THE PROBABILITY OF COLLISION DURING VESSEL OVERTAKING

PRAWDOPODObIEŃSTWO KOLIZJI PODCZAS WYPRZEDZANIA STATKÓW

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Abstract. There are many close quarter situations at sea, especially in narrow channels. The problem of overtaking on fairways is a complex issue. Navigation, when carried out in such areas causes reduce of a vessel’s safety level, it is necessary to consider limits: ship’s particulars, fairway’s parameters, human factor, vessel traffic. If these factors are not considered during overtaking, it will cause ship out of fairway or collision. The paper contains the probability of collision during overtaking.

Keywords: overtaking, collision


Słowa kluczowe: wyprzedzanie, kolizja
1. Introduction

Navigation when carried out in such areas causes a reduction in the vessel’s safety level. The navigator, watch officer should take into consideration the factors which have influence on it. These limits are: ship’s particulars and her manoeuvring characteristics, fairway’s parameters: depth, breadth, hydro-meteorological conditions, direction and speed of the wind, currents, waves, vessel traffic in the examined area and visibility. If these factors are not considered by navigators in narrow waters, it will lead to the hazard of transport safety, as well as the risk of the ship getting out of the fairway and as a consequence, the possibility of running aground. Nowadays aids of navigation systems are used. ARPA (Automatic Radar Plotting Aid) is a universally used system whose aim is to plan and assess anticollision manoeuvres. However, when the distance between two vessels is about a few of own vessel’s lengths (for larger ships 2000 – 3000 meters), the watch officer makes a decision based only on visual observation, “good sea practice” rules and his own experience. In this case advices given by anticollision system are not useful. The problem of making decision about availability overtaking manoeuvre in uncertain conditions is connected with the evaluation of system in order to take on action. Systems object – human should proceed to execute tasks in random time moments. Probability it means the realization of different random variables [2]. The system human – ship in case of too close approach in the fairway should proceed to execute the avoidance collision task, it means to execute random variables such as an anticollision overtaking manoeuvre in restricted area. The measure of availability is the probability of random variables multiplication. That system will be on permanent availability and proceed to carry out task and will not lose its ability to realization [3]. Apart from technical factors and environment parameters, availability also depends on the navigator’s decision about anticollision manoeuvre – kind of action.

2. Overtaking on the fairway

During the overtaking manoeuvre on the fairway a navigator must take into consideration the limits, factors which outline the safe manoeuvre area [4]:

a) external factors
   - traffic, position of other vessels (different types and particulars), speed of other vessels,
   - the fairway’s parameters (breadth, depth, length),
   - hydro-meteorological conditions (wind, wave, visibility, state of sea),
   - day time,
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b) internal factors
- own vessel (manoeuvre characteristics, size of the ship – length, draft, speed, breadth, loading or ballast condition),
- navigational equipment of own vessel,
- overtaken vessel particulars (course, speed, size of the ship – length, breadth, draught),
c) human factor
- experience,
- education, knowledge,
- stress,
- hours of work – exhaust.

In order to overtake safely another ship situated on the traffic lane, it is necessary to find the minimum distance to commence that manoeuvre, and also the value of rudder angles to alter the course. The execution of an overtaking manoeuvre on the fairway (alternatively in the traffic separation scheme) will require from the navigator taking such measures that the ship, as a result of the course alteration, will avoid collision with the overtaken object and will not cross fairway limits.

The ship carrying out navigation in the restricted area is permanently availability to take a manoeuvre to secure proceeding the route safely.

In the consecutive time intervals some states may be distinguished:
- expectations that the event „situation of collision” will occur,
- permanent availability during navigation,
- the time interval after the random event „collision possibility with another ship” occurred,
- taking action to avoid collision and keeping the ship in the fairway’s boundaries.

The occurrence of random event „collision with another ship” is pointed by ARPA. The watch officer is making a subjective assessment of the distance S and time of making a manoeuvre decision in accordance with his own knowledge, experience and distraction factors, fairway’s limits.

The actions taken by the navigator after occurrence of random event have an influence on final result of the manoeuvre:
- avoiding collision and keeping in the fairway,
- avoiding the collision and crossing fairway’s limits,
- the collision.

Due to the lack of precisely information, that aids the navigator in making decisions in restricted areas, received from navigational equipment (ARPA), anticollision manoeuvres should be supported by other advisory systems, which show the critical area around the overtaken object. When that area is
crossed by a ship as a result of no making a manoeuvre or making a prohibited manoeuvre (the use of unacceptable rudder angles, crash – stop), it leads to maritime accidents. In practice the watch officer while assessing the critical overtaking distance $S$, depends on his own knowledge and intuition.

![Overtaking manoeuvre in restricted areas](image)

**Fig. 1** Overtaking manoeuvre in restricted areas

3. The probability of overtaking

The ship carrying out navigation in the restricted areas should be in availability to make an overtaking manoeuvre. When random event occurs – collision with another object, it determines the decision of taking manoeuvre (see Figure 1). That decision should result in overtaking object and keeping in the fairway [1]. Therefore it is essential to describe the probability of overtaking maneuver.

To avoid collision the vessel should alter the course. The angle of steering is given by formula:

$$
\alpha = \alpha_0 + \alpha_m
$$
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where: \( \alpha \) – the angle of steering \(^\circ\),
\( \alpha_0 \) – the rudder command \(^\circ\),
\( \alpha_m \) – the error of steering \(^\circ\).

In accordance with figure 1:

\[
d = S \cdot \tan(\alpha) - \frac{B_1 + B_2}{2}
\]  

(2)

where: \( d \) – side distance of overtaking [m],
\( B_1, B_2 \) – vessels breadth [m].

\[
F_d(u) = P(d < u) = P(S \cdot \tan(\alpha) - \frac{B_1 + B_2}{2} < u)
\]

\[
= F_u \left[ \arctg \left( \frac{u + \frac{B_1 + B_2}{2}}{S} \right) \right]
\]  

(3)

That is necessary to find the distribution of random variable \( d \), assuming that \( \alpha \) can be describe by the normal distribution \( N(\alpha_0, \sigma) \).

\[
F_d(u) = \Phi_{(0,1)} \left( \frac{\arctg \left( \frac{u + \frac{B_1 + B_2}{2}}{S} \right) - \alpha_0}{\sigma} \right)
\]  

(4)

Using the equation:

\[
f_d(u) = F'_d(u)
\]  

(5)

As a result:

\[
f_d(u) = \frac{S}{\sqrt{2\pi}\sigma} \left( \frac{u + \frac{B_1 + B_2}{2}}{2} \right)^2 e^{-\frac{(u + \frac{B_1 + B_2}{2})^2}{2\sigma^2}}
\]  

(6)
The side distance $d$ will depend on random factors, that is a result from the error of steering and the impact of disturbances like wind and tide. The probability of overtaking manoeuvre $P(C)$ in safe side distance $d$ is expressed as:

$$P(C) = \int_{u_1}^{u_2} f_d(u) du , \quad 0<u_1<u_2$$ (7)

where: $P(C)$ – the probability of overtaking manoeuvre,
$u_1$ – the minimum side distance for overtaking [m],
$u_2$ – breadth of the fairway [m].

The density function of side distance $f_d(u)$ will make it possible to calculate the probability of safe overtaking the other vessel in a given distance $S$ in restricted areas. When limits of the fairway (breadth) and the value of side distance as a result from hydrodynamic interaction of two ships during overtaking are known, it will lead to determine that each manoeuvre is safe and possible to execute.

For vessels breadth: overtaking – $B_1=57$ m, overtaken – $B_2=32$ m, overtaking distance $S=300$ m, the rudder command $30^\circ$ and various steering errors, permissible overtaking side distance $u_1=57$m, the right limit of the fairway $u_2=120$m received results (see Figure 2):

| Table 1. Overtaking for $S=300$ m and various steering errors |
|-------------------|-----|-----|-----|
| Overtaking distance $S$ [m] | 300 | 300 | 300 |
| Rudder command $\alpha_0$ [$^\circ$] | 030 | 030 | 030 |
| Steering error $\alpha_m$ [$^\circ$] | 3   | 7   | 10  |
| $P(C)$             | 0,42| 0,41| 0,34|


4. Conclusion

The essential issue for overtaking manoeuvre is the time interval measured from the appearing of random event, which is the possibility of collision, to the time of making the manoeuvre decision. In this time interval, the navigator has to decide about the action that will allow him to safely pass of the ship. The determination of the permissible maneuvering area (dependent on critical overtaking distance) will make it possible to overtaking safely another ship being on i.e. the fairway. This area will also inform the navigator about the minimum distance that the overtaking ship is able to approach to execute the manoeuvre, when limit factors are considered. The model of probability for overtaking manoeuvre in restricted areas was presented. The model takes into consideration: human factor (steering error), rudder command, the fairway limit (breadth).

References


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