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The Relation with Width of Fairway and Marine Traffic Flow

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ABSTRACT: Nowadays, many of changes have arisen in maritime traffic due to the enlargement of ship's size and improvement of ship's speed. It is common that the risks of handling a ship in narrow water area is increasing according to increase traffic volume. In order to correspond to these changes and risks, it should be necessary to make sure the relation between proper width of route in fairway and allowable traffic volume. The conventional method of designing a fairway takes into consideration of movement by one ship of maximum size. But the congestion by traffic volume is not taken in the concept. In a while, a case of road design is generally considered about a traffic volume. From such a view point, this research proposes the method of determining fairway-width in consideration of traffic flow. To evaluate traffic congestion in a route, the Environmental Stress model is adopted as the index of standard, using traffic simulation with avoiding a collision for reproducing traffic flow.

1 INTRODUCTION

For two decades, many of changes have arisen in sizes and shapes of a ship in maritime traffic. Since many ships are navigating inside of narrow fairway in a harbor area specially, the navigational difficulty by traffic congestion is also increasing. In order to correspond to such a change and to secure the safety of navigation, it is required to presume the relation between a width of route in fairway and allowable traffic volume.

Generally, a fairway can be explained to be a maritime passage where ships cruise and maneuver. It can classify into ocean route and coastal route as like narrow water service as like Incheon entrance located westly in Korea. The base elements which constitute a route in fairway are a width, a length, and a depth. As usual, because the length of a route changes according to each geographical condition, there is no standard uniform in a fairway or route. However, a width and a depth are closely concerned with the safe navigation of a ship.

The existing method of route design which calculates a width is common concept that the movement of a maximum size ship in the route has taken into consideration for designing a route, but taken into consideration for another ships passing around. On other hand, in case of road design in land transport, numbers and widths of a lane are decided in consideration for designed traffic volume.

This research aims at approaching the design in consideration of traffic flow on a route width from such a view point, concurrently on the assumption that the design of route which took the movement of the one maximum model of a ship into consideration. In addition as the first approach, this research examines for one-way route in comparatively large water area which is not influenced by an island and a shoal, which has sufficient margin depth of water too.

2 NECESSITY FOR APPROPRIATE WIDTH TO CORRESPOND TRAFFIC FLOW

As a conventional method determining route width, "Approach Channels A Guide for Design" (It calls to PIANC-Rule below) is internationally proposed by PIANC and IAPH in 1997.

PIANC Rule considers a wind, a current and navigational aids such as a beacon for calculated elements in design of the width. The required width of route is needed to the multiple numbers of maximum size ship's beam (B) and a curvature radius is expressed with the multiple numbers of lengths (L) of the ship. Contrarily when it is calculated for movement of the one maximum model of ship which cruises a route, it has considered neither passing nor the existence of another ships which carries out simultaneously is taken into consideration.

In actual, various ships exist in the route in which route's state is very crowded with traffic rushes depending on time zone.

The method such as PIANC rule designs a route only depending on the basis of maneuvering maximum size model. Therefore it cannot be guaranteed of the navigational safety in such a situation.

This research will examine required width of a route from a viewpoint of navigational safety. For this examination, it is necessary to clarity two points. First is that one ship of the maximum model can guarantee safety up to how much traffic congestions become. Second point is how much width of route is needed to the capable degree of traffic volume.

3 SIMULATION OF MARINE TRAFFIC

3.1 *Algorithm of Collision Avoiding*

In order to calculate the width of a route in consideration of a congestion of traffic flow, it is required to reproduce a traffic congestion state under the conditions of certain given width of route, to evaluate the navigation difficulty. Here, the simulation technique based on desirability of collision avoiding was used in this research.

As an evaluation index showing the navigation difficulty under traffic congestion, the environmental stress value by an ES(Environmental Stress) model was adopted. The method of a judgment and a rule of collision avoiding in the simulation model used here is explained below.

3.1.1 *Judgment of collision avoiding>*

A start domain of collision avoiding is a standard area which sets up the start of collision avoiding according to approach a collision distance by another (target) ship, just when there is a possibility of colliding with ownship.

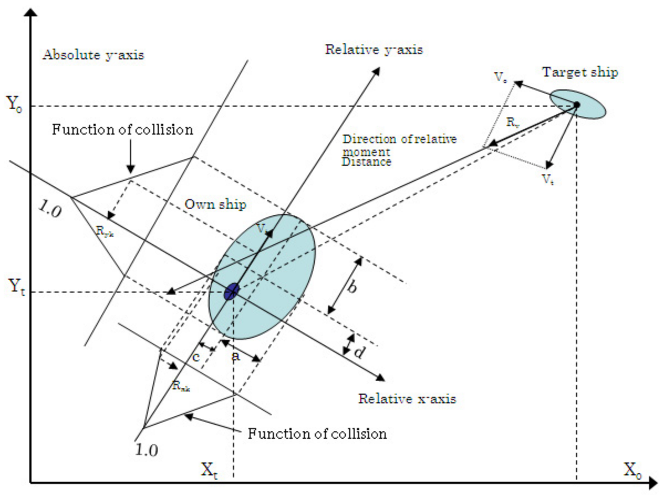

Fig.1 Concept of Collision Avoidance

In the model used in this paper, it also sets to the relative speed of an ownship and target ships according to average lengths among the ships, as shown in Fig.1.

3.1.2 *Process of collision avoiding*

As shown in a formula (1), the efficiency of collision avoiding and the safety of ownship are calculated by all navigational means including change a course and a speed. The optimal area finally is chosen by an evaluation.

$$u(X_{i,j}) = Pb(X_{i,j}) - a \times \underset{K=1,m}{Max}\{R_k(X_{i,j})\} \quad (1)$$

$u(X_{i,j})$: Evaluation Function to choose optimal navigation

$Pb(X_{i,j})$: Probability changing all courses and speeds to avoid

$R_k(X_{i,j})$: Risk colliding with ships or obstacles

$X_{i,j}$: Area to avoid collision with other ships or obstacles

$i = 1 \sim p$: Preference group to change a course

$j = 1 \sim q$: Preference group to change a speed

a: Weight factor, m: Ship's numbers of encountering

Probability changing a course to avoid:

$$Pb(X_{i,0}) = \exp(-a_c \cdot \Delta C_0)$$

Probability changing a speed to avoid:

$$Pb(X_{0,j}) = \exp(-a_v \cdot \Delta V)$$

Probability changing a courses and a speed to avoid:

$$Pb(X_{i,j}) = Pb(X_{i,0}) \cdot Pb(X_{0,j})$$

ΔC_0 : An angle of course change (deg)

ΔV : A ratio of speed change (%)

a_c= 0.0190(Left change of course), 0.0260(Light change of course), a_v=0.0456

3.2 *Condition of simulation*

A simulation area is considered to one-way passage, which the length is 10000m. The evaluation section is 4000m off the center of this area. This water area is not influenced by an island, a shoal, etc, which has also sufficient depth of water.

About a condition of a simulation, three components were set up parametrically; a width of route, composition of ship's appearance and traffic volume as shown in Fig.2 Process simulation.

The width of a route was considered as three patterns (300m, 500m, and 700m) by referring to main ports of Korea. The compositions of ship which form a traffic flow set up for small size, medium size and large size patterned to be a percentage of 7:2:1 and 4:5:1. Traffic volumes could be 10, 20 and 30 ships per an hour.

The size of a ship was classified into the small ship (48.26m±20m), middle ship (104.08m±20m) and the large ship (240.00m±50m) based on the actual data of an entrance to Mokpo in Korea. The ship's speed was used as the small ship (9.7kts±2.2kts) and middle ship (14.5kts±3.2kts) and the large ship (15.4kts±3.0kts).

Simulation time is recommended that the time be longer in order to obtain a reliable evaluation result. However, a simulation by increasing time recklessly will be wasted. So this simulation could be up to 100 hours.

In addition, the interval time generating ships (making traffic volume) asks for the average time interval according to the number of target ships. The ships were generated using exponential distribution with such an average value.

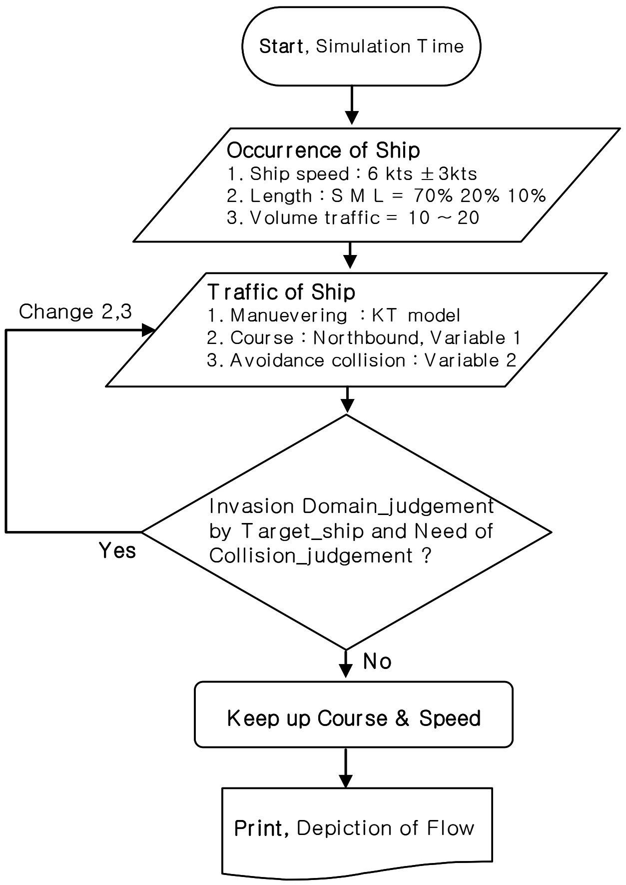

Fig.2 Process of Simulation.

4 ANALYSIS ON SIMULATION'S RESULTS

4.1 *Index of evaluation*

In this research, the environmental stress value by an ES model was adopted as an evaluation index showing the navigation difficulty under traffic congestion. A description is simply added to below about the ES model.

4.1.1 *Environmental Stress model, ES model*

The elements of the environmental conditions that can be taken into account in the model are as follows;

1 Topographical conditions such as land, shoals, shore protection, breakwaters, buoys, fishing nets, moored ships and other fixed or floating obstacles.
2 Traffic conditions such as the density of other ships and traffic flow.
3 External disturbances such as winds and currents.

The proposed model, which expresses in quantitative terms the degree of stress imposed by topographical and traffic environments on the mariner, is called the Environmental Stress Model (ES-model). The ES-model is composed of the following three parts:

1 Evaluation of ship-handling difficulty arising from restrictions to the water area available for maneuvering. A quantitative index expressing the degree of stress forced on the mariner by topographical restrictions (ES_L value) is calculated on the basis of the time to collision (TTC) with any obstacles.
2 Evaluation of ship-handling difficulty arising from restrictions on the freedom to make collision-avoidance maneuvers. A quantitative index expressing the degree of stress forced on the mariner by traffic congestion (ES_S value) is calculated on the basis of the time to collision (TTC) with other ships.
3 Aggregate evaluation of ship-handling difficulty forced by both the topographical and traffic environments, in which the stress value(ES_A value) is derived by superimposing the value ES_L and the value ES_S.

The model is a practical method for evaluating the ship-handling difficulty of navigation in topographically restricted and congested waterways, and in ports and harbors. The strength of the model lays in its ability to evaluate simultaneously or individually the difficulties of ship-handling arising from topographical restrictions and encounters with other ships and because it includes acceptance criteria based on a mariner's perception of safety.

4.2 *The standard of allowance judgment*

The marine traffic simulation with collision avoiding was carried out. The environmental stress model was applied to all the ships which form a traffic flow in a simulation. The difficulty which a ship operator felt in combinative conditions was calculated by this model.

In evaluation, it adopted as an index of a judgment of the appearance ratio [P (ESA>=890)] of the environmental stress value 890 equivalent to the state where 80 percent of ship operator groups are nonpermissible.

In addition to the judgment of the limit of permissible traffic volume, P (ESA>=890) of the ship for evaluation was made into less than 5% of the permissible judging standard, from the meaning in consideration of existence of the uncertain factor which cannot be specified.

4.3 *Result of simulation*

4.3.1 *Calculation of allowable traffic on route width*

In evaluation of ship traffic, it could not consider that a small ship and a large ship were the same traffic of 1 vessel, but traffic was normalized using L conversion traffic by using a 70m [in full length] ship as a standard ship.

Fig.3 compares route width with the appearance ratio of load nonpermissible for every combination of an ownship model. In simulation, it has a plot which case route width is from 300m to 700m.

In these figures, ship's percentages are <4:5:1> and <7:2:1> is united and plotted. Since these ships were expected that they could normalize using L conversion traffic, there were some variations. But the graphs performed linear regressions for the group of six points respectively.

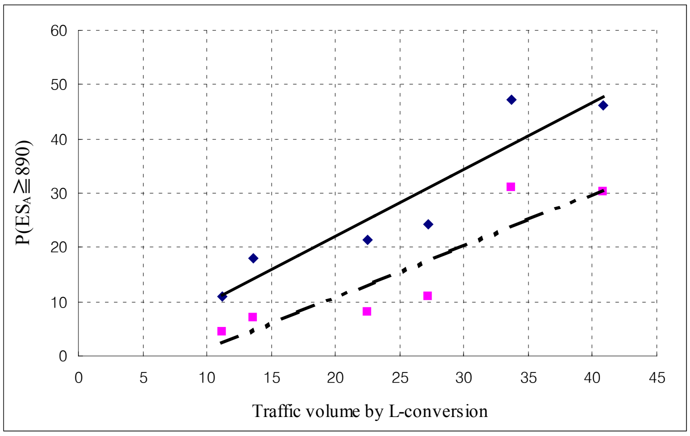

Fig. 3 Rate of appearance of P (ESA>=890) by width of route in 500m (◆: Large ownship, ■: Middle ownship)

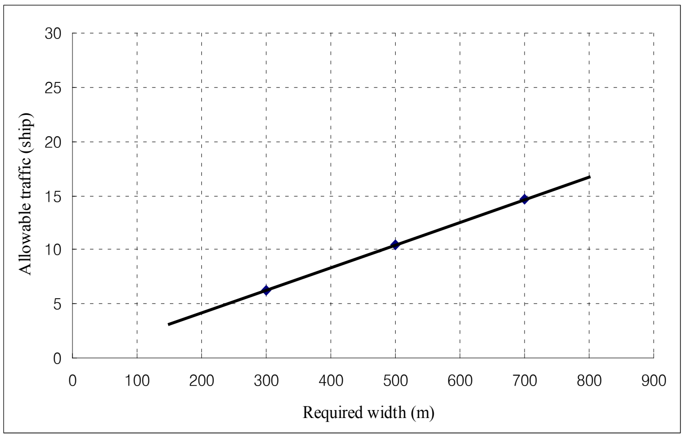

Fig. 4. Required route-width according to traffic volume (In case ownship is middle-sized)

Although an ownship is extrapolated as a part, the amount of allowable traffic to each width of route and each case of ownship's size can be obtained if an approximation straight line reads L conversion traffic in case the value of a vertical axis [P (ESA>=890)] used as 5% based on these figures.

Thus, the amount of allowable traffic to each route width can be presumed from Fig.4 when an ownship are each a large size and a middle size ship.

4.3.2 *Presumption of allowable traffic on route width*

Fig.4 shows plotted graphs presumed result of the amount of allowable traffic to each route width when taking from the case in a middle size of ownship.

From this figure, the required route width to the allowable limit of the traffic can be read to the given route width conditions or the traffic conditions.

If it becomes route to 500m for a large ship, 10 ships per an hour will become as for the amount of allowable traffic of which L conversion was done. If 700m, 15 ships per an hour will become.

When it comes from a middle size ship, it turns out that permissible traffic volume increases respectively by every 5 ships per an hour.

4.4 *Relation to existing rule of route design*

The existing route design method is a common method of designing in consideration of movement of one maximum ship in a route.

However on an actual route, the states that ships navigate to compete with other ships would be a normal state. In this research, the design of the route width in consideration of traffic was approached, escaped from the conventional route width design method which is width in consideration of movement of the one maximum model of a ship.

Fig.5 is a mimetic diagram shows the mutual relation of the design method in consideration of the existing route width design method and the congestion of traffic based on Fig.4.

If the route width designed by the existing method cannot allows a certain traffic to exceed, it can explain the need of increment of fairway which the concept of shifting to the view based on the route width in consideration of traffic volume designed by this research.

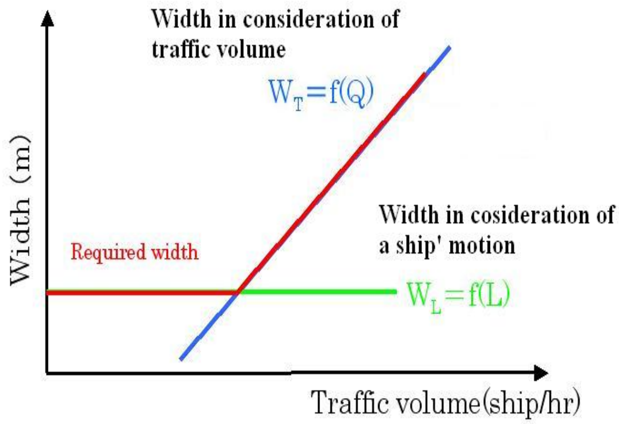

Fig. 5, Idea of required route-width over traffic volume

5 CONCLUSION

As many changes in maritime conditions have arisen in narrow waterway including the enlargement of ships, so navigational difficulty by traffic confusion is increasing. In order to secure the safety of navigation to such a change, it is needed the concept based on ship's traffic, which concept considers ship's traffic in congested situation and the maneuvering movement of maximum size ship in the traffic.

From such a viewpoint, the route design method in consideration of traffic congestion was approached by presuming the relation between route width and permissible traffic amount.

This paper examined for one-way route in comparatively large water area which is not influenced by ships and any obstacles as the first approach, which has sufficient margin depth of water. Asked for appropriate width of simulated route in consideration of congested traffic, the traffic congestion state was reproduced by marine traffic simulation. The navigation difficulty under traffic confusion was evaluated with the application of Environmental Stress model.

As a result, it could clarity that how much of width in a route be able to guarantee a state of traffic congestion to navigational safety in the simulation.

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