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Integrated Study on Marine Traffic Accidents

Étude intégrée des accidents de trafic maritime

Integrierte Forschung über Schiffverkehrs-Unfälle

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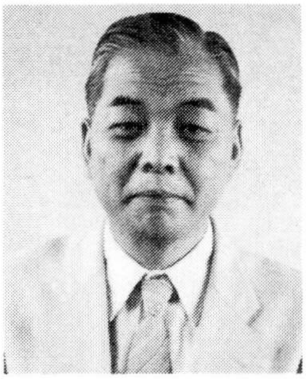

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SUMMARY
The frequency of a ship collision with a fixed object or a ship depends on the hypothetical frequency of ship collision with fixed autopilots and the probability of mismaneuver.

RÉSUMÉ
La fréquence de la collision d'un navire avec un objet fixe ou un navire est fonction de la fréquence hypothétique de la collision de navires avec pilotage automatique fixe et de la probabilité de fausse manoeuvre.

ZUSAMMENFASSUNG
Die Frequenz einer Schiffskollision mit einem festen Gegenstand oder einem Schiff ist von der hypothetischen Kollisionsfrequenz eines automatisch gesteuerten Schiffes und der Wahrscheinlichkeit falschen Manövrieren abhängig.

1. INTRODUCTION

Estimation of the number of ship collisions with bridge and offshore structure would be one of the main topics of the colloqium. Therefore, summary of marine traffic study is briefly introduced here which, author wishes, might give basis for further discussion.

2. ESTIMATION OF COLLISION FREQUENCY

2.1 Definition

Three frequencies have interested people involved in the study, namely,
(1) the number of collisions, Nc, or of ships in collision, Ns, in a certain area in a unit time,
(2) the frequency of collisions per ship in a unit time, Fs, and
(3) the frequency of collisions per trip, Ft, e.g., per port entry or per trip through a strait.

Though Fs is obtained without difficulty, Nc and Ft are more adequate for the accident analysis. The frequencies depends on the degree of damage. Therefore, the probability of degree of damage, Pr, is an important factor for the study. We should like to include all accidents even with practically no damage. However, there is a large unceruainty in the number of accident reports since exaustive record is scarcely expected. The frequencies for total loss accident may be written as NcPr(100%). Other scale for the degree of damage is also employed. For example, the Maritime Safety Agency (Japan) uses the definition, "required rescue", which is closely related with "operable".
Nc and Ft are dependent on the ship length, L, the speed, V, the density of ships, ρ, weather and many other factors. Let us try to estimate the number of collisions with traffic-related quantities.

2.2 Collision with Fixed Objects

Suppose that many ships proceed with fixed autopilots toward an fixed object as shown in Fig.1. The number of ships in collision, Nau, in a time length, T, is roughly represented as

$$Nau = \rho V D T \quad \cdots (1)$$

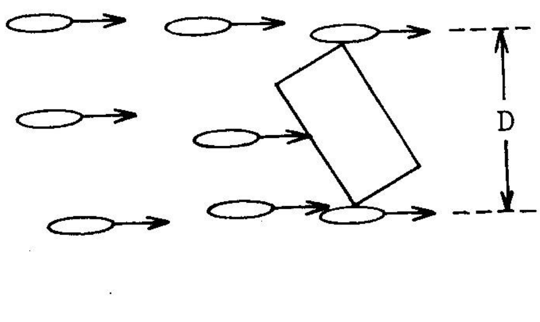

Fig. 1 Collision with fixed object

where D is the cross section and is equal to the sum of the width of ship and the width of the object looking in the direction of the velocity.
When the density is uniform, following approximation is possible,

$$Nau = QTD/W \quad \cdots (2)$$

where W is the width of traffic flow and Q $(=\rho WV)$ is the traffic volume.
We may rewrite Eq. (1) as

$$Nau = \int_{0}^{T}\int_{L}\int_{\vec{V}} \rho V D \Phi dL\, d\vec{V}\, dt \quad \cdots (3)$$

where Φ is the normalized distribution function of the ship length and the velocity.
The ratio, P, of the number of collision, Nc, and Nau, is important and interesting. 16 cases of collision with drilling platforms are reported in the Akashi Channel where a large bridge is to be constructed. The average width of the traffic flow was about 4km. The total number of drilling points was 22 and the total time length that each platformwas present was 70 months ($T = 70\times30\times24$ hr). The cross section, D, of a platform including stays and guys was about 0.2 km and the traffic volume per day was 1100 ($Q = 1100/24$). Then, Eq. (2) yields

$$P = Nc/Nau = 16/[(1100/24)\times(70\times30\times24)\times0.2/4)$$
$$= 1.39/10{,}000 \fallingdotseq 10^{-3.86}$$

Similarly, Nau is easily calculated for grounding. The logarithms of the ratios, log P, thus obtained are [1]:

Uraga Strait	(Fort No.2)	−3.9,
Bisanseto	(Oseishima)	−3.5,
Akashi Channel	(Hiraiso)	−3.2,
Akashi Channel	(Sementoiso)	−3.0
and Naruto Strait	(Nakaze)	−4.0.

Above values with −3.9 for drilling platforms give

$$\log P = -3.7\pm0.4.$$

This indicates that the probability of mismaneuvers leading to collision to fixed object or grounding is about 2/10,000.

2.3 Collision of Ships

Nau is easily calculated in a water area where there are two groups of ships as shown in Fig. 2. The number of collisions with one of ships in the group "i" in a time length T is $\rho jVrDijT$ where Vr is the relative speed and Dij is the cross section and hence, the number of collisions in area S is

$$\rho i \rho j V r D i j\ S T \quad \cdots (4)$$

since there are $S\rho i$ ships in the area. This formula is generalized by increasing the number of groups and employing following representation,

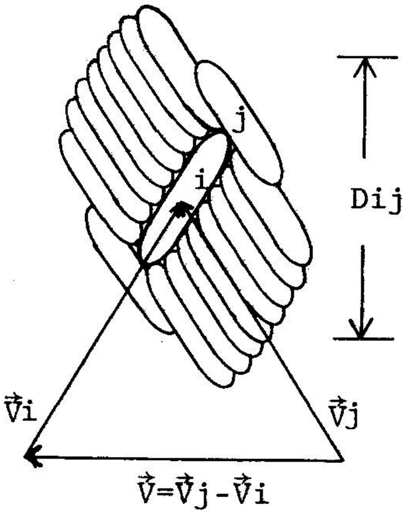

Fig.2 Collision of a ship in group "i" with ships in group "j"

$$\sum_i \sum_j \rho i \rho j V r \rightarrow \int_{L_1}\int_{L_2}\int\int_{\vec{V}_1}\int\int_{\vec{V}_2}(\rho^2/2)\Phi_1\Phi_2 V r\ dL_1 dL_2 d\vec{V}_1 d\vec{V}_2,$$

where Φ_1 and Φ_2 are normalized distribution function of ship size and velocity. Since Vr vanishes for ships in the same group, $\rho^2/2$ gives cross product ($\rho i \rho j$) only where $\rho(=\sum\rho i=\sum\rho j)$ is total density. Finally, considerably complicated expression,

$$Nau = \int_0^T\int_S\int_{L_1}\int_{L_2}\int\int_{\vec{V}_1}\int\int_{\vec{V}_2}(\rho^2/2)\Phi_1\Phi_2 V r dL_1 dL_2 d\vec{V}_1 d\vec{V}_2 dS dt \quad \cdots (5)$$

is obtaind.

The values of log P in three Japanese straits are[2]

$\log P = -4.1 \pm 0.2$ for codirectional encounter

and $\log P = -3.9 \pm 0.3$ for head-on encounter.

Above calculation is based on accident record from 1962 to 1968 and traffic data in those years were far from sufficient. Lewison's data[3] in Dover Strait gives −4.0 for codirectional encounter and −3.9 for head-on encounter.

Our group is performing an extensive study on log P in Japanese water for years from 1970 to 1981 and interim result in Bisanseto gives

$\log P = -4.08 \pm 0.16$ for co-directional collision,

$\log P = -4.86 \pm 0.23$ for head-on collision,

$\log P = -4.29 \pm 0.18$ for crossing collision and

$\log P = -4.44 \pm 0.43$ for collision to fishing boat at work.

These convince us that the ratio, P $(=N/Nau)$, is of the order of

1/10000 either for collision of ships or collision to object.

2.4 Various Factors

2.4.1 Degree of Damage

The damage rate, x, defined here as the ratio between the estimated damage to the ship (excluding loss of cargo) and the estimated value of the vessel, depends mainly on the gross tonnage ratio, y, between the gross tonnages of two ships iovolved. The cumulative relative frequency, F(x,y), of the probability of damage over x, is[4]

$0.033\ x^{-0.60}$ for $y=10$,

$0.008\ x^{-0.63}$ for $y=1$,

$0.004\ x^{-0.90}$ for $y=0.1$

and $0.00001\ x^{-1.1}$ for $y=0.01$.

This permits, together with PNau, estimation of loss due to ship collision in a certain area. However, information on damage is deficient for collisions with objects.

2.4.2 Weather

562 collisions and 354 groundings in 6 Japanese straits from 1966 to 1971 are classified with respect to the visual range. Analysis with these data and the frequency of visual ranges indicates that P is inversely proportional to the visual range for both collision and grounding[5].

Influence of darkness on P is studied in four Japanese straits where diurnal change in the traffic volume is compensated. Result shows that Ps for collision and grounding at night are 4 times those at daytime.

2.4.3 Type and nationality

Study in several straits in Japan yields that the ratio, P of ferry or passenger boat is about 1/6 that of freighter while P of fishing boat is about 3 times larger[6]. This indicates that reduction of P to P/6 is possible by with analysis of operation of ferries and passenger boats. Difference in Ps of freighter and tanker is abut 17% and may be neglected. Lunde and others[7] show that the annual rate of total loss of vessels over 499 g.t. due to collision ranges from 1/1000 to 8/1000 and also, significant difference exists among ship groups of different nationalities. This indicates the possibility of further improvement.

3. DOMAIN AND ENCOUNTER

3.1 Domain and Bumper Model

Fujii and others[8] indicated the presence of the effective domain around a ship into which other ships avoid entering. The domain for co-directional encounter is approximately elliptic with a long radius of 8L and short radius of 3.2L under ordinary navigation condition. Behavior studies in different types of encounter gives very simple model. Ship movement is well simulated withthe elliptic bumper model as shown TYPE A in Fig. 3. Ships proceed along their route so long as their bumpers do not overlap. When overlap is anticipated, evasive action is taken to resolve the encounter situation.

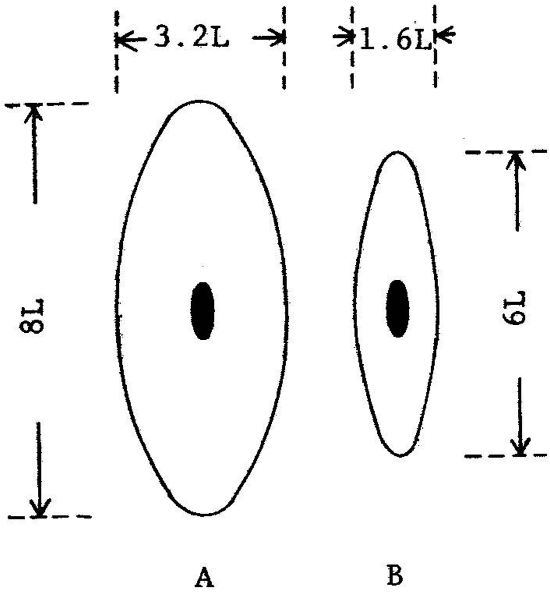

Fig.3 Size of bumper model

Since determination of bumper size requires considerably long traffic observation with high resolution radar(s), dependence of the bumper size on the speed has not been obtained.
Observation at port entrance suggests shrunk bumper shown as "B" in Fig. 3 when navigating at harbor speed.
Goodwin[9] has introduced "ship domain" which is closely related to our "effective domain" and "bumper model" in idea, but not in size. We expect observation on domains in other counuries.

3.2 Encounter and Traffic Capacity

The number of encounters, Nen, can be estimated from traffic related data by substituting the bumper for ship contour line in the calculation of Nau in the former section. Estimated values agree with observed values within a factor of $10^{\pm 0.5}$.
Therefore, we may relate three frequencies, Nc, Nau, and Nen with approximate ratio, 1/10000 : 1 : 10.
Theoretical traffic capacity of one-way route, Cth, is obtained as

$$Cth = 1.15WV/(8L \times 3.2L) \quad \cdots (6)$$

where the bumper model A is employed and 1.15 is the close-packing factor. Okuyama[10] has studied the capacity of one-way route and route network by mathematical simulation with the bumper model.
Traffic capacity of route between bridge piers can also be estimated by such simulation. The practical capacity, often called the design capacity, is influenced by many factors which are still under study.

3.3 Multiple Encounter

The number of collisions where influence of the third ship is reported occupies a considerable part, about 6% of the total in Japan. Fujii[11] defined multiple encounter as simultaneous overlaps three or more bumper models. Mathematical analysis yields a considerably complicated formula for estimating the frequency of multiple encounters in which an index, ρE, the product of the density and the area of single overlap, plays an important role. When ρE approaches unity, the share of multiple encounter increases steeply.

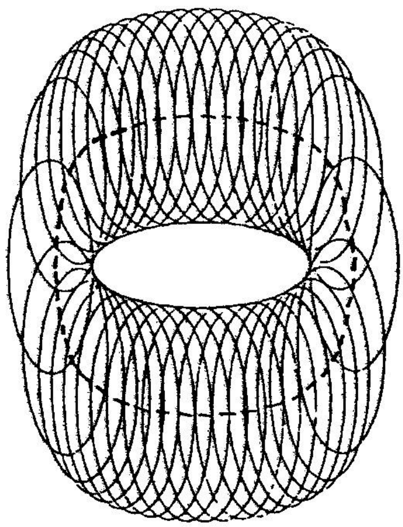

Fig.4 Area of singme overlap shown with dotted line (90° encounter)

E is a function of ship length and encounter condition and is about $90L^2$ when the ships are of a same size.
Multiple encounter, as Jensen[12] has pointed out, is a dangerous situation and should be avoided. If we admit $\rho E=1$ as the limit, the traffic capacity may decrease to about 1/4 of the theoretical capacity, Cth. If we regard a bridge pier as the third ship, encounters of ships in approach area to a bridge should be avoided.
There is another approach to estimate the frequency of multiple encounter. estimation of the probability of simultaneous presence of two or more ships in an effectiwe domain. This also leads to similar result.

4. CONCLUSION

The number of collisions to stationary objects or of ships is approximated with PNau, where P is the probability of mismaneuver and Nau is the

number of collisions when ships navigate with fixed autopilots. Result of survey shows that P seems a constant close to 1/10000 under ordinary condition. This allows estimation of such such collisions in the viscinity of a bridge.
The relation of the number of encounters and the number of collisions is also studied where the bumper model seems adequate to simulate the behavior of ships and allows furtier esuimation of multiple encounters.
The author wishes information exchange on such data in differenu water of the world.

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