A Basic Study on Difficulties of Ship Operation Under Restricted Visibility Due to Heavy Fog

Kenji SASA,* Shinji MIZUI,* and Tadashi HIBINO**

Abstract

It is very important to provide daily maritime transportation services, especially, in island areas. However, navigation is sometimes cancelled because of heavy fog. Although this is well known among ship operators, the associated situations and problems are not fully understood. In this study, we focus on the difficulties of ship operations under conditions of restricted visibility. First, casualties that occur under conditions of restricted visibility are researched. Then, a nationwide questionnaire was distributed to ship operators to learn the details of the current situations and operational problems. These results were statistically analyzed to demonstrate their operational limits. Moreover, interviews were conducted with a local ferry company to obtain recent cancellation records of navigation. The weather parameters on the dates of cancellations were analyzed and compared in a few cases with the other findings from the questionnaire and the interview research.

Key words: Ship Operation, Restricted Visibility, Heavy Fog, Casualty, Questionnaire, Weather Conditions

1.Introduction

It is very important that ship operators maintain enough visibility to navigate safely. However, many vessels encounter difficult situations at sea under conditions of limited visibility in heavy fog. Because visibility is sometimes limited, navigation is often cancelled or delayed, resulting in operational losses for shipping companies, cargo owners, and passengers. This is especially serious for cargo owners or passengers who depend exclusively on maritime transportation. Casualties, such as collisions and grounding, sometimes occur when vessels navigate under unsafe conditions\(^1\) despite the improvement of nautical instruments. Although navigation under fog signals is currently recommended,\(^2\) not all casualties should be attributed to human error. We think that the casualties are rather influenced by meteorological factors, such as seawater temperature or humidity. This study focuses on limited conditions during navigation as a result of restricted visibility. First, attention is given to casualties that occurred under conditions of restricted visibility. Statistics relating to casualties are analyzed here. Then, a nationwide questionnaire was distributed to shipping companies to learn more about conditions that limit operations, such as weather or other problems. The questionnaire expanded the available pool of knowledge. When the navigation schedules of the local ferry were canceled due to heavy fog, the weather database was analyzed. Finally, the results and how they relate to one another are considered.

2.Casualties under Conditions of Restricted Visibility in Recent Years

It was important to determine which of the recent casualties had been caused by restricted visibility. Casualties occurring near Japan that were recorded by marine authorities\(^3\) and involved indictments were studied. There were 58 accident reports attributed to restricted visibility in 2001-2002 (30 in 2001 and 28 in 2002). As the total number of

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casualties is 1580(779 in 2001 and 801 in 2002), nearly four percents of them are occurred under restricted visibility. It means that this type of casualty occurs per 25 cases. This is not negligible probability. A map of the seas surrounding Japan is shown in Fig. 1.

![Map of the seas surrounding Japan](image)

**Fig. 1 Map of the seas surrounding Japan**

The generation of fog seems to be influenced by meteorological and oceanographic conditions in a measure. Currents are strong at straights in inland seas. In open seas, waves and winds become stronger. Thus, situations of casualties are categorized in each sea area shown in Fig. 1. The percentage of casualties classified by the specific body of water in which they occurred is shown in Fig. 2.

Almost one half of the casualties occurred in the Pacific Ocean, and 33% occurred in the Seto Inland Sea. Others happened in the Kanmon Straight, the Osaka Bay, and the Tsugaru Straight. There were few casualties in the Sea of Japan. The percentages of casualties by season are shown in Fig. 3. The seasons are defined by month in Table 1.

![Percentage of casualties](image)

**Fig. 2 Percentage of casualties classified by the specific body of water in which they occurred in 2001-2002**

<table>
<thead>
<tr>
<th>Table 1 Definition of seasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasons</td>
</tr>
<tr>
<td>Spring</td>
</tr>
<tr>
<td>Summer</td>
</tr>
<tr>
<td>Fall</td>
</tr>
<tr>
<td>Winter</td>
</tr>
</tbody>
</table>

![Percentage of casualties by season](image)

**Fig. 3 Percentage of casualties every season and 6 hours in 2001-2002**

Ninety percents of casualties occurred in spring and summer, and 10% occurred in the cold seasons. The percentages of casualties by hour are shown in Fig. 4. Fifty-three percent of the casualties occurred from 0-6h, and 29% from 6-12h. These results provide evidence that casualties in restricted visibility tend to concentrate in the early morning, when air and seawater temperatures are the lowest. However, 17% of the casualties occurred in the afternoon and at night. This indicates that visibility may be limited at other hours than in the early morning.

3. Questionnaire to Gain Information about Current Shipping Operations
In Chapter 2, the characteristics of casualties are
reported in location, season, and hour of occurrence. In particular, it is necessary to point out that nearly one half of the casualties occurred in the relatively narrow seas of western Japan, such as the Seto Inland Sea, Osaka Bay, and the Kanmon Straight. A questionnaire was distributed among operators of domestic liners known to operate under conditions of heavy fog. The ratio of respondent was 55% (48 of 86 responded).

3.1 Cancellations of Navigation
The percentage of cancellations attributed to heavy fog is shown in Fig. 4.

![Diagram showing percentages of companies that have cancelled navigation]

Fig. 4 Percentage of companies that have cancelled navigation

The result shows that 77% of the respondents cancelled navigation due to heavy fog. We also found that navigation was cancelled from 1 to 5 days in the last year. Even closings from 1 to 5 days will have a significant impact on transportation systems such as ferries, which run on a specific schedule. The percentages of cancellations are shown by season and hour in Fig. 5.

![Diagram showing percentages of cancellations by season and hour]

Fig. 5 Percentages of cancellations by season and hour

The results shown above are similar to those shown in Fig. 3, which demonstrate that operators believe that spring is the most difficult season for navigation. However, there are a few cancellations in the fall and winter. Cancellations occurred during the morning. The percentages of limit conditions that caused cancellations are shown in Fig. 6. The limit condition is commonly defined as 500m (75%) or 300m (25%).

3.2 Characteristics of Heavy Fog
The percentage of respondents that have suddenly encounter heavy fog during navigation is shown in Fig. 7.

![Diagram showing percentages by limit conditions causing cancellations]

Fig. 6 Percentages by limit conditions causing cancellations

The figure shows that 73% of respondents have suddenly encounter heavy fog during navigation. This means that the danger of casualties still exists, even though navigation is cancelled when visibility is limited. This is a very important point when considering the danger caused by restricted
visibility. The main countermeasures in the present circumstances are considered, as shown in Fig. 8, which indicates that there are no other effective countermeasures than the enhancement of look out, the reduction of speed, etc. Locations at which heavy fog frequently appears are shown in Fig. 10. Eighty-two percent of the respondents reported that heavy fog occurs in the vicinity of harbors and narrow channels. These findings indicate that visibility is more likely to be reduced in areas where ship handling is critical. The evidence shows that heavy fog hinders navigation.

Fig. 8 Main countermeasures in the present circumstances

![Graph](image1)

Fig. 8 Main countermeasures in the present circumstances

Fig. 9 Locations in which heavy fog frequently appears

![Graph](image2)

Fig. 9 Locations in which heavy fog frequently appears

3.3 Application Limits of Nautical Instruments

Nautical instruments, such as radar, become very important when the visibility is restricted. Nautical instruments, such as those associated with radar, are critical when visibility is restricted. Some studies have focused on navigation instrumentation with restricted visibility to be used during airplane takeoff and landing. In addition, this present research examines the contribution made by nautical instrumentation. The maximum distance that ships can navigate while depending on radar under conditions of restricted visibility is shown in Fig. 10.

![Graph](image3)

Fig. 10 Maximum distances that ships can navigate by radar under conditions of restricted visibility

The respondents have reported various maximum distances. Nearly one half of the operators reported that navigation by radar is not possible when visibility is limited to 500m or less. However, 31% reported that navigation by radar is possible when visibility exceeds 500m. No information, however, was gained regarding navigation limitations of less than 2 nautical miles. The results regarding the parameters emphasized by respondents are shown in Fig. 11.

![Graph](image4)

Fig. 11 Main parameters emphasized by operators under conditions of restricted visibility
Only 33% of the respondents offered information navigation by radar, even though more modern nautical instruments are currently improved. The actual visibility is still the most emphasized factor under limited visibility.

3.4 Weather Parameters Focusing on Restricted Visibility
Weather conditions emphasized by respondents when heavy fog appeared at sea were researched. The percentage of each weather parameter that was emphasized by respondents in case of heavy fog is shown in Fig. 12. Nearly one half of the respondents emphasized rainfall and humidity. Humidity increases with rainfall, and fog is produced when humidity is high. Thirty-six percent of the respondents reported that the temperatures of seawater and air are important, as is the humidity.

![Weather Chart]

Fig. 12 Percentage of each weather parameter emphasized

Table 2 shows sample answers with numerical information about weather conditions under which heavy fog occurs at sea.

Table 2 Numerical information about weather conditions under which heavy fog occurs

<table>
<thead>
<tr>
<th>Respondent</th>
<th>OK Corp.</th>
<th>SD Corp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>Higher than 80%</td>
<td>High</td>
</tr>
<tr>
<td>Air Temp.</td>
<td>14-25 °C</td>
<td>14-17 °C</td>
</tr>
<tr>
<td>Seawater Temp.</td>
<td>20-25 °C</td>
<td>8-10 °C</td>
</tr>
</tbody>
</table>

Even though high humidity was reported by most respondents, the seawater temperatures are so different each other. This point has to be considered in future studies.

3.5 Countermeasures against present situations
The percentage of respondents who want countermeasures to be established is shown in Fig. 13.

![Countermeasures Chart]

Fig. 13 Percentage of respondents who believe that countermeasures should be established

Figure 13 shows that 51% of the respondents want new effective countermeasures. Although improvements in nautical instrumentation are common, the results obtained here demonstrate that the present state of navigation is insufficient to assure safe operations.

3.6 Other Comments on Ship Operations under Conditions of Restricted Visibility
Some comments on ship operations under conditions of limited visibility are summarized in Table 3.

Many respondents felt that navigation in heavy fog should be cancelled whenever possible. They also felt that nautical instrumentation provides insufficient support. It is obvious that new effective countermeasures are necessary for the safe operation of ships when visibility is limited.
Table 3 Main comments on ship operation under conditions of limited visibility

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK Corp.</td>
<td>We should use ARPA, navigate at slow speeds, and cancel navigation under these situations.</td>
</tr>
<tr>
<td>N Corp.</td>
<td>It is dangerous to navigate depending on radar.</td>
</tr>
<tr>
<td>OK Corp.</td>
<td>It is not safe to navigate on an inland sea with visibility of less than 1 mile.</td>
</tr>
<tr>
<td>NK Corp.</td>
<td>It would be best to cancel navigation in heavy fog.</td>
</tr>
<tr>
<td>K Corp.</td>
<td>It is very dangerous when pleasure boats and fishing boats navigate without fog signals under conditions of limited visibility.</td>
</tr>
<tr>
<td>SB Corp.</td>
<td>An empirical rule is used to predict the influence of heavy fog. However, it is very difficult to predict the occurrence of such conditions.</td>
</tr>
<tr>
<td>NA Corp.</td>
<td></td>
</tr>
<tr>
<td>SE Corp.</td>
<td></td>
</tr>
<tr>
<td>RK Corp.</td>
<td></td>
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<tr>
<td>EH Corp.</td>
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<tr>
<td>CS Corp.</td>
<td></td>
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</tbody>
</table>

4. Analysis of Weather Conditions under Conditions of Restricted Visibility in Heavy Fog

The weather conditions when ships cancel navigation as a result of heavy fog should be thoroughly studied. Here, some weather parameters resulting in cancellations of the CS ferry company were analyzed. Here, two cases of time series of weather parameters are shown.

4.1 Case 1 (June 22-23, 2003)

Changes in air temperatures, seawater temperatures, volumes of rainfalls, and averaged wind speeds on T Port from June 22-23, 2003, are shown in Fig. 14. Ferries did not navigate from 5 to 8 a.m. on June 23. Weather charts during the period are shown in Fig. 15.

In Fig. 14, the air temperatures and seawater temperatures are shown to be almost the same in the early morning on June 23. A small amount of rain had fallen from midnight to early morning, before the occurrence of heavy fog. Wind conditions were relatively calm during that period.

Fig. 14 Changes in weather parameters on T Port from June 22-23

Fig. 15 Weather charts from June 22-23

In Fig. 15, a stationary front with an atmospheric depression is seen to move from China to the Japan Islands on June 22. It then locates in western Japan on June 23. As the front destabilizes the atmospheric air, it is possible that the humidity increases because of the rainfall from midnight to early morning on June 23. Restricted visibility is likely to occur when such weather conditions occur at the same time.

4.2 Case 2 (June 17, 2003)

Changes in air temperatures, seawater temperatures, volumes of rainfalls, and averaged wind speeds on June 17, 2003, are shown in Fig. 16.
Ferries did not navigate from 4 to 9 a.m. on June 23. Weather charts during the period are also shown in Fig. 17.

![Graphs of Air Temperature, Sea Water Temperature, Amount of Rainfall, and Wind Speed from June 17](image)

Fig. 16 Changes in weather parameters on T Port from June 17

As shown in the Figure 16, air temperatures are 1-2 degrees higher than seawater temperatures during the cancellation of navigation. Although volumes of rainfall are little heavier than the Case 1, the tendency that rainfalls are observed until an hour before the cancellation seems is almost the same. The wind speed seems to be calm, too. In Fig. 17, a front have been located near Japan since June 16 of the previous day of the cancellation.

These are just two examples about the generation of heavy fog. Detailed mechanism cannot be known only by these data. It will be necessary to observe and analyze much more weather and oceanographic data for longer periods. We are preparing the following research plan as shown in Fig. 18.

![Flowchart of Research Plan](image)

Fig. 18 Research plan in future studies

We think that the accumulation of various data related the difficulty of navigation under heavy fog, first of all. The field observation will be carried out on the route of the ferry company that generates heavy fog at sea. Main observation factors are the visibility, the ship motions during the navigation, the seawater temperature, the air temperature, the humidity, the current direction and velocity, the salinity of seawater, the turbidity of seawater, the wind direction and speed, the atmospheric pressure, etc. These factors have not observed at the same time from the viewpoint of the difficulty of ship operation under restricted visibility. We want to find out some relations among these parameters to explain the mechanism of heavy fog at sea. Then, the new prediction model of heavy fog will be constructed to prevent the danger of casualties on...
these statistic analysis of observed data in future studies. Furthermore, hardware side countermeasure against the difficulty of ship operation under restricted visibility is also necessary to consider in future studies, too. This study is expected to develop future studies as the first report of this topic.

5. Conclusions
In this study, present occurrences of limited visibility were studied with the use of a nationwide questionnaire distributed among ship operators. Some of the findings are reported as follows:
(1) Fifty-eight casualties occurred under conditions of limited visibility, as reported on the marine inquiry records in 2001-2002. The numbers of these casualties remain relatively stable. Half of them occurred in the Pacific Ocean, and the other half in the inland seas of western Japan, such as the Seto Inland Sea.
(2) Seventy-seven percent of respondents experienced cancellation of navigation due to heavy fog. The cancellations occurred from spring to summer in most cases. They also happened throughout the morning in most cases. However, there are some exceptions.
(3) Seventy-three percent of the respondents suddenly encountered heavy fog during navigation. However, the only countermeasures currently enforced by operators are to increase their look out, decrease their speed, or cancel navigation. There are no effective countermeasures now for these situations.
(4) Time series of weather conditions are researched when local ferries canceled navigation. Some rainfall had been reported before the cancellation as a result of the influence of a moving front. The difference between air and seawater temperatures was insubstantial in Case 1. There is a difference of 1-2 degrees between them in Case 2. However, these data are not enough to explain these phenomena at all. It will be necessary to study the relationship between weather data and heavy fog as we show in the future study.

Acknowledgements

This study was based on the results of a questionnaire. We are grateful to the shipping companies that participated in this study. We want to express our appreciation to Mr. Shunsuke Kubo, a student of Hiroshima National College of Maritime Technology, for his assistance in analyzing the results of the questionnaire and weather database.

References

(2) "International Regulations for Preventing Collisions at Sea," Brown Son & Ferguson Ltd., p.36 (1995).