Ship domain in the restricted area – analysis of the influence of ship speed on the shape and size of the domain

Domena statku na akwenie ograniczonym – analiza wpływu szybkości statku na kształt i rozmiar domeny

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Abstract
The ship domain is one of the criteria proposed for the safety of ships in restricted areas. Its shape is influenced by many factors. The paper presents the results of ship domain determination in a restricted area. The influence of ship speed on the shape and size of the domain was examined. The method of determining ship domain based on ship traces and partial domains was characterized. The results have been presented and conclusions formulated.

Słowa kluczowe: domena statku, akwen ograniczony, badania symulacyjne, prędkość statku

Abstract

Introduction
Attention is increasingly paid to the problem of using a domain in the process of safe ship conduct, particularly in restricted areas [1, 2, 3, 4, 5, 6, 7, 8, 9]. This results from, inter alia, difficulties in applying safety assessment criteria typical of the open sea area. The basic difficulty is the determination of ship domain in the way that would account for important factors affecting the domain shape and size. One such factor is the speed of own ship and target or targets. Some authors propose analytical descriptions defining the domain shape and size depending on, e.g. the speeds and courses of encountered ships [10, 11]. However, no research is available to verify these proposals.

Simulation-based research is one of the methods commonly used for the domain identification and verification of developed domain descriptions. The method allows to precisely define simulation conditions, including selected factors used and analyzed in the process of domain determination. The work [12] presents the results of research on the influence of ship size on the domain shape and size. This article describes the continuation of that research and analyzes the impact of own ship and targets’ speeds on the domain shapes and sizes of encountered ships. As in the research referred to above, the simulation method was also used for ship domain determination.

The research
Simulations were carried out using an ECDIS simulator (Electronic Chart Display and Information System), located at the ECDIS laboratory at
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the Maritime University of Szczecin. The participants in the tests were active seafarers of all ranks. Simulated passages took place at daylight, in good visibility and good hydro-meteorological conditions (no waves, currents or wind). Thus, the other factors affecting domain shape and size were eliminated.

**Ship’s particulars**

The model ship used in simulations was a medium size LO-RO vessel (Fig. 1). Its particulars are given in table 1.

<table>
<thead>
<tr>
<th>Table 1. Particulars of the model LO-RO ship</th>
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<tr>
<td><strong>Displacement [t]</strong></td>
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<tr>
<td><strong>Length overall LOA [m]</strong></td>
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<tr>
<td><strong>Breadth B [m]</strong></td>
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<tr>
<td><strong>Draft T [m]</strong></td>
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<td><strong>Speed [w]</strong></td>
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</table>

The model ship was equipped with one main engine, a controllable pitch propeller and bow thruster, and could be steered manually or by an autopilot. The participating navigators could make use of all standard navigational equipment and systems. Therefore, movement parameters of own ship and the target could be observed using an ARPA, AIS and radar as independent equipment / systems or tracked in the ECDIS system. Two ship speeds were used in the simulation tests:

- 18.9 [kn] (full sea speed);
- 10 [kn] (intermediate speed between slow and half ahead);

hereinafter referred to as “full” and “slow” speed, respectively.

The participants were neither forced nor recommended to use a particular manoeuvre (course or speed alteration). Nor were they informed if the target would take action to avoid a collision.

**Area description**

The Dover Strait was chosen for simulated passages (Fig. 2). The choice of that particular area was made to get an area naviagtionally similar to the area where previous research on ship size impact on domain size and shape was done [12].
In terms of width, depths, aids to navigation, traffic separation scheme, vessel traffic services and traffic intensity the area is similar to the Singapore Strait, where simulated passages were previously performed. In terms of navigation, the area can be regarded as restricted. The strait width in the region of tests is about 16 Nm, while the depth of navigable parts of the strait ranges between 20 and 50 metres. There is a traffic separation scheme along the strait, including coastal traffic, traffic lanes and separation zones. The lanes are 3.5 to 4.5 Nm wide.

The domain determination method based on ships’ traces

The research comprised encounter situations of ships proceeding at various speeds, where one ship was steered by the operator, the other, non-maneuvering ship, was automatically controlled by a computer (simulator):

a) Full-slow speeds – the ship operated by test participants moved at full speed of 18.9 knots, while the target controlled by a simulator maintained a speed described as “slow” (10 knots);

b) Slow-full speeds – the ship operated by test participants moved at a speed referred to as “slow”, while the target, non-maneuvering, controlled by a simulator maintained a speed described as “full”.

For research purposes 10 scenarios were prepared altogether, five for each of the ship-speed combinations. In both groups, the scenarios were developed for five relative bearings on which initially the non-maneuvering target was observed. The relative bearings were as follows: 000° (head-on situation), 180° (overtaking) and 045°, 112°, 315° (crossing courses).

All in all 300 passages were simulated and recorded, 30 for each of ten scenarios. The recorded data came from the AIS of the model ships. Passage data were recorded at time steps $\Delta t = 1 \ [s]$.

On this basis, ship traces were determined around the central ship: computer-controlled ship and the ship steered by the navigator, taking into account the ships’ hull sizes and GPS antenna positions. Ship traces were assumed to be water plane points of the other ship on preset relative bearings, the closest to the centre of the central ship.

Example charts with recorded ship traces for two ships proceeding at “full-slow” speeds and relative bearing 315° are given in figures 3 and 4.

On this basis collective charts of maneuvering and non-maneuvering ships were made (Figs 5, 6).

Similarly, calculations were made for both ships with slow-full speeds.
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Research results

Making use of the collected ships’ traces the authors determined domains of the manoeuvring and non-manoeuvring ships, with two different speed combinations, respectively, full-slow and slow-full speeds.

The domain boundaries were defined by the method proposed in [2], based on an analysis of ship traces density around the central ship. Ship traces were assumed to be the waterplane points of the other ship on preset relative bearings, the closest to the central ship (Fig. 1).

The results are graphically presented on charts of total domains, indicating the minimum, mean and maximum domains (Figures 7 and 8) and the respective data are shown in tables.

Table 2 shows the lengths and widths of both ship domains for the two speed combinations, and
includes the total length, length ahead and astern of the ship, total width and widths to the port and starboard sides for the minimum, mean and maximum domains.

The comparison of resultant sizes and shapes of the domains has led to these observations:

- domain shape changes only slightly as the speeds are changed in each scenario;
- two-dimensional domain can be described as a non-symmetrical figure resembling an ellipse;
- semi-axes of the ellipse were determined in the research;
- ship proceeding at slower speed attempts to maintain a larger domain;
- proportions between the maximum, mean and minimum domains are kept in each scenario where introduced ships proceeded at various speeds;
- total length of the domain is approximately equal to its double width.

**Conclusions**

It has been observed that the domain shape changes only slightly as the ship’s speed changes. The domain is a geometrical figure shaped like an ellipse with the ship shifted off the ellipse axis. The simulations show that the ship moving at a slower speed tries to maintain a larger area clear of other vessels, i.e. a larger domain, which is contrary to common beliefs that domain size increases in proportion to speed. Regardless of the speed, the total length to width ratio of the domain roughly equals 2:1. Another observation is that proportions between domain length and width are not affected by ship speed. It seems purposeful to continue research in order to get a better insight into factors essential for the shape and size of ship’s domain.

**References**