TransNav
International Journal on Marine Navigation and Safety of Sea Transportation
Volume 4 Number 1 March 2010

Defining of Minimally Admitted Head-on Distance Before the Ships Start Maneuvering

V. M. Bukaty & E. N. Dimitrieva
Baltic Fishing Fleet State Academy, Kaliningrad, Russia

ABSTRACT: Without stating the very fact of head-on situation, an attempt has been made to define the minimum admitted head-on distance between the ships in order to carry out safe maneuvering at a determined the closest point of approach, taking into account the ships' maneuvering characteristics.

1 INTRODUCTION

The practical use of Rule 14 article of COLREG-72 is complicated by non-indication of minimal admitted distance till the oncoming vessel for the purpose of the maneuver to keep well clear. The COLREG-72 Comments together with ship's guide textbooks recommend to start the maneuver «to act accordingly to the existing situation» for this case. But obscure maneuver start definition accompanied with the nearest admitted head-on distance (i.e. ships beam distance) at the keeping clear moment together with other factors may be the common cause of dangerous getting closer of ships which involve risk of collision or ending with collision. Unrestricted meeting distance between vessels before the maneuver and uncontrolled beam distance at the clear moment cause the vessels to take the clearing maneuver non-simultaneously. More of this, if one of the vessels watches the other have turned starboard, the former often sustains the present course and speed until the situation becomes threatening. But we should mind that the vessels' head off angles defining depend upon the head-on distance. These angles should be as such that at the moment of divergence the abeam distance between the vessels has no less than prescribed safe value. To fulfil such requirement navigators have to solve the task on vessels meeting at a fixed distance, that is to define their own vessels' maneuvers so as the distance between the vessels at the beam passage moment is no less than the prescribed value. So far this task is solved by navigators without any calculation but based upon their own experience and ocular estimation together with shaky ground of Rule 14 article of COLREG-72 as quoted «acting accordingly the factors of existing situation...».

2 ANALYTIC REVIEW

Taking into account the fact that a considerable number of collisions take place at the meeting vessels courses in particular (Karapuzov, A. I. & Mironov, A. I. 2005. Maneuvering…) there was suggested to bring under regulation navigators' actions at maneuvering for safe divergence. So we made some attempts in our articles (Zelenkov, A. I. 1999. The Distance…; Karapuzov, A. I. 1986. Determination…) define the minimal admitted distance between vessels approaching each other meeting on the almost reciprocal course by the minimal nearest admitted vessels' head-on distance criterion depending on rudder angle at the maneuver start. As the result we have deduced expression for defining minimal admitted distance S_{min} between the vessels at the maneuver start and for defining necessary head-off (turn) angles ΔC_A and ΔC_B for vessels A and B respectively to provide the divergence at the closest point of approach d_{cpa} (Fig. 1):

$$\Delta C_A = arctg\frac{d_{cpa}}{4S\min}\left(1+\frac{v_B}{v_A}\right)$$

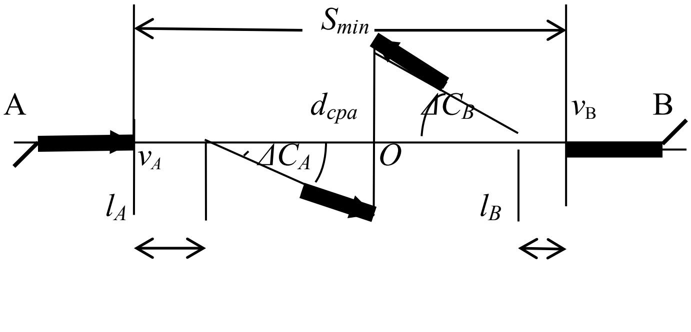

Figure 1. For calculation of minimal admitted distance between vessels approaching on reciprocal courses

$$\Delta C_B = arctg \frac{d_{cpa}}{4S_{min}} \left(1 + \frac{v_A}{v_B}\right)$$

$$S_{min} = l_{1A} + l_{1B} + \frac{L_A + L_B}{2} + S_A + S_B$$

where v_A and v_B - the vessel's speed at the turn moment; l_{1A} and l_{1B} - the vessels' advance at moments of head-offs; S_A and S_B - the ways passed by the vessels within the wheel orders fulfilment; L_A and L_B - the vessels' lengths overall.

The above given task solution is eventually defective as in this regard the vessels were suggested to turn from their courses immediately while proceeding at rectilinear motion. As the result the distance, between the vessels' fore ends at moment of the O meeting point entry along with unaltered courses, taken as d_{cpa}, is not the nearest head-on distance as the actual distance exceeds it. Such a deficiency has been caused by consideration the vessels' motion straight but through maneuverable path, i.e. turning circle.

3 TASK SOLUTION

But starting from the rudder displacement (starboard as required by the COLREG Rule 14 in this case) the vessel is known to pass first so called «dead interval» (that is considerable for heavy-tonnage vessels) keeping the present course for a while. Than after declining the course to port that is called as the reversed bias l_3, the vessel will proceed to the turning circle (Fig. 2). In the theory of turning circle the advance l_1 is called a distance for which the center of gravity is shifted from putting the wheel to the vessel's exit to the point at the curve of the turning circle, that corresponds to the course alter through 90º. Meanwhile the forward bias l_2 (Snopkov, W. I. 2004. Ships'…; Woytkunsky, Y. I. & Perschitz, R. Y. & Titov, I. A. 1973. The Ships…) is the least distance from the previous course line to point on the turning circle curve, corresponding to the course alteration by the same value. The distance from the moment of the vessel's exit to the circulation start till her turn to 180º is called the tactical diameter D_T. The advance l_1 value, forward bias l_2 and the tactical diameter D_T are give in the vessel's maneuvering fact sheet inevitably.

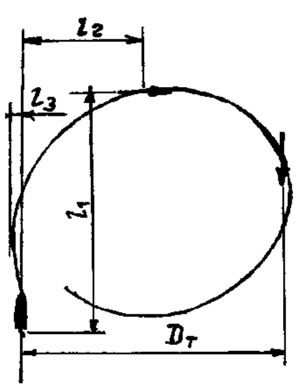

Figure 2. Center of vessel's gravity path on circulation

The following correlations are typical for vessels of all types (Woytkunsky, Y. I & Perschitz, R.Y. & Titov, I.A. 1973. The Ships…)

$$l_1 \approx D_T; \quad l_2 \approx 0{,}5D_T; \quad l_3 \approx 0{,}1D_T \qquad (1)$$

The tactical circulation radius depends on the rudder angle ψ and vessel's rate of sailing v. Based on field testing results Table 1 presents the following data: tactical circulation radius, the advance, the forward bias of «the Atlantic» type full-freezing trawler (FFT) at full steam ahead (FSA), at half steam ahead (HSA), at slow steam ahead (SSA), for rudder deflection by 15º, 25º, 35º (Karapuzov, A. I. 1984. Ships…).

Table 1. Circulation items of the «Atlantic» full-freezing trawler (FFT) type

Rate of sailing	FSA 13 *kts*			HAS 10.5 *kts*		LSA 7 *kts*	
Rudder angle	15º	25º	35º	15º	35º	15º	35º
Circulation tactical radius, cab	2.35	1.73	1.51	2.16	1.40	1.99	1.25
Advance, cab	2.03	1.51	1.40	1.92	1.29	1.75	1.25
Forward bias, cab	1.27	0.97	0.93	1.08	0.80	1.02	0.71

As we can see from the table in fact the forward bias l_2 makes 50% of the tactical diameter D_T on an average , and the advance is approximately equal to the tactical diameter D_T.

Suggested that the both vessels navigators having known the tactical diameters of his vessel as well as the oncoming vessel's one (e.g. these data could have been included within the information transmitted by AIS) began the passing maneuver in accordance with COLREG Rule 14 with turning starboard for the distance S_{min} equal to sum of advances l_{1A}+l_{1B} of own (A) and oncoming (B) vessels (Fig. 3).

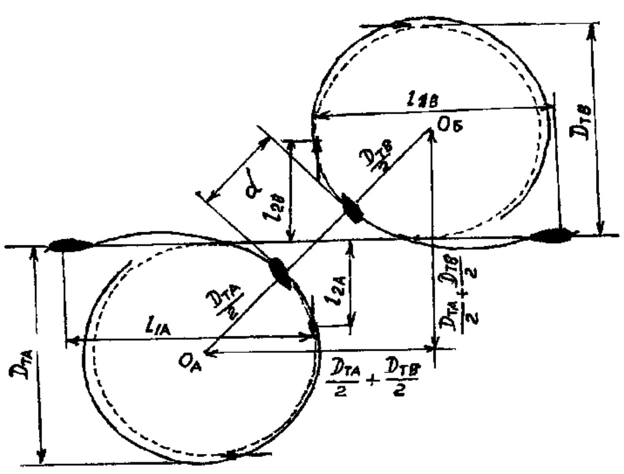

Figure 3. Scheme of vessels' manoeuvering at divergence as per COLREG-72 Rule 14 at the minimal distance equal to advances sum

We can take adequately that vessels' turning effect centers, before they achieve the course altering by 90°, move along curves coinciding with circles which diameters are equal to tactical diameters D_{TA} and D_{TB} of vessels (indicated with dashed lines at Fig. 3).Then as we can see from figure 3 D_{TB} the closest range d to which the vessels' centers of gravity will get closer, will be placed at straightway crossing centers of circles with diameters D_{TA} and

Consequently, taking into account the geometrical configuration of the task coming from figure 3 we can write down as follows:

$$\left(\frac{D_{TA}}{2} + d + \frac{D_{TB}}{2}\right)^2 = 2\left(\frac{D_{TA}}{2} + \frac{D_{TB}}{2}\right)^2 \quad (2)$$

Then we calculate the following from equation (2):

$$d = \left(\frac{D_{TA}}{2} + \frac{D_{TB}}{2}\right)\left(\sqrt{2} - 1\right) = 0{,}41\left(\frac{D_{TA}}{2} + \frac{D_{TB}}{2}\right) \quad (3)$$

However we have not considered the reduction of the closest vessels' head-on range due to that while turning circle there will be inevitably leeway angle β which can be estimated on the approximate correlation (Karapuzov, A. I. & Mironov, A. I. 2005. Maneuvering…) by reason of its low values (order of 10°-15°):

$$\beta = 0{,}9\frac{L}{D_T} \quad (4)$$

where L - the vessel's length.

While the vessel is sailing with leeway angle she will occupy a lane which width S is found from the expression:

$$S = L\sin\beta + B\cos\beta \quad (5)$$

where B = the vessel's breadth.

Thus we can draw the following for defining the closest point of approach d_{cpa} between the two vessels:

$$d_{cpa} = d - \frac{1}{2}\left(S_A + S_B\right) \quad (6)$$

where S_A and S_B - the A and B vessels motion lane widths respectively.

Otherwise we can obtain from (3)-(5) as follows:

$$d_{cpa} = 0{,}41\left(\frac{D_{TA}}{2} + \frac{D_{TB}}{2}\right) - \frac{1}{2}\left(L_A \sin(0{,}9\frac{L_A}{D_{TA}} + L_B \sin(0{,}9\frac{L_B}{D_{TB}}\right) \quad (7)$$

where L_A and L_B - the vessels A and B lengths respectively.

The diameter tactical $D_{T\psi}$ at the arbitrary rudder angle ψ is connected with diameter tactical during rudder deflection full helm (ψ=35°) D_{T35} by correlation (Karapuzov, A. I. & Mironov, A. I. 2005. Maneuvering …)

$$D_{T\psi} = 6.1\psi^{-0{,}509} D_{T35} \quad (8)$$

Using this connection between diameter tactical and rudder angle we can attempt to define the rudder angle necessary for divergence at the prescribed nearest distance. However if rudder angles are small so the vessel's circulation diameter is larger and consequently the nearest distance between vessels is larger at the distance accepted by us for divergence that is equal to vessels' advances sum. In this case we can agree to limit the rudder angles to 15° on both vessels.

For instance, we calculate the closest point of approach between vessels of FFT the «Atlantic» type that proceed at full steam in reciprocal to each other's courses. According to the table 1 data the at the rudder angle of 15° D_T=436 m (2.35 cab.). The vessel's length is 82.2 m, breadth is 13,6m. According to (7) we obtain d_{cpa}=337.5 m ≈ 1.8 cab. Thus if two FFT the «Atlantic» type vessels start divergence maneuvering simultaneously at the following distance between them

$$S_{min} = l_{1A} + l_{1B} \quad (9)$$

according to COLREG Rule 14, having displaced rudder starboard 15°, they will get closer at the divergence distance no more than 1,8 cab. that corresponds to mutual vessels' position abeam. After this maneuver the vessels can set their previous courses since theoretically the head-on distance is sufficient for safe divergence, the more so the vessels will make the same course for some time passing the dead interval. At least the closest point of approach will not exceed the hydrodynamic coupling distance that amounts to no more than half of lesser vessel's hull width at parallel reciprocal courses (Snopkov, W.I. 2004. Ships′…).

We draw the attention that if the distance exceeds S_{min} (9) at the divergence maneuver start, the nearest vessels' approach distance will not increase really provided turning to previous courses are carried out at the moment of mutual abeam vessels' position. It is determined by the fact that while displace the rudder to the previous courses accounting the dead interval and reversed bias the abeam distance between vessels will be sustained approximately the same as it was at the mutual abeam position of vessels at the circulation curve. To increase the vessels' closest of point approach in any case it is necessary to make turns to the previous courses after the vessels' mutual abeam position, for example, when courses are altered to 90º. In this case upon the vessels' returning to their previous courses they will diverge at the abeam distance approximately equal to fore biases sum. For the case with FFT the «Atlantic» type vessels this would mean that they diverge at the abeam distance amounting according to the table 1 $d_{cpa} \approx$ 2.5 cab.

4 CONCLUSION

Our suggested divergence maneuver regimentation at approaching of vessels on reciprocal courses we find advantageous as it complies with the common sense: the more heavy-tonnage the vessels are the more is the closest point of approach between them during the divergence. For example, at full steam while rudder displacement the vessels 200m long and 20 m wide will have the circulation diameters of order 0.5 mile (Karapuzov, A. I. & Mironov, A. I. 2005. Maneuvering…) While rudder displacement to 15º the circulation diameters will make up 1 mile according to (8). Therefore in our opinion the vessel's closest point of approach should make up about 1 mile which is crucially sufficient for safe vessels' divergence maneuver according to our suggested maneuver regimentation of vessels' minimal distance that is equal to doubled sum of vessels advances, on condition that the rudder displacement is 15º, turning to previously set courses after the vessels turn is to 90º on circulation path.

REFERENCES

Karapuzov, A.I. 1984. Ships Maneuvering Safety Issues during the Joint Trawling. Moscow: The Light and Food Industry.

Karapuzov A.I. 1986. Determination of Ships Maneuvering Stages at Reciprocal Counter-Courses to Provide Safe Clearance. Proceeding “Navigation and Fishing Safety”, ed. 81. Leningrad: Transport.

Karapuzov, A. I. & Mironov, A.W. 2005. Maneuvering of Large-tonnage Ships. Novorossiysk, NGMA

Snopkov, W. I. 2004. Ships′ Navigation: Text-book. Sunct-Petersburg, Professional.

Voytkunsky, Y.I. & Pershitz, R.Y. & Titov, I.A. 1973. The Ship’s Theory Reference-book. Leningrad: Shipbuilding

Zelenkov, A. I. 1999. The Distance Determination for Maneuvering Start while ships’ Clearing at Sharp Steering Angles. VO “Marine Technical Information Advertisement”, MMF EI, series “Navigation”, ed. 7 (362). VO “Marine Technical Information Advertisement”.