = \sum (d_1/V_1 + d_2/V_2 + D_0/V_3 + d_4/V_4 + d_5/V_5) \tag{23}$$

Determining ETA to the port of destination (B) is defined by the equation:

$$t_B = t_A + t_C \tag{24}$$

Therefore, speeds on designated sections of the route should be determined on the basis of speed planning forecasts.

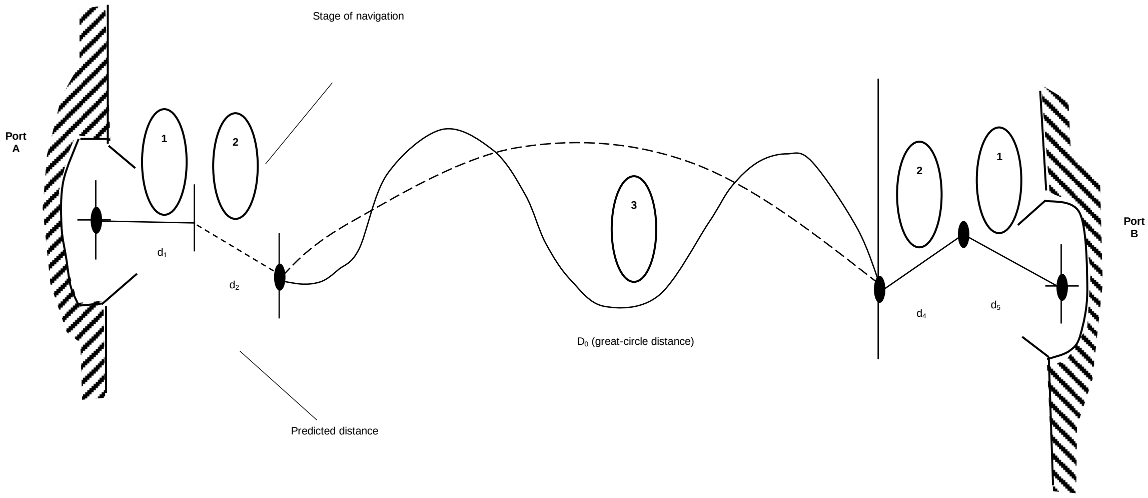

Fig. 11. Route composition in passage planning

ETA prognostic calculation in ocean shipping.

Based on the data from 14-day forecasts, it is possible to assess the conditions of external disturbances on the route, based on winds, wave directions and direct currents on the route section A to B, and you can determine the ship's speed for given propeller RPM (also the ship's speed characteristics). For example, the data of ship movement parameters along the Great-circle distance (Fig. 12) is presented.

An example of calculating the ETA value at a ship crossing from port A to port B along the great-circle distance.

Parameters of the forecast ship speeds are given in Table 2.

Data: The ship unmoored in port A (tA) on 10/05 at 0800 GMT.

Specify the ETA for port B for data planned in navigation.

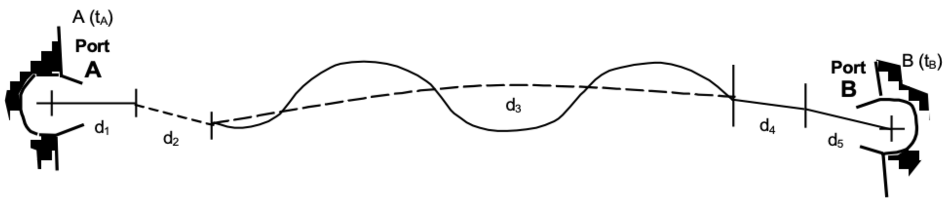

Fig. 12. Speed prediction in different phases of navigation

Table 2. Parameters of the predicted speed of the ship

	Distance d [Mm]	**Speed V_i [knots]**	**Time of sailing Δt_i [hours]**
1	5.0	V_1 – 3.0	1.7
2	15.0	V_2 – 10.0	1.5
3	1050.0	V_3 – 14.0	75 (navigating the great-circle distance)
4	40.0	V_4 – 11.0	3.6
5	6.0	V_5 – 4.0	1.5

Total route length: **$\Sigma\, d_i$ = 1117 [Mm]**

Total shipping duration: **$\Sigma\, \Delta t_2$ 83.3 [godz.] $\Delta t_i = 3^D.475$**

1. $t_B = t_A + \Sigma\, \Delta t_i$ time of arrival at port B

t_A = 10/05 hours 08^h00^m GMT, moment of departure from port A

+ $\Delta t_i = 3^D$ 11^h18^m time of shipping on the whole route

2. t_B = 13/05 19^h18^m time of arrival at port B (ETA)

3. ETA to port B 13/05 h. 19h40m GMT

or 13/05 at 2000 GMT

At the end of the calculation, time zones in port B are taken into account.

7. FINAL CONCLUSIONS

1. It is the captain's responsibility in accordance with the SOLAS Convention to prepare a ship's travel plan before traveling.

2. The planning process takes stock of the entire movement process of the ship from the A port quay to the B point quay (destination).

3. On the basis of hydrometeorological, archival and current forecasts, it is possible to determine the speed prediction of the ship along the entire route.

4. On the basis of the forecasts and information obtained, the captain of the ship is able to prepare the initial ETA for the port of destination to the port authorities.

5. The initial ETA may be charged with error due to inaccurate prognostic information regarding hydrometeorological conditions along the ship's route.

6. Continuous control of weather forecasts during the cruise allows for increasing the accuracy of ETA determination and correction.

7. In the integrated navigation model, the ECDIS system specifies the ETA of the ship to the port of destination. Classic forecasts are comparative data for calculation values.

REFERENCES

1. Barrass C.B., Ship Design and Performance for Masters and Mates, ELSEVIER, Oxford 2004, p. 176.
2. Calkoen Ch., How open data can improve ship arrival times www.meloditsprojects.en/kontent/how-open-data.
3. ETA – Crawford Nautical School. www.crofdordnautical.com/eta/.../
4. Inglish R., Price W., Merton of the Ship in Shallow Water, Transsetion RINA, Vol. 122, 1989.
5. Jurdziński M., Nawigacyjne planowanie podróży, Wydawnictwo Morskie, Gdańsk 1989, s. 24.
6. Jurdziński M., Planowanie nawigacji w obszarach ograniczonych, Akademia Morska w Gdyni, Gdynia 2003, s. 90–92.

7. Jurdziński M., Ocena zapasu wody pod stępką w żegludze morskiej, Akademia Morska w Gdyni, Gdynia 2007, s. 61.
8. Kent J.L., Ship in Rough Weather, Thomal Nelson & Sons, London 1958.
9. Nowicki A., Osiadanie statku, Technika i Gospodarka Morska, nr 819, 1970.
10. Schonttke R., Ship Sway. Rolland Yaw on Oblique Seas. Transaction SNAME, Vol. 86, 1978.
11. Valćić M et al., ANFIS Based Model for Ship Speed Prediction, BRODOGRADNIJA, 62(2011)4, Rijeka 2011, p. 373–382.
12. Zimmerman R., Bier V.M., Risk Assessment of Extreme Events, www.ldeo.columbia.edu/.../
13. https://www.ecmwf.int/en/forecasts/charts
14. www.intertanko.com/.../
15. https://polar.ncep.noaa.gov/waves
16. http://marine.copernicus.eu/
17. https://www.onthemosway.eu/.../Voyage-Passage-Planning